FLVT – NEW FORCE MEASUREMENT METHOD FOR INSTRUMENT AND EQUIPMENT TESTING

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OVERVIEW

A standard qualification procedure for space equipment includes vibration tests of each single unit. The vibration test shall verify the design qualification or workmanship of all equipment mounted to a spacecraft. The instruments are usually mounted to the spacecraft on relatively soft structures like sandwich panels or lightweight substructures. These structures are usually unable to pass high-energetic high-frequency vibrations to the instrument.

The vibration test, however, is usually conducted mounting the Equipment under test (EUT) directly, via a very stiff adapter, to the shaker head or slip table. Now, even high-frequency vibrations can be induced into the EUT with high energy. This can cause severe overtesting.

One method of solving this problem is to consider the original mounting in the spacecraft as a system of two coupled masses, where the first mass is the holding structure of the satellite and the second mass is the EUT. In this kind of system, the forces acting on the second mass are usually not greater than twice the magnitude of the forces on the first mass. Therefore, the introduction of a force limit to the interconnection between first and second mass (i.e. satellite substructure and EUT) at the point of mechanical interface is highly recommended.

This is the starting point for creating a Force Limited Vibration Test (FLVT).

This paper gives a short description of the problems encountered setting up a proper force measurement on the interface of the EUT as well as the problems related to the measurement itself. Furthermore it presents a practical solution of these problems including examples where this method was successfully implemented.

1. INTRODUCTION

Due to the complex nature of the properties of coupled dynamic systems with two or more masses, an extensive research would be necessary before conducting the FLVT. To avoid this, a practical approach to simplify the determination of force limits is given in the NASA Handbook 7004 “Force Limited Vibration Testing”. This is the basis for all the work described here.

2. THE PROBLEMS

There are several problems encountered during setting up a force limited vibration test.

2.1. Special instrument interface

Usually, the EUT has a special interface designed to meet functional requirements, e.g. a thermally insulating brackets. Thus, an adapter is needed for mounting the EUT to the shaker.

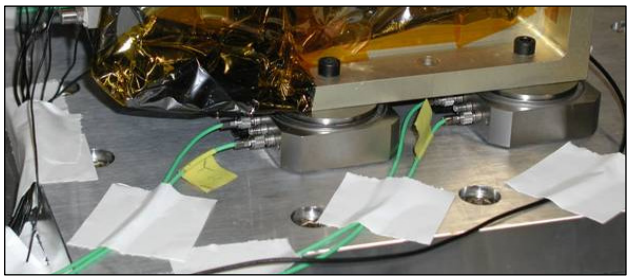

FIG. 1 Direct mounting of EUT on force gages

FIG. 2 Special mounting studs require adapter

2.2. Different bolt sizes

The size of the bolts for the instrument is different from the force gages requirements. Usually, the used force gages need a certain pretension to measure the force accurately in both directions. This pretension can not be achieved with bolts used for space equipment of the size around five millimetres. In addition to this, an attachment of the EUT directly on the force gages would be impossible due to the restricted foot surface dimensions of the EUT. For these reasons, an adapter is needed to assure proper measurement with the used force gages.

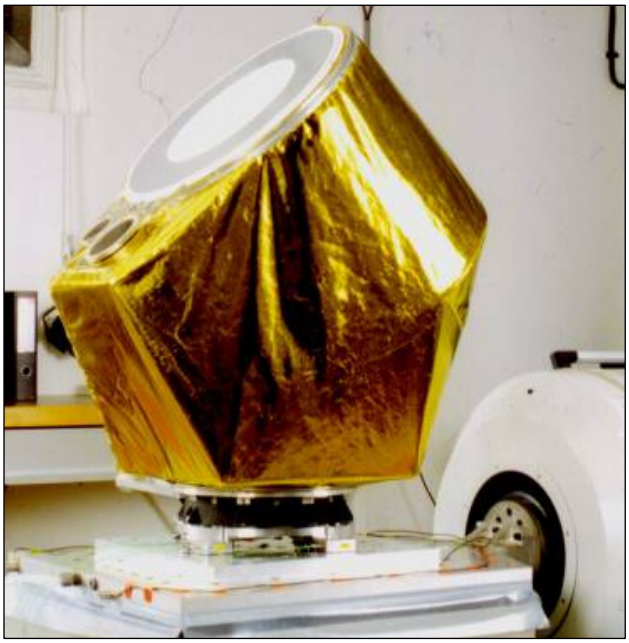

FIG. 3 CASSINI CDA with M5 bolts on shaker with M8 bolts

2.3. Very large adapter mass

For a vibration test, an ideal adapter is very stiff. This is necessary to avoid resonances in the test frequency range and thus a possible overtesting of the EUT. In order to make adapters very stiff, they are usually quite thick and heavy, often twice as heavy as the EUT or more.

