VIRTUAL TESTING SIMULATION TOOL FOR THE NEW QUAD HEAD EXPANDER ELECTRODYNAMIC SHAKER

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Outline

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Introduction (1/3)

The main reasons to test satellites on shakers are:

- qualify the satellite to the launcher loads
- correlate the mathematical model (FEM) for the launcher authorities Coupled Load Analyses

This means reproducing on ground the same dynamic behaviour of the one encountered during flight ("test as you fly"), both in terms of:

- boundary conditions, and
- energy input at the satellite interface
Introduction (2/3)

The ideal situation would be:

- Having a theoretically fix-free interface;
- Following a desired profile (acceleration) with a certain frequency content within tight margins in terms of amplitude deviation (and null cross-coupling), and an unchanged damping for the spacecraft eigenmodes.

This becomes a difficult matter when dimension of spacecrafts and shakers’ tables are comparable and in the order of few tons, since:

- The structure dynamics of the facility couples with the test specimen one in the frequency range of interest.
Introduction (3/3)

There are theoretically two possible ways to tackle the issue:

- Controlling (shifting and damping) the dominant modes related to modal coupling; this allows to achieve qualification loads and boundary conditions at the interface.

- Accounting for the modal coupling in simulation; this allows to “predict” test performance and in turn to better correlate the Finite Element Model.

The first option is only possible until a certain extent for large structures!
Description of the Quad Head Expander (1/2)

Table

Vertical Guiding System

Seismic Mass

Shakers Cluster
Description of the Quad Head Expander (2/2)

**Working Area:**
3 x 3 m

**Performance:**
500-2000 kg up to 12.5 g  
300 kg up to 18 g

**Compliant with payloads of up to 10 t generating:**
Lateral forces up to 90 kN  
Overturning moment up to 350 kNm
The usual first step to analyse modal coupling is to make a FEM:
Structural Model (2/4)

Empty table: rocking mode
Structural Model (3/4)

Empty table: saddle mode
It is important to notice how the bending mode of the dummy payload couples dynamically with the rocking mode of the table. However, this says still little about the performance of the facility once the control system is in the loop!
Virtual Testing (1/2)

We observed in the modal model some possible couplings between payload and facility. This does not say anything definitive about test performance.

A series of items/parameters can be identified which may have an influence on test performance:

- Stiffness of the expander (table)
- Stiffness of the vertical actuator
- Stiffness of the guiding system
- Payload centre of gravity offset
- Shaker force synchronisation
- Closed Loop vibration control system
Therefore, virtual testing means:

Performing a simulation which is representative of the vibration test on the specific facility which is used for it, accounting for all the parameters which may impact or alter the dynamic behaviour of the payload.
The Quad Head Expander Simulator (1/3)

The Simulink model overview:
The Quad Head Expander Simulator (2/3)

Preliminary results: Empty Table Case
The Quad Head Expander Simulator (3/3)

Preliminary results: Dummy Payload Case
Conclusions

A virtual testing simulation tool for the new QHE electrodynamic shaker has been presented.

Despite the complexity in obtaining the theoretical boundary conditions during a vibration test for large spacecraft, the tool will allow structural analysts and test engineers to obtain reliable indications of the test performance before the test is physically taking place (virtual testing) and improve the model correlation.

This in turn will lead to avoid “overtesting” of large spacecrafts and to optimise margins of safety.

The implications of such an approach are potentially very important, because it will also heavily reduce postprocessing time, often underestimated during test campaign.
Thank you for your attention!

Questions?