Z-Damper
Z-Coupled Full System for Attenuation of Vibrations

State of the art – Background

Transmission of vibrations through a structure and systems to reduce, mitigate or supress them are one of the most studied topics in Mechanical Engineering

Damping of vibrations has been traditionally limited by two main factors:

1) Service temperature: Damping elements such as fluid dampers or elastomers rarely operate at temperatures above 100ºC
2) Lowe frequency vibration isolation: Dampers dissipate energy proportionally to the input speed. In addition, vibration isolation at very low frequencies requires very elastic support which is not always possible due to static deflection requirements or dynamic envelope limitations of the structure.

In the FP7 Clean Sky Z-Damper Project, Mag Soar Sl and University of Alcalá de Henares (UAH) has developed a new vibration isolation technology that eliminates this two limitations at the same time.

The Z-Damper technology has been developed for isolation of the high levels of vibrations at low frequency coming from the Counter Rotating Open Rotor engine in the rare event of a blade lose.

In order to isolate efficiently the vibrations coming from the engine that might compromise the manoeuvrability of the aircraft, the Z-Damper takes advantage of impedance matching to maximize damping in a desired frequency bandwidth. In addition, the high range of working temperatures of the Z-Damper allows allocation of the device closer to the vibration source, improving the effectivity of the isolation

Objectives

Z-Damper project has provided the birth of a new breakthrough technology in vibration isolation. The solution could be a key enabling technology for the success of the CROR engine in the SFWA. However, the applications of the Z-Damper technology cover a wide range of applications: from microvibration isolation to passive protection of buildings and structures against earthquakes.

The Z-Damper takes advantage of impedance matching to, similarly to an electric transformer, transform a high-force low-frequency vibration into a high speed low-force vibration source much easier to isolate.

Using magnetic contactless technology, the Z-Damper does not require lubrication or any fluid to operate, does not present backlash and wear is virtually eliminated, improving lifetime and performance of the device.

In addition, a temperature range from -55 to up to 250ºC has been demonstrated for the technology. Further analysis show potential of similar devices to operate to temperatures up to 500ºC.

Two main prototypes were manufactured and tested in order to demonstrate the performance of the Z-Damper technology in two different ways:

1) Z-Transmitter prototype: A prototype of an impedance coupling device which has been connected to external elements such as springs or inertial mass (Tuned Vibration Absorber)
2) Z-Damper prototype: A prototype of an integrated high-temperature damper with a nominal service temperature of 200ºC. The objective has been to demonstrate a high damping ratio (up to 35 Ns/mm) at low frequency (about 12 Hz).

Description of work

The project work plan has been divided in seven Work Packages according to the topic requirements. Five of them are related to RTD activities:

<u>**RTD:**</u>

WP1: Trade-off study
WP2: Evaluation and adaptation of the technology
WP3: Detailed design of the prototype and test rig
WP4: Manufacturing of the prototypes and test rig
WP5: Experimental characterization

<u>**Other activities:**</u>

WP6: Protection, diffusion and exploitation

<u>**Management activities**</u>

WP7: Project Management

Mag Soar Sl is the inventor of the technology and acts as coordinator of the consortium. UAH is partner of the consortium and has contributed to the success in the project.

All tasks were completed successfully with an appropriate allocation of the resources.

Results

Clean Sky

TESTBENCH

A dedicated testbench has been specifically designed, manufactured and set-up. It has the capacity to generate high input vibrations in a frequency bandwidth from 0 to up to 120 Hz. A heat and ventilation circuit allows to control the test temperature and ventilation requirements from -55ºC to up to 250ºC. A picture of the testbench is shown in Fig. 1.

In addition, two prototypes have been manufactured and tested:

Z-TRANSMITTER PROTOTYPE

A prototype of an impedance coupling device (see Fig.2). It has been tested as an enhanced spring system and as a Tuned Vibration Absorber. A transmittable force up to 4700 N has been demonstrated in a temperature range from room temperature to up to 100ºC. The impedance coupling concept has been validate and a clear potential as TVA has been observed.

