

## OBJECTIVE

Passive proof mass dampers are useful for the reduction of vibrations in flexible structures. A proof-mass damper is basically a dissipating spring connected on one end to a free reaction mass. The reaction mass generates dynamic inertial forces due to its linear acceleration at and above resonance. On its other end, the proof mass damper is fixed to the flexible structure to be dampened. When the resonant frequency of the proof mass damper is tuned with the vibration mode of the flexible structure, such a structural mode is broken and the associated vibration level is significantly reduced (Fig 1).

However effectiveness of passive proof mass dampers depends strongly on how precisely they are tuned. In many applications, the tuning frequency is not quite constant and varies with the operating conditions of the system. For example in an helicopter, the rotor frequency varies with the flight conditions, which changes slightly the structural modes. Another limitation of usual proof mass dampers is in their incapability to address both very low frequency operations (<100Hz) and very large force generation (>1kN), as needed in aircraft or civil engineering applications.

To address these issues, a Tunable Dynamic Force Generator (TDFG) has been developed within the MESEMA EU project. In contrast to usual proof mass dampers, the TDFG is based on a pendulum structure. In this case, governing parameters are the moving mass and a returning force. This pendulum structure allows achieving a low resonant frequency associated with large inertial forces. It also allows using an electrically adjustable returning force to obtain the desired tunability.

## DESCRIPTION

Based on the concept from LPA-ZIP, the TDFG prototype was designed, manufactured and tested by Cedrat Technologies within the MESEMA FP6 EU project. Application tests are being performed by U.Naples (DII-SUN). The TDFG (Fig.2) is based on a pendulum principle: A usual pendulum makes use of gravity to generate the returning force and to define the natural resonant frequency. In the TDFG the returning force combines a mechanically adjustable preload thanks to a spring mechanism and an electrically adjustable preload component thanks to an internal preloading actuator. As a consequence, the pendulum resonant frequency can be adjusted mechanically (by easy manual screwing operation) and electrically. Different types of preloading actuators have been tested: an amplified magnetostrictive actuator called AMA 230L and an amplified piezoelectric actuator APA 230L. The AMA & APA® use a metallic shell to amplify motions from the smart material and to pre-stress it. Both actuators are good candidates for this application since they have the benefit to be small, compact and produce high forces with low power consumption.

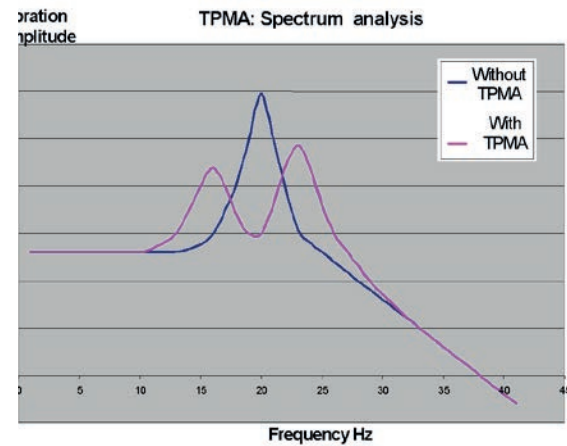


Fig. 1: Effect of a proof mass damper on the frequency response of flexible structure.

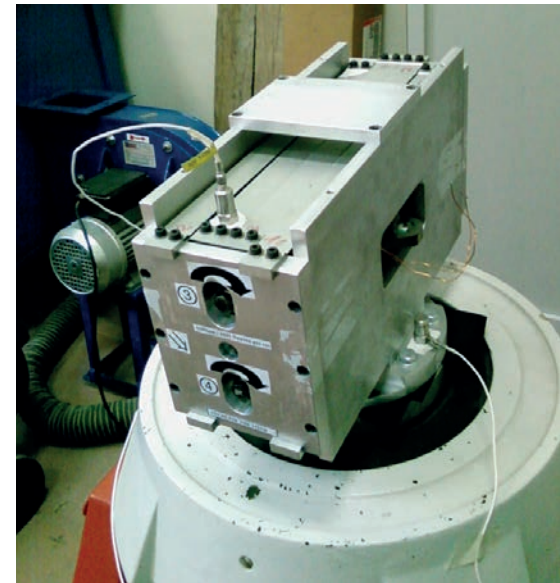


Fig. 2: TPMA in vibration test at DII-Sun, Naples.

