System Life and Reliability Modeling for Helicopter Transmissions

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SUMMARY

A computer program which simulates life and reliability of helicopter transmissions is presented. The helicopter transmissions may be composed of spiral bevel gear units and planetary gear units - alone, in series or in parallel. The spiral bevel gear units may have either single or dual input pinions, which are identical. The planetary gear units may be stepped or unstepped and the number of planet gears carried by the planet arm may be varied. The reliability analysis used in the program is based on the Weibull distribution lives of the transmission components. The computer calculates the system lives and dynamic capacities of the transmission components and the transmission. The system life is defined as the life of the component or transmission at an output torque at which the probability of survival is ninety percent. The dynamic capacity of a component or transmission is defined as the output torque which can be applied for one million output shaft cycles for a probability of survival of ninety percent. A complete summary of the life and dynamic capacity results is produced by the program.
INTRODUCTION

In the helicopter industry, experimental testing programs are used to measure the relative merits of different transmissions [1,2,3]. These tests are costly in terms of time and resources. The tests should be complemented with computer simulations of many possible designs, so that only optimal designs are brought forward to the testing stage in helicopter transmission development.

This report describes a computer simulation program which models the life and reliability of a helicopter transmission. The computer program uses the lives and reliabilities of the individual components to compute the life and reliability of the transmission.

The life and reliability models are based on the assumption that the transmission is adequately lubricated and well designed. This means that its gears have sufficient rims and are made of adequate materials so that premature tooth breakage will not occur. Also, it is assumed that the tooth form geometry and lubricant have been selected to prevent tip scoring. Both of these failure modes can be prevented [4].

However, surface pitting is not preventable due to the lack of a surface fatigue endurance limit for high strength gears. As with rolling element bearings, gear teeth will fail eventually in surface pitting even in a well designed, well lubricated transmission,
regardless of the loads [5-11]. Thus, the life and reliability models for spiral bevel gear reduction and planetary gear units are based on the pitting fatigue life and reliability models for the bearings and gears in the transmission.

In this program, a modular approach is used in which the force and motion analyses of the reduction are separated from the life and reliability analyses. The dynamic capacity models are also separated algebraically from the prior calculations. In this way, the calculations can be performed sequentially and the complexity and diversity of the analyzed transmissions can be increased greatly.

The computer program can simulate a number of configurations of spiral bevel gear units, dual spiral bevel gear units, planetary gear units and combinations of units. The eight transmission configurations analyzed by this program are shown in figure 1. Configuration 3 is found in the OH-58 light duty helicopter and consists of a spiral bevel gear unit combined with a planetary gear unit. Configuration 8 is found in the Black Hawk helicopter and consists of parallel spiral bevel units combined with a dual spiral bevel gear unit. The power is then transmitted to the rotor through a planetary gear unit. The power inputs to the two input pinions of the dual spiral bevel gear unit do not have to be equal, so that the loss of power in one engine can be simulated. The program also allows the planetary gear unit to be composed of stepped or unstepped planet gears. The program can simulate transmissions at different power levels and load duty cycles. The program can calculate the lives and dynamic capacities of a single unit or the transmission as a whole.
1. Spiral Bevel

2. Planetary

3. Spiral Bevel & Planetary

4. Spiral Bevel & Planetary & Planetary
5. Dual Spiral Bevel

6. Dual Spiral Bevel & Planetary

7. Dual Spiral Bevel & Planetary & Planetary

8. Spiral Bevel & Dual Spiral Bevel & Planetary
TRANSMISSION POWER FLOW

In a helicopter, power is typically produced by a turbine engine oriented horizontally and close to the main rotor shaft. The rotor shaft is nearly vertical and the power from the turbine must be transmitted through approximately ninety degrees. The transmission must handle a speed reduction from the turbine engine to the rotor shaft in the range of 80:1. To accomplish this in a small amount of space, spiral bevel gear units are used in conjunction with planetary gear units.

In the analysis, the spiral bevel gear units and planetary units are treated separately. Even though the units are treated separately, they must have a common counting base to allow combinations of lives and reliabilities. In helicopters, a significant part is the output rotor shaft. Therefore the common counting base in this program is the output torque and speed of this rotor shaft which is unchanged from design to design.

In helicopters, a common configuration is a spiral bevel gear unit from the turbine followed by a planetary unit along the output shaft. There may be more than one spiral bevel gear unit in series or parallel and there may be more than one planetary gear unit in series.
along the output shaft. The couplings between the units are assumed to be splined, only able to transmit torque loads between the units.

**Spiral Bevel Gear Unit**

For the spiral bevel gear unit there are many inputs which define the geometry [12]. In figure 2, the geometry which is required for analysis of the gear mesh is shown. The main measure of bevel size is the cone distance, \( a_0 \). The cone distance is the distance from the apex of the bevel cones to the back edge of the tooth face. This distance is measured along the pitch line of the two pitch cones of the mating gears. The contact face width of the gear set, \( f \), is measured along the same pitch line.

To define the geometry of the pitch cones, the following inputs are required, number of teeth on the pinion, \( N_p \), number of teeth on the gear, \( N_g \), and the shaft angle. The shaft angle is the angle between the input pinion shaft and the output gear shaft. The pitch angles, which are half the cone angle of the gear, are related by these inputs in the following equations.

\[
\tan \Gamma_g = \frac{\sin \Sigma}{(N_p/N_g) + \cos \Sigma} \quad (1)
\]

\[
\tan \Gamma_p = \frac{\sin \Sigma}{(N_g/N_p) + \cos \Sigma} \quad (2)
\]
Figure 2
Spiral Bevel Gear Pitch Cone Geometry
The point of gear contact used in the analysis is the pitch point. The distance from the apex to the midpoint of the face locates the pitch point.

\[ D_0 = A_0 - \left( \frac{f}{2} \right) \]  

(3)

The pitch diameters of the equivalent spur gear for the spiral bevel pinion and gear can be found by:

\[ D_p = 2 \times D_0 \times \sin \gamma_p \]  

(4)

\[ D_g = 2 \times D_0 \times \sin \gamma_g \]  

(5)

Also in this analysis, the teeth in the mesh at the pitch point are modeled as planar spur gears. Figure 3 is a composite drawing showing the bevel and reference spur gear. The diameter of the reference planar spur gear is double the backcone distance. The backcone distance is defined as the perpendicular distance from the pitch point at the midpoint of the gear face to the centerline of the gear shaft.

The backcone distance of the pinion and gear are calculated by:

\[ B_{cp} = \tan \gamma_p \times D_0 \]  

(6)

\[ B_{cg} = \tan \gamma_g \times D_0 \]  

(7)

In addition to the size and shape of the pitch surface, the gears are defined by the geometry of the meshing gears. In figure 4 one sees a spiral bevel gear in the pitch plane which is tangent to the pitch cones at the line of contact.
Figure 3
Composite Section of Spiral Bevel Gear and Reference Planar Spur Gear
In the figure, the spiral angle, \( \varphi \), is shown as the angle between the pitch ray and a tangent to the circular cutter at the mid-point of the tooth. This angle is positive for right hand advance of the spiral along the axis of the gear toward the cone apex. The figure shows a right hand spiral. In the spiral bevel mesh the pinion and the gear must have the same spiral angle but the hands of the meshing gears must be opposite.

The diametral pitch of the teeth is defined at the mid-tooth radius.

\[
P_d = \frac{N_g}{2 \times D_o \times \sin \varphi_g}
\]  

(8)

It can be noted that the pitches are direct functions of the numbers of teeth on the gears and the pitch cone geometry. Figure 5 shows the normal tooth geometry at the mid-plane of the tooth. Figure 5 corresponds to section AA in figure 4. The normal pressure angle \( \alpha_n \), addendum \( a_b \), and dedendum \( d_b \), are shown at the mid-plane of a bevel tooth.

The direction of rotation of the pinion is required to define the loads transmitted at the point of gear contact. In this paper, clockwise rotation is defined looking at the back of the pinion along the pinion shaft toward the cone apex.

One must also specify the bearing supports of the gears. The two bearing configurations most commonly used, straddle and overhung, are shown in figure 6. In both cases distance A is the distance from
Figure 6

Bearng Mounting Configuration

b) Overhung

a) Straddle
the gear to the bearing closest to the apex. In case 2, distance A takes on a negative value. Distance B is defined as the distance from the gear to the bearing furthest away from the apex. All distances are measured from the mid-point of the gear to the mid-point of the bearing. One bearing on each shaft must be identified as a thrust bearing to take the axial thrust loads produced by the bevel gear mesh.

In the case of dual inputs, the pinions and their mounting are considered to be identical. The only difference can be the load levels applied by the pinions. Figure 7 shows the twin input bevel in the plane of the two input shafts.

Planetary Gear Unit

For the planetary gear unit one must define whether the unit is stepped or non-stepped and the number of planets carried by the planet arm. Figures 8 and 9 show an unstepped and stepped planetary gear unit, respectively, with three planet gears. For the planetary units, the sun gear is the input shaft, the ring gear is fixed and the planet arm is the output shaft. In the case of the non-stepped planetary unit, the number of teeth of the sun gear, planet gear, and ring gear are required. Figure 10 shows a mesh of an unstepped planetary gear unit. In the case of a stepped planetary unit, the number of teeth on the sun gear, planet-sun gear, planet-ring gear, and the ring gear are required. The planet-sun gear is defined as the planet gear meshing with the sun gear in a stepped planetary gear unit. The planet-ring gear is the planet gear meshing with the ring gear in a stepped planetary gear unit. Figure 11 shows a mesh of a stepped planetary
Twin Input Spiral Bevel Gear

Figure 7
Figure 8
Unstepped Planetary Gear Unit
Figure 9
Stepped Planetary Gear Unit
Figure 10
Unstepped Planetary Gear Unit Gear Mesh
Figure 11

Stepped Planetary Gear Unit Gear Mesh
gear unit. The diametral pitch of the gears in each mesh must be known to define the size of the planetary transmission. The diameter of the gears is found from the diametral pitch, $P_d$ and number of teeth, $N$.

$$D = \frac{N}{P_d}$$  \hspace{1cm} (9)

Due to the motion of the planetary arm carrying the planet gears, each component will not see the same number of load cycles as it would in a fixed axis reduction. Table 1 gives the relationship between one output revolution and the load cycle of each component [13]. The ratios in this table are found by a standard planetary gear motion analysis.

In all units, the mesh material strength must be known to calculate the dynamic capacity of the gear tooth. In the case of the bearings, catalog values of the dynamic capacities must be given. The Weibull exponents must be specified for each component. The load-life exponent must be specified for each gear. The program automatically assumes an exponent of 3.0 for ball bearings and an exponent of 3.333 for roller bearings [14].
TABLE 1
Ratio of the Number of Component Load Cycles
to One Output Shaft Revolution
Planetary Gear Unit

<table>
<thead>
<tr>
<th>Component</th>
<th>Non-Stepped</th>
<th>Stepped</th>
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<tbody>
<tr>
<td>Sun</td>
<td>n*R_r</td>
<td>n*(R_r*R_p)</td>
</tr>
<tr>
<td></td>
<td>R_s</td>
<td>(R_s*R_p)</td>
</tr>
<tr>
<td>Planet (Sun)</td>
<td>R_r</td>
<td>R_r</td>
</tr>
<tr>
<td></td>
<td>R_p</td>
<td>R_p</td>
</tr>
<tr>
<td>Planet (Ring)</td>
<td>R_r</td>
<td>R_r</td>
</tr>
<tr>
<td></td>
<td>R_p</td>
<td>R_p</td>
</tr>
<tr>
<td>Ring</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>Spider</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
COMPONENT LOADING

The load on each component can be calculated from the applied input torque and the geometry of the components. Due to the many configurations of bearing and gear location, no single formula can be used to calculate the component load. Instead, a series of steps is required to obtain the component load.

Spiral Bevel Gear Unit Loading

The loading on the spiral bevel gear units can be analyzed by calculating the force developed in the gear teeth. This force can be divided into three orthogonal components shown in figure 12.

These forces are the tangential load, $W_t$, which is produced by the torque on the gear shaft [12,14]. The radial load, $W_r$, and the axial load, $W_a$, are produced by the geometry of the gear teeth transmitting the tangential load. These loads are

$$W_t = \frac{T_0}{D_o \sin \Gamma_g}$$  \hspace{1cm} (10)

$$W_r = \frac{W_t \times (\tan \phi_n \times \cos \Gamma_g + \sin \psi \times \sin \Gamma_g)}{\cos \psi}$$  \hspace{1cm} (11)
Figure 12
Spiral Bevel Gear Forces
In equation 11 and 12, the sign of the last term changes with respect to the spiral hand, direction of gear rotation and whether the gear is driving or being driven. These equations are valid for a driving gear with a right hand spiral which is rotating clockwise. The equations are also good for a driving gear with a left hand spiral which is rotating counterclockwise. For a driven gear, the equations are valid for a right hand spiral gear driven counterclockwise and a left hand spiral gear driven clockwise. For the four other conditions with power flow in the opposite direction, the signs of the equations are switched.

\[ W_a = \frac{W_t \ast (\tan \phi_n \ast \sin \phi_g - \sin \psi \ast \cos \phi_g)}{\cos \psi} \]  

(12)

For a shaft angle of 90 degrees, the radial load of the pinion will be equal to the axial load of the gear. Also the axial load of the pinion will be equal to the radial load of the gear. Regardless of shaft angle, the tangential force will be equal on pinion and gear. Also, the total resultant tooth load on the pinion and the gear must be equal in all cases. The total resultant tooth load is given by:

\[ W_r = \frac{W_t \ast (\tan \phi_n \ast \cos \phi_g - \sin \psi \ast \sin \phi_g)}{\cos \psi} \]  

(13)

\[ W_a = \frac{W_t \ast (\tan \phi_n \ast \sin \phi_g + \sin \psi \ast \cos \phi_g)}{\cos \psi} \]  

(14)
\[ W_n = \sqrt{W_t^2 + W_r^2 + W_a^2} \]  

(15)

The three force components of the gear will transmit forces to the support bearings. In this analysis one bearing will take the thrust load, transmitted axially from the gear.

\[ F_t = W_a \]  

(16)

The radial forces on the bearings are a result of the moment produced by the axial load on the gear, and the radial and tangential loads. Bearing 1 is the bearing closest to the gear cone apex. Bearing 2 is the bearing furthest away from the cone apex.

**Bearing 1**

Tangential load

\[ F_{t1} = \frac{W_t \cdot B}{A + B} \]  

(17)

Radial Load

\[ F_{r1} = \frac{(W_a \cdot N_g / (2 \cdot P_d)) - W_r \cdot B}{A + B} \]  

(18)

Combined Radial Load

\[ F_{rT1} = \sqrt{F_{t1}^2 + F_{r1}^2} \]  

(19)

**Bearing 2**

Tangential load

\[ F_{t2} = \frac{W_t \cdot A}{A + B} \]  

(20)
Radial Load
\[ F_{r2} = \frac{\left( W_a \times N_g / (2 \times P_d) \right) + W_r \times A}{A + B} \]  

Combined Radial Load
\[ F_{rT2} = \sqrt{F_{t2}^2 + F_{r2}^2} \]  

These equations are good for any pinion and a gear loaded by one pinion. In the case of straddle mounted gear, distance A is considered to be positive. In the overhung case, distance A is considered negative. For the case of dual pinion input, each bearing carries two sets of tangential and radial loads which can be reduced into one tangential and radial load. The direction of the combined tangential and radial loads is taken to be the direction of the load from the contact with the right pinion. The resultant of these two orthogonal components is the total radial load on the bearing. The vectoral combination of the forces into one total radial load is shown in figure 13. The axial load on the bearing is the sum of the reactions of the right and left pinion axial gear forces. The total torque output from the gear is also the sum of the two pinion gear torques on the output gear.

Combined Radial Load
\[ F_R = F_{rr} + F_{r1} \cos \Lambda - F_{t1} \sin \Lambda \]  

Combined Tangential Load
\[ F_T = F_{tr} + F_{r1} \sin \Lambda + F_{t1} \cos \Lambda \]
Total Radial Load

\[ F_{RT} = \sqrt{F_R^2 + F_T^2} \]  

(25)

Planetary Gear Unit Loading

In the planetary gear unit all loads on the components are either tangential or radial. All loads are assumed to be acting in the same plane. It is assumed that each planet gear carries an equal amount of the input torque of the sun gear.

For the sun or planet gear, the tangential force on a tooth at each sun-planet gear mesh is:

\[ F_S = \frac{T_i}{n * R_S} \]  

(26)

The tangential force on a tooth of the ring or planet gear in each ring-planet mesh is:

\[ F_R = \left( \frac{R_{ps}}{R_{pr}} \right) \left( \frac{T_i}{n * R_S} \right) \]  

(27)

Figure 14 shows the loading on the planet gear from the sun-planet and ring-planet gear meshes. The total tangential force on the planet gear bearing is:

\[ F_{t} = F_R + F_S \]  

(28)
The bearing may also see a radial load due to the radial components produced by the pressure angle of the gear meshes.

\[ F_r = F_R \cdot \tan \phi_r - F_S \cdot \tan \phi_S \]  \hspace{1cm} (29)

The total load on the bearing is:

\[ F_T = \sqrt{F_t^2 + F_r^2} \]  \hspace{1cm} (30)
LIFE AND DYNAMIC CAPACITY

Life and Dynamic Capacity Models

Surface pitting fatigue from cyclic loading is the mode of failure for the components considered in this simulation program for the life of a helicopter transmission. Loaded surfaces of rolling element bearings and the gears, will fail due to surface pitting after a number of repeated loadings. The model used to predict failure which relates the number of load cycles at failure to the applied load is Palmgren's model. Palmgren's model was originally developed for rolling element bearings. It has also been applied to gear teeth in this computer simulation program. The Palmgren model is:

\[ l_{10} = \left( \frac{C}{F} \right)^p \]  

\( l_{10} \) is the life of the component in millions of load cycles for a 90 percent probability of survival [15,16]. \( F \) is the equivalent load on the component. \( C \), the basic dynamic capacity, is the reference load for which 90 percent of a large sample of the components will survive one million load cycles. The exponent \( p \) is called the load-life factor.
Equation 31 is the analytical expression for a load verses life diagram in which there is no endurance limit. Using the Palmgren-Minor linear damage rule and equation 31 an equivalent nominal load for a component in terms of a mission spectrum of loads can be obtained as:

\[
F = \left( \frac{F_a^p L_a + F_b^p L_b + \ldots}{L_a + L_b + \ldots} \right)^{1/p}
\]  

(32)

Where \( L_a \) is the life at load \( F_a \).

The model for component life as a function of load has been combined with the Weibull distribution for probability of survival as a function of life at a given load for ball and roller bearings [15,16] and for gear teeth [5-9]. The equation resulting from the combination describes the life and reliability as a function of the applied equivalent load. The two parameter Weibull distribution is:

\[
\log \left( \frac{1}{S} \right) = \log \left( \frac{1}{0.9} \right) \times \left( \frac{1}{110} \right)^e
\]  

(33)

Here, \( S \) is the reliability which is also the probability of survival. \( L \) is the component life at the reliability \( S \). \( L_{10} \) is the component life at 90 percent reliability, and \( e \) is the Weibull slope.
The transmission life and reliability models used in this program combine these models for the components with a strict series probability law that states that the probability of survival of the transmission is the product of the probabilities of survival of the components:

\[ S_T = S_1 \times S_2 \times S_3 \times ... \]  \hspace{1cm} (34)

This strict series probability law is justified on the basis of the high speed of the transmission components and the effect of loose debris. If any component fails, debris present in the transmission can accelerate wear damage of other components of the transmission. In the case of a transmission run until failure occurs in one component, a complete transmission overhaul is required. The complete overhaul is recommended to repair all components which could have been damaged by debris of the failed component. The overhaul would return the transmission to a high state of reliability.

Component Dynamic Capacity

Each bearing and gear in a transmission has a load which will cause ten percent of a large sample of these components to fail by pitting at or before one million load cycles. This is the component dynamic capacity.

The dynamic capacity for bearings, \( C_b \), can be obtained from the manufacturer of the bearing. The load-life exponent for rolling element
bearings are normally taken as \( p_b = 3.0 \) for ball bearings and as \( p_b = 3.33 \) for cylindrical and tapered roller bearings [19].

For gears, the dynamic capacity is not tabulated directly. The dynamic capacity of a gear tooth is proportional to the Hertzian contact pressure squared for applications in which the major axis of the contact ellipse is significantly larger than the minor axis. In spur gears there is line contact. With this proportionality, the dynamic capacity of a gear tooth, \( C_t \), can be expressed as:

\[
C_t = \frac{B_1 \cdot b}{\sum \rho}
\]

(35)

Where \( B_1 \) is the material constant, \( b \) is the length of the major axis of the contact ellipse or line contact and \( \sum \rho \) is the curvature sum in the direction of gear tooth rotation. The material constant, \( B_1 \), is the experimental load-stress factor, \( K_1 \) of Buckingham [17].

Component System Lives - Gears

To obtain the system life of a gear in a transmission the component life of a single tooth of the gear has to be calculated. The load cycles it sees must be adjusted to the output shaft rotations [18,19,20]. Gears with more than one loading are treated separately.

Using a strict series reliability model we can convert the reliability of a single gear tooth to the reliability of a gear.

\[
N_g = S_g = S_t
\]

(36)
Where, $S_g$ is the probability of survival of the gear, $S_t$ is the probability of survival of the gear tooth, $N_g$ is the number of teeth on the gear. If the reciprocal of this equation is taken, the result is:

\[
\left(\frac{1}{S_g}\right)^N_g = \left(\frac{1}{S_t}\right)
\]

(37)

Taking the natural logarithm of the equation:

\[
\log\left(\frac{1}{S_g}\right) = N_g \times \log\left(\frac{1}{S_t}\right)
\]

(38)

Substituting equation 33, which relates reliability to $l_{10}$ life, into equation 38 yields:

\[
\log\left(\frac{1}{0.9}\right) \times \left(\frac{L_g}{L_g10}\right)^{e_g} = N_g \times \log\left(\frac{1}{0.9}\right) \times \left(\frac{L_t}{L_t10}\right)^{e_g}
\]

(39)

Where, $L_g$ is the life of the gear, $L_g10$ is the 90 percent reliability of the gear, $L_t$ is the life of the gear tooth, $L_t10$ is the 90 percent reliability life of the gear tooth, and $e_g$ is the Weibull exponent of the gear. Cancelling terms and taking the equation to the $(1/e_g)$ power yields:

\[
\left(\frac{l_g}{l_g10}\right) = N_g \times \left(1/e_g\right) \times \left(\frac{l_t}{l_t10}\right)
\]

(40)
The equation relating gear tooth dynamic capacity and load to gear tooth life is:

\[ l_{t10} = \left( \frac{C_t}{W_n} \right)^{P_g} \]  

(41)

Where, \( C_t \) is the dynamic capacity of a gear tooth and \( W_n \) is the load on the gear tooth. This equation can be substituted into equation 40 to yield.

\[ \left( \frac{1}{l_{gl10}} \right)^{N_g} = \left( \frac{1}{l_{g10}} \right)^{(1/e_g)} \left( \frac{l_t}{C_t} \right)^{P_g} \]  

(42)

This equation relates gear life to tooth load. \( W_n \), is the normal tooth load on a single pinion input. When there is a dual pinion input to a gear an equivalent gear tooth load is used. Since the loads from the two pinions may differ, an equivalent load must be used to simulate the same fatigue damage as the two separate loads. To derive the equivalent load we use equation 32.

\[ F = \left( \frac{F_a^{P} L_a + F_b^{P} L_b}{L_a + L_b} \right)^{(1/p)} \]  

(43)

Substituting \( W_{n1} \), the right pinion normal load, and \( W_{n2} \), the left pinion normal load, and substituting, \( L \), for the number of cycles for each pinion.
\[ W_{ne} = \left( \frac{W_{n1}^p \ast L + W_{n2}^p \ast L}{L + L} \right) \]  
\[ \text{(1/p)} \]  

Cancel terms:

\[ W_{ne} = \left( \frac{W_{n1}^p + W_{n2}^p}{2.0} \right) \]  
\[ \text{(1/p)} \]  

This equivalent load is a weighted average of the two loads. \( W_{ne} \) is substituted for \( W_n \) in the dual input.

In equation 42 the gear tooth load cycles will not always equal the number of gear rotations. Also the gear rotations will not always equal the output shaft rotations. To get all components on the same counting base, a factor must be inserted. The relationship between output rotations, \( l_g \), and tooth load cycles, \( l_t \), is:

\[ l_g = \left( \frac{1}{m_g} \right) \ast l_t \]  
\[ \text{(46)} \]

The factor \( m_g \) is a combination ratio:

\[ m_g = m_1 \ast m_{g2} \]  
\[ \text{(47)} \]

Where, \( m_1 \) is the gear ratio from the unit output shaft to the final output shaft of the transmission, and \( m_{g2} \) is the ratio from tooth load cycles to the unit output shaft. \( m_{g2} \) can be found in table 2.
TABLE 2

Ratio Relating Gear Tooth Load Cycles to Unit Output Shaft Rotations

<table>
<thead>
<tr>
<th>Spiral Bevel</th>
<th>Single Input</th>
<th>Dual Input</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pinion</strong></td>
<td>$N_g$</td>
<td>$N_g$</td>
</tr>
<tr>
<td></td>
<td>$N_p$</td>
<td>$N_p$</td>
</tr>
<tr>
<td><strong>gear</strong></td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>planetary</strong></td>
<td>non-stepped</td>
<td>stepped</td>
</tr>
<tr>
<td><strong>sun</strong></td>
<td>$n*R_r$</td>
<td>$n*(R_r*R_s)$</td>
</tr>
<tr>
<td></td>
<td>$R_s$</td>
<td>$(R_s*R_pr)$</td>
</tr>
<tr>
<td><strong>planet</strong></td>
<td>$R_r$</td>
<td>$R_r$</td>
</tr>
<tr>
<td></td>
<td>$R_p$</td>
<td>$R_pr$</td>
</tr>
<tr>
<td><strong>ring</strong></td>
<td>$n$</td>
<td>$n$</td>
</tr>
</tbody>
</table>
If the factor \( m_g \) of equation 46, is substituted into equation 42 a relation to calculate gear life in output rotations from the gear tooth load is obtained.

\[
\log_{10} \left( \frac{1}{N_g} \right) \left( \frac{1}{m_g} \right) \left( \frac{C_t}{W_t} \right) = p_g
\]

(48)

There is one exception to this equation. In the case of a non-stepped planet gear in a planetary unit, the gear will mesh with two different gears. Since the planet gear meshes with two different gears, the life analysis must take into account the different levels of damage done in each gear mesh [19]. The probability of survival for the planet gear, \( S_p \), is the product of the probability of survival of the teeth in the planet-sun mesh, \( S_{ps} \) and the probability of survival of the teeth in the planet-ring mesh, \( S_{pr} \).

\[
S_p = S_{ps} \times S_{pr}
\]

(49)

The probabilities can be combined under one power, since the power of the two probabilities is the same.

\[
S_p = (S_{ps} \times S_{pr})^{N_p}
\]

(50)
Take the reciprocal of the equation

\[
\frac{1}{S_p} = \left( \frac{S_p}{S_{ps} \cdot S_{pr}} \right)^{N_p}
\]  

(51)

Take the logarithm

\[
\log \left( \frac{1}{S_p} \right) = N_p \cdot \log \left[ \frac{1}{\left( S_{ps} \cdot S_{pr} \right)} \right]
\]  

(52)

By expanding equation 52, the relation is seen to be similar to the Weibull distribution, equation 33:

\[
\log \left( \frac{1}{S_p} \right) = N_p \cdot \left[ \log \left( \frac{1}{S_{ps}} \right) + \log \left( \frac{1}{S_{pr}} \right) \right]
\]  

(53)

Substitute equation 33, relating reliability to L10 life into the expanded equation to yield:

\[
\log \left( \frac{1}{L_p} \right) = N_p \cdot \left[ \log \left( \frac{1}{L_{ps10}} \right) + \log \left( \frac{1}{L_{pr10}} \right) \right]
\]  

(54)

Where \( L_p \) and \( L_{pt} \) are the lives of the planet gear and planet gear tooth respectively. \( L_{ps10}, \ L_{ps10}, \) and \( L_{pr10} \) are the 90 percent probability of survival life of the planet gear, of a gear tooth in the planet-sun mesh, and of a gear tooth in the planet-ring mesh respectively. \( e_g \) is the gear Weibull exponent. Cancel terms and factor common terms:
Combine fractions:

\[
\left( \frac{L_p}{L_{p10}} \right)^{e_g} = N_p \times L_{pt} \times \left[ \frac{1}{L_{ps10}} + \frac{1}{L_{pr10}} \right]^{e_g}
\]

By taking the reciprocal and rearranging the terms the following relation is found:

\[
\left( \frac{L_{p10}}{L_p} \right)^{e_g} = N_p \times L_{pt} \times \left[ \frac{L_{pr10} \times L_{ps10}}{L_{ps10} \times L_{pr10}} \right]^{e_g}
\]

Take the equation to the \( e_g \)th root

\[
L_{p10} = \left( \frac{1}{N_p} \right)^{1/e_g} \times \left( \frac{L_p}{L_{pt}} \right)^{1/e_g} \times \left[ \frac{L_{pr10} \times L_{ps10}}{L_{ps10} \times L_{pr10}} \right]^{1/e_g}
\]

Sustitute the \( m_g \) factor for relating output revolutions to tooth load cycles.
Substitute equation 31 relating tooth life to tooth dynamic capacity and load.

\[
L_{p10} = \left( \frac{1}{N_p} \right) \left( \frac{1}{m_g} \right) \frac{L_{pr10} \ast L_{ps10}}{L_{ps10} + L_{pr10}} \left( \frac{1}{e_g} \right) \left( \frac{e_g}{L_{ps10}} \right) \left( \frac{1}{e_g} \right)
\]  

Where \( C_{pr} \) and \( C_{ps} \) are the dynamic capacities of a tooth in the planet-ring gear mesh and a tooth in the planet-sun gear mesh respectively. \( W_{pr} \) and \( W_{ps} \) are the load on a tooth in the planet-ring and planet-sun mesh respectively. \( p_g \) is the load-life exponent of the gear.

Component System Lives - Bearings

Using a similar approach to the gears [18,19,20], the relationship obtained for bearings is:

\[
\frac{L_{bs10}}{L_{b10}} = \frac{L_{bs}}{L_{b}} \tag{61}
\]
Where $L_b$ is the life of the bearing in terms of bearing cycles, $L_{bs}$ is the life of the bearing in terms of output shaft revolutions. $L_{b10}$ is the 90 percent reliability life in terms of bearing cycles. $L_{bs10}$ is the 90 percent reliability life in terms of output shaft revolutions. By substituting equation 31, which relates bearing life to bearing capacity and load, the relationship becomes:

$$\left(\frac{L_{bs}}{L_{bs10}}\right) = \left[\frac{L_b}{\left(\frac{C_b}{M_b}\right)^{P_b}}\right]$$

(62)

In equation 62 the bearing load cycles will not always equal the number of output shaft rotations. To get all components on the same counting base a factor must be inserted. The relationship relating output rotations, $L_{bs}$, and bearing load cycles, $L_b$, is:

$$L_{bs} = \left(\frac{1}{m_b}\right) * L_b$$

(63)

The factor $m_b$ is a combination ratio:

$$m_b = m_1 * m_{b2}$$

(64)

Where, $m_1$, is the gear ratio from the unit output shaft to the final output shaft of the transmission, and $m_{b2}$ is the ratio from bearing load cycles to the unit output shaft revolutions. $m_{b2}$ can be found in table 3.

If one substitutes factor $m_b$, equation 63, into equation 62 a relation is obtained which will calculate gear life in output shaft
TABLE 3

Ratio Relating Bearing Load Cycles to Unit Output Shaft Rotations

<table>
<thead>
<tr>
<th>Spiral bevel</th>
<th>single input</th>
<th>dual input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinion</td>
<td>( N_g )</td>
<td>( N_g )</td>
</tr>
<tr>
<td></td>
<td>( N_p )</td>
<td>( N_p )</td>
</tr>
<tr>
<td>Gear</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Planetary</td>
<td>non-stepped</td>
<td>stepped</td>
</tr>
<tr>
<td>Planet</td>
<td>( R_r )</td>
<td>( R_r )</td>
</tr>
<tr>
<td></td>
<td>( R_p )</td>
<td>( R_{pr} )</td>
</tr>
</tbody>
</table>
rotations from the gear tooth load. The equation for the bearings becomes:

\[
L_{bs10} = \left( \frac{1}{m_b} \right) \left( \frac{C_b}{F_b} \right)^{\frac{P_b}{(65)}}
\]

This equation gives the bearing life in terms of output rotations.

Component System Dynamic Capacities

The dynamic capacity of each component can now be expressed as an output torque. By taking the \( p \)th root of equation 31 and replacing the ratio of the component system capacity to the component equivalent load by the ratio of component system dynamic capacity to reduction output torque, the component system lives can be used to determine the component system dynamic capacities.

\[
D_i = \left( \frac{1}{p_i} \right) \left( L_{i10} \right) \ast (T_o)
\]

These dynamic capacities are in units of output torque and express the output torque of the reduction at which 90 percent of a set of similar components will survive for one million rotations.

Transmission Life

To calculate the life of the transmission, the probability of survival of the transmission is expressed as the product of the probabilities of survival of the components.
\[ S_T = \prod_{i=1}^{n} S_i \quad (67) \]

The reciprocal of the equation is:

\[ \frac{1}{S_T} = \prod_{i=1}^{n} \left( \frac{1}{S_i} \right) \quad (68) \]

Taking the natural logarithm of this equation:

\[ \log \left( \frac{1}{S_T} \right) = \log \left( \prod_{i=1}^{n} \left( \frac{1}{S_i} \right) \right) \quad (69) \]

Using the Weibull distribution equation relating life to probability of survival, equation 33, the preceding equation becomes:

\[ \log \left( \frac{1}{S_T} \right) = \log \left( \frac{1}{0.9} \right) + \sum_{i=1}^{n} \left( \frac{L_T}{L_{i10}} \right)^{e_i} \quad (70) \]

In this equation \( L_T \) is the life of each component and of the entire transmission for a transmission reliability of \( S_T \). This equation is not a strict Weibull relationship between transmission life and reliability. The equation would be a true Weibull distribution if all the Weibull exponents, \( e_i \), were equal. This is not true since Weibull exponents for gears and bearings will differ from each other significantly. This equation can be solved for \( S_T \) as a function of the transmission life, \( L_T \), and plotted on Weibull coordinates.
On this plot of percent probability of failure versus transmission, life a straight line can be fit to the model. Linear regression can be used to approximate the straight line. The range of this linear regression is for probability of survival between fifty and ninety-five percent. The slope of the straight line approximation is the transmission Weibull exponent $e_T$. The transmission life, $L_{T10}$, is the life calculated from the straight line approximation at a reliability $S_T = 0.9$. This $L_{T10}$ life is the life of the transmission at the given output torque. The equation using the transmission life $L_{T10}$ and Weibull exponent, $e_T$ is:

$$\log \left( \frac{1}{S_T} \right) = \log \left( \frac{1}{0.9} \right) \left( \frac{L_T}{L_{T10}} \right)^{e_T}$$ \hspace{1cm} (71)

Transmission Dynamic Capacity

The basic dynamic capacity for the transmission, $D_T$, is the output torque which will give a transmission life of one million output shaft rotations, at a reliability of 90 percent. Setting $S_T = 0.9$ in equation 69 yields:

$$\log \left( \frac{1}{0.9} \right) = \log \left( \frac{1}{0.9} \right) \sum_{i=1}^{n} \left( \frac{L_T}{L_{i10}} \right)^{e_i}$$ \hspace{1cm} (72)
By canceling terms the equation becomes:

\[ 1 = \sum_{i=1}^{n} \left( \frac{L_T}{L_{i10}} \right)^{\alpha_i} \]  

Expressing the Palmgren load-life model in terms of component system torques and lives:

\[ L_{i10} = \left( \frac{D_i}{T_o} \right)^{\rho_i} \]  

Substitute into equation 73

\[ 1 = \sum_{i=1}^{n} \left[ \left( \frac{D_T}{T_o} \right)^{\rho_i} \frac{D_i}{T_o}^{\rho_i} \right] \]  

Cancel terms and rearrange:

\[ 1 = \sum_{i=1}^{n} \left( \frac{D_T}{D_i} \right)^{\rho_i} \]  

This equation can be solved by iteration to obtain the transmission dynamic capacity, \( D_T \).

To find the load life exponent, a series of 90 percent reliability lives of the transmission are calculated at output torques between 10 and 100 percent of the dynamic capacity. The lives are plotted against torque on a log versus log plot. This curve can be approximated by a straight line. Using a linear regression, the slope and value of the function at one million cycles can be found. The negative reciprocal of the slope is the load life exponent for the
transmission. The value of the function at one million cycles will be the dynamic capacity of the transmission corresponding to the load life exponent. With the values from the linear regression, the load life relation for the transmission is given by:

\[ L_{T10} = \left( \frac{D_T}{T_0} \right)^{p_T} \]  

(77)

Where, \( D_T \) is the output torque for one million output rotations, \( p_T \) is the load-life exponent and \( L_{T10} \) is the 90 percent reliability life of the transmission.
PROGRAM USE

To use the program one must define the geometry of the transmission. One can run the program interactively or by batch file. To run the program interactively, one will have to answer the prompts (questions) with the proper information. If a mistake is made entering the information according to the prompts, all is not lost. After a series of questions, the value of the last few will be printed out. A prompt will ask if you wish to change any of the previous answers. If one answers yes, the program will return to the beginning of the section and then one can input the correct information.

The program will prompt the user with a list of eight types of transmissions which can be analyzed. The eight types of transmissions are shown in figure 15. Any one of these eight types can be analyzed. Once the type of transmission is chosen, the program will ask for information to define each gear unit making up the transmission. The inputs for spiral bevel gear units are asked for separately from the inputs for the planetary gear units.