The device acting as a tuned vibration absorber has demonstrated the potential of weight saving in a factor of 10 with regard to classical tuned vibration absorbers. A case study has been generated using the experimental results from the test for comparison of two classical TVA, one incorporating the Z-Transmitter and the other not. Results of that study are shown in Fig.3

Z-DAMPER PROTOTYPE

A prototype of a high-temperature integrated eddy current damper with a multiplication factor of 7. A picture of the prototype is shown in Fig. 4.

The prototype has demonstrated a very high damping capacity (7 kN maximum damping force, equivalent viscous damping coefficient of 35 Ns/mm) at low frequencies. Thanks to the impedance matching concept, the Z_Damper has been tuned to maximize damping at 12 Hz while vibration isolation at higher frequencies is not reduced at all.

The damping performance of the device has been demonstrated at temperatures up to 200ºC. A hysteresis loop (input force vs. vibration amplitude) is shown in Fig. 5 at 200ºC

SOFTWARE TOOL

After experimental validation of the design procedures and multhiphysical FEM models, a software tool has been developed.

This software tool allows mechanical engineers to preliminary design a vibration isolation system incorporating the Z-Damper technology.

The software has been designed to be user friendly and to not require any specific and complex training or specific software programs to be used.

PATENT

A European Patent Application has been presented (EP 153824610.0).

a) Timeline & main milestones

The project was developed in 22 months from July 2014 to April 2016. 12 deliverables have been delivered during the project.

6 Milestones have been reached during the project:

1: Evaluation and selection of a technology (M3)
2: PDR approved (M6)
3: CDR approved (M12)
4: Demonstrator manufactured and assembled (M17)
5: Final Report (M22)
6.1 Patent Register (M 22)
6.2 Exploitation business plan (M 22)

b) Environmental benefits

According to IATA (2008), aviation contributes about a 3% to the total worldwide CO2 emissions.CROR engines has the potential to provide a 25-30% reduction in fuel consumption and CO emissions relative to current turbofan engines. In other to fulfil EU CO2 and NOx emission reduction goals, the utilization of the CROR engine technology would represent a major milestone, however, the technology present some drawbacks that might increase the risk of using this motor technology and compromise the manoeuvrability of the aircraft under the most critical scenarios.

Z-Damper technology has important environmental benefits by de-risking of the CROR by providing a unique vibration damping performance. In this context, Z-Damper could be a key enabling technology for the success of the CROR concept.

In addition, the Z-Damper technology will eliminate the need of hydraulic actuators or resilient materials used for suppression of vibrations reducing the environmental impact of its process of manufacturing and elimination after their service life.

Finally, the Z-Damper technology could be further developed for vibration energy harvesting, obtaining electric energy from vibrations and therefore increasing overall aircraft efficiency. This can be especially relevant in the future aircrafts which follows a policy of transition to a more electrical aircraft.

c) Dissemination / exploitation of results

PAPERS

A paper has been published in the open source peer-review journal *"Machines"*:
J.L. Perez-Diaz, I. Valiente-Blanco and C.Cristache: Z-Damper A New-Paradigm for Attenuation of Vibrations, Machines 43 pp. 1-10, 2016.

CONFERENCES/CONGRESS

Results of the Z-Damper project has been presented at the following conferences/congress:

ESA Final Mechanism Presentation Days 2016, ESTEC, Norrdwicjk, the Netherlands 17th June 2016

EUROMODAL 2015, Alcalá de Henares Spain, from 16th to 18th of June 2015

Magnetics in a Green Future, UK Magnetic Society of Europe conference, Copenhagen Denmark, 2nd and 3rd of June 2015

Space Robotics Symposium, Glasgow UK, 29th and 30th of October 2015

Demonstration and Exhibition of the Z-Damper to the students of Industrial Engineering of the University of Alcalá de Henares, Valdemoro Spain

WEBSITE

Z-Damper project news and main milestones, pictures and videos are available for public access at MAGSOAR website:
http://www.magsoar.com/z-damper.html

After the end of the project dissemination activities will continue. Three more papers are planned and a couple of congress communications.

