MULTIPURPOSE HOLDDOWN AND RELEASE MECHANISM (MHRM)

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ABSTRACT

Within the framework of ESTEC's GSTP-2 programme a new Multipurpose Holddown and Release Mechanism (MHRM) is being developed by Fokker Space. It is intended as a release unit for general application.
In summary, the new device is easier to customize for an application than the present Thermal Knife / aramid holddown cable based release mechanisms.
At present, the MHRM Engineering Model tests have been completed.

1. INTRODUCTION

The MHRM (see figures 1 and 2) is a follow-on development of the existing release devices for Fokker Space solar arrays that, per holddown point, make use of an electrically heated Thermal Knife (upto approximately 900 °C) to establish release by cutting an aramid (Kevlar) holddown cable.
In the MHRM, however, "Dyneema" cable material will be utilised. Dyneema is a super-fiber as well (stronger than steel), but since it has, unlike aramid, a melting point (around 150 °C), a minimum cable tension is not required to establish cutting. A mechanism ensuring minimum tension is thus no longer required, which makes the device more compact and lighter.
Furthermore, the straight aramid cable with endfittings has been replaced by a Reel cable element, for which a patent has been granted. The Reel allows cutting to be almost independent from the application.
The present development has focussed on single panel and general applications; modification of the MHRM for multi-panel applications has meanwhile been initiated.

2. WORKING PRINCIPLE

The cable element, named the Reel, consists of 2 abutting parts that are clamped together by a pretensioned Dyneema wire bundle; the clamp load delivers the required holddown load.
The lower Reel part is attached to the holddown bracket, which supports the Thermal Knives; the upper Reel part provides the mounting I/F for the deployable application. Up until the moment of release, both Reel parts, due to the presence of the pretensioned wire bundle, constitute a single unit, capable of holding down the application during launch and ascent to the intended orbit. During release, the Thermal Knife cuts the wire bundle, thus releasing the upper Reel part from the lower part and enabling the upper part to deploy along with the application without shock.
Because the Reel constitutes a single unit, cutting is almost independent from the application.
In-situ tensioning of applications that deploy a single panel is no longer required, which makes handling easy.

3. DESIGN

The MHRM design consists of 3 major parts:

1. the Reel cable element (see figures 3 and 4), consisting of 2 abutting parts that are clamped together by a pretensioned Dyneema wire bundle. The lower part of the Reel is attached to the holddown bracket; the upper part provides the mounting I/F for the deployable application
2. the holddown bracket, which is in general attached to the satellite
3. the release/cutting device, consisting of two Thermal Knives for redundancy. The Knives are mounted onto the holddown bracket such that they are able to cut the Dyneema wire bundle

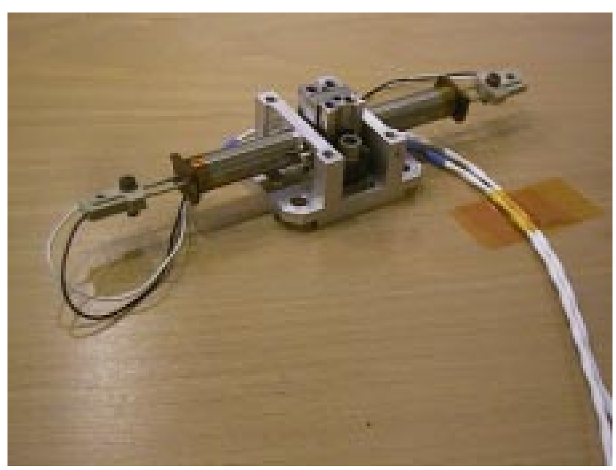

Figure 1. MHRM Engineering Model

Figure 2. MHRM and released upper Reel part

Figure 3. Reel; consumable part of the MHRM

The dimensions of the Engineering Model are 38 (height) by 50 by 250 mm, including Thermal Knives and electrical wiring.

