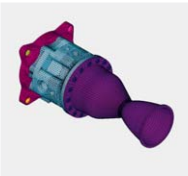
DYNAMIC STRUCTURAL ANALYSIS AND STRENGTH VERIFICATION OF A THRUSTER

When dealing with random vibrations, a non-linear dynamic analysis with ANSYS® helps to verify the strength of a thruster regarding complex loading conditions.



Analysis Task

In state-of-the-art dynamic load assessments, random loads are considered by Power Spectral Density (PSD) analysis using the model super position method. In fact, this is the only possible evaluation of linear stress cases where the linear system behaviour, as a basic assumption of the modal decomposition, is considered.

Fig.2: Thruster with combustion chamber

Fig. 1: Test of the ASTRIUM Homer Landing Vehicle

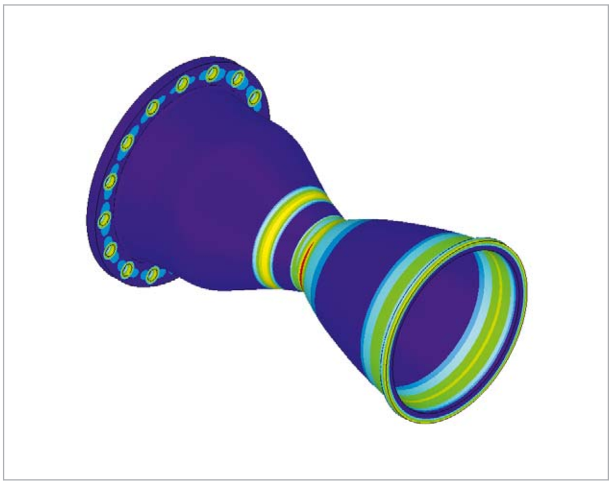


Fig.3: Accumulated plastic strain in the nozzle

During the flight of a transport rocket to the earth atmosphere, the equipment, such as the ASTRIUM Homer Landing Vehicle, is exposed to random excitation due to turbulent air flow. The structural strains caused by this highly dynamic load must be superposed with the plastic strains resulting from the high temperature pre-load which occurs during the test phase of the vehicle (Fig. 1). Therefore, an assumption of linearity is no longer given because of the undetermined uncertainty that would be introduced by forcing the superposition principle.

Methodology

In Figure 2, the finite element mesh of the thruster is shown. The model consists of many parts connected by pre-stressed bolts and spring elements. In addition, temperature dependent non-linear stress-strain-curves were included in order to model the plastic material behaviour. The resulting accumulated plastic strain in the nozzle of the thruster after applying the static load cases and 0.1 s of random excitation can be seen in principle in Figure 3.

Throughout this project, a procedure was applied that allows a correct consideration of random loads within a nonlinear analysis. The method is based on a random realization of the given PSD-spectrum (see Fig. 4) in the time domain (see Fig. 5) using an inverse Fast Fourier Transformation (FFT) and step by step incremental load analysis (static load cases + dynamic random accelerations).

In order to verify the critical time size within a sufficiently long total simulation time, a test run was performed with a single degree of freedom (SDOF) system and identical first natural frequency and damping ratio. In Fig. 6, the spring force of the SDOF-System under the defined random load is shown. The criteria that determines the required simulation time is basically the convergence of the variance of the systems response according to [1].

Customer Benefits

As a result of the analysis, it could be validated that the strain amplitudes during the atmosphere flight do not cross the critical failure limits of the material. In addition, the strength of the bolted connections could be verified under true dynamic load conditions which would not be possible conducting a linear PSD analysis. Furthermore, the analysis showed that the location of the maximum plastic strain along the nozzle is not identical to the location of the maximum equivalent stress found by simple superposition of the linearized load cases.

In summary, a full non-linear transient analysis under random load excitation allows a more detailed evaluation of the mechanical stress of the structure including non-linear material and contact behavior.

