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ENERGY ABSORBER FOR THE CETA

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ABSTRACT

The energy absorber that has been developed for the CETA (Crew Equipment and Translation Aid) on Space Station Freedom is a metal on metal frictional type and has a load regulating feature that prevents excessive stroking loads from occurring while in operation. This paper highlights some of the design and operating aspects and the testing of this energy absorber.

INTRODUCTION

EVA systems offer many challenges for developing mechanisms that will function properly for a 10 year or longer life span. The design challenges arise because of these numerous factors of which the following three are considered key design drivers:

1. Requirement to operate over a temperature range of approximately 110 deg. C,
2. Long non-operating storage under hard vacuum, and
3. Atomic oxygen and micro meteorite effects on exposed surfaces.

One such case in point is the development of energy absorbers that will be used on the CETA carts. These devices will be used for dissipating the kinetic energy if the CETA cart brakes fail without imposing excessive G's on other space station hardware, structure, or EVA crew member.

Common methods of dissipating energy such as forcing fluids through an orifice or crushing some deformable material have some serious disadvantages. The combined effects of space environments render most solutions developed for ground, air, or even marine operations unacceptable. For example, changes in fluid viscosity with temperature, lack of long term stability of most elastomers, creep of Teflon and other classic sealing materials under load render most pneumatic or hydraulic solutions inappropriate. Using crushable or deformable material is also undesirable because of the necessity of refurbishment each time the energy absorber is used. A frictional energy absorber design offers the best solution to the problem. However, using the current design for frictional energy absorbers has known drawbacks such as; lubricated surfaces subjected to wear and exposed to vacuum are currently at the limits of certified materials, and because of uncertainty of the friction coefficient of sliding surfaces, the stroking load is unpredictable.

DEVELOPMENT TEST ARTICLE

EVA Systems has developed a frictional energy absorber that will meet the stringent requirements of long orbital life and yet have a stroking load that is predictable within reasonable bounds. In principle, this energy absorber uses a hardened Inconel 718 shaft sliding through several beryllium copper diaphragm elements as shown in Figure 1. As noted in Figures 2 and 3, there is a significant interference fit between the shaft diameter and the inside diameter of the diaphragm elements so that a high friction drag load occurs in the compression direction. A return spring resets the absorber after each stroke. Most important in the advancement of this art is that this absorber uses a force sensing and regulating (in principle a force feedback mechanism) device. The operating principle is shown in Figure 4. In stroking, the friction diaphragms are reacted by one or more Belleville springs. If the friction load becomes too high, the Belleville springs deflect more, which in turn reduces the normal pressure acting against the friction rod, thus lowering the stroking load. This novel feature will serve to keep the stroking load at a reasonable level even if the friction coefficient increases greatly. The force feedback device also serves to desensitize the singular and combined effects of manufacturing tolerances, sliding surface wear, temperature changes, dynamic effects, and lubricity. Analysis suggests that the stroking force will increase only 30% if the coefficient of friction should happen to increase from 0.10 to 0.30. This 30% variation is an acceptable level of predictability for the energy absorber to assure that the space station is protected from high structural loads. With conventional friction energy absorbers, the stroking force is nearly directly proportional to the friction coefficient. This means that a friction coefficient change from 0.10 to 0.30 would result in the stroking load increasing by a factor of 3.0 if a conventionally designed energy absorber were used. Such an uncertain performance would offer the possibility of very high loads on the space station structure.

TESTING HIGHLIGHTS

A prototype of the EVA Systems' energy absorber has been fabricated and tests have been conducted that prove the concept. Eight (8) diaphragms were used in the test article for each test that was performed. Using the Instron machine, stroking loads have been measured for various conditions and compare favorably to predicted values. The tests also indicate that the force regulating feature of this absorber works according to analytical predictions. As shown in Figure 5, for instance, a test was run with dry unlubricated surfaces. With no force regulation, the stroking load reached a maximum of 180 N. When the force regulating Belleville springs were put back in, the stroking load reached 84 N.

A new set of eight diaphragms was then installed in the test article. Then repetitive cycling tests at ambient conditions were run in an Instron machine to compare the merits of two candidate lubricants. Five hundred load cycles were run using Krytox LVP grease as the lubricant. The stroking force gradually increased from 61 N to 83 N at the end of the 500 cycles. The diaphragm ID wear was measured at 0.01mm. Next, the unit was degreased and refurbished with a new set of eight diaphragms. It was re-lubricated with a thin, wipe-off film of Braycote 815Z oil. Then 500 load cycles were run again. The stroking load started at 63 N and had a slight decline of load to 61 N at the end of the 500 cycles. The diaphragm inner diameter (ID) wear was almost negligible at 0.005 mm. Since the wear limit is .05 mm, both of these lubricants performed quite well. It was also obvious that Braycote 815Z lubricant was the better choice of lubricants under ambient test conditions.

