N88-23241

ROLLER DRIVE MATERIALS PERFORMANCE

Douglas A. Rohn
Structural Dynamics Branch
NASA Lewis Research Center

ABSTRACT

Roller drives offer several beneficial characteristics in servomechanism applications. The best use of these inherent qualities in a given design is often dependent on the performance of the materials chosen for traction rollers. This presentation outlines roller traction performance basics, a test program at Lewis to measure performance, and the need for and typical use of the information.

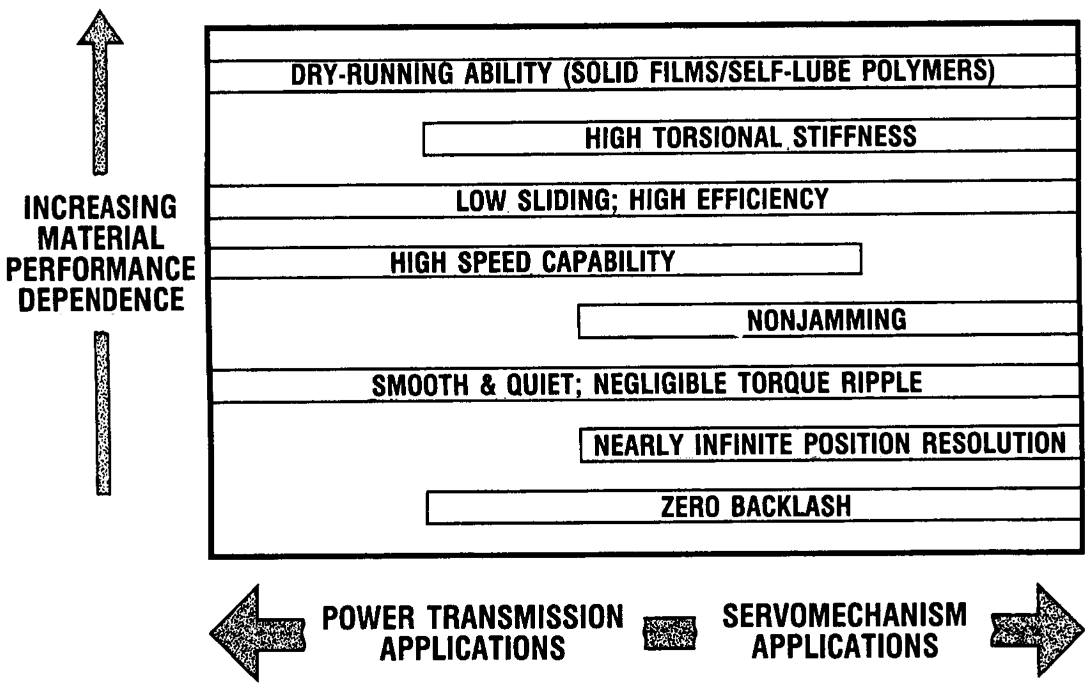
Smooth rollers can transmit torque when pressed together in a rolling contact. The amount of torque depends directly on the available traction coefficient and indirectly on the normal load capacity of the roller materials. Durability and life are related to both rolling element fatigue and wear. Application of roller drives to space mechanisms requires this performance data under typical traction conditions in suitable environments, for example, vacuum.

A test rig has been designed and fabricated to develop this information. Parametric conditions and specimen materials have been chosen so that the resulting data and understanding will be valuable to the design and development of advanced, roller-driven space mechanisms, from precision positioning devices to telerobot joints.

