UNLIMITED RESETTABLE NO-SHOCK HOLD-DOWN AND RELEASE MECHANISM

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ABSTRACT

This paper presents the design, analysis and test of an Unlimited Resettable No Shock (URNS) Hold Down and Release Mechanism (HDRM) based on a magnetic clamp suitable for space applications. The device holds the appendage via permanent magnetic force, and releases via a counter-oriented electromagnetic force pulse. The HDRM developed is dedicated to small deployable appendages and payloads of future spacecraft. An engineering model was manufactured and tested.

1. INTRODUCTION

The Unlimited Resettable No Shock (URNS) Hold Down and Release Mechanism (HDRM) was developed under an ESA contract. It is based on a magnetic clamp which is driven by a permanent magnet and therefore has no power consumption during hold down. The release is performed by an electric current pulse through one of the two implemented redundant coils.

The permanent magnet is located in one part and the coils in the other part as can be seen from Fig.1. According to the need for electric connections the part with the coils will be the fixed part. As the other part with the permanent magnet needs no power supply this will therefore be the moveable part.

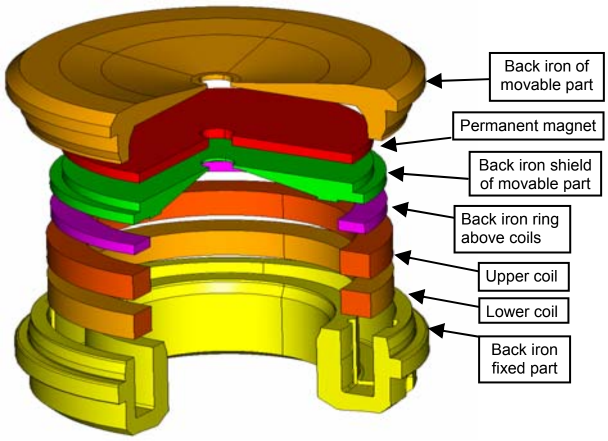

Figure 1 – Parts of URNS HDRM

2. DESIGN DESCRIPTION

Main characteristics of the URNS are:

- ITAR free
- Resettable > 100 cycles
- Low shock: < 100 g SRS
- Mass: < 0.4 kg
- No power consumption stowed
- Preload: > 1500 N
- Temperature range: -80 / +120 °C (operational)
- Magnetic Dipole Moment: 3Am² (open device)
- Two electrical redundant coils (110wdgs)
- Voltage drive, nom. voltage: 26 VDC ± 10 %
- Actuation time: 10 to 250 ms
- No-Actuation current: 1.0 A (5 min)
- Acceleration: 90g (static); 30.7g (rms)
- Lifetime : 10 years

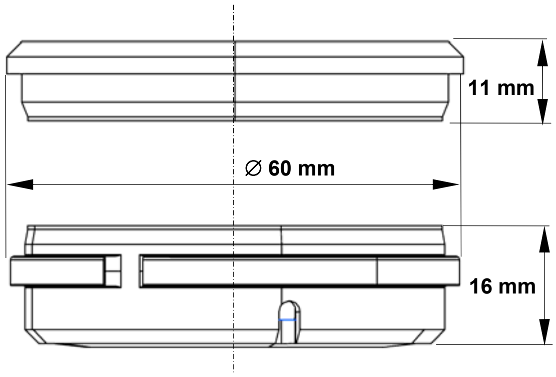

Figure 2 –Dimensions of URNS HDRM

Figure 3 – Engineering Model of URNS HDRM

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The material used for the permanent magnet is Samarium-Cobalt (SmCo) with the material properties according to [1]. The material used for the back iron is Cobalt-Iron (CoFe) with material properties according to [2]. To avoid cold welding between the parts one side has been protected by a special coating given by [3].

The electrical insulation of the coils is primarily done by using enamel-insulated wires. A second insulation has been added by kapton foil between coil and back iron to realize double insulation. The coils are secured by filling with RTV-S 691 providing thermal contact and additional insulation.

3. FINITE ELEMENTE ANALYSIS

To achieve the required features static and transient magnetic analyses have been performed with the software tool ANSYS®. The design has been optimized by analyses trade offs.

The magnetic field and the field lines of the final design are shown in Fig.4 for the hold down state without current and in Fig.5 for the release state with nominal release current. In these two pictures the different magnetic circuits with and without current in the coils are shown.

