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GEOMETRICAL ASSUMPTIONS REGARDING VISCOUS FLUID DAMPERS

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ABSTRACT

The specific innovative device presented in this paperwork is a hydraulic system operating with viscous fluid that provides damping for shocks and vibrations. A basic viscous fluid device is constructed on the principle of linear hydraulic motor (cylinder with a plunger), but the device presented here has a certain number of orifices made inside the piston head. This allows the fluid circulation during the forced displacement of the piston within the cylinder body, without the need of any external hydraulic connection. Therefore it may be considered to be a passive system that will run without any other attached devices, on a passive principle. Typically, this particular device is used for bridges or viaducts endowment, as connection point between structural elements (base pier and path-way) ensuring in this way a safe anchoring and displacements limitation for the superstructure, especially when unexpected dynamic actions occur. The viscous fluid device operation achieves an energy dissipation role, because it opposes to the relative motion between structural frames, where it was positioned. Due to the viscosity properties of the working fluid, the piston movement is strongly attenuated and the energy received from the environment is partially consumed by the internal viscous friction, then it is transmitted back to the external environment, as heat energy. The value of the diameter of crossing orifices made in the piston head is important for an adequate operation of the viscous fluid device. Therefore, in this paperwork are presented the CFD analysis results obtained for a virtual model of a hydraulic device, when the orifices diameter is changed.

KEYWORDS*:* viscous fluid damper, energy dissipation, passive isolation, CFD

1. INTRODUCTION

Currently, there are multiple solutions for the endowment of the construction structures with devices that will make them more secure and more resilient in time. There are already multiple mechanical systems that can be attached to both new buildings and rehabilitated old ones. A real classification for these systems can be made according to their principle of operation.

As modern solutions, there are two main categories of mechanical systems intended for structures endowment against unexpected dynamic actions:

- isolation systems against various dynamic actions such as shocks, vibrations, seismic ground motions;
- dissipation energy systems, used mainly to consume a part of the energy input, converting it into another form of energy (heat) and then transferring it into the environment.

Most seismic isolation and energy dissipation devices are considered as passive structural control systems, because their operation does not depend on external energy sources. It relies only on the properties of its constituent materials (viscosity, elasticity, yielding, friction coefficient, shear modulus). [1].

The use of modern anti-seismic techniques, namely the seismic vibrations passive control techniques such as energy dissipation and, especially, seismic isolation, is certainly the best way as to guarantee a very high seismic safety level of constructions.

The dissipative devices or dampers are usually inserted inside the structure between elements subjected to significant relative displacement. These special devices are able to absorb and dissipate in the environment most of the seismic energy which, in their absence, would be dissipated by the entire structure leading to its damage and, for highly violent earthquakes, even to collapse. [5]

Fluid viscous dampers are special devices embedded in bridge or viaduct structures for damping the shocks and vibration to which they are subjected. Because they work in dynamic regime, special knowledge is necessary to estimate their optimal lifetime depending on the dynamic loads to which they are subjected. [4]

The viscous fluid dissipation devices are successfully used worldwide for bridges and viaducts endowment in order to reduce the relative displacement between pier and superstructure when seismic ground motions occur. So it is important to study the behavior of these devices on virtual models that can be launched in numerical analysis using specific software.

2. THE 3D MODEL OF THE VISCOUS FLUID DAMPER

Usually, a fluid viscous energy dissipation device comprises a steel cylinder with a piston.

In this paper it was analyzed a dissipative device whose piston has a special construction. The viscous fluid dissipation device presented here has a piston with a special construction, i.e. it is a double piston with a total of 12 orifices disposed concentrically around the piston rod. It is expected that such special construction for the dual piston system will provide improved mechanical energy dissipation in operation, i.e. it will deliver a higher movement resistance for the piston inside the cylinder.

Three distinct cases have been considered to be analyzed for this viscous fluid dissipation model. We have studied, on the 3D model, 3 constructive cases, having the same position and number (12) of orifices, but a different diameter (2mm, 1.5 mm and 1 mm), in each case. (Table 2-1).

Table 2-1 Orifices geometrical data

Case no.	Number of orifices	Orifices diameter (mm)	Total orifices area (mm^2)
1	12	10	78,54
2	12	15	176,71
3	12	20	314,15

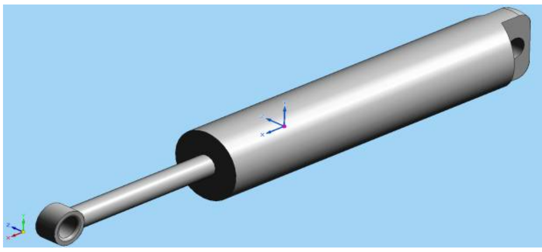


Fig. 2-1 Assembly model for viscous fluid device

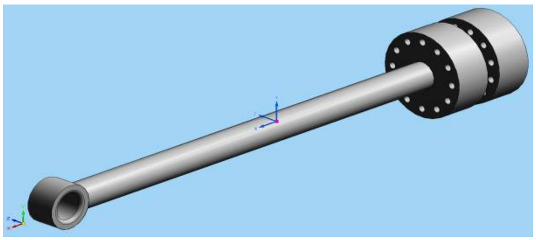


Fig. 2-2 Viscous fluid dissipation device piston, with orifices

In order to have better damping results, we chose silicone oil as working fluid. The 3D model assembly of the viscous fluid device is presented in Fig. 2-1 and the special construction piston is presented in Fig. 2-2 .