OVERVIEW

BENEFICIAL CHARACTERISTICS OF ROLLER TRACTION DRIVES

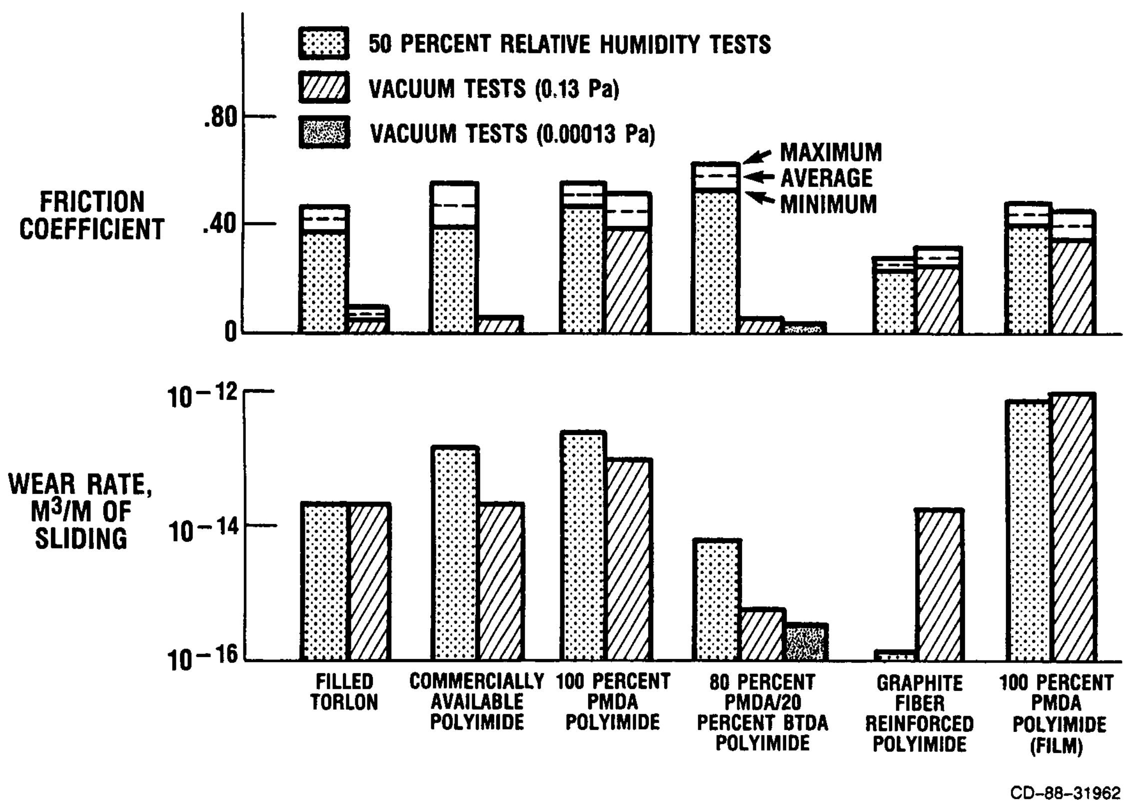
Roller drives offer several beneficial characteristics in servomechanism applications. Potential aerospace applications include antenna or solar array positioners, control moment gyro actuators, and robotic joints. In these and similar applications the zero backlash, low torque ripple, high stiffness, high efficiency, and ability to run without liquid lubrication of roller traction drives are important. Application of these inherent qualities to a given aerospace mechanism often depends on the roller material performance, in terms of available traction coefficient, load capacity, and wear rate under the design conditions.



CD-88-31961

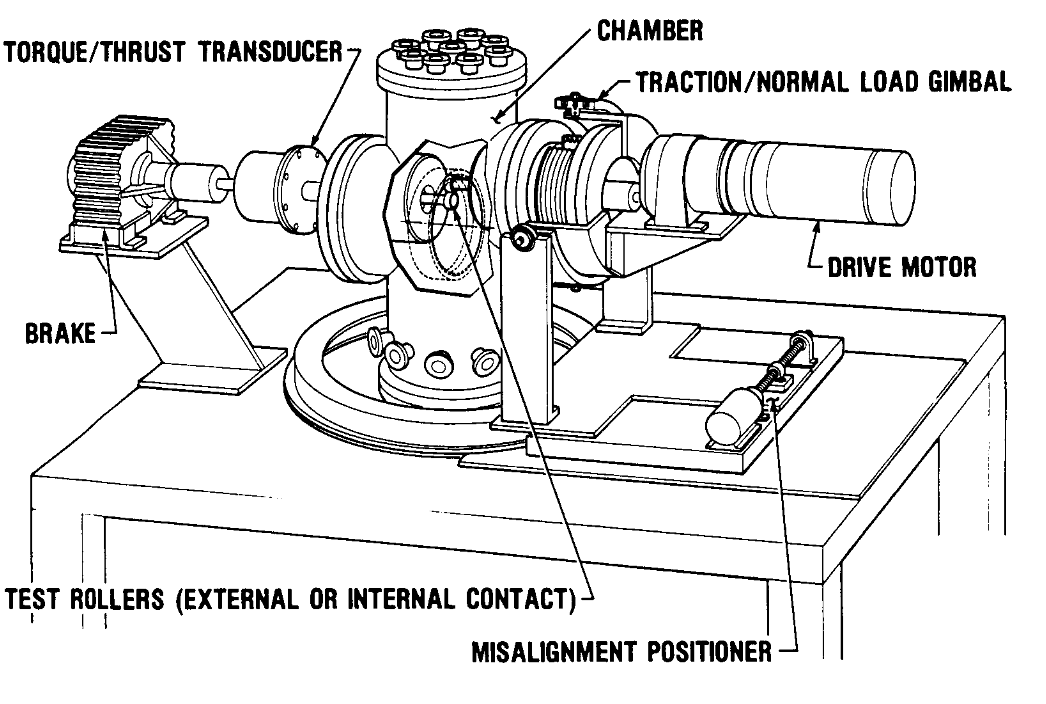
FRICTION AND WEAR OF SEVERAL POLYMERS

Particularly in the case of space mechanisms, performance in the thermal-vacuum environment is critical. A large body of friction and wear data exists for sliding contact in air, as well as a fair amount for sliding in vacuum. Comparatively less information is available for rolling traction contacts (i.e., rolling and sliding) in air and very little for traction in a vacuum. Extrapolation from sliding to traction contacts is generally possible; however, exact condition data are preferred. In addition, the differences in performance in air and vacuum can be quite large.