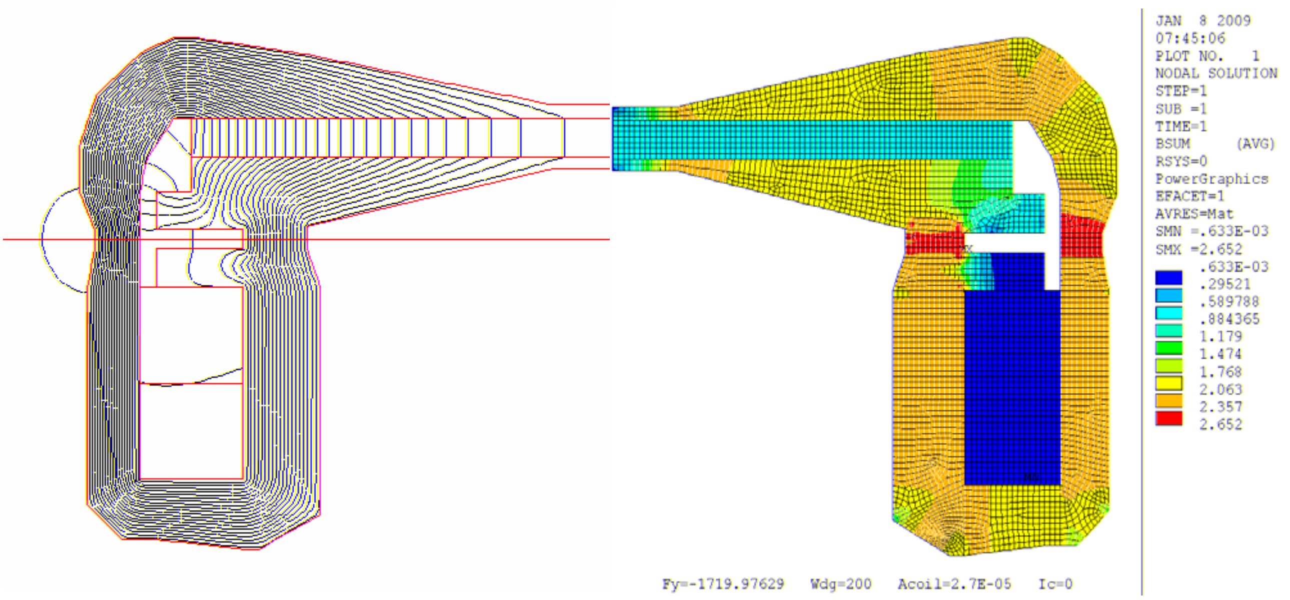

Figure 4 – Static Magnetic Analysis without Current

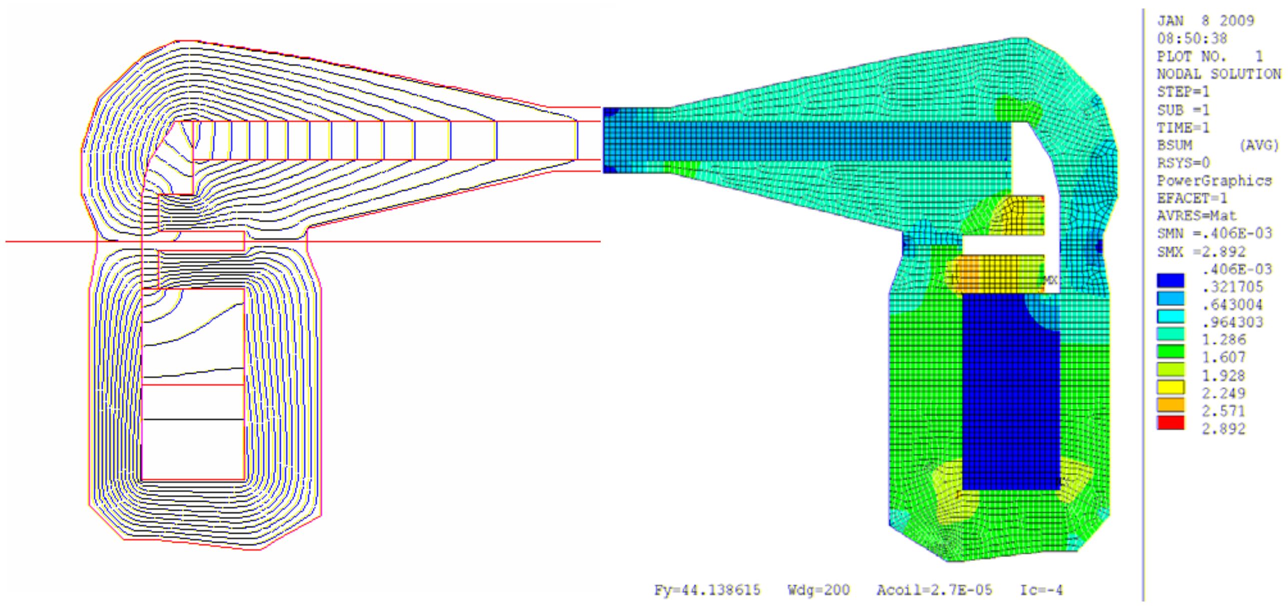

Figure 5 – Static Magnetic Analysis with Release Current

The shield of the moveable part reduces not only the stray field of the open device but also guides the field lines during the release. The same is done by the iron ring above the coils for the fixed part.

