LOW FREQUENCY DAMPER

Ion NILA, INCAS, inila@incas.ro
Viorica ILINOIU, INCAS, ilivio@incas.ro
Dan ABABEI, INCAS, adan@incas.ro
Bogdan DOBRESCU, INCAS, bdobrescu@incas.ro
Radu BOGATEANU, INCAS, radub@incas.ro

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Abstract

The low frequency damper is an autonomous equipment for damping vibrations with the 1-20Hz range.

Its autonomy enables the equipment to be located in various mechanical systems, without requiring special hydraulic installations.

The low frequency damper was designed for damping the low frequency oscillations occurring in the circuit controls of the upgraded IAR-99 Aircraft.

The low frequency damper is a novelty in the aerospace field ,with applicability in several areas as it can be built up in an appropriate range of dimensions meeting the requirements of different beneficiaries. On this line an equipment able to damp an extended frequency range was performed for damping oscillations in the pipes of the nuclear power plants.

This damper, tested in INCAS laboratories matched the requirements of the beneficiary.

The low frequency damper is patented – the patent no. 114583C1/2000 is held by INCAS.

Introduction

Low frequency vibrations or infrasound occur in the aircraft system control. They operate permanently causing the pilot fatigue, discomfort, and in some cases induce a delay between the pilot reaction and the deflection of the control area. The analysis and synthesis of a low frequency damper came as a necessity for the IAR-99 aircraft. At longitudinal controls the pilot is subject to tiring efforts in the small and medium deflection area of the control surface.

The designed equipment was studied in the laboratory through numerical simulations by the INCAS specialists which made evident the decrease and/or elimination of these vibrations. It is also useful to install in the mechanical circuits of the automatic systems of various complex installations from different activity fields a 1÷20 Hz range frequency damper.

This equipment contributes substantially to the increase of the operating life of those installations.

Construction

The low frequency damper shown in Fig.1 consists of two modules designed independently: a hydrostatic module and a mechanical module. These modules are assembled inside a common cylinder.

The hydrostatic module – located in the central area of the equipment provides the vibrations damping and the damage function. The elements of this module form a compact construction as follows:

- double -acting hydraulic cylinder;
- Supply valve;
- Piston hydraulic accumulator;
- Throttle;
- Relief valves to overpressure;
- Bleeder utilised only when loading the module with hydraulic fluid.

The mechanical module – developed in cascade, from the exterior surface of the hydrostatic module to the common cylinder of the equipment, maintains the neutral position of the equipment and implicitly of the aircraft control circuit, giving an extra effort to the stick which is proportional to its stroke, thus, generating a sensibility decrease of the control in the small deflection area. The elements of this module are concentrically assembled with the hydraulic module in the following configuration:

- Special bush;
- Spring operating beakers
- Compression spring;

The ends of the common cylinder are provided with arc limiting caps and installation elements.