d) Communication

Periodical press release and communications have been published in Mag Soar website

http://magsoar.com/news---media.html

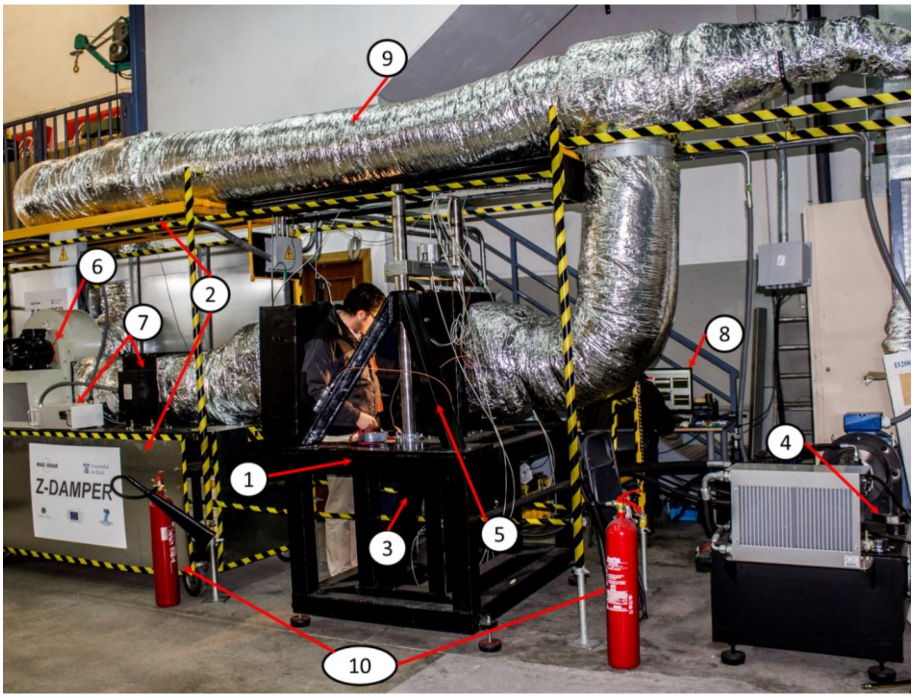


Figure 1: Z-Damper Testbench

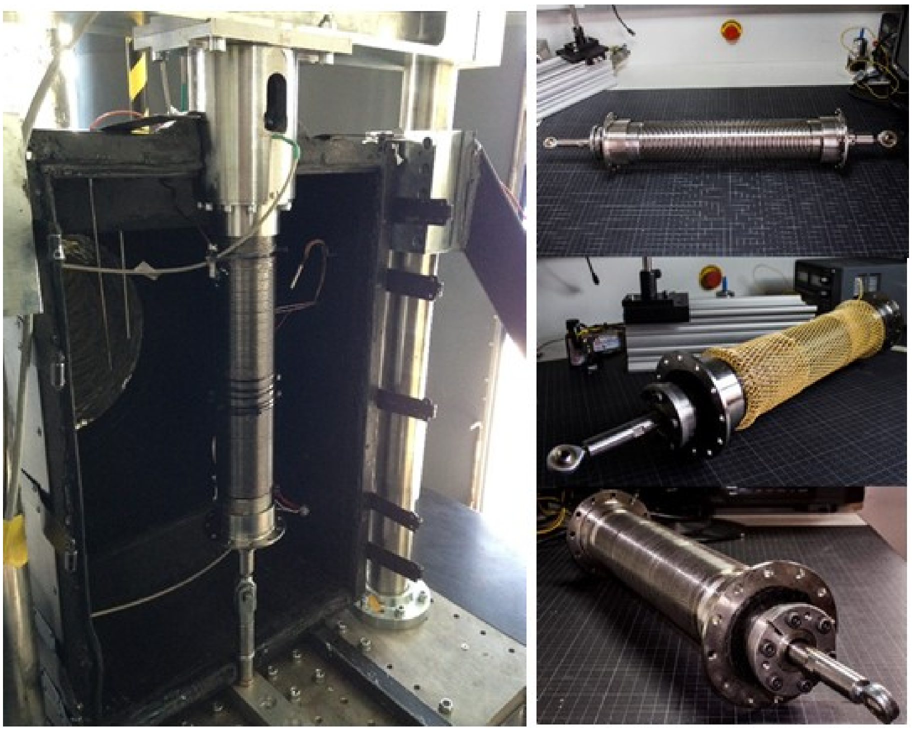