The inputs required for the spiral bevel gear unit are divided into three main parts: the geometry of the gear mesh, the mounting of the bearings and gears, and the characteristics of the bearings. These three sets of inputs can be found in table 4, 5, and 6 respectively.
1. Spiral Bevel

2. Planetary

3. Spiral Bevel & Planetary

4. Spiral Bevel & Planetary & Planetary
## TABLE 4

Inputs to Define the Geometry of the Spiral Bevel Gear Unit Gear Mesh

1. Number of teeth of the pinion
2. Number of teeth of the gear
3. The Cone distance of the gear mesh (in)
4. Face width of the gear mesh (in)
5. Normal pressure angle (deg)
6. Spiral angle of the gear mesh (deg)
7. Spiral hand of the gear mesh
8. Shaft angle between the pinion shaft centerline and the gear shaft centerline (deg)
9. Shaft angle between dual pinion inputs (deg) (dual pinion inputs only)
10. Input speed of pinion shaft (rpm)
11a. Input torque of the pinion shaft (lb-in)
11b. Input torque of the right pinion shaft (lb-in)
     Input torque of the left pinion shaft (lb-in) (dual pinion inputs only)
12. Direction of input torque
13. Gear mesh material constant
14. Gear mesh Weibull exponent
15. Gear mesh Load-Life exponent

## TABLE 5

Inputs to Define the Mounting of the Spiral Bevel Gear Unit Bearings and Gears

1. The case of mounting - either straddle or overhung mounting
2. Distance A - Gear to bearing closest to the gear mesh apex
3. Distance B - Gear to bearing furthest from the gear mesh apex
4. The bearing which takes the thrust load
TABLE 6

Inputs to Define the Characteristics of the
Spiral Bevel Gear Unit Bearings

The bearings can be of the following types:

1. Single row ball bearings
2. Double row ball bearings
3. Single row roller bearings
4. Double row roller bearings
5. Single row tapered roller bearings
6. Double row tapered roller bearings

For types 1 and 2 - Single and Double row ball bearings the inputs required are:

1. Number of rolling elements in the bearing
2. Diameter of the rolling elements in the bearing (in)
3. Bearing contact angle (deg)
4. Basic dynamic capacity (lbs)
5. Rotational factor (inner race or outer race rotation)
6. Weibull exponent
7. Life adjustment factor

For types 3 and 4 - Single and Double row roller bearings the inputs required are:

1. Basic dynamic capacity (lbs)
2. Rotational factor (inner race or outer race rotation)
3. Weibull exponent
4. Life adjustment factor

For types 5 and 6 - Single and Double row tapered roller bearings the inputs required are:

1. Thrust ratio
2. Basic dynamic capacity (lbs)
3. Weibull exponent
4. Life adjustment factor
In the planetary gear unit, the inputs will be for either an unstepped planetary or a stepped planetary. The stepped planetary gear unit will require extra inputs to define the stepped planet gears. Inputs for a planetary gear unit are found in table 7.

In the program, the spiral bevel gear unit and planetary gear unit analysis are done in separate parts. The method of analysis is the same in both parts. First the geometry of the gears is completed from the information given and the geometric relations. Next the loads on each component of the unit are calculated. The life of the component is calculated from the load on the component and the load cycle ratio of the component. The dynamic capacity is then calculated for each component. From the calculated lives of the components, the life and the Weibull exponent of the transmission is found by iteration. The program next figures a series of transmission lives verses output torques between 10 and 100 percent transmission dynamic capacity. Using a linear approximation of the output load verses life of the transmission, the transmission dynamic capacity and load-life exponent is found. Figure 16 is a basic flow chart of the program. Appendix C contains the computer listing for the program.

In the output of the program one will find the complete dimensions of the gear meshes and the forces on the components. Also the component system lives and dynamic capacities are in the output. The transmission life and dynamic capacity are the final results produced by the program. Table 8 lists the format of the transmission analysis results.
<table>
<thead>
<tr>
<th>Inputs to Define the Geometry of the Planetary Gear Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basic dynamic capacity of planet bearing (lbs)</td>
</tr>
<tr>
<td>2. Rotational factor (inner race or outer race rotation)</td>
</tr>
<tr>
<td>3. Weibull exponent for the planet bearing</td>
</tr>
<tr>
<td>4. Load-life exponent for the planet bearing</td>
</tr>
<tr>
<td>5. Life adjustment factor for the planet bearing</td>
</tr>
<tr>
<td>6. Number of planet bearings</td>
</tr>
<tr>
<td>7. Is the diametral pitch the same for the sun and ring gear?</td>
</tr>
<tr>
<td>When the pitches are the same:</td>
</tr>
<tr>
<td>7a. Diametral pitch of the meshes</td>
</tr>
<tr>
<td>When the pitches are different:</td>
</tr>
<tr>
<td>7b. Diametral pitch of the sun-planet mesh</td>
</tr>
<tr>
<td>Diametral pitch of the ring-planet mesh</td>
</tr>
<tr>
<td>8. Is the pressure angle the same for the sun and ring gear?</td>
</tr>
<tr>
<td>When the pressure angle is the same:</td>
</tr>
<tr>
<td>8a. Pressure angle of the meshes (deg)</td>
</tr>
<tr>
<td>When the pressure angles are different:</td>
</tr>
<tr>
<td>8b. Pressure angle of the sun-planet mesh (deg)</td>
</tr>
<tr>
<td>Pressure angle of the ring-planet mesh (deg)</td>
</tr>
<tr>
<td>9. Number of teeth on the sun gear</td>
</tr>
<tr>
<td>10. Face width of the sun gear (in)</td>
</tr>
<tr>
<td>11. Weibull exponent for the sun-planet mesh</td>
</tr>
<tr>
<td>12. Load-life exponent for the sun-planet mesh</td>
</tr>
<tr>
<td>13. Material constant for the sun-planet mesh</td>
</tr>
<tr>
<td>14. Does the transmission have stepped planet gears?</td>
</tr>
<tr>
<td>When the planets are unstepped:</td>
</tr>
<tr>
<td>14a. Number of teeth on the unstepped planet gear</td>
</tr>
<tr>
<td>When the planets are stepped:</td>
</tr>
<tr>
<td>14b. Number of teeth on planet gear meshed with sun gear</td>
</tr>
<tr>
<td>Number of teeth on planet gear meshed with ring gear</td>
</tr>
<tr>
<td>15. Number of teeth on the ring gear</td>
</tr>
<tr>
<td>16. Face width of the ring-planet mesh (in)</td>
</tr>
<tr>
<td>17. Weibull exponent of the ring-planet mesh</td>
</tr>
<tr>
<td>18. Load-life exponent of the ring-planet mesh</td>
</tr>
<tr>
<td>19. Input torque (lb-in)</td>
</tr>
<tr>
<td>20. Input speed (rpm)</td>
</tr>
</tbody>
</table>
Pick type of transmission
1. Spiral Bevel
2. Planetary
3. Spiral Bevel + Planetary
4. Spiral Bevel + Planetary + Planetary
5. Dual Spiral Bevel
6. Dual Spiral Bevel + Planetary
7. Dual Spiral Bevel + Planetary + Planetary
8. Spiral Bevel + Dual Spiral Bevel + Planetary

Input: input shaft torque and speed

Input: geometry of gears

Check if geometry is correct; If not: re-enter gear geometry

Input: geometry of bearings

Check if geometry is correct; If not: re-enter bearing geometry

Figure 16
Computer Program Flow Chart
Complete calculation of geometry

Calculate output torque and speed of transmission

Calculate loads on the components

Calculate lives of the components

Calculate dynamic capacities of the components

Iterate for L5 to L50 lives of the transmission, and do a linear regression to find the L10 life and Weibull exponent of the transmission

Figure 16 continued

Computer Program Flow Chart
Estimate 10% of the dynamic capacity of the transmission

Start loop to calculate lives for torques between 10% and 100% of the dynamic capacity

Calculate loads on the components

Calculate lives of the components

Iterate for L5 to L50 lives of the transmission, and do a linear regression to find the L10 life of the transmission

Do a linear regression on life versus load to find the transmission dynamic capacity and load-life exponent

Figure 16 continued

Computer Program Flow Chart
Figure 16 continued

Computer Program Flow Chart
TABLE 8
Output of the Program

For each gear unit the following will be output:

1. The gear mesh geometry
2. The gear mounting geometry
3. The forces on the gears and bearings

For each component the following will be output:

1. Component system dynamic capacity
2. Component system load-life exponent
3. Component system life in output shaft rotations
4. Component system life in hours
5. Component system Weibull exponent

For the transmission the following will be output:

1. Transmission system dynamic capacity
2. Transmission system load-life exponent
3. Transmission system life in output shaft rotations
4. Transmission system life in hours
5. Transmission system Weibull exponent
NUMERICAL EXAMPLE

In the design of a transmission the components are sized from the power transfer requirement. The initial design does not consider the effects of the components on one another. The initial design contains some overdesigned and weak parts. One can change the parameters on the overdesigned and weak components to see the overall effect in the transmission.

In this example, the transmission being designed is a 320 horsepower single input helicopter transmission. The input speed is 6180 rpm and the output speed is 354 rpm. The $L_{10}$ life of the transmission is to be approximately 3500 hours at the rated power level.

The layout chosen for this transmission is a spiral bevel unit followed by an unstepped planetary unit, figure 17. The spiral bevel unit will produce a gear reduction of $3.736 : 1$. The input torque will be transferred through 95 degrees from an approximately horizontal input to a vertical output shaft. Table 9 lists the geometry of the spiral bevel unit. The planetary unit will produce a gear reduction of $4.66 : 1$ along the output shaft. Table 10 lists the geometry of the planetary unit. Appendix A shows how the input is entered into the program for this original design.
<table>
<thead>
<tr>
<th>Gear mesh geometry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of teeth on the pinion</td>
<td>19</td>
</tr>
<tr>
<td>Number of teeth on the gear</td>
<td>71</td>
</tr>
<tr>
<td>Cone distance</td>
<td>5.199 in.</td>
</tr>
<tr>
<td>Normal pressure angle</td>
<td>20. deg.</td>
</tr>
<tr>
<td>Face width</td>
<td>1.8 in.</td>
</tr>
<tr>
<td>Spiral angle</td>
<td>25 deg.</td>
</tr>
<tr>
<td>Clockwise rotation</td>
<td></td>
</tr>
<tr>
<td>Left hand spiral</td>
<td></td>
</tr>
<tr>
<td>Shaft angle</td>
<td>95 deg.</td>
</tr>
<tr>
<td>Gear mesh material constant</td>
<td>35000. psi</td>
</tr>
<tr>
<td>Gear mesh weibull exponent</td>
<td>2.5</td>
</tr>
<tr>
<td>Gear mesh load-life exponent</td>
<td>4.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pinion mounting</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Straddle mount with bearing 2 taking thrust load</td>
<td></td>
</tr>
<tr>
<td>Distance A</td>
<td>1.3 in.</td>
</tr>
<tr>
<td>Distance B</td>
<td>2.5 in.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pinion bearing 1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Single row roller bearing</td>
<td></td>
</tr>
<tr>
<td>Basic dynamic capacity</td>
<td>14000. lbs.</td>
</tr>
<tr>
<td>Rotational factor (inner race rotation)</td>
<td>1.0</td>
</tr>
<tr>
<td>Weibull exponent</td>
<td>1.5</td>
</tr>
<tr>
<td>Bearing life adjustment factor</td>
<td>2.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pinion bearing 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Double row ball bearing</td>
<td></td>
</tr>
<tr>
<td>Number of rolling elements</td>
<td>14</td>
</tr>
<tr>
<td>Diameter of rolling elements</td>
<td>.5625 in.</td>
</tr>
<tr>
<td>Contact angle</td>
<td>35 deg.</td>
</tr>
<tr>
<td>Basic dynamic capacity</td>
<td>25000. lbs</td>
</tr>
<tr>
<td>Rotational factor (inner race rotation)</td>
<td>1.0</td>
</tr>
<tr>
<td>Weibull exponent</td>
<td>1.5</td>
</tr>
<tr>
<td>Bearing life adjustment factor</td>
<td>2.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gear mounting</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhung mount with bearing 2 taking thrust load</td>
<td></td>
</tr>
<tr>
<td>Distance A</td>
<td>0.9 in.</td>
</tr>
<tr>
<td>Distance B</td>
<td>2.6 in.</td>
</tr>
</tbody>
</table>
Table 9 Continued

<table>
<thead>
<tr>
<th>Gear bearing 1</th>
<th>Gear bearing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single row roller bearing</td>
<td>Double row ball bearing</td>
</tr>
<tr>
<td>Basic dynamic capacity</td>
<td>20000 lbs</td>
</tr>
<tr>
<td>Rotation factor (inner race rotation)</td>
<td>1.0</td>
</tr>
<tr>
<td>Weibull exponent</td>
<td>1.5</td>
</tr>
<tr>
<td>Bearing life adjustment factor</td>
<td>2.5</td>
</tr>
<tr>
<td>Number of rolling elements</td>
<td>25</td>
</tr>
<tr>
<td>Diameter of rolling elements</td>
<td>.375 in.</td>
</tr>
<tr>
<td>Contact angle</td>
<td>27 deg.</td>
</tr>
<tr>
<td>Basic dynamic capacity</td>
<td>19076 lbs</td>
</tr>
<tr>
<td>Rotational factor (inner race rotation)</td>
<td>1.0</td>
</tr>
<tr>
<td>Weibull exponent</td>
<td>1.5</td>
</tr>
<tr>
<td>Bearing life adjustment factor</td>
<td>2.5</td>
</tr>
<tr>
<td>Description</td>
<td>Value</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Basic dynamic capacity of bearings</td>
<td>20895 lbs.</td>
</tr>
<tr>
<td>Bearing Life adjustment factor</td>
<td>2.5</td>
</tr>
<tr>
<td>Rotational factor (inner race rotation)</td>
<td>1.0</td>
</tr>
<tr>
<td>Weibull exponent</td>
<td>1.5</td>
</tr>
<tr>
<td>Load-life exponent</td>
<td>3.33</td>
</tr>
<tr>
<td>Number of planet bearings</td>
<td>3</td>
</tr>
<tr>
<td>Number of teeth on sun gear</td>
<td>27</td>
</tr>
<tr>
<td>Number of teeth on planet-sun gear</td>
<td>35</td>
</tr>
<tr>
<td>Number of teeth on planet-ring gear</td>
<td>35</td>
</tr>
<tr>
<td>Number of teeth on ring gear</td>
<td>99</td>
</tr>
<tr>
<td>Diametral pitch of sun gear mesh</td>
<td>8.8710</td>
</tr>
<tr>
<td>Diametral pitch of ring gear mesh</td>
<td>9.1429</td>
</tr>
<tr>
<td>Pressure angle of sun gear mesh</td>
<td>20 deg.</td>
</tr>
<tr>
<td>Pressure angle of ring gear mesh</td>
<td>14.0682 deg.</td>
</tr>
<tr>
<td>Face width of sun gear mesh</td>
<td>3.178 in.</td>
</tr>
<tr>
<td>Face width of ring gear mesh</td>
<td>2.540 in.</td>
</tr>
<tr>
<td>Weibull exponent of sun gear mesh</td>
<td>2.5</td>
</tr>
<tr>
<td>Weibull exponent of ring gear mesh</td>
<td>2.5</td>
</tr>
<tr>
<td>Load-life exponent of sun gear mesh</td>
<td>4.3</td>
</tr>
<tr>
<td>Load-life exponent of ring gear mesh</td>
<td>4.3</td>
</tr>
<tr>
<td>Material constant of sun gear mesh</td>
<td>20800. psi</td>
</tr>
<tr>
<td>Material constant of ring gear mesh</td>
<td>20800. psi</td>
</tr>
</tbody>
</table>
The program was run with the geometry described in table 9 and 10. The output of the program can be found in appendix B. The program first calculates the loading on each component in the transmission. This intermediate step of calculating the life of the components is useful to a designer. If the designer changes the geometry of the transmission the loads on the components will change. The change in loading of the component will change the life of the component without changing the dynamic capacities of the components.

After the intermediate step of calculating the loads, the program computes the life of each component. The dynamic capacity of each component is calculated next. The life and Weibull exponent is then calculated for the spiral bevel unit, planetary unit, and the total transmission. Finally the dynamic capacity and load life exponent is calculated for the spiral bevel unit, planetary unit, and the total transmission.

The intermediate calculation of life and dynamic capacity of the spiral bevel unit and the planetary unit are valuable since a change within one unit will not effect the components in the other unit. Therefore the effects of design change within a unit are readily observed.

The values of the total transmission life and dynamic capacity will help the designer determine the critical elements in the transmission by comparing the values for the transmission to the life and dynamic capacity of each unit. Table 11 shows the values of dynamic capacity, load-life exponent, life in output rotations, life in hours, and Weibull exponent for the initial design. By checking the values of
<table>
<thead>
<tr>
<th>Component</th>
<th>dynamic capacity</th>
<th>load-life exponent</th>
<th>life in output rotations</th>
<th>life in hours</th>
<th>Weibull exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spiral Bevel Unit</td>
<td>77,327</td>
<td>4.02</td>
<td>17*10E6</td>
<td>797</td>
<td>2.27</td>
</tr>
<tr>
<td>Input Pinion</td>
<td>79,215</td>
<td>4.3</td>
<td>20*10E6</td>
<td>957</td>
<td>2.5</td>
</tr>
<tr>
<td>Input Bearing 1</td>
<td>194,082</td>
<td>3.3</td>
<td>194*10E6</td>
<td>9,140</td>
<td>1.5</td>
</tr>
<tr>
<td>Input Bearing 2</td>
<td>446,909</td>
<td>3.0</td>
<td>1.469*10E9</td>
<td>69,124</td>
<td>1.5</td>
</tr>
<tr>
<td>Output Gear</td>
<td>95,272</td>
<td>4.3</td>
<td>44*10E6</td>
<td>2,111</td>
<td>2.5</td>
</tr>
<tr>
<td>Output Bearing 1</td>
<td>139,135</td>
<td>3.3</td>
<td>64*10E6</td>
<td>3,047</td>
<td>1.5</td>
</tr>
<tr>
<td>Output Bearing 2</td>
<td>163,966</td>
<td>3.0</td>
<td>72*10E6</td>
<td>3,413</td>
<td>1.5</td>
</tr>
<tr>
<td>Planetary Unit</td>
<td>136,760</td>
<td>3.43</td>
<td>70*10E6</td>
<td>3,370</td>
<td>1.509</td>
</tr>
<tr>
<td>Planet Bearing</td>
<td>175,807</td>
<td>3.3</td>
<td>147*10E6</td>
<td>6,929</td>
<td>1.5</td>
</tr>
<tr>
<td>Sun Gear</td>
<td>174,807</td>
<td>4.3</td>
<td>605*10E6</td>
<td>28,474</td>
<td>2.5</td>
</tr>
<tr>
<td>Ring Gear</td>
<td>3,970,348</td>
<td>4.3</td>
<td>415*10E12</td>
<td>19*10E9</td>
<td>2.5</td>
</tr>
<tr>
<td>Planet-Ring Gear</td>
<td>233,424</td>
<td>4.3</td>
<td>2.122*10E9</td>
<td>99,815</td>
<td>2.5</td>
</tr>
<tr>
<td>Planet-Sun Gear</td>
<td>4,433,816</td>
<td>4.3</td>
<td>668*10E12</td>
<td>31*10E9</td>
<td>2.5</td>
</tr>
<tr>
<td>Total Transmission</td>
<td>76,841</td>
<td>3.966</td>
<td>16*E6</td>
<td>758</td>
<td>2.2</td>
</tr>
</tbody>
</table>
the spiral bevel unit and planetary unit against the values for the total transmission, it can be seen that the spiral bevel unit values are very close to the transmission values. This is also illustrated in figure 18. The spiral bevel unit dominates the life and dynamic capacity of the total transmission. Therefore it is the weakest part of the transmission. By further examination it can be seen that the life and dynamic capacity of the spiral bevel unit is dominated by the input pinion and output gear. The value of these components are much lower than any other component in the system, therefore a redesign of the gear mesh would be recommended.

In this example the size of the spiral bevel gear mesh was increased. The size of the cone distance, $A_0$, was increased from 5.199 inches to 8.5 inches, and the face width, $f$, was increased from 1.8 inches to 3.5 inches. This redesign causes an increase in spiral bevel unit life of 400 percent and an increase in transmission life of 300 percent. The results of this redesign are shown in table 12. The life verses probability of failure graph for this case is shown in figure 19.

The life of the transmission is still less than the life required in the specifications. Since the life of the spiral bevel unit and planetary unit are about equal, the lives of both units will have to be increased. In the spiral bevel unit, the output bearings have the lowest life. In this case the dynamic capacity of the bearings are increased. For the planetary unit the planet bearings have the lowest life. There are two choices to increase the life of the planet bearing, either increase the number of planet bearings or
Figure 18
Life Versus Probability of Failure Design 1
## Table 12
Life and Dynamic Capacity of Transmission

Re-Design 1

<table>
<thead>
<tr>
<th>Component</th>
<th>dynamic capacity</th>
<th>load-life exponent</th>
<th>life in output rotations</th>
<th>life in hours</th>
<th>Weibull exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spiral Bevel Unit</td>
<td>156,406</td>
<td>3.15</td>
<td>78*10E6</td>
<td>3,631</td>
<td>1.5</td>
</tr>
<tr>
<td>Input Pinion</td>
<td>379,730</td>
<td>4.3</td>
<td>1.720*10E10</td>
<td>81*10E4</td>
<td>2.5</td>
</tr>
<tr>
<td>Input Bearing 1</td>
<td>292,227</td>
<td>3.3</td>
<td>750*10E6</td>
<td>35,278</td>
<td>1.5</td>
</tr>
<tr>
<td>Input Bearing 2</td>
<td>707,016</td>
<td>3.0</td>
<td>5.819*10E9</td>
<td>273,592</td>
<td>1.5</td>
</tr>
<tr>
<td>Output Gear</td>
<td>456,416</td>
<td>4.3</td>
<td>3.794*10E10</td>
<td>18*10E5</td>
<td>2.5</td>
</tr>
<tr>
<td>Output Bearing 1</td>
<td>177,080</td>
<td>3.3</td>
<td>143*10E6</td>
<td>6,754</td>
<td>1.5</td>
</tr>
<tr>
<td>Output Bearing 2</td>
<td>191,072</td>
<td>3.0</td>
<td>114*10E6</td>
<td>5,402</td>
<td>1.5</td>
</tr>
<tr>
<td>Planetary Unit</td>
<td>136,760</td>
<td>3.43</td>
<td>70*10E6</td>
<td>3,370</td>
<td>1.50</td>
</tr>
<tr>
<td>Planet Bearing</td>
<td>175,807</td>
<td>3.3</td>
<td>147*10E6</td>
<td>6,929</td>
<td>1.5</td>
</tr>
<tr>
<td>Sun Gear</td>
<td>174,807</td>
<td>4.3</td>
<td>605*10E6</td>
<td>28,474</td>
<td>2.5</td>
</tr>
<tr>
<td>Ring Gear</td>
<td>3,970,348</td>
<td>4.3</td>
<td>415*10E12</td>
<td>19*10E9</td>
<td>2.5</td>
</tr>
<tr>
<td>Planet-Ring Gear</td>
<td>233,424</td>
<td>4.3</td>
<td>2.122*10E9</td>
<td>99,815</td>
<td>2.5</td>
</tr>
<tr>
<td>Planet-Sun Gear</td>
<td>4,433,816</td>
<td>4.3</td>
<td>668*10E12</td>
<td>31*10E9</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>125,832</strong></td>
<td><strong>3.31</strong></td>
<td><strong>47*10E6</strong></td>
<td><strong>2,199</strong></td>
<td><strong>1.5</strong></td>
</tr>
</tbody>
</table>
Figure 19
Life Versus Probability of Failure Re-Design 1
increase the dynamic capacity of the bearings. In this case the number of bearings is increased. The life of the bearings will increase because the load on each bearing will be lower. This also increases the life of the other components in the planetary since the loads transmitted by each planet gear will be lower.

The results of this redesign are shown in table 13. The life verses probability of failure graph for this case is shown in figure 20. The modifications doubled the life of each unit. The life of the total transmission increased to 4500 hours which is above the design requirement of 3500 hours. By examining the Weibull and load-life exponents one can see that the design is dominated by the life of the bearings. The Weibull and load-life exponents are very close to the most common exponent values of bearings. This indicates that the life and dynamic capacity of the transmission are dominated by the bearings. This is a good test to find which components dominate the life of the transmission or any unit in the transmission.

The results of each following design run will give a great deal of information on which design changes can be based. These design changes will allow the designer to approach an optimal transmission design.
Table 13
Life and Dynamic Capacity of Transmission
Re-Design 2

<table>
<thead>
<tr>
<th>Component</th>
<th>dynamic load-life life in life in Weibull</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>capacity exponent output rotations hours exponent</td>
</tr>
<tr>
<td>Spiral Bevel Unit</td>
<td>190,350 3.19 153*10E6 7,208 1.5</td>
</tr>
<tr>
<td>Input Pinion</td>
<td>379,730 4.3 1.720<em>10E10 81</em>10E4 2.5</td>
</tr>
<tr>
<td>Input Bearing 1</td>
<td>292,227 3.3 750*10E6 35,278 1.5</td>
</tr>
<tr>
<td>Input Bearing 2</td>
<td>707,016 3.0 5.819*10E9 273,692 1.5</td>
</tr>
<tr>
<td>Output Gear</td>
<td>456,416 4.3 3.794<em>10E10 18</em>10E5 2.5</td>
</tr>
<tr>
<td>Output Bearing 1</td>
<td>212,497 3.3 262*10E6 12,328 1.5</td>
</tr>
<tr>
<td>Output Bearing 2</td>
<td>250,409 3.0 258*10E6 12,159 1.5</td>
</tr>
<tr>
<td>Planetary Unit</td>
<td>171,938 3.43 152*10E6 7,158 1.50</td>
</tr>
<tr>
<td>Planet Bearing</td>
<td>234,410 3.3 384*10E6 18,077 1.5</td>
</tr>
<tr>
<td>Sun Gear</td>
<td>217,442 4.3 1.564*10E9 73,578 2.5</td>
</tr>
<tr>
<td>Ring Gear</td>
<td>4,951,214 4.3 1.070<em>10E15 50</em>10E9 2.5</td>
</tr>
<tr>
<td>Planet-Ring Gear</td>
<td>311,232 4.3 7.312*10E9 343,900 2.5</td>
</tr>
<tr>
<td>Planet-Sun Gear</td>
<td>5,911,754 4.3 2.300<em>10E15 11</em>10E9 2.5</td>
</tr>
<tr>
<td>Total Transmission</td>
<td>156,765 3.32 96*10E6 4,526 1.5</td>
</tr>
</tbody>
</table>
Figure 20
Life Versus Probability of Failure Re-Design 2
DISCUSSION OF RESULTS

This computer program was developed to model the life and reliability of helicopter transmissions. The calculation of the life of a transmission is based on a strict series probability law. The strict series probability law states that the probability of survival of a transmission is the product of the probabilities of survival of all the components. The relationship between the probability of survival of a component and its life is the two parameter Weibull distribution. The resulting reliability model for the transmission is also a two parameter Weibull distribution.

The computer program is written in a modular form to model many different types of transmissions. In addition to results for the overall transmission, intermediate results for modules of the transmission are given.

Input to the computer program is to be given in an interactive format. The program prompts the user with questions which ask for the parameters required to describe the transmission. In this interactive format, a screen by screen review of the input data is provided to the user. If any data on the screen is incorrect, the user may return to the input stream at a point just prior to this screen to input this data correctly. If more than one design is to be
modeled at a time, an input data file may be used to speed up the use of the program. The user can change one parameter in a data file and quickly run the program again to determine the effects of this change on the components and the transmission.

The output of the computer program gives a complete overview of the transmission analysis. The geometry of the components entered into the program and the geometry calculated for the components are both printed out. Lives and dynamic capacities of the components are printed out in terms of component cycles and loads and in terms of system cycles and load. Each result listed in the output includes a title and the proper units.

By using the program in a systematic manner, a user can approach an optimal design. An example of this use is given in the proceeding chapter to illustrate the use of the program. Sample input and output listings are included in the first two appendices. The third appendix is a listing of the fortran source code for the program.
SUMMARY OF RESULTS

This report describes a computer simulation program which models the life and reliability of a helicopter transmission. The computer program uses the lives and reliabilities of the individual bearings and gears in the transmission to compute the life and reliability of the transmission. This model is a strict series probability model which is based on the pitting fatigue life and reliability models for the components of the transmission.

In this program, a modular approach is used in which the force and motion analyses of the transmission are separated from the life and reliability analyses. The dynamic capacity models are also separated algebraically from the prior calculations. In this way, the calculations can be performed sequentially and the complexity and diversity of the analyzed transmissions can be increased greatly.

The computer program can simulate a number of transmission configurations built up from spiral bevel gear units, a dual spiral bevel gear unit and stepped or unstepped planetary gear units. The eight transmission configurations analyzed by the program are:

1) a spiral bevel reduction,
2) a planetary reduction,
3) a spiral bevel reduction followed by a planetary reduction,
4) a spiral bevel reduction followed by two planetary reductions in series,
5) a dual spiral bevel reduction with two input pinions of equal size,
6) a dual spiral bevel unit followed by a single planetary reduction,
7) a dual spiral bevel unit followed by two planetary reductions in series, and
8) a dual spiral bevel unit followed by a planetary reduction and proceeded by two spiral bevel input reductions.

The program allows any planetary unit to be composed of stepped or unstepped planets. It can simulate transmission designs at different power levels and load duty cycles. The program can calculate the lives and dynamic capacities of a single unit or the transmission as a whole.

This report includes a development of the theory behind the program model, a listing of the program in fortran source code and examples illustrating the use of the program.
APPENDIX A

PROGRAM INPUT

HELIICOPTER TRANSMISSION ANALYSIS
ENTER THE NUMBER FOR THE TYPE OF TRANSMISSION
SPIRAL BEVEL......................................1
PLANETARY.........................................2
SPIRAL BEVEL + PLANETARY..........................3
SPIRAL BEVEL + PLANETARY + PLANETARY...........4
DUAL SPIRAL BEVEL..................................5
DUAL SPIRAL BEVEL + PLANETARY....................6
DUAL SPIRAL BEVEL + PLANETARY + PLANETARY.....7
SPIRAL BEVEL + DUAL SPIRAL BEVEL + PLANETARY...8

WHAT IS THE INPUT TORQUE OF THE TRANSMISSION
3262
WHAT IS THE INPUT SPEED OF THE TRANSMISSION
6180

SPIRAL BEVEL GEAR UNIT INPUTS

DO YOU WISH TO USE A DATA SET
ANSWER YES OR NO
NO
WHAT IS THE NUMBER OF TEETH ON THE PINION
19
WHAT IS THE NUMBER OF TEETH OF THE GEAR
71
WHAT IS THE CONE DISTANCE OF THE GEAR MESH
5.1999
WHAT IS THE NORMAL PRESSURE ANGLE (DEG)
20
WHAT IS THE FACE WIDTH OF THE GEAR MESH (IN)
1.8
WHAT IS THE SPIRAL ANGLE OF THE PINION
25
WHAT IS THE DIRECTION OF PINION ROTATION
LOOKING FROM THE APEX TO THE FACE OF THE PINION
(COUNTERCLOCKWISE INPUT 1)
(CLOCKWISE INPUT -1 )
-1
WHAT IS THE HAND OF THE SPIRAL ANGLE ON THE PINION
(RIGHT INPUT 1)
(LEFT INPUT -1)
-1
WHAT IS THE SHAFT ANGLE BETWEEN THE CENTER LINE OF THE
PINION SHAFT AND THE CENTER LINE OF THE GEAR SHAFT (DEG)
95
WHAT IS THE MESH MATERIAL CONSTANT (PSI)
35000
WHAT IS THE MESH WEIBULL EXPONENT
2.5
WHAT IS THE MESH LOAD-LIFE FACTOR
4.3
WHAT IS THE LIFE ADJUSTMENT FACTOR OF THE BEARINGS
2.5

NUMBER OF TEETH ON PINION 19.000
NUMBER OF TEETH ON GEAR 71.000
COE距ANCE 5.19990
NORMAL PRESSURE ANGLE 20.00000
FACE WIDTH 1.80000
SPIRAL ANGLE 25.00000
DIRECTION OF ROTATION -1.00000
HAND OF SPIRAL -1.00000
SHAFT ANGLE BETWEEN PINION AND GEAR 95.00000
GEAR MESH MATERIAL CONSTANT 35000.00000
WEIBULL EXPONENT 2.50000
MESH LOAD LIFE FACTOR 4.30000

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS
ENTER 1 TO CHANGE
0

PINION MOUNTING
WHICH CASE OF BEARING PLACEMENT IS BEING USED
CASE # 1
BEARING-------GEAR--------BEARING
 #1  #2
*------A--------*------B-------*

CASE # 2
GEAR--------BEARING-------BEARING
 #1  #2
*------A--------*
#--------B--------#
1
WHICH BEARING CARRIES THE THRUST LOAD
BEARING #1 OR BEARING #2
2
ENTER DISTANCE A - DISTANCE FROM * TO * (IN)  
1.3
ENTER DISTANCE B - DISTANCE FROM * TO * (IN) 
2.5

<table>
<thead>
<tr>
<th>CASE NUMBER</th>
<th>BEARING TAKING THE THRUST LOAD</th>
<th>DISTANCE A</th>
<th>DISTANCE B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1.3000</td>
<td>2.5000</td>
</tr>
</tbody>
</table>

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS  
ENTER 1 TO CHANGE 0

PINION BEARING #1  
TYPE OF BEARING - ENTER NUMBER  
1 - SINGLE ROW BALL BEARING  
2 - DOUBLE ROW BALL BEARING  
3 - SINGLE ROW ROLLER BEARING  
4 - DOUBLE ROW ROLLER BEARING  
5 - SINGLE ROW TAPERED ROLLER BEARING  
6 - DOUBLE ROW TAPERED ROLLER BEARING  

ENTER THE BASIC DYNAMIC CAPACITY OF BEARING  
14000  
ENTER THE ROTATION FACTOR  
1.0 FOR INNER RACE ROTATION  
1.2 FOR OUTER RACE ROTATION  
1.0  
WHAT IS THE WEIBULL EXPONENT FOR THE BEARING  
1.5

<table>
<thead>
<tr>
<th>TYPE OF BEARING</th>
<th>NUMBER OF ROLLING ELEMENTS</th>
<th>DIAMETER OF ROLLING ELEMENTS</th>
<th>CONTACT ANGLE (BALL BEARING ONLY)</th>
<th>RADIAL TO THRUST RATIO (TAPER ROLLER BEARING ONLY)</th>
<th>BASIC DYNAMIC CAPACITY</th>
<th>ROTATION FACTOR</th>
<th>WEIBULL EXPONENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>14000.00000</td>
<td>1.00000</td>
<td>1.50000</td>
</tr>
</tbody>
</table>

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS  
ENTER 1 TO CHANGE 0

PINION BEARING #2  
TYPE OF BEARING - ENTER NUMBER  
1 - SINGLE ROW BALL BEARING  
2 - DOUBLE ROW BALL BEARING  
3 - SINGLE ROW ROLLER BEARING  
4 - DOUBLE ROW ROLLER BEARING  
5 - SINGLE ROW TAPERED ROLLER BEARING  
6 - DOUBLE ROW TAPERED ROLLER BEARING  

2
NUMBER OF BALLS OR ROLLERS 14
DIAMETER OF BALLS OR ROLLERS 0.5625
BEARING CONTACT ANGLE 35
ENTER THE BASIC DYNAMIC CAPACITY OF BEARING 25000
ENTER THE ROTATION FACTOR
1.0 FOR INNER RACE ROTATION
1.2 FOR OUTER RACE ROTATION
1.
WHAT IS THE WEIBULL EXPONENT FOR THE BEARING 1.5

<table>
<thead>
<tr>
<th>TYPE OF BEARING</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER OF ROLLING ELEMENTS</td>
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<tr>
<td>DIAMETER OF ROLLING ELEMENTS</td>
<td>0.56250</td>
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<td>CONTACT ANGLE (BALL BEARING ONLY)</td>
<td>35.00000</td>
</tr>
<tr>
<td>RADIAL TO THRUST RATIO (TAPER ROLLER BEARING ONLY)</td>
<td>0.00000</td>
</tr>
<tr>
<td>BASIC DYNAMIC CAPACITY</td>
<td>25000.00000</td>
</tr>
<tr>
<td>ROTATION FACTOR</td>
<td>1.00000</td>
</tr>
<tr>
<td>WEIBULL EXPONENT</td>
<td>1.50000</td>
</tr>
</tbody>
</table>

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS
ENTER 1 TO CHANGE
0

GEAR MOUNTING
WHICH CASE OF BEARING PLACEMENT IS BEING USED
CASE # 1
BEARING------GEAR--------BEARING
#1 #2
*----A--------*----B--------*

CASE # 2
GEAR--------BEARING------BEARING
#1 #2
*----A--------*
#--------B--------#
2
WHICH BEARING CARRIES THE THRUST LOAD
BEARING #1 OR BEARING #2
2
ENTER DISTANCE A - DISTANCE FROM * TO * (IN) .9
ENTER DISTANCE B - DISTANCE FROM * TO * (IN) 2.6
| CASE NUMBER | 2 |
| BEARING TAKING THE THRUST LOAD | 2 |
| DISTANCE A | -0.9000 |
| DISTANCE B | 2.6000 |

Do you wish to change any of these parameters? Enter 1 to change.

0

PINION BEARING #1
Type of bearing - enter number
1 - Single Row Ball Bearing
2 - Double Row Ball Bearing
3 - Single Row Roller Bearing
4 - Double Row Roller Bearing
5 - Single Row Tapered Roller Bearing
6 - Double Row Tapered Roller Bearing

3

Enter the basic dynamic capacity of bearing 20000
Enter the rotation factor
1.0 for inner race rotation
1.2 for outer race rotation
1.0

What is the Weibull exponent for the bearing
1.5

| Type of bearing | 3 |
| Number of rolling elements | 0.00000 |
| Diameter of rolling elements | 0.00000 |
| Contact angle (Ball Bearing only) | -0.00000 |
| Radial to thrust ratio (Taper Roller Bearing only) | 0.00000 |
| Basic dynamic capacity | 20000.00000 |
| Rotation factor | 1.00000 |
| Weibull exponent | 1.50000 |

Do you wish to change any of these parameters? Enter 1 to change.