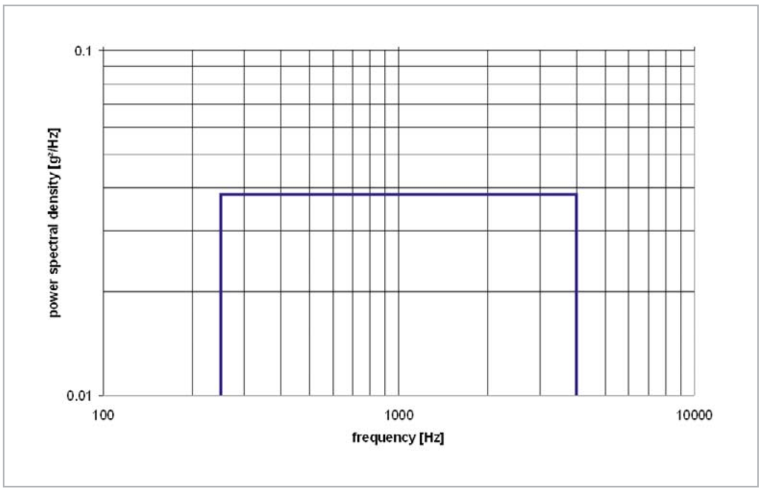


Fig.4: PSD-spectrum

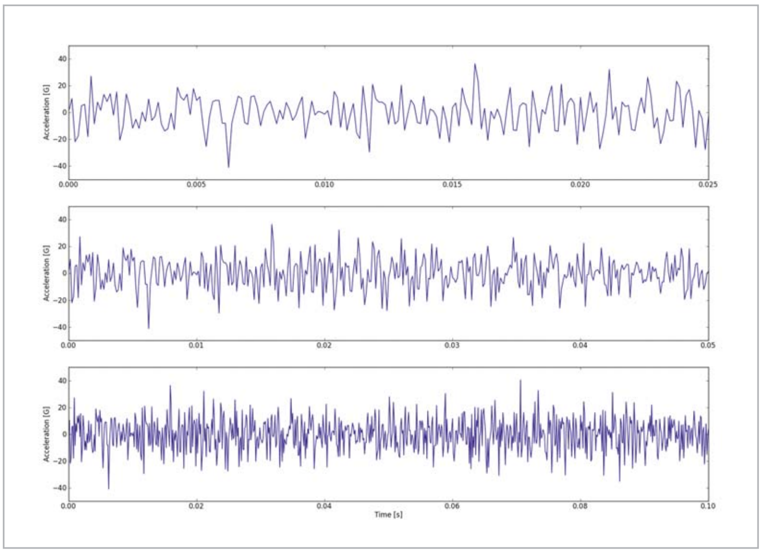


Fig.5: Random realization of time-signal with defined PSD-spectrum

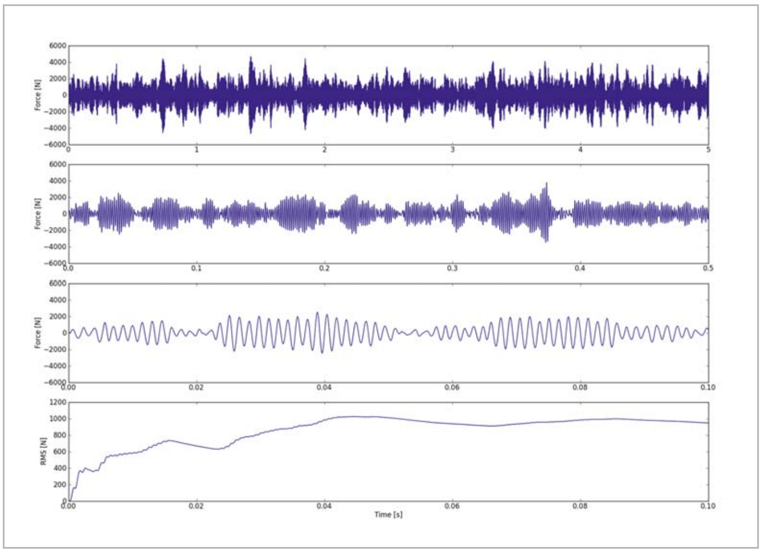


Fig.6: Random response of SDOF-system / time for convergence of RMS value

Source [1]: Bucher, C.: Computational Analysis of Randomness in Structural Mechanics, Taylor & Francis, 2009. | **Pictures:** by courtesy of ASTRIUM GmbH Space Transportation