In-orbit CFIE Experiment

In 1993, at the request of *ESA*, we developed a laboratory demonstration model of an active plate (35 $cm \times 60$ cm) controlled by *PZT* piezoceramics; it was later transformed into a flight model (to be flown in a canister) by our industrial partner *SPACEBEL* and the experiment (named *CFIE*: Control-Flexibility Interaction Experiment), was successfully flown by *NASA* in the space shuttle in September 1995 (Loix, 1994). According to the specifications, the experiment should fit into a *GAS*

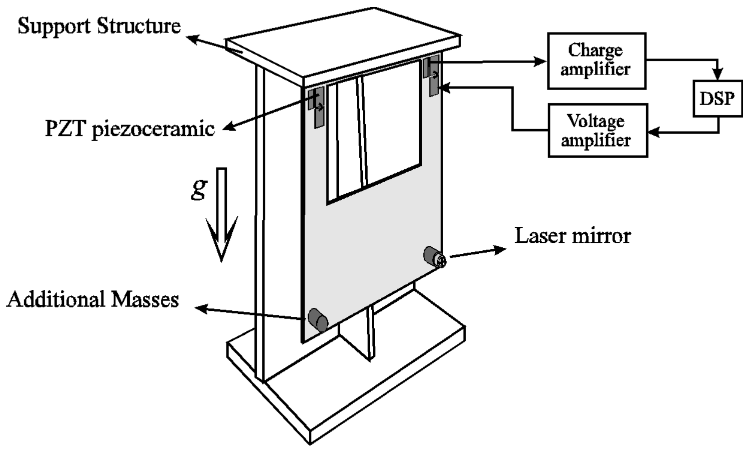

Figure 1: Laboratory demonstration model of the*CFIE* experiment.

canister (cylinder of 50 cm diameter and 80 cm high), demonstrate significant gravity effects, and use the piezoelectric technology. We settled on a very flexible steel plate of 0.5 mm thickness hanging from a support as shown in Fig.1; two additional masses were mounted, as indicated in the figure, to lower the natural frequencies of the system. The first mode is in bending and the second one is in torsion. Because of the additional masses, the structure has a significant geometric stiffness due to the gravity loads, which is responsible for a rise of the first natural frequency from $f_1 = 0.5$ Hz in zero gravity to 0.9 Hz with gravity.

E_{steel}	210	GPa
ν_{steel}	0.3	
ρ_{steel}	7800	kg/m^3
E_{piezo}	65	GPa
ν_{piezo}	0.3	
ρ_{piezo}	7800	kg/m^3
ε_r	2600	
ε_0	$8.854.10^{-12}$	F/m
$d_{31} = d_{32}$	205.10^{-12}	mV^{-1}

Table 1: Characteristics of the materials

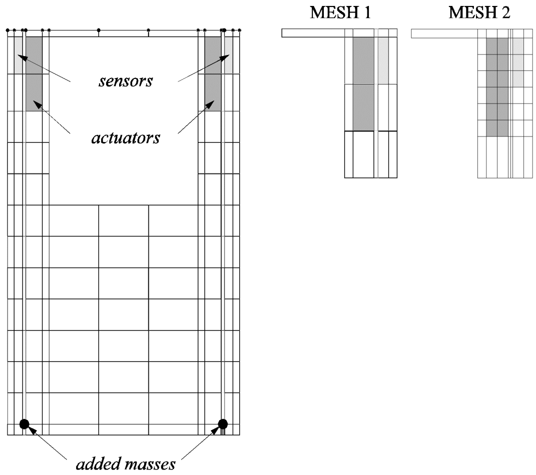

Figure 2: *FE* meshes

Each sensor is formed by a 12.5 $mm \times 55$ mm strip of 0.25 mm thick PZT piezoceramic bonded to the steel structure. Each actuator is formed by two 25 $mm \times 55$ mm strip of 0.25 mm thick PZT piezoceramic bonded to the steel structure and wired in parallel. The material properties are summarized in table 1. Figure 2 shows the FE mesh used to model the $CFIE$ experimental model, the two sensor/actuator pairs are represented by the shaded elements. The preconstraint induced by the gravity has been determined by a static analysis and taken into account for the dynamic analysis.

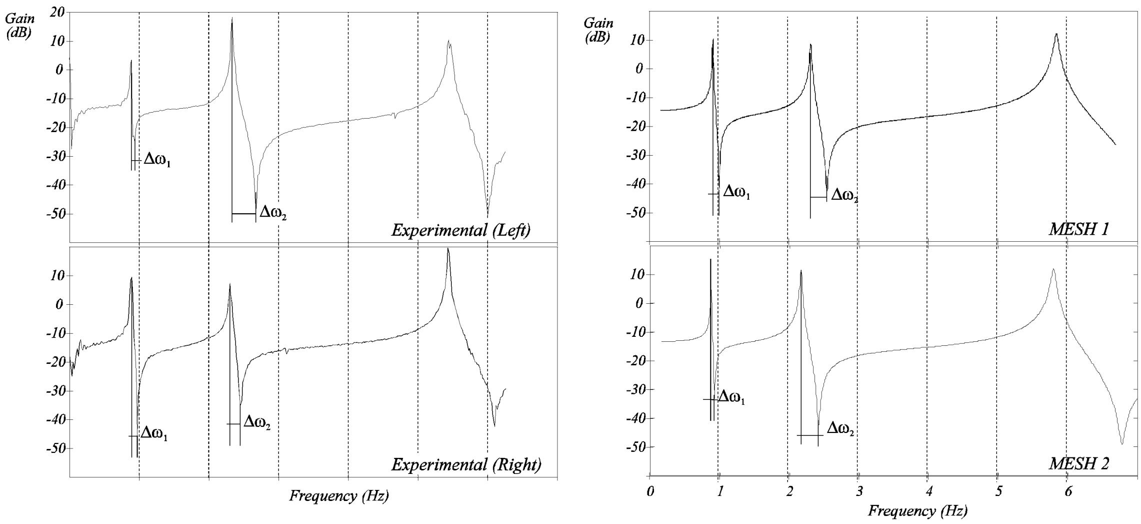

Figure 3: Results;

The transfer functions between the voltage applied on the piezoactuator and the charge appearing on the collocated piezosensor are considered. The comparison between experimental results (from the two sensor/actuator pairs) and the FE simulation are presented in figure 3. The controllability of a collocated system is mainly related to the distance between the zeros and poles of the open-loop transfer function (Preumont, 1997). The difference of the pole/zero distances measured experimentally between the left and right sides of the *CFIE* plate results from the mechanical dissymetry. Therefore, from the experimental results, we could expect a larger authority on the first vibration mode from the right actuator/sensor pair and on the second vibration mode from the left actuator/sensor pair. Such a difference of controllability of the first and the second modes between the two collocated actuator/sensor pairs was also observed on the flight model.

References

Loix, N., 1994, "CFIE Assessment Report", ULB-CMR.

Preumont, A., 1997, *Vibration Control of Active Structures - An Introduction*, Kluwer Academic Publishers.