Using the force directly measured with the force gages, this large mass would impair the measurement in a degree that the often delicate reactions of the EUT would be hardly recognizable.

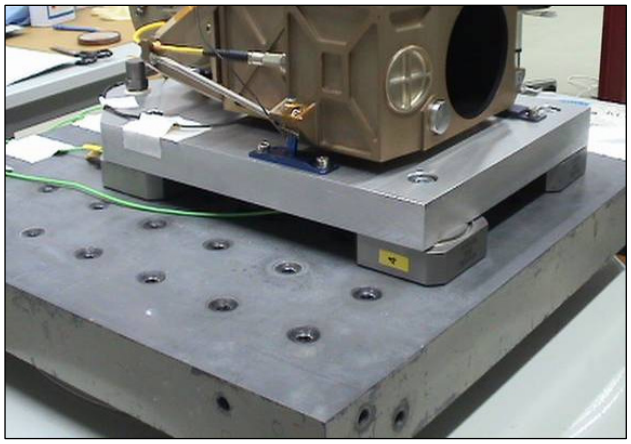

FIG. 4 EUT with heavy vibration adapter

3. THE SOLUTION

(1) $F_{test\ item} = F_{measured} - (acceleration_{input} \times mass_{adapter})$

A proper evaluation of the forces generated by instrument resonances and the corresponding modal masses can only be achieved when a possibility to compensate the forces coming from the "dead mass" (i.e. the adapter) is given. Therefore, Astro- und Feinwerktechnik Adlershof GmbH together with Kistler Instruments developed a method to subtract the force signal of the dead mass from the measured force signal on-line, getting a force signal only from the EUT.

3.1. Test setup

The force sensors are mounted between shaker and test adapter. The test fixture thus allows for the measurement of accelerations and forces at the same time. The force resulting from the acceleration of the test adapter will be compensated.

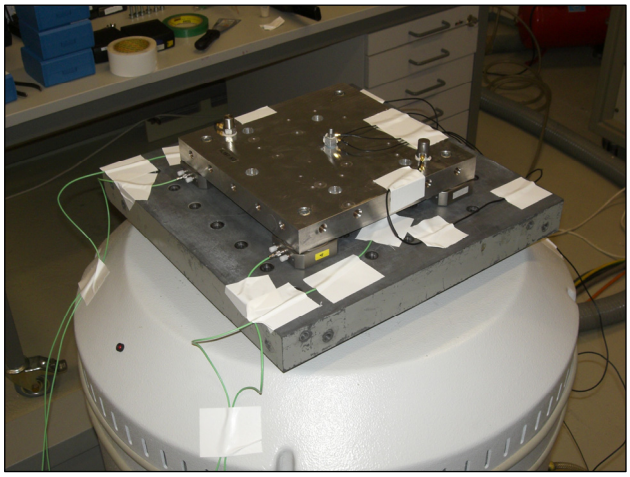

FIG. 5 Force gages between shaker and adapter

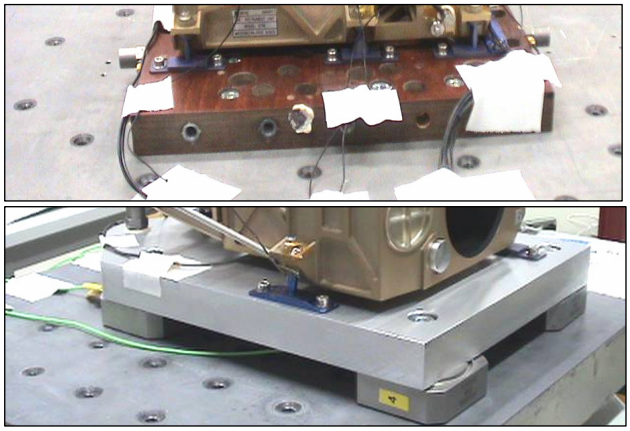

FIG. 6 Special mounting studs require heavy adapter, force gages in place

3.2. Force compensation

With the help of a KISTLER measurement system, it is possible to eliminate the force of the "dead mass" from the force sum signal. The measurement system allows for a measurement of eight forces together with three accelerations and computes three forces and three moments from this data (in three orthogonal axes) in real-time. This on-line processing allows for a real-time evaluation of the EUT's reaction and thus even a force limited vibration testing. Force notching can be applied to this residual force signal.

