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DEVELOPMENT AND TESTING OF A PINPULLER FOR HOLD DOWN AND RELEASE MECHANISM

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Abstract

During the presented project a compact, low weight, low shock and cost-efficient pinpuller for space applications based on thermo-mechanical release mechanism has been developed, manufactured and tested by RUAG Space Germany (RSG). As an alternative to current devices, the new developed RSG pinpuller, called LIP500, is able to work in a wider range of temperatures, such as from -70ºC to +100ºC and under vacuum conditions. On top, this release device allows multiple resets with a minimum effort.
Up to now the built qualification models of the pinpuller did undergo different tests and analysis in order to elaborate the maximum force and life time by the mechanism components of the device. Test conduction and results of the qualification campaign will be presented with focus on deviations from the expected behaviour and on lessons learned. Especially investigations on the shock generation of the pinpuller as well as the reliability will be presented.

Keywords

Pinpuller, Hold Down and Release Mechanism, Environmental Tests, Shock Tests

1. INTRODUCTION

The pinpuller is a linear actuator that contains a pin deployed at the non-actuated position and withdrawn at the actuated position. These pinpuller has to support high preloads during launch and has to be able to release these loads when required. A hold down and release mechanism (HDRM) is a mechanism to hold, lock or secure large deployable structures like antennas, solar arrays or moveable parts like instrument or cover mechanism during launch phase of a spacecraft.

The prime component of such a HDRM is a reliable release actuator. Typical non explosive actuators are actuators to break a locking bolt, separation nuts and pinpullers. The process of breaking a part or release of bolt induces a risk of particle contamination, even though that this technology is reliable. For debris and fragment-free operation pinpullers are used typically. For securing optical instruments this issue is critical. Another drawback of numerous release devices is that they cannot be reset without replacing a part or even to replace the whole device. In addition shocks emitted by the release device are critical with a look to the functional integrity of the fixed components and mechanisms. Furthermore frequently used devices are disposed by US American enterprise with strong International Traffic in Arms Regulations (ITAR) and long lead times.

In this paper we present a new pinpuller based on thermo-mechanical release mechanism for holding down and release deployment systems. In order to be independent of non European release devices RUAG Space Germany (RSG), developed an easy resettable, fully European pinpuller following the ECSS design rules and margins [1, 2]. The result is a low shock, low mass and cost-efficient release device based on a proven principle which is able to provide equal or higher performances than equivalent non European pinpullers available on the market. Engineering models of the pinpuller have been built as well as tested and Qualification Models of the pinpuller have been built and tested. The main characteristics of the new developed pinpuller as well as the results of the qualification test campaign are presented hereafter.

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2. REQUIREMENTS

As a design baseline of the pinpuller, a dedicated target application was selected, and the technical requirements were derived. A selection of the baseline requirements which have driven the development and verification effort is given in TAB 1.

Requirement	Quantity
Lateral Load (Actuation)	≥ 500 N
Pull stroke	≥ 8 mm
Activation time	≤ 90 sec
Separation time	25 ± 5 msec
Mass	≤ 150 g
Life	50 Cycles MIN
Operational temperature range	-70°C / +80°C
Non-operational temperature range	-100°C / +110°C

TAB 1. Baseline requirements for the pinpuller

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A major design requirement was to avoid electro explosive devices for actuation due to creation of high mechanical shock. As non explosive pinpullers can be actuated electromagnetic, mechanical or by shape memory alloy (SMA), the decision at RSG was made for mechanical actuation. Another major design requirement was addressed to the refurbishment after the actuation. In general pinpullers can be reset without replacing parts but it is often necessary to dismount the whole device to enable refurbishment. The approach at RSG was to design a pinpuller which is resettable after use, e.g. on-ground testing, without the need of dismounting.

3. PINPULLER DESIGN

The pinpuller design is divided in several subsystems consisting of structure, pin, moving elements and the thermo-mechanical actuator. The RSG pinpuller is characterized by its compact design, low shock and a low mass. The design is described in FIGURE 1 and is based on spheres which support the release pin at the initial position and a compression spring to perform the driving force once the release takes place. When the thermo-mechanical actuator moves, a sphere holder shifts allowing the spheres displacement, and thus the pin is moved to the actuated position. The reset is done by means of a M6 threaded pressure screw allocated inside the lower cover without replacing a part or even to remove the whole device. Manufacturing tolerances of main parts can be compensated by variable shims.