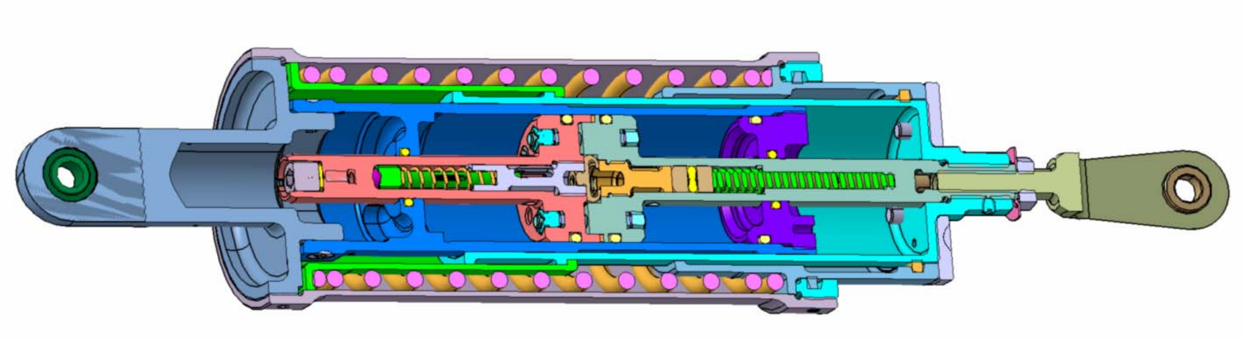

Fig.1. Low frequency damper

Operation

When applying a strong disturbing force, in one direction or other, the piston rod moves and through the beakers disposed in cascade acts on the big spring stressed only to compression. The spring ensures the neutral position of the equipment and collects the shocks caused by the disturbing force. Simultaneously with the resort compression, in the hydrostatic module, the pressure Δp increases, which compels the hydraulic liquid to enter through the holes of the piston rod to pass through the throttle and to enter into the chamber opposite the direction of the piston displacement. The vibration damping takes place in this working sequence, the working pressure being equal in the two chambers of the module. The pressure difference on the throttle $\Delta p_{throttle}$, constant throughout the working stroke corresponds to the D force of the diagram shown in Fig.2. When increasing the force higher than the $F_{max\ damping}$ a pressure difference $\Delta p_{valve} > \Delta p_{throttle}$ appears overcoming the forces from the relief valves springs; they open allowing the hydraulic liquid to pass easily from one chamber to another. At this moment the damping function is cancelled because the hydraulic fluid doesn't achieve the required hydraulic resistance. There are pairs of discharge valves on each operating direction, which return on the initial position when the pressure force decreases.

To compensate the pressure loss in the working chambers of the double-acting hydraulic module, a piston hydraulic accumulator incorporated in the big piston rod is provided. Under the action of a prestressed compression spring, the accumulator pushes the hydraulic fluid in the working chambers as the pressure within them decreases.

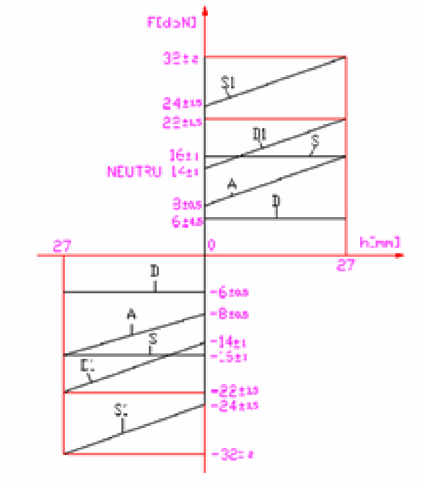

Fig.2. Working diagram of the damper

Technical characteristics:

Frequency: Min.1Hz;
Amplitude: Min. 3 mm;
Min. Force: 22 daN;
Static pressure: 3 daN/cm^2;
Temperatures range: –55º C ÷ 70º C.

Damping constant

$$c = \frac{S^2 \rho}{2\, c_d^2 a^2} \qquad (1)$$

Where:

c_d – Flow coefficient through throttle
ρ – Hydraulic fluid density
S – Useful area of the piston damper
a – Central throttle surface

A representation of the response amplitude variations and phase shift, which are the most important elements of the response, with the disturbing force ripple is given in Fig.3; ξ is the damping factor corresponding to a damping coefficient.