3.1 Reel

The lower Reel part (hard anodised aluminium) has 2 shoulders that each provide a hole through which a CRES M5 bolt is inserted for attachment to the holddown bracket via Helicoil wire inserts. The design is such that the bolts can not be lost when handling the Reel.
Underneath the head of each of the M5 bolts a pair of CRES "Nord-lock" locking rings is applied; their function is to prevent the bolts from loosening under mechanical vibrations during launch. The attachment shoulders are located halfway up the Reel's height to allow the lower part of the Reel to protrude into the holddown bracket; in that way a minimum height of the Reel/holddown bracket assembly is achieved.

The upper Reel part consists of stainless steel; by having two different materials for both Reel parts, adhesion at the separation plane is prevented.
The upper part is provided with 4 M4 wire inserts for attachment of an application. By making use of self-locking Helicoils, attachment of the application can take place without the need for further locking (e.g. adhesive).

The shape of both Reel parts at their separation plane is such that both in-plane translations and in-plane rotation are restrained (cup/cone principle). Out-of-plane translation and rotation along the remaining axes are restrained by the clamping force of the pretensioned wire bundle.

The wire bundle that keeps the Reel parts clamped together consists of a single Dyneema wire that has been coiled around the parts approximately 140 times under preload using a dedicated coiling machine (see figure 5).

Figure 4. Upper and lower Reel parts after cutting

Figure 5. Coiling machine for applying tensioned Dyneema wire around Reel parts

3.2 Holddown bracket

The holddown bracket, which is in general attached to the satellite, supports the Thermal Knives and passes the mechanical loads exerted by the application on the Reel, to the S/C structure during launch.

Its shape is straightforward: two flanges for Thermal Knife support perpendicular to a base plate onto which (in-between the flanges) the Reel is mounted. The base plate's footprint is 50 by 60 mm.

The Thermal Knife support flanges provide M5 wire inserts (4 in total), suitable for installation of optional kick-off spring plungers. As a rule, some customers require the possibility to apply kick-off springs near separable surfaces. During Engineering Model testing kick-off spring plungers were not part of the MHRM.

The base plate has 2 M5 Helicoil wire inserts for attachment of the Reel and at its corners 4 boltholes for attachment to a S/C sidewall with M5 bolts, as well as machined sockets for thermal washers.

The bracket is made from space-grade Aluminium alloy. It is coated with Alodine 1000, which provides adequate alpha/epsilon properties, as well as a conductive surface to prevent static loading.

3.3 Thermal Knife

When operated, the Thermal Knife heater plate is pushed through the wire bundle by a compression spring.

Both the prime and redundant Thermal Knives operate along the same centre line; as a consequence the heater plates will make contact at their cutting edges after cutting the wire bundle. To assure head-on contact, each Thermal Knife is attached to the holddown bracket under an angle of approximately 8°.

4. VERIFICATION

Engineering model testing comprised the following:

1. stiffness and strength testing
2. on-ground release testing (in ambient)
3. sine, sine dwell and random vibration
4. release testing under thermal vacuum circumstances

4.1 Stiffness and strength testing

Three MHRMs were loaded in 3 orthogonal directions on a tensile test bench, while recording force/displacement diagrams. The in-plane forces were acting in the separation plane of both Reel parts. Finally they were loaded in out-of-plane direction until failure.

When loaded in-plane, the minimum yield load is approximately 2 kN. Cup/cone play travel can occur above 500 N; upto that load level the stiffness is approximately 20 kN/mm. The minimum ultimate load is 5 kN.

In out-of-plane direction loads upto 10 kN are sustained without detrimental effects. The minimum ultimate load proved to be 14 kN; failure mode is fracture of the aluminium lower Reel part where it supports the Dyneema wire bundle, as can be seen in figure 6.

After production, each Reel was proofloaded in out-of-plane direction; the clamp load between both Reel parts proved to be between 5.5 and 6 kN. This clamp load is determined by Dyneema's creep limit at room temperature.

