Active Control of Vibrations of a Space Truss using APAs

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The new piezo actuators manufactured by Cedrat Technologies have been developed for the positioning control of space optics but they are spreading widely in various engineering fields such as precise positioning, intelligent control of shapes and generation or control of vibrations.
Their ability for the control or active damping of vibrations has been successfully demonstrated at the lab scale in space applications. In a first case, the piezo actuators were used for both for the control of launching vibrations and the positioning control in orbit of a telescope mirror. In a second set of space applications, these piezo actuators have been successfully integrated in a space truss using active tendons for control of micro vibrations, as publicly released at the Industry Space Days (ISD2001, Noordwijk, 9-10 Mai 2001) and as presented in this paper.

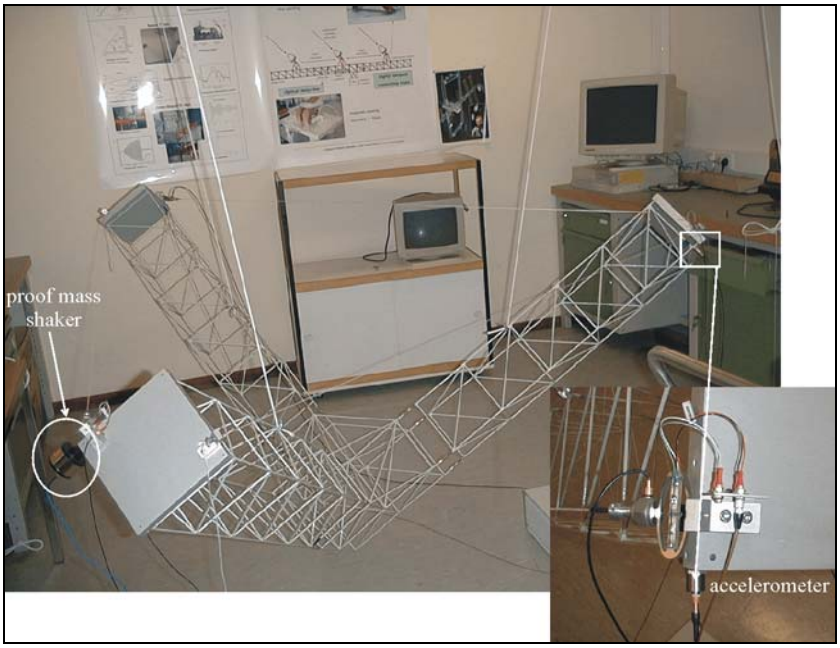
Free-floating space trusses are intended to hold interferometric equipments, which require a very high positioning accuracy and a very low level of vibrations. These equipments find applications in IASI instrument (Interféromètre Atmosphérique de Sondage dans l'Infrarouge) on METOP satellites and in IRSI/DARWIN. Fine mechanical stability in a free-floating space truss is difficult to achieve because this kind of structure is generally large. Consequently it is compliant, it possesses low frequency modes and might be sensitive to thermo-mechanical deformations. A first technique of mechanical control consists in replacing some truss bars by active bars, for example by Piezo Actuators as shown by the CASTOR experiments performed by CNES on the MIR space station.
Another technique consists in adding actuated cables (active tendon concept) between various points of the truss. The advantage of this method is that the truss mechanical properties (the modes base) are not modified and that the implementation of active tendons can be performed at a later development stage of the truss.

A demonstrator of an active tendon control of a free-floating space truss was performed by ULB (Univ. Libre de Bruxelles) in 1998, on its own funding. The truss is representative of a scaled model of the JPL-Micro-Precision-Interferometer. High damping ratios of the vibration modes were achieved. However, the active tendon mechanism proposed at that time relied on conventional piezo actuators amplified by a leverage mechanism based on ball bearings. Therefore this system was bulky, had a limited lifetime and was not compatible with space requirements.

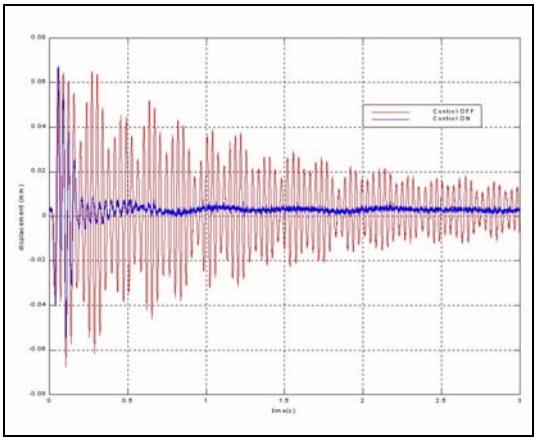
A recent work performed by Micromega Dynamics, ULB and Cedrat Technologies (Project Coordinator) for ESA/ESTEC (the European Space Agency) has consisted in implementing Amplified Piezo Actuators (APAs), in the active tendon control experiment of ULB and in testing the capabilities to actively damp the whole structure (ESA/ESTEC/ARCOP Contract N° 14425/00/NL/MV).

As a result, it was shown that the use of the APAs of CEDRAT in the active truss of ULB simplifies drastically the hardware implementation of active tendon control system while preserving the control performances of the previous design. The proposed actuator (APA100M) is a pulling device and experiences an internal amplification mechanism. Therefore the heavy leverage mechanism used for the Direct Piezo Actuator (DPA) can be replaced completely by a APA actuator acting directly on the cable structure (reducing the mass by more than a factor 10). As the actuator is still much stiffer than the cable, the reduced stiffness of the APA compared to the DPA does not deteriorate the control performances. Furthermore, the high resistance of the APA to bending moments and transverse forces allows removing the flexures used in the previous design. This is important because, for dynamic applications, these flexures are usually the weak points during fatigue testing.

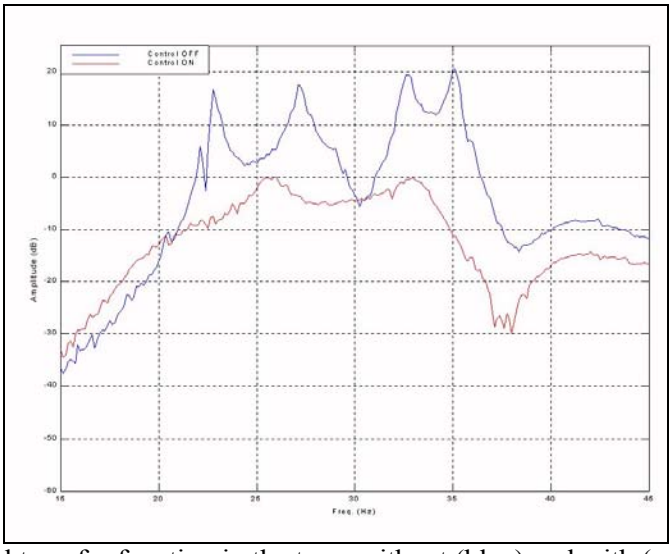
In conclusion, the integration of the APA actuators in the experimental truss was considered successful by ESA and brought a significant improvement on the previous state of the art.



Space truss from ULB, integrating an active control of vibrations based on tendons actuated by APA100Ms



Truss vibration level after a shock excitation, without (red) and with (blue) control.



Mechanical transfer function in the truss without (blue) and with (red) control.