0

PINION BEARING #2
Type of bearing - enter number
1 - Single Row Ball Bearing
2 - Double Row Ball Bearing
3 - Single Row Roller Bearing
4 - Double Row Roller Bearing
5 - Single Row Tapered Roller Bearing
6 - Double Row Tapered Roller Bearing

2
NUMBER OF BALLS OR ROLLERS
25
DIAMETER OF BALLS OR ROLLERS
.375
BEARING CONTACT ANGLE
27
ENTER THE BASIC DYNAMIC CAPACITY OF BEARING
19076
ENTER THE ROTATION FACTOR
1.0 FOR INNER RACE ROTATION
1.2 FOR OUTER RACE ROTATION
1.
WHAT IS THE WEIBULL EXPONENT FOR THE BEARING
1.5

TYPE OF BEARING
2
NUMBER OF ROLLING ELEMENTS
25.00000
DIAMETER OF ROLLING ELEMENTS
0.37500
CONTACT ANGLE (BALL BEARING ONLY)
27.00000
RADIAL TO THRUST RATIO
(TAPER ROLLER BEARING ONLY)
0.00000
BASIC DYNAMIC CAPACITY
19076.00000
ROTATION FACTOR
1.00000
WEIBULL EXPONENT
1.50000

DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS
ENTER 1 TO CHANGE
0

PLANETARY GEAR UNIT INPUTS

DO YOU WISH TO USE A DATA FILE (YES OR NO)
NO

PLANETARY TRANSMISSION RELIABILITY ANALYSIS

(AALL NNUMERICAL INPUT MUST BE IN F-FORMAT)

WHAT IS THE BASIC DYNAMIC CAPACITY OF ONE PLANET BEARING? (LB)
20895

WHAT IS THE COMPOSITE LIFE ADJUSTMENT FACTOR?
2.5

WHAT IS THE OUTER RACE ROTATION FACTOR?
1.0

WHAT IS THE WEIBULL FACTOR FOR THE BEARINGS?
1.5

WHAT IS THE LOAD-LIFE FACTOR FOR THE BEARINGS?
3.33

HOW MANY PLANET BEARINGS ARE IN THE TRANSMISSION?
3
IS THE DIAMETRAL PITCH THE SAME FOR BOTH MESHES?
NO
ENTER THE DIAMETRAL PITCH OF THE SUN MESH FIRST,
THEN, ENTER THE DIAMETRAL PITCH OF THE RING MESH. (TEETH/IN)
8.8710
9.1429

HOW MANY TEETH DOES THE SUN GEAR HAVE ON IT?
27

IS THE PRESSURE ANGLE FOR THE SUN MESH AND
THE RING MESH THE SAME?
NO
ENTER THE PRESSURE ANGLE FOR THE SUN MESH FIRST,
THEN ENTER THE PRESSURE ANGLE OF THE RING MESH. (DEG)
20
14.0682

WHAT IS THE FACE WIDTH OF THE SUN MESH? (IN)
3.178

WHAT IS THE WEIBULL EXPONENT OF THE SUN MESH?
2.5

WHAT IS THE LOAD-LIFE FACTOR OF THE SUN MESH?
4.3

WHAT IS THE MATERIAL CONSTANT OF THE SUN MESH? (PSI)
20800

DOES THE TRANSMISSION HAVE STEPPED PLANETS?
YES
ENTER THE NUMBER OF TEETH ON ONE PLANET MESHED
WITH THE SUN, THEN ENTER THE NUMBER OF TEETH ON THE
PLANET MESHED WITH THE RING.
35
35

HOW MANY TEETH ARE ON THE RING GEAR?
99

WHAT IS THE FACE WIDTH OF THE RING GEAR MESH? (IN)
2.540

WHAT IS THE WEIBULL EXPONENT OF THE RING GEAR MESH?
2.5

WHAT IS THE LOAD-LIFE FACTOR OF THE RING GEAR MESH?
4.3

WHAT IS THE MATERIAL CONSTANT OF THE RING GEAR MESH? (TEETH/IN)
20800
## APPENDIX B

### PROGRAM OUTPUT

## SPIRAL BEVEL GEAR UNIT

### GEAR MESH CHARACTERISTICS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch</td>
<td>8.39</td>
</tr>
<tr>
<td>Normal Pressure Angle</td>
<td>20.00</td>
</tr>
<tr>
<td>Spiral Angle</td>
<td>25.00</td>
</tr>
<tr>
<td>Hand of the Spiral of the Pinion Gear</td>
<td>-1.00</td>
</tr>
<tr>
<td>Face Width</td>
<td>1.800 IN</td>
</tr>
<tr>
<td>Cone Distance</td>
<td>5.200 IN</td>
</tr>
<tr>
<td>Input Speed of the Pinion Shaft</td>
<td>6180.00 RPM</td>
</tr>
<tr>
<td>Output Speed of Gear Shaft</td>
<td>1653.80 RPM</td>
</tr>
<tr>
<td>Direction of Input Shaft Rotation</td>
<td>-1.00</td>
</tr>
<tr>
<td>Input Torque of the Pinion Shaft</td>
<td>3262.00 IN-LB</td>
</tr>
<tr>
<td>Output Torque of the Gear Shaft</td>
<td>12189.58 IN-LB</td>
</tr>
<tr>
<td>Angle Between Input and Output Shaft</td>
<td>95.00 DEG</td>
</tr>
</tbody>
</table>

### PINION CHARACTERISTICS AND MOUNTING

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Teeth</td>
<td>19.00</td>
</tr>
<tr>
<td>Pitch Angle</td>
<td>15.27 DEG</td>
</tr>
<tr>
<td>Pitch Diameter</td>
<td>2.26 IN</td>
</tr>
<tr>
<td>Reference Pitch Diameter</td>
<td>1.174 IN</td>
</tr>
<tr>
<td>Addendum</td>
<td>0.144 IN</td>
</tr>
<tr>
<td>Dedendum</td>
<td>0.230 IN</td>
</tr>
<tr>
<td>Forces on a Tooth in the Mesh</td>
<td></td>
</tr>
<tr>
<td>Axial Force</td>
<td>991.4 LB</td>
</tr>
<tr>
<td>Radial Force</td>
<td>-1469.9 LB</td>
</tr>
<tr>
<td>Tangential Force</td>
<td>-2881.0 LB</td>
</tr>
<tr>
<td>Total Force</td>
<td>3382.8 LB</td>
</tr>
<tr>
<td>Dynamic Capacity in Force</td>
<td>4712.7 LB</td>
</tr>
</tbody>
</table>
MOUNTING CHARACTERISTICS

<table>
<thead>
<tr>
<th>TYPE OF MOUNTING</th>
<th>DISTANCE A</th>
<th>DISTANCE B</th>
</tr>
</thead>
<tbody>
<tr>
<td>AXIAL LOAD</td>
<td>0.00 LBS</td>
<td></td>
</tr>
<tr>
<td>RADIAL LOAD</td>
<td>1262.43 LBS</td>
<td></td>
</tr>
<tr>
<td>TANGENTIAL LOAD</td>
<td>1895.38 LBS</td>
<td></td>
</tr>
<tr>
<td>TOTAL EQUIVALENT FORCE</td>
<td>2277.33 LBS</td>
<td>7771.4 LBS</td>
</tr>
</tbody>
</table>

BASIC DYNAMIC CAPACITY OF BEARING #1

| AXIAL LOAD       | 991.35 LBS |
| RADIAL LOAD      | 207.48 LBS  |
| TANGENTIAL LOAD  | 985.60 LBS  |
| TOTAL EQUIVALENT FORCE | 1665.07 LBS | 13084.3 LBS |

DYNAMIC CAPACITY IN FORCE

GEAR CHARACTERISTICS AND MOUNTING

<table>
<thead>
<tr>
<th>NUMBER OF TEETH</th>
<th>PITCH ANGLE</th>
<th>PITCH DIAMETER</th>
<th>REFERENCE PITCH DIAMETER</th>
<th>ADDENDUM</th>
<th>DEPENDUM</th>
<th>FORCES ON A TOOTH IN THE MESH</th>
</tr>
</thead>
<tbody>
<tr>
<td>71.00</td>
<td>79.73 DEG</td>
<td>8.46 IN</td>
<td>23.738 IN</td>
<td>0.058 IN</td>
<td>0.172 IN</td>
<td>AXIAL FORCE -1377.9 LB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RADIAL FORCE 1115.7 LB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TANGENTIAL FORCE -2881.0 LB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TOTAL FORCE 3382.8 LB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DYNAMIC CAPACITY IN FORCE 5664.4 LB</td>
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</tbody>
</table>

MOUNTING CHARACTERISTICS

<table>
<thead>
<tr>
<th>TYPE OF MOUNTING</th>
<th>DISTANCE A</th>
<th>DISTANCE B</th>
</tr>
</thead>
<tbody>
<tr>
<td>AXIAL LOAD</td>
<td>0.00 LBS</td>
<td></td>
</tr>
<tr>
<td>RADIAL LOAD</td>
<td>-5135.78 LBS</td>
<td></td>
</tr>
<tr>
<td>TANGENTIAL LOAD</td>
<td>4406.21 LBS</td>
<td></td>
</tr>
<tr>
<td>TOTAL EQUIVALENT FORCE</td>
<td>6766.90 LBS</td>
<td>16553.4 LBS</td>
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</table>

BASIC DYNAMIC CAPACITY OF BEARING #1

89
<table>
<thead>
<tr>
<th>Load Type</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>AXIAL LOAD</td>
<td>-1377.92 LBS</td>
</tr>
<tr>
<td>RADIAL LOAD</td>
<td>4020.09 LBS</td>
</tr>
<tr>
<td>TANGENTIAL LOAD</td>
<td>-1525.23 LBS</td>
</tr>
<tr>
<td>TOTAL EQUIVALENT FORCE</td>
<td>5374.48 LBS</td>
</tr>
<tr>
<td>BASIC DYNAMIC CAPACITY OF BEARING #2</td>
<td>15492.9 LBS</td>
</tr>
</tbody>
</table>

**DYNAMIC CAPACITY IN FORCE**

**DYNAMIC CAPACITY AND LIFE IN TERMS OF OUTPUT TORQUE AND SPEED**

**INPUT PINION**

<table>
<thead>
<tr>
<th>Dynamic Capacity</th>
<th>79248.2031 LB-IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Life Exponent</td>
<td>4.3000</td>
</tr>
<tr>
<td>Life in Million Output Rotations</td>
<td>4.1608</td>
</tr>
<tr>
<td>Life in Hours</td>
<td>195.6793</td>
</tr>
<tr>
<td>Weibull Exponent</td>
<td>2.5000</td>
</tr>
</tbody>
</table>

**INPUT BEARING #1**

<table>
<thead>
<tr>
<th>Dynamic Capacity</th>
<th>194120.0313 LB-IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Life Exponent</td>
<td>3.3000</td>
</tr>
<tr>
<td>Life in Million Output Rotations</td>
<td>57.4310</td>
</tr>
<tr>
<td>Life in Hours</td>
<td>2700.9629</td>
</tr>
<tr>
<td>Weibull Exponent</td>
<td>1.5000</td>
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</table>

**INPUT BEARING #2**

<table>
<thead>
<tr>
<th>Dynamic Capacity</th>
<th>447005.4375 LB-IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Life Exponent</td>
<td>3.0000</td>
</tr>
<tr>
<td>Life in Million Output Rotations</td>
<td>485.2344</td>
</tr>
<tr>
<td>Life in Hours</td>
<td>22820.4141</td>
</tr>
<tr>
<td>Weibull Exponent</td>
<td>1.5000</td>
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</tbody>
</table>

**OUTPUT GEAR**

<table>
<thead>
<tr>
<th>Dynamic Capacity</th>
<th>95251.9375 LB-IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Life Exponent</td>
<td>4.3000</td>
</tr>
<tr>
<td>Life in Million Output Rotations</td>
<td>9.1765</td>
</tr>
<tr>
<td>Life in Hours</td>
<td>431.5667</td>
</tr>
<tr>
<td>Weibull Exponent</td>
<td>2.5000</td>
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</table>

**OUTPUT BEARING #1**

<table>
<thead>
<tr>
<th>Dynamic Capacity</th>
<th>139153.4688 LB-IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Life Exponent</td>
<td>3.3000</td>
</tr>
<tr>
<td>Life in Million Output Rotations</td>
<td>19.1445</td>
</tr>
<tr>
<td>Life in Hours</td>
<td>900.3616</td>
</tr>
<tr>
<td>Weibull Exponent</td>
<td>1.5000</td>
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</table>
### OUTPUT BEARING #2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Capacity</td>
<td>163979.9688 LB-IN</td>
</tr>
<tr>
<td>Load Life Exponent</td>
<td>3.0000</td>
</tr>
<tr>
<td>Life in Million Output Rotations</td>
<td>23.9544</td>
</tr>
<tr>
<td>Life in Hours</td>
<td>1126.5688</td>
</tr>
<tr>
<td>Weibull Exponent</td>
<td>1.5000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Torque</td>
<td>12189.58008 LB-IN</td>
</tr>
<tr>
<td>Output Torque</td>
<td>56884.71094 LB-IN</td>
</tr>
<tr>
<td>Input Speed</td>
<td>1653.80273 RPM</td>
</tr>
<tr>
<td>Output Speed</td>
<td>354.38629 RPM</td>
</tr>
</tbody>
</table>

### PLANET BEARING

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Planets</td>
<td>3.000000</td>
</tr>
<tr>
<td>Rotational Factor</td>
<td>1.000000</td>
</tr>
<tr>
<td>Dynamic Capacity (Catalog Value)</td>
<td>20895.00000 LBS</td>
</tr>
<tr>
<td>Dynamic Capacity (System Value)</td>
<td>20107.14844 LBS</td>
</tr>
<tr>
<td>Total Force</td>
<td>5421.77441 LBS</td>
</tr>
</tbody>
</table>

### SUN GEAR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Teeth</td>
<td>27.000000</td>
</tr>
<tr>
<td>Pitch of the Mesh</td>
<td>8.87100</td>
</tr>
<tr>
<td>Pressure Angle</td>
<td>20.00000 DEG</td>
</tr>
<tr>
<td>Face Width</td>
<td>3.17800 IN</td>
</tr>
<tr>
<td>Material Constant of the Mesh</td>
<td>20800.00000 PSI</td>
</tr>
<tr>
<td>Dynamic Capacity</td>
<td>8184.11816 LBS</td>
</tr>
<tr>
<td>Force on Gear Tooth</td>
<td>2669.96924 LBS</td>
</tr>
</tbody>
</table>

### RING GEAR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Teeth</td>
<td>99.00000</td>
</tr>
<tr>
<td>Pitch of the Mesh</td>
<td>9.14290</td>
</tr>
<tr>
<td>Pressure Angle</td>
<td>14.06820 DEG</td>
</tr>
<tr>
<td>Face Width</td>
<td>2.54000 IN</td>
</tr>
<tr>
<td>Material Constant of the Mesh</td>
<td>20800.00000 PSI</td>
</tr>
<tr>
<td>Dynamic Capacity</td>
<td>19206.60547 LBS</td>
</tr>
<tr>
<td>Force on Gear Tooth</td>
<td>2751.80518 LBS</td>
</tr>
</tbody>
</table>
### PLANET GEAR

**PLANET-SUN GEAR**

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NUMBER OF TEETH</strong></td>
<td>35.00000</td>
</tr>
<tr>
<td><strong>PITCH OF THE MESH</strong></td>
<td>8.87100</td>
</tr>
<tr>
<td><strong>PRESSURE ANGLE</strong></td>
<td>20.00000 DEG</td>
</tr>
<tr>
<td><strong>FACE WIDTH</strong></td>
<td>3.17800 IN</td>
</tr>
<tr>
<td><strong>MATERIAL CONSTANT OF THE MESH</strong></td>
<td>20800.00000 PSI</td>
</tr>
<tr>
<td><strong>DYNAMIC CAPACITY</strong></td>
<td>10956.11523 LBS</td>
</tr>
<tr>
<td><strong>FORCE ON GEAR TOOTH</strong></td>
<td>2669.96924 LBS</td>
</tr>
</tbody>
</table>

**PLANET-RING GEAR**

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NUMBER OF TEETH</strong></td>
<td>35.00000</td>
</tr>
<tr>
<td><strong>PITCH OF THE MESH</strong></td>
<td>9.14290</td>
</tr>
<tr>
<td><strong>PRESSURE ANGLE</strong></td>
<td>14.06820 DEG</td>
</tr>
<tr>
<td><strong>FACE WIDTH</strong></td>
<td>2.54000 IN</td>
</tr>
<tr>
<td><strong>MATERIAL CONSTANT OF THE MESH</strong></td>
<td>20800.00000 PSI</td>
</tr>
<tr>
<td><strong>DYNAMIC CAPACITY</strong></td>
<td>21448.64063 LBS</td>
</tr>
<tr>
<td><strong>FORCE ON GEAR TOOTH</strong></td>
<td>2751.80518 LBS</td>
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### DYNAMIC CAPACITY AND LIFE IN TERMS OF OUTPUT TORQUE AND SPEED

**PLANET BEARING**

<table>
<thead>
<tr>
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<th>Value</th>
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<tbody>
<tr>
<td><strong>DYNAMIC CAPACITY</strong></td>
<td>210962.1875 LB-IN</td>
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<tr>
<td><strong>LOAD LIFE EXPONENT</strong></td>
<td>3.3300</td>
</tr>
<tr>
<td><strong>LIFE IN MILLION OUTPUT ROTATIONS</strong></td>
<td>78.6079</td>
</tr>
<tr>
<td><strong>LIFE IN HOURS</strong></td>
<td>3696.9014</td>
</tr>
<tr>
<td><strong>WEIBULL EXPONENT</strong></td>
<td>1.5000</td>
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**SUN GEAR**

<table>
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<tr>
<td><strong>DYNAMIC CAPACITY</strong></td>
<td>174365.7500 LB-IN</td>
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<tr>
<td><strong>LOAD LIFE EXPONENT</strong></td>
<td>4.3000</td>
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<tr>
<td><strong>LIFE IN MILLION OUTPUT ROTATIONS</strong></td>
<td>123.5385</td>
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<tr>
<td><strong>LIFE IN HOURS</strong></td>
<td>5809.9727</td>
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<tr>
<td><strong>WEIBULL EXPONENT</strong></td>
<td>2.5000</td>
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<tr>
<td>Component</td>
<td>Dynamic Capacity</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------</td>
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<tr>
<td>RING GEAR</td>
<td>397034.7500 LB-IN</td>
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<tr>
<td>PLANET-SUN GEAR</td>
<td>233424.2188 LB-IN</td>
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<tr>
<td>PLANET-RING GEAR</td>
<td>443381.5625 LB-IN</td>
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<tr>
<td>SPIRAL BEVEL UNIT</td>
<td>77358.9844 LB-IN</td>
</tr>
<tr>
<td>PLANETARY UNIT</td>
<td>153544.4688 LB-IN</td>
</tr>
<tr>
<td>TOTAL TRANSMISSION</td>
<td>77164.9063 LB-IN</td>
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APPENDIX C

PROGRAM LISTING

WRITE(1,10)
FORMAT(//
1' HELICOPTER TRANSMISSION ANALYSIS'/
2' ENTER THE NUMBER FOR THE Type OF TRANSMISSION'/
3' SPIRAL BEVEL........................................... 1'/
4' PLANETARY............................................. 2'/
5' SPIRAL BEVEL + PLANETARY.......................... 3'/
6' SPIRAL BEVEL + PLANETARY + PLANETARY........... 4'/
7' DUAL SPIRAL BEVEL.................................... 5'/
8' DUAL SPIRAL BEVEL + PLANETARY.................... 6'/
9' DUAL SPIRAL BEVEL + PLANETARY + PLANETARY....... 7'/
1' SPIRAL BEVEL + DUAL SPIRAL BEVEL + PLANETARY... 8'/)
READ(1,*)NT
IF(NT.EQ.1)CALL SPBV
IF(NT.EQ.2)CALL PLAN
IF(NT.EQ.3)CALL SBPL
IF(NT.EQ.4)CALL SBPLPL
IF(NT.EQ.5)CALL DPBV
IF(NT.EQ.6)CALL DBPL
IF(NT.EQ.7)CALL DBPLPL
IF(NT.EQ.8)CALL SBDBPL
STOP
END
SUBROUTINE SPBV
INTEGER CASEP,CASEG,PTL,GTL
REAL NP,NG,NBP1,NBP2,NBG1,NBG2, MG, MG1, L SB
REAL L1(6), D1(6), E1(6), H1(6), P1(6), DYN(10), LI(10)

101 FORMAT('WHAT IS THE INPUT TORQUE OF THE TRANSMISSION')
102 FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
WRITE(1,101)
READ(1,*)TI
WRITE(1,102)
READ(1,*)SI

INPUT SPIRAL BEVEL GEAR GEOMETRY

CALL SPBVIN(NP, NG, AO, PHE, F, PHSI, RQT, SPR, THETA, E, E1(1), PG,
1PHE1, PHSI1, THETA1, CASEP, PTL, AP, BP, ITYPEP1, NBP1, DP1, ACPI, AK1,
2BCAP1, RFP1, E1(2), ITYPEP2, NBP2, DP2, ACPI2, AK2, BDCAP2, RFPP2, E1(3),
3CASEG, GTL, AG, BG, ITYPEG1, NBG1, DG1, ACQ1, AK3, BDCAG1, RFG1, E1(5),
4ITYPEG2, NBG2, DG2, ACQ2, AK4, BDCAG2, RFG2, E1(6), MG, GAMMA1, GAMMA, ZZ,
5Z1, DP, DG, RP, RP, RG, HK, AOG, AOP, HT, BOG, BOP, PITCH,
6ADJP1, ADJP2, ADJP1, ADJP2)
EI(4)=EI(1)
P1(1)=PG
P1(4)=PG

CALCULATE OUTPUT TORQUE AND SPEED OF TRANSMISSION

TOF=TI*MG
SOF=SI/MG
MG1=1.0

CALCULATE LIVES AND DYNAMIC CAPACITIES OF SPIRAL BEVEL COMPONENTS AND LIFE OF THE TRANSMISSION

CALL SPBVCA(
1TI, TOF, SI, SOF, MG, MG1, NP, NG,
2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1,
3PTL, AP, BP, RP, GTL, AG, BG, RG,
4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
6ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2,
8F, E, PG, E1(1), RPD, RGD,
9PXP, PYP, PZP, TOTFOR, PXG, PYG, PZG, TOTFOR,
1R1XP, R1YP, R1ZP, R2XP, R2YP, R2ZP,
2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
3L1(2), H1(2), TOFORP1, P1(2), BDCAP10, D1(2),
4L1(3), H1(3), TOFORP2, P1(3), BDCAP20, D1(3),
5L1(5), H1(5), TOFORG1, P1(5), BDCAG10, D1(5),
6L1(6), H1(6), TOFORG2, P1(6), BDCAG20, D1(6),
7L1(1), H1(1), DCAP, D1(1),
8L1(4), H1(4), DCAG, D1(4),
9LSB, HSB, ESB)

PRINT OUT LIVES AND DYNAMIC CAPACITIES OF COMPONENTS

CALL SPBVOT(PD, PHE, PHSI, SPR, F, AO, SI, SOF, ROT, TI, TOF, THETA,
1NP, GAMMA, DP, RPD, AOP, BOP, PITCH,
2PXP, PYP, PZP, TOTFOR, DCAP, CASEP, AP, BP,
3R1XP, R1YP, R1ZP, TOFORP1, BDCAP10,
4R1XG, R1YG, R1ZG, TOFORP2, BDCAP20,
5NG, ZZ, DG, RGD, AOG, BOG,
6PXG, PYG, PZG, TOTFOR, DCAG, CASEG, AG, BG,
7R1XG, R1YG, R1ZG, TOFORG1, BDCAG10,
8R2XG, R2YG, R2ZG, TOFORG2, BDCAG20,
C
C ESTIMATE 10 PERCENT DYNAMIC CAPACITY OF TRANSMISSION
C
DMIN=D1(1)
DO 10 I=2,6
10 IF(D1(I).LT.DMIN)DMIN=D1(I)
DELTATO=.1*DMIN
DELTATI=DELTATO/MG
DTI=0.0
DTO=0.0
C
C START COUNTER FOR DYNAMIC CAPACITIES BETWEEN 10 AND 100 PERCENT
C OF TRANSMISSION DYNAMIC CAPACITY
C
DO 20 I=1,10
   DTI=DTI+DELTATI
   DTO=DTO+DELTATO
   DYN(I)=DTO
C
C CALCULATE LIFE FOR EACH DYNAMIC CAPACITY
C
CALL SPBVCA(1DTI,DTO,SI,SOF,MG,MG1,NP,NG,
2AO,GAMMA1,ROT,SPR,PHE1,PHE1I,ZZ1,
3PTL,AP,BP,RP,GTL,AG,BG,RG,
4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
6ITYPEG1,RFG1,NG1,DO1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
7ITYPEG2,RFG2,NG2,DO2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
8F,E,P,G,E1(1),RDP,RGD,
9PXP,PYP,PZP,TOTFOR,PXG,PYG,PZG,TOTFOR,
1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
3L1(2),H1(2),TOTFORP1,P1(2),BDCAP10,D1(2),
4L1(3),H1(3),TOTFORP2,P1(3),BDCAP20,D1(3),
5L1(5),H1(5),TOTFORG1,P1(5),BDCAG10,D1(5),
6L1(6),H1(6),TOTFORG2,P1(6),BDCAG20,D1(6),
7L1(1),H1(1),DCAP,D1(1),
8L1(4),H1(4),DCAG,D1(4),
9L1(I),HSB1,ESB1)
20 CONTINUE
C
C CALCULATE DYNAMIC CAPACITY AND LOAD LIFE EXPONENT FOR TRANSMISSION
C
CALL CAP(DYN, LI, 10, DSB, PSP)
C PRINT OUT LIFE AND DYNAMIC CAPACITY OF TRANSMISSION
C WRITE(1,1220)
1220 FORMAT(' TOTAL TRANSMISSION')
CALL DPLHE(DSB, PSP, LSB, HSB, ESB)
STOP
END
SUBROUTINE SBPL
INTEGER CASEP, CASEG, PTL, GTL
REAL NP, NG, NBP1, NBP2, NBG1, NBG2, MG, LSB
REAL LI(10), D1(6), E1(6), H1(6), P1(6), DYN(10), LI(10)
REAL NS, NPS, NPSR, NSR, N. LS, LR, LPLAN
REAL NCOMP(5), AD1(5), AP1(5), AL1(5), AH1(5), AE1(5), AL1(10)
REAL MGS, MGP, ZNCOMP(11), ZE1(11), ZL1(11), LTRANS, ZLI(10)
101 FORMAT(' WHAT IS THE INPUT TORQUE OF THE TRANSMISSION')
102 FORMAT(' WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
WRITE(1,101)
READ(1,*) TI
WRITE(1,102)
READ(1,*) SI
C READ IN VALUES OF THE SPIRAL BEVEL UNIT
C
CALL SPBVIN(NP, NG, AO, PHE, F, PHSI, ROT, SPR, THETA, E, E1(1), PG,
1PHE1, PHSI1, THETA1, CASEP, PTL, AP, BP, IYPEP1, NBP1, DP1, ACP1, AK1,
2BDACP1, RF1, E1(2), IYPEP2, NBP2, DP2, ACP2, AK2, BDACP2, RF2, E1(3),
3CASEG, GTL, AG, BG, IYPEG1, NBG1, DG1, AGC1, AK3, BDAG1, RFG1, E1(5),
4IYPEG2, NBG2, DG2, AGC2, AK4, BDAG2, RFG2, E1(6), MG, GAMMA1, GAMMA, ZZ,
5ZI, DP, DG, RPD, RP, RGD, RG, HK, ADG, ADP, HT, BOG, BOP, PITCH,
6ADJP1, ADJP2, ADJG1, ADJG2)
C
E1(4)=E1(1)
P1(1)=PG
P1(4)=PG
C CALCULATE OUTPUT TORQUE AND SPEED OF SPIRAL BEVEL UNIT
C TOS=TI*MG
SOS=SI/MG
C READ IN VALUES OF PLANETARY UNIT
C
CALL PLANIN(CB, A, V, EB, PB, N, NCOMP, PDS, PDR, NS, PHIS, PHIS1,
CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT

TOF = TOS * (1. + (RR * RPS) / (RS * RPR))
SOF = SOS / (1. + (RR * RPS) / (RS * RPR))
MGS = (1. + (RR * RPS) / (RS * RPR))
MGP = 1.0
INC = 6 + ISTEP
DO 5 IN = 1, 6
ZNCOMP (IN) = 1.0
DO 6 IN = 1, ISTEP
ZNCOMP (IN + 6) = NCOMP (IN)

CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS

CALL SPBVCA(
1TI, TOF, SI, SOF, MG, MGS, NP, NG,
2AO, GAMMA1, ROT, SPR, PHE1, PHS11, ZZ1,
3PTL, AP, BP, RP, GTL, AQ, BG, RG,
4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1 (2), ADJP1,
5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E2 (3), ADJP2,
6ITYPEQ1, RFG1, NBQ1, DG1, ACQ1, BDCAG1, AK3, E1 (5), ADJQ1,
7ITYPEQ2, RFG2, NBQ2, DQ2, ACQ2, BDCAG2, AK4, E2 (6), ADJQ2,
8F, E, PQ, E1 (1), RPD, RGD,
9PXP, PYP, PZP, TOTFOR, PXG, PYG, PZG, TOTFOR,
1R1XP, R1YP, R1ZP, R2XP, R2YP, R2ZP,
2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
3L1 (2), H1 (2), TOFORP1, P1 (2), BDCAP10, D1 (2),
4L1 (3), H1 (3), TOFORP2, P1 (3), BDCAP20, D1 (3),
5L1 (5), H1 (5), TOFORQ1, P1 (5), BDCAG10, D1 (5),
6L1 (6), H1 (6), TOFORQ2, P1 (6), BDCAG20, D1 (6),
7L1 (1), H1 (1), DCA, D1 (1),
8L1 (4), H1 (4), DCAG, D1 (4),
9LSB, HSB, ESB)

PRINT OUT RESULTS FOR SPIRAL BEVEL UNIT
CALL SPBVOT(PD, PHE, PHSI, SPR, F, AO, SI, SOS, ROT, TI, TOS, THETA,
1NP, GAMMA, DP, RPD, AOP, BOP, PITCH,
2PXP, PYP, PZP, TOFOR, DCAP, CASEP, AP, BP,
3R1XP, R1YP, R1ZP, TOFORP1, BDCAP10,
4R2XP, R2YP, R2ZP, TOFORP2, BDCAP20,
5NG, ZZ, DG, ROD, AOG, BOG,
6PXG, PYG, PZG, TOFOR, DCAG, CASEG, AG, BG,
7R1XG, R1YG, R1ZG, TOFORG1, BDCAG10,
8R2XG, R2YG, R2ZG, TOFORG2, BDCAG20,
9D1, P1, L1, HI, EI)

C CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
C CALCULATE LIFE OF PLANETARY UNIT
C
CALL PLANCA(ISTEP, NCOMP, MQP, NS, NPS, NPR,
NR, PHIS1, PHIR1,
1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
3TOS, TOF, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1,
4LPLAN, HPLAN, EPLAN)

C PRINT OUT RESULTS FOR THE PLANETARY UNIT
C
CALL PLANOT(ISTEP, N, V, CB, FB, NS, PDS, PHIS, WDSM, B1SM, FS,
1NR, PDR, PHIR, WDRM, B1RM, FR, NP, NPS, NPR, TOS, TOF, SOS, SOF, FTT,
2AD1, AP1, AL1, AH1, AE1)

C DEFINE TRANSMISSION LIFE ARRAYS
C
DO 8 IE=1, 6
ZE1(IE)=E1(IE)
8
ZL1(IE)=L1(IE)
DO 9 IE=1, ISTEP
ZE1(IE+6)=AE1(IE)
9
ZL1(IE+6)=AL1(IE)

CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, LTRANS, ETRANS)
HTRANS=LTRANS*16666.667/SOF

C START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC CAPACITY
C
DMIN=D1(1)
DO 21 I=2, 6
IF(D1(I).LT.DMIN)DMIN=D1(I)
21
DELTATO=.15*DMIN
DELTAT=DELTATO/MGS/MG
DTO=0.0
DTI=0.0
DO 22 I=1,10
  DTI=DTI+DELTATI
  DTO=DTO+DELTATO
  DYN(I)=DTO
  CALL SPBVCA(DTI,DTO,SI,SOF,MG,MGS,NP,NG,
               2AO,GAMMA1,ROT,SPR,PHI1,PHI11,ZI1,
               3PTL,AP,BP,RP,GT,AG,BG,RG,
               4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,AK1,E1(2),ADJP1,
               5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,AK2,E1(3),ADJP2,
               6ITYPEG1,RFG1,NBG1,DG1,ACG1,BDCAG1,AK3,E1(5),ADJG1,
               7ITYPEG2,RFG2,NBG2,DG2,ACG2,BDCAG2,AK4,E1(6),ADJG2,
               8F,E,PG,EL1(1),RPD,REGD,
               9PXP,PYP,PZP,TOTFOR,PXG,PYG,PZG,TOTFOR,
               1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
               2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
               3L1(2),H1(2),TORDP1,P1(2),BDCAP10,D1(2),
               4L1(3),H1(3),TORDP2,P1(3),BDCAP20,D1(3),
               5L1(5),H1(5),TORDG1,P1(5),BDCAG10,D1(5),
               6L1(6),H1(6),TORDG2,P1(6),BDCAG20,D1(6),
               7L1(1),H1(1),DCAP,D1(1),
               8L1(4),H1(4),DCAG,D1(4),
               9L1(1),DUMB,DUMB)
22 CONTINUE
CALL CAP(DYN,L1,10,DSB,PSP)

C START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC CAPACITY
C
ADMIN=AD1(1)
DO 23 I=2,ISTEP
  IF(AD1(I).LT.ADMIN)ADMIN=AD1(I)
  DELTATO=15*ADMIN
  DELTATOS=DELTATO/MGS
  DTO=0.0
  DTOS=0.0
  DO 24 I=1,10
    DTOS=DTOS+DELTATOS
    DTO=DTO+DELTATO
    DYN(I)=DTO
  CALL PLANCA(ISTEP,NCOMP,MGP,NS,NPS,NPR,NR,PHIS1,PHIR1,
               1RS,RPS,RPR,RR,CB,A,V,PB,N,EB,FTT,
CONTINUE
CALL CAP (DYN, ALI, 10, DPLAN, PPLAN)

C START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC CAPACITY

IF (ADMIN, LT, DMIN) DMIN = ADMIN
   DELTATO = 15 * DMIN
   DELTATOS = DELTATO / MGS
   DELTAT1 = DELTATOS / MG
   DTI = 0.0
   DTOS = 0.0
   DTO = 0.0
DO 20 I = 1, 10
   DTI = DTI + DELTATI
   DTOS = DTOS + DELTATOS
   DTO = DTO + DELTATO
   DVN (I) = DTO
20
CALL SPBVCA (IDTI, DTO, SI, SOF, MG, MGS, NP, NG, 2AO, GAMMA1, ROT, SPR, PHE1, PHS1, ZZ1, 3PTL, AP, BP, RP, GXL, AG, BG, RO, 4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1, 5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2, 6ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1, 7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2, 8F, E, PG, E1(1), RPD, RGD, 9PXP, PYP, PZP, TOTFOR, PXG, PYG, PZQ, TOTFOR, 1R1XP, R1YP, R1ZP, R2XP, R2YP, R2ZP, 2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG, 3L1(2), H1(2), TOFDRP1, P1(2), BDCAP10, D1(2), 4L1(3), H1(3), TOFDRP2, P1(3), BDCAP20, D1(3), 5L1(5), H1(5), TOFDRG1, P1(5), BDCAG10, D1(5), 6L1(6), H1(6), TOFDRG2, P1(6), BDCAG20, D1(6), 7L1(1), H1(1), DCAP, D1(1), 8L1(4), H1(4), DCAG, D1(4), 9L1(1), DUMB, DUMB)
 CALL PLANCA (ISTEP, NCOMP, MGP, NS, NPS, NPR, NR, PHIS1, PHIR1, 1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM, 3DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, ALI(I), DUMB, 4DUMB)

DO 12 IE=1,6
   ZL1(IE)=L1(IE)
12    DO 13 IE=1,ISTEP
        ZL1(IE+6)=AL1(IE)
13    CONTINUE
    CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, ZLI(I), DUMB)
20 CONTINUE

CALL CAP(DYN, ZL1, 10, DTRANS, PTRANS)
1220 FORMAT(’ TOTAL TRANSMISSION’)
1221 FORMAT(’ SPIRAL BEVEL UNIT’)
1222 FORMAT(’ PLANETARY UNIT’)
WRITE(1,1221)
CALL DPLHE(DSB, PSP, LSB, HSB, ESB)
WRITE(1,1222)
CALL DPLHE(DPLAN, PPLAN, LPLAN, HPLAN, EPLAN)
WRITE(1,1220)
CALL DPLHE(DTRANS, PTRANS, LTRANS, HTRANS, ETRANS)
STOP
END
SUBROUTINE SBPLPL
INTEGER CASEP,CASEG,PTL,GTL,BISTEP
REAL NP,NG,NBP1,NBP2,NBG1,NBG2,MG,LSB
REAL LI(6),D1(6),E1(6),H1(6),P1(6),DYB(10),LI(10)
REAL NS,NPS,NPR,NR,N,LS,LR,LPLAN
REAL NCOMP(5),AD1(5),AL1(5),AH1(5),AE1(5),ALI(10)
REAL MGS,MGPA,MGBP,ZNCOMP(16),ZE1(16),ZL1(16),LTRANS,ZLI(I)
REAL NCOMP(5),BD1(5),BP1(5),BL1(5),BH1(5),BE1(5),BLI(l0)

101 FORMAT(’WHAT IS THE INPUT TORQUE OF THE TRANSMISSION’)
102 FORMAT(’WHAT IS THE INPUT SPEED OF THE TRANSMISSION’)
WRITE(1,101)
READ(1,*)TI
WRITE(1,102)
READ(1,*)SI

C
READ IN VALUES OF THE SPIRAL BEVEL UNIT

C
CALL SPBVIN(NP,NG,AO,PHE,F,PHSI,ROT,SPR,THETA,E,E1(1),PQ,
1PHE1,PHSI1,THETA1,CASEP,PTL,AP,BP,ITYPEP1,NBP1,DP1,ACP1,AK1,
2BDCAP1,RFP1,E1(2),ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,E1(3),
3CASEG,GTL,AG,BG,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,E1(5),
4ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,E1(6),MG,GAMMA1,GAMMA2,ZZ,
5Z1,DP,DG,RPD,RP,RGD,RG,PK,ADG,ADP,H2,BOG,BOG,PITCH,
102
6ADJP1, ADJP2, ADJG1, ADJG2)

E1(4)=E1(1)
P1(1)=PQ
P1(4)=PQ

CALCULATE OUTPUT TORQUE AND SPEED OF SPIRAL BEVEL UNIT

TOS=TI*MG
SOS=SI/MG

READ IN VALUES OF PLANETARY UNIT

CALL PLANIN(CB, A, V, EB, PB, N, NCOMP, PDS, PDR, NS, PHIS, PHIS1,IPHIR, PHIR1, WDSM, ES, PS, B1SM, ISTEP, NPS, NPR, NR, WDRM, ER, PR, B1RM,2RPR, RPS, RR, RS)
AP1(1)=PB
AP1(2)=PS
AP1(3)=PR
AP1(4)=PS
AP1(5)=PR

CALL PLANIN(BCB, BA, BV, BEB, BPB, BN, BNCOMP, BPDS, BPDR, BNS, BPHIS,IBPHIS1, BPHIR, BPHIR1, BWDSM, BES, BPS, BB1SM, BISTEP, BNPS,2BNPR, BNR, BWDRM, BER, BPR, BB1RM, BRPR, BRPS, BRR, BRS)
BP1(1)=BP
BP1(2)=BPS
BP1(3)=BPR
BP1(4)=BPS
BP1(5)=BPR

CALL PLANIN(CB, A, V, EB, PB, N, NCOMP, PDS, PDR, NS, PHIS, PHIS1,IPHIR, PHIR1, WDSM, ES, PS, B1SM, ISTEP, NPS, NPR, NR, WDRM, ER, PR, B1RM,2RPR, RPS, RR, RS)
AP1(1)=PB
AP1(2)=PS
AP1(3)=PR
AP1(4)=PS
AP1(5)=PR