In addition to cycling tests that were run under ambient conditions, cycling tests were also performed in an environmental thermal vacuum chamber. Because of negligible wear from the previous test, the same test article was used in the "as is" condition and Braycote 815Z lubricant was used for these tests. Six runs of 100 load cycles each were performed. Run #1 was performed at room temperature; run #2 at -51 deg C and the rest of the runs were alternated in this manner. All of these tests were performed under vacuum conditions. Fig. 6 shows the results of these tests. Note that at ambient temperatures, the load held steady at about 55 N. At -51 deg C, the load had a small increase up to about 75 N. The wear for these tests was 0.03 mm from the diaphragm ID, which was also below the wear limit.

CONCLUSIONS

The design goal of having an energy absorber that will function predictably over a long orbital life can be achieved with the EVA Systems design. On the basis of the tests that have been performed, the energy absorber has low sensitivity to manufacturing tolerances, lubricity, and other variables. Test results indicate that it will fulfill all of the requirements in the expected environments in a very satisfactory way. By choosing the appropriate design parameters, this energy absorber can find many uses for commercial, marine, military, and aerospace applications.

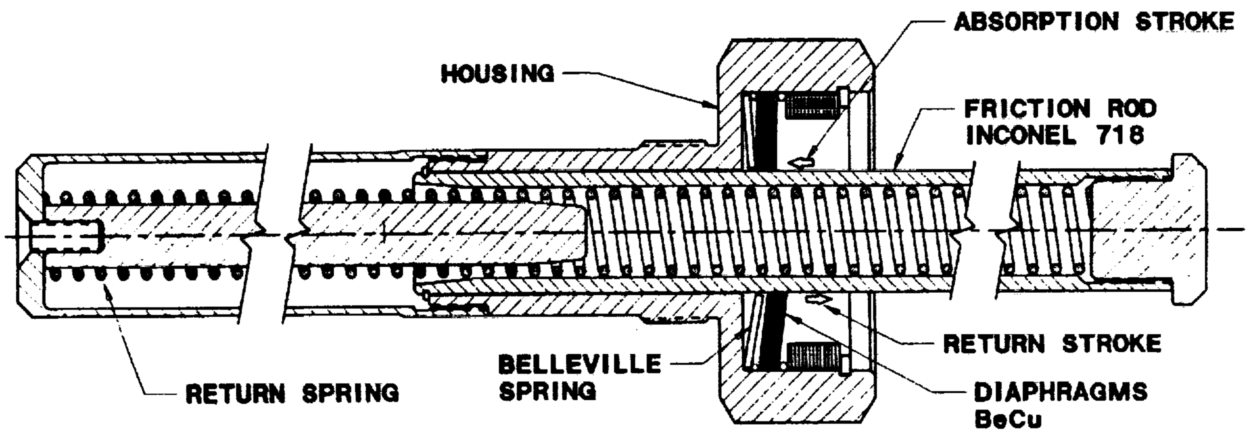

Fig. 1. Energy Absorber Cross Section.

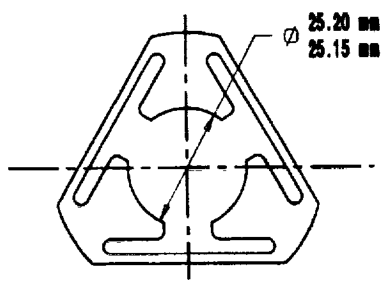

Fig. 2. Friction Diaphragm.

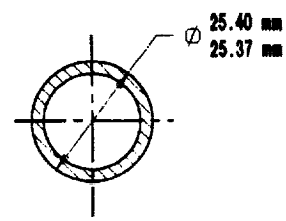

Fig. 3. Friction Rod Cross Section.