ENVIRONMENT SIMULATION ROLLER CONTACT PERFORMANCE RIG

An experimental program is under way at NASA Lewis to evaluate materials and coatings for application to roller drives in space mechanisms. Central to this effort is a test rig which properly duplicates conditions to provide valuable data for understanding rolling traction performance phenomena and to support current and future space mechanism projects.



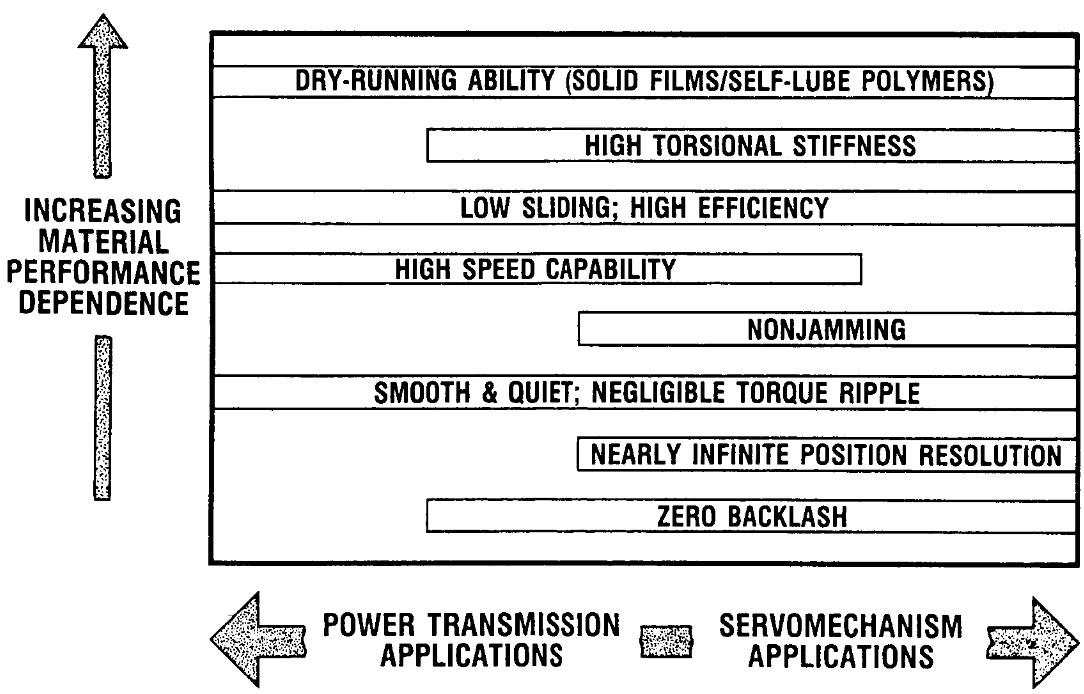
POSTER PRESENTATION

BENEFICIAL CHARACTERISTICS OF ROLLER TRACTION DRIVES

An interesting class of mechanisms utilize traction as the means to transfer torque. Applications range from dry contacts, such as the locomotive wheel against the rail and elastomer-coated rollers in paper handling equipment, to lubricated contacts in industrial adjustable-speed traction drives (Loewenthal et al., 1983).

As power transmissions, few mechanical drives match the low noise, smooth torque transfer characteristics, high speed capability, and speed regulating accuracy of traction drives. For servo drive system applications, their ability to provide a smooth transfer of motion with relatively low hysteresis losses and high torsional stiffness while producing no detectable "backlash" upon direction reversal are obviously beneficial qualities. (Loewenthal et al., 1985).

These characteristics are inherent in the nature of roller traction drives (i.e., smooth rollers running against other smooth rollers). However, the degree to which the characteristics can be put to use depends on the performance of the roller materials.