CALL PLANIN(BCB, BA, BV, BEB, BPB, BN, BNCOMP, BPDS, BPDR, BNS, BPHIS,IBPHIS1, BPHIR, BPHIR1, BWDSM, BES, BPS, BB1SM, BISTEP, BNPS,2BNPR, BNR, BWDRM, BER, BPR, BB1RM, BRPR, BRPS, BRR, BRS)
BP1(1)=BP
BP1(2)=BPS
BP1(3)=BPR
BP1(4)=BPS
BP1(5)=BPR

CALL PLANIN(CB, A, V, EB, PB, N, NCOMP, PDS, PDR, NS, PHIS, PHIS1,IPHIR, PHIR1, WDSM, ES, PS, B1SM, ISTEP, NPS, NPR, NR, WDRM, ER, PR, B1RM,2RPR, RPS, RR, RS)
AP1(1)=PB
AP1(2)=PS
AP1(3)=PR
AP1(4)=PS
AP1(5)=PR

TOS=TOS*(1.+(RR*RPS)/(RS*RPR))
SOS=SOS/(1.+(RR*RPS)/(RS*RPR))

READ IN VALUES OF PLANETARY UNIT

CALL PLANIN(CB, A, V, EB, PB, N, NCOMP, PDS, PDR, NS, PHIS, PHIS1,IPHIR, PHIR1, WDSM, ES, PS, B1SM, ISTEP, NPS, NPR, NR, WDRM, ER, PR, B1RM,2RPR, RPS, RR, RS)
AP1(1)=PB
AP1(2)=PS
AP1(3)=PR
AP1(4)=PS
AP1(5)=PR

TOS=TOS*(1.+(RR*RPS)/(RS*RPR))
SOS=SOS/(1.+(RR*RPS)/(RS*RPR))

MGA=(1.+(BRR*BRPS)/(BRS*BRPR))
MGS=(1.+(RR*RPS)/(RS*RPR))*MGA
MGPB=1.0
INCOMP=6+ISTEP+BISTEP
DO 5 IN=1,6
5 ZNCOMP(IN)=1.0
DO 6 IN=1,ISTEP
6 ZNCOMP(IN+6)=NCOMP(IN)
IX=6+ISTEP
DO 77 IN=1,BISTEP
77 ZNCOMP(IN+IX)=BNCOMP(IN)

C C CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS
C C CALCULATE LIFE OF SPIRAL BEVEL UNIT

CALL SPBVCA(
1TI, TOF, SI, SOF, MG, MGS, NP, NG,
2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1,
3PTL, AP, BP, RP, GTL, AG, BG, RG,
4ITYYPE1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
5ITYYPE2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
6ITYPEG1, RFG1, NBG1, DG1, ACQ1, BDCAG1, AK3, E1(5), ADJG1,
7ITYPEG2, RFG2, NBG2, DG2, ACQ2, BDCAG2, AK4, E1(6), ADJG2,
8F, E, PG, E1(1), RPD, RGD,
9PXP, PYP, PIZ, TOTFOR, PXG, PYG, PIG, TOTFOR,
1R1XP, R1YP, R1ZP, R2XP, R2YP, R2ZP,
2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
3L1(2), H1(2), TOFORP1, P1(2), BDCAP10, D1(2),
4L1(3), H1(3), TOFORP2, P1(3), BDCAP20, D1(3),
5L1(5), H1(5), TOFORG1, P1(5), BDCAG10, D1(5),
6L1(6), H1(6), TOFORG2, P1(6), BDCAG20, D1(6),
7L1(1), H1(1), DCAP, D1(1),
8L1(4), H1(4), DCAG, D1(4),
9LSB, HSB, ESB)

C C PRINT OUT RESULTS FOR SPIRAL BEVEL UNIT
C

CALL SPBVOT(PD, PHE, PHSI, SPR, F, AO, SI, SOS, ROT, TI, TOS, THETA,
1NP, GAMMA, DP, RPD, AOP, BOP, PITCH,
2PXP, PYP, PIZ, TOTFOR, DCAP, CASEP, AP, BP,
3R1XP, R1YP, R1ZP, TOFORP1, BDCAP10,
4R2XP, R2YP, R2ZP, TOFORP2, BDCAP20,
5NG, ZZ, DG, RGD, AOG, BOG,
6PXP, PYP, PIZ, TOTFOR, DCAG, CASEG, AG, BG,
7R1XG, R1YG, R1ZG, TOFORG1, BDCAG10,
8R2XG, R2YG, R2ZG, TOFORG2, BDCAG20,
9DL1, P1, L1, H1, E1)
CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
CALCULATE LIFE OF PLANETARY UNIT

CALL PLANCA(ISTEP, NCOMP, MQPA, NS, NPS, NPR, NR, PHIS1, PHIR1,
1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
3TOS, TOF, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1,
4LPLAN, HPLAN, EPLAN)

PRINT OUT RESULTS FOR THE PLANETARY UNIT

CALL PLANOT(ISTEP, N, V, CB, FB, NS, PDS, PHIS, WDSM, B1SM, FS,
1NR, PDR, PHIR, WDRM, B1RM, FR, NP, NPS, NPR, TOS, TOF, SOS, SOF, FTT,
2AD1, AP1, AL1, AH1, AE1)

CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
CALCULATE LIFE OF PLANETARY UNIT

CALL PLANCA(BISTEP, BNCOMP, MQPB, BNS, BNPS, BNPR, BNR,
1BPHIS1, BPHIR1, BRS, BPRS, BRR, BCB, BA, BV, BPB, BN, BEB,
2BFTT, B1BSM, BPS, BES, WDSM, B1RM, BPR, BER, WDRM,
3TOPA, TOF, SOPA, SOF, BCS, BLS, BFS, BCR, BLR, BFR, BD1, BL1, BH1, BE1,
4BPLAN, BHPLAN, BPLAN)

PRINT OUT RESULTS FOR THE PLANETARY UNIT

CALL PLANOT(BISTEP, BN, BV, BCB, BFB, BNS, BPDS, BPHIS, BWDSM,
1BB1SM, BFS, BNR, BPDR, BPHIR, WBDRM, BB1RM, BFR, BNP, BNPS, BNPR,
2TOPA, TOF, SOPA, SOF, BTFT, BD1, BP1, BL1, BH1, BE1)

DEFINE TRANSMISSION LIFE ARRAYS

DO 8 IE=1,6
   ZE1(IE)=E1(IE)
8    ZL1(IE)=L1(IE)
     DO 9 IE=1,ISTEP
        ZE1(IE+6)=AE1(IE)
9     ZL1(IE+6)=AL1(IE)
     DO 99 IE=1,BISTEP
        ZE1(IE+6+ISTEP)=BE1(IE)
99    ZL1(IE+6+ISTEP)=BL1(IE)
CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, LTRANS, ETRANS)
HTRANS=LTRANS*16666.667/SOF
START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC CAPACITY

DMIN=D1(1)
DO 21 I=2,6
21 IF(D1(I).LT.DMIN)DMIN=D1(I)
DELTATO=.15*DMIN
DELTATI=DELTATO/MGS/MG
DTO=0.0
DTI=0.0
DO 22 I=1,10
   DTI=DTI+DELTATI
   DTO=DTO+DELTATO
   DYN(I)=DTO
   CALL SPBVCA(1DTI,DTO,SI,SOF,MG,MGS,NP,NG,
              2AO,GAMMA1,ROT,SPR,PHE1,PHS11,ZI1,
              3PTL,AP,BP,RP,QTL,AQ,BQ,RG,
              4ITYPEP1,RFP1,NBP1,DP1,ACP1,BDCAP1,A1,E1(2),ADJP1,
              5ITYPEP2,RFP2,NBP2,DP2,ACP2,BDCAP2,A2,E1(3),ADJP2,
              6ITYPEG1,RFQ1,NBQ1,DQ1,ACQ1,BDCAG1,AK3,E1(5),ADJG1,
              7ITYPEG2,RFQ2,NBQ2,DQ2,ACQ2,BDCAG2,AK4,E1(6),ADJG1,
              8F,E,PG,E1(1),RPD,RGD,
              9PXP,PYP,PZP,TOTFOR,PXG,PYQ,PZG,TOTFOR,
             1R1XP,R1YP,R1ZP,R2XP,R2YP,R2ZP,
             2R1XG,R1YG,R1ZG,R2XG,R2YG,R2ZG,
             3L1(2),H1(2),TOTFORP1,P1(2),BDCAP10,D1(2),
             4L1(3),H1(3),TOTFORP2,P1(3),BDCAP20,D1(3),
             5L1(5),H1(5),TOTFORQ1,P1(5),BDCAG10,D1(5),
             6L1(6),H1(6),TOTFORQ2,P1(6),BDCAG20,D1(6),
             7L1(1),H1(1),DCAP,D1(1),
             8L1(4),H1(4),DCAG,D1(4),
             9L1(I),DUMB,DUMB)
22 CONTINUE
CALL CAP(DYN,LI,10,DSB,PSP)

START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC CAPACITY

ADMIN=AD1(1)
DO 23 I=2,ISTEP
23 IF(AD1(I).LT.ADMIN)ADMIN=AD1(I)
   DELTATO=.15*ADMIN
   DELTATOS=DELTATO/MGS

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DTO=0.0
DTOS=0.0
DO 24 I=1,10
   DTOS=DTOS+DELTATOS
   DTO=DTO+DELTATO
   DYN(I)=DTO
   CALL PLANCA(ISTEP, NCMP, MGP, NS, NPS, NPR, NR, PHIS1, PHIR1, 1RS, RPS, RR, RB, A, V, PB, N, EB, FTT, 2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM, 3DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, ALI(I), DUMB, 4DUMB)
24 CONTINUE
CALL CAP(DYN, ALI, 10, DPLAN, PPLAN)

C
C
C
START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC
C CAPACITY
C
BDMIN=BD1(I)
DO 30 I=2, BISTEP
   IF(BD1(I).LT.BDMIN) BDMIN=BD1(I)
   DELTATO=.15*BDMIN
   DELTATOS=DELTATO/MGPA
   DTO=0.0
   DTOS=0.0
   DO 31 I=1,10
      DTOS=DTOS+DELTATOS
      DTO=DTO+DELTATO
      DYN(I)=DTO
      CALL PLANCA(BISTEP, BNCOMP, MGPB, BNS, BNPS, BNPR, BNR, BPHIS1, 1BPHIR1, BRS, BRPS, BRPR, BRR, BCB, BA, BV, BPB, BN, BEB, BFTT, 2B1SM, BPS, BES, WDSM, B1RM, BPR, BER, WDRM, 3DTOS, DTO, S0PA, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, ALI(I), DUMB, 4DUMB)
31 CONTINUE
CALL CAP(DYN, BL1, 10, BDPLAN, BPPLAN)
C
C
START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC
C CAPACITY
C
IF(ADMIN.LT.DMIN) DMIN=ADMIN
IF(BDMIN.LT.DMIN) DMIN=BDMIN
   DELTATO=.15*DMIN
   DELTATOP=DELTATO/MGPA

107
DELTATOS = DELTATO / MGS
DELTATI = DELTATOS / MG
DTI = 0.0
DTOS = 0.0
DTOPA = 0.0
DTO = 0.0
DO 20 I = 1, 10
   DTI = DTI + DELTATI
   DTOS = DTOS + DELTATOS
   DTOPA = DTOPA + DELTATOP
   DTO = DTO + DELTATO
   DVN(I) = DTO
CALL SPBVCA(1, DTI, DTO, SI, SOF, MG, MGS, NP, NG,
2 AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1,
3 PTL, AP, BP, RP, GTL, AG, BG, RG,
4 TYPEP1, RF1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
5 TYPEP2, RF2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
6 TYPEG1, RG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
7 TYPEG2, RF2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2,
8 F, E, PG, E1(1), RPD, RGD,
9 PXP, PYP, PZP, TOTFOR, PXG, PYG, PZG, TOTFOR,
1 R1XP, R1YP, R1ZP, R2XP, R2YP, R2ZP,
2 R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
3 L1(2), H1(2), TOTFORP1, P1(2), BDCAP10, D1(2),
4 L1(3), H1(3), TOTFORP2, P1(3), BDCAP20, D1(3),
5 L1(5), H1(5), TOTFORQ1, P1(5), BDCAG10, D1(5),
6 L1(6), H1(6), TOTFORQ2, P1(6), BDCAG20, D1(6),
7 L1(1), H1(1), DCAP, D1(1),
8 L1(4), H1(4), DCAG, D1(4),
9 L1(I), DUMB, DUMB)
CALL PLANCA(ISTEP, NCOMP, MGPA, NS, NPS, NPR, NR, PHIS1, PHIR1,
1 RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
2 B1SM, BS, WDSM, B1RM, PR, ER, WDRM,
3 DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, ALI(I),
4 DUMB, DUMB)
CALL PLANCA(BISTEP, BNCOMP, MGPB, NS, NPS, NPR, NR, BPHIS1,
1 BPFR1, BRS, BRRS, BRRP, BRR, BCB, BA, BV, BPP, BN, BEB, BFTT,
2 B21SM, BPS, BES, BWDSM, B21RM, BPR, BER, BWDRM,
3 DTOPA, DTO, SOPA, SOF, CS, BCS, BL, BFS, BCR, BLR, BFR, BD1, BL1,
4 BH1, B1, BL(I), DUMB, DUMB)
DO 12 IE = 1, 6
108
12 \text{ZL1(IE)=L1(IE)}
\text{DO 13 IE=1,ISTEP}
13 \text{ZL1(IE+6)=AL1(IE)}
\text{DO 14 IE=1,BISTEP}
14 \text{ZL1(IE+6+ISTEP)=BL1(IE)}
\text{CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, ZLI(I), DUMB)}
20 \text{CONTINUE}
\text{CALL CAP(DVN, ZLI, T10, DTRANS, PTRANS)}
1220 \text{FORMAT(' TOTAL TRANSMISSION')}
1221 \text{FORMAT(' SPIRAL BEVEL UNIT')}
1222 \text{FORMAT(' PLANETARY UNIT')}
\text{WRITE(1,1221)}
\text{CALL DPLHE(DSB, PSP, LSB, HSB, ESB)}
\text{WRITE(1,1222)}
\text{CALL DPLHE(DPLAN, PPLAN, LPLAN, HPLAN, EPLAN)}
\text{WRITE(1,1220)}
\text{CALL DPLHE(DTRANS, PTRANS, LTRANS, HTRANS, ETRANS)}
\text{STOP}
\text{END}
\text{SUBROUTINE DPBV}
\text{INTEGER CASEP, CASEG, PTL, GTL}
\text{REAL NP, NG, NBP1, NBP2, NBG1, NBG2, MG, MG1, LSB}
\text{REAL L1(9), D1(9), E1(9), H1(9), P1(9), DYN(10), LI(10)}
101 \text{FORMAT('WHAT IS THE INPUT TORQUE OF THE RIGHT PINION')}\text{WRITE(1,101)}
102 \text{FORMAT('WHAT IS THE INPUT TORQUE OF THE LEFT PINION')}\text{WRITE(1,102)}
103 \text{FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')}\text{WRITE(1,103)}\text{READ(1,
\text{*})TIR}\text{WRITE(1,101)}\text{READ(1,
\text{*})TIL}\text{WRITE(1,102)}\text{READ(1,
\text{*})SI}\text{INPUT SPIRAL BEVEL GEAR GEOMETRY}
\text{CALL DPBVIN(NP, NG, AO, PHE, F, PHSI, ROT, SPR, THETA, E, E1(1), PG,}
1PHE1, PHSI1, THETA1, CASEP, PTL, AP, BP, ITYPEP1, NBP1, DP1, ACP1, AK1,
2BDCAP1, RFP1, E1(2), ITYPEP2, NBP2, DP2, ACP2, AK2, BDCAP2, RFP2, E1(3),
3CASEG, GTL, AG, BG, ITYPEG1, NBG1, DG1, ACQ1, AK3, BDCAG1, RFG1, E1(5),
4ITYPEG2, NBG2, DG2, ACQ2, AK4, BDCAG2, RFG2, E1(6), MG, GAMMA1, GAMMA, ZZ,
5ZZ1, DP, DG, RPD, RP, RGD, RG, HK, AQG, AOP, HT, BOG, BOP, PD,
6ADJP1, ADJP2, ADJP1, ADJP2, ZIP)
E1(4)=E1(1)  
E1(7)=E1(1)  
E1(8)=E1(2)  
E1(9)=E1(3)  
P1(1)=PG  
P1(4)=PG  
P1(7)=PG  

CALCULATE OUTPUT TORQUE AND SPEED OF TRANSMISSION

TOF=TIR*MG+TIL*MG  
SOF=SI/MG  
MG1=1.0

CALCULATE LIVES AND DYNAMIC CAPACITIES OF SPIRAL BEVEL COMPONENTS AND LIFE OF THE TRANSMISSION

CALL DPBVCA(  
1TIR, TIL, TOF, SI, SOF, MG, MG1, NP, NG,  
2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZI1, ZIP,  
3PTL, AP, BP, RP, GTL, AG, BG, RG,  
4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,  
5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,  
6ITYPEG1, RFG1, NBG1, DG1, ACQ1, BDCAG1, AK3, E1(5), ADJG1,  
7ITYPEG2, RFG2, NBG2, DG2, ACQ2, BDCAG2, AK4, E1(6), ADJG2,  
8F, E, PG, E1(1), RPD, RGD,  
9PXPR, PYPR, PZPR, TOTFORR, PXGR, PYGR, PZGR, TOTFORGE,  
9PXPL, PYPL, PZPL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE,  
1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,  
1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,  
2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,  
3L1(2), H1(2), TOFORPIR, P1(2), BDCAP1IR, D1(2),  
4L1(3), H1(3), TOFORP2R, P1(3), BDCAP2IR, D1(3),  
5L1(5), H1(5), TOFORQ1, P1(5), BDCAG1Q, D1(5),  
6L1(6), H1(6), TOFORQ2, P1(6), BDCAG2Q, D1(6),  
7L1(1), H1(1), DCAQ, D1(1),  
8L1(4), H1(4), DCAG, D1(4),  
*L1(7), H1(7), DCAPR, D1(7),  
*L1(8), H1(8), TOFORPL, P1(8), BDCAP10L, D1(8),  
*L1(9), H1(9), TOFORPL, P1(9), BDCAP10L, D1(9),  
9LSB, HSB, ESB)

PRINT OUT LIVES AND DYNAMIC CAPACITIES OF COMPONENTS
CALL DPBVOT(PD, PHE, PHSI, SPR, F, AO, SI, SOF, ROT, TIR, TIL, TOF,
ITHETA, NP, GAMMA, DP, RPD, AOQ, BOP,
2PXPR, PYPR, PZPR, TOTFORR, DCPAR, CASEP, AP, BP,
3R1XPR, R1YPR, R1ZPR, TOFORP1R, BDCAP10R,
4R2XPR, R2YPR, R2ZPR, TOFORP2R, BDCAP20R,
2PXPL, PYPL, PZPL, TOTFORL, DCPAL, CASEP, AP, BP,
3R1XPL, R1YPL, R1ZPL, TOFORP1L, BDCAP10L,
4R2XPL, R2YPL, R2ZPL, TOFORP2L, BDCAP20L,
5NG, ZZ, DG, RGD, ADG, BDG,
6PXQR, PYQR, PZQR, TOTFORQE, DCAQ, CASEQ, AG, BQ,
6PXQL, PYQL, PZQL, TOTFORQE, DCAQ, CASEQ, AG, BQ,
7R1XG, R1YG, R1ZG, TOFORG1, BDCAG10,
8R2XG, R2YG, R2ZG, TOFORG2, BDCAG20,
9D1, P1, L1, H1, E1)

C ESTIMATE 10 PERCENT DYNAMIC CAPACITY OF TRANSMISSION

DMIN=D1(1)
DO 10 I=2,9
   IF(D1(I).LT.DMIN)DMIN=D1(I)
   DELTATO=1*DMIN
   DELTATI=0.5*DELTATO/MQ
   DTIR=0.0
   DTIL=0.0
   DTO=0.0

C START COUNTER FOR DYNAMIC CAPACITIES BETWEEN 10 AND 100 PERCENT
C OF TRANSMISSION DYNAMIC CAPACITY

C DO 20 I=1,10
   DTIR=DTIR+DELTATI
   DTIL=DTIL+DELTATI
   DTO=DTO+DELTATO
   DYN(I)=DTO

C CALCULATE LIFE FOR EACH DYNAMIC CAPACITY

CALL DPBVCA(
1DTIR, DTIL, DTO, SI, SOF, MG, MG1, NP, NG,
2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1, ZIP,
3PTL, AP, BP, RP, QTL, AQ, BG, RG,
4ITYPEP1, RF1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
5ITYPEP2, RF2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
6ITYPEQ1, RFQ1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2, 
SF, E, PG, E1(1), RPD, RQD, 
9PXPR, PYPR, PZPR, TOTFORR, PXGR, PYGR, PZGR, TOTFORGE, 
9PXPL, PYPL, PZPL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE, 
1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR, 
1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL, 
2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG, 
3L1(2), H1(2), TOFORP1R, P1(2), BDCAP1QR, D1(2), 
4L1(3), H1(3), TOFORP2R, P1(3), BDCAP2QR, D1(3), 
5L1(5), H1(5), TOFORG1, P1(5), BDCAG10, D1(5), 
6L1(6), H1(6), TOFORG2, P1(6), BDCAG20, D1(6), 
7L1(1), H1(1), DCAPR, D1(1), 
8L1(4), H1(4), DCAG, D1(4), 
*L1(7), H1(7), DCAPL, D1(7), 
*L1(8), H1(8), TOFORP1L, P1(8), BDCAP1OL, D1(8), 
*L1(9), H1(9), TOFORP2L, P1(9), BDCAP1OL, D1(9), 
9LI(I), HSB1, ESB1) 
20 CONTINUE 
C 
C CALCULATE DYNAMIC CAPACITY AND LOAD LIFE EXPONENT FOR 
C TRANSMISSION 
C CALL CAP(DYN, LI, 10, DSB, PSP) 
C 
C PRINT OUT LIFE AND DYNAMIC CAPACITY OF TRANSMISSION 
C 
WRITE(1,1220) 
1220 FORMAT(’TOTAL TRANSMISSION’) 
CALL DPLHE(DSB, PSP, LSB, HSB, ESB) 
STOP 
END 
SUBROUTINE SBDBPL 
INTEGER CASEP, CASEG, PTL, QTL 
INTEGER CCASEP, CCASEG, CPTL, CGTL 
REAL NP, NG, NBP1, NBP2, NBG1, NBG2, MG, LSB 
REAL L1(9), D1(9), E1(9), H1(9), P1(9), DYN(10), LI(10) 
REAL CNP, CNG, CNBP1, CNBP2, CNBG1, CNBG2, CMS, CLSB 
REAL CL1(6), CD1(6), CE1(6), CH1(6), CP1(6), CDYN(10), CLI(10) 
REAL DL1(6), DH1(6), DD1(6) 
REAL NS, NPS, NPR, NR, NS, LS, LR, LPLAN 
REAL NCOMP(5), AD1(5), AP1(5), AL1(5), AH1(5), AE1(5), ALI(10) 
REAL MG5, MG6, ZNCOMP(26), ZE1(26), ZL1(26), LTRANS, ZLI(10) 
101 FORMAT(’WHAT IS THE INPUT TORQUE OF THE RIGHT PINION’) 
102 FORMAT(’WHAT IS THE INPUT TORQUE OF THE LEFT PINION’) 
103 FORMAT(’WHAT IS THE INPUT SPEED OF THE TRANSMISSION’)
WRITE(1,101)
READ(1,*), CTIR
WRITE(1,102)
READ(1,*), CTIL
WRITE(1,103)
READ(1,*), CSI

READ IN VALUES OF THE SPIRAL BEVEL UNIT

CALL SPBVIN(CNP, CNQ, CAO, CPHE, CF, CPHSI, CROT, CSPR, CTHETA, 
1CE, CE1(1), CPG, CPHE1, CPHS11, CTHETA1, CCASEP, CPTL, CCAP, CBP, 
2CITYPEP1, CNBP1, CDP1, CACP1, CAK1, CBDACP1, CRFP1, CE1(2), 
3CITYPEP2, CNBP2, CDP2, CACP2, CAK2, CBDACP2, CRFP2, CE1(3), 
4CCASEG, CGL, CAG, CBG, CTYP9E01, CNBG1, CDG1, CACG1, CAK3, 
5CBDCG1, CRFG1, CE1(5), CTYPEG2, CNBG2, CDG2, CACG2, CAK4, 
6CBDCG2, CRFG2, CE1(6), CMG, CGAMMA1, CGAMMA, CZZ, CZI1, CDP, 
7CDG, CRPD, CRP, CRGD, CRG, CHK, CAOG, CAOP, CHT, CBG, CBOP, CPITCH, 
8CADJP1, CADJP2, CADJP1, CADJP2)

CE1(4)=CE1(1)
CP1(1)=CPG
CP1(4)=CPG

CALCULATE OUTPUT TORQUE AND SPEED OF SPIRAL BEVEL UNIT

TIR=CTIR*CMG
TIL=CTIL*CMG
SI=CSI/CMG

INPUT SPIRAL BEVEL GEAR GEOMETRY

CALL DPBVIN(NP, NG, AO, PHE, F, PHSI, ROT, SPR, Theta, E, E1(1), PG, 
1PHE1, PHSI1, TETHA1, CASEP, PTL, AP, BP, ITYPEP1, NB1, DP1, ACP1, AK1, 
2BDCAP1, RFP1, E1(2), ITYPEP2, NB2, DP2, ACP2, AK2, BDACP2, RFP2, E1(3), 
3CASEG, CGL, AG, BG, ITYPEG1, NBG1, DG1, ACQ1, AK3, BDAG1, RFG1, E1(5), 
4ITYPEG2, NBG2, DG2, ACG2, AK4, BDAG2, RFG2, E1(6), MSG, GAMMA1, GAMMA, ZZ, 
5ZI1, DP, DG, RP, RP, RGD, RG, HK, AOQ, AOP, HT, BQG, B0P, PD, 
6ADJP1, ADJP2, ADJP1, ADJP2, ZIP)

E1(4)=E1(1)
E1(7)=E1(1)
E1(8)=E1(2)
E1(9)=E1(3)
P1(1)=PG
P1(4)=PG
P1(7)=PG

CALCULATE OUTPUT TORQUE AND SPEED OF TRANSMISSION

TOS=TIR*MG+TIL*MG
SOS=SI/MG

READ IN VALUES OF PLANETARY UNIT

CALL PLANIN(CB,A,V,EB,PS,N,NCOMP,PDS,PDR,NS,PHIS,PHIS1,
1PHIR,PHIR,WD3M,ES,PS,B1SM,ISTEP,NPS,NPR,HR,WDRM,ER,PR,B1RM,
2RPR,RPS,RR,RS)
AP1(1)=PB
AP1(2)=PS
AP1(3)=PR
AP1(4)=PS
AP1(5)=PR

CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT

TOF=TOS*(1.+(RR*RPS)/(RS*RPR))
SOF=SOS/(1.+(RR*RPS)/(RS*RPR))
MGS=(1.+(RR*RPS)/(RS*RPR))
CMGS=MGS*NG/NP
MGP=1.0
INCOMP=21+ISTEP
DO 5 IN=1,21
ZNCOMP(IN)=1.0
DO 6 IN=1,ISTEP
ZNCOMP(IN+21)=NCOMP(IN)

CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS
CALCULATE LIFE OF SPIRAL BEVEL UNIT

CALL SPBVCA(1CTIR,TQF,CSI,SOE,CMG,CMGS,CNP,CNG,
2CAO,CAMMA1,CROT,CSR,CHE1,CPH21,CZI1,
3CPTL,CCAP,CBP,CRP,CGLT,CAG,CBG,CRG,
4CITYPEP1,CRFP1,CNBP1,CDP1,CACP1,CBDAP1,CAK1,CE1(2),CADJP1,
5CITYPEP2,CRFP2, CNBP2,CDP2,CACP2,CBDAP2,CAK2,CE1(3),CADJP2,
6CITYPQ1,CRFG1, CNQ1,CDG1,CACG1,CBDQ1,CAK3,CE1(5),CADQ1,
7CITYPEG2,CRFG2, CNBG2,CDG2,CACG2,CBDCG2,CAK4,CE1(6),CADQ2,
8CF,CE,CPG,CE1(1),CRPD,CRG,
9CPXP,CPYP,CPZP,CTOTFOR,CPXG,CPYG,CPZG,CTOTFOR,
PRINT OUT RESULTS FOR SPIRAL BEVEL UNIT

CALL SPBVOT(CPD, CPHE, CPHSI, CSPR, CF, CAO, CSI, CSOS, CROT, 1CTIR, TIR, CTHETA, CNP, CGAMMA, CDP, CROP, CB0P, CPITCH, 2CPXP, CPYP, CPZP, CTOFORP, CDCAP, CCASEP, CCP, CBP, 3CR1XP, CR1VP, CR1ZP, CTOFORP1, CBDCAP10, 4CR2XP, CR2VP, CR2ZP, CTOFORP2, CBDCAP20, 5CNG, CZZ, CQG, CRG, CB0G, 6CPQG, CPZQG, CTOFORQ, CDCAG, CCASEQ, CAG, CB0Q, 7CR1XQ, CR1VQ, CR1ZQ, CTOFORG1, CBDCAG10, 8CR2XQ, CR2VQ, CR2ZQ, CTOFORG2, CBDCAG20, 9CD1, CP1, CL1, CH1, CE1)

CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS

CALL SPBVCA( 1CTIL, TOF, CSI, SOF, CMG, CMGS, CNP, CNG, 2CAO, CGAMMA1, CROT, CSPR, CPHE1, CPHSI1, CZZ1, 3CPTL, CCAP, CPB, CRP, CGLT, CAG, CB0, CRG, 4CITYPEP1, CRFP1, CNBP1, CP1, CACP1, CBDCAP1, CAK1, CE1(2), CADJP1, 5CITYPEP2, CRFP2, CNBP2, CP1, CACP2, CBDCAP2, CAK2, CE1(3), CADJP2, 6CITYPEQ1, CRFG1, CNBG1, CP1, CACG1, CBDCAG1, CAK3, CE1(5), CADJG1, 7CITYPEQ2, CRFG2, CNBG2, CP1, CACG2, CBDCAG2, CAK4, CE1(6), CADJG2, 8CF, CE, CPQ, CE1(1), CRPD, CRGD, 9DPXP, DPYP, DPZP, DTOTFOR, DPXG, DPYG, DPZG, DTOTFOR, 1DR1XP, DR1VP, DR1ZP, DR2XP, DR2VP, DR2ZP, 2DR1XP, DR1YP, DR1ZG, DR2XG, DR2YG, DR2ZG, 3DL1(2), DH1(2), DTOTFORP1, CP1(2), DBDCAP10, DD1(2), 4DL1(3), DH1(3), DTOTFORP2, CP1(3), DBDCAP20, DD1(3), 5DL1(5), DH1(5), DTOTFORQ1, CP1(5), DBDCAQ10, DD1(5), 6DL1(6), DH1(6), DTOTFORQ2, CP1(6), DBDCAQ20, DD1(6), 7DL1(1), DH1(1), DDCAP, DD1(1), 8DL1(4), DH1(4), DDCAG, DD1(4), 9DLSB, DHSB, DSSB)
CALL SPBVOT (CPD, CPHE, CPHSI, CSPR, CF, CAO, CSI, CSOS, CROT, 
1CTIL, CTOS, CTHETA, CNP, CGAMMA, CDP, CRPD, CAQP, CBQP, CPITCH, 
2DPXP, DPYP, DPZP, DTOTFOR, DDCAP, CCASEP, CCAP, CBP, 
3DR1XP, DR1YP, DR1ZP, DTOFORP1, DBDCAP10, 
4DR2XP, DR2YP, DR2ZP, DTOFORP2, DBDCAP20, 
5CNG, CZZ, CDG, CRGD, CAQG, CBDG, 
6DPXG, DPYG, DPZG, DTOTFOR, DDCAG, CCASEG, CAG, CBG, 
7DR1XG, DR1YG, DR1ZG, DTOFORG1, DBDCAG10, 
8DR2XG, DR2YG, DR2ZG, DTOFORG2, DBDCAG20, 
9DD1, CP1, DL1, DH1, CE1)

CALL DPBVCA ( 
1TIR, TIL, TOF, SI, SDF, MG, MSG, NP, NG, 
2AQ, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1, ZIP, 
3PTL, AP, BP, RP, GTL, AG, BG, RG, 
4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1 (2), ADJP1, 
5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1 (3), ADJP2, 
6ITYPEG1, RFQ1, NBG1, DG1, ACG1, BDCAG1, AK3, E1 (5), ADJG1, 
7ITYPEG2, RFQ2, NBG2, DG2, ACG2, BDCAG2, AK4, E1 (6), ADJG2, 
8F, E, PG, E1 (1), RP, RGD, 
9PXPR, PYPR, PZPR, TOTFORR, PXGR, PYQR, PZGR, TOTFORGE, 
9PXPL, PYPL, PZPL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE, 
1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR, 
1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL, 
2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG, 
3L1(2), H1(2), DTOFORP1R, P1(2), BDCAP10R, D1(2), 
4L1(3), H1(3), DTOFORP2R, P1(3), BDCAP20R, D1(3), 
5L1(5), H1(5), DTOFORG1, P1(5), BDCAG10, D1(5), 
6L1(6), H1(6), DTOFORG2, P1(6), BDCAG20, D1(6), 
7L1(1), H1(1), DCAPR, D1(1), 
8L1(4), H1(4), DCAG, D1(4), 
#L1(7), H1(7), DCAPL, D1(7), 
*L1(8), H1(8), DTOFORP1L, P1(8), BDCAP10L, D1(8), 
*L1(9), H1(9), DTOFORP2L, P1(9), BDCAP10L, D1(9), 
9LSB, HSB, ESB)

PRINT OUT LIVES AND DYNAMIC CAPACITIES OF COMPONENTS
CALL DPBVOT(PD, PHE, PSF, SPR, F, AO, SI, SOF, ROT, TIR, TIL, TOF,
1THETA, NP, GAMMA, DP, RPD, AOP, BOP,
2PXPR, PYPR, PZPR, TOTFORR, DCAFR, CASEP, AP, BP,
3R1XPR, R1YPR, R1ZPR, TOTFOR1R, BDCAP1R,
4R2XPR, R2YPR, R2ZPR, TOTFOR2R, BDCAP2R,
2PXPL, PYPL, PZPL, TOTFORL, DCAFL, CASEP, AP, BP,
3R1XPL, R1YPL, R1ZPL, TOTFOR1L, BDCAP1L,
4R2XPL, R2YPL, R2ZPL, TOTFOR2L, BDCAP2L,
5NG, ZI, DG, ROG, AQG, BQG,
6PXQR, PYQR, PZQR, TOTFORGE, DCAG, CASEG, AG, BG,
6PXQL, PYQL, PZQL, TOTFORGE, DCAG, CASEG, AG, BG,
7R1XQ, R1YQ, R1ZQ, TOTFORQ1, BDCAG1,
8R2XQ, R2YQ, R2ZQ, TOTFORQ2, BDCAG2,
9D1, P1, L1, H1, E1

C CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
C CALCULATE LIFE OF PLANETARY UNIT

CALL PLANCA(ISTEP, NCOMP, MGP, NS, NPS, NPR, NR, PHIS, PHIR,
1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
2BIS, PS, ES, WDSM, B1RM, PR, ER, WDRM,
3TOS, TOF, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1,
4LPLAN, HPLAN, EPLAN)

C PRINT OUT RESULTS FOR THE PLANETARY UNIT

CALL PLANOT(ISTEP, N, V, CB, FB, NS, PDS, PHIS, WDSM, B1SM, FS,
1NR, PDR, PHIR, WDRM, B1RM, FR, NP, NPS, NPR, TOS, TOF, SOS, SOF, FTT,
2AD1, AP1, AL1, AH1, AE1)

C DEFINE TRANSMISSION LIFE ARRAYS

DO 50 IE=1, 6
   ZE1(IE)=CE1(IE)
   ZE1(IE+6)=CE1(IE)
   ZL1(IE)=CL1(IE)
50
   ZL1(IE+6)=DL1(IE)
DO 8 IE=1, 9
   ZE1(IE+12)=E1(IE)
   ZL1(IE+12)=L1(IE)
8   DO 9 IE=1, ISTEP
      ZE1(IE+21)=AE1(IE)
      ZL1(IE+21)=AL1(IE)
9   CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, LTRANS, ETRANS)
HTRANS=LTRANS*16666.667/SOF

C ESTIMATE 10 PERCENT DYNAMIC CAPACITY OF TRANSMISSION

CDMIN=CD1(1)
DO 51 I=2,6
IF(CD1(I).LT.CDMIN)CDMIN=CD1(I)
DELTATO=.1*CDMIN
DELTATI=0.5*NP/NG*DELTATO/MG/MGS
DTO=0.0
DTI=0.0
DO 52 I=1,10
   DTI=DTI+DELTATI
   DTO=DTO+DELTATO
   DVNCI)=DTO
   CALL SPBVCA(
   1DTI, TOF, CSI, SOF, CMG, CMGS, CNP, CNG,
   2CAO, CGAMMA1, CROT, CSGPR, CPHE1, CPHS1, CZZ1,
   3CPTL, CCAP, CBP, CRP, CGTL, CAQ, CBG, CRG,
   4CITYPEP1, CRFP1, CNBP1, CD1P, CAPP1, CBDCAP1, CAK1, CE1(2), CADJP1,
   5CITYPEP2, CRFP2, CNBP2, CD1P, CAPP2, CBDCAP2, CAK2, CE1(3), CADJP2,
   6CITYPEQ1, CRFQ1, CNBQ1, CD1Q, CACQ1, CBDCAGQ1, CAK3, CE1(5), CADJQ1,
   7CITYPEG2, CRFG2, CNBG2, CD1G, CACG2, CBDCAG2, CAK4, CE1(6), CADJG2,
   8CF, CE, CG, CE1(1), CRPD, CRGD,
   9CPXP, CPYP, CPZP, CTOTFOR, CPXG, CPYG, CPZG, CTOTFOR,
   1CR1XP, CR1YP, CR1ZP, CR2XP, CR2YP, CR2ZP,
   2CR1XG, CR1YG, CR1ZG, CR2XG, CR2YG, CR2ZG,
   3CL1(2), CH1(2), CTOTFORP1, CP1(2), CBDCAP10, CD1(2),
   4CL1(3), CH1(3), CTOTFORP2, CP1(3), CBDCAP20, CD1(3),
   5CL1(5), CH1(5), CTOTFORQ1, CP1(5), CBDCAG10, CD1(5),
   6CL1(6), CH1(6), CTOTFORG2, CP1(6), CBDCAG20, CD1(6),
   7CL1(1), CH1(1), CDCAP, CD1(1),
   8CL1(4), CH1(4), CDCAG, CD1(4),
   9LI(I), DUMB, DUMB)
52 CONTINUE
   CALL CAP(DYN, LI, 10, CDSB, CPSB)

C ESTIMATE 10 PERCENT DYNAMIC CAPACITY OF TRANSMISSION

CDMIN=D1(1)
DO 21 I=2,9
IF(D1(I).LT.DMIN)CDMIN=D1(I)
DELTATO=.1*CDMIN
DELTATI=0.5*DELTATO/MG/MGS
DTIR=0.0
DTIL=0.0
DTO=0.0

