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THE ACTUATED LATCH PIN AND ITS DEVELOPMENT

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ABSTRACT

An actuated latch pin has been developed to meet the need for a reusable locking device. The unit can function as a pin puller or as a pin pusher latch. Initial prototype testing demonstrated the feasibility of the device with the unit being driven from a 28 V d.c. supply and using 15 W to drive a 12 mm diameter pin through a stroke of 10 mm with a side load of 100 N in 120 ms.

High wear rates with the MOS_2 lubrication on the ballscrew and angular contact bearings have necessitated the reduction in the duty cycle from 1000 cycles in air and vacuum to 100 in air and 1000 in vacuum.

REASON FOR DEVELOPMENT

The Actuated Latch Pin (ALP) has been developed to meet the need for a reusable locking device suitable for use in a hard vacuum of the order of 10^{-7} torr. Currently, locking and unlocking devices which need to be remotely controlled utilize pyrotechnics to achieve movements; however, these components have several drawbacks including one or two shot operations and the inability to be repositioned once activated.

Specifically the development of the ALP was initiated by the European Space Research and Technology Centre (ESTEC) as there was a need for a device to restrain the piston of the pneumatic ejection system of the Spin Up and Ejection Mechanism (S.U.E.M.), which was to be used to launch spacelab sub-satellites. This device was to retract to permit firing of the piston and to extend to lock the piston after it had been retracted.

SPECIFICATION

The ALP requirements were based on the ESTEC specification and the major requirements are tabulated in Table 1.

A close look at the specification revealed several potential problem areas. The basic requirement of mass, envelope, power strength and side load indicated that high efficiency components would be required and it was doubtful if indeed this could be achieved. However, the major potential problem related to the duty cycle of running in air and a vacuum and only being allowed to use dry lubricants. Therefore, there was a requirement for a dry lubricant which could perform in air and a vacuum. Since the wear rates on lead lubricated components are very high in air, it was decided that another form of dry lubrication would be necessary. After discussions with several manufacturers and the National Centre of Tribology at Risley, England, it was decided that the MoS_2 sputtered process should be used as the lubricant. (See ref. 1.)

TABLE 1.- ALP FUNCTIONAL REQUIREMENTS

Mass	500 gms
Envelope	34 mm x 34 mm x 80 mm
Stroke	10 mm repeatable to 0.1 mm
Retraction Force	25 N over whole of travel above any friction
Side force sensitivity	Meet requirements with side load of 100 N
Duty Cycle - Ground Orbit	10,000 cycles in air 1,000 cycles in vacuum harder than 10^{-7} torr
Alignment	Maintained with its nominal axis within $\pm$ 0.05 degrees under all conditions
Stiffness	Greater than 10^5 $\frac{Nm}{Rad}$
Ultimate Strength	1.8×10^4 N Radial force on pin top
Proof Strength	1×10^4 N Radial force on pin top
Power	Operating power not to exceed 15 W Average power not to exceed 1 W
Voltage	28 V $\pm$ 4 V dc
Time to Retract or Extend.	120 ms

CONCEPTUAL DESIGN

There were several possible ways of achieving the design requirement but two approaches were singled out for more detailed study, these were solenoid and motor ballscrew configurations. Initially, the solenoid characteristics looked eminently suitable for the design but on closer inspection it was found that several major problems would have to be overcome if a satisfactory design was to be achieved. These problems were associated with the size, weight and power consumption of a solenoid device which would meet the force criteria of the specification. There were additional problems of cost and timescale quoted by several manufacturers and these were outside the scope of the ALP contract.

The motor ballscrew configuration looked more attractive in terms of meeting the power requirements but the problems of switching the motor off and actually stopping the device at the end of its stroke had to be overcome. The approach of solving these problems was to use reed switches, potted in a suitable compound, to act as the switching and indicating device and to use buffers to absorb the surplus energy at the end of the stroke to prevent bounce.

FIRST PROTOTYPE DEVELOPMENT

Description

The first prototype consisted of a smarium cobalt permanent d.c. motor driving a precision ballscrew to move the latch pin in or out (fig. 1). The direction of the latch pin is a function of the applied voltage polarity. The latch pin slides on a dry plain bearing with pin rotation being prevented by a guide located in the nose cap.