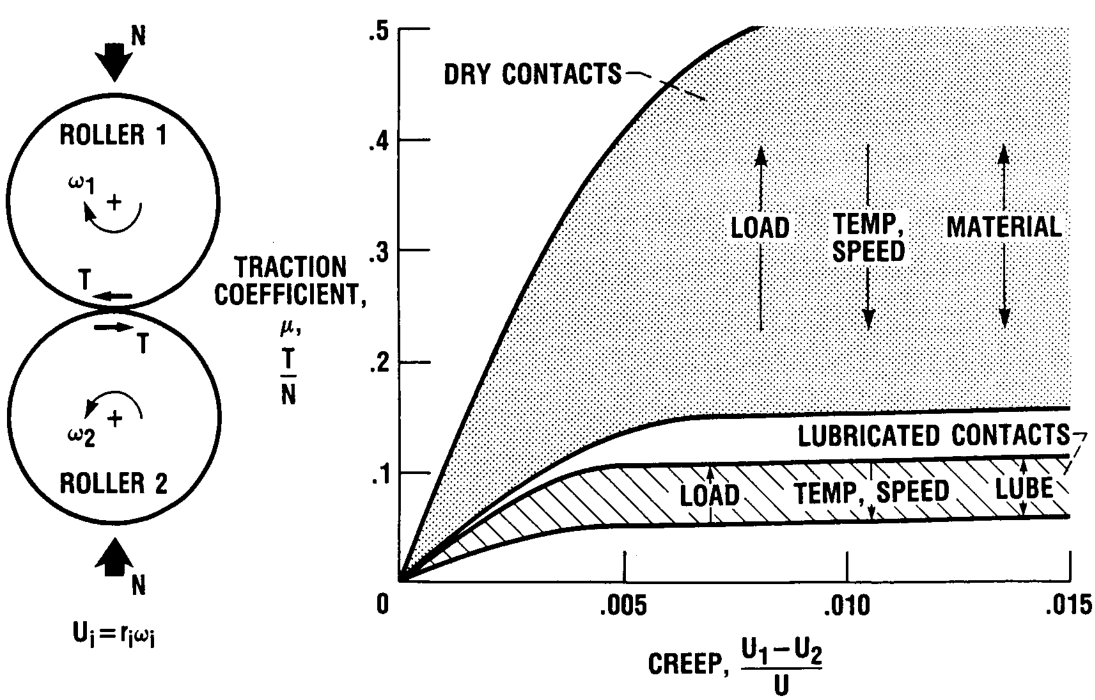
CD-88-31961

TRACTION CURVE

A simple roller traction drive consists of a pair of rollers pressed together with a normal load N. The traction force T capable of being transmitted through the contact is a function of many parameters: normal load, rolling speed U, temperature, materials, and lubricants, when present. The relationship between these factors is typically shown by a set of traction curves. The speed variation between traction rollers due to torque transfer is generally referred to as creep (Loewenthal and Zaretsky, 1985). The traction coefficient is typically plotted against this value for a variety of speeds, temperatures, loads, etc. The shape of any one of the family of curves follows the range boundary lines of this figure.

Roller drives are designed to operate in the linear ascending portion of the traction curve at some point below the peak. Operating creep rates range from 0.1 to 0.2 percent for dry contacts or those lubricated with traction fluids at low speeds, to 3 or 4 percent for lightly loaded, high-speed contacts lubricated with mineral oils. This speed difference is not due to slip between driver and driven roller but is, in fact, the accumulated lost motion due to the tangential stretching and compressing motion or compliance occurring at the roller contact interface. A "locked" or "zero slip" region exists at the leading edge of the contact, and only at the peak traction point (i.e., point of impending slip) will this region completely disappear. In the case of a lubricated contact, lost motion due to viscous shear of the lubricant film in the contact is also added.