At the state without current there is a high field density around the gap for achievement of the maximum possible hold down force.

The final design and the analysis have been assessed by comparison with test results.

4. TEST SETUP

The test setup shown in Fig.6 has been used for all test activities. For the vibration, shock and thermal vacuum tests the base plate has been fixed by screws to the interface of the test facility.

A combination of two springs has been used to secure the movable part after the release and therefore be able to measure the generated release shock only.

The mass of active elements of the engineering model was 0.38kg and the total mass with test setup was 1.3kg.

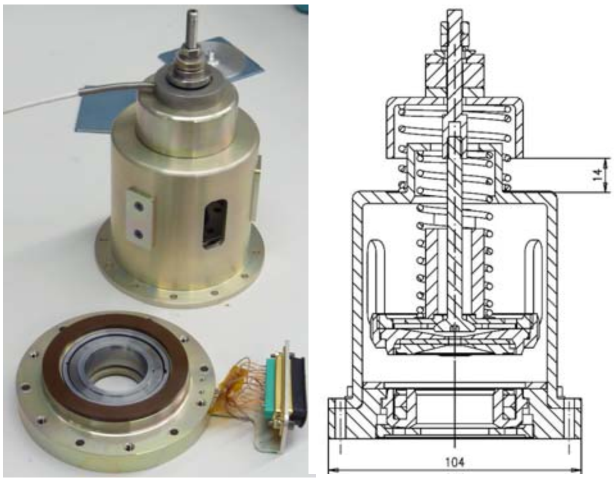

Figure 6 –Test setup of URNS HDRM

5. MEASUREMENTS AT OPEN DEVICE

The magnetisation of the permanent magnet has been performed inside the assembled movable part to avoid unsecured handling of the magnet. The performance of the permanent magnet and of the back iron has been verified by measurements at the open device.

For measurement of the magnetic field a small sensor has been used which fit into the gap between the back iron shield and the back iron as shown in Fig.7.

Figure 7 – Measurement Sensor for Magnetic Field

The calculated field around the movable part shown in Fig.8 and the field inside the gap has been verified. The measured field is shown in Fig.9.

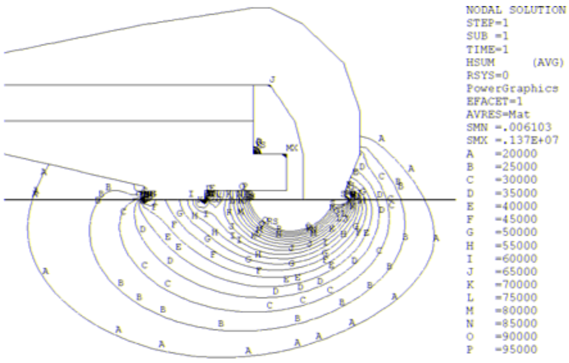

Figure 8 – Calculated Magnetic Field around Movable Part

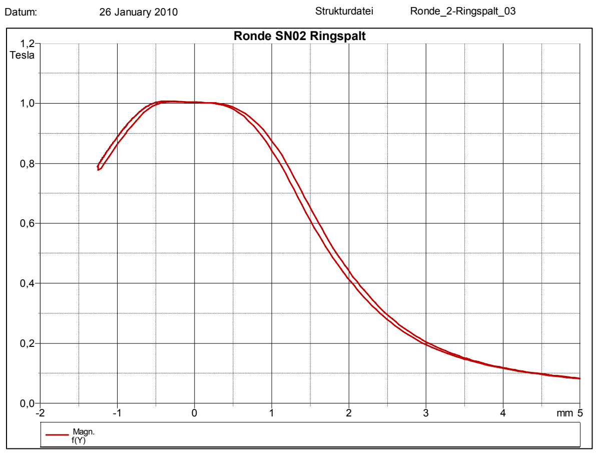

Figure 9 – Measured Magnetic Field inside Gap of Movable Part

Similar measurements have been performed at the fixed part with a reduced current of maximum 1.0A to avoid damage of the coils. By these measurements the calculated release current times windings for maximum repulsive force of about 800A has been verified.

