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CENTRIFUGAL REGULATOR FOR CONTROL OF DEPLOYMENT RATES OF DEPLOYABLE ELEMENTS

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ABSTRACT

Centrifugal brakes or clutches are currently used in a number of mechanisms. This paper describes the requirements, design, and performance of a centrifugal regulator aimed at limiting deployment rates of deployable elements.

This mechanism, which uses centrifugal force to produce friction of studs, has been designed, manufactured, and tested to specification for the IUE (see "Acknowledgement") solar array.

INTRODUCTION

Deployment of the IUE solar array is characterized by a complex motion which can be broken into elementary rotations and translation.

The deployment is initiated by a pyrotechnic device, and the various operations are fulfilled in automatic sequence to final lockup. The motion is controlled by a centrifugal regulator driven by a cable continuously pulled out throughout all phases of deployment.

This solution was selected in view of the following factors:

1. Limiting end of travel shocks to values compatible with mechanical strength of the frame and spacecraft attachment
2. Low sensitivity to the operating temperature range (in contrast to a hydraulic system, which is sensitive to the variation of viscosity)
3. Good cleanliness and, in particular, low outgassing without seal problems
4. Availability of a large number of parameters which are easily adjustable during tests

MAIN REQUIREMENTS OF THE DESIGN

The main requirements of the design are given in the following table:

Unwound length, m	0.75
Nominal load, N	40
Maximum load, N	100
Nominal unwinding cable rate (corresponding to 10^o/sec), mm/sec	36
Operating threshold, N	2
Passive mechanism	
Temperature range, °C	$-75 < T < 75$
Mass including cable and attachment, kg	0.15

DESCRIPTION

General Description

A general description of the centrifugal regulator is given in figures 1, 2, and 3. The overall mechanism is comprised of 4 distinct functional parts in a machined housing:

1. The centrifugal brake device, which checks the payout of the cable

2. The reducing gear, which produces the spin rate necessary for the braking device

3. The payout device, which allows the unwinding of the cable

4. The locking device, which prevents untimely unwinding

The centrifugal regulator is set into operation by a threshold tension of the cable which unlocks the mechanism and allows unwinding. The pulley of the windout device drives the centrifugal brake with the help of the reducing gear.

The centrifugal force pushes aside weights that produce friction of the studs in a cylindrical housing.

Centrifugal Braking Device

The centrifugal braking device (fig. 3) revolves within a cylindrical bore through the housing; the bore's walls serve as a braking track for the device which consists of

1. One flail, rotating idly about the driving axis

2. Two weights hinged to the flail equipped with friction studs

3. One spring for return of the weights

4. One drive bar pinned on to the axis and directly acting on the weight

Pressure of the brake blocks upon the braking track is the result of three combined forces: (1) centrifugal force on the weights, (2) driving torque, and (3) counteraction by the spring.

Reducing Gear

This is of two stages and gives an overall multiplication ratio of $6.5 \times 6.5 = 42.25$.

The Windout Device

This consists of a helical throat pulley in which the cable is held within the throats by a cylindrical shell integrated to the housing. A slot allows windout for the cable.

The windout device is linked to the driving hub of the reduction gear through a torsion spring lodged within the pulley. This spring, which provides flexible linkage, is aimed at limiting cable tension as well as dynamic loads transmitted to the regulating device. A cable-guide bogie allows the windout for various positions of the cable.

The Blocking Device

The blocking device is intended to avoid untimely unwinding of the cable. It blocks the centrifugal brake when the cable's tension is below the operating threshold. This acts through axial pressure of the primary gear's shaft on the spindle of the braking device. Such pressure is applied by a torsion spring, producing differential rotation of both driving hub and shaft.

The axial motion is initiated by a pin engaged through the two helical slots of the hub. As soon as the applied torque exceeds the value of the spring's initial tension, the device releases the centrifugal brake. The reduction gear is then driven from stop position of the spin at the end of the helical slots. As soon as the cable's tension is slackened, the spring's action causes immediate blocking of the centrifugal regulator.

TEST RESULTS

During tests, the plastic bearing was replaced by bronze pads because expansion of the plastic led to excessive clearance with respect to the toothed gears. The nominal unwinding cable rate was obtained by adjustment of the weight return spring.

The mechanism behaved well at qualification temperature and vibrations.

PERFORMANCE

The main performance data are given in the following table:

Unwinding length[1], m	0.75
Operating threshold, N	2
Nominal load, N	40
Maximum load, N	100
Nominal cable payout rate, mm/sec	36
Nominal brake rotation rate, rad/sec	60
Operating temperature, °C	$-75 \leq T \leq 120$
Mass, kg	0.135

[1]To control the deployment speed of the Aerospatiale designed GSE solar array, the length of the cable has been increased to 6 m in the same housing. All other characteristics are identical.