START COUNTER FOR DYNAMIC CAPACITIES BETWEEN 10 AND 100 PERCENT OF TRANSMISSION DYNAMIC CAPACITY

DO 22 I=1,10
   DTIR=DTIR+DELTATI
   DTIL=DTIL+DELTATI
   DTO=DTO+DELTATO
   DYN(I)=DTO

CALCULATE LIFE FOR EACH DYNAMIC CAPACITY

CALL DPBVCA(
  1DTIR, DTIL, DTO, SI, SOF, MG, MGS, NP, NG,
  2AQ, GAMMA1, ROT, SPR, PHE1, PHSI1, ZI1, ZIPI,
  3PTL, AP, BP, GTRL, AG, BG, RG,
  4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
  5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
  6ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
  7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2,
  8F, E, PG, E1(1), RD, RG,
  9XPXR, PYPR, PZPR, TOTFORR, PXGR, PYGR, PZGR, TOTFORGE,
  9XPXL, PYXL, PZXL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE,
  1R1XPR, R11YPYR, R11ZPR, R2XPR, R2YPR, R2ZPR,
  1R1XPL, R11YPL, R11ZPL, R2XPL, R2YPL, R2ZPL,
  2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
  3L1(2), H1(2), TOFORPR1, P1(2), BDCAP10R, D1(2),
  4L1(3), H1(3), TOFORPR2, P1(3), BDCAP20R, D1(3),
  5L1(5), H1(5), TOFORG1, P1(5), BDCAG10, D1(5),
  6L1(6), H1(6), TOFORG2, P1(6), BDCAG20, D1(6),
  7L1(1), H1(1), DCAPR, D1(1),
  8L1(4), H1(4), DCAG, D1(4),
  *L1(7), H1(7), DCAPL, D1(7),
  *L1(8), H1(8), TOFORPL1, P1(8), BDCAP10L, D1(8),
  *L1(9), H1(9), TOFORPL2, P1(9), BDCAP10L, D1(9),
  9LI(I), DUMB, DUMB)

CONTINUE
CALL CAP(DYN, LI, 10, DSB, PSP)

START COUNTER FOR LOADS BETWEEN 15 AND 100 PERCENT OF DYNAMIC CAPACITY
C
ADMIN=AD1(1)
DO 23 I=2,ISTEP
23
IF(AD1(I).LT.ADMIN)ADMIN=AD1(I)
DELTATO=.1*ADMIN
DELTATOS=DELTATO/MGS
DTO=.0
DTOS=.0
DO 24 I=1,10
DTOS=DTOS+DELTATOS
DTO=DTO+DELTATO
DYN(I)=DTO
CALL PLANCA(ISTEP,NCOMP,MGP,NS,NPS,NPR,NR,PHIS1,PHIR1,
1RS,RP,RRR,CB,A,V,PB,N,EB,FTT,
2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
3DTOS,DTO,SOS,SOF,CS,LS,FS,CR,LR,FR,AD1,AL1,AH1,AE1,ALI(I),DUMB,
4DUMB)
24 CONTINUE
CALL CAP(DYN,ALI,10,DPLAN,PPLAN)

C
START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC CAPACITY
C
IF(ADMIN.LT.DMIN)DMIN=ADMIN
IF(CDMIN.LT.DMIN)DMIN=CDMIN
DELTATO=.1*DMIN
DELTATOS=DELTATO/MGS
DELTATIR=DELTATOS/MG/2.
DELTATIL=DELTATOS/MG/2.
CDELTI=DELTATIR*CNP/CNG
CTI=.0
DTIR=.0
DTIL=.0
DTOS=.0
DTO=.0
DO 20 I=1,10
CTI=CTI+CDELTI
DTIR=DTIR+DELTATIR
DTIL=DTIL+DELTATIL
DTOS=DTOS+DELTATOS
DTO=DTO+DELTATO
DYN(I)=DTO

C
CALL SPSVCA(
1CTI, DTO, CSI, SOF, CMG, CMGS, CNP, CNG,
2CAO, CGAMMA1, CRQT, CSPR, CPE1, CPHSI1, CZZ1,
3CPM, CCAP, CBP, CPR, CGTL, CAG, CBG, CRG,
4CITYPE1, CRFP1, CNBP1, CD1, CACP1, CBDCAP1, CAK1, CE1(2), CADJP1,
5CITYPE2, CRFP2, CNBP2, CD2, CACP2, CBDCAP2, CAK2, CE1(3), CADJP2,
6CITYPEG1, CRFG1, CNBG1, CDG1, CACG1, CBDCAG1, CAK3, CE1(5), CADJG1,
7CITYPEG2, CRFG2, CNBG2, CDG2, CACG2, CBDCAG2, CAK4, CE1(6), CADJG2,
8CE, CF, CP, CE1(1), CPD, CRG,
9CPXP, CPYP, CPZP, CTOTFORP, CPXG, CPYG, CPZG, CTOTFOR,
1CR1XP, CR1YP, CR1ZP, CR2XP, CR2YP, CR2ZP,
2CR1XG, CR1YG, CR1ZG, CR2XG, CR2YG, CR2ZG,
3CL1(2), CH1(2), CTOTFORP1, C1(2), CBDCAP10, CD1(2),
4CL1(3), CH1(3), CTOTFORP2, C1(3), CBDCAP20, CD1(3),
5CL1(5), CH1(5), CTOTFORG1, C1(5), CBDCAG10, CD1(5),
6CL1(6), CH1(6), CTOTFORG2, C1(6), CBDCAG20, CD1(6),
7CL1(1), CH1(1), CDCAP, CD1(1),
8CL1(4), CH1(4), CDCAG, CD1(4),
9DUMB, DUMB, DUMB)

CALL DPBVCA(
1DTIR, DTIL, DTO, SI, SOF, MG, MGS, NP, NG,
2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1, ZIP,
3PTL, AP, BP, RP, GXL, AG, BG, RG,
4ITYPE1, RFP1, NB1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
5ITYPE2, RFP2, NB2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
6ITYPEG1, RFG1, NBG1, D1, AG1, BDCAG1, AK3, E1(5), ADJG1,
7ITYPEG2, RFG2, NBG2, D2, AG2, BDCAG2, AK4, E1(6), ADJG2,
8F, E, PG, E1(1), RP, RG,
9PXPR, PYPR, PZPR, CTOTFORP, PXGR, PYGR, PZGR, CTOTFORGE,
9FXPL, PYPL, PZPL, CTOTFORL, PXGL, PYGL, PZGL, CTOTFORGE,
1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,
1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,
2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
3LI(2), H1(2), TOFORP1R, P1(2), BDCAP10R, D1(2),
4LI(3), H1(3), TOFORP2R, P1(3), BDCAP20R, D1(3),
5LI(5), H1(5), TOFORG1, P1(5), BDCAG10, D1(5),
6LI(6), H1(6), TOFORG2, P1(6), BDCAG20, D1(6),
7LI(1), H1(1), DCAPR, D1(1),
8LI(4), H1(4), DCAP, D1(4),
*LI(7), H1(7), DCAPL, D1(7),
*LI(8), H1(8), TOFORP1L, P1(8), BDCAP10L, D1(8),
*LI(9), H1(9), TOFORP2L, P1(9), BDCAP10L, D1(9),
9DUMB, DUMB, DUMB)

CALL PLANCA(ISTEP, NCOMP, MGP, NS, NPS, NPR, NR, PHIS1, PHIR1,
1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
2B1SM, FS, ES, WDSM, B1RM, PR, ER, WDRM,
3DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, DUMB, DUMB,
4DUMB)

DO 54 IE=1,6
   ZL1(IE)=CL1(IE)
   ZL1(IE+6)=CL1(IE)
54

DO 12 IE=1,9
   ZE1(IE+12)=E1(IE)
12

DO 13 IE=1,ISTEP
   ZE1(IE+21)=AE1(IE)
13

   ZL1(IE+21)=AL1(IE)

CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, ZLI(I), DUMB)

CONTINUE

CALL CAP(DYN, ZLI, 10, DTRANS, PTRANS)

READ(1,1220)
FORMAT(' TOTAL TRANSMISSION'/)
1220 FORMAT( ' SPIRAL BEVEL UNIT'/)
1222 FORMAT( ' PLANETARY UNIT'/)

WRITE(1,1221)
CALL DPLHE(CDSB, CPSB, CLSB, CHSB, CESB)
WRITE(1,1222)
CALL DPLHE(DSB, PSP, LSB, HSB, ESB)
WRITE(1,1220)
CALL DPLHE(DPLAN, PPLAN, LPLAN, HPLAN, EPLAN)

STOP

SUBROUTINE PLAN

REAL NS, NPS, NPR, NR, LS, LR, LPLAN
REAL NCOMP(5), D1(5), P1(5), L1(5), H1(5), E1(5), MG1, LI(10), DYN(10)

C
C CB  DYNAMIC CAPACITY OF THE BEARINGS
C A  LIFE ADJUSTMENT FACTOR OF THE BEARINGS
C EB  WEIBULL EXPONENT OF THE BEARINGS
C PB  LOAD LIFE EXPONENT OF THE BEARINGS
C N  NUMBER OF PLANETARY GEARS
C NCOMP(1)  NUMBER OF PLANET BEARINGS
C NCOMP(2)  NUMBER OF SUN GEARS
C NCOMP(3)  NUMBER OF RING GEARS
C NCOMP(4) NUMBER OF PLANET-SUN GEARS
C NCOMP(5) NUMBER OF PLANET-RING GEARS
C PDS PITCH OF PLANET-SUN MESH
C PDR PITCH OF PLANET-RING MESH
C NS NUMBER OF SUN GEAR TEETH
C NPS NUMBER OF PLANET-SUN GEAR TEETH
C NPR NUMBER OF PLANET-RING GEAR TEETH
C NR NUMBER OF RING GEAR TEETH
C PHIS PRESSURE ANGLE OF SUN GEAR (DEG)
C PHIS1 PRESSURE ANGLE OF SUN GEAR (RAD)
C PHIR PRESSURE ANGLE OF RING GEAR (DEG)
C PHIR1 PRESSURE ANGLE OF RING GEAR (RAD)
C WDSM WIDTH OF THE SUN GEAR MESH
C WDRM WIDTH OF THE RING GEAR MESH
C ES WEIBULL EXPONENT OF THE SUN GEAR MESH
C ER WEIBULL EXPONENT OF THE RING GEAR MESH
C PS LOAD-LIFE EXPONENT OF THE SUN GEAR MESH
C PR LOAD-LIFE EXPONENT OF THE RING GEAR MESH
C B1SM MATERIAL CONSTANT OF THE SUN GEAR MESH
C B1RM MATERIAL CONSTANT OF THE RING GEAR MESH
C RS RADIUS OF THE SUN GEAR
C RPS RADIUS OF THE PLANET-SUN GEAR
C RPR RADIUS OF THE PLANET-RING GEAR
C RR RADIUS OF THE RING GEAR
C ISTEP NUMBER OF COMPONENTS IN THE PLANETARY
C ISTEP = 4 UNSTEPED PLANETARY UNIT
C ISTEP = 5 STEPPED PALETARY UNIT

C
C INPUT TORQUE AND SPEED

101 FORMAT('WHAT IS THE INPUT TORQUE OF THE TRANSMISSION')
102 FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
WRITE(1,101)
READ(1,*)TI
WRITE(1,102)
READ(1,*)SI
CALL PLANIN(CB, A, V, EB, PB, N, NCOMP, PDS, PDR, NS, PHIS, PHIS1,
PHIR, PHIR1, WDSM, ES, PS, B1SM, ISTEP, NPS, NPR, NR, WDRM, ER, PR, B1RM,
2RPR, RPS, RR, RS)
P1(1)=PB
P1(2)=PS
P1(3)=PR
P1(4)=PS
P1(5)=PR
MG1=1.0
TOF = TI * \((1. + (RR * RPS)/(RS * RPR))\)
SOF = SI / \((1. + (RR * RPS)/(RS * RPR))\)

CALL PLANCA(ISTEP, NCOMP, MG1, NS, NPS, NPR, NR, PHIS1, PHIR1, 
1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT, 
2BISM, PS, ES, WDSM, B1RM, PR, ER, WDRM, 
3TI, TOF, SI, SOF, CS, LS, FS, CR, LR, FR, D1, L1, H1, E1, LPLAN, HPLAN, EPLAN)

CALL PLANOT(ISTEP, N, V, CB, FB, NS, PDS, PHIS, WDSM, B1SM, FS, 
1NR, PDR, PHIR, WDRM, B1RM, FR, NP, NPS, NPR, Ti, TOF, SI, SOF, FTT, 
2D1, P1, L1, H1, E1)
DMIN = D1(I)
DO 10 I = 2, ISTEP
IF(D1(I).LT.DMIN) DMIN = D1(I)
DELTATO = 1 * DMIN
DELTATI = DELTATO / \((1. + (RR * RPS)/(RS * RPR))\)
DTI = 0.0
DTO = 0.0
DO 20 I = 1, 10
   DTI = DTI + DELTATI
   DTO = DTO + DELTATO
   DYN(I) = DTO
   CALL PLANCA(ISTEP, NCOMP, MG1, NS, NPS, NPR, NR, PHIS1, PHIR1, 
1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT, 
2BISM, PS, ES, WDSM, B1RM, PR, ER, WDRM, 
3TI, DTO, SI, SOF, CS, LS, FS, CR, LR, FR, D1, L1, H1, E1, L(I), DUMB, DUMB)
20 CONTINUE
CALL CAP(DYN, LI, 10, DPLAN, PPLAN)
WRITE(1, 1000)
1000 FORMAT(’ TOTAL TRANSMISSION’/)
CALL DPLHE(DPLAN, PPLAN, LPLAN, HPLAN, EPLAN)
STOP
END

SUBROUTINE DBPL
INTEGER CASEP, CASEG, PTL, G1L
REAL NP, NG, NBP1, NBP2, NG1, NG2, MG, LSB
REAL L1(9), D1(9), E1(9), H1(9), P1(9), DYN(10), LI(10)
REAL NS, NPS, NPR, NR, N, LS, LR, LPLAN
REAL NCOMP(5), AD1(5), AP1(5), AL1(5), AH1(5), AE1(5), ALI(10)
REAL MGS, MG1, ZNCOMP(14), ZE1(14), ZL1(14), LTRANS, ZLI(10)
WHAT IS THE INPUT TORQUE OF THE RIGHT PINION

WHAT IS THE INPUT TORQUE OF THE LEFT PINION

WHAT IS THE INPUT SPEED OF THE TRANSMISSION

WRITE(1,101)
READ(1,*)TIR
WRITE(1,102)
READ(1,*)TIL
WRITE(1,103)
READ(1,*)SI

CALL DPBVIN(NP, NG, AO, PHE, F, PSI, ROT, SPR, THETA, E, E1(1), PG, 1PH1, PSI1, THET1, CASEP, PT, AP, BP, ITYPEP1, NBP1, DP1, ACP1, AK1, 2BCAP1, RFP1, E1(2), ITYPEP2, NBP2, DP2, ACP2, AK2, BDCAP2, RFP2, E1(3), 3CASEG, QTL, AO, BQ, ITYPEG1, NBG1, DG1, ACQ1, AK3, BDCAG1, RFG1, E1(5), 4ITYPEG2, NBG2, DG2, ACQ2, AK4, BDCAG2, RFG2, E1(6), MG, GAMMA1, GAMMA, ZZ, 5GZ1, DP, DG, RPD, RP, RQG, RG, HK, AQ, AQ, HT, BQ, BQ, PD, 6ADJP1, ADJP2, ADJP1, ADJP2, ZIP)

E1(4)=E1(1)
E1(7)=E1(1)
E1(8)=E1(2)
E1(9)=E1(3)
P1(1)=PG
P1(4)=PG
P1(7)=PG

CALL PLANIN(CK, A, V, EB, PB, N, NCOMP, PDS, PDR, NS, PHIS, PHIS1, 1PHI1, PHIR1, WD5M, ES, PS, B1SM, ISTEP, NPS, NPR, NR, WDRM, ER, PR, B1RM, 2RPR, RPS, RR, RS)
AP1(1)=PB
AP1(2)=PS
AP1(3)=PR
AP1(4)=PS
AP1(5)=PR

CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT

TOS=TIR*MG+TIL*MG
SOS=SIS/MG

READ IN VALUES OF PLANETARY UNIT

CALL PLANIN(CK, A, V, EB, PB, N, NCOMP, PDS, PDR, NS, PHIS, PHIS1, 1PHI1, PHIR1, WD5M, ES, PS, B1SM, ISTEP, NPS, NPR, NR, WDRM, ER, PR, B1RM, 2RPR, RPS, RR, RS)
AP1(1)=PB
AP1(2)=PS
AP1(3)=PR
AP1(4)=PS
AP1(5)=PR

CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT
TOF = TOS * (1 + (RR * RPS) / (RS * RPR))
SOF = SOS * (1 + (RR * RPS) / (RS * RPR))
MGS = (1 + (RR * RPS) / (RS * RPR))
MGP = 1.0
INCOMP = 9 + ISTEP
DO 5 IN = 1, 9
5 ZNCOMP(IN) = 1.0
DO 6 IN = 1, ISTEP
6 ZNCOMP(IN + 9) = NCOMP(IN)

CALL OPBVCA(
  1TIR, TIL, TOF, SI, SOF, MG, MGS, NP, NQ,
  2AO, GAMMA1, ROT, SPR, PHE1, PHS1, ZZ1, ZIP,
  3TPL, AP, BP, GPL, AG, BG, RG,
  4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
  5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
  6ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
  7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2,
  8F, E, PG, E1(1), RPD, RGD,
  9PXPR, PYPR, PZPR, TOTFORR, PXGR, PYGR, PZGR, TOTFORGE,
  9PXPL, PYPL, PZPL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE,
  1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,
  1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,
  2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
  3L1(2), H1(2), TOFORP1R, P1(2), BDCAP1OR, D1(2),
  4L1(3), H1(3), TOFORP2R, P1(3), BDCAP2OR, D1(3),
  5L1(5), H1(5), TOFORG1, P1(5), BDCAG1OR, D1(5),
  6L1(6), H1(6), TOFORG2, P1(6), BDCAG2OR, D1(6),
  7L1(1), H1(1), DCAPR, D1(1),
  8L1(4), H1(4), DCAG, D1(4),
  *L1(7), H1(7), DCAPL, D1(7),
  *L1(8), H1(8), TOFORP1L, P1(8), BDCAP1OL, D1(8),
  *L1(9), H1(9), TOFORP2L, P1(9), BDCAP1OL, D1(9),
  9LSB, HSB, ESB)

CALL DPBVOT(PD, PHE, PHSI, SPR, F, AO, SI, SOF, ROT, TIR, TIL, TOF,
  1THETA, NP, GAMMA, DP, RPD, AOP, BOP,
  126
2PXPR, PYPR, PZPR, TOTFORR, DCA PR, CASEP, AP, BP,
3R1XPR, R1YPR, R1ZPR, TOF OR1R, BDCA P1OR,
4R2XPR, R2YPR, R2ZPR, TOF OR2R, BDCA P2OR,
2PXPL, PYPL, PZPL, TOTFORL, DCA PL, CASEP, AP, BP,
3R1XPL, R1YPL, R1ZPL, TOF OR1L, BDCA P1OL,
4R2XPL, R2YPL, R2ZPL, TOF OR2L, BDCA P2OL,
5NG, ZZ, DG, RG1, AG, BG,
6PXGR, PYGR, PZGR, TOTFORGE, DCA G, CASEG, AG, BG,
6PXGL, PYGL, PZGL, TOTFORGE, DCA G, CASEG, AG, BG,
7R1XG, R1YG, R1ZG, TOFORG1, BDCA G10,
8R2XG, R2YG, R2ZG, TOFORG2, BDCA G20,
9D1, P1, L1, H1, E1)

C CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
C CALCULATE LIFE OF PLANETARY UNIT

CALL PLANCA(ISTEP, NCOMP, MGP, NS, NPS, NPR, NR, PHIS1, PHIR1,
1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
3TOS, TOF, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1,
4LPLAN, HPLAN, EPLAN)

C PRINT OUT RESULTS FOR THE PLANETARY UNIT

CALL PLANOT(ISTEP, N, V, CB, FB, NS, PDS, PHIS, WDSM, B1SM, FS,
1NR, PDR, PHIR, WDRM, B1RM, FR, NP, NPS, NPR, TOS, TOF, SOS, SOF, FTT,
2AD1, AP1, AL1, AH1, AE1)

C DEFINE TRANSMISSION LIFE ARRAYS

DO 8 IE=1,9
     ZE1(IE)=E1(IE)
8  ZL1(IE)=L1(IE)
DO 9 IE=1,ISTEP
     ZE1(IE+9)=AE1(IE)
9  ZL1(IE+9)=AL1(IE)

CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, LTRANS, ETRANS)
HTRANS=LTRANS*16666.667/SOF

C ESTIMATE 10 PERCENT DYNAMIC CAPACITY OF TRANSMISSION

DMIN=D1(1)
DO 21 I=2,9
     IF(D1(I).LT.DMIN)DMIN=D1(I)
21  DELTATO=.1*DMIN

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DELTA I = 0.5 \times \text{DELTATO/MG/MGS}

DTIR = 0.0
DTIL = 0.0
DTO = 0.0

START COUNTER FOR DYNAMIC CAPACITIES BETWEEN 10 AND 100 PERCENT OF TRANSMISSION DYNAMIC CAPACITY

DO 22 I = 1, 10
   DTIR = DTIR + DELTA I
   DTIL = DTIL + DELTA I
   DTO = DTO + DELTA I
   DYN(I) = DTO

CALL DPBVCA(
   1DTIR, DTIL, DTO, SI, SOF, MG, MGS, NP, NG,
   2AO, GAMMA1, ROT, SPR, PHE1, PHE1, ZZ1, ZIP,
   3PTL, AP, BP, RP, QTL, AG, BG, RQ,
   4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
   5ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
   6ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
   7ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2,
   8F, E, PG, E1(1), RPD, RGD,
   9PXPR, PYPR, PZPR, TOFORR, PXGR, PYGR, PZGR, TOFORGE,
   9PXPL, PYPL, PZPL, TOFORL, PXGL, PYGL, PZGL, TOFORGE,
   1R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,
   1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,
   2R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
   3L1(2), H1(2), TOFORP1R, P1(2), BDCAP1OR, D1(2),
   4L1(3), H1(3), TOFORP2R, P1(3), BDCAP2OR, D1(3),
   5L1(5), H1(5), TOFORG1, P1(5), BDCAG1OR, D1(5),
   6L1(6), H1(6), TOFORG2, P1(6), BDCAG2OR, D1(6),
   7L1(1), H1(1), DCAPR, D1(1),
   8L1(4), H1(4), DCAG, D1(4),
   *L1(7), H1(7), DCAPL, D1(7),
   *L1(8), H1(8), TOFORP1L, P1(8), BDCAP1OL, D1(8),
   *L1(9), H1(9), TOFORP2L, P1(9), BDCAP1OL, D1(9),
   9L1(I), DUMB, DUMB)

22 CONTINUE

CALL CAP(DYN, LI, 10, DS8, PSP)
START COUNTER FOR LOADS BETWEEN 15 AND 100 PERCENT OF DYNAMIC CAPACITY

ADMIN = AD1(I)

DO 23 I = 2, ISTEP
   IF (AD1(I).LT.ADMIN) ADMIN = AD1(I)
   DELTATO = 1 * ADMIN
   DELTATOS = DELTATO / MGS
   DTO = 0.0
   DTOS = 0.0
   DO 24 I = 1, 10
      DTOS = DTOS + DELTATOS
      DTO = DTO + DELTATO
      DYN(I) = DTO
   CALL PLANCA(ISTEP, NCOMP, MGP, NS, NPS, NPR, NR, PHIS1, PHIR1,
               1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
               2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
               3DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, ALI(I), DUMB, 4DUMB)
   24 CONTINUE
   CALL CAP(DYN, ALI, 10, DPLAN, PPLAN)

START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC CAPACITY

IF (ADMIN .LT. DMIN) DMIN = ADMIN
   DELTATO = 1 * DMIN
   DELTATOS = DELTATO / MGS
   DELTATIR = DELTATOS / MG / 2.
   DELTATIL = DELTATOS / MG / 2.
   DTIR = 0.0
   DTIL = 0.0
   DTOS = 0.0
   DTO = 0.0
   DO 20 I = 1, 10
      DTIR = DTIR + DELTATIR
      DTIL = DTIL + DELTATIL
      DTOS = DTOS + DELTATOS
      DTO = DTO + DELTATO
      DYN(I) = DTO
   CALL DPBVCA(
               1DTIR, DTIL, DTO, SI, SOF, MG, MGS, NP, NG,
CALL PLANCA(ISTEP, NCOMP, MGP, NS, NPS, NPR, NR, PHIS1, PHIR1, 1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT, 2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM, 3DTS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, ALI(I), DUMB, 4DUMB)
DO 12 IE=1, 9
   ZL1(IE)=L1(IE)
DO 13 IE=1, ISTEP
   ZL1(IE+9)=ALI(IE)
12 CONTINUE
CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, ZL1(I), DUMB)
13
20 CONTINUE
CALL CAP(DYN, ZL1, 10, DTRANS, PTRANS)
1220 FORMAT(' TOTAL TRANSMISSION')
1221 FORMAT(' SPIRAL BEVEL UNIT')
1222 FORMAT(' PLANETARY UNIT')
WRITE(1, 1221)
CALL DPLHE(DSB, PSP, LSB, HSB, ESB)
WRITE(1, 1222)
CALL DPLHE(DPLAN, PPLAN, LPLAN, HPLAN, EPLAN)
WRITE(1, 1220)
CALL DPLHE(DTRANS, PTRANS, LTRANS, HTRANS, ETRANS)
STOP
END
SUBROUTINE DBPLPL
INTEGER CASEP, CASEG, PTL, GTL, BISTEP
REAL NP, NG, NBP1, NBP2, NBG1, NBG2, MG, LSB
REAL L1(9), D1(9), E1(9), H1(9), P1(9), DYN(10), LI(10)
REAL NS, NPS, NPR, NR, N, LS, LR, LPLAN
REAL NCOMP(5), AD1(5), AP1(5), AL1(5), AE1(5), ALI(10)
REAL MGS, MGPA, MGPB, ZNCOMP(19), ZE1(19), ZL1(19), LTRANS, ZLI(10)
REAL BNCOMP(5), BD1(5), BP1(5), BL1(5), BE1(5), BLI(10)

101 FORMAT('WHAT IS THE INPUT TORQUE OF THE RIGHT PINION')
102 FORMAT('WHAT IS THE INPUT TORQUE OF THE LEFT PINION')
103 FORMAT('WHAT IS THE INPUT SPEED OF THE TRANSMISSION')
WRITE(1,101)
READ(1,*)TIR
WRITE(1,102)
READ(1,*)TIL
WRITE(1,103)
READ(1,*)SI

INPUT SPIRAL BEVEL GEAR GEOMETRY

CALL DPBVIN(NP,NG,AO,PHE,F,PHSI,ROT,SPR,THETA,E,E1(1),PG,
1PHE1,PHSI1,THETA1,CASEP,PTL,AP,BP,ITYPEP1,NBP1,DP1,ACP1,AK1,
2BDCAP1,RFP1,E1(2),ITYPEP2,NBP2,DP2,ACP2,AK2,BDCAP2,RFP2,E1(3),
3CASEQ,GTL,AG,BG,ITYPEG1,NBG1,DG1,ACG1,AK3,BDCAG1,RFG1,E1(5),
4ITYPEG2,NBG2,DG2,ACG2,AK4,BDCAG2,RFG2,E1(6),MG,GAMMA1,GAMMA,ZZ,
5ZIZI,DP,DRD,RP,RGD,RG,HK,AOG,AOP,HT,BDG,BDP,PD,
6ADJP1,ADJP2,ADJG1,ADJG2,ZIP)
E1(4)=E1(1)
E1(7)=E1(1)
E1(8)=E1(2)
E1(9)=E1(3)
P1(1)=PG
P1(4)=PG
P1(7)=PG

CALCULATE OUTPUT TORQUE AND SPEED OF TRANSMISSION
TOS=TIR*MG+TIL*MG
SOS=SI/MG

READ IN VALUES OF PLANETARY UNIT
CALL PLANIN(CB,A,V,EB,PB,N,NCOMP,PDS,PDR,NS,PHIS,PHIS1,
1PHIR,PHIR1,WDSM,ES,PS,B1SM,ISTEP,NPS,NPR,NR,WDRM,ER,PR,BIRM,
2RPR, RPS, RR, RS)
AP1(1) = PB
AP1(2) = PS
AP1(3) = PR
AP1(4) = PS
AP1(5) = PR

C C C C C
CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT

TOPA = TOS * (1. + (RR * RPS) / (RS * RPR))
SOPA = SOS / (1. + (RR * RPS) / (RS * RPR))

C C C C C
READ IN VALUES OF PLANETARY UNIT

CALL PLANIN (BCB, BA, BV, BEB, BPS, BN, BNCOMP, BPDS, BPDR, BNS, BPHIS,
1BPHIS1, BPHIR, BPHIR1, BWDQM, BES, BPS, BB1SM, BISTEP, BNPS,
2BNPR, BNR, BWDQM, BER, BPR, BB1RM, BRPR, BRPS, BRR, BRS)
BP1(1) = BPB
BP1(2) = BPS
BP1(3) = BPR
BP1(4) = BPS
BP1(5) = BPR

C C C C C
CALCULATE OUTPUT TORQUE AND SPEED OF PLANETARY UNIT

TOF = TOPA * (1. + (BRR * BRPS) / (BRS * BRPR))
SOF = SOPA / (1. + (BRR * BRPS) / (BRS * BRPR))
MGPA = (1. + (BRR * BRPS) / (BRS * BRPR)) * MGPA
MGPB = 1.0
INCOMP = 9 + ISTEP + BISTEP
DO 5 IN = 1, 9
5 ZNCOMP(IN) = 1.0
DO 6 IN = 1, ISTEP
6 ZNCOMP(IN + 9) = NCOMP(IN)
IX = 9 + ISTEP
DO 77 IN = 1, BISTEP
77 ZNCOMP(IN + IX) = BNCOMP(IN)

C C C C C
CALCULATE LIFE AND DYNAMIC CAPACITY OF SPIRAL BEVEL UNIT COMPONENTS
C C C C C
CALCULATE LIFE OF SPIRAL BEVEL UNIT

CALL DPBVCA(
1TIR, TIL, TOF, SI, SOF, MG, MGS, NP, NG,

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PRINT OUT LIVES AND DYNAMIC CAPACITIES OF COMPONENTS

CALL DPBVOT(PD, PHE, PHSI, SPR, F, AO, SI, SOF, ROT, TIR, TIL, TOF,
1THETA, NP, GAMMA, DP, RPD, AOP, BOP,
2PXPR, PYPR, PZPR, TOTFARR, DCAO, CASEP, AP, BPN,
3R1XPR, R1YPR, R1ZPR, TOFORR1, BDCAP10R, D1(1),
4R2XPR, R2YPR, R2ZPR, TOFORR2, BDCAP20R, D1(1),
5LI(2), H1(2), TOFORP1R, P1(2), BDCAP10R, D1(2),
6LI(3), H1(3), TOFORP2R, P1(3), BDCAP20R, D1(1),
7LI(5), H1(5), TOFORG1, P1(5), BDCAG10, D1(5),
8LI(6), H1(6), TOFORG2, P1(6), BDCAG20, D1(6),
9LSB, HSB, ESB)

PRINT OUT LIVES AND DYNAMIC CAPACITIES OF PLANETARY UNIT COMPONENTS

CALL PLANCA(ISTEP, NCOMP, MP, NS, NPS, NPR, NR, PHISI, PHIR1,
CLRS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM,
3TOS, TOF, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1,
4LPLAN, HPLAN, EPLAN)

PRINT OUT RESULTS FOR THE PLANETARY UNIT

CALL PLANOT(ISTEP, N, V, CB, FB, NS, PDS, PHIS, WDSM, B1SM, FS,
1NR, PDR, PHIR, WDRM, B1RM, FR, NP, NPS, NPR, TOS, TOF, SOS, SOF, FTT,
2AD1, AP1, AL1, AH1, AE1)

CALCULATE LIFE AND DYNAMIC CAPACITY OF PLANETARY UNIT COMPONENTS
CALCULATE LIFE OF PLANETARY UNIT

CALL PLANCA(BISTEP, BNCOMP, MGPB, BNS, BNPS, BNPR, BNR,
1BPHIS1, BPHIR1, BRS, BRPS, BRPR, BRR, BCB, BA, BV, BPB, BN, BEB,
2BFTT, BB1SM, BPS, BES, BWDWM, BB1RM, BPR, BER, BWDWM,
3TOPA, TOF, SOPA, SOF, BCS, BLS, BFS, BCR, BLR, BFR, BD1, BL1, BH1, BE1,
4BPLAN, BHPLAN, BEPLAN)

PRINT OUT RESULTS FOR THE PLANETARY UNIT

CALL PLANOT(BISTEP, BN, BV, BCB, BFB, BNS, BPDS, BPHIS, BWDWM,
1BB1SM, BFS, BNR, BPDR, BPHIR, BWDWM, BB1RM, BFR, BNP, BNPS, BNPR,
2TOPA, TOF, SOPA, SOF, BFTT, BD1, BP1, BL1, BH1, BE1)

DEFINE TRANSMISSION LIFE ARRAYS

DO 8 IE=1, 9
   ZE1(IE)=E1(IE)
   ZL1(IE)=L1(IE)
   DO 9 IE=1, ISTEP
      ZE1(IE+9)=AE1(IE)
      ZL1(IE+9)=AL1(IE)
   9
   DO 99 IE=1, BISTEP
      ZE1(IE+9+ISTEP)=BE1(IE)
     99
   CALL LIFE(ZL1, INCOMP, ZE1, ZNCOMP, LTRANS, ETRANS)
      HTRANS=LTRANS*16666.666/SOF

START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC
CAPACITY

DMIN=D1(1)
   DO 21 I=2, 9
      IF(D1(I).LT.DMIN)DMIN=D1(I)
   21
DELTATO= 1*DMIN
DELTATI=0.5*DELTATO/MG/MGS
DTIR=0.0
DTIL=0.0
DTO=0.0

START COUNTER FOR DYNAMIC CAPACITIES BETWEEN 10 AND 100 PERCENT OF TRANSMISSION DYNAMIC CAPACITY

DO 22 I=1,10
   DTIR=DTIR+DELTATI
   DTIL=DTIL+DELTATI
   DTO=DTO+DELTATO
   DYN(I)=DTO

CALCULATE LIFE FOR EACH DYNAMIC CAPACITY

CALL DPBVCA(
   1DTIR, DTIL, DTO, SI, SOF, MG, MGS, NP, NG,
   2AO, GAMMA1, ROT, SPR, PHE1, PHS1I, ZZ1, ZIP,
   3PTL, AP, BP, RP, GTL, AG, BG, RG,
   4ITYYPEP1, RFP1, NB1, DP1, ACP1, BDCAP1, AK1, EI(2), ADJP1,
   5ITYYPEP2, RFP2, NB2, DP2, ACP2, BDCAP2, AK2, EI(3), ADJP2,
   6ITYPEG1, RFG1, NBG1, DG1, ACQ1, BDCAG1, AK3, EI(5), ADQ1,
   7ITYPEG2, RFG2, NBG2, DG2, ACQ2, BDCAG2, AK4, EI(6), ADQ2,
   8F, E, PG, EI(1), RP, RG,
   9PXPR, PYPR, PZPR, TOTFORR, PXQR, PYQR, PZQR, TOTFORGE,
   9PXPL, PYPL, PZPL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE,
   1R1XR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,
   1R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,
   2R1XR, R1YR, R1ZR, R2XR, R2YR, R2ZR,
   3L1(2), H1(2), TOFORP1R, P1(2), BDCAP1OR, D1(2),
   4L1(3), H1(3), TOFORP2R, P1(3), BDCAP2OR, D1(3),
   5L1(5), H1(5), TOFORG1, P1(5), BDCAG10, D1(5),
   6L1(6), H1(6), TOFORG2, P1(6), BDCAG20, D1(6),
   7L1(1), H1(1), DCAPR, D1(1),
   8L1(4), H1(4), DCAG, D1(4),
   *L1(7), H1(7), DCAPL, D1(7),
   *L1(8), H1(8), TOFORP1L, P1(8), BDCAP1OL, D1(8),
   *L1(9), H1(9), TOFORP2L, P1(9), BDCAP1OL, D1(9),
   9L1(I), DUMB, DUMB)

22 CONTINUE

CALL CAP(DYN, LI, 10, DSB, PSP)

C
C     START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC CAPACITY
C
ADMIN=AD1(1)
DO 23 I=2, ISTEP
   IF(AD1(I).LT.ADMIN)ADMIN=AD1(I)
   DELTATO=.1*ADMIN
   DELTATOS=DELTATO/MGPA
   DTO=0.0
   DTOS=0.0
   DO 24 I=1,10
      DTOS=DTOS+DELTATOS
      DTO=DTO+DELTATO
      DYN(I)=DTO
   CALL PLANCA(ISTEP, NCOMP, MGPA, NS, NPS, NPR, NR, PHIS1, PHIR1,
   1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT,
   2BS1SM, PS, ES, WDSM, BR1RM, PR, ER, WDMR,
   3DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, ALI(I), DUMB,
   4DUMB)
24 CONTINUE
   CALL CAP(DYN, ALI, 10, DPLAN, PPLAN)
C     START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC CAPACITY
C
BDMIN=BD1(1)
DO 30 I=2, BISTEP
   IF(BD1(I).LT.BDMIN)BDMIN=BD1(I)
   DELTATO=.1*BDMIN
   DELTATOS=DELTATO/MGPA
   DTO=0.0
   DTOS=0.0
   DO 31 I=1,10
      DTOS=DTOS+DELTATOS
      DTO=DTO+DELTATO
      DYN(I)=DTO
   CALL PLANCA(BISTEP, BNCOMP, MGPB, BNS, BNPB, BNPR, BNBR, BPHIS1,
   1BPHIR1, BRS, BRPS, BRPR, BRR, BCB, BA, BV, BPB, BN, BEB, BFTT,
   2BB1SM, BPS, BES, BWDSM, BB1RM, BPR, BER, BWDMR,
   3DTOS, DTO, SOPA, SOF, CBS, BLS, BFS, BCR, BLR, BFR,
   4BD1, BL1, BH1, BE1, BLI(I), DUMB, DUMB)
31 CONTINUE
CALL CAP(DYN, BLI, 10, BDPLAN, BPPLAN)

