A PASSIVE MAGNETIC BEARING HINGE

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1. INTRODUCTION

The problem to be addressed was to develop a deployment hinge with a very low resistive torque and to have mass and cost saving with regard to usual lateral hinges.

Thales Alenia Space has successfully designed, manufactured and ground tested a passive Magnetic Bearing Hinge (MBH) structural model with the support from the European Space Agency.

The MBH will :
✓ perform the deployment of solar array lateral panels.
This could be divided in two sub-functions :
  ☒ to guide the panel (from 0° to 180°),
  ☒ to ensure the motorization of the opening.
✓ link the central panel to the lateral panel.

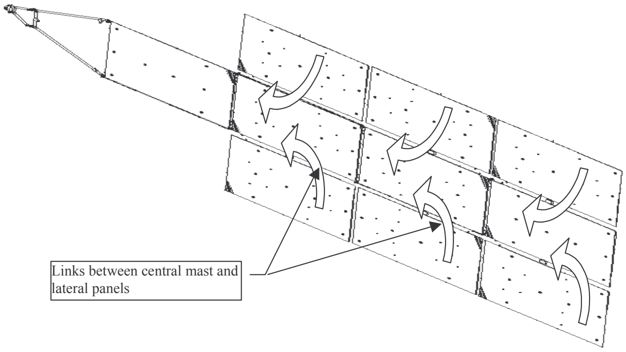


Figure 1. Example of application on solar array

2. THE INNOVATION

The new concept is based on passive magnetic bearings and punctual stops.
The magnetic hinge is composed of two magnetic bearings composed of a rotor and a stator having a stable radial stiffness and an unstable axial stiffness.
During launch, a gap remains between the hub tip and the bearing stop. This position is maintained thanks to hold down points.
During functional phase, the contact between the hub tip and the bearing stop is a sphere/plan contact.

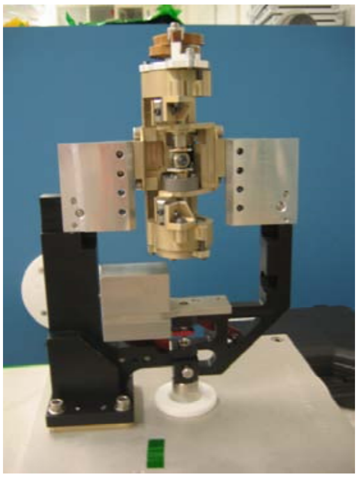


Figure 2. MBH facilities

The principal advantages of the concept are :

- **The capacity, thanks to magnetic use, to offer a stowed configuration without mechanical contact (no**

Proc. '12th Euro. Space Mechanisms & Tribology Symp. (ESMATS)', Liverpool, UK, 19–21 September 2007 (ESA SP-653, August 2007)

sensitivity under thermal and mechanical loads), which avoid
    - deployment test at system level,
    - specific load analysis (robustness of hinge to the mission : generic hinge).
- A very low resistive torque during deployment phase with punctual axial contact.
- The opening guidance done by one or two points (1 or 2 hinges) at system level.
- Manufacturing easy and fast.

On this design a patent was deposed in 2004.

3. OVERALL DESCRIPTION

Magnetic bearings

Each hinge is composed with two magnetic bearings, themselves composed with 2 magnet rings on the inner part and 2 magnet rings on the outer part.
The following scheme shows the magnetic architecture of the hinge.
Each magnetic bearing is radially stable, axially unstable and unstable in gimballing.
Each hinge is radially stable, axially unstable and the gimballing stiffness depends on the interval between bearings.

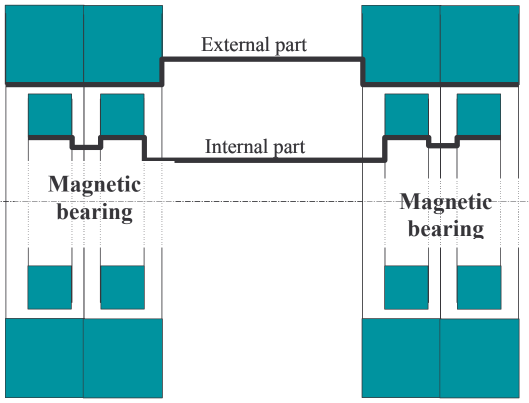


Figure 3. Magnetic architecture of a hinge (two magnetic bearings)

According to the mechanical architecture which is considered (two hinges on the edges of the panel or one hinge on the centre), the magnetic configuration will change :
- 2 hinges on the panel extremities : there are 2 pairs of magnetic bearings. In one hinge, bearings are spaced out by 40 mm, the gimballing stiffness is positive and near zero. Hinges are spaced out by around 3.6 m.
- 1 hinge on the centre: there is only one pair of magnetic bearings. The two bearings are spaced out by 110 mm, the gimballing stiffness is much higher than in the first case.