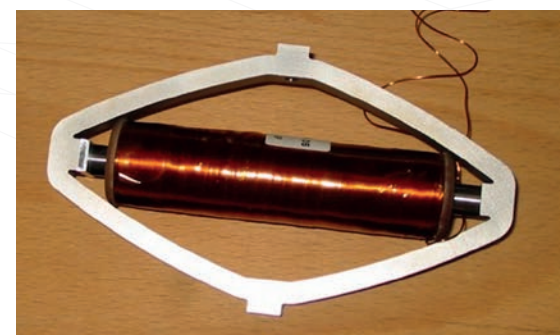


Fig. 3: AMA preloading actuator.

## PERFORMANCES OF THE TUNABLE PROOF MASS ACTUATOR

The TDFG prototype provides several proofs of concept:

- The resonant frequency can vary from 4 to 20Hz.
- The amplitude of motion of the moving mass (6.7kg) can achieve up to 10mm.
- The dynamic inertial force produced by the TDFG can achieve up to 1kN.
- The mechanical tunability is observed over a very large frequency range versus preload (Fig.4).
- The electrical tunability is observed by a frequency shift of the resonance versus applied voltage (Fig.5).
- The required electric power for the tunability can be lower than 1W.

The mechanical tunability given by the relationship between the preload and the resonant frequency has been measured with manual mechanical setting of the preload.

The electrical tunability has been established experimentally with both the AMA 230L and the APA 230L. However, the AMA 230L is a current-driven, low-voltage actuator while the APA 230L is a voltage-driven, low-current actuator. The preloading actuator leads to preload variation of 700N at max. At 1kN preload, the TDFG resonant frequency shifted from 6.4Hz to 7.7Hz, representing an absolute shift of  $\Delta f = 1.26\text{Hz}$  and a relative shift of 20%. The absolute and relative shifts decrease with higher preloads.

Other semi active proof mass dampers, vibration absorbers or active vibration damping solutions can be designed by CEDRAT TECHNOLOGIES using its design tools, lab facilities and technological know-how.

## APPLICATIONS

Applications of semi active proof mass dampers are in the damping of medium to large structures such as those meet in aircraft, helicopters, civil engineering, machine tools, ...

In summary, TPMA offer:

- An easy mounting on existing structure, simple interface and compact device
- No impact on the structural stiffness
- Great damping with low additional weight
- A resonance mode split
- Robustness & compliance with industrial requirements
- Large reaction force at very low frequency
- Mechanical and electric tunability with low electrical power requirement

## COLLABORATIONS, SUPPORTS

CEDRAT TECHNOLOGIES is partner of the FP6 EC MESEMA project collaborating with ALENIA, EADS, TACT, U.Naples, ZIP-LPA, ZFL.

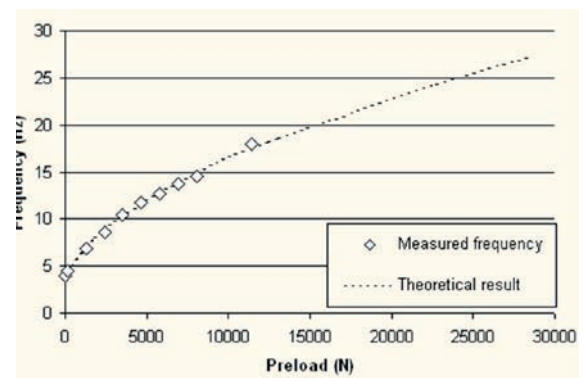


Fig. 4: Measured Frequency Vs Preload curve

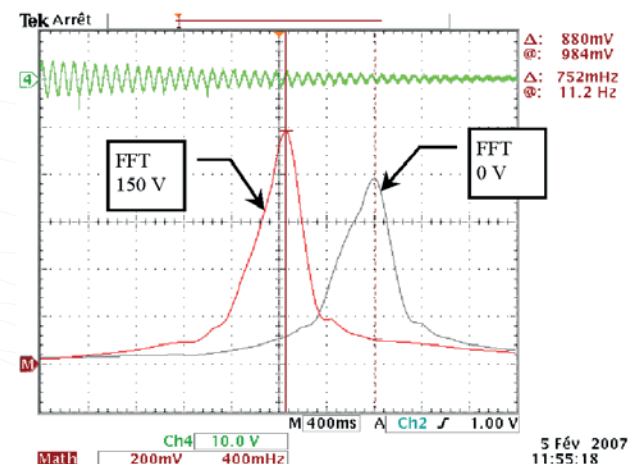


Fig. 5: Frequency response of TPMA vibration speed (Ch4) when preload actuator supplied (150V) or not supplied (0V)