START COUNTER FOR LOADS BETWEEN 15 AND 150 PERCENT OF DYNAMIC CAPACITY

IF(ADMIN. LT. DMIN) DMIN=ADMIN
IF(BDMIN. LT. DMIN) DMIN=BDMIN
DELTATO= 1*DMIN
DELTATOP=DELTATO/MGPA
DELTATOS=DELTATO/MGS
DELTATIR=.5*DELTATOS/MG
DELTATIL=.5*DELTATOS/MG
DTIR=0.0
DTIL=0.0
DTOS=0.0
DTOPA=0.0
DTO=0.0
DO 20 I=1, 10
   DTIR=DTIR+DELTATIR
   DTIL=DTIL+DELTATIL
   DTOS=DTOS+DELTATOS
   DTOPA=DTOPA+DELTATOP
   DTO=DTO+DELTATO
   DYN(I)=DTO

CALCULATE LIFE FOR EACH DYNAMIC CAPACITY

CALL DPBVCA(
1 DTIR, DTIL, DTO, SI, SOF, MG, MGS, NP, NG,
2 A0, GAMMA1, ROT, SPR, PHE1, PHS11, ZI1, ZIP,
3 PTL, AP, BP, RP, GTL, AG, BG, RG,
4 ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, E1(2), ADJP1,
5 ITYPEP2, RFP2, NBP2, DP2, ACP2, BDCAP2, AK2, E1(3), ADJP2,
6 ITYPEG1, RFG1, NBG1, DG1, ACG1, BDCAG1, AK3, E1(5), ADJG1,
7 ITYPEG2, RFG2, NBG2, DG2, ACG2, BDCAG2, AK4, E1(6), ADJG2,
8 F, E, PG, E1(1), RPD, RGD,
9 PXPR, PYPR, PZPR, TOTFORR, PXGR, PYGR, PZGR, TOTFORGE,
9 PXPL, PYPL, PZPL, TOTFORL, PXGL, PYGL, PZGL, TOTFORGE,
1 R1XPR, R1YPR, R1ZPR, R2XPR, R2YPR, R2ZPR,
1 R1XPL, R1YPL, R1ZPL, R2XPL, R2YPL, R2ZPL,
2 R1XG, R1YG, R1ZG, R2XG, R2YG, R2ZG,
3 L1(2), H1(2), TOFORP1R, P1(2), BDCAP10R, D1(2),
4 L1(3), H1(3), TOFORP2R, P1(3), BDCAP20R, D1(3),
5 L1(5), H1(5), TOFORG1, P1(5), BDCAG10, D1(5),
6 L1(6), H1(6), TOFORG2, P1(6), BDCAG20, D1(6),

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7L1(1), H1(1), DCApR, D1(1),
8L1(4), H1(4), DCAg, D1(4),
*L1(7), H1(7), DCApL, D1(7),
*L1(8), H1(8), TQFDP1L, P1(8), BDCAP1L, D1(8),
*L1(9), H1(9), TQFDP2L, P1(9), BDCAP1L, D1(9),
9L1(I), DUMB, DUMB)

CALL PLANCA(ISTEP, NCOMP, MGPA, NS, NPS, NPR, NR, PHIS1, PHIR1, 1RS, RPS, RPR, RR, CB, A, V, PB, N, EB, FTT, 2B1SM, PS, ES, WDSM, B1RM, PR, ER, WDRM, 3DTOS, DTO, SOS, SOF, CS, LS, FS, CR, LR, FR, AD1, AL1, AH1, AE1, AL1(I), 4DUMB, DUMB)
CALL PLANB(BISTEP, BNCOMP, MGPB, BNS, BNPS, BNPR, BNR, BPHIS1, 1BPHIR1, BRS, BPRS, BPR, BRR, BCB, BA, BV, BPB, BN, BEB, BFTT, 2B1SM, BPS, BES, BWDSM, B1RM, BPR, BER, BWDRM, 3DTOPA, DTO, SOPA, SOF, CBS, BLS, BFS, BCR, BLR, BFR, BD1, BL1, 4B1H1, BE1, BLI(I), DUMB, DUMB)
DO 12 IE=1, 9
12 ZL1(IE)=L1(IE)
DO 13 IE=1, ISTEP
13 ZL1(IE+9)=AL1(IE)
DO 14 IE=1, BISTEP
14 ZL1(IE+9+ISTEP)=BL1(IE)
CALL LIFEC(ZL1, INCOMP, ZE1, INCOMP, ZL1(I), DUMB)
CONTINUE
CALL CAP(10, DTRANS, PTRANS)
1220 FORMAT('TOTAL TRANSMISSION'/)
1221 FORMAT('SPIRAL BEVEL UNIT'/)
1222 FORMAT('PLANETARY UNIT'/)
WRITE(1,1221)
CALL DPLHE(1,1222)
WRITE(1,1222)
CALL DPLHE(1,1222)
WRITE(1,1220)
CALL DPLHE(1,1220)
STOP
END
SUBROUTINE DPBVCA(
1TIR, TIL, TOF, SI, SOF, MG, MG1, NP, NG,
2AO, GAMMA1, ROT, SPR, PHE1, PHISI1, ZZ1, ZIP,
3TTL, AP, BP, RT, AT, AG, BG, RG,
4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, EGPI, ADJP1,
C-------------------------------~--------------------------------------
C CALCULATION OF
THE
LOADS
TRANSMITTED FROM THE LEFT
PINION
C----------------------------------------------------------------------
CALL GPSPR(TIR,AO,F,GAMMA1,ROT,SPR,PHE1,PHSI1,PXPR,PYPR,PZPR)
TOTFORR=SGRT(PXPR**2+PYPR**2+PZPR**2)
C----------------------------------------------------------------------
C CALCULATION OF THE LOADS TRANSMITTED FROM THE LEFT PINION
C----------------------------------------------------------------------
CALL GPSPR(TIL,AO,F,GAMMA1,ROT,SPR,PHE1,PHSI1,PXPL,PYPL,PZPL)
TOTFORL=SGRT(PXPL**2+PYPL**2+PZPL**2)
C----------------------------------------------------------------------
C CALCULATION OF THE LOADS TRANSMITTED TO THE GEAR FROM EACH PINION
C----------------------------------------------------------------------
TOTR=MG*TIR
TOTL=MG*TIL
ROT1=-ROT
CALL GPSPR(TOTR,AO,F,ZZ1,ROT1,SPR1,PHE1,PHSII1,PXGR,PYGR,PZGR)
CALL GPSPR(TOTL,AO,F,ZZ1,ROT1,SPR1,PHE1,PHSII1,PXGL,PYGL,PZGL)
C----------------------------------------------------------------------
C CHECK CASE FOR BEARING POSITION AND CALCULATE THE LOADS
C ON THE BEARINGS TRANSMITTED FROM THE LEFT PINION
  
  IF(PTL.EQ.2)GO TO 18
  R1XPL=PXPL
  R2XPL=0.0
  GO TO 19
18 R1XPL=0.0
  R2XPL=PXPL
19 CONTINUE
  CALL BLC1(PXPL, PVPL, PZPL, AP, BP, RP, R1VPL, R1ZPL, R2VPL, R2ZPL)
  
C CHECK CASE FOR BEARING POSITION AND CALCULATE THE LOADS
C ON THE BEARINGS TRANSMITTED FROM THE RIGHT PINION
  
  IF(PTL.EQ.2)GO TO 20
  R1XPR=PXPR
  R2XPR=0.0
  GO TO 21
20 R1XPR=0.0
  R2XPR=PXPR
21 CONTINUE
  CALL BLC1(PXPR, PYPR, PZPR, AP, BP, RP, R1YPR, R1ZPR, R2YPR, R2ZPR)
C----------------------------------------------------------------------
C CHECK CASE FOR BEARING POSITION CALCULATE THE LOADS
C ON THE BEARINGS TRANSMITTED FROM THE GEAR DUE TO THE RIGHT PINION
  
  IF(GTL.EQ.2)GO TO 22
  R1XGR=PXGR
  R2XGR=0.0
  GO TO 23
22 R1XGR=0.0
  R2XGR=PXGR
23 CONTINUE
  CALL BLC1(PXGR, PYGR, PZGR, AG, BG, RG, R1YGR, R1ZGR, R2YGR, R2ZGR)
C----------------------------------------------------------------------
C CHECK CASE FOR BEARING POSITION CALCULATE THE LOADS
C ON THE BEARINGS TRANSMITTED FROM THE GEAR DUE TO THE PINION
  
  IF(GTL.EQ.2)GO TO 24
  R1XGL=PXGL
  R2XGL=0.0
  GO TO 25
24 R1XGL=0.0
  R2XGL=PXGL
25 CONTINUE
CALL BLC1(PXGL, PYGL, PZGL, AG, BG, RG, R1YGL, R1ZGL, R2YGL, R2ZGL)

---

SUM OF THE TWO RADIAL AND TWO TANGENTIAL FORCES INTO TWO COMPONENTS IN THE RADIAL DIRECTION

AZIP = (ZIP - 90.) * PI / 180.
R1YG = R1YGR - R1YGL * SIN(AZIP) - R1ZGL * COS(AZIP)
R1ZG = R1ZGR + R1YGL * COS(AZIP) - R1ZGL * SIN(AZIP)
R2YG = R2YGR - R2YGL * SIN(AZIP) - R2ZGL * COS(AZIP)
R2ZG = R2ZGR + R2YGL * COS(AZIP) - R2ZGL * SIN(AZIP)
R1XG = R1XGR + R1XGL
R2XG = R2XGR + R2XGL

---

CALCULATE THE LIFE OF RIGHT PINION BEARING #1

TOFR = TIR * MG * MG1 * 2.0
CALL BDCAP(ITYPEP1, R1XPR, R1YPR, R1ZPR, RFP1, NBP1, DP1, ACP1, SOF, ADJP1 *
*, BDCAP1, L10P1R, H10P1R, MG, MG1, AK1, TOFORP1R, PGP1, BDCAP1OR)
BDCAP1TR = BDCAP10R * TOFR / TOFORP1R
LL(2) = L10P1R
EE(2) = EGP1

---

CALCULATE THE LIFE OF RIGHT PINION BEARING #2

CALL BDCAP(ITYPEP2, R2XPR, R2YPR, R2ZPR, RFP2, NBP2, DP2, ACP2, SOF, ADJP2 *
*, BDCAP2, L10P2R, H10P2R, MG, MG1, AK2, TOFORP2R, PGP2, BDCAP2OR)
BDCAP2TR = BDCAP20R * TOFR / TOFORP2R
LL(3) = L10P2R
EE(3) = EGP2

---

CALCULATE THE LIFE OF LEFT PINION BEARING #1

TOFL = TIL * MG * MG1 * 2.0
CALL BDCAP(ITYYPEP1, R1XPL, R1YPL, R1ZPL, RFP1, NBP1, DP1, ACP1, SOF, ADJP1 *
*, BDCAP1, L10P1L, H10P1L, MG, MG1, AK1, TOFORP1L, PGP1, BDCAP10L)
BDCAP1TL = BDCAP10L * TOFL / TOFORP1L
LL(8) = L10P1L
EE(8) = EGP1

---

CALCULATE THE LIFE OF LEFT PINION BEARING #2

CALL BDCAP(ITYPEP2, R2XPL, R2YPL, R2ZPL, RFP2, NBP2, DP2, ACP2, SOF, ADJP2 *
*, BDCAP2, L10P2L, H10P2L, MG, MG1, AK2, TOFORP2L, PGP2, BDCAP20L)
BDCAP2TL = BDCAP20L * TOFL / TOFORP2L
LL(9) = L10P2L
EE(9) = EGP2

C CALCULATE THE LIFE OF GEAR BEARING #1

CALL BDCAP (ITYPEG1, R1XG, R1YG, R1ZG, RFG1, NBG1, DG1, ACG1, SOF, ADJG1
*, BDCAG1, L10G1, H10G1, 1., MG1, AK3, TOFORG1, PGG1, BDCAG10)
BDCAG10T = BDCAG10 * TOF / TOFORG1
LL(5) = L10G1
EE(5) = EGG1

C CALCULATE THE LIFE OF GEAR BEARING #2

CALL BDCAP (ITYPEG2, R2XG, R2YG, R2ZG, RFG2, NBG2, DG2, ACG2, SOF, ADJG2
*, BDCAG2, L10G2, H10G2, 1., MG1, AK4, TOFORG2, PGG2, BDCAG20)
BDCAG20T = BDCAG20 * TOF / TOFORG2
LL(6) = L10G2
EE(6) = EGG2

C CALCULATE THE LIFE OF THE GEAR

CALL SET1 (PHE1, F, E, MG, MG1, NP, NG, SOF, LP10R, HP10R, LP10L, HP10L,
* LG10, HG10, PG, EG, TOTFORR, TOTFORL, RPD, RGD, DCAPR, DCAPL, DCAG,
* TOTFORGE)
DCAPTR = DCAPR * TOFR / TOTFORR
DCAPTL = DCAPL * TOFL / TOTFORL
DCAGT = DCAG * TOF / TOTFORGE
LL(1) = LP10R
LL(7) = LP10L
LL(4) = LG10
EE(1) = EG
EE(4) = EG
EE(7) = EG

C CALCULATE THE LIFE OF THE TRANSMISSION

CALL LIFE (LL, 9, EE, NCOMP, LSB, ESB)
HSB = LSB * 16666.667 / SOF
RETURN

FUNCTION BASCAP (R1, R2, PHI, WD, K1)

C FUNCTION SUBROUTINE BASCAP CALCULATES THE BASIC DYNAMIC CAPACITY OF
C A GEAR TOOTH
REAL K1, R1, R2, WD, PHI, BASCAP

INPUTS

K1  MATERIAL CONSTANT OF THE MESH (PSI)
R1  PITCH RADIUS OF THE DRIVING GEAR (IN)
R2  PITCH RADIUS OF THE DRIVEN GEAR (IN)
WD  FACE WIDTH OF THE GEAR MESH (IN)
PHI  PRESSURE ANGLE OF THE GEAR MESH (RADIANS)

OUTPUT

BASCAP  BASIC DYNAMIC CAPACITY OF ONE TOOTH IN THE MESH (LB)

BASCAP = K1 * WD * SIN(PHI) / (1.0/R1 + 1.0/R2)
RETURN
END

SUBROUTINE BDCAP(ITYPE, RX, RY, RZ, V, BALLS, DIA, ANGLE, SPEED2, LAF, *BDC, LF, HF, MG, MG1, AK, FE, A, BDCOUT)

REAL LF, L10, MG, MG1, L101, LF1, LAF

---------------------------------------------------------------
THIS SUBROUTINE CALCULATES THE BASIC DYNAMIC CAPACITY AND THE LIFE OF THE BEARING
---------------------------------------------------------------

INPUT

ITYPE  - TYPE OF BEARING
1  SINGLE ROW BALL BEARING
2  DOUBLE ROW BALL BEARING
3  SINGLE ROW ROLLER BEARING
4  DOUBLE ROW ROLLER BEARING
5  SINGLE ROW BALL BEARING + SINGLE ROW ROLLER BEARING
6  SINGLE ROW TAPER ROLLER BEARING
7  DOUBLE ROW TAPER ROLLER BEARING
RX  - AXIAL LOAD ON THE BEARING
RY  - RADIAL LOAD ON THE BEARING
RZ  - TANGENTIAL LOAD ON THE BEARING
V  - ROTATION FACTOR
BALLS  - NUMBER OF BALLS OR ROLLERS

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DIA - DIAMETER OF BALLS OR ROLLERS
ANGLE - CONTACT ANGLE
(OFFLY FOR BALL BEARINGS)
SPEED2 - OUTPUT SPEED OF GEAR SHAFT (RPM)
BDC - BASIC DYNAMIC CAPACITY OF THE BEARING
AK - RATIO OF RADIAL LOAD RATING TO THRUST LOAD RATING
(ONLY FOR TAPERED ROLLER BEARINGS)
MG - SPEED RATION FROM OUTPUT SHAFT TO COMPONENT
INPUT
LF - LIFE OF THE BEARING (MILLIONS OF CYCLES)
HF - LIFE OF THE BEARING (HOURS)
FE - TOTAL FORCE ON THE BEARING

ARX=ABS(RX)
A10=SQRT(RY**2+RZ**2)
IF(ITYPE.GT.1)GOT020
10 CALL XYY1(A10,ARX,V,BALLS,DIA,ANGLE,X,Y)
A=3.0
GOT080

20 IF(ITYPE.GT.2)GOT030
CALL XYY2(A10,ARX,V,BALLS,DIA,ANGLE,X,Y)
A=3.0
GOT080

30 IF(ITYPE.GT.4)GOT060
X=1.0
Y=0.0
A=3.3
GOT080

60 IF(ITYPE.GT.5)GOT070
CALL TAPER1(A10,ARX,AK,FE)
A=3.3
GOT081

70 CONTINUE
CALL TAPER2(A10,ARX,AK,FE)
A=3.3
GOT081

80 CONTINUE
FE=X*V*A10+Y*ARX
81 CONTINUE
L10=(BDC/FE)**A
LF=LAF*L10/MG/MG1
HF=LF*16666.6666/SPEED2
VEG=1./A
BDGOUT=(LAF*1. /MG/MG1)**VEG*BDC
90 RETURN
END

SUBROUTINE BLC1(PX, PY, PZ, A, B, RP, R1Y, R1Z, R2Y, R2Z)
C-----------------------------------------------------------------------
THIS SUBROUTINE CALCULATES THE BEARING REACTION FOR CASE #1
C-----------------------------------------------------------------------
C INPUTS
C
A DISTANCE FROM BEARING TO GEAR (IN)
B DISTANCE FROM GEAR TO BEARING (IN)
PX FORCE AXIAL ON THE GEAR (LB)
PY FORCE RADIAL ON THE GEAR (LB)
PZ FORCE TANGENTIAL ON THE GEAR (LB)
RP PITCH RADIUS OF THE GEAR (LB)

C OUTPUT
C
R1Y REACTION OF BEARING #1 IN THE Y-DIRECTION (LB)
R2Y REACTION OF BEARING #2 IN THE Y-DIRECTION (LB)
R1Z REACTION OF BEARING #1 IN THE Z-DIRECTION (LB)
R2Z REACTION OF BEARING #2 IN THE Z-DIRECTION (LB)

R1Y=(-PY*B+PX*RP)/(A+B)
R1Z=-PZ*B/(A+B)
R2Y=(-PY*A-PX*RP)/(A+B)
R2Z=-PZ*A/(A+B)
RETURN
END

SUBROUTINE GPSPR(TI, AO, F, GAMMA, ROT, SPR, PHE, PHSI, PX, PY, PZ)
C-----------------------------------------------------------------------
THIS SUBROUTINE CALCULATES THE LOADS PRODUCED BY THE PINION
C-----------------------------------------------------------------------
C INPUTS
C
TI INPUT TORQUE (LB-IN)
AO CONE DISTANCE (IN)
GAMMA CONE ANGLE (RADIANS)
ROT DIRECTION OF ROTATION
1 FOR CLOCKWISE
-1 FOR COUNTERCLOCKWISE
SPR SPIRAL DIRECTION
1 RIGHT HAND
C -1 LEFT HAND
C PHE PRESSURE ANGLE (RADIANS)
C PHSI SPIRAL ANGLE (RADIANS)

OUTPUT

C PXP THRUST LOAD ON GEAR
C PYP RADIAL LOAD ON GEAR
C PZP TANGENTIAL LOAD ON GEAR

C TANGENTIAL TOOTH LOAD
C
PZP = -TI/((AO-F/2.0)*SIN(GAMMA))

C CHECK FOR ROTATION AND HAND OF THE PINION
C
ROTSPR = ROT*SPR
IF (ROTSPR .LT. 1.0) GO TO 10

C THRUST LOAD
C
PXP = PZP*(TAN(PHE)*SIN(GAMMA)-SIN(PHSI)*COS(GAMMA))
*/COS(PHSI)

C RADIAL TOOTH LOAD
C
PYP = PZP*(TAN(PHE)*COS(GAMMA)+SIN(PHSI)*SIN(GAMMA))
*/COS(PHSI)
GO TO 20
10 CONTINUE

C THRUST LOAD
C
PXP = PZP*(TAN(PHE)*SIN(GAMMA)+SIN(PHSI)*COS(GAMMA))
*/COS(PHSI)

C RADIAL LOAD
C
PYP = PZP*(TAN(PHE)*COS(GAMMA)-SIN(PHSI)*SIN(GAMMA))
*/COS(PHSI)
20 RETURN
END

C
C
SUBROUTINE LEASGR(N, X, Y, A, B)

LEASGR FITS DATA PAIRS WITH A LINEAR EQUATION OF THE FORM
Y = A + B * X + E

WHERE,
X IS THE INDEPENDENT VARIABLE AND
Y IS THE DEPENDENT VARIABLE.
E IS THE RESIDUAL (WHICH IS MINIMIZED)
THE ESTIMATED EQUATION IS THEN Y = A + B * X.

INTEGER I, N
REAL A, B, DENOM, NUMA, NUMB, SSX, SXY, SX, SY, X, Y
DIMENSION X(N), Y(N)

THE VARIABLES ARE:
N--NUMBER OF DATA PAIRS, (X, Y) (PASSED TO PROGRAM)
X--INDEPENDENT VARIABLE OF DATA TO BE FITTED (PASSED TO PROGRAM)
Y--DEPENDENT VARIABLE OF DATA TO BE FITTED (PASSED TO PROGRAM)
A--Y INTERCEPT OF FITTED LINE (PASSED FROM PROGRAM)
B--SLOPE OF THE FITTED LINE (PASSED FROM PROGRAM)
I--DO LOOP COUNTER
DENOM--INTERMEDIATE CALCULATION
NUMA--INTERMEDIATE CALCULATION
NUMB--INTERMEDIATE CALCULATION
SSX--SUMMATION OF THE SQUARES OF X
SXY--SUMMATION OF THE PRODUCT OF X AND Y
SX--SUMMATION OF X
SY--SUMMATION OF Y

INITIALIZE SUMMATIONS
SSX=0.0
SX=0.0
SXY=0.0
SY=0.0

CALCULATE SUMS
DO 10 I=1, N
SX=SX+X(I)
SY=SY+Y(I)
SXY=SXY+X(I)*Y(I)
10 CONTINUE
SSX=SSX+X(I)**2
10 CONTINUE

C CONVERT N TO REAL TYPE, CALCULATE SLOPE, B AND INTERCEPT, A

C

NUMA=SY*SSX-SXY*SX
NUMB=FLOAT(N)*SXY-SX*SY
DENOM=FLOAT(N)*SSX-SX**2
A=NUMA/DENOM
B=NUMB/DENOM
RETURN
END

SUBROUTINE LIFE(ALIFE,NN,EW,NCOMP,LT10,ET)

C-----------------------------------------------------------------------
C
C LIFE CALCULATES THE WEIBULL EXPONENT FOR THE SPIRAL BEVEL
C TRANSMISSION AND THE L10 LIFE OF THE TRANSMISSION.
C-----------------------------------------------------------------------

REAL A,E,L,N,S,EB,EG,ET,DIFF,DELTAL,OLDIFF,LT10,NCOMP(NN)
INTEGER I
DIMENSION L(25),S(25),ALIFE(NN),EW(NN)

C INPUTS
NCOMP(I) NUMBER OF EACH COMPONENT
EW(I) WEIBULL EXPONENT OF THE COMPONENT
ALIFE(I) L10 LIFE OF COMPONENT

C OUTPUT
ET WEIBULL EXPONENT OF THE GEAR TRANSMISSION
LT10 L10 LIFE OF THE TRANSMISSION IN INPUT
REvolutions (CYCLES)

C MISCELLANEOUS VARIABLES:
L(I) GENERATED SET OF TRANSMISSION LIVES SUN REV
S(I) SET OF TRANSMISSION RELIABILITIES CORRESPONDING TO THE SET OF TRANSMISSION LIVES
A INTERCEPT OF LINE CALCULATED BY LEAST SQUARE ROUTINE
I DO LOOP COUNTER
E SMALLER OF THE TWO WEIBULL EXPONENTS
DIFF DIFFERENCE BETWEEN ITERATED PROBABILITY OF SURVIVAL AND DESIRED VALUE
DELTAL HALF INTERVAL LIFE INCREMENT SUN REV
OLDIFF PAST VALUE OF DIFF; USED WITH DIFF FOR DETERMINING
IF ITERATION HAS PASSED DESIRED VALUE

CALCULATE THE TRANSMISSION'S L5 LIFE USING A HALF INTERVAL METHOD
DETERMINE MINIMUM L10 LIFE & CALCULATE SEED VALUE FOR FINDING L5 LIFE

CALL MINIMUM(ALIFE, NN, ASLL)
L(1)=ASLL/10.
OLDIFF=1.0
DELTAL=L(1)

ITERATION Follows

DO 10 I=1, 50
   SLIFE=0.0
   DO 31 IN=1, NN
      SLIFE=SLIFE+NCOMP(IN)*(L(1)/ALIFE(IN))**EW(IN)
   31 CONTINUE
   S(1)=0.9**SLIFE
   IF(S(1).GE.0.94. AND. S(1).LE.0.96)GOTO20
   DIFF=S(1)-0.95
   IF(DIFF*OLDIFF.LT.0.0)DELTAL=-DELTAL/2.0
   OLDIFF=DIFF
   L(1)=L(1)+DELTAL
10 CONTINUE

CONTINUE
20 CONTINUE
OLDIFF=1.0
SL=ASLL/10.
DELTAL=SL
DO 11 I=1, 50
   SLIFE=0.0
   DO 37 IN=1, NN
      SLIFE=SLIFE+NCOMP(IN)*(SL/ALIFE(IN))**EW(IN)
   37 CONTINUE
   SD=SLIFE
   IF(SD.GE.0.99. AND. SD.LE.1.01)GOTO21
   DIFF=SD-1.00
   IF(DIFF*OLDIFF.LT.0.0)DELTAL=-DELTAL/2.0
   OLDIFF=DIFF
   SL=SL-DELTAL
11 CONTINUE

WRITE(1,100)
100 FORMAT(5X,'ITERATION FOR THE TRANSMISSION'S L5 LIFE WAS',
1   'UNSUCCESSFUL.'/,5X,'PROGRAM TERMINATING')
C CALCULATE THE TRANSMISSION'S L50 LIFE USING A HALF INTERVAL METHOD
C CALCULATE A SEED VALUE LARGER THAN L50 AND ITERATE DOWN TO L50 LIFE
C
21 CONTINUE
   CONTINUE
   E=100.
   DO 34 I=1, NN
      IF(EW(I).LT.E)E=EW(I)
34 CONTINUE
   L(25)=L(1)*((ALOG(1.0/0.5)/ALOG(1.0/0.95))**(1.0/E))
   DELTAL=L(1)
   OLDIFF=1.0
C C ITERATION FOLLOWS
C
   DO 30 I=1,50
      SLIFE=0.0
      DO 32 IN=1, NN
         SLIFE=SLIFE+NCOMP(IN)*(L(25)/ALIFE(IN)**EW(IN)
      32 CONTINUE
      S(25)=0.9**SLIFE
      IF(S(25).GE.0.49.AND.S(25).LE.0.51)GOTO35
      DIFF=0.5-S(25)
      IF(DIFF*OLDIFF.LT.0.0)DELTAL=-DELTAL/2.0
      OLDIFF=DIFF
      L(25)=L(25)-DELTAL
   30 CONTINUE
   WRITE(1,110)
   110 FORMAT(5X,'ITERATION FOR THE TRANSMISSION'S L50 LIFE WAS',1X,'UNSUCCESSFUL.',5X,'PROGRAM TERMINATING')
   STOP
C C ITERATIONS FOR L5 AND L50 ARE COMPLETE; CALCULATE LIFE INCREMENT
C FOR GENERATION OF TABLE OF LIVES AND RELIABILITIES (25 DATA PAIRS)
C
35 CONTINUE
   DELTAL=(L(25)-L(1))/24.0
C C CALCULATE TABLE OF LIVES AND RELIABILITIES (L,S)
C
   DO 40 I=2,24
      L(I)=L(I-1)+DELTAL
      SLIFE=0.0
      DO 33 IN=1, NN
         SLIFE=SLIFE+NCOMP(IN)*(L(I)/ALIFE(IN)**EW(IN)
   33 CONTINUE
   WRITE(1,110)
   110 FORMAT(5X,'ITERATION FOR THE TRANSMISSION'S L50 LIFE WAS',1X,'UNSUCCESSFUL.',5X,'PROGRAM TERMINATING')
   STOP
C
CONTINUE
S(I)=0.9**SLIFE
CONTINUE

C TRANSFORM USING NATURAL LOGS SO A LINEAR REGRESSION MAY BE USED

DO 50 I=1,25
L(I)=ALOG(L(I))
S(I)=ALOG(ALOG(1.0/S(I)))
50 CONTINUE

C CALCULATE THE TRANSMISSION’S WEIBULL EXPONENT

CALL LEASQR(25,L,S,A,ET)

C CALCULATE THE TRANSMISSION’S L10 LIFE

LTI0=EXP(ALOG(ALOG(1.0/S(I)))-A)/ET)
RETURN
END

SUBROUTINE MINIMUM(ALIFE,N,AMIN)

C CHECK FOR MINIMUM NUMBER IN ARRAY

DIMENSION ALIFE(N)
AMIN=1000000.
DO 30 I=1,N
  IF(ALIFE(I).LT. AMIN) AMIN=ALIFE(I)
30 CONTINUE
RETURN
END

SUBROUTINE SET1(PHE,F,E,MG,MG1,NP,NG,SPEED2,LPIOR,HPIOR,
LPIOL,HPIOL,LG10,HG10,PG,EG,FOR,FOL,R1,R2,DCAPR,DCAPL,
DCAG,FE)

C CALCULATION OF THE LIFE OF THE PINION AND GEAR MESH

C INPUTS

PHE - PRESSURE ANGLE OF THE MESH (RADIANS)
F - FACE WIDTH (IN)
E - MESH MATERIAL CONSTANT (PSI)
C MG -GEAR RATIO
C NP -NUMBER OF TEETH OF THE PINION
C NG -NUMBER OF TEETH OF THE GEAR
C SPEED2 -SPEED OF OUTPUT SHAFT
C PG -MESH MATERIAL CONSTANT
C EG -MESH WEIBULL EXPONENT
C FOR -TOTAL FORCE TRANSMITTED
C R1 -REFERENCE PLANE RADIUS OF SPIRAL BEVEL PINION (IN)
C R2 -REFERENCE PLANE RADIUS OF SPIRAL BEVEL GEAR (IN)

OUTPUT

LP10 -THE L10 LIFE OF THE PINION (CYCLES)
HP10 -THE L10 LIFE OF THE PINION (HOURS)
LG10 -THE L10 LIFE OF THE GEAR (CYCLES)
HG10 -THE L10 LIFE OF THE GEAR (HOURS)
DCAP -THE DYNAMIC CAPACITY OF THE PINION (LBS)
DCAQ -THE DYNAMIC CAPACITY OF THE GEAR (LBS)
FOR -FORCE ON THE PINION
FE -FORCE ON THE GEAR

REAL NP, NG, MG, MG1, LP10R, LP10L, LG10, LP10TR, LP10TL, LG10T
F1=.5*F
CBG = BASCAP(R1, R2, PHE, F1, E)
FE = ((FOR**PG+FOL**PG)/2.)*(1./PG)

CALCULATE LIFE OF GEAR TEETH

LP10TR = (CBG/FOR)**PG
LP10TL = (CBG/FOL)**PG
LG10T = (CBG/FE)**PG
VEG = 1./EG
VPG = 1./PG

CALCULATE LIFE OF PINION AND GEAR

LP10R = (1./NP)**VEG/MG/MG1*LP10TR
HP10R = LP10R*16666.666/SPEED2
LP10L = (1./NP)**VEG/MG/MG1*LP10TL
HP10L = LP10L*16666.666/SPEED2
LG10 = (1./NG)**VEG/MG1*LG10T
HG10 = LG10*16666.666/SPEED2

CALCULATE BASIC DYNAMIC CAPACITY OF PINION AND GEAR
DCAPR=((1./NP)**VEG/MG/MG1)**VPG*CBG
DCAPL=((1./NP)**VEG/MG/MG1)**VPG*CBG
DCAG=((1./NG)**VEG/MG1)**VPG*CBG
RETURN
END
SUBROUTINE TAPER1(R,T,AK,REA)
C  THIS SUBROUTINE CALCULATES THE EQUIVALENT REACTION AT A
C  SINGLE ROW TAPERED ROLLER BEARING
C-----------------------------------------------
C  INPUT
C    R   -RADIAL LOAD
C    T   -THRUST LOAD
C    AK  -RATIO OF BASIC RADIAL RATING TO BASIC THRUST RATING
C  OUTPUT
C    RE  -EQUIVALENT RADIAL LOAD
C
REA=  .4*R+AK*T
IF(REA.LT.R)REA=R
RETURN
END
SUBROUTINE TAPER2(R,T,AK,REA)
C  THIS SUBROUTINE CALCULATES THE EQUIVALENT REACTION AT A
C  DOUBLE ROW TAPERED ROLLER BEARING
C-----------------------------------------------
C  INPUT
C    R   -RADIAL LOAD
C    T   -THRUST LOAD
C    AK  -RATIO OF BASIC RADIAL RATING TO BASIC THRUST RATING
C  OUTPUT
C    RE  -EQUIVALENT RADIAL LOAD
C
CHECK=0.60*R/AK
IF(T.GT.CHECK)GOTO10
REA=R*.5+.83*AK*T
GOTO20
10  REA=0.40*R+AK*T
20  CONTINUE
RETURN
END
SUBROUTINE XXYY1(FR1, FA, V, BALLS, DIA, ANGLE, X, Y)

C---------------------------------------------------------------------
C
C
C THIS SUBROUTINE CALCULATES THE RADIAL FACTOR AND THRUST FACTOR
FOR SINGLE ROW BALL BEARINGS
C---------------------------------------------------------------------
C
C INPUTS
C
FR1 TOTAL RADIAL LOAD (LBS)
C FA TOTAL THRUST LOAD (LBS)
C V ROTATION FACTOR OF BEARING
C 1.0 FOR INNER RACE ROTATION
C 1.2 FOR OUTER RACE ROTATION
C BALLS NUMBER OF BALLS PER BEARING
C DIA DIAMETER OF THE BALLS
C ANGLE CONTACT ANGLE OF THE BALL BEARING
C
C OUTPUTS
C
X RADIAL FACTOR
C Y THRUST FACTOR
C
DIMENSION A(10), Y1(9), Y2(9), Y3(9), E1(9), E2(9), E3(9)
DATA X1, X2, X3, X4, X5, X6, X7, X8/0.56, 0.46, 0.44, 0.41, 0.39, 0.37, 0.35/
DATA Y4, Y5, Y6, Y7, Y8/1.00, 0.87, 0.76, 0.66, 0.57/
DATA E4, E5, E6, E7, E8/0.57, 0.68, 0.80, 0.95, 1.14/
DATA A/25.50, 100., 150., 200., 300., 500., 750., 1000., 10000./
DATA Y1/2.30, 1.99, 1.71, 1.55, 1.45, 1.31, 1.15, 1.04, 1.00/
DATA Y2/1.88, 1.71, 1.52, 1.41, 1.34, 1.23, 1.10, 1.01, 1.00/
DATA Y3/1.47, 1.40, 1.30, 1.23, 1.19, 1.12, 1.02, 1.00, 1.00/
ROWS=1.0
CHECK2=FA/(V*FR1)
IF(ANGLE.GT.5.00)GOTO10
CHECK1=FA/(ROWS*BALLS*DIA**2)
DO 1 I=1,9
1 IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO2
CONTINUE
IF(I.GT.9)I=9
2 IF(CHECK2.LE.E1(I))GOTO1000
X=X1
Y=Y1(I)
GOTO999
10 CHECK1=FA/(BALLS*DIA**2)
IF(ANGLE.GT.10.0)GOTO20
DO 11 I=1,9
11 IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO12

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CONTINUE
IF(I. GT. 9)I=9
IF(CHECK2. LE. E2(I))GOTO1000
X=X2
Y=Y2(I)
GOTO999
IF(ANGLE. GT. 15. 0)GOTO30
DO 21 I=1, 9
IF(CHECK1. GT. A(I). AND. CHECK1. LT. A(I+1))GOTO22
21 CONTINUE
IF(I. GT. 9)I=9
IF(CHECK2. LE. E3(I))GOTO1000
X=X3
Y=Y3(I)
GOTO999
IF(ANGLE. GT. 20. 0)GOTO40
IF(CHECK2. LE. E4)GOTO1000
X=X4
Y=Y4
GOTO999
IF(ANGLE. GT. 25. 0)GOTO50
IF(CHECK2. LE. E5)GOTO1000
X=X5
Y=Y5
GOTO999
IF(ANGLE. GT. 30. 0)GOTO60
IF(CHECK2. LE. E6)GOTO1000
X=X6
Y=Y6
GOTO999
IF(ANGLE. GT. 35. 0)GOTO70
IF(CHECK2. LE. E7)GOTO1000
X=X7
Y=Y7
GOTO999
IF(CHECK2. LE. E8)GOTO1000
X=X8
Y=Y8
GOTO999
1000 X=1.0
Y=0.0
999 RETURN
END
SUBROUTINE XXYY2(FR1, FA, V, BALLS, DIA, ANGLE, X, Y)
C---------------------------------------------------------------
THIS SUBROUTINE CALCULATES THE RADIAL FACTOR AND THRUST FACTOR FOR DOUBLE ROW BALL BEARINGS

INPUTS

FR1  TOTAL RADIAL LOAD (LBS)
FA   TOTAL THRUST LOAD (LBS)
V    ROTATION FACTOR OF BEARING
     1.0 FOR INNER RACE ROTATION
     1.2 FOR OUTER RACE ROTATION
BALLS NUMBER OF BALLS PER BEARING ROW
DIA  DIAMETER OF THE BALLS
ANGLE CONTACT ANGLE OF THE BALL BEARING