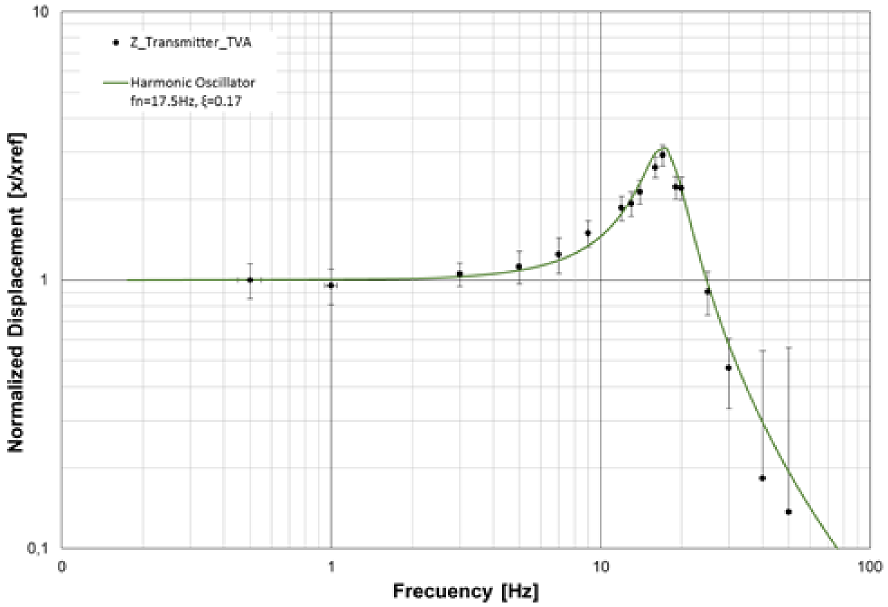


Figure 2: Z-Transmitter Prototype



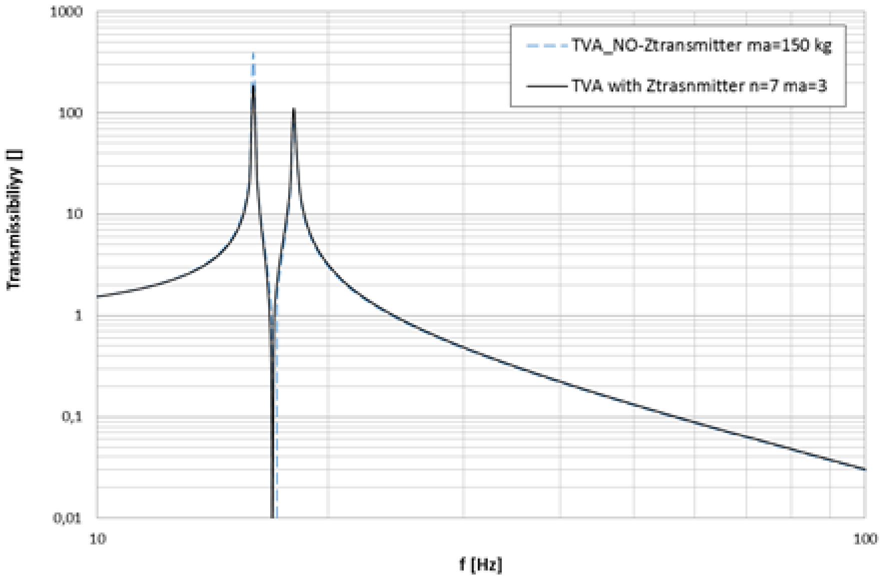


Figure 3: Z-Transmitter normalized displacement vs. frequency curve (top) and comparison of ideal behaviour of a TVA with (9.6 kg) and without (150 kg) Z-Transmitter.