TRACTION CURVE

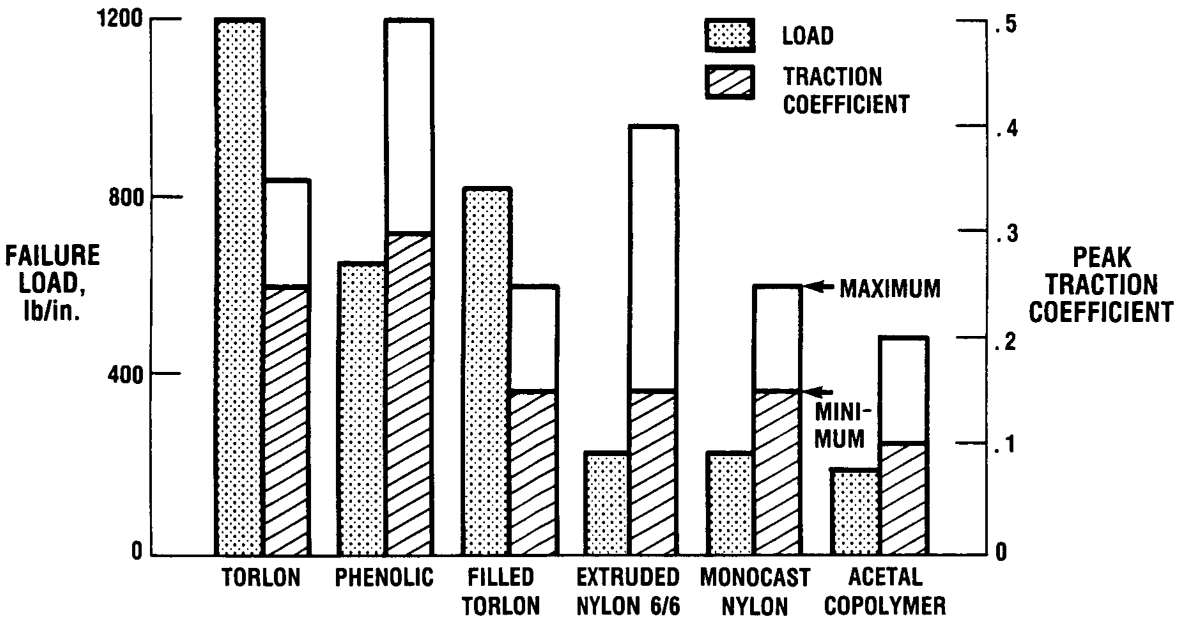


CD-88-31964

TRACTION CAPACITY OF POLYMER ROLLERS

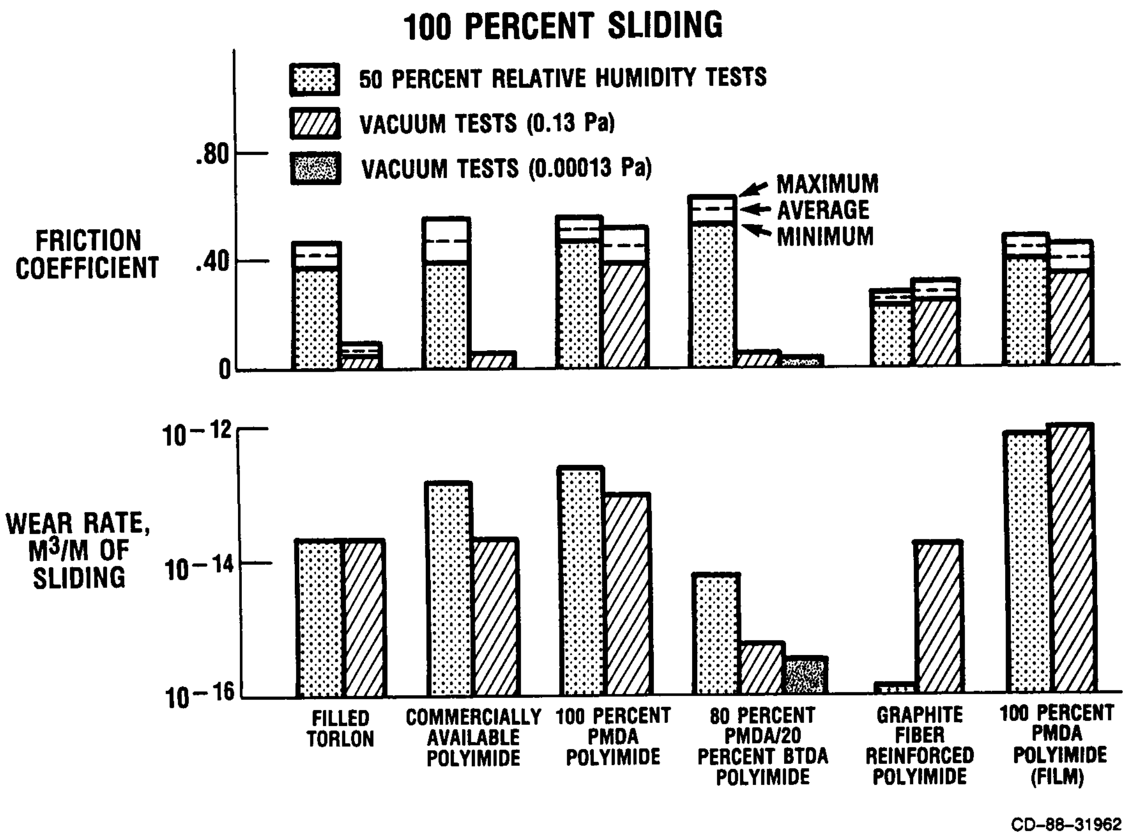
The torque and power capacity of roller traction drive contacts are dependent on the material combination's peak available traction coefficient and the amount of normal load sustained before failure. The failure modes of lubricated roller drive contacts are very similar to those of ball and roller bearings. Rolling-element fatigue, or pitting, is the likely mode when the quality of lubrication is good. When the lubrication quality is not good, and also in the case of dry-contact roller drives, the failure mode shifts from fatigue to one that is predominantly wear.

