THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICHAL ENGINEERING, ISSN 1224-5615
2012

ENERGY DISSIPATION DEVICE USING FLUID DAMPERS

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ABSTRACT

This scientific paper presents a solution that is adequate for the seismic isolation of small and medium size buildings and bridges. Comprising two seismic isolating devices, the described arrangement is suitable for dissipating an increased level of energy induced to infrastructure by the seism. As other hybrid arrangements, this one uses viscous dampers in order to limit the distance of induced movement of the infrastructure. The internal design of the fluid damper is analyzed using CFD software, to ensure a proper dissipation of the seismic action and to limit its destructive effects.

KEYWORDS: fluid damper device, viscous damper, seismic isolation, energy dissipation, CFD

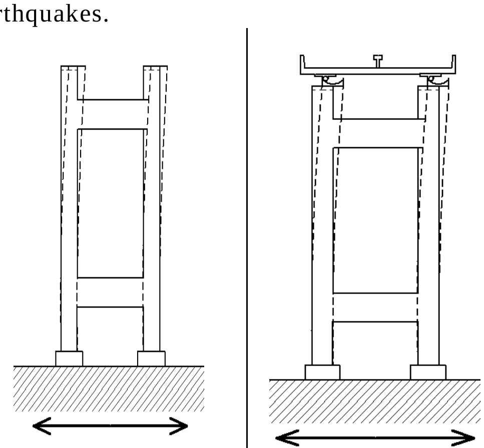
1. INTRODUCTION

The main concern of designers and building structures manufacturers is to be able to provide a high level of safety for their work in terms of seismic action. For this reason, engineers make use of special devices included in the structure that performs seismic isolation. These devices, considered structural control devices, perform decoupling of the superstructure from the foundation thus avoiding transmission of seismic forces from the foundation, to superstructure when an earthquake occurs. The simplest isolation devices, considered as passive control devices, are the rubber based systems, friction systems, or fluid-based systems. The study presented in this scientific paper investigates an adaptive seismic isolation system meant to protect bridge or viaduct structures subjected to a variety of seismic ground motions. The seismic isolation system solution proposed by the authors is one of a composed type. The research concentrates on the analysis and implementation of an adaptive hybrid isolation system composed of two kinds of passive isolation devices, one based on mechanical friction force and the other based on viscous fluid friction. Isolator system combines the actions of sliding on a concave surface achieved by friction bearings with movement resistance acquired by viscous fluid dampers. This composed solution can accomplish partial disconnection of the superstructure from foundation as providing freedom of movement for superstructure on friction bearings up to a certain amount of displacement when the hydraulic system starts to play the role of anchor point at the end of the stroke of friction systems.

CFD analysis of the fluid damper system focused on the behavior of the friction viscous device (FVD), during the dynamic regime.

2. ISOLATION DEVICE OPERATION PRINCIPLE

The study focuses on the analysis of seismic isolation systems that can be used for bridges and viaducts in order to protect their pathway against shocks or vibrations that can occur usually from road and rail traffic or exceptionally from the occurrence of an earthquake. In the past, resistance structures were based mainly on ductility, a procedure that has changed with the development of seismic isolation systems now used worldwide for insulation against the destructive action of earthquakes.



a. Conventional bridge or viaduct structure

b. Friction system isolated bridge structure

Figure 1 Comparative behavior of a conventional bridge structure and friction bearing isolated structure

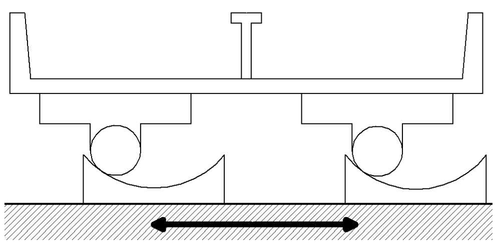


Figure 2 Operation principle of a friction based isolation system

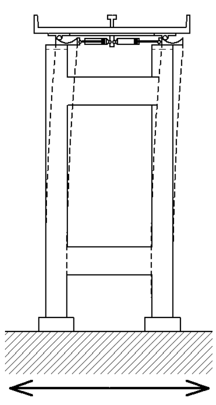
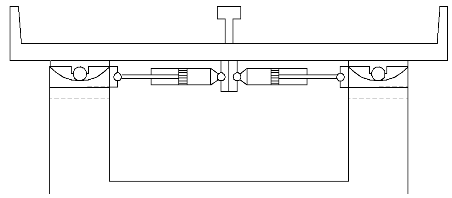
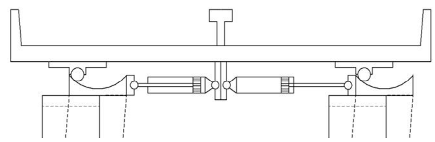