Detent action was by permanent magnets which moved with the pin and were located at each end. Located at either end of the stroke path are reed switches which serve the dual function of indicating latch pin status and acting as a limit switch for the motor.

The complete mechanism is located in a stainless steel housing. The end cap is adapted to enable a simple tool to be used for manual override. The nose cap is threaded to enable the ALP to be screwed into a suitable housing. However, alternative nose cap designs could be evolved for various mounting configurations. Electrical power is supplied vi. an external socket.

Operation

When extend or retract is selected the motor rotates approximately six times and peak velocity of the motor is about 3600 r.p.m.

Testing

Test results achieved with the first prototype are tabulated in Table 2.

TABLE 2.- FIRST PROTOTYPE TESTING

Test	Result	Specification Target
Ground Duty 10,000 cycles	ALP Functional for 10,000 cycles	ALP functioning ALP meeting performance requirements after cycling
Sample Functioning Test	ALP Functioned	ALP Functioning
Stroke - Movement (No sideload)	6.78 mm	10 mm
Stroke - Repeatibility	0.5 mm	0.1 mm
Retaining Force	44.7 N	2.5 N
Peak Power	Limited to 14 W.	15 W.
Passive Sensitivity-location	0.645 mm	1.0 mm
Passive Sensitivity-Movement	0.01 mm	No movement
Retraction Force	37.7 N	25 N
Operating Time - Retraction	119 msec	120 msec
Operating Time - Extension	113 msec	120 msec
Alignment - Angle, degrees	< 0.02	<+0.05
Linear	< 0.005 mm	< 0.005 mm

PROBLEMS WITH FIRST PROTOTYPE

Detent

During initial functioning testing it became apparent that permanent magnet detents were not suitable as it was found impossible to align all the magnets simultaneously. Also, the pin which was to prevent rotation caused a considerable increase in friction when a side load was imposed. Thus, a further development was carried out and a cantilever spring detent, which located on a Delrin housing, was chosen. This Delrin housing also incorporated the anti-rotation device. This set-up proved highly successful with a retaining force of 30 N being achieved. This approach is currently incorporated in the design.

Energy Absorbing Device

There was a requirement for the ALP to move through a distance of 10 mm and be repeatable to within 0.1 mm with a side load of 100 N. The maximum energy input to the ALP was related to that energy required to achieve performance with sideload. The problem then arose as to how to dissipate this energy when the side load was removed. It was decided to remove the surplus energy with an energy absorbent material. At this time, several materials have been tried and the best results have been achieved with a fibrous nylon.

ENGINEERING MODEL

The engineering model was constructed using components of a type suitable for use in a vacuum. Modifications found necessary during testing of the first prototype were also incorporated.

Basic Test Requirement

The engineering model test programme was to consist of testing in air and clocking up 1000 cycles and then testing in a vacuum of 10^{-7} torr and interface temperature of -30^{o} C to 60^{o} C.

Test Programme in Air

Testing was conducted in a clean room of class 100,000 with a mean temperature of 20^{o} C and relative humidity of 45%.

PROBLEMS WITH ENGINEERING MODEL

Energy Absorbing Device

As the results in Table 3 indicate the improved energy absorbing device did not meet the full requirements. However, further investigations are going on to try and find a suitable space qualifiable material which will meet this requirement.

Brush Gear Failure

After the initial testing, the ALP was set up for cyclic testing. The cycle time was set to 10 seconds. The cycle operation was set in motion and proceeded without fault until 710 cycles had been clocked up; then the ALP ceased to function. Tests on the drive electrics and switch gear indicated that they were functioning satisfactorily. Thus, it was decided to strip down the ALP for investigation. On strip down it was revealed that one of the motor brushes had broken off. The brush gear and broken off brush were removed and sent to ESTEC for a failure investigation. The resulting failure investigation report has been sent to the motor manufacturer for comment, but at this time none has been received.