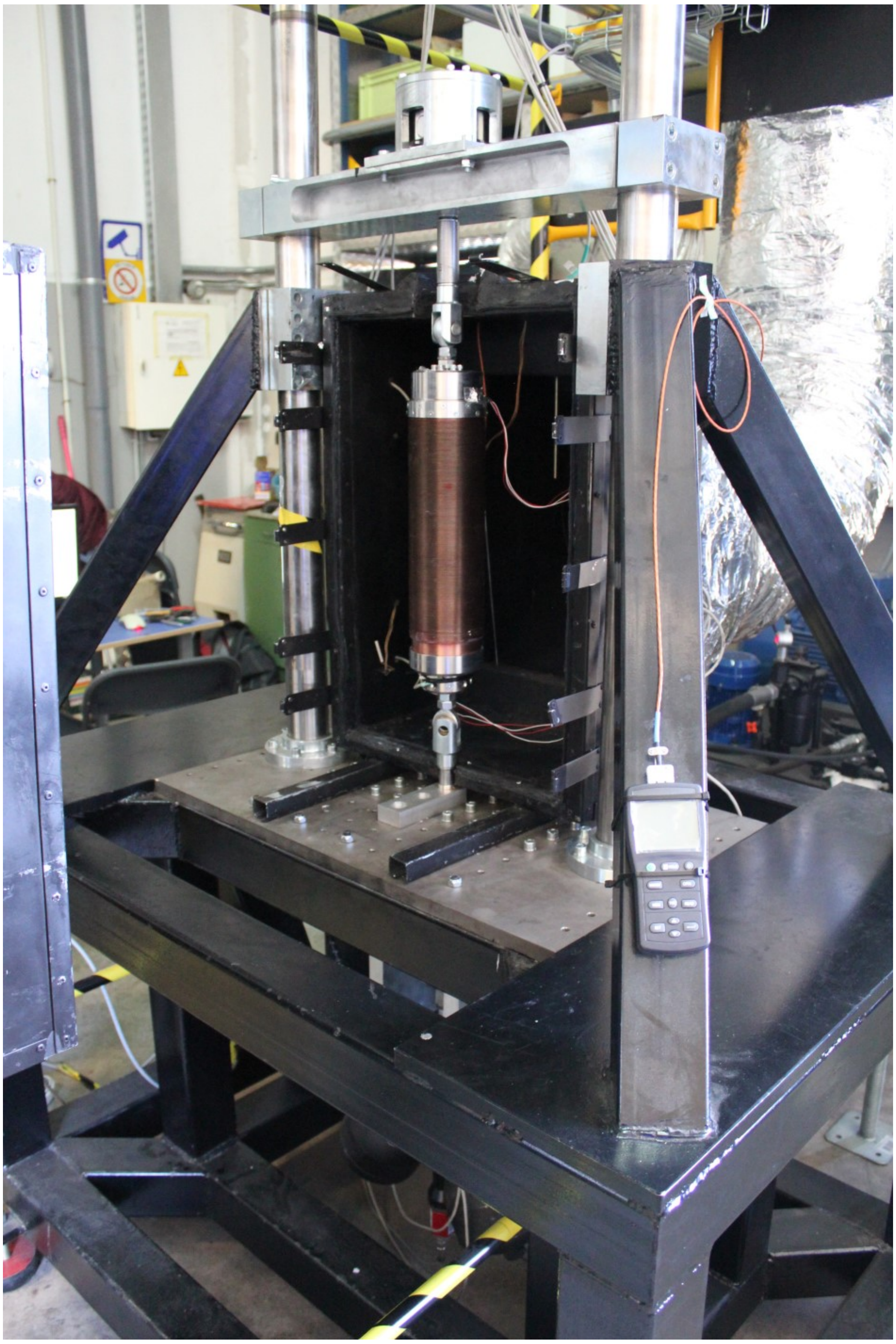
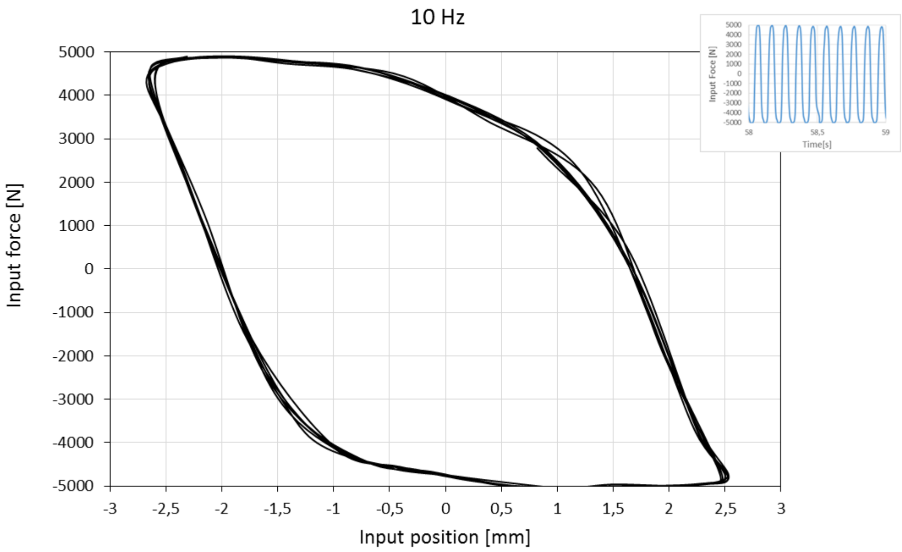