Figure 3 Operation of composed isolation system

Due to a considerable height of a bridge or viaduct pier, large displacements may occur at the upper side, event that should be avoided. A seismic isolation system is able to reduce these displacements by maintaining the pathway in a balanced position. The superstructure has to be disconnected from bridge pier and this may be carried out using friction system bearings. For some friction systems, acting as a safety device at stroke end, hydraulic fluid damper system devices are used. These systems act as anchoring points and through their action, energy dissipation is achieved.



a. system in a balanced position



b. system in action at maximum displacement

Figure 4 Detailed view of composed isolation system operation

Figure 4 is the illustration of the basic operating mode of a composed isolation system with a detailed position for both a steady/balanced position and an extreme position at maximum displacement on bearings.

3. HYDRAULIC FLUID DAMPER DEVICE STUDY

In order to accomplish an overview of the working principle of a typical fluid damper system, several 3D models were built. The CFD analysis of the digital of the fluid damper system highlighted the behavior of the hydraulic fluid during the dynamic regime.

The device was designed as a cylinder with piston. The piston head for different models of the device had a total of 8, 16 or 24 cylindrical orifices, through which fluid is forced to flow.

The relation force/velocity for this type of damper device is characterized as:

$$F = C\left|\dot{D}\right|^{\alpha} \operatorname{sgn}\left(\dot{D}\right) \qquad (1)$$

where F [N] is the output force, $\dot{D}$ [ms-1] the relative velocity across the damper, C is the damping coefficient and α is a constant exponent (usually between 0.3 and 1.0).

In order to have higher viscous friction, the stainless steel piston moves between chambers that are filled with silicone oil. The silicone oil is inert, nonflammable, nontoxic and stable for extremely long periods of time [6].

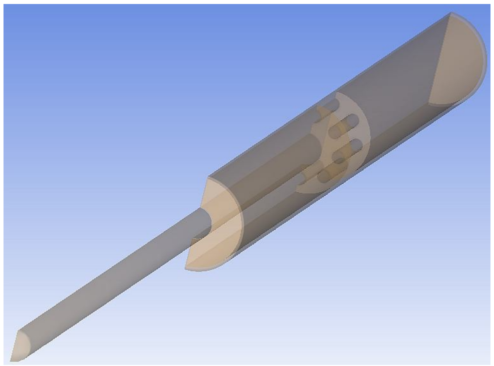


Figure 5 Flowizard 3D model

For a better damping, the chosen fluid is a high-viscosity silicone-oil type, with a viscosity of 29.1 $kgm^{-1} \cdot s^{-1}$ and a density of 970.0 kg/m^3.

The pressure difference between the two chambers cause silicone oil to flow through some orifices made in the piston head and the seismic energy is transformed into heat which dissipates to the external environment. FVDs may operate over temperature fluctuations ranging from –40°C to +70°C.

Mesh Information

Variable	Value
Mesh type	Tetrahedral mesh
Total number of cells	343778
Tetrahedral cells	343778
Wedge cells	0
Hexahedral cells	0
Pyramid cells	0
Polyhedral cells	0

Figure 6 Model tetrahedral mesh

The mesh used in CFD methods is part of the specific method used to solve numerically the CFD problems. The mesh used in our analysis with 8 orifices had a total of 343778 tetrahedral cells.

FD analysis was conducted in Flowizard, software from Ansys. The analysis evaluated the pressures, velocities and forces inside the fluid viscous damper device during a 5Hz seismic oscillation, a typical one for ground movements. Then, with Flowizard, as a CFD solver program, were solved the pressures and forces developed into this model (Table 1). Using the 3D model in Figure 5, the calculation completed after 89 iterations, when the solution converged to a stable one.

Table 1 Force (N) distribution

Boundary	X-Axis	Y-Axis	Z-Axis
Cylinder	-7604.0	-2.8	-13636.6
Piston	7603.9	2.8	2796.9
Net	-0.1	0.0	-10839.6