3 Reels were proofloaded after exposing them to 50 °C for 12 hours; the clamp load appeared to have decreased to 4 kN. This shows that the creep limit of Dyneema is temperature dependent.

Figure 6. Reel after ultimate strength testing; fractured lower Reel part and still intact wire bundle and upper Reel part

4.2 On-ground release testing

During the release tests a balance arm and a counterweight were used to apply a deployment force of 0.05 N to the upper Reel part.

The results were such that for the 50 Volts version of the Thermal Knife, a voltage range from 48 to 52 is recommended. Release time will then approximately be between 10 and 15 seconds.

4.3 Sine, sine dwell and random vibration testing

Two MHRMs were vibration tested, both with and without a circular dummy mass attached to the upper Reel part. Each dummy mass was approximately 5 kg and its center of gravity was at 16 mm from the top of the Reel and 32.5 mm from the separation plane.

The table below summarizes the achieved levels; the X- and Z-axes are in-plane and respectively perpendicular and in line with the centre lines of the Thermal Knives, the Y-axis is out-of-plane.

TEST DESCRIPTION	LEVELS with **dummy masses**
sine dwell 20 g X-axis	21-22 Hz; 1 sweep 1 Hz/min
sine 10 g X-axis	5-100 Hz; 1 sweep up/down 2 Oct./min
random 8.35 gRMS X-axis	20-2000 Hz; 120 sec.
sine dwell 10 g Z-axis	19.5-20.5 Hz; 1 sweep up 1 Hz/min
sine 10 g Z-axis	5-100 Hz. 1 sweep up/down 2 Oct./min
random 5.1 gRMS Z-axis	20-2000 Hz; 120 sec
sine dwell 20 g Y-axis	20.5-21.5 Hz; 1 sweep 1 Hz/min
sine 20 g Y-axis	5-100 Hz. 1 sweep up/down 2 Oct./min
random 18.1 gRMS Y-axis	20-2000 Hz; 120 sec

TEST DESCRIPTION	LEVELS **without** dummy masses
random 18.1 gRMS X-axis	20-2000 Hz; 120 sec
sine dwell 30 g Z-axis	25-26 Hz; 1 sweep up 1 Hz/min
sine 20 g Z-axis	5-100 Hz. 1 sweep up/down 2 Oct./min
random 18.1 gRMS Z-axis	20-2000 Hz; 120 sec
sine dwell 30 g Y-axis	25.5-26.5 Hz; 1 sweep up 1 Hz/min
sine 20 g Y-axis	5-100 Hz. 1 sweep up/down 2 Oct./min
random 18.1 gRMS Y-axis	20-2000 Hz; 120 sec

Figure 7. Two MHRMs with dummy masses on shaker facility

Afterwards it appeared that some transfer of material between upper and lower Reel parts had taken place during vibration. There is, however, no indication that this phenomenon affects the MHRM release capability. The clamp load between both Reel parts was unaffected by the vibration testing.

4.4 Cuttings under thermal vacuum circumstances

During the release tests a balance arm and a counterweight were used to apply a deployment force of 0.05 N to the upper Reel part.

Several releases were performed at temperatures between -114 and +130 °C.

The results were such that for the 50 Volts version of the Thermal Knife, a voltage range from 48 to 52 is recommended. Release time will then range from 5 (hot case) to 20 seconds (cold case).

5. CONCLUSIONS

The overall conclusion is that the MHRM design is viable.

In summary the performance is as follows:

- non-pyrotechnic release
- mass including Thermal Knives: approximately 0.2 kg
- envelope: 38 (height) by 50 by 250 mm, including Thermal Knives and electrical wiring.
- simple installation of application by bolting to top of Reel
- holddown load upto 5.5 kN (room temperature)
- suitable for implementation of kick-off springs
- in-situ testing of flight units possible
- zero risk of spontaneous release
- release time between 5 and 20 seconds
- no release shock
- no debris after release