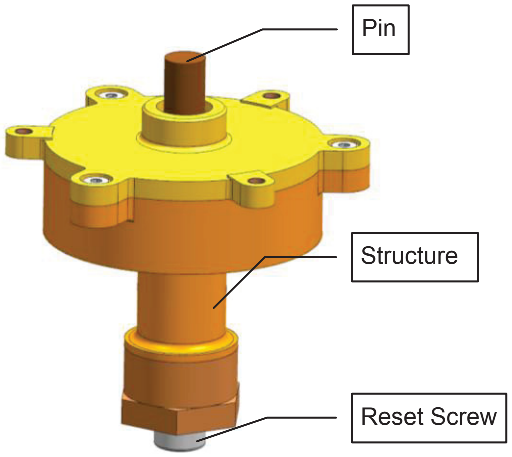

FIGURE 1. Breadboard design of pinpuller

The mechanical interface is established by means of three M3 bolts with a section diameter of 62 mm divided by 120° and a cylindrical fit in the middle of the top cover. The electrical and data interface is established by means of a pig tail harness where a bundle of two wires is used for the heater power supply, a bundle of four wires for the thermal sensor system and a bundle of three wires for position detection system.

As the pinpuller function is based on a thermo-mechanical effect, a power supply is necessary to achieve the triggering temperature. In order to avoid defects as a result of overheat, a thermal sensor and position detection system are installed. These systems will be used to monitor the heating system temperature and to cut the power supply after pin release or in case of achieving the safety temperature.

4. PINPULLER TESTING

A test campaign for the pinpuller has been developed in order to check suitability of the developed device for space applications. The qualification test campaign started with performance testing focused on verifying the functionality and reliability. The further tests have been sine and random vibrations, external shock, thermal vacuum cycling including actuation at temperature extremes and release shock. Some of the major results will be presented in the following.

4.1. Functional Test

FIGURE 2 shows the qualification model (QM) of the pinpuller after assembly and integration. All steps were noted in the as-run assembly and integration procedure. The resulting hardware was photographic documented and all functional and test steps are recorded at the pinpuller log card.

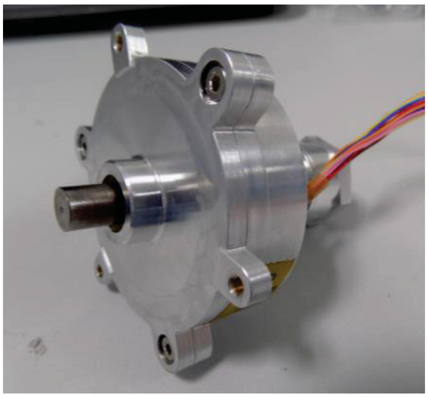

FIGURE 2. Pinpuller QM after assembly

The performance and functional tests started after successfully performing the physical properties tests with mass, mechanical interface and electrical parameter measurement. During the first set of actuations no lateral load was applied to the pin to prevent damage of mechanism or heater. After successful verification of the pinpuller function, a stepwise increase of lateral load was applied to the pinpuller. By means of a lever ground support equipment (GSE) a maximum lateral load of 500 N was identified to allow correct functioning of the mounted pinpuller.

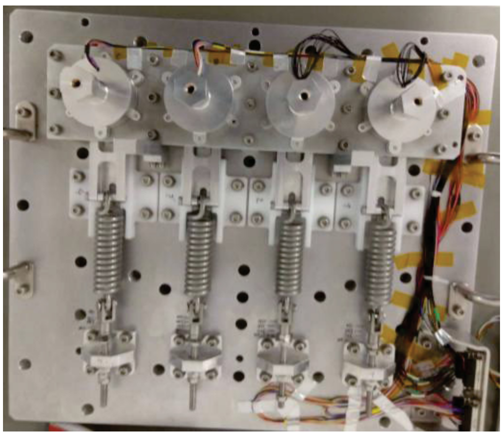

FIGURE 3. Pinpuller test setup for qualification test

The following table summarizes the main results of the physical properties, performance and functional tests achieved during qualification test campaign. The test results reveal a good compliance with the requirements.