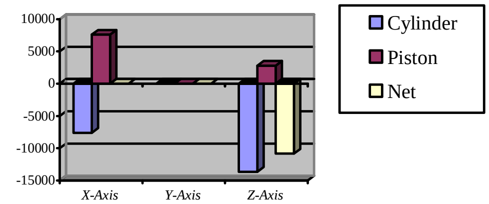
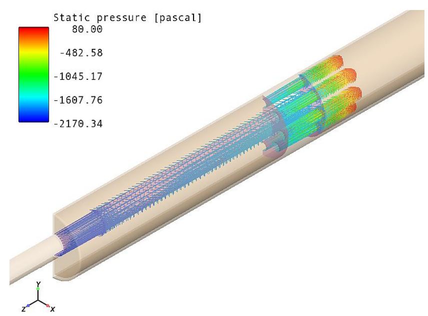
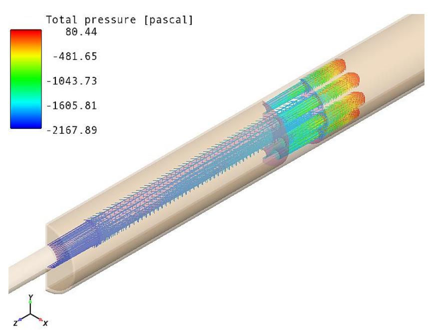


Figure 7 Force (N) distribution

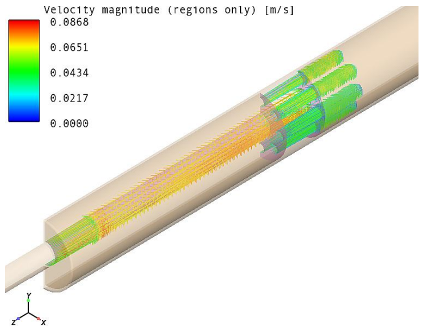


a. Static pressure

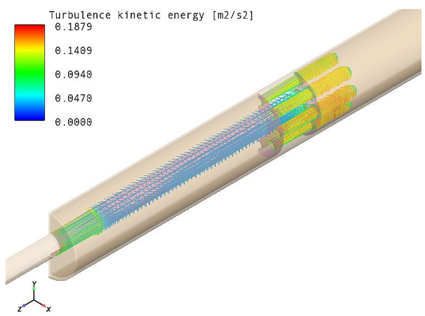


b. Total pressure

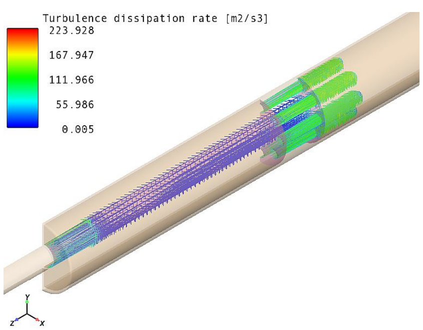
Figure 8 Illustration of pressure during device operation



a. Velocity magnitude for piston region



b. Turbulence kinetic energy



c. Turbulence dissipation rate

Figure 9 Flow parameters during device forced action

4. CONCLUSIONS

This composed solution can achieve partial disconnection of the superstructure from foundation as providing freedom of movement for superstructure on friction bearings up to a certain amount of displacement when the hydraulic system starts to play the role of anchor point at the end of the stroke of friction systems.

Since the proposed system is a hybrid one and has a composed structure, it is therefore more complex than a FP or a FVD system, used separately, but is capable to ensure isolation for a wider range of frequencies than the component devices.

Nevertheless, the proposed system is also capable to limit simultaneously the responses of both coupled devices, for a large variety of seismic ground motions, corresponding to wave patterns both of near-field and far-field regions of an earthquake.

In addition, the proposed system provides isolation also for everyday vibrations generated by heavy traffic.

References

[1] **Axinti**, **G**., *Acţionări hidraulice şi pneumatice*, Editura "Tehnica-Info", Chişinău, 2009

[2] **Beards, C. E**, *Structural Vibration: Analysis and Damping*, ISBN 0-340-64580-6, Arnold, UK, 1996

[3] **Hauk**, **N.**, *The influence of kinematic of mechanisms drive with hydraulic cylinders* **about** *the output of the system*, Al VIII-lea Simpozion Internaţional de Teoria Maşinilor şi Mecanismelor - SYROM, Bucureşti, 2001

[4] **Scheaua F, Nedelcut F.,** *Study on a Seismic Isolation Method Suitable for an Architectural Monument*, The Annals of "Dunarea de Jos" University of Galati, Fascicle XIV, Mechanical Engineering, ISSN 1224 – 5615,pp 65-70, 2012

[5] **Symans**, **M. D.**, **Madden**, **G. J.**, **Wongprasert**, **N.**, *Experimental study of an adaptive base isolation system for buildings*, 12WCEE 2000, in http://www.iitk.ac.in/nicee/wcee/article/1965.pdf

[6] *http://www.clearcoproducts.com/pdf/high-viscosity/NP-PSF-30000cSt-60000cSt.pdf.*