A NEW LARGE SLIP TABLE TO VIBRATE ARIANE 5 PAYLOADS

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ABSTRACT

This paper presents some of the main features of the new ESA Large Slip Table project designed for the future needs of ESTEC's Testing Division. This new table will be able to vibrate ARIANE 5 single passenger-class spacecraft.
The trend in this class of payload is towards six tons and above. ESTEC's Testing Division has therefore decided to replace the existing mono-axial slip table to be able to handle this class of specimen.
This paper presents some key points of the design used to develop such a large slip table.

1. MAIN TECHNICAL REQUIREMENTS

ESA's technical requirements are listed in Tables 1 to 7. The requirements for the flexible modes of the table coupled to the shakers are defined in Table 7.
Adequate local stiffness will be provided at any location of the table surface interfacing with the test specimen.

Table 1. Slip Plate

Length	3000 mm
Width	3000 mm
Envelope	Compatible Ariane 5
Displacement	50 mm peak-peak
Moving mass	< 3000 kg

Table 2. Interfaces

With shakers	LDS V984LS 2x Push or 1 Push 2 x Push-2 x Pull
With specimen: M10 inserts Location accuracy Table top surface: Flatness	 80 x 80 mm grid 0.1 mm < 0.2 mm
Roughness	< 3.2 µm
With clean room	Molecular contamination $< 2.10^{-7}$g.cm^{-2}

Table 3. Operational frequency range

Sine	3 - 2000 Hz
Random	10 - 20000 Hz

Table 4. Loading

Payload mass	11000 kg
CoG above the table	5000 mm
Max excitation force Fx Push-pull	320 kN 640 kN
Max lateral force Fy	90 kN
Max vertical force Fz	40 kN
Max yaw moment Mz	80 kNm
Max pitch moment My	1300 kNm
Max roll moment Mx	700 kNm

Table 5. Input acceleration

Controllability outside resonance frequencies: Sine: 3-100 Hz 100-2000 Hz Random	 ± 1 dB or 0.025g ± 3 dB ± 3 dB
Controllability through resonance frequencies: Sine: 3-100 Hz 100-2000 Hz Random	 ± 6 dB or 0.025g ± 6 dB ± 6 dB
Deviation of acceleration from excitation acceleration: 3-100 Hz 100-2000 Hz (excluding isolated peaks)	 < ± 10% or 0.025g < ± 30%

Cross-axis response: 3-100 Hz 100-2000 Hz	<± 10% or 0.025g <± 100%
Distortion in excitation direction: 3-100 Hz 100-2000 Hz (excluded isolated peaks)	<± 10% or 0.025g <± 20%

Table 6 Perturbation of the test specimen dynamics

Test specimen resonance frequencies deviation	< 5%
Test specimen damping deviation	< 30%

Table 7. Global stiffness

Empty table	> 250 Hz
Through full load range	> 130 Hz

2. KEY EQUIPMENT

To comply with these very demanding technical specifications, it was decided to select the following key equipment.

2.1 Hydrostatic bearings

The size of the slip plate and the challenging requirements have imposed the use of low-friction guiding devices associated with an outstandingly high vertical stiffness. The Team Corporation [1] – a company well known all over the world – has produced the medium pressure standard hydrostatic bearings which were selected.

2.2 Bearing arrangement

The bearing arrangement (Fig. 1), is the standard one proposed by Team Corporation for large slip tables:

- 2 x "Yaw only" bearings define the axis of vibration and the yaw restraint.
- 69 x T2 film bearings arranged in a grid matrix provide the vertical stiffness and the pitch and roll restraint.
- 8 x dummy bearings located at each corner of the table maintain the oil film continuity below the whole slip plate surface.

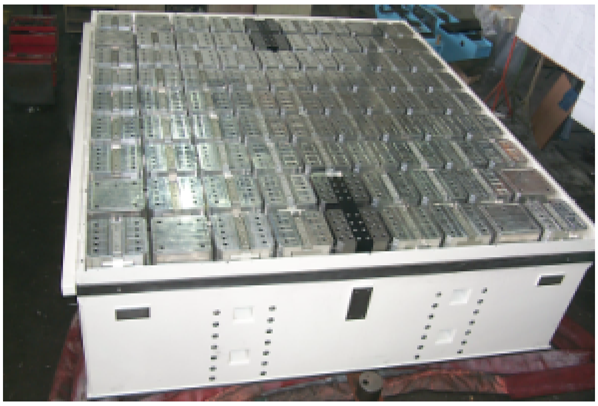

Fig.1. Bearing arrangement

2.3 Bearing stiffness

As the high figures on the apparent stiffness were not validated by direct measurements on bearings, it was decided to set up a test (Fig. 2), with a T2 film bearing.
The aim of this test was to confirm that the bearing stiffness was constant, from 5 Hz up to 2000 Hz, and to verify the high value quoted by Team.
This test was performed in co-operation with the Team Corporation, at the Northwest Environmental Lab, near Portland, Oregon, USA.