Dry-running contacts, whether of polymer rollers or solid lubricant films, are obviously advantageous where liquid lubrication is impractical. The traction coefficient and particularly the load capacity of some commercial polymers are surprisingly high. Data shown here were generated in air, with a polymer roller running against a steel roller (Tevaarwerk, 1985).



CD-88-31965

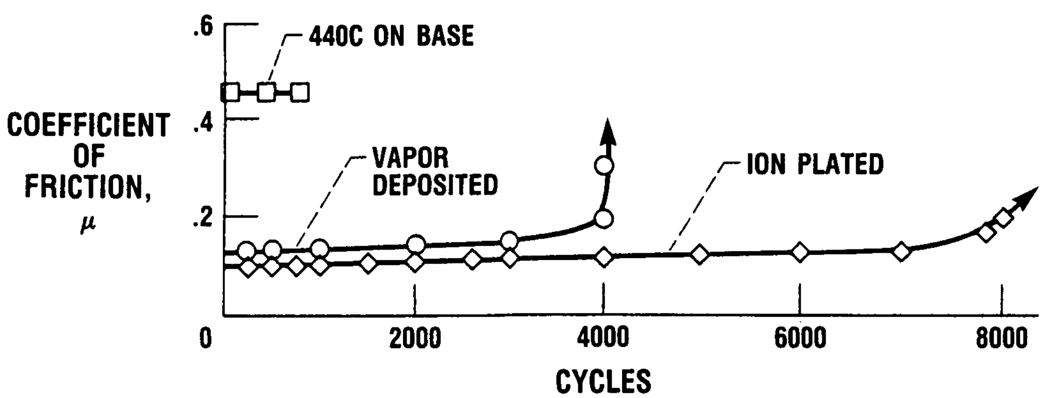
In order to make use of polymer rollers in space mechanism applications, their friction and wear properties must be known in representative environments. At present, data exist only for contacts undergoing full sliding. Data for several representative commercial and experimental polymers in air and vacuum are presented here (Fusaro, 1987).



FRICTION OF GOLD-PLATED 440C

Another promising roller drive material combination is steel rollers with soft metal films (lead, silver, and gold) or hardfaced coatings (TiN and TiC). These materials serve as solid lubricants or extremely wear-resistant barriers (respectively) between the rollers which would otherwise cold weld in the nonoxidative vacuum environment. The data shown here (Spalvins, 1985) display friction as well as wear life information for gold in vacuum. Friction increases dramatically when the initial coating layer wears off and the 440C substrate is rapidly damaged.

This and the previous data charts illustrate typical available data, which are primarily for full sliding. Performance data in terms of traction coefficient, load capacity, and wear rate for all materials in a roller traction contact (combined sliding and rolling) under air, vacuum, and other environmental conditions are needed for roller drive space mechanism design.



CD-88-31966

ENVIRONMENT SIMULATION ROLLER CONTACT PERFORMANCE RIG CAPABILITIES

An in-house program is under way to determine roller contact performance in nonatmospheric environments. Understanding the data and phenomena will support efforts in Lewis' Microgravity Mechanisms and Robotics Program, as well as in the space station, telerobotics research, and future space missions.

A rig has been designed and is being fabricated to satisfy the experimental criteria outlined here. Data on rolling traction contacts in a vacuum are essentially nonexistent today. Proposed specimen materials include the full range, from liquid lubricated steel, to solid film coatings, to polymers, and to ion-plated or vapor-deposited hardface materials.

PARAMETERS:
- **LONGITUDINAL AND SIDE-SLIP TRACTION (ROLLING/SLIDING)**
- **AIR, VACUUM, GAS**
- **200 lb NORMAL LOAD, 500 rpm, 600 in.-lb**