Requirement	Test Result
Mass (incl. harness and connector)	150 g
Box shape	Ø 70.5 x 63 mm³
Heat up sequence	60 ± 15 s @ 25W
Pull stroke	9 mm
Separation time	20 msec

TAB 2. Pinpuller QM test results

4.2. Vibration Test

FIGURE 4 shows the setup used for the vibration and shock test. These tests of the pinpuller were performed at dedicated shaker with slip table. The vibration test was done axis by axis in the sequence sine sweep, sine vibration, sine sweep, random vibration, sine sweep with the loads shown in FIGURE 5. During sweep the natural frequencies were determined and compared to test prediction values. The functional integrity of the pinpuller was tested by means of short electrical test between, before and after every vibration direction in order to detect failures.

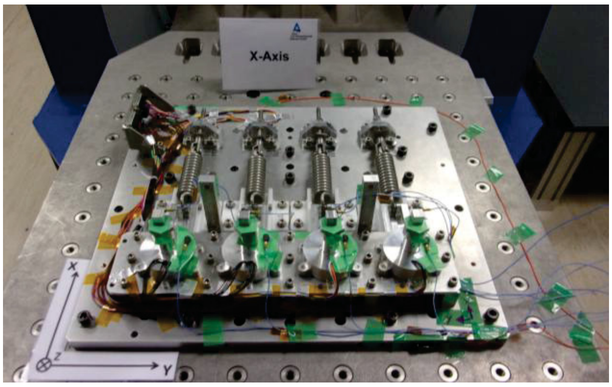

FIGURE 4. Test setup for vibrations test

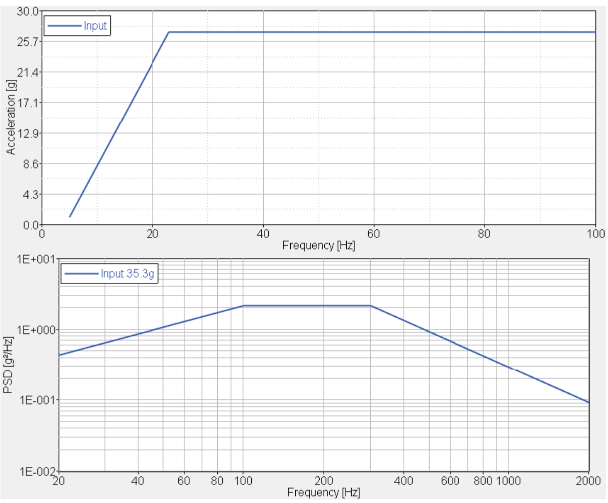

FIGURE 5. Vibration test loads

The vibration test was concluded successfully. No difference between pre and post vibration test states of the pinpuller was observed. A successful actuation of the four tested pinpullers was performed after passing the vibration test.

4.3. Thermal Vacuum Cycle Test

In pre-loaded conditions, the four pinpullers were subjected to thermal vacuum cycling (TVC) over eight cycles from +90°C to -80°C operating temperature, including margin. At the beginning of the TVC one cycle with the non-operating temperature limits from -110°C to +120°C, including margin, was performed. FIGURE 6 shows the temperature-time profile during TVC. The average pressure reached during the tests has been $1 \cdot 10^{-6}$ mbar.

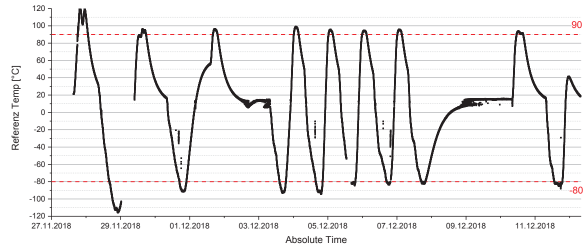

FIGURE 6. Temperature profile during TVC

The pinpuller has presented excellent results of actuation during the test campaign. Successful actuations have been obtained before and after the TVC. Similar, successful actuations have been obtained at -80ºC and +90ºC. In addition there were no visible changes before and after the TVC test. These results validate the feasibility of the tested pinpuller as suitable alternative to the traditional deployment devices.

4.4. Release Shock Test

One major requirement for the pinpuller design was to minimize the shock imparted from the separation device, achieve a low shock device according ESA classification [3]. The measurement was performed at RSG premises with a test setup used a 609 mm x 609 mm x 19 mm thick (2 ft. x 2 ft. x 0.75 in.) aluminum plate. The plate was suspended using a bungee cord on each corner. After pretests with different accelerometers, in the final configuration one tri-axial accelerometer was mounted approximately 12.7 mm (1 in.) away from the center of the plate as shown in FIGURE 7.