Fig. 2. T2 film bearing test set-up

Measuring such high stiffness was really a challenge.
Nevertheless, with the help of a mathematical model of the test set-up, it was possible to identify systematic errors and to take them into account in the final data processing.
The stiffness results we obtained (Fig. 3) confirm that the apparent stiffness of a T2 film bearing, in the

vertical direction is in the order of 3.10^{10} $N.m^{-1}$ and is nearly constant from 5 Hz up to 2000 Hz. This result was very encouraging and confirmed that the Team Corporation's hydrostatic bearings were the right choice for this demanding application.

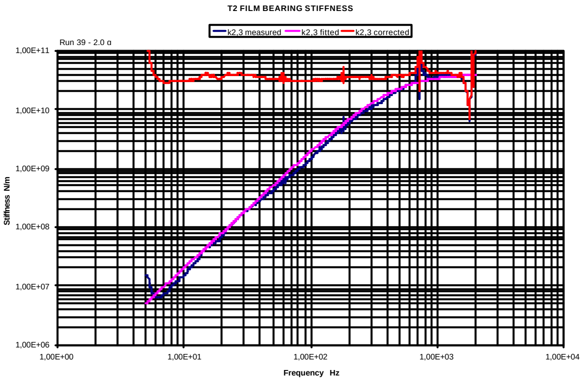

Fig. 3. Team bearing vertical stifness

2.4 Bearing clamping modification

The maximum overturning moment capability for this large slip table (Fig. 4) depends on the average diameter and the dimension of the interface adapter. Due to the high pulling force, which can be applied, on each bearing and in order to comply with the European standard safety margin, it was decided to update the Team standard design. The modification consisted simply in reinforcing the standard clamping system by changing from M12 steel bolts class 8.8 to M14 steel bolts class 12.9.

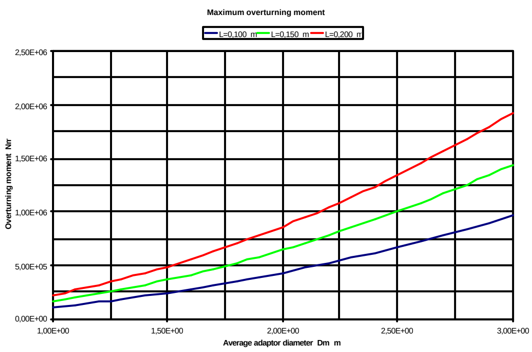

Fig. 4. Maximum overturning moment capability

2.5 Slip plate

In Europe it is not difficult to get a large laminated raw plate when aluminium is elected.
This is not the case with magnesium and it would have been necessary to weld three standard laminated magnesium plates. This constraint would have complicated the whole manufacturing process and constituted a severe handicap as compared to the aluminium solution.
To avoid any welding, it was decided to use an aluminium raw laminated plate (3020x3660x60 mm) and to control the total weight by optimising the final plate thickness.
This final thickness was set up to 49 mm which results in a total mass of 1450 kg for the slip plate. The first symmetrical elastic mode would appear at 600 Hz when the bare slip plate is sitting on the bearings but not connected to the drive bars.
Adding the 226 kg of the drive bars, the 361 kg of the bearings moving elements, and the 260 kg of the shaker moving elements, we obtain a total moving mass of 2297 kg which is well below the specified maximum moving mass.

2.6 Bearing base plate

As for the slip plate, the choice was to use a raw laminated steel plate, in order to avoid any welding. Here again it was not difficult to find in Europe a steel plate of those dimensions.

3. MANUFACTURING AND INTEGRATION APPROACH

Reducing the vibration test facility down time as well as minimising the risks of contamination of the test hall, were two issues of paramount importance for the ESTEC test centre. Therefore it was decided to assemble and set up the table at the factory and to perform all inspections and end to end functional tests prior to transport the whole assembly in one piece to ESTEC. The design was adapted to take into account this approach.

3.1 Handling of the Large Slip Table

The weight of the large slip table fully integrated is close to 35 tons.
At ESTEC, transport from the unloading point to the final location on top of the seismic block in the vibration test hall cannot be done by crane. Instead the table will be flown on four air cushions connected to the side of the table through four steel legs (Fig. 6).