FIG. 7 KISTLER Force Measurement System

4. CALIBRATION AND APPLICATION OF FORCE MEASUREMENT

4.1. Measurement System

The measurement system for FLVT comprises four three-axis force gages. The signals from these gages are amplified and, together with acceleration signals, fed into the heart of the system, an on-line signal processor allowing for the execution of mathematical operations with these signals in real-time. The signal processor forwards the computed signal to the measurement and control system of the shaker.

4.2. Calibration

Prior to a test, the force measurement system needs to be calibrated to make sure it works correctly. This is done by adding calibration masses step by step and analysing the measured signal.

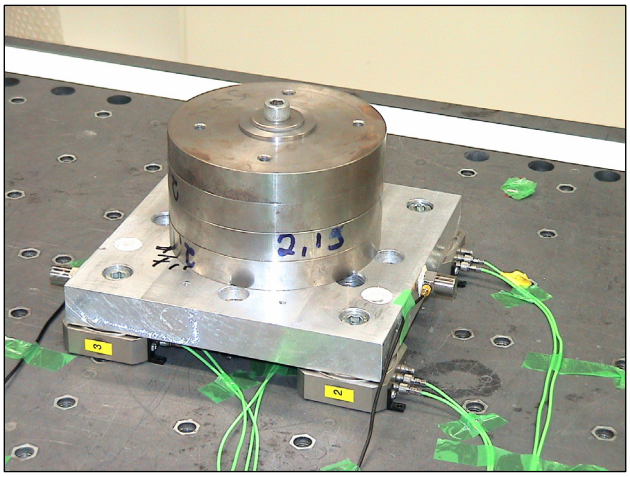

FIG. 8 Test adapter with calibration masses

4.3. Application

A successful application of force measurement and force notching is the test conducted for the Max-Planck-Institute for Solar System Research. Their SIR-2 SHRU-Unit was vibrated using force notching in order not to overstress the fragile construction.

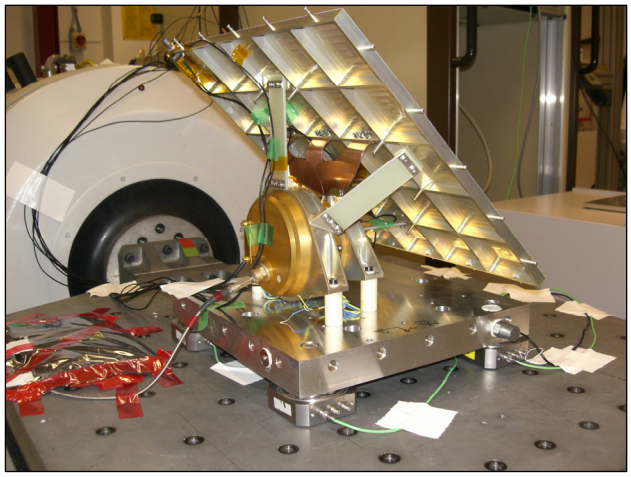

FIG. 9 MPIfS SHRU Unit on force measurement adapter

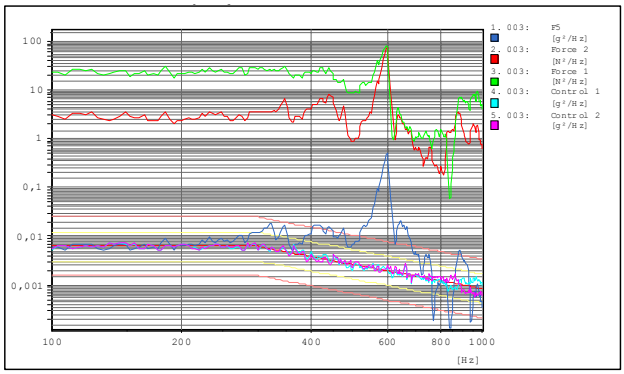

FIG. 10 Test curves force measurement

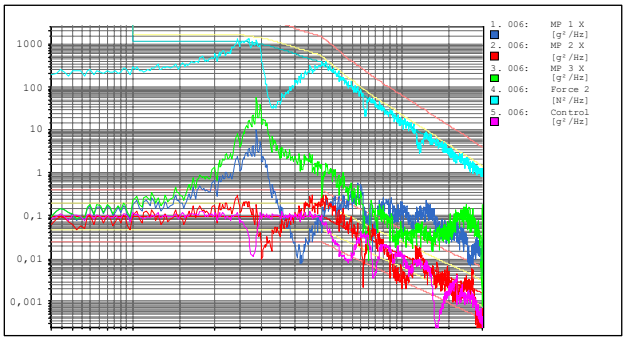

FIG. 11 Test curves force notching