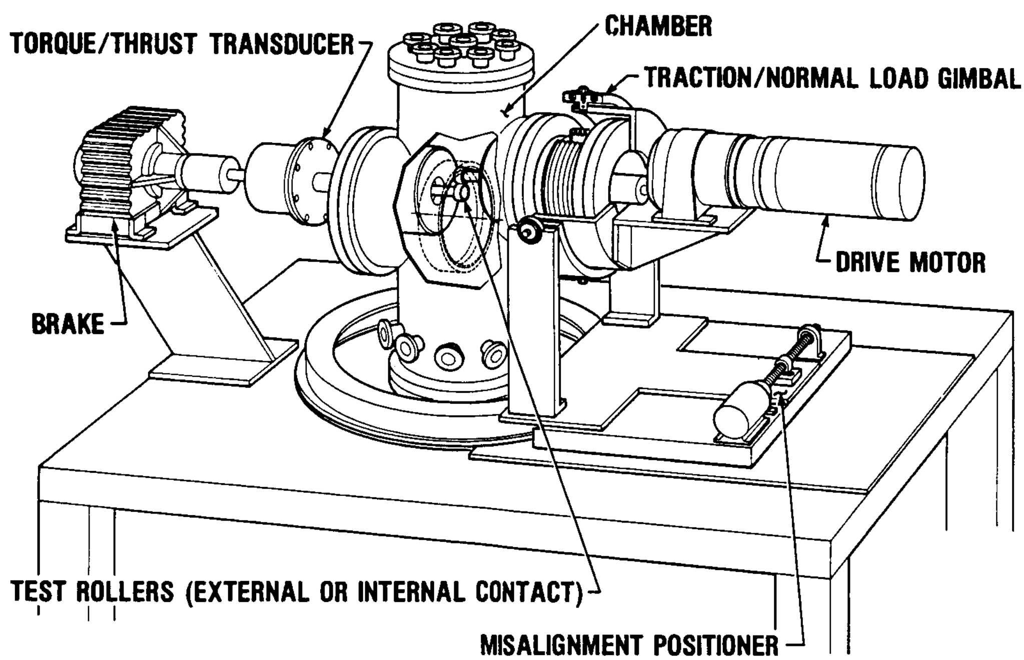
OUTPUT DATA:
- **TRACTION COEFFICIENT**
- **LOAD CAPACITY**
- **WEAR RATE**
- **EFFECTS OF MISALIGNMENT**

SPECIMENS:
- **SOLID ROLLERS**
  - **METALLIC**
  - **POLYMER**
- **COATINGS/FILMS**
  - **ION-PLATED METALS**
  - **HARDFACED LAYERS**
  - **POLYMERS**
  - **ELASTOMERS**
- **LIQUID LUBRICANTS**

CD-88-31967

ENVIRONMENT SIMULATION ROLLER CONTACT PERFORMANCE RIG

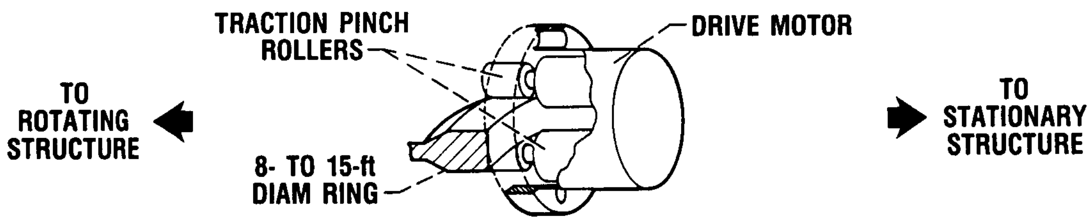
An illustration of the rig concept is shown here. Test rollers are supported in vacuum-rated rotary feedthroughs and surrounded by a chamber which can be evacuated to 10^{-6} torr or filled with suitable gases at or below ambient pressure. A dc variable-speed motor provides rotation, and a magnetic particle brake absorbs power for longitudinal traction torque transfer testing. A more sensitive method of testing, side-slip traction (where the rollers are deliberately misaligned and the axial thrust is a measure of traction force), can also be accommodated. Misalignment is also a potential source of power loss in an actual roller drive mechanism; thus its effects on torque transfer will also be studied. Short-term, accelerated wear measurements will be possible. Presently planned future additions to the rig include the means to heat and cool the rollers to represent thermal conditions.



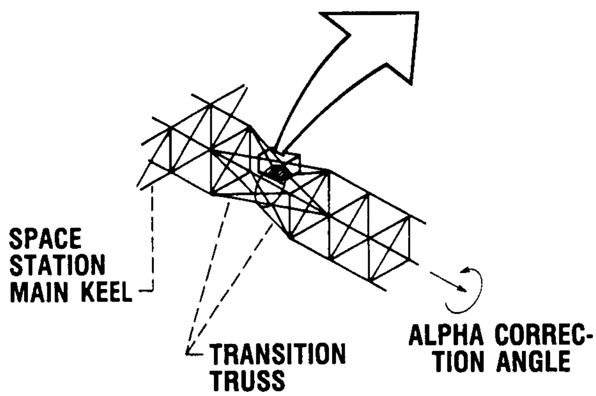
CD-88-31963

SPACE STATION ROTARY JOINT PINCH ROLLER DRIVE CONCEPT

The data from this effort have been used to develop a concept for the space station power module alpha joint. Loewenthal and Schuller (1986) demonstrated the feasibility of a pinch roller drive. Several performance advantages relative to gears were noted, including overtorque or jamming protection, inherent acceptability to dry or self-lubricating materials, ease of manufacture, and in situ assembly and maintenance. Data to predict wear rates were extracted from plasma-nitrided steel gear data in vacuum and from pin-on-disk, 100 percent sliding data for polyimides in vacuum. While use of such data was made conservatively, actual rolling traction capacity and wear data are certainly required before committing to space flight hardware fabrication.