3.2 Machining of the large plates

The milling and drilling of plates of those dimensions to the specified accuracy required selecting the sub-contractor very carefully.

Ets A. DESHORS [2] were selected based on their references and the availability of large capacity and high-accuracy milling machines.
This inertia block is made of concrete poured into a reinforced metallic box (Fig. 6).
The base plate is a thick large steel plate, which is pasted and connected to the inertia block.
The very challenging flatness requirement of 0.2 mm for the slip plate has been translated for the bearing base plate in a challenging flatness requirement of 0.1 mm over the 3000x3000 mm surface.
To permit to mill and drill both bottom plate and bearing base plate with the required accuracy, the sandwich, bottom plate-concrete-cement-base plate was handled and machined as one single piece. The achieved bearing base plate flatness was measured better than 0.1 mm and the local flatness was measured better than 0.025 mm thus compliant with the TEAM bearing requirement.

Fig.6. Steel casing and air cushion steel legs

In addition, this approach has allowed the very accurate grinding of two keys dedicated to the exact absolute positioning and relative orientation of both "yaw only" bearings. These keys contribute as well to ease and simplify the mounting and alignment of these two very critical bearings.

3.4 Dedicated alignment tools

In order to simplify the operation of connecting the slip plate to the top of the bearing moving elements, a dedicated tooling was designed (Fig. 7). This tooling allows to pre-align all the moving elements so that this operation of connecting the slip plate can be performed by the users in a very short time.

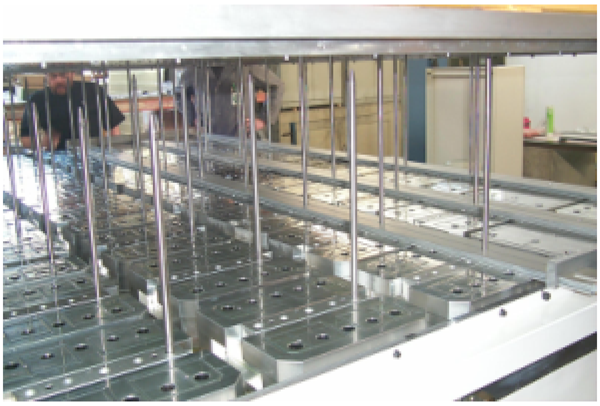

Fig 7. Table connection alignment tooling

3.5 Clamping of the Large Slip Table on site

On site, the Large Slip Table is connected to the seismic foundation using 44 large diameter tie rods of high quality steel material.
Each tie rod is pre-loaded up to about 400 kN.
The top surface of the seismic foundation is drilled using a steel template, which defines accurately the location of each tie rod.

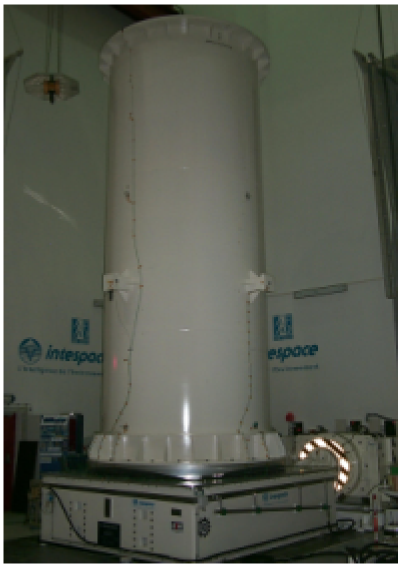

Fig. 8. Large Slip Table at INTESPACE

A similar large slip table, based on the same design has been delivered to INTESPACE, Toulouse, France, and is currently undergoing acceptance tests using the large, high and heavy ESA/ESTEC mass dummy (fig.8).

4. CONCLUSIONS

Despite the very demanding ESA requirements, the design of such a large slip table is not very different from the usual design for smaller slip tables.
However, special care has been taken to overcome the very high overturning moments whilst maintaining clean input accelerations at very low level excitation.
Innovative approaches were also introduced to minimise the impact on the ESTEC test centre during table installation:

- by reducing significantly the final setting up time on site.
- by minimising the risks of contamination for the clean room
- by simplifying the bearing moving element alignment process.

This new Large Slip Table is scheduled to be delivered to ESTEC during August 2001 and put in operation in September-October 2001.

5. REFERENCES

1. TEAM Corporation, 11591 Waterbank Road, Burlington, WA 98233
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2. Ets. DESHORS, B.P. 550, F19107 Brive la Gaillarde, www.deshors.fr