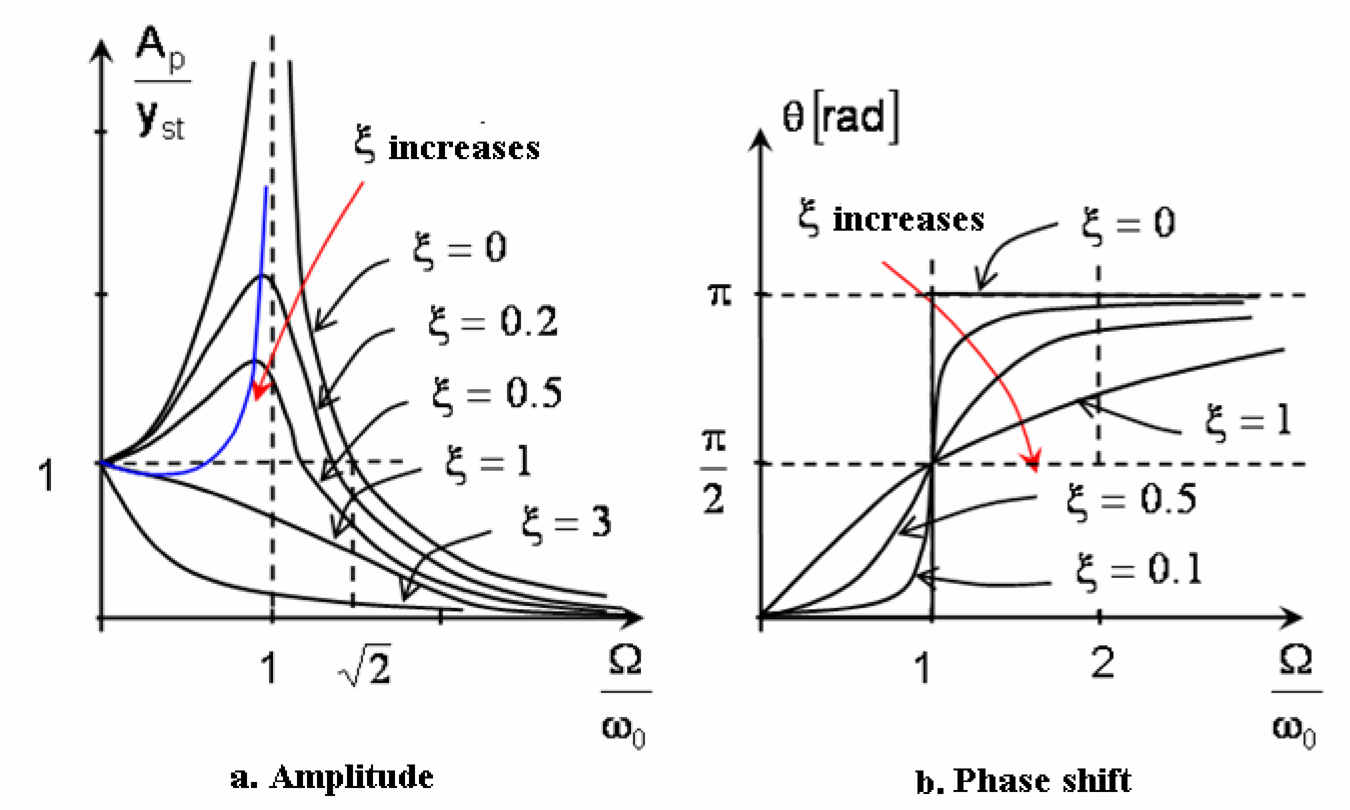

Fig.3. Amplitude variation and phase shift

Related applications

By extending its dimensional range, the damper was tested for damping oscillations occurring in nuclear plants pipes, up to 120 Hz frequencies and amplitudes of less than 12 mm.

Experiments were assisted by a system of data acquisitions and processing which highlighted the response of the damping system according to the damping diagram shown in Fig.4.

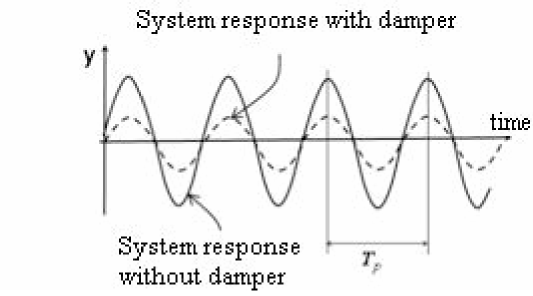

Fig.4. Variation with time of the amplitude response for the pipeline section with and without attached dampers

If the disturbing force has a certain variation with becomes repetitive after a T period, the vibrations analysis of the pipeline system and their effectiveness damping assume the following:

The force expression in the Fourier series expansion:

$$\Omega = \frac{2\pi}{T} \quad (2)$$

$$F_p(t) = F_0 + \sum_{n=1}^{\infty} F_n \cos(n\Omega t - \psi_n) \quad (3)$$

Average

$$F_0 = \frac{1}{T}\int_0^T F_p(t)dt \quad (4)$$

Amplitude of the harmonics of n

$$F_n = \frac{2}{T}\int_0^T F_p(t)\cos(n\Omega t)dt \quad (5)$$

Applying the principle of the overlapping effects of each disturbing force harmonic and evaluating the stationary response, we have

$$y(t) = A_0 + \sum_{n=1} A_{pn} \cos(n\Omega t - \psi_n - \theta_n) (6)$$

where the amplitudes are

$$A_0 = \frac{F_0}{k} \quad (7)$$

$$A_{pn}=\frac{\frac{F_n}{k}}{\sqrt{4\xi^2\left(\frac{n\Omega}{\omega_0}\right)^2+\left(1-\left(\frac{n\Omega}{\omega_0}\right)^2\right)^2}} \quad (8)$$

and the phase shifting between the harmonic of n order of the response and the harmonic of n order of the disturbing force are

$$\theta_n=arctg\frac{2\xi\frac{n\Omega}{\omega_0}}{1-\left(\frac{n\Omega}{\omega_0}\right)^2} \quad (9)$$

The spectral analysis makes evident the response amplitudes of the pipelines system in the two versions :with or without damping system attached. The disturbing force amplitude spectrum,(see Fig.5), is presented in correlation with the response amplitude spectrum, shown in Fig.6 for the two experimental versions.