ROLLER/RING ALPHA JOINT DRIVE



WEAR LIFE ESTIMATE:

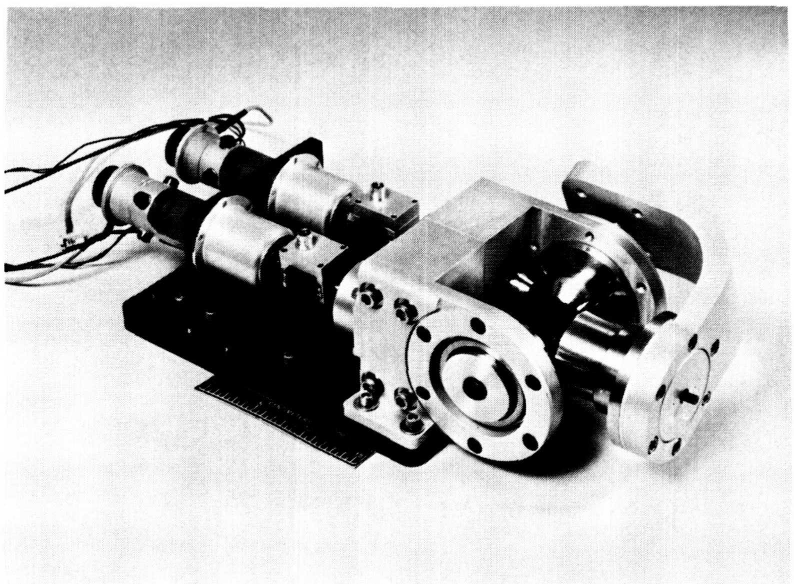
- 76-mm-DIAMETER ROLLERS
- 50-μm EXP. POLYIMIDE COATING
- $>$16-yr SERVICE LIFE

LST '88 CD-88-31968

ORIGINAL PAGE IS
OF POOR QUALITY

ORNL BENCH-TEST TELEROBOT JOINT WITH ROLLER DRIVE DIFFERENTIAL

Another application of advanced roller drive actuators is in robot manipulator joints. The Oak Ridge National Laboratory (ORNL) developed a design for a laboratory and ultimately a space telerobot system (Kuban and Williams, 1987). Critical to its performance is a differential pitch/yaw joint, having high torque in a compact volume, low loss, ability to operate in space, and zero backlash. A roller drive design was selected to meet these needs. High roller load capacity and reasonably high traction coefficient are both desirable to minimize the size of the joint while still carrying the required torque. Low wear is important for long life. Ion-plated gold on hardened steel was selected as the initial material combination. Data from the Roller Drive Material Performance Program are essential to this and other advanced roller drive mechanism designs.



DESIGN REQUIREMENTS

- **HIGH TORQUE/ LOW LOSS**
- **DRY/VACUUM OPERATION**
- **ZERO BACKLASH**

CD-88-32530

SUMMARY

Roller drives offer several beneficial characteristics in servomechanism applications. The best use of these inherent qualities in a given design is often dependent on the performance of the materials chosen for traction rollers. Application of roller drives to space mechanisms requires this performance data under typical traction conditions in suitable environments.

An experimental program is under way to develop this information. Parametric conditions and specimen materials have been chosen so that the resulting data and understanding will be valuable to the design and development of advanced, roller space mechanisms, from precision positioning devices to telerobot joints.

REFERENCES

Fusaro, R.L., 1987, "Tribological Properties of Polymer Films and Solid Bodies in a Vacuum Environment," NASA TM-88966.

Kuban, D.P., and Williams, D.M., 1987, "Traction-Drive, Seven-Degree-of-Freedom Telerobot Arm: A Concept for Manipulation in Space," 21st Aerospace Mechanisms Symposium, NASA CP-2470, pp. 111-130.

Loewenthal, S.H., Rohn, D.A. and Anderson, N.E., 1983, "Advances in Traction Drive Technology," SAE Trans., Vol. 92, Sect. 3.

Loewenthal, S.H., and Zaretsky, E.V., 1985, "Traction Drives," Section 34, Mechanical Design and Systems Handbook, H. Rothbart, ed., McGraw-Hill Book Co., New York.

Loewenthal, S.H., and Schuller, F.T., 1986, "Feasibility Study of a Discrete Bearing/Roller Drive Rotary Joint for the Space Station," NASA TM-88800.

Spalvins, T., 1985, "The Structure of Ion Plated Films in Relation to Coating Properties," NASA TM-87055.

Tevaarwerk, J.L., 1985, "Rolling, Slip and Endurance Traction Measurements on Low Modules Materials," NASA CR-174909.