Failure of MOS_2 Lubrication on the Ballscrew

The ALP was reassembled with another set of brush gears and cyclic testing continued after initial functional testing. After 100 extra cycles the retraction and extension times started to increase. Further running showed that the rate of slow down was accelerating. Initially it was thought that the brush gear was again causing trouble so the ALP was stripped down and the space qualifiable motor was replaced with the standard prototype motor. This combination was then run but the results showed no improvement. The ballscrew was then removed and tests showed that the friction in the ballscrew had increased. This increase in friction was not determined quantitively but a comparison test was carried out to compare the ballscrew ability to back-drive itself. A study of the ballscrew under a microscope at x 40 magnification showed indications of wear on the lubricative surface. Thus, it was decided to return the ballscrew to the manufacturer for investigation.

Test Results

Test results achieved with the engineering model in air are tabulated in Table 3.

TABLE 3.- ENGINEERING MODEL TEST RESULTS

TEST	RESULT	SPECIFICATION TARGET
Simple functioning test	ALP functioned	ALP functioning
Stroke[I] - Movement	9.31 mm	10 mm
- Repeatibility	0.4 mm	0.1 mm
Retaining Force	39.3 N	2.5 N
Peak Power - 1st 10 ms	53 W*	15 W
after 10 ms	12 W	15 W
Approx. Average Power for stroke	9 W	15 W
Passive Sensitivity - Location	Zero	1.0 mm
Passive Sensitivity - Movement	Zero	No movement
Retraction Force	32.4 N	25 N
Operating Time - Retraction	112 ms	120 ms
" " - Extension	100 ms	120 ms
Alignment - Angle	$< 0.02^{0}$	$< 0.05^{0}$
- Linear	< 0.005 mm	< 0.05 mm

I No sideload

* Instantaneous Power

MANUFACTURERS REPORT

The manufacturers indicated that MOS_2 sputtered coat had worn away along the rolling area of the ball to the thread, i.e. there was metal to metal contact. It was also suggested that a possible cause of the increased friction within the ballscrew was the breakaway debris of MOS_2. They also pointed out that the MOS_2 coat thickness of 0.2 micrometre was compatible with the ballscrew surface finish which had a C.L.A. of 0.05 to 0.1 micrometre and the balls which had a C.L.A. of 0.02 micrometre.

IMPLICATIONS OF FAILURES

The failures incurred during the design of the ALP were catastrophic in nature; thus, satisfactory answers must be found to account for them. The brush gear failure is being thoroughly investigated and it is hoped that the cause of the failure will be ascertained. However, the failure of the MOS_2 sputtered coating leads one to wonder if this approach is suitable for the type of duty cycle required by the ALP, i.e., of relatively high speed and operation in air and in vacuum. Some researchers (ref. 2) have obtained good results under laboratory conditions, but there was some doubt as to the performance at high speeds and operation in air. Thus, it would be pertinent for these areas to be investigated further as certainly there is a requirement for a lubrication technique which will meet the requirements as specified for the ALP.

NEXT STEP IN ALP DEVELOPMENT

After discussions with ESA and the National Tribology Centre, Risley, it was decided that the number of cycles specified for the ALP was too great considering the duty cycle and the environment. Thus, ESA decided to relax the number of cycles from 1000 to 100 cycles in air while retaining 1000 cycles in a vacuum.

They also decided that the balls of the ballscrew should also be coated with MOS_2.

RECOMMENDATIONS FOR FURTHER ALP DEVELOPMENT

Future trends in Space Technology indicate that reusable components must now be designed. The ALP is a fundamental mechanism which meets this criteria and should find use in a considerable number of varied functions. The current work was aimed at developing a locking device of a particular size. However, the ALP design could be thought of in terms of a family of devices covering a range of sizes. A further interesting development would be the incorporation of a stepper motor. This would add an inching capability to the device which would considerably increase its usefulness as it could be used to control other components such as valves, etc. Thus it can be seen that further development of the mechanism is essential as it fulfills a fundamental requirement and can be considered a basic reusable building block in the field of space mechanisms.

The shortcoming of the MOS_2 lubrication process indicates that further work be carried out as there is certainly a requirement for improvement in this area.

REFERENCES

(1) Talivaldis Spalvins, Bearing Endurance Tests in Vacuum for Sputtered Molybdenum Disulfide Films. NASA TMX-3193, 1975.