Locking Mechanism

The locking mechanism is constituted by a magnet in sandwich between two iron pieces. This set, fixed on the stator for example, is strongly attracted by another iron panel fixed on the rotor (see Figure 4).

The whole locking system is constituted by 4 modules: a set of 2 central magnets and 2 independent external magnets. A cross section of a module and the location of the four parts are given by the following views.

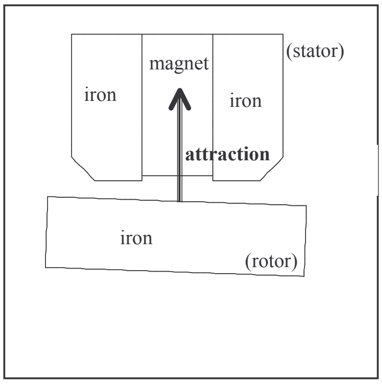


Figure 4. Cross section of a locking magnet

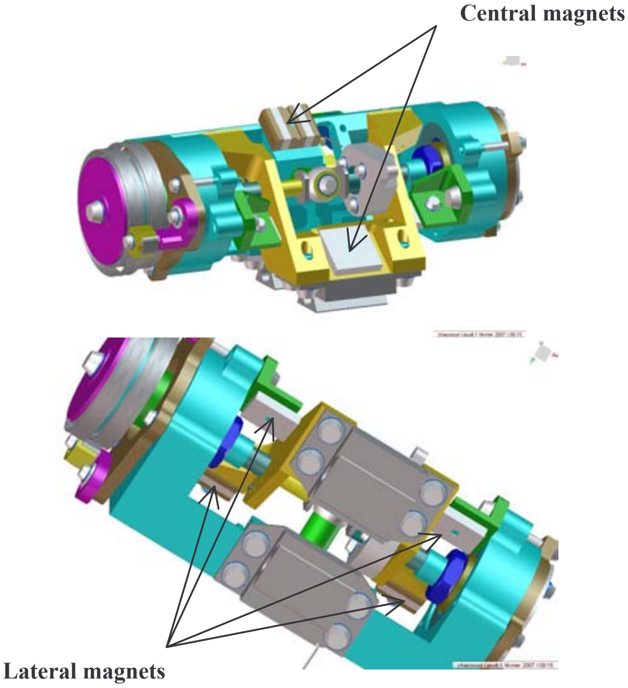


Figure 5. MBH design

The locking mechanism is completed with a mechanical anti-return device (functioning at the end of the hinge deployment)

Motorisation

The hinge motorisation is made with flat spiral springs

4. TEST ACTIVITIES RESULTS

The performances assessed during the test sequence performed (vibration, resistive torque calculation, motorisation torque calculation, stiffness measurement) permit to demonstrate feasibility and reliability of this concept.

Main test values

The maximal resistive torques measured without springs are :
C_R = 0,0158 Nm (due to axial contact),
C_R = 0,077 Nm (due to anti return catch).

The motorisation torques measured with springs are :
C_M (end of deployment) = 0,23 Nm
C_M (stowed) = 0,37 Nm
C_R maxi = 0,08 Nm
This concept allows to have motorisation safety margin greater than 3.

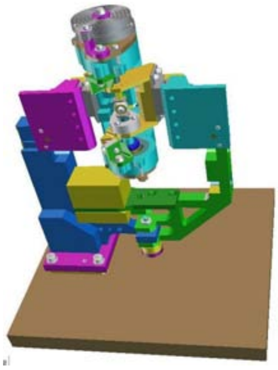


Figure 6. MBH resistive torque test configuration

Main Stiffness values :
Stiffness value Kθz = 4825 Nm/rd (due to magnets).
Stiffness value Kθz = 589 Nm/rd (due to anti return catch contact).
Average stiffness value Kθz = 4000 Nm/rd (due to contact on magnets supports).