OUTPUTS

X    RADIAL FACTOR
Y    THRUST FACTOR

DIMENSION A(10), Y1(9), Y2(9), Y3(9), Y4(9), Y5(9), Y6(9), Y7(9)
DIMENSION E1(9), E2(9), E3(9), E4(9)
DATA A/25., 50., 100., 150., 200., 300., 500., 750., 1000., 10000./
DATA Y1/2.30, 1.99, 1.71, 1.55, 1.45, 1.31, 1.15, 1.04, 1.00/
DATA Y2/2.78, 2.40, 2.07, 1.87, 1.75, 1.58, 1.39, 1.26, 1.21/
DATA Y3/3.74, 3.23, 2.78, 2.52, 2.36, 2.13, 1.87, 1.69, 1.63/
DATA Y4/2.18, 1.98, 1.76, 1.63, 1.55, 1.42, 1.27, 1.17, 1.16/
DATA Y5/3.06, 2.78, 2.47, 2.29, 2.18, 2.00, 1.79, 1.64, 1.63/
DATA Y6/1.65, 1.57, 1.46, 1.38, 1.34, 1.26, 1.14, 1.12, 1.12/
DATA Y7/2.39, 2.28, 2.11, 2.00, 1.93, 1.82, 1.66, 1.63, 1.63/
DATA E1/0.19, 0.22, 0.26, 0.28, 0.30, 0.34, 0.38, 0.42, 0.44/
DATA E2/0.23, 0.26, 0.30, 0.34, 0.36, 0.40, 0.45, 0.50, 0.52/
DATA E3/0.29, 0.32, 0.36, 0.38, 0.40, 0.44, 0.49, 0.54, 0.54/
DATA E4/0.38, 0.40, 0.43, 0.46, 0.47, 0.50, 0.55, 0.56, 0.56/
DATA X1, X2, X3, X4, X5, X6, X7, X8/0.56, 1., 0.78, 1., 0.75, 1., 0.72, 1./
DATA X9, X10, X11, X12, X13, X14, X15, X16, X17/0.70, 1., 0.67, 1., 0.63
*, 1., 0.60, 1., 0.93/
DATA Y8, Y9, Y10, Y11, Y12, Y13, Y14, Y15, Y16, Y17/1.09, 1.63, 0.92, 1.41
*, 0.78, 1.24, 0.66, 1.07, 0.55, 0.93/
DATA E5, E6, E7, E8, E9/0.57, 0.68, 0.80, 0.95, 1.14/
ROWS=2.0
CHECK2=FA/(V*FR1)
IF(ANGLE.GT.5.0)GOTO10
CHECK1=FA/(ROWS*BALLS*DIA**2)
DO 1 I=1, 9
   IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO2
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1 CONTINUE
IF(I.GT.9)I=9
2 IF(CHECK2.LE.E1(I))GOTO3
   X=X1
   Y=Y1(I)
   GOTO999
3 X=1.0
   Y=0.0
   GOTO999
10 CHECK1=FA/(BALLS*DIA**2)
   IF(ANGLE.GT.10.0)GOTO20
   DO 11 I=1,9
      IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO12
11 CONTINUE
   IF(I.GT.9)I=9
12 IF(CHECK2.LE.E2(I))GOTO13
   X=X3
   Y=Y3(I)
   GOTO999
13 X=X2
   Y=Y2(I)
   GOTO999
20 IF(ANGLE.GT.10.)GOTO30
   DO 21 I=1,9
      IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO22
21 CONTINUE
   IF(I.GT.9)I=9
22 IF(CHECK1.LE.E3(I))GOTO23
   X=X5
   Y=Y5(I)
   GOTO999
23 X=X4
   Y=Y4(I)
   GOTO999
30 IF(ANGLE.GT.15.)GOTO40
   DO 31 I=1,9
      IF(CHECK1.GT.A(I).AND.CHECK1.LT.A(I+1))GOTO32
31 CONTINUE
   IF(I.GT.9)I=9
32 IF(CHECK2.LE.E4(I))GOTO33
   X=X7
   Y=Y7(I)
   GOTO999
33 X=X6
   Y=Y6(I)
SUBROUTINE DPBVIN(NP, NG, AO, PHE, F, PHSI, ROT, SPR, THETA, E, EQ, P0, 
1PHE1, PHSI1, THETA1, CASEP, PTL, AP, BP, ITYPEP1, NBP1, DP1, ACP1, AK1, 
2BDCA P1, RF P1, EGP1, ITYPEP2, NBP2, DP2, ACP2, AK2, BDCAP2, RF P2, EGP2, 
3CASEG, GTL, AG, BG, ITYPEG1, NBG1, D G1, AC G1, AK3, BDCAG1, RF G1, EGG1, 

GOTO999
40 IF (ANGLE.GT.20.) GOTO50
   IF (CHECK2.LE.E5) GOTO43
   X=X9
   Y=Y9
   GOTO999
43 X=X8
   Y=Y8
   GOTO999
50 IF (ANGLE.GT.25.0) GOTO60
   IF (CHECK2.LE.E6) GOTO53
   X=X11
   Y=Y11
   GOTO999
53 X=X10
   Y=Y10
   GOTO999
60 IF (ANGLE.GT.30.0) GOTO70
   IF (CHECK2.LE.E7) GOTO63
   X=X13
   Y=Y13
   GOTO999
63 X=X12
   Y=Y12
   GOTO999
70 IF (ANGLE.GT.35.0) GOTO80
   IF (CHECK2.LE.E8) GOTO73
   X=X15
   Y=Y15
   GOTO999
73 X=X14
   Y=Y14
   GOTO999
80 IF (CHECK2.LE.E9) GOTO83
   X=X17
   Y=Y17
   GOTO999
83 X=X16
   Y=Y16
999 RETURN
END
**SPIRAL BEVEL INPUT**

**CHARACTER*9 DATAFILE**

**INTEGER NO, YES, ANSWER, CASEP, CASEG, PTL, GTL**

**REAL NP, NG, MQ, NBP1, NBP2, NBG1, NBG2**

**PARAMETER(NO='NO', YES='YES')**

**PII=3.141592654**

**WRITE(1,300)**

**300 FORMAT('DUAL PINION SPIRAL BEVEL GEAR UNIT INPUTS',/)**

**WRITE(1,999)**

**READ(1,99)ANSWER**

**IF(ANSWER.EQ.NO)GO TO 501**

**WRITE(1,502)**

**502 FORMAT('WHAT IS THE NAME OF THE INPUT FILE')**

**READ(l,503)DATAFILE**

**503 FORMAT(A)**

**OPEN(UNIT=55, FILE=DATAFILE, STATUS='UNKNOWN')**

**NRE=55**

**GO TO 500**

**501 NRE=1**

**500 CONTINUE**

**CALL GEARINP(NRE, NP, NG, AO, PHE, F, PHSI, ROT, SPR,**

*THETA, E, EQ, PG)**

**CALL GEAROUT(NP, NG, AO, PHE, F, PHSI, ROT, SPR,**

*THETA, E, EQ, PG)**

**WRITE(1,1070)**

**READ(NRE,*)LL1**

**IF(LL1.EQ.1)GOTO500**

**WRITE(1,5000)GOTO500**

**READ(NRE,*)ZIP**

**PHE1=PHE*PII/180.**

**PHSI1=PHSI*PII/180.**

**TI=TI*ROT**

**THETA1=THETA*PII/180.**

**ENTERING THE VALUES FOR THE PINION AND ITS BEARINGS**

**WRITE(1,1074)**

**600 CONTINUE**
CALL CASEINP(NRE, CASEP, PTL, AP, BP)  
CALL CASEOUT(CASEP, PTL, AP, BP)  
WRITE(1, 1070)  
READ(NRE, *) L1  
IF(L1 .GT. 1) GOTO 600  
601 CONTINUE  
WRITE(1, 1040)  
CALL BEARINP(NRE, ITYPEP1, NBP1, DP1, ACP1, AK1, BDCAP1, RFP1, EGP1, ADJP1)  
CALL BEAROUTP(ITYPEP1, NBP1, DP1, ACP1, AK1, BDCAP1, RFP1, EGP1, ADJP1)  
WRITE(1, 1070)  
READ(NRE, *) L2  
IF(L2 .GT. 1) GOTO 601  
602 CONTINUE  
WRITE(1, 1045)  
CALL BEARINP(NRE, ITYPEP2, NBP2, DP2, ACP2, AK2, BDCAP2, RFP2, EGP2, ADJP2)  
CALL BEAROUTP(ITYPEP2, NBP2, DP2, ACP2, AK2, BDCAP2, RFP2, EGP2, ADJP2)  
WRITE(1, 1070)  
READ(NRE, *) L3  
IF(L3 .GT. 1) GOTO 602  
C  
C  
INPUT THE GEAR AND ITS SUPPORTING BEARINGS  
C  
C  
WRITE(1, 1075)  
CONTINUE  
CALL CASEINP(NRE, CASEG, GTL, AG, BG)  
CALL CASEOUT(CASEG, GTL, AG, BG)  
WRITE(1, 1070)  
READ(NRE, *) L4  
IF(L4 .GT. 1) GOTO 603  
604 CONTINUE  
WRITE(1, 1040)  
CALL BEARINP(NRE, ITYPEG1, NBG1, DG1, ACG1, AK3, BDCAG1, RFG1, EGG1, ADJG1)  
CALL BEAROUTP(ITYPEG1, NBG1, DG1, ACG1, AK3, BDCAG1, RFG1, EGG1, ADJG1)  
WRITE(1, 1070)  
READ(NRE, *) L5  
IF(L5 .GT. 1) GOTO 604  
605 CONTINUE  
WRITE(1, 1045)  
CALL BEARINP(NRE, ITYPEG2, NBG2, DG2, ACG2, AK4, BDCAG2, RFG2, EGG2, ADJG2)  
CALL BEAROUTP(ITYPEG2, NBG2, DG2, ACG2, AK4, BDCAG2, RFG2, EGG2, ADJG2)  
WRITE(1, 1070)  
READ(NRE, *) L6  
IF(L6 .GT. 1) GOTO 605
CLOSE(55)

C CALCULATION OF GEAR RATIO AND OUTPUT SPEED

MG=NG/NP
SPEED2=SPEED/MG

C CALCULATION OF GAMMA

GAMMA1=ATAN(SIN(THETA1)/(MG+COS(THETA1))
GAMMA=GAMMA1*180./PII
ZZ=THETA-GAMMA
ZZ1=ZZ*PII/180.

C CALCULATION OF PITCH DIAMETER OF GEAR AND PINION
AND REFERENCE PITCH DIAMETER OF GEAR AND PINION

DP=(AO-F/2.)*(2.*SIN(GAMMA1))
DG=(AO-F/2.)*(2.*SIN(ZZ1))
PD=NG/DG
RPD=DP*.5/COS(GAMMA1)
RP=DP*.5
RGD=DG*.5/COS(ZZ1)
RG=DG*.5

C WORKING DEPTH

HK=1.70/PD

C ADDENDUM OF GEAR AND PINION

AOG=0.46/PD+0.390/(PD*MG**2)
APO=HK-AOG

C WHOLE DEPTH

IF(PD.LT.10.)GO TO 50
HT=1.888/PD
GOTO51
50 HT=1.888/PD+.005
51 CONTINUE

C DEEDENDUM OF THE GEAR AND PINION

BOG=HT-AOG
BOP=HT-AOP

BOP=HT-AO

999 FORMAT('DO YOU WISH TO USE A DATA SET'/  
* 'ANSWER YES OR NO')
1040 FORMAT('PINION BEARING #1')
1045 FORMAT('PINION BEARING #2')
1046 FORMAT('GEAR BEARING #1')
1047 FORMAT('GEAR BEARING #2')
1070 FORMAT('DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS'/  
* 'ENTER 1 TO CHANGE')
1074 FORMAT('PINION MOUNTING')
1075 FORMAT('GEAR MOUNTING')
5000 FORMAT('WHAT IS THE ANGLE BETWEEN THE TWO PINIONS')
99 FORMAT(1A4)
RETURN
END

SUBROUTINE CASEINP(NRE,CS,TL,A,B)
INTEGER CS,TL

C----------------------------------------------------------------------
C INPUT FOR CASE OF BEARING AND GEAR MOUNTING
C----------------------------------------------------------------------
C
WRITE(1,1017)
READ(NRE,*)CS
WRITE(1,1048)
READ(NRE,*)TL
WRITE(1,1018)
READ(NRE,*)A
WRITE(1,1019)
READ(NRE,*)B
IF(CS.EQ.2)A=-A

1017 FORMAT('WHICH CASE OF BEARING PLACEMENT IS BEING USED'/  
* 'CASE # 1'/  
* 'BEARING--------GEAR---------BEARING'/'  
* ' #1'  
* '------A----------B------------'/'  
* 'CASE # 2'/  
* 'GEAR---------BEARING--------BEARING'/  
* '-------#1'  
* 'A-----------#2'/'  
* '---------------B----------------')
1048 FORMAT('WHICH BEARING CARRIES THE THRUST LOAD'/  
* 'BEARING #1 OR BEARING #2')
1018 FORMAT('ENTER DISTANCE A - DISTANCE FROM * TO * (IN)')
SUBROUTINE CASEOUT(CS, TL, A, B)
INTEGER CS, TL
C
C CASE ECHO
C
WRITE(1, 100)CS, TL, A, B
100 FORMAT(/  
  *CASE NUMBER*, I3/
  *BEARING TAKING THE THRUST LOAD*, I3/
  *DISTANCE A*, F14.4/
  *DISTANCE B*, F14.4/)  
RETURN  
END
SUBROUTINE BEARINPCNRE, ITYPE, NB, D, AC, AK, BDCAP, RF, EG, ADJ)
C
C BEARING INPUT
C
REAL NB
WRITE(1, 1000)
READ(NRE, *)ITYPE
IF(ITYPE.EQ.3.OR.ITYPE.EQ.4)GOTO410
IF(ITYPE.GT.4)GOTO400
WRITE(1, 1001)
READ(NRE, *)NB
WRITE(1, 1002)
READ(NRE, *)D
WRITE(1, 1003)
READ(NRE, *)AC
GOTO410
400 CONTINUE
IF(ITYPE.LE.5)GOTO410
WRITE(1, 1004)
READ(NRE, *)AK
410 CONTINUE
WRITE(1, 1005)
READ(NRE, *)BDCAP
IF(ITYPE.GT.4)GOTO420
WRITE(1, 1007)
READ(NRE, *)RF
420 CONTINUE
WRITE(1,1008)
READ(NRE,*)EG
WRITE(1,1010)
READ(NRE,*)AD~
1000 FORMAT('TYPE OF BEARING - ENTER NUMBER'/
  *' 1 - SINGLE ROW BALL BEARING'/
  *' 2 - DOUBLE ROW BALL BEARING'/
  *' 3 - SINGLE ROW ROLLER BEARING'/
  *' 4 - DOUBLE ROW ROLLER BEARING'/
  *' 5 - SINGLE ROW TAPERED ROLLER BEARING'/
  *' 6 - DOUBLE ROW TAPERED ROLLER BEARING')
1001 FORMAT('NUMBER OF BALLS OR ROLLERS')
1002 FORMAT('DIAMETER OF BALLS OR ROLLERS')
1003 FORMAT('BEARING CONTACT ANGLE')
1004 FORMAT('WHAT IS THE RATIO OF BASIC RADIAL RATING TO'/
  *' BASIC THRUST RATING FOR TAPERED ROLLER BEARINGS')
1005 FORMAT('ENTER THE BASIC DYNAMIC CAPACITY OF BEARING')
1007 FORMAT('ENTER THE ROTATION FACTOR'/
  *' 1.0 FOR INNER RACE ROTATION'/
  *' 1.2 FOR OUTER RACE ROTATION')
1008 FORMAT('WHAT IS THE WEIBULL EXPONENT FOR THE BEARING')
1010 FORMAT('WHAT IS THE LIFE ADJUSTMENT FACTOR')
100 FORMAT(F15.5)
12 FORMAT(I1)
RETURN
END
SUBROUTINE BEAROUT(ITYPE,NB,D,AC,AK,BDCAP,RF,EG,AD~)
C ----
C BEARING ECHO
C ----
REAL NB
WRITE(1,100)ITYPE,NB,D,AC,AK,BDCAP,RF,EG,AD~
100 FORMAT(/}
  *' TYPE OF BEARING__________________________ ',I3/
  *' NUMBER OF ROLLING ELEMENTS______________ ',F14.5/
  *' DIAMETER OF ROLLING ELEMENTS___________ ',F14.5/
  *' CONTACT ANGLE (BALL BEARING ONLY)________ ',F14.5/
  *' RADIAL TO THRUST RATIO'/
  *' (TAPER ROLLER BEARING ONLY)______________ ',F14.5/
  *' BASIC DYNAMIC CAPACITY_________________ ',F14.5/
  *' ROTATION FACTOR________________________ ',F14.5/
  *' WEIBULL EXPONENT_______________________ ',F14.5/
  *' LIFE ADJUSTMENT FACTOR_________________ ',F14.5/)
RETURN
END
SUBROUTINE GEARINPC(NRE, NP, NG, AO, PHE, F, PHSI, ROT, SPR, *THETA, E, EG, PG)
REAL NP, NG
WRITE(1, 1050)
READ(NRE, *)NP
WRITE(1, 1051)
READ(NRE, *)NG
WRITE(1, 1052)
READ(NRE, *)AO
WRITE(1, 1053)
READ(NRE, *)PHE
WRITE(1, 1054)
READ(NRE, *)F
WRITE(1, 1058)
READ(NRE, *)PHSI
WRITE(1, 1059)
READ(NRE, *)ROT
WRITE(1, 1060)
READ(NRE, *)SPR
WRITE(1, 1061)
READ(NRE, *)THETA
WRITE(1, 1063)
READ(NRE, *)E
WRITE(1, 1064)
READ(NRE, *)EG
WRITE(1, 1065)
READ(NRE, *)PG

1050 FORMAT('WHAT IS THE NUMBER OF TEETH ON THE PINION')
1051 FORMAT('WHAT IS THE NUMBER OF TEETH OF THE GEAR')
1052 FORMAT('WHAT IS THE CONE DISTANCE OF THE GEAR MESH')
1053 FORMAT('WHAT IS THE NORMAL PRESSURE ANGLE (DEG)')
1054 FORMAT('WHAT IS THE FACE WIDTH OF THE GEAR MESH (IN)')
1058 FORMAT('WHAT IS THE SPIRAL ANGLE OF THE PINION')
1059 FORMAT('WHAT IS THE DIRECTION OF PINION ROTATION'/
* 'LOOKING FROM THE APEX TO THE FACE OF THE PINION'/
* '(COUNTERCLOCKWISE INPUT 1)'/
* '(CLOCKWISE INPUT -1)')
1060 FORMAT('WHAT IS THE HAND OF THE SPIRAL ANGLE ON THE PINION'/
* '(RIGHT INPUT 1)'/
* '(LEFT INPUT -1)')
1061 FORMAT('WHAT IS THE SHAFT ANGLE BETWEEN THE CENTER LINE OF THE'/
* 'PINION SHAFT AND THE CENTER LINE OF THE GEAR SHAFT (DEG)')
1063 FORMAT('WHAT IS THE MESH MATERIAL CONSTANT (PSI)')
1064 FORMAT('WHAT IS THE MESH WEIBULL EXPONENT')
1065 FORMAT('WHAT IS THE MESH LOAD-LIFE FACTOR')
RETURN
END

SUBROUTINE GEAROUT(NP, NG, AO, PHE, F, PHSI, ROT, SPR, *THETA, E, EG, PG)
REAL NP, NG
WRITE(1, 1071) NP, NG, AO, PHE, F, PHSI
*, ROT, SPR, THETA, E, EG, PG
1071 FORMAT(/'*
* NUMBER OF TEETH ON PINION *) F14.3/
* NUMBER OF TEETH ON GEAR *) F14.3/
* CONE DISTANCE *) F14.5/
* NORMAL PRESSURE ANGLE *) F14.5/
* FACE WIDTH *) F14.5/
* SPIRAL ANGLE *) F14.5/
* DIRECTION OF ROTATION *) F14.5/
* HAND OF SPIRAL *) F14.5/
* SHAFT ANGLE BETWEEN PINION AND GEAR *) F14.5/
* GEAR MESH MATERIAL CONSTANT *) F14.5/
* WEIBULL EXPONENT *) F14.5/
* MESH LOAD LIFE FACTOR *) F14.5/
RETURN
END

SUBROUTINE CAP(T, TLIO, N, DYCAPT, PGT)
T SET OF TORQUES
TLIO SET OF TRANSMISSION LIVES AT TORQUE
N NUMBER OF DATA SETS
DYCAPT DYNAMIC CAPACITY OF THE TRANSMISSION
PGT LOAD LIFE EXPONENT FOR THE TRANSMISSION

DIMENSION T(N), TLIO(N), ALT(100), ALTLIO(100)
DO 20 I=1, N
   ALT(I)=ALOG(T(I))
   ALTLIO(I)=ALOG(TLIO(I))
20 CONTINUE
CALL LEASGR(N, ALTLIO, ALT, TINT, SLOPE)
DYCAPT=EXP(TINT)
PGT=-1./SLOPE
RETURN
END

SUBROUTINE DPBVOT(PD, PHE, PHSI, SPR, F, AO, SI, SOF, ROT, TIR, TIL, TOF,
ITHETA, NP, GAMMA, DP, RPD, AOP, BOP,
2PXR, PYPR, PZPR, TOTFORR, DCAPR, CASEP, AP, BP,
3RXPR, R1YPR, R1ZPR, TOFORPR, BDCAP1OR,
C --- PRINT OUT RESULTS
C
REAL NP, NG, D1(9), P1(9), L1(9), H1(9), E1(9)
INTEGER CASEP, CASEG
WRITE(1,1000)
1000 FORMAT /// SPIRAL BEVEL GEAR UNIT ///
 WRITE(1,1200) PD, PHE, PHSI, SPR, F, AO, SI, SOF
     * ROT, TIR, TIL, TOF, THETA
 WRITE(1,1208)
 WRITE(1,1202) NP, GAMMA, DP, RPD, AOP, BOP, PXPR, PYPR, PZPR
     * TOTFORR, DCAPR
 WRITE(1,1205) CASEP, AP, BP, R1XPR, R1YPR, R1ZPR
     * TOTFORP1R, BDCAP10R, R2XPR, R2YPR, R2ZPR, TOTFORP2R, BDCAP20R
 WRITE(1,1209)
 WRITE(1,1202) NP, GAMMA, DP, RPD, AOP, BOP, PXPL, PYPL, PZPL
     * TOTFORL, DCAPL
 WRITE(1,1205) CASEP, AP, BP, R1XPL, R1YPL, R1ZPL
     * TOTFORP1L, BDCAP10L, R2XPL, R2YPL, R2ZPL, TOTFORP2L, BDCAP20L
 WRITE(1,1210)
 WRITE(1,1202) NG, ZZ, DG, RGD, AOG, BOG, PXGR, PYGR, PZGR,
     * TOTFORGE, DCAG
 WRITE(1,1230)
 WRITE(1,1202) NG, ZZ, DG, RGD, AOG, BOG, PXGL, PYGL, PZGL,
     * TOTFORGE, DCAQ
 WRITE(1,1205) CASEG, AG, BG, R1XG, R1YG, R1ZG
     * TOTFORG1, BDCAG10, R2XG, R2YG, R2ZG, TOTFORG2, BDCAG20
1200 FORMAT /// GEAR MESH CHARACTERISTICS ///
     * PITCH ', F8.2/
     * NORMAL PRESSURE ANGLE ', F8.2/
     * SPIRAL ANGLE ', F8.2/
     * HAND OF THE SPIRAL OF THE PINION GEAR ', F8.3/
     * FACE WIDTH ', F8.3,' IN'/
     * CONE DISTANCE ', F8.3,' IN'/
* INPUT SPEED OF THE PINION SHAFT 'F10.2, ' RPM '/
* OUTPUT SPEED OF GEAR SHAFT 'F10.2, ' RPM '/
* DIRECTION OF INPUT SHAFT ROTATION 'F8.3 /
* INPUT TORQUE OF THE RIGHT PINION SHAFT 'F10.2, ' IN-LB '/
* INPUT TORQUE OF THE LEFT PINION SHAFT 'F10.2, ' IN-LB '/
* OUTPUT TORQUE OF THE GEAR SHAFT 'F10.2, ' IN-LB '/
* ANGLE BETWEEN INPUT AND OUTPUT SHAFT 'F8.2, ' DEG '/

1202 FORMAT( /
* NUMBER OF TEETH 'F8.2 /
* PITCH ANGLE 'F8.2, ' DEG '/
* PITCH DIAMETER 'F8.2, ' IN '/
* REFERENCE PITCH DIAMETER 'F8.3, ' IN '/
* ADDENDUM 'F8.3, ' IN '/
* DEEDENDUM 'F8.3, ' IN '/
* FORCES ON A TOOTH IN THE MESH ///
* AXIAL FORCE 'F9.1, ' LB '/
* RADIAL FORCE 'F9.1, ' LB '/
* TANGENTIAL FORCE 'F9.1, ' LB '/
* TOTAL FORCE 'F9.1, ' LB '/
* DYNAMIC CAPACITY IN FORCE 'F9.1, ' LB '/

1205 FORMAT( ' MOUNTING CHARACTERISTICS ///
* TYPE OF MOUNTING '15 /
* DISTANCE A 'F8.3 /
* DISTANCE B 'F8.3 //
* AXIAL LOAD 'F10.2, ' LBS '/
* RADIAL LOAD 'F10.2, ' LBS '/
* TANGENTIAL LOAD 'F10.2, ' LBS '/
* TOTAL EQUIVALENT FORCE 'F10.2, ' LBS '/
* BASIC DYNAMIC CAPACITY OF BEARING #1 'F10.1, ' LBS //
* AXIAL LOAD 'F10.2, ' LBS '/
* RADIAL LOAD 'F10.2, ' LBS '/
* TANGENTIAL LOAD 'F10.2, ' LBS '/
* TOTAL EQUIVALENT FORCE 'F10.2, ' LBS '/
* BASIC DYNAMIC CAPACITY OF BEARING #2 'F10.1, ' LBS //)

1208 FORMAT( /// RIGHT PINION CHARACTERISTICS AND MOUNTING ///)
1209 FORMAT( /// LEFT PINION CHARACTERISTICS AND MOUNTING ///)

1210 FORMAT( ///
* GEAR CHARACTERISTICS AND MOUNTING-MESH WITH RIGHT PINION ///)

1230 FORMAT( ///
* GEAR CHARACTERISTICS AND MOUNTING-MESH WITH LEFT PINION ///)

WRITE(1,1220)
WRITE(1,1211)
CALL DPLHE(D1(1),P1(1),L1(1),H1(1),E1(1))
WRITE(1,1213)
CALL DPLHE(D1(2),P1(7),L1(2),H1(2),E1(2))
WRITE(1,1214)
CALL DPLHE(D1(3),P1(8),L1(3),H1(3),E1(3))
WRITE(1,1212)
CALL DPLHE(D1(7),P1(7),L1(7),H1(7),E1(7))
WRITE(1,1215)
CALL DPLHE(D1(8),P1(8),L1(8),H1(8),E1(8))
WRITE(1,1216)
CALL DPLHE(D1(9),P1(9),L1(9),H1(9),E1(9))
WRITE(1,1217)
CALL DPLHE(D1(4),P1(4),L1(4),H1(4),E1(4))
WRITE(1,1218)
CALL DPLHE(D1(5),P1(5),L1(5),H1(5),E1(5))
WRITE(1,1219)
CALL DPLHE(D1(6),P1(6),L1(6),H1(6),E1(6))
1220 FORMAT(///
   *' DYNAMIC CAPACITY AND LIFE IN TERMS OF'/
   *' OUTPUT TORQUE AND SPEED'/)
1221 FORMAT(' RIGHT INPUT PINION'/)
1222 FORMAT(' RIGHT INPUT BEARING #1'/)
1223 FORMAT(' RIGHT INPUT BEARING #2'/)
1224 FORMAT(' LEFT INPUT PINION'/)
1225 FORMAT(' LEFT INPUT BEARING #1'/)
1226 FORMAT(' LEFT INPUT BEARING #2'/)
1227 FORMAT(' OUTPUT GEAR'/)
1228 FORMAT(' OUTPUT BEARING #1'/)
1229 FORMAT(' OUTPUT BEARING #2'/)
RETURN
END
SUBROUTINE DPLHE(DCAP,PG,LIFE,HOUR,EG)
REAL DCAP,PG,LIFE,HOUR,EG
WRITE(1,1221)DCAP,PG,LIFE,HOUR,EG
1221 FORMAT(///
   *' DYNAMIC CAPACITY'/
   *' LOAD LIFE EXPONENT '/
   *' LIFE IN MILLION OUTPUT ROTATIONS '/
   *' LIFE IN HOURS '/
   *' WEIBULL EXPONENT '/
RETURN
END
SUBROUTINE PLANCA(ISTEP,NCOMP,MG1,NS,NPS,NPR,NR,PHIS1,PHIR1,
   1RS,RPS,RRR,RB,AV,PB,N,EB,FTT,
   2B1SM,PS,ES,WDSM,B1RM,PR,ER,WDRM,
CALL BEAR(MG1, CB, A, V, PB, PHIR1, PHIS1, RR, RS, RPR, RPS, N, FTT,
1       TI, TOF, SI, SOF, DB, LB10, HB10)
L10(1)=LB10
H1(1)=HB10
E1(1)=EB
D1(1)=DB
CALL SUN(MG1, NS, PHIS1, B1SM, PS, ES, RR, RS, RPR, RPS, N, WDSM,
1       TI, TOF, SI, SOF, CS, LS, FS, DS, LS10, HS10)
L10(2)=LS10
H1(2)=HS10
E1(2)=ES
D1(2)=DS
CALL RING(MG1, NR, PHIR1, B1RM, PR, ER, RR, RS, RPR, RPS, N, WDRM,
1       TI, TOF, SI, SOF, CR, LR, FR, DR, LR10, HR10)
L10(3)=LR10
H1(3)=HR10
E1(3)=ER
D1(3)=DR
IF(ISTEP.EQ.5)GOT025
CALL PLANET1(MG1, ES, PS, ER, PR, RS, RR, RPS, RPR, TI, TOF, SI, SOF,
*       N, NPR, LS, FS, LR, FR, LP10, DP, HP10)
E1(4)=ES
L10(4)=LP10
H1(4)=HP10
D1(4)=DP
GO TO 26
CONTINUE
CALL PLANET2(MG1, NPS, LS, FS, PS, ES, RR, RS, RPR, RPS, N,
1       TI, TOF, SI, SOF, CS, DPS, LPS10, HPS10)
L10(4)=LPS10
H1(4)=HPS10
E1(4)=ES
D1(4)=DPS
CALL PLANET3(MG1, NPR, LR, FR, PR, ER, RR, RS, RPR, RPS, N,
1       TI, TOF, SI, SOF, CR, DPR, LPR10, HPR10)
L10(5)=LPR10
H1(5)=HPR10
E1(5)=ER
D1(5)=DPR
CONTINUE
CALL LIFE(L10,ISTEP,E1,NCOMP,LPLAN,EPLAN)
HPLAN=LPLAN*16666.667/SOF
RETURN
END

SUBROUTINE BEAR(MG1, CB, A, V, PB, PHIR, PHIS, RR, RS, RPR, RPS, N, FTT,
                 TI, TO, SI, SOF, DB, LB10, HB10)

BEAR CALCULATES THE BASIC DYNAMIC CAPACITY OF ONE PLANET
BEARING AND THE L10 LIFE OF THE BEARING FOR THE GIVEN INPUT
TORQUE IN TERMS OF SUN REVOLUTIONS.

REAL A, N, V, CB, PB, RR, RS, TI, RPR, RPS, LB10, PHIR, PHIS,
    DB, TNPHIR, TNPHIS, MG1

THE VARIABLES PASSED TO THE PROGRAM ARE:
  CB--BASIC DYNAMIC CAPACITY OF A SINGLE BEARING
  A--COMPOSITE BEARING LIFE ADJUSTMENT FACTOR
  PB--LOAD LIFE EXPONENT OF THE BEARING
  RPR--PITCH RADIUS OF PLANET MESHING WITH THE RING
  RPS--PITCH RADIUS OF PLANET MESHING WITH THE SUN
  RR--PITCH RADIUS OF THE RING
  RS--PITCH RADIUS OF THE SUN
  TI--INPUT TORQUE TO THE SUN
  V--OUTER RACE ROTATION LOAD ADJUSTMENT FACTOR
  PHIR--PRESSURE ANGLE OF RING MESH RADIANS
  PHIS--PRESSURE ANGLE OF SUN MESH RADIANS
  N--NUMBER OF PLANET BEARINGS IN THE TRANSMISSION

THE VARIABLES PASSED FROM THE PROGRAM ARE:
  DB--BASIC DYNAMIC CAPACITY OF ONE PLANET BEARING
  LB10--L10 LIFE OF ONE PLANET BEARING SUN REVS

CALCULATE THE TANGENTS OF THE PRESSURE ANGLES

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TNPHIR = SIN(PHIR) / COS(PHIR)
TNPHIS = SIN(PHIS) / COS(PHIS)

C FS: FORCE FROM SUN GEAR
   FS = TI / (N*RS)
C
C FR: FORCE FROM RING GEAR
   FR = RPS / RPR * FS
C
C FTT: TOTAL TANGENTIAL FORCE
   FTT = FS + FR
C
C FTR: TOTAL RADIAL FORCE
   FTR = FR * TNPHIR - FS * TNPHIS
C
C FB: TOTAL FORCE ON BEARING
   FB = V * SQRT(FTT**2 + FTR**2)
C
C AMGB: LOAD CYCLES PER INPUT REVOLUTION
   AMGB = A * RPR / RR
C
C LB10: L10 LIFE OF ONE PLANET BEARING
   LB10 = AMGB / MG1 * (CB / FB)**PB
   HB10 = LB10 * 16666.667 / SOF
C
C DB: THE BASIC DYNAMIC CAPACITY OF ONE PLANET BEARING
   DB = (AMGB / MG1)**(1.0 / PB) * (CB * TO / FB)
RETURN
END

C SUBROUTINE SUN(MG1, NS, PHIS, B1SM, PS, ES, RR, RS, RPR, RPS, N, WDSM, 1
   TI, TO, SI, SOF, CS, LS, FS, DS, LS10, HS10)
C
SUN CALCULATES THE BASIC DYNAMIC CAPACITY OF THE SUN GEAR AND
THE L10 LIFE OF THE SUN GEAR FOR THE GIVEN INPUT TORQUE.

REAL N, CS, DS, ES, NS, PS, RR, RS, TI, RPR, RPS, B1SM, LS10,
1   PHIS, WDSM, LS, MG1
C VARIABLES WHICH ARE PASSED TO THE PROGRAM:
C     BISM—MATERIAL CONSTANT FOR THE SUN-PLANET MESH
C     ES—WEIBULL EXPONENT OF THE SUN MESH
C     N—NUMBER OF PLANETS
C     NS—NUMBER OF TEETH ON SUN
C     PHIS—PRESSURE ANGLE OF THE SUN MESH RADIANS
C     PS—LOAD LIFE FACTOR OF ONE TOOTH OF THE MESH
C     RPR—PITCH RADIUS OF THE PLANET MESHING WITH RING
C     RPS—PITCH RADIUS OF THE PLANET MESHING WITH SUN
C     RR—PITCH RADIUS OF THE RING
C     RS—PITCH RADIUS OF THE SUN
C     TI—INPUT TORQUE TO THE SUN
C     WDSM—EFFECTIVE FACE WIDTH OF THE MESH
C VARIABLES WHICH ARE PASSED FROM PROGRAM:
C     DS—BASIC DYNAMIC CAPACITY OF THE SUN GEAR
C     LS10—L10 LIFE OF THE SUN GEAR SUN REVS
C     CS—BASIC DYNAMIC CAPACITY OF ONE TOOTH OF THE MESH
C
C CALCULATE THE CAPACITY OF ONE TOOTH IN THE SUN MESH
C
CS=BASCAP(RS,RPS,PHIS,WDSM,BISM)
C
FS: FORCE ON SUN GEAR
FS=TI/(N*RS)
C
LS: LIFE OF ONE TOOTH ON THE SUN GEAR
LS=(CS/FS)**PS
C
AMGS: LOAD CYCLES PER INPUT REVOLUTION
AMGS=(RS*RPR)/(N*RR*RPS)
C
LS10: L10 LIFE OF THE SUN GEAR
LS10=(1./NS)**(1./ES)*AMGS/MG1*LS
    HS10=16666.667*LS10/50
C
DS: BASIC DYNAMIC CAPACITY OF THE SUN GEAR
DS=(1.0/NS)**(1.0/ES/PS)*(AMGS/MG1)**(1./PS)*(CS/FS*T0)
RETURN
END

C
C
C

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SUBROUTINE PLANET1(MG1, ES, PS, ER, PR, RS, RR, RPS, RPR, TI, TO, SI, SOF, *
            N, NP, LS, FS, LR, FR, LP10, DP, HP10)

PLANET CALCULATES THE BASIC DYNAMIC CAPACITY OF A PLANET GEAR
AND THE L10 LIFE OF A PLANET GEAR FOR THE GIVEN INPUT TORQUE.

REAL N, NP, LP10, LS, LR, LP, MG1

VARIABLES WHICH ARE PASSED TO THE PROGRAM:
ES--WEIBULL EXPONENT OF THE PLANET-SUN MESH
PS--LOAD LIFE FACTOR OF THE PLANET-SUN MESH
ER--WEIBULL EXPONENT OF THE PLANET-RING MESH
PR--LOAD LIFE FACTOR OF THE PLANET-RING MESH
RS--PITCH RADIUS OF THE SUN
RR--PITCH RADIUS OF THE RING
RPS--PITCH RADIUS OF THE PLANET MESHING WITH SUN
RPR--PITCH RADIUS OF THE PLANET MESHING WITH RING
TI--INPUT TORQUE TO THE SUN LB-IN
N--NUMBER OF PLANETS
NP--NUMBER OF TEETH ON THE PLANET
LS--LIFE OF ONE TOOTH IN THE PLANET-SUN MESH
FS--FORCE ON ONE TOOTH IN THE PLANET-SUN MESH
LR--LIFE OF ONE TOOTH IN THE PLANET-RING MESH
FR--FORCE ON ONE TOOTH IN THE PLANET-RING MESH

VARIABLES WHICH ARE PASSED FROM PROGRAM:
DP--BASIC DYNAMIC CAPACITY OF THE PLANET
LP10--L10 LIFE OF THE PLANET SUN REVS

AMGP: LOAD CYCLES PER INPUT REVOLUTION
AMGP=RPR/RR

LP: LIFE OF ONE TOOTH OF PLANET DUE TO DUAL LOADING
LP=(LS*LR)/(LS**ES+LR**ES)**(1./ES)

LP10: LIFE OF STEPPED PLANET GEAR
LP10=(1.0/NP)**(1.0/ES)*AMGP/MG1*LP
HP10=16666.667*LP10/SOF

DP: DYNAMIC CAPACITY OF PLANET GEAR
DP=(1.0/NP)**(1.0/ES/PS)*(AMGP/MG1)**(1.0/PS)
1*LP**(1.0/PS)*TO
RETURN
END

SUBROUTINE PLANET2(MG1, NP, LS, FS, PS, ES, RR, RS, RPR, RPS, N, 1
TI, TO, SI, SOF, CS, DPS, LPS10, HPS10)

PLANET2 CALCULATES THE BASIC DYNAMIC CAPACITY OF THE
PLANET-SUN GEAR AND THE L10 LIFE OF THE PLANET-SUN GEAR
FOR THE GIVEN INPUT TORQUE.