(2) Lammer, J., Niederhauser, P., Hinterman H. E., MOS_2 Thin Layers Deposited by R.F. Sputtering. International Conference on Plating and Allied Techniques, London, July 1979, Proceeding 1 Pat 79, pp. 204-210.

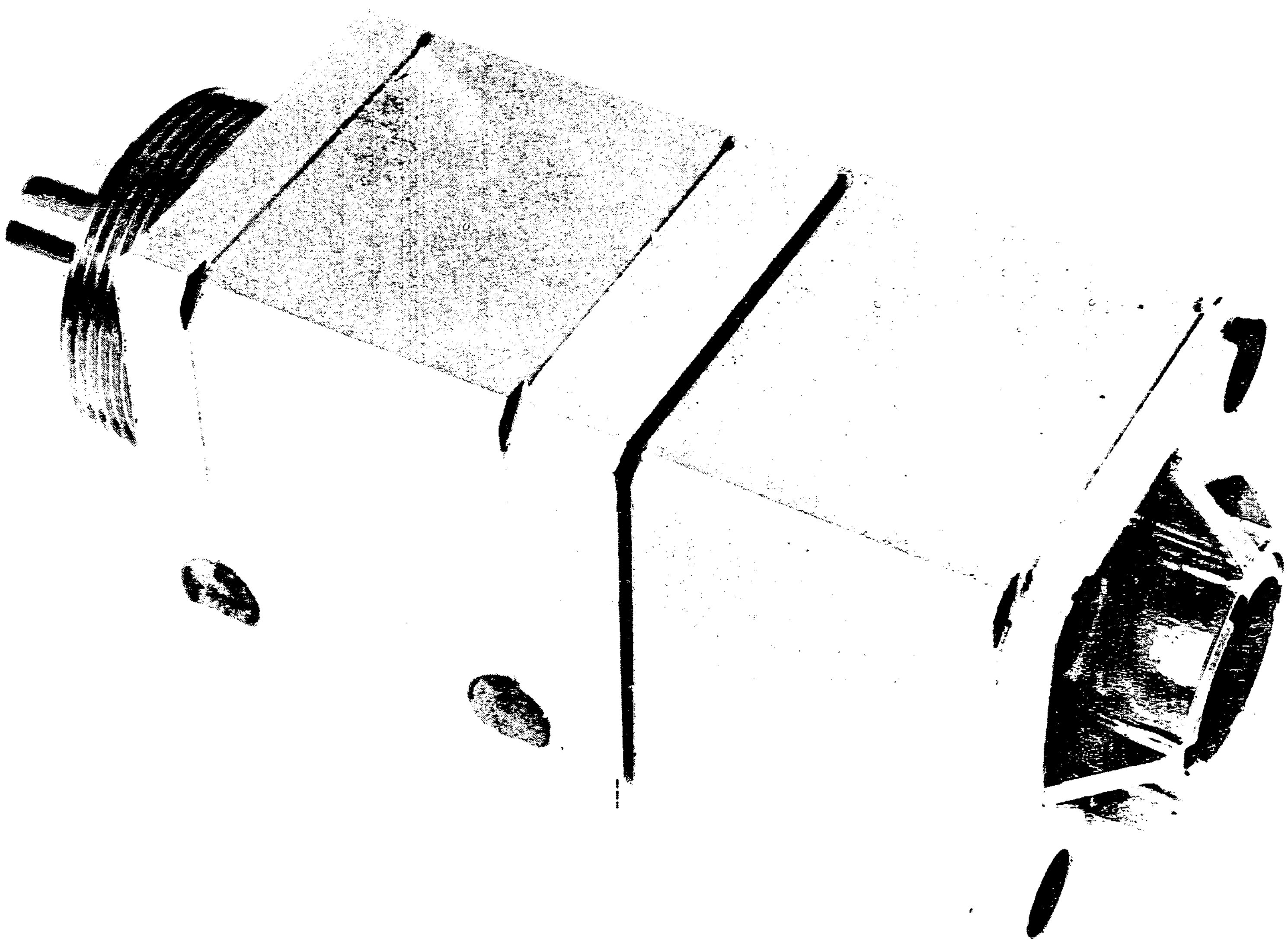

Figure 1.- First prototype.