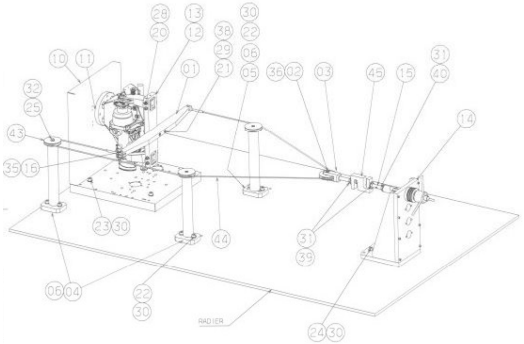
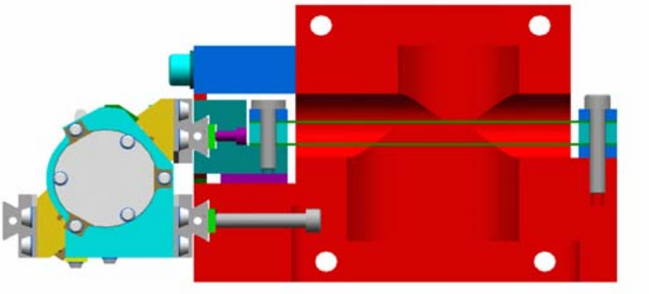
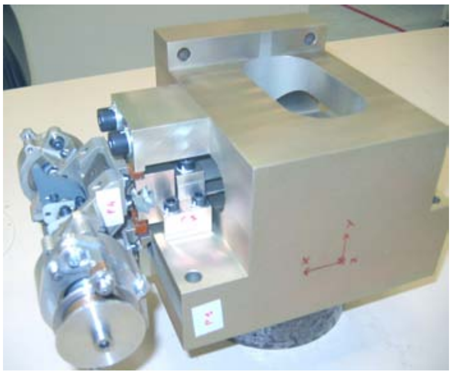


Figure 7. MBH stiffness test configuration





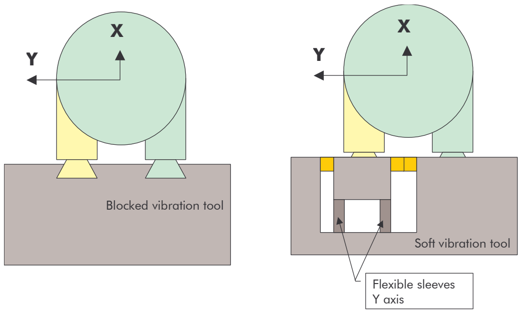


Figure 8. MBH vibration test configuration

During vibration :
No shift on frequency modes between low level sine,
No damage on the hinge (visual inspection).

The flexible configuration tests have shown that there were contacts between mobile and fixed parts of the hinge at 0dB random level.

With fixed limit boundaries (rotor and stator are fixed rigidly), random 0dB didn't show any abort.

The maximal amplification measured is about 3,4.

To prevent contact from mobile and fixed parts, we have to increase stiffness between both brackets. We can also accept this contact and check with a coupled analysis the real hinge behaviour.

5. NEXT ACTIVITIES AND CONCLUSION

The next steps will be :

- **To optimize mechanical architecture (redesign to cost),**
- **To convince satellite costumer to use MBH concept on Solar Array (in comparison with other existing hinge),**
- **To qualify it.**

Hereafter the tests forecast on Figure 9 :

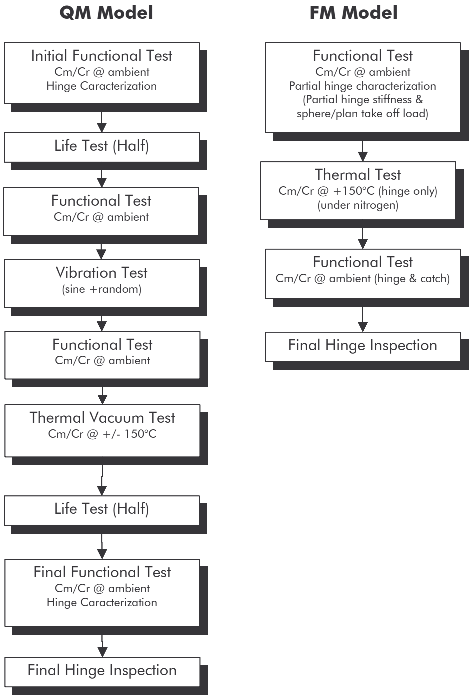


Figure 9. MBH QM and FM Tests

This product proved efficient, cheap and easy to operate.

The price is divided by two with regard to the existing lateral hinge.

The hinge realised is a functional mock up, the MBH qualification model mass should be inferior to 500 g.

Nevertheless, this new tested and efficient product needs flight experience before taking place in a telecommunication satellite program (see MBH schedule on Figure 10).

This concept could be adapted to other multiple deployments.

Figure 10. MBH Schedule