The connection to the structure can be achieved using different types of clamping flange connections. With the help of this mounting scheme, when the viscous fluid dissipative elements are the connecting link between the ground and the bridge or viaduct structures, a high level of stability for the entire structural assembly system can be assured. [6]

3. VISCOUS FLUID SYSTEM CASE STUDIES

In this paper is presented a description of a specific viscous fluid dissipation device that can be used at bridges or viaducts. First it was created a three-dimensional model, later this was analyzed through CFD methods with the help of Ansys CFD software, in order to highlight specific functional characteristics for the hydraulic device. The multiple analyses performed while changing the diameter value for the fluid circulation orifices through the piston head, on the same three-dimensional (3D) model, have led to the results presented below.

4. CFD ANALISYS RESULTS

During the design phase of a structural system subjected to dynamic actions, it is necessary to accompany the experimental evaluation with an appropriate mathematical and dynamic model. So it can be correctly estimated the dynamic impact that the dynamic phenomenon can have on the respective structural system. The complete and correct definition of the impulsive type loadings can be summarized to quantifying the following three characteristic parameters: the duration of application, the form and the amplitude. [2], [3]

The 3D model created for the viscous fluid dissipation device has been introduced in computational fluid dynamics (CFD) analysis performed with ANSYS CFD.

As working fluid was chosen a special fluid (silicone oil) whose properties are shown in Table 4-1.

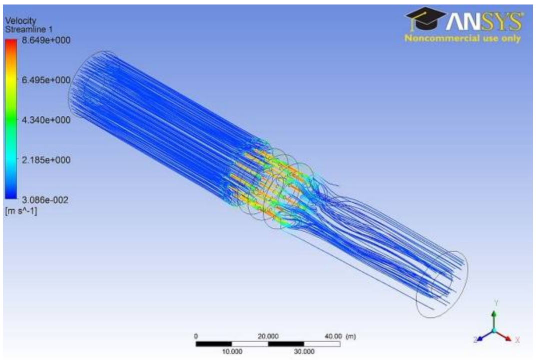
Table 4-1 Working fluid parameters

Density	970 kg/m^3
Viscosity	29.1 kg/ms
Thermal conductivity	0.286 $W/m \cdot K$
Specific Heat	2427 $J/kg \cdot K$

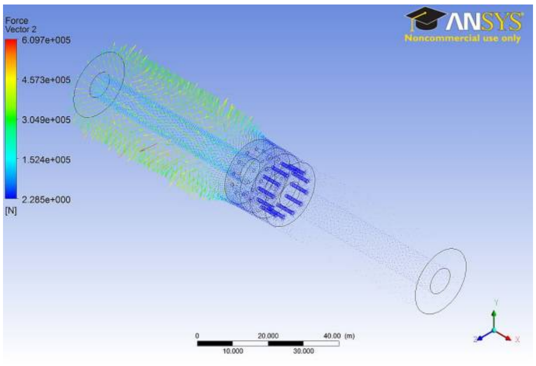
As initial conditions we chose a specific velocity (of 0.4m/s) for the piston moving along the cylinder, corresponding to a 5 Hz seismic wave. Consecutively, the piston displacement should force the viscous working fluid to flow through the orifices of the double head piston.

When the total piston orifices area will be reduced, the drag resistance to the movement of the piston will increase, i.e. the force this device will adsorb will increase, as the diameter of the orifices will decrease. Three distinct cases were analyzed in order to highlight this correlation between the viscous drag forces and the total orifices area.

The results we got are presented in the following pictures and tables. In Table 2-1 are presented the cases taken into consideration. The diagrams for the total viscous drag force created by the special piston and for the velocity magnitude for case no. 1 are presented in Fig. 4-1 and values obtained are shown in Tabel 4-1.



a) Velocity magnitude



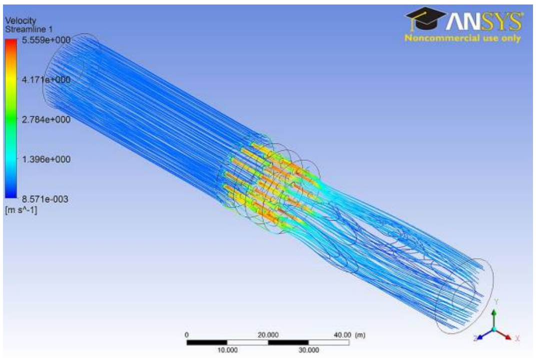
b) Viscous drag force

Fig. 4-1 Results for case 1

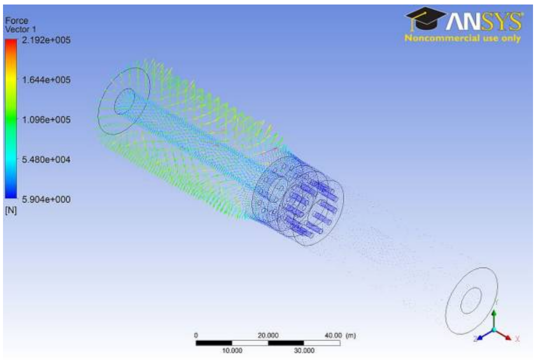
Tabel 4-1 Case 1 values