FIGURE 7. Example Test setup for shock measurement

The pinpuller was electrically actuated for each shock test, starting with zero lateral load and thereafter a stepwise increase of lateral load up to 500N. The measured acceleration vs. time for zero load, 200 N and 500 N lateral load were transferred to the shock response spectrum (SRS) and revealed maximum acceleration of 600 g up to 800 g. The SRS results shows that the lateral load is the dominant source of shock for a pre-loaded pinpuller and that the preload spring, internal to the device, is the dominant source of shock without lateral load on the pinpuller.

5. VERIFICATION RESULTS

TAB 3 summarizes some of the achieved results from the pinpuller qualification.

Parameter	Test Result
Lateral Load	500 N
Pull stroke	9 mm
Activation time	60 ± 15 sec
Separation time	20 msec
Mass	150 g
Life	50 Cycles MIN
Operational temperature range	-70°C / +80°C
Non-operational temperature range	-100°C / +110°C

TAB 3. Pinpuller performance summary

6. LESSONS LEARNED

The use of correct shims is a major concern to be regarded during integration. Due to manufacturing, the used shims have a sharp overlapping edge which leads to variations in thickness if multiple shims were used. Attention should be paid to use shims without sharp overlapping edges and to use only one shim with the corresponding thickness.

The testing campaign delivered valuable inputs into the temperature measurement of the device. A problematic area was the failure of PT1000 sensors after a few actuations of the pinpuller. However, the use of PT100 temperature sensors showed reasonable improvements. A reliable operation of the PT100 temperature sensors could be observed for more than 100 actuations of each individual pinpuller.

In terms of the measurement of the induced shock a more detailed investigation has been performed. A detailed analysis of correct shock measurement as well as damping characteristics and a large number of pre-test including verification of shock sensor positioning were performed. The pre-tests revealed better understanding as well as preferred solutions for the use of adhesive for shock sensor fixation, to ensure proper fixation of harness and to place shock sensors at least 20 mm away from holes or other disturbances of the test setup structure. These results will be used to improve the shock measurement setup and the subsequent analysis.

7. SUMMARY AND OUTLOOK

RUAG Space Germany successfully tested a new pinpuller for space application. Four complete pinpuller devices were built and the results of the qualification test campaign have demonstrated the capabilities to be used as space mechanisms. The easy operation and resetting could also be demonstrated. Once the pinpuller is mounted, the lateral load can be attached with a maximum of 500 N. The pinpuller can be wired to a typical heating circuit to allow actuation. As defined by the requirements, resetting of the pinpuller is accomplished within a minute. The only tools needed for resetting are a M6 threaded pressure screw and a driver. The customer will be able to reset on the pinpuller with minimal downtime during the test campaign.

Currently two pinpullers are in stowed configuration for 6 months in order to access storage effects of the thermo-mechanical release mechanism. This test will be followed by functional tests in order to access aging processes. In addition RSG is part of the core team for the European Commission (EC) funded project “Development of Large Deployable Structures for Antennas”: LEA, Large European Antenna [4, 5]. RSG is developing, building and testing the deployable hinges of the LEA deployable arm assembly and is responsible for all hold-down and release mechanisms of the LEA-subsystem. Two of the RSG pinpullers will be used to hold down and release the LEA reflector.

8. ACKNOWLEDGEMENT

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9. REFERENCES

[1] K. Zajac, T. Endler, et al., Entwicklung, Test und Lessons Learned des Multiaxialen Entfaltungs- und Positionier-mechanismus MEP, 5. Nationale Konferenz Satellitenkommunikation in Deutschland, 2017

[2] K. Zajac, C. Raum, et al., Design, Tests and Lessons Learned of a Low Shock, Low Mass and Low Cost Pinpuller, Deutscher Luft- und Raumfahrtkongress 2017, DocumentID: 450103

[3] EUROPEAN SPACE COMPONENTS COORDINATION: Hold-Down And Separation, Systems. ESA, 2014

[4] The first Large European Antenna with a diameter larger than 5 meters, URL: https://cordis.europa.eu/project/rcn/212435/factsheet/de, 20.09.2019

[5] LEA – Large European Antenna, URL: http://www.welea.eu/, 20.09.2019