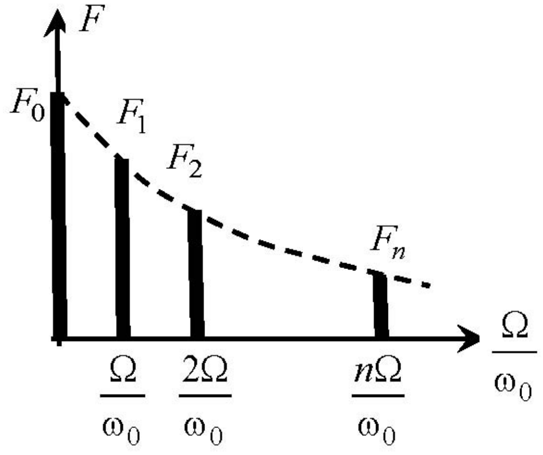

Fig. 5. Amplitude spectrum of the disturbing force

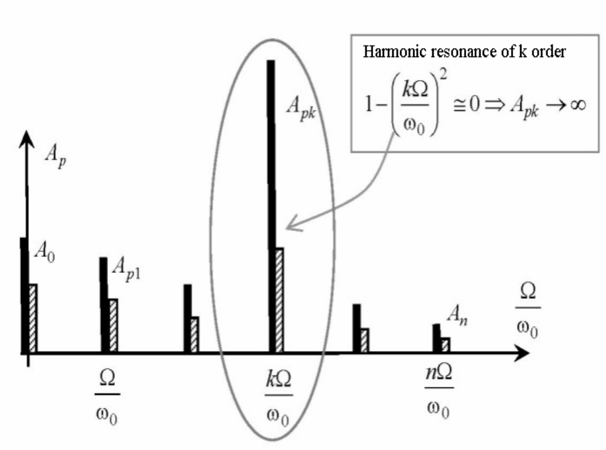

Fig.6. Amplitude response spectrum

Tests were made for each measuring point. On the test bench, with the attached damping system, the response amplitudes were reduced in different proportions for a large part of its harmonics.

Results highlighted malfunctioning around a resonant harmonics of k order as seen in Fig.6.

On the test bench in Fig.7, for a representative assembly of a pipe section, typical for nuclear plants installations, the ripple of the disturbing force was induced by a servo-valve actuator. Dampers were installed in the critical areas of the pipeline section for oscillation damping.

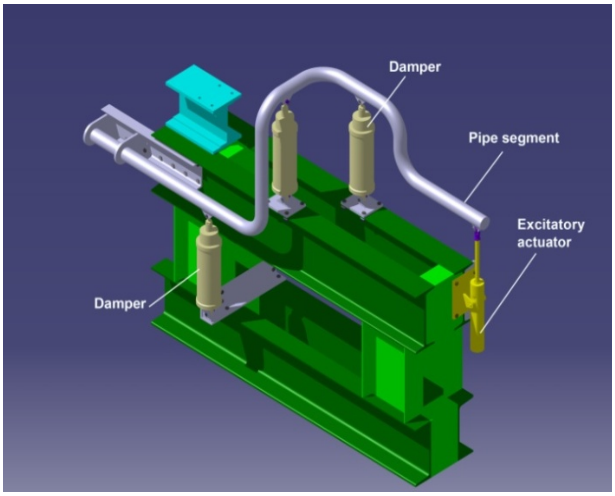

Fig.7. Test bench

Conclusions

The low frequency damper is unique in the field. Its novelty lies in its (hydrostatic) operational autonomy together with its design and compact construction. Its operating life is substantially improved by the incorporated hydrostatic accumulator which ensures the replacement of the hydrostatic hydraulic fluid lost at the outer rod level. To protect the controls circuit in case of the force exceeding over a certain limit, the damper is provided with a damage function ensured by pairs of discharge valves located on each operating direction. When the circuit returns to the operating nominal parameters the damper resumes by itself the damping function.

The modular design and construction of the damper allow it to be diversified in a wide dimensional range and consequently to damp a wide frequency and amplitudes ranges. The paper deals with a related application for damping oscillations occurring in the nuclear plant pipelines.

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