REAL N, CS, DPS, ES, NP, PS, RR, RS, TI, RPR, RPS, LPS10, 1
LS, MG1

VARIABLES WHICH ARE PASSED TO THE PROGRAM:
LS--LIFE OF ONE TOOTH IN THE PLANET-SUN MESH
FS--FORCE ON ONE TOOTH IN THE PLANET-SUN MESH
ES--WEIBULL EXPONENT OF THE SUN MESH
N--NUMBER OF PLANETS
NP--NUMBER OF TEETH ON SUN
PS--LOAD LIFE FACTOR OF ONE TOOTH OF THE MESH
RPR--PITCH RADIUS OF THE PLANET MESHING WITH RING
RPS--PITCH RADIUS OF THE PLANET MESHING WITH SUN
RR--PITCH RADIUS OF THE RING
RS--PITCH RADIUS OF THE SUN
TI--INPUT TORQUE TO THE SUN

VARIABLES WHICH ARE PASSED FROM PROGRAM:
DS--BASIC DYNAMIC CAPACITY OF THE SUN GEAR
LS10--L10 LIFE OF THE SUN GEAR SUN REVS

AMGP: LOAD CYCLES PER INPUT REVOLUTION
AMGP=RPR/RR

LS10: L10 LIFE OF THE SUN GEAR
LPS10=(1./NP)**(1./ES)*AMGP/MG1*LS
HPS10=LPS10*16666.667/SOF

DS: BASIC DYNAMIC CAPACITY OF THE SUN GEAR
DPS=(1.0/NP)**(1.0/ES/PS)*(AMGP/MG1)**(1./PS)*(CS/FS*TO)
RETURN
END
SUBROUTINE PLANET3(MG1, NP, LR, FR, PR, ER, RR, RS, RPR, RPS, N, 
1 TI, TO, SI, SOF, CR, DPR, LPR10, HPR10)

C PLANET3 CALCULATES THE BASIC DYNAMIC CAPACITY OF THE
C PLANET-RING GEAR AND THE L10 LIFE OF THE PLANET-RING
C GEAR FOR THE GIVEN INPUT TORQUE.

C REAL N, CR, DR, ER, NP, PR, RR, RS, TI, RPR, RPS, LPR10, 
1 LR, MG1

C VARIABLES WHICH ARE PASSED TO THE PROGRAM:
C LR--LIFE OF ONE TOOTH IN THE PLANET-RING MESH
C FR--FORCE ON ONE TOOTH IN THE PLANET-RING MESH
C ER--WEIBULL EXPONENT OF THE RING MESH
C NP--NUMBER OF TEETH ON ONE PLANET
C NR--NUMBER OF TEETH ON RING
C PR--LOAD LIFE FACTOR OF ONE TOOTH OF THE MESH
C RPR--PITCH RADIUS OF THE PLANET MESHING WITH RING
C RPS--PITCH RADIUS OF THE PLANET MESHING WITH SUN
C RR--PITCH RADIUS OF THE RING
C RS--PITCH RADIUS OF THE SUN
C TI--INPUT TORQUE TO THE SUN

C VARIABLES WHICH ARE PASSED FROM PROGRAM:
C DPR--BASIC DYNAMIC CAPACITY OF THE RING GEAR
C LPR10--L10 LIFE OF THE RING GEAR SUN REVS

C AMGP: LOAD CYCLES PER INPUT REVOLUTION
AMGP=RPR/RR

C LR10: L10 LIFE OF THE RING GEAR
LPR10=(1./NP)**(1./ER)*AMGP/MG1*LR
HPR10=LPR10*16666.667/SOF

C DR: THE BASIC DYNAMIC CAPACITY OF THE RING GEAR
DPR=(1./NP)**(1./ER/PR)*(AMGP/MG1)**(1./PR)*CR/TO/FR
RETURN

END

SUBROUTINE RING(MG1, NR, PHIR, B1RM, PR, ER, RR, RS, RPR, RPS, N, WDRM, 
1 TI, TO, SI, SOF, CR, LR, FR, DR, LR10, HR10)
RING CALCULATES THE BASIC DYNAMIC CAPACITY OF THE RING GEAR AND THE $L_{10}$ LIFE OF THE RING GEAR FOR THE GIVEN INPUT TORQUE.

REAL N, CR, DR, ER, NR, PR, RR, RS, TI, RPR, RPS, B1RM, LR10, 1 PHIR, WDRM, LR, MG1

VARIABLES WHICH ARE PASSED TO THE PROGRAM:
B1RM--MATERIAL CONSTANT OF THE RING-PLANET MESH
ER--WEIBULL EXPONENT OF THE RING MESH
NP--NUMBER OF TEETH ON ONE PLANET
NR--NUMBER OF TEETH ON RING
PHIR--PRESSURE ANGLE OF THE RING MESH RADIANS
PR--LOAD LIFE FACTOR OF ONE TOOTH OF THE MESH
RPR--PITCH RADIUS OF THE PLANET MESHING WITH RING
RPS--PITCH RADIUS OF THE PLANET MESHING WITH SUN
RR--PITCH RADIUS OF THE RING
RS--PITCH RADIUS OF THE SUN
TI--INPUT TORQUE TO THE SUN
WDRM--EFFECTIVE FACE WIDTH OF THE GEAR

VARIABLES WHICH ARE PASSED FROM PROGRAM:
DR--BASIC DYNAMIC CAPACITY OF THE RING GEAR
LR10--$L_{10}$ LIFE OF THE RING GEAR SUN REVS
CR--BASIC DYNAMIC CAPACITY OF ONE TOOTH OF THE RING MESH

CALCULATE THE CAPACITY OF ONE TOOTH IN THE RING MESH
THE -RR IN FUNCTION BASCAP INDICATES AN INTERNAL GEAR MESH.

$CR = BASCAP(RPR, -RR, PHIR, WDRM, B1RM)$

$FR$: FORCE ON THE RING GEAR
$FR = RPS*TI/(RPR*RS*N)$

$LR$: LIFE OF ONE TOOTH ON THE RING GEAR
$LR = (CR/FR)**PR$

$AMGR$: LOAD CYCLES PER INPUT REVOLUTION
$AMGR = 1./N$

$LR10$: $L_{10}$ LIFE OF THE RING GEAR
$LR10 = (1./NR)**(1./ER)*AMGR/MG1*LR$
\[ HR10 = LR10 \times \frac{16666.667}{SOF} \]

\[ DR = (1. / NR) \times (1. / ER/PR) \times (AMGR/ MG1) \times (1. / PR) \times CR \times TQ/FR \]

RETURN
END

SUBROUTINE PLANIN(CB, A, V, EB, PB, N, NCOMP, PDS, PDR, NS, PHIS, PHIS1, 1PHIR, PHIR1, WDSM, ES, PS, B1SM, ISTEP, NPS, NPR, NR, WDRM, ER, PR, B1RM, 2RPR, RPS, RR, RS)
CHARACTER*9 DATAFILE
REAL N, NCOMP(5), NS, NPS, NPR, NR
INTEGER NO, YES, ANSWER
PARAMETER (NO='NO', YES='YES')
WRITE(1,300)
300 FORMAT('PLANETARY GEAR UNIT INPUTS'/)
WRITE(1,999)
999 FORMAT('DO YOU WISH TO USE A DATA FILE (YES OR NO)')
READ(1,110)ANSWER
IF(ANSWER.EQ. NO) GO TO 501
WRITE(1,502)
502 FORMAT('WHAT IS THE NAME OF THE INPUT FILE')
READ(1,503)DATAFILE
503 FORMAT(A)
OPEN(UNIT=56, FILE=DATAFILE, STATUS='UNKNOWN')
NRE=56
GO TO 500
501 NRE=1
500 CONTINUE
WRITE(1,1000)
READ(NRE, *)CB
WRITE(1,1010)
READ(NRE, *)A
WRITE(1,1020)
READ(NRE, *)V
WRITE(1,1030)
READ(NRE, *)EB
WRITE(1,1040)
READ(NRE, *)PB
WRITE(1,1050)
READ(NRE, *)N
NCOMP(1)=N
NCOMP(2)=1.
NCOMP(3)=1.
NCOMP(4)=N
NCOMP(5)=N
WRITE(1,1060)
READ(NRE,110)ANSWER
IF(ANSWER.EQ.YES)WRITE(1,1070)
IF(ANSWER.EQ.NO)WRITE(1,1080)
READ(NRE,*)PDS
IF(ANSWER.EQ.YES)PDR=PDS
IF(ANSWER.EQ.NO)READ(NRE,*)PDR
WRITE(1,1090)
READ(NRE,*)NS
WRITE(1,1100)
READ(NRE,110)ANSWER
IF(ANSWER.EQ.YES)WRITE(1,1110)
IF(ANSWER.EQ.NO)WRITE(1,1120)
READ(NRE,*)PHIS
IF(ANSWER.EQ.YES)PHIR=PHIS
IF(ANSWER.EQ.NO)READ(NRE,*)PHIR
PHIS1=PHIS*3.1415927/180.0
PHIR1=PHIR*3.1415927/180.0
WRITE(1,1130)
READ(NRE,*)WDSM
WRITE(1,1140)
READ(NRE,*)ES
WRITE(1,1150)
READ(NRE,*)PS
WRITE(1,1160)
READ(NRE,*)B1SM
WRITE(1,1170)
READ(NRE,110)ANSWER
ISTEP=4
IF(ANSWER.EQ.NO)WRITE(1,1180)
IF(ANSWER.EQ.YES)WRITE(1,1190)
IF(ANSWER.EQ.YES)ISTEP=5
READ(NRE,*)NPS
IF(ANSWER.EQ.NO)NPR=NPS
IF(ANSWER.EQ.YES)READ(NRE,*)NPR
WRITE(1,1200)
READ(NRE,*)NR
WRITE(1,1210)
READ(NRE,*)WDRM
WRITE(1,1220)
READ(NRE,*)ER
WRITE(1,1230)
READ(NRE,*)PR
WRITE(1,1240)
READ(NRE,*)B1RM
CLOSE(56)

RPR=NPR/2.0/PDR
RPS=NPS/2.0/PDS
RR=NR/2.0/PDR
RS=NS/2.0/PDS

INPUT WRITE FORMATS

110 FORMAT(1A4)
1000 FORMAT(20X,'PLANETARY TRANSMISSION RELIABILITY ANALYSIS''/
1     20X,'(ALL NUMERICAL INPUT MUST BE IN F-FORMAT)'/
2     5X,'WHAT IS THE BASIC DYNAMIC CAPACITY OF ONE PLANET?',
3     ' BEARING? (LB)'
1010 FORMAT(5X,'WHAT IS THE COMPOSITE LIFE ADJUSTMENT FACTOR?')
1020 FORMAT(5X,'WHAT IS THE OUTER RACE ROTATION FACTOR?')
1040 FORMAT(5X,'WHAT IS THE WEIBULL FACTOR FOR THE BEARINGS?')
1050 FORMAT(5X,'WHAT IS THE LOAD-LIFE FACTOR FOR THE BEARINGS?')
1060 FORMAT(5X,'HOW MANY PLANET BEARINGS ARE IN THE TRANSMISSION?')
1070 FORMAT(5X,'WHAT IS THE DIAMETRAL PITCH OF THE TRANSMISSION?'
1     ' (TEETH/IN)')
1080 FORMAT(5X,'ENTER THE DIAMETRAL PITCH OF THE SUN MESH FIRST, '/
1     5X,'THEN ENTER THE DIAMETRAL PITCH OF THE RING MESH. ','
2     ' (TEETH/IN)')
1090 FORMAT(5X,'HOW MANY TEETH DOES THE SUN GEAR HAVE ON IT?')
1100 FORMAT(5X,'IS THE PRESSURE ANGLE FOR THE SUN MESH AND?' /
1     5X,'THE RING MESH THE SAME?')
1110 FORMAT(5X,'WHAT IS THE PRESSURE ANGLE? (DEG)')
1120 FORMAT(5X,'ENTER THE PRESSURE ANGLE FOR THE SUN MESH FIRST, '/
1     5X,'THEN ENTER THE PRESSURE ANGLE OF THE RING MESH. (DEG)')
1130 FORMAT(5X,'WHAT IS THE FACE WIDTH OF THE SUN MESH? (IN)')
1140 FORMAT(5X,'WHAT IS THE WEIBULL EXPONENT OF THE SUN MESH?')
1150 FORMAT(5X,'WHAT IS THE LOAD-LIFE FACTOR OF THE SUN MESH?')
1160 FORMAT(5X,'WHAT IS THE MATERIAL CONSTANT OF THE SUN MESH? (PSI)')
1170 FORMAT(5X,'DOES THE TRANSMISSION HAVE STEPPED PLANETS?')
1180 FORMAT(5X,'HOW MANY TEETH DOES ONE PLANET GEAR HAVE?')
1190 FORMAT(5X,'ENTER THE NUMBER OF TEETH ON ONE PLANET MESHED'),
1 FORMAT(5X,'WITH THE SUN, THEN ENTER THE NUMBER OF TEETH ON THE'),
5X,'PLANET MESHED WITH THE RING.')
1200 FORMAT(5X,'HOW MANY TEETH ARE ON THE RING GEAR?')
1210 FORMAT(5X,'WHAT IS THE FACE WIDTH OF THE RING GEAR MESH? (IN)')
1220 FORMAT(5X,'WHAT IS THE WEIBULL EXPONENT OF THE RING GEAR MESH?')
1230 FORMAT(5X,'WHAT IS THE LOAD-LIFE FACTOR OF THE RING GEAR MESH?')
1240 FORMAT(5X,'WHAT IS THE MATERIAL CONSTANT OF THE RING GEAR MESH?',
5X, '(TEETH/IN)')
RETURN
END

SUBROUTINE PLANOT(ISTEP,N,V,FB,NS,PDS,PHIS,WDSM,B1SM,FS,
1NR, PDR, PHIR, WDRM, B1RM, FR, NP, NPS, NPR, TI, TOF, SI, SOF, FTT,
2D1, P1, L1, H1, E1)
REAL N, NS, NR, NP, NPS, NPR, D1(5), P1(5), L1(5), E1(5), H1(5)
WRITE(1, 5049) TI, TOF, SI, SOF
WRITE(1, 5002)
DB1 = D1(1)*FTT/TOF
WRITE(1, 5051) N, V, CB, DB1, FTT
WRITE(1, 5000)
DS1 = D1(2)*FS/TOF
WRITE(1, 5050) NS, PDS, PHIS, WDSM, B1SM, DS1, FS
WRITE(1, 5001)
DR1 = D1(3)*FR/TOF
WRITE(1, 5050) NR, PDR, PHIR, WDRM, B1RM, DR1, FR
WRITE(1, 5003)
DP1 = D1(4)*FS/TOF
IF(ISTEP.EQ. 5) GOTO 10
WRITE(1, 5050) NPS, PDS, PHIS, WDSM, B1SM, DP1, FS
GOTO 20
10 DPS1 = D1(4)*FS/TOF
WRITE(1, 5004)
WRITE(1, 5050) NPS, PDS, PHIS, WDSM, B1SM, DPS1, FS
DPR1 = D1(5)*FR/TOF
WRITE(1, 5005)
WRITE(1, 5050) NPR, PDR, PHIR, WDRM, B1RM, DPR1, FR
CONTINUE
WRITE(1, 4999)
WRITE(1, 5002)
CALL DPLHE(D1(1), P1(1), L1(1), H1(1), E1(1))
WRITE(1, 5000)
CALL DPLHE(D1(2), P1(2), L1(2), H1(2), E1(2))
WRITE(1, 5001)
CALL DPLHE(D1(3), P1(3), L1(3), H1(3), E1(3))
IF(ISTEP.EQ. 5) GOTO 11
WRITE(1,5003)
CALL DPLHE(D1(4),P1(4),L1(4),H1(4),E1(4))
GOTO21
11 WRITE(1,5004)
CALL DPLHE(D1(4),P1(4),L1(4),H1(4),E1(4))
WRITE(1,5005)
CALL DPLHE(D1(5),P1(5),L1(5),H1(5),E1(5))
21 CONTINUE
4998 FORMAT(///
1' PLANETARY GEAR UNIT'///)
4999 FORMAT(///
* DYNAMIC CAPACITY AND LIFE IN TERMS OF'/'
* OUTPUT TORQUE AND SPEED'///)
5000 FORMAT( ' SUN GEAR'/'
5001 FORMAT( ' RING GEAR'/'
5002 FORMAT( ' PLANET BEARING'/'
5003 FORMAT( ' PLANET GEAR'/'
5004 FORMAT( ' PLANET-SUN GEAR'/'
5005 FORMAT( ' PLANET-RING GEAR'/'
5049 FORMAT(/' INPUT TORQUE........................... ',F14.5, ' ', LB-IN'/
2' OUTPUT TORQUE........................... ',F14.5, ' ', LB-IN'/
3' INPUT SPEED.............................. ',F14.5, ' ', RPM'/
4' OUTPUT SPEED............................. ',F14.5, ' ', RPM'/
5050 FORMAT(/' NUMBER OF TEETH....................... ',F14.5/
2' PITCH OF THE MESH.......................... ',F14.5/
3' PRESSURE ANGLE............................ ',F14.5, ' ', DEG'/
4' FACE WIDTH.................................. ',F14.5, ' ', IN'/
5' MATERIAL CONSTANT OF THE MESH............. ',F14.5, ' ', PSI'/
6' DYNAMIC CAPACITY......................... ',F14.5, ' ', LBS'/
7' FORCE ON GEAR TOOTH........................ ',F14.5, ' ', LBS'/
5051 FORMAT(/' NUMBER OF PLANETS.................... ',F14.5/
2' ROTATIONAL FACTOR.......................... ',F14.5/
3' DYNAMIC CAPACITY (CATALOG VALUE)......... ',F14.5, ' ', LBS'/
4' DYNAMIC CAPACITY (SYSTEM VALUE)........... ',F14.5, ' ', LBS'/
5' TOTAL FORCE.................................. ',F14.5, ' ', LBS'/)
RETURN
END
SUBROUTINE SPBVCA(
1TI, TOF, SI, SOF, MG, MQ1, NP, NG,
2AO, GAMMA1, ROT, SPR, PHE1, PHSI1, ZZ1,
3PTL, AP, BP, RP, GTO, AG, BG, RG,
4ITYPEP1, RFP1, NBP1, DP1, ACP1, BDCAP1, AK1, EGP1, ADJP1,
C----------------------------------------------------------------------
C CALCULATION OF THE LOADS TRANSMITTED FROM THE PINION
C----------------------------------------------------------------------
CALL GPSPR(TI, AO, F, GAMMA1, ROT, SPR, PHE1, PHSI1, PXP, PYP, PZP)
TOTFOR=SGRT(PXP**2+PYP**2+PZP**2)
C----------------------------------------------------------------------
C CALCULATION OF THE LOADS TRANSMITTED TO THE GEAR FROM EACH PINION
C----------------------------------------------------------------------
TOUT=MG*TI
ROT1=-ROT
SPR1=SPR
CALL GPSPR(TOUT, AO, F, ZZ1, ROT1, SPR1, PHE1, PHSI1, PXG, PYG, PZG)
C----------------------------------------------------------------------
C CHECK CASE FOR BEARING POSITION AND CALCULATE THE LOADS ON THE BEARINGS TRANSMITTED FROM THE RIGHT PINION
C----------------------------------------------------------------------
IF(PTL.EQ.2)GO TO 18
R1XP=PXP
R2XP=0.0
GO TO 19
18 R1XP=0.0
R2XP=PXP
19 CONTINUE
CALL BLC1(PXP, PYP, PZP, AP, BP, RP, R1YP, R1ZP, R2YP, R2ZP)
C----------------------------------------------------------------------
C CHECK CASE FOR BEARING POSITION CALCULATE THE LOADS ON THE BEARINGS TRANSMITTED FROM THE GEAR DUE TO THE PINION
C----------------------------------------------------------------------
IF(GTL.EQ.2)GO TO 22
R1XG=PXG
R2XG=0.0
GO TO 23

22 R1XG=0.0
R2XG=PXG

23 CONTINUE

CALL BLC1(PXG,PYG,PIG,AG,BG,RO,R1YG,R1ZG,R2YG,R2ZG)

C---------
C CALCULATE THE LIFE OF PINION BEARING #1
C---------

CALL BDCAP(ITYPEP1,R1XP,R1YP,R1ZP,RFP1,NBP1,DP1,ACP1,SOF,ADJP1
*,BDCAP1,L1OP1,H1OP1,MG, MG1, AK1, TDFORP1,PGP1,BDCAP10)
BDCAP10T=BDCAP10*TOF/TOFORP1
LL(2)=L1OP1
EE(2)=EGP1

C---------
C CALCULATE THE LIFE OF PINION BEARING #2
C---------

CALL BDCAP(ITYPEP2,R2XP,R2YP,R2ZP,RFP2,NBP2,DP2,ACP2,SOF,ADJP2
*,BDCAP2,L1OP2,H1OP2,MG, MG1, AK2, TDFORP2,PGP2,BDCAP20)
BDCAP20T=BDCAP20*TOF/TOFORP2
LL(3)=L1OP2
EE(3)=EGP2

C---------
C CALCULATE THE LIFE OF GEAR BEARING #1
C---------

CALL BDCAP(ITYPEG1,R1XG,R1YG,R1ZG,RFG1,NBG1, DG1, ACG1, SOF, ADJG1
*,BDCAG1,L1OG1,H1OG1,1.,MG1,AK3,TOFORG1,PGG1,BDCAG10)
BDCAG10T=BDCAG10*TOF/TOFORG1
LL(5)=L1OG1
EE(5)=EGG1

C---------
C CALCULATE THE LIFE OF GEAR BEARING #2
C---------

CALL BDCAP(ITYPEG2,R2XG,R2YG,R2ZG,RFG2,NBG2, DG2, ACG2, SOF, ADJG2
*,BDCAG2,L1OG2,H1OG2,1.,MG1,AK4,TOFORG2,PGG2,BDCAG20)
BDCAG20T=BDCAG20*TOF/TOFORG2
LL(6)=L1OG2
EE(6)=EGG2

C---------
C CALCULATE THE LIFE OF THE GEAR
C---------

184
CALL SET(PHE, F, E, MG, MG1, NP, NG, SOF, LP10, HP10, LG10, *HG10, PG, EG, TOTFOR, RPD, RGD, DCAP, DCAG, TOTFOR)
DCAP = DCAP * TOTFOR / TOTFOR
DCAGT = DCAG * TOTFOR / TOTFOR
LL(1) = LP10
LL(4) = LG10
EE(1) = EG
EE(4) = EG

C -----------------------------------------------
C CALCULATE THE LIFE OF THE TRANSMISSION
C -----------------------------------------------
CALL LIFE(LL, 6, EE, NCOMP, LSB, ESB)
HSB = LSB * 16666.667 / SOF
RETURN
END

C-----------------------------------------------
SUBROUTINE SET(PHE, F, E, MG, MG1, NP, NG, SPEED2, LP10, HP10, LG10, *HG10, PG, EG, FOR, R1, R2, DCAP, DCAG, FE)

C -----------------------------------------------
C CALCULATION OF THE LIFE OF THE PINION AND GEAR MESH
C -----------------------------------------------

C INPUTS
C
C PHE - PRESSURE ANGLE OF THE MESH (RADIANS)
C F - FACE WIDTH (IN)
C E - MESH MATERIAL CONSTANT (PSI)
C MG - GEAR RATIO
C NP - NUMBER OF TEETH OF THE PINION
C NG - NUMBER OF TEETH OF THE GEAR
C SPEED2 - SPEED OF OUTPUT SHAFT
C PG - MESH MATERIAL CONSTANT
C EG - MESH WEIBULL EXPONENT
C FOR - TOTAL FORCE TRANSMITTED
C R1 - REFERENCE PLANE RADIUS OF SPIRAL BEVEL PINION (IN)
C R2 - REFERENCE PLANE RADIUS OF SPIRAL BEVEL GEAR (IN)

C OUTPUT
C
C LP10 - THE L10 LIFE OF THE PINION (CYCLES)
C HP10 - THE L10 LIFE OF THE PINION (HOURS)
C LG10 - THE L10 LIFE OF THE GEAR (CYCLES)
C HG10 - THE L10 LIFE OF THE GEAR (HOURS)
C DCAP - THE DYNAMIC CAPACITY OF THE PINION (LBS)
C DCAG - THE DYNAMIC CAPACITY OF THE GEAR (LBS)
FOR   -FORCE ON THE PINION
FE   -FORCE ON THE GEAR

REAL NP, NQ, MG, MG1, LP1O, LG1O, LP1OT, LG1OT
F1= 5*F
CBG=BASCAP(R1, R2, PHE, F1, E)

CALCULATE LIFE OF GEAR TEETH

LP1O=(CBG/FOR)**PG
LG1O=(CBG/FE)**PG
VEQ=1./EQ
VPG=1./PG

CALCULATE LIFE OF PINION AND GEAR

LP10=(1./NP)**VEG/MG/MG1*LP1OT
HP10=LP10*16666.666/SPEED2
LG10=(1./NG)**VEG/MG1*LG1OT
HG10=LG10*16666.666/SPEED2

CALCULATE BASIC DYNAMIC CAPACITY OF PINION AND GEAR

DCAP=((1./NP)**VEG/MG/MG1)**VPG*CBG
DCAQ=((1./NG)**VEG/MG1)**VPG*CBG
RETURN

END

SUBROUTINE SPBVIN(NP, NG, AO, PHE, F, PHSI, ROT, SPR, THETA, E, EQ, PQ,
1PHE1, PHSI1, THETA1, CASEP, PTL, AP, BP, ITYPEP1, NBP1, DP1, ACP1, AK1,
2BCAP1, RFPI, EQP1, ITYPEP2, NBP2, DP2, ACP2, AK2, BDCAPI, RFPI, EGP2,
3CASEG, GTL, AQ, BG, ITYPEG1, NBG1, DG1, ACG1, AK3, BDCAG1, RFG1, EGG1,
4ITYPEG2, NBG2, DG2, ACG2, AK4, BDCAG2, RFG2, EGG2, MG, GAMMA1, GAMMA2, ZS,
5ZS1, DP, DG, RPD, RP, RGD, RG, HK, AOG, AOP, HT, BOG, BOP, PD,
6ADJP1, ADJP2, ADJG1, ADJG2)

SPIRAL BEVEL INPUT

CHARACTER*9 DATAFILE
INTEGER NO, YES, ANSWER, CASEP, CASEG, PTL, GTL
REAL NP, NG, MG, NBP1, NBP2, NBG1, NBG2
PARAMETER(NO='NO', YES='YES')
PII=3.141592654
WRITE(1,300)
300 FORMAT(//'SPIRAL BEVEL GEAR UNIT INPUTS'//)
WRITE(1,999)
READ(1, 99) ANSWER
IF (ANSWER. EQ. NO) GO TO 501
WRITE(1, 502)

502 FORMAT('WHAT IS THE NAME OF THE INPUT FILE')
READ(1, 503) DATAFILE

503 FORMAT(A)
OPEN(UNIT=55, FILE=DATAFILE, STATUS='UNKNOWN')
NRE=55
GO TO 500

501 NRE=1
500 CONTINUE
CALL GEARINP(NRE, NP, NG, AO, PHE, F, PHSI, ROT, SPR,
* THETA, E, EG, PG)
CALL GEAROUT(NP, NG, AO, PHE, F, PHSI, ROT, SPR,
* THETA, E, EG, PG)
WRITE(1, 1070)
READ(NRE, *) LL1
IF(LL1. EQ. 1) GO TO 500
PHE1=PHE*PI/180.
PHSI1=PHSI*PI/180.
TI=TI*ROT
THETA1=THETA*PI/180.

C
C ENTERING THE VALUES FOR THE PINION AND ITS BEARINGS

C

WRITE(1, 1074)

600 CONTINUE
CALL CASEINP(NRE, CASEP, PTL, AP, BP)
CALL CASEOUT(CASEP, PTL, AP, BP)
WRITE(1, 1070)
READ(NRE, *) LL1
IF(LL1. EQ. 1) GO TO 600

601 CONTINUE
WRITE(1, 1040)
CALL BEARINP(NRE, ITYPEP1, NBP1, DP1, ACP1, AK1, BDCAP1, RFP1, EGP1, ADJP1)
CALL BEAROUT(ITYPEP1, NBP1, DP1, ACP1, AK1, BDCAP1, RFP1, EGP1, ADJP1)
WRITE(1, 1070)
READ(NRE, *) LL2
IF(LL2. EQ. 1) GO TO 601

602 CONTINUE
WRITE(1, 1045)
CALL BEARINP(NRE, ITYPEP2, NBP2, DP2, ACP2, AK2, BDCAP2, RFP2, EGP2, ADJP2)
CALL BEAROUT(ITYPEP2, NBP2, DP2, ACP2, AK2, BDCAP2, RFP2, EGP2, ADJP2)
WRITE(1, 1070)
READ(NRE, *) L3
IF(L3. EQ. 1) GOTO 602

C
C
C
WRITE(1, 1075)
CONTINUE
CALL CASEINP(NRE, CASEG, GTL, AG, BG)
CALL CASEOUT(CASEG, GTL, AG, BG)
WRITE(1, 1070)
READ(NRE, *) L4
IF(L4. EQ. 1) GOTO 603

603 CONTINUE
WRITE(1, 1040)
CALL BEARINP(NRE, ITYPEG1, NBG1, DG1, ACG1, AK3, BDCAG1, RFG1, EGG1, ADJG1)
CALL BEAROUT(ITYPEG1, NBG1, DG1, ACG1, AK3, BDCAG1, RFG1, EGG1, ADJG1)
WRITE(1, 1070)
READ(NRE, *) L5
IF(L5. EQ. 1) GOTO 604

604 CONTINUE
WRITE(1, 1045)
CALL BEARINP(NRE, ITYPEG2, NBG2, DG2, ACG2, AK4, BDCAG2, RFG2, EGG2, ADJG2)
CALL BEAROUT(ITYPEG2, NBG2, DG2, ACG2, AK4, BDCAG2, RFG2, EGG2, ADJG2)
WRITE(1, 1070)
READ(NRE, *) L6
IF(L6. EQ. 1) GOTO 605
CLOSE(55)

C---CALCULATION OF GEAR RATIO AND OUTPUT SPEED---

MG=NG/NP
SPEED2=SPEED/MG

C---CALCULATION OF GAMMA---

GAMMA1=ATAN(SIN(THETA1)/(MG+COS(THETA1)))
GAMMA=GAMMA1*180./PII
ZZ=THETA-GAMMA
ZZ1=ZZ*PII/180.

C---CALCULATION OF PITCH DIAMETER OF GEAR AND PINION---
C AND REFERENCE PITCH DIAMETER OF GEAR AND PINION---
DP = (AO - F/2.) * (2. * SIN(GAMMA1))
DG = (AO - F/2.) * (2. * SIN(ZZ1))
PD = NG / DG
RPD = DP * .5 / COS(GAMMA1)
RP = DP * .5
RGD = DG * .5 / COS(ZZ1)
RG = DG * .5

C WORKING DEPTH

HK = 1.70 / PD

C ADDENDUM OF GEAR AND PINION

AOG = 0.46 / PD + 0.390 / (PD * MG**2)
AOP = HK - AOG

C WHOLE DEPTH

IF (PD < 10.) GO TO 50
HT = 1.888 / PD
GOTO 51
50 HT = 1.888 / PD + .005
51 CONTINUE

C DEEDENDUM OF THE GEAR AND PINION

BOG = HT - AOG
BOP = HT - AOP

999 FORMAT('DO YOU WISH TO USE A DATA SET?/
* 'ANSWER YES OR NO')
1040 FORMAT('PINION BEARING #1')
1045 FORMAT('PINION BEARING #2')
1046 FORMAT('GEAR BEARING #1')
1047 FORMAT('GEAR BEARING #2')
1070 FORMAT('DO YOU WISH TO CHANGE ANY OF THESE PARAMETERS?/
* 'ENTER 1 TO CHANGE')
1074 FORMAT('PINION MOUNTING')
1075 FORMAT('GEAR MOUNTING')
99 FORMAT(1A4)
RETURN
END
SUBROUTINE SPBVOT(PD, PHE, PHSI, SPR, F, AO, SI, SOF, ROT, TI, TOF, THETA,
1NP, GAMMA, DP, RPD, AOP, BOP, PD,
2PX, PYP, PZP, TOTFOR, DCAP, CASEP, AP, BP,
3R1XP, R1YP, R1ZP, TOFORP1, BDCAP10,
4R2XP, R2YP, R2ZP, TOFORP2, BDCAP20,
5NG, ZZ, DG, RGD, AOG, BOG,
6PXG, PYG, PZG, TOTFOR, DCAG, CASEG, AG, BG,
7R1XG, R1YG, R1ZG, TOFORG1, BDCAG10,
8R2XG, R2YG, R2ZG, TOFORG2, BDCAG20,
9D1, P1, L1, H1, E1)

C -----------------------------------------------
C -----------------------------------------------
REAL NP, NG, D1(6), P1(6), L1(6), H1(6), E1(6)
INTEGER CASEP, CASEG
WRITE(1,1000)
1000 FORMAT(///
1' SPIRAL BEVEL GEAR UNIT'///)
WRITE(1,1200)PD, PHE, PHSI, SPR, F, AO, SI, SOF
*, ROT, TI, TOF, THETA
WRITE(1,1209)
WRITE(1,1202)NP, GAMMA, DP, RPD, AOP, BOP, PX, PYP, PZP
*, TOTFOR, DCAP
WRITE(1,1205)CASEP, AP, BP, R1XP, R1YP, R1ZP
*, TOFORP1, BDCAP10, R2XP, R2YP, R2ZP, TOFORP2, BDCAP20
WRITE(1,1210)
WRITE(1,1202)NG, ZZ, DG, RGD, AOG, BOG, PXG, PYG, PZG,
*, TOTFOR, DCAG
WRITE(1,1205)CASEG, AG, BG, R1XG, R1YG, R1ZG
*, TOFORG1, BDCAG10, R2XG, R2YG, R2ZG, TOFORG2, BDCAG20

1200 FORMAT(/// ' GEAR MESH CHARACTERISTICS '///
*' PITCH ',F8.2/
*' NORMAL PRESSURE ANGLE ',F8.2/
*' SPIRAL ANGLE ',F8.2/
*' HAND OF THE SPIRAL OF THE PINION GEAR ',F8.3/
*' FACE WIDTH ',F8.3, ' IN'/
*' CONE DISTANCE ',F8.3, ' IN'/
*' INPUT SPEED OF THE PINION SHAFT ',F10.2, ' RPM'/
*' OUTPUT SPEED OF GEAR SHAFT ',F10.2, ' RPM'/
*' DIRECTION OF INPUT SHAFT ROTATION ',F8.3/
*' INPUT TORQUE OF THE PINION SHAFT ',F10.2, ' IN-LB'/
*' OUTPUT TORQUE OF THE GEAR SHAFT ',F10.2, ' IN-LB'/
*' ANGLE BETWEEN INPUT AND OUTPUT SHAFT ',F8.2, ' DEG'/

1202 FORMAT(///
*' NUMBER OF TEETH ',F8.2/
* PITCH ANGLE
  * PITCH DIAMETER
  * REFERENCE PITCH DIAMETER
  * ADDENDUM
  * DEPENDUM
  * FORCES ON A TOOTH IN THE MESH
  * AXIAL FORCE
  * RADIAL FORCE
  * TANGENTIAL FORCE
  * TOTAL FORCE
  * DYNAMIC CAPACITY IN FORCE

1205 FORMAT(' MOUNTING CHARACTERISTICS'

* TYPE OF MOUNTING
  * DISTANCE A
  * DISTANCE B
  * AXIAL LOAD
  * RADIAL LOAD
  * TANGENTIAL LOAD
  * TOTAL EQUIVALENT FORCE
  * BASIC DYNAMIC CAPACITY OF BEARING #1
  * AXIAL LOAD
  * RADIAL LOAD
  * TANGENTIAL LOAD
  * TOTAL EQUIVALENT FORCE
  * BASIC DYNAMIC CAPACITY OF BEARING #2
  * DYNAMIC CAPACITY IN FORCE

1209 FORMAT(' PINION CHARACTERISTICS AND MOUNTING '

1210 FORMAT(' GEAR CHARACTERISTICS AND MOUNTING ')

WRITE(1,1220)
WRITE(1,1211)
CALL DPLHE(D1(1),P1(1),L1(1),H1(1),E1(1))
WRITE(1,1213)
CALL DPLHE(D1(2),P1(2),L1(2),H1(2),E1(2))
WRITE(1,1214)
CALL DPLHE(D1(3),P1(3),L1(3),H1(3),E1(3))
WRITE(1,1217)
CALL DPLHE(D1(4),P1(4),L1(4),H1(4),E1(4))
WRITE(1,1218)
CALL DPLHE(D1(5),P1(5),L1(5),H1(5),E1(5))
WRITE(1,1219)
CALL DPLHE(D1(6),P1(6),L1(6),H1(6),E1(6))

1220 FORMAT(' DYNAMIC CAPACITY AND LIFE IN TERMS OF '

1211 FORMAT(' INPUT PINION')
1213 FORMAT(‘ INPUT BEARING #1’/)
1214 FORMAT(‘ INPUT BEARING #2’/)
1217 FORMAT(‘ OUTPUT GEAR’/)
1218 FORMAT(‘ OUTPUT BEARING #1’/)
1219 FORMAT(‘ OUTPUT BEARING #2’/)
RETURN
END
APPENDIX  D

SYMBOLS

Variables

A  distance from gear to front bearing in inches  
A₀  distance from apex to back of gear along pitch ray in inches  
b  major axis contact length in inches  
B  distance from gear to rear bearing in inches  
Bₜ  back cone radius in inches  
B₁  material constant in psi  
C  dynamic capacity in pounds  
D  gear diameter in inches or dynamic capacity in pound-inches  
D₀  distance from apex to center of gear along pitch ray in inches  
f  face width in inches  
F  bearing force in pounds  
l  life in million component cycles  
L  life in million transmission cycles  
m  gear ratio  
n  number of planet gears  
N  number of teeth  
Pₚ  diametral pitch in 1.0/inches  
R  gear radius in inches
S  probability of survival
T_i  input torque in pound inches
T_o  output torque in pound inches
W  gear load in pounds
\( \Gamma \)  cone angle in degrees
\( \Lambda \)  angle between input pinion shafts in degrees
\( \Sigma \)  shaft angle in degrees
\( \Sigma_p \)  curvature sum in 1.0/inches
\( \phi \)  pressure angle in degrees
\( \psi \)  spiral angle in degrees

Superscripts

e  Weibull slope
p  load-life factor

Subscripts

a  axial
b  bearing
bs  bearing in sun rotation units
g  gear
i  i'\text{th} unit
n  normal
ne  equivalent normal
p  pinion or planet
pr  planet meshing with ring
ps  planet meshing with sun
pt  planet tooth
r  ring or radial
R  combined radial
rl  left radial
rr  right radial
s  sun
t  tangential, thrust or tooth
T  combined tangential or transmission
tl  left tangential
tr  right tangential
1  first
2  second
3  third
10  90 percent reliability
REFERENCES


A computer program which simulates life and reliability of helicopter transmissions is presented. The helicopter transmissions may be composed of spiral bevel gear units and planetary gear units - alone, in series or in parallel. The spiral bevel gear units may have either single or dual input pinions, which are identical. The planetary gear units may be stepped or unstepped and the number of planet gears carried by the planet arm may be varied. The reliability analysis used in the program is based on the Weibull distribution lives of the transmission components. The computer calculates the system lives and dynamic capacities of the transmission components and the transmission. The system life is defined as the life of the component or transmission at an output torque at which the probability of survival is 90 percent. The dynamic capacity of a component or transmission is defined as the output torque which can be applied for one million output shaft cycles for a probability of survival of 90 percent. A complete summary of the life and dynamic capacity results is produced by the program.
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