6. TEST RESULTS

The objective of these tests has been to demonstrate that the design of the URNS HDRM is in compliance with the requirements at different temperatures and to compare the measurement with the analysis results.

The measurements and tests comprised are:

- Shock generation
- Maximum hold down force
- Release at ambient and in vacuum at -80 & +120°C with and without preload
- Random vibration & shock
- Thermal vacuum cycling
- Life test
- Repulsive force during release

The shock generation measurement shown in Fig.10 proves the small values which are well below the required 100g in the Shock Response Spectrum (SRS).

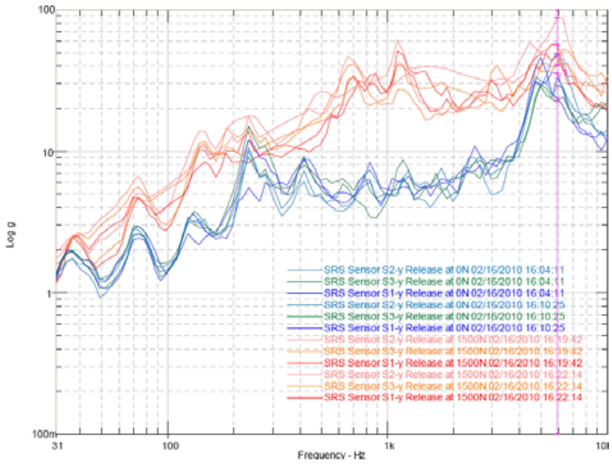

Figure 10 – Shock generation Measurement

The measurement of the hold down force versus distance is shown in Fig.11. This measurement shows that the maximum force is well above the required force of 1500N. The comparison of the measurement with the calculated values shows good correlation.

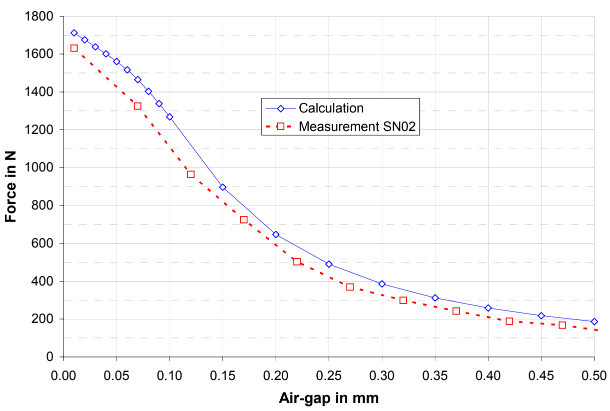

Figure 11 – Force vs. Distance – Comparison of Measurement & Analysis

The measurement of the repulsive force during release is shown in Fig.12. This measurement shows that there is a repulsive force as required. The comparison of the measurement with the calculated values shows good correlation.

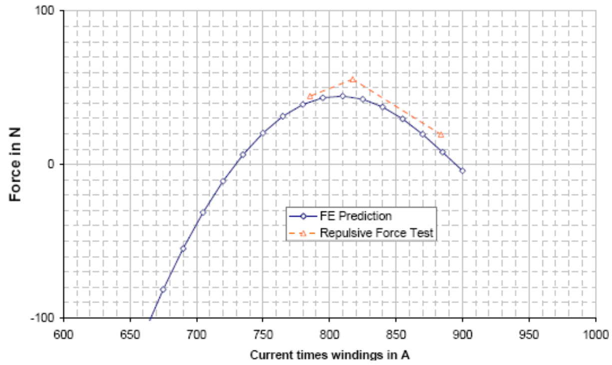

Figure 12 – Repulsive Force vs. Current - Comparison of Measurement & Analysis

7. SUMMARY AND CONCLUSIONS

RUAG Space has developed a lightweight magnetic clamp for space applications according to given requirements. A Samarium-Cobalt (SmCo) permanent magnet provides the hold down force without need for electrical power. The electrical release by coils prevents high shock loads.

This hold down and release concept has been assessed as very versatile and suitable for space applications. The unlimited release without refurbishment is very convenient for extended testing with a representative release actuator.

RUAG Space has applied for a patent for the URNS HDRM concept.

8. REFERENCES

1. Permanent magnet material VACOMAX® 225 http://www.vacuumschmelze.de/index.php?id=209

2. Back iron material VACOFLUX® 50 http://www.vacuumschmelze.de/fileadmin/docroot/medialib/documents/broschueren/htbrosch/Pht-004_d.pdf

3. Coating BALINIT® CNI http://www.oerlikon.com/ecomaXL/index.php?site=BALZERS_EN_balinit_cni