THE INFLUENCE OF COMPRESSIBILITY ON THE DYNAMIC BEHAVIOUR OF THE ESC-TANKS

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Abstract

The dynamic behaviour of fluid filled tanks may be influenced by the compressibility of the fluid. Especially, it is known that the first axial mode of the LH_2-tank of the A5 stage ESC is significantly influenced.

Boundary Element Techniques provide powerfull tools for modelization and calculation of the dynamic fluid behaviour. However, the system matrices for a compressible fluid depends on the frequency. A solution will be presented that allow for the compressibility of the fluid. The search for the change of the sign of a certain determinant of the system yields both the eigenfrequencies of the structure and the frequencies of the cavity (fluid with rigid walls). Eigenfrequencies and pressure distribution within the LH_2 tank will be compared with the solutions of the incompressible tank.

Because the characteristic modal behaviour of the tanks with compressible and incompressible fluids is comparable, an update procedure of the mathematical models calculated with incompressible fluids seems to be an appropriate and powerful solution.

1 Introduction

The tanks of the upper cryogenic stage ESC of the launcher Ariane 5 (see figure 1) are pressurized axisymmetric structures filled with the fluids LH_2 and LOX. The software Dynost [1] was originally developed to overcome severe difficulties in the dynamic analysis of those tanks. The basic idea of Dynost is to use Fourier series combined with numerical correct solutions of the shell theory (no finite approximations, see e.g. [2], [3], [4]) and the boundary element technique [5]. Special account is taken to the correct representation of the internal pressure of the tanks.

The idealization is not restricted to axisymmetric structures. Dynost allows the generation of axisymmetric substructures e.g. in terms of Craig-Bampton matrices and the coupling with 3D finite elements.

Typical propellants used in space technology may be idealized by incompressible fluids. However, LH_2 has a very low bulk modulus. While the sonic velocity of LH_2 is 1200 m/sec and comparable to that of other fluids, the density is 71 kg/m^3 and very low. The sonic velocity of LOX is 913 m/sec and the density is 1140 kg/m^3, for comparison. Therefore, the evaluation of the influence of the compressibility becomes necessary.

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