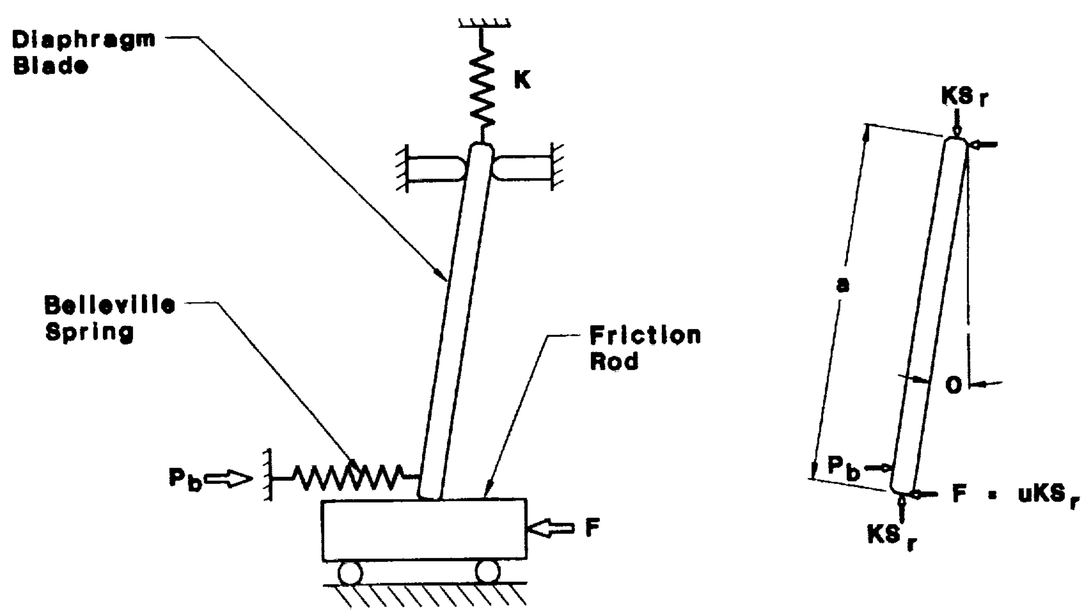

Fig. 4. Schematic of Operating Principle.

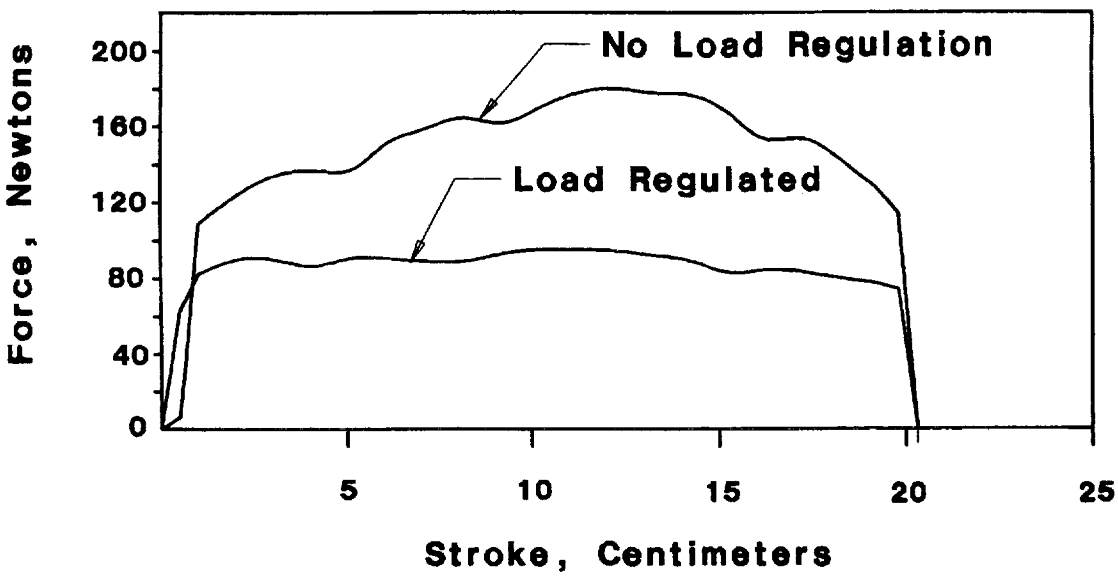

Fig. 5. Load vs Stroke for Unlubricated Conditions.

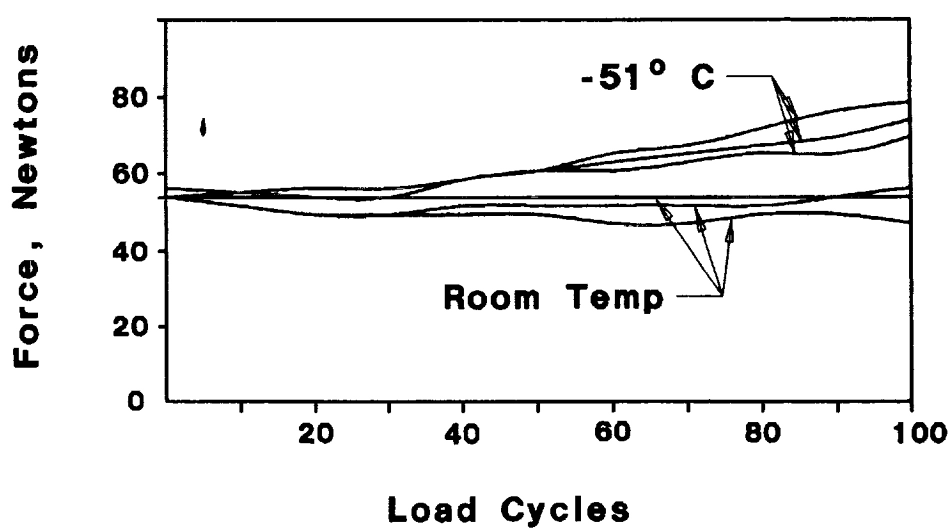

Fig. 6. Environmental Tests in Vacuum Chamber.