CONCLUDING REMARKS

The reason for interest in centrifugal regulators is obvious since they allow the deployment control of solar arrays, antennas, booms and telescopic booms actuated by springs, compressed gas, etc. . . .

A most attractive aspect is that all the mechanical characteristics are packaged within a very small volume and mass (0.135 kg).

The use of the mechanism allows (1) mass saving, the deployment sequence not being considered as a determinating calculation case, and (2) very good reliability, since the safety factor is not a compromise between the minimum energy needed for deployment and the maximum acceptable end of travel shock.

In addition, a large number of parameters are easily adjustable, including (1) diameter of pulley, (2) weight of tip masses, (3) calibration of weight return spring, and (4) calibration of initial tension for threshold spring.

Many adaptations of the mechanism can be envisaged. These include (1) increase of the energy absorbed by increasing the cable length or the nominal and maximum loads and (2) modification of the cable payout rate.

ACKNOWLEDGEMENT

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- The UK Science Research Center Council which provided flight TV camera system
- The European Space Agency which provided the solar array (Aerospatiale) and the European ground observatory
- The US National Aeronautics and Space Administration which provided the spacecraft, launch vehicle, and the US ground observatory. (The spacecraft was launched in January 1978 from Kennedy Space Center.)

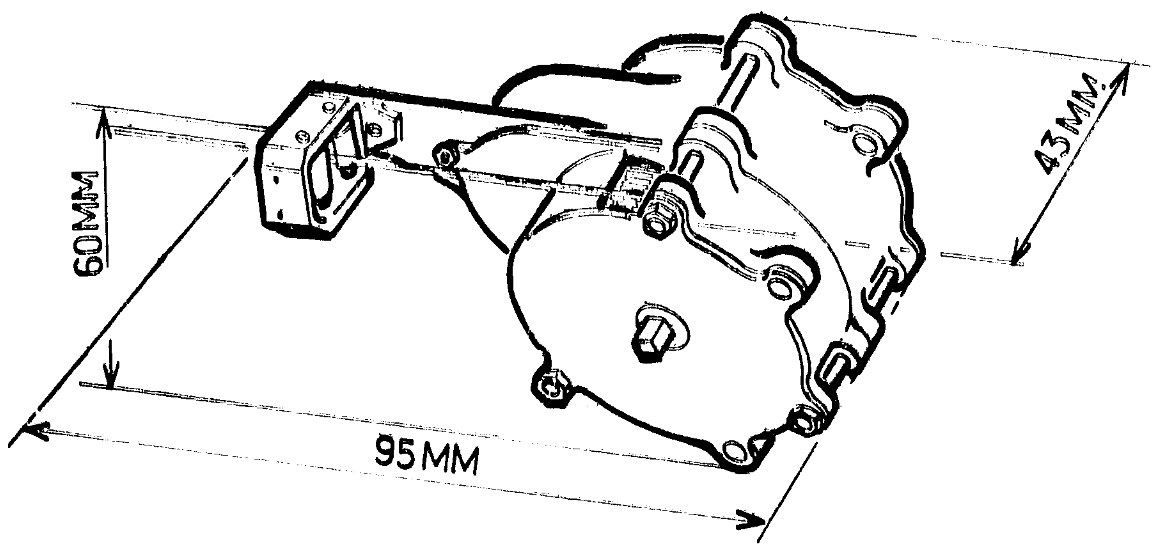

Figure 1.- General view of centrifugal regul..t...

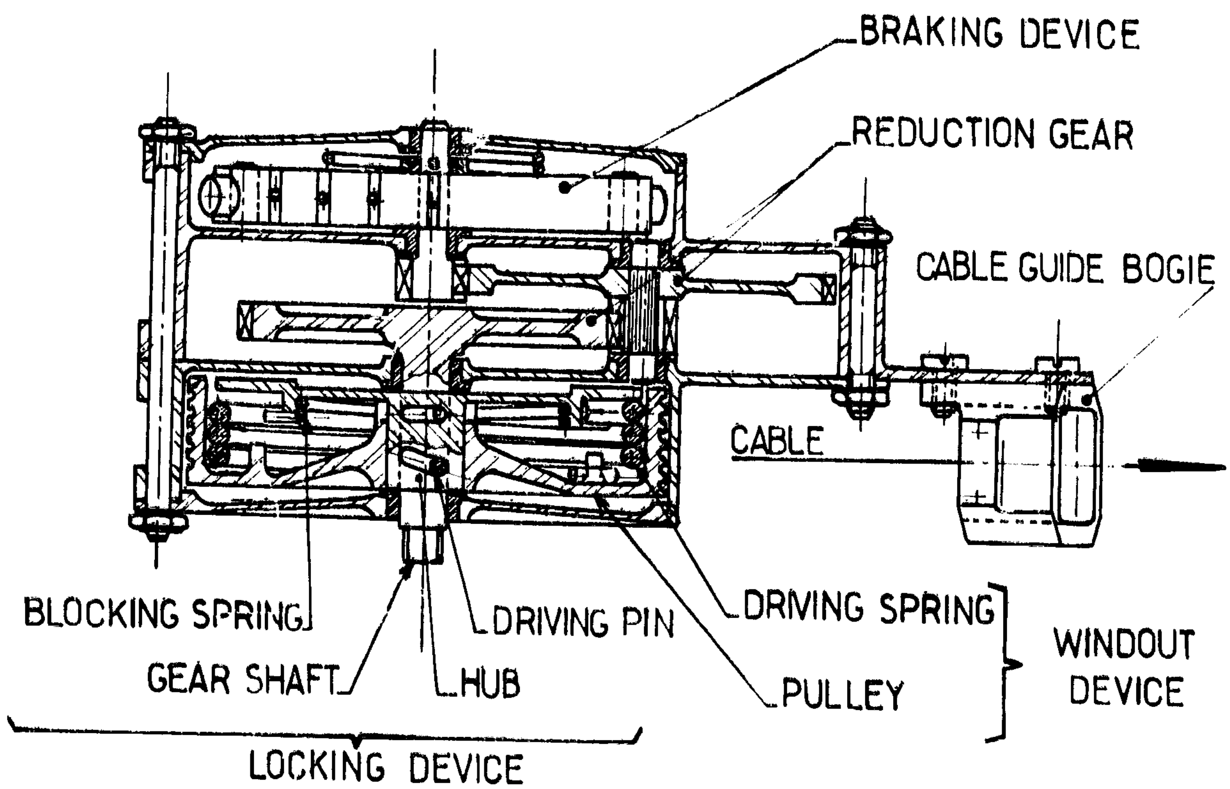

Figure 2.- Cross-sectional view of centrifugal regulator.

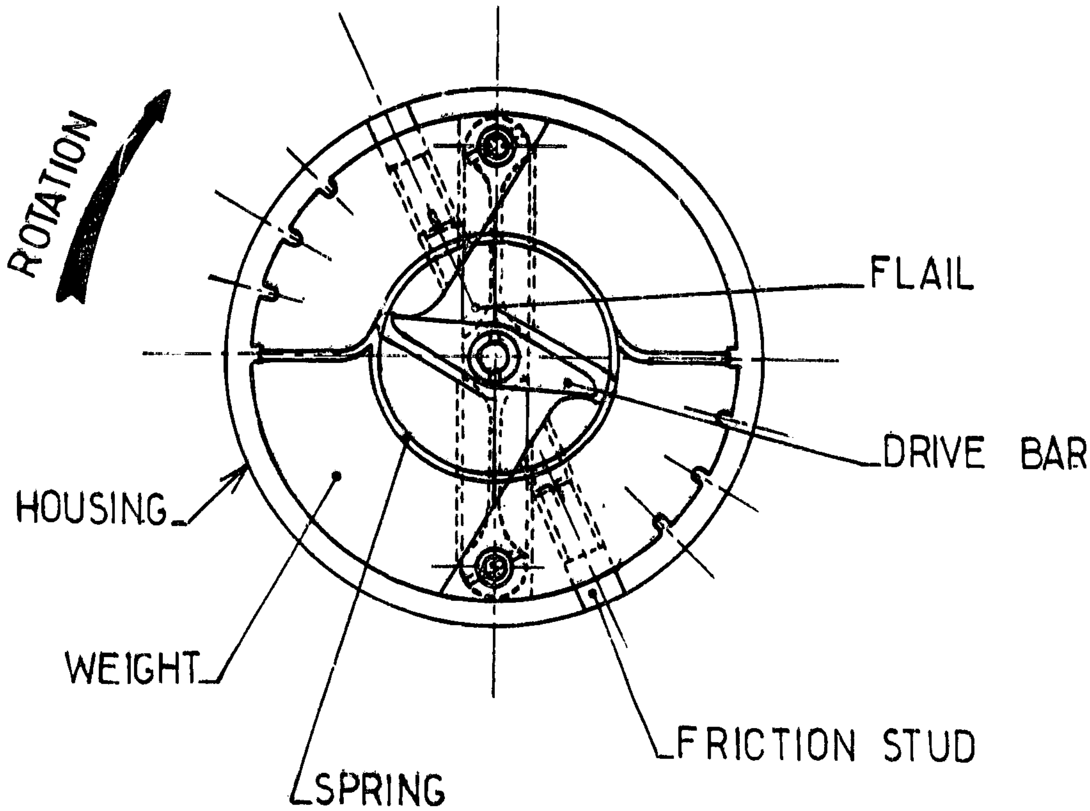

Figure 3.- Centrifugal regulator braking device.