Figure 4. Z-Damper high temperature prototype



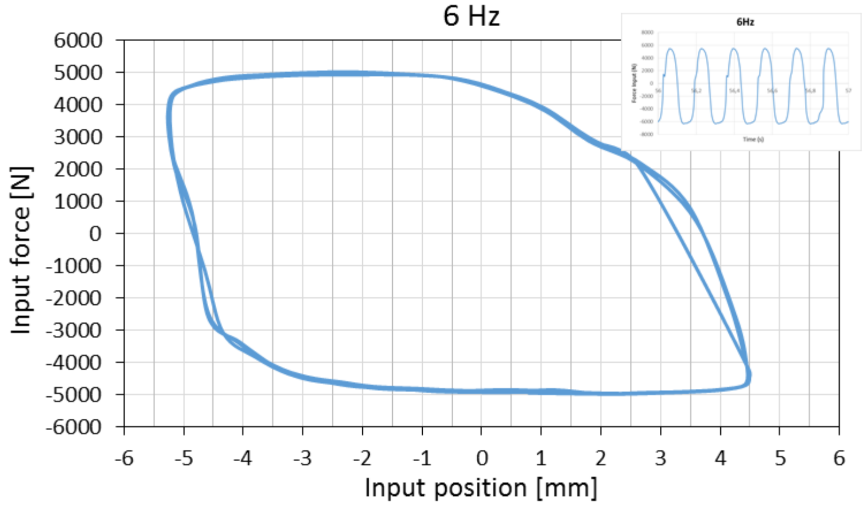


Figure 5. Input force vs. input position for an input sinusoidal vibration of 2.5 (top) and 5 mm (bottom) amplitude at 10 and 6 Hz respectively. Results at 200ºC.

Project Summary

Acronym: Z-Damper

Name of proposal: Z Damper— Z-Coupled Full System for Attenuation of Vibrations

Involved ITD	Smart Fixed Wing Aircraft ITD
Grant Agreement:	632492
Instrument:	Clean Sky
Total Cost:	696052,00 €
Clean Sky contribution:	522039,00 €
Call:	JTI-CS-2013-02-SFWA-03-014. Vibration reduction systems in pylon area.
Starting date:	1st July 2014
Ending date:	30th April 2016
Duration:	22 months
Coordinator contact details:	Mag Soar SL Address: Avenida de Europa 82, 28341 Valdemoro, Spain Contact email: info@magsoar.com Website: www.magsoar.com Scientific contact: Ignacio Valiente-Blanco ivaliente@magsoar.com
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Participating members:	Mag Soar Sl (Coordinator) University of Alcalá de Henares Scientific contact: José Luis Pérez-Díaz jl.perezd@uah.es