MULTIPURPOSE HOLDDOWN AND RELEASE MECHANISM (MHRM)

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ABSTRACT

Within the framework of ESTEC's GSTP-3 programme a new Multipurpose Holddown and Release Mechanism (MHRM) is being developed and qualified by Dutch Space. It is intended as a small release unit for general application, giving a very smooth release.
In summary, the new device is easier to customize for an application than the present Thermal Knife / aramid holddown cable based release mechanisms.
The first launching customers for the MHRM release mechanism are Proba-2 and Aeolus. For Proba-2, which launch is scheduled on 6 July 2009, the MHRM is a single holddown point for each solar panel. In the Aeolus programme the MHRM mechanism releases the SARM (Solar Array Rotation Mechanism), Ref.1.

1. INTRODUCTION

The standard solar array release system employs the principle of cutting an aramid hold-down cable by an electrically heated Thermal Knife. This principle has significant advantages over, for instance, pyrotechnic devices. It is insensitive to electro-magnetic disturbances, emits a very low release shocks and the Thermal Knife, as actuator, can be used a number of times. Also the electrical circuit can be tested safely at system level.

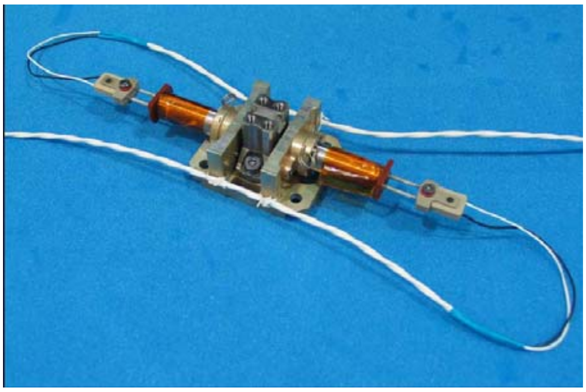

Figure 1. MHRM with leads for Thermal Knives

Dutch Space has extended the application range of its Thermal Knife based release principle by developing and qualifying the versatile Multipurpose Hold-down and Release Mechanism (MHRM) for general space applications.
The same principle of cutting a polymer cable with an electrically heated Thermal Knife is applied for the MHRM. The aramid cable, which is in general used for our solar array tie down, is replaced by Dyneema.

The MHRM holddown transfer unit is designed as a compact unit and is therefore independent from the application. The MHRM unit can transfer launch loads in all 6 load directions.

2. WORKING PRINCIPLE

The launch load transfer and the release function are located in the Reel. The Reel cable element, see figure 2, consists of 2 abutting parts that are clamped together by a Dyneema wire bundle. The Dyneema cord, with 0.4 mm cross-section, is coiled-up with dedicated production equipment around the 2 titanium brackets. During this coiling process the cord is kept at high tension (80 N), initially resulting in a high pre-load between the 2 titanium brackets. Due to relaxation the preload drops to around a stabilized level of 3000 N during storage.

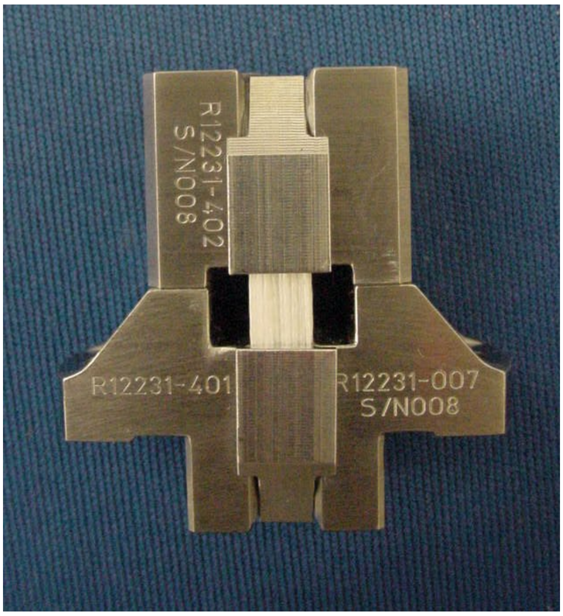

Figure 2. Assembled Reel.

Proc. '13th European Space Mechanisms and Tribology Symposium – ESMATS 2009', Vienna, Austria
23–25 September 2009 (ESA SP-670, July 2009)

On command the Thermal knife is electrically powered and the hot ceramic plate melts the fibres, see figure 3. The Thermal knife heaterblade edge is during operation pushed permanently with a spring against the Dyneema cords.
The small amount of energy stored in the tensioned fibres disappears very gradually. Thus at the end of the cutting process no energy is transferred in shock energy.

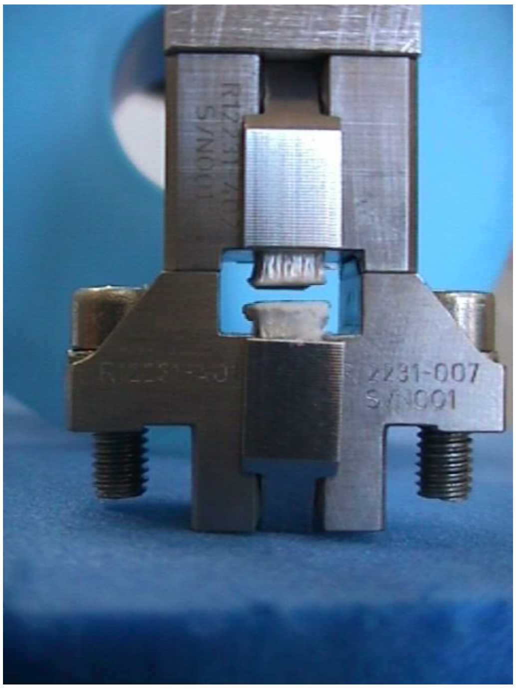

Figure 3. Cut Reel, upper and lower part rejoined.

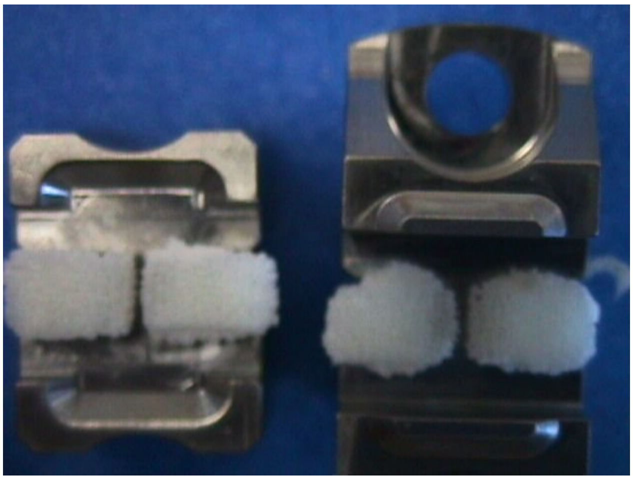

Figure 4. Cut Reel, view on cut cable bundles

As soon as both branches of the wire bundle are cut, the brackets can release, see figure 4, and separate under virtually no force. The upper titanium bracket has a Chrome Nitride coating (by Hauser), to avoid fretting or cold welding, which could jeopardise the release function.

Because no separation forces are involved, the emitted shock is also very low.
Dyneema is a gel spun Ultra High Molecular Weight Polyethylene (UHMW PE), produced by DSM (Dutch State Mines). The fibre is extremely slippery and only low adhesion forces can be obtained with standard adhesive systems.

Dyneema is the only possible candidate fibre for this application. The PRO's are:
- a melting point at 150 ºC
- space compatible
- the fibre is ultrastrong.
- not sensitive to humidity
- no moisture or debris release during the cutting process

The fibre has also some CON's:
- a considerable relaxation (but stabilizes at 3000 N)
- thermal conductivity (the Thermal Knife delivers enough power to accommodate that in worst case conditions)

3. DESIGN OF ASSEMBLY

The MHRM design consists of 3 major parts, ref. figure 3.1:
- The reel element decribed above and shown in figure 5.
- The release/cutting device, consisting of two Thermal Knives for redundancy. The Knives are mounted onto the hold-down bracket such that they are able to cut the entire Dyneema wire bundle independently from each other.
- The hold-down bracket, which fixes the bottom part of the Reel and supports the 2 Thermal Knives. This bracket is in general attached to the satellite.

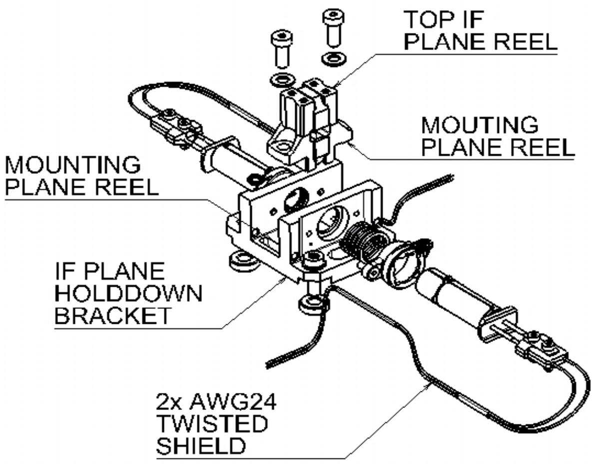

Figure 5. The 2 Thermal Knives are a redundant pair.

Up until the moment of release, both Reel parts, due to the presence of the Dyneema wire bundle, constitute a

single unit, capable of holding down the application during launch and ascent to the intended orbit.
On command, one of the Thermal Knives is powered and cuts both branches of the wire bundle, thus releasing the upper part of the Reel from the lower part and enabling it to deploy along with the application.

The dimensions of the MHRM Model, as shown in figure 1, are 38 (height) by 50 by 250 mm, including Thermal Knives and electrical wiring; the hold-down bracket footprint size is 50 by 60 mm.

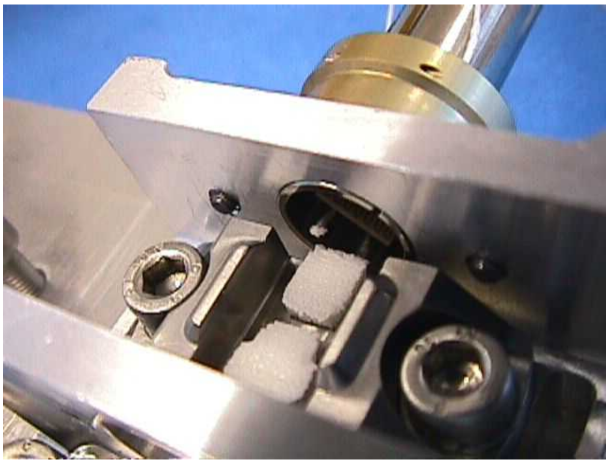

Figure 6. View on bottom part MHRM after release and retraction of knife

The Thermal Knife is a heater element that is mounted on a piston in an aluminum cylinder. The piston is actuated by a spring.
The resistance element is a Silicon Nitride substrate with a Platinum resistance pattern on both sides, glass coated for protection

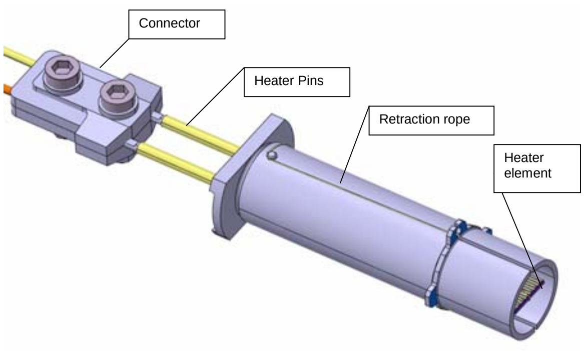

Figure 7. Impression of Thermal Knife, armed position left, fired position right

When the Knife is electrically powered via the 2 leads the substrate edge runs hot and melts the branches of the coiled cords, one after each other.

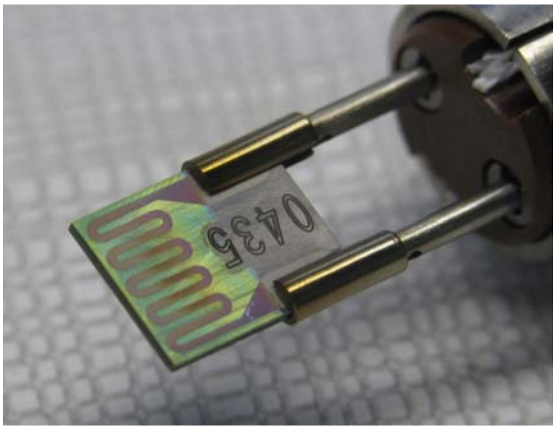

Figure 8 Thermal Knife after cutting tests

A dedicated retraction wire keeps the heater plate of the Thermal Knife separated from the Reel. The wire, which is the same Dyneema cord as used for Reel production, melts during the first seconds of powering.
Contamination of the heater blade or damage of the resistance pattern of the redundant knife is therewith avoided.
This retraction wire improves the testability; the non-powered Thermal Knife is thus kept away from the melting zone of the primary Thermal Knife.

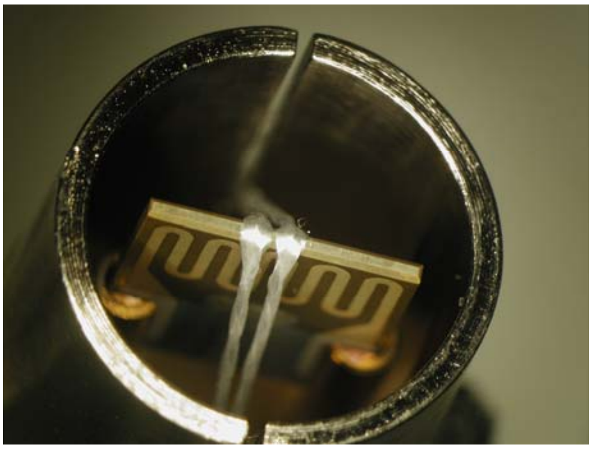

Figure 9 Thermal Knife housing with heaterblade and retraction wire

Figure 10. Aluminum basebracket with bayonets for Thermal Knife fixation

The main characteristics of the MHRM design are:

- Non Explosive Actuation (NEA) concept
- simple attachment of the deployable item on top of the Reel
- in-situ testing of flight units possible
- no risk of spontaneous release (EMI compatible)
- full actuation redundancy
- very low release shock
- no debris generation

4. QUALIFICATION TESTS

The MHRM is qualified for the tests shown in table 1

All qualification cutting tests were performed on 3 mechanisms in parallel, 2 of them were conventional DC powered, one item was powered by a Power Width Modulation with a duty cycle corresponding to the power as from the DC source.

Vacuum tests and vibration tests were also performed on 3 mechanisms simultaneously to use the facilities efficiently.

Strength and stiffness tests and relaxation tests were also performed on 2, 3 or 4 test items to obtain more data.

Contamination and outgassing of the cutting process was measured on 3 stacks in one vacuum test run. Measurements were performed with a QMC and a mass spectrometer and the transparency measurement on a coverglass indicated no changes.

Qualification test	**Range in qual tests / Remarks**
Cutting and release tests for ambient conditions and in vacuum	within 60 seconds DC voltage 19.0 – 21.5 V PWM power 44.5 V max. inrush current: 2.0 A nominal current 0.8 A
Non-oper. dwell in TV	-100 to +100 °C
Operational test in TV	-60 to +70 °C
Relaxation test	Pretension drops from 10 kN to 3 kN in 8 month storage
Vibration test -Sine -Random	Sine dwell in all 3 dir. with 5 Kg dummy mass Random in 3 dir. With 2.5 Kg dummy mass 5.12 g_{rms} for 120 sec Without dummy mass 18.1 g_{rms} for 120 sec
Bending moment - stiffness test - strength linear /ultimate	 5550 Nm/rad around X- 12500 Nm/rad around Z- +/- 30 / 140 Nm around X- +/- 70 / 200 Nm around Z-
Shear test (in plane) - stiffness test - strength linear /ultimate	Kz = 19500 N/mm +/- 1500 / 10000 N
Out-of plane load test - stiffness test - strength linear /ultimate	120000 N/mm 3500 / 28000 N
Redundancy demonstration test	At -60 °C vacuum
Mass measurement and other phys. aspects	0.282 Kg (incl. Thermal Knives and flying leads)
Contamination and outgassing test	Negligible VCM/TML
Humidity exposure test	30% RH at 35 ºC, 4 days 90% RH at 35 ºC, 4 days
Emitted shock test	25 g peak max in any dir

Table 1 Summary of qualification tests

5. REFERENCES

1. Doejaaren, F. (2009), *SARM Solar Array Rotation Mechanism* ESMATS-13, Vienna

2. Cremers, J., Gooijer, E.& Kester, G. *Multipurpose holddown and release mechanism (MHRM)* ESA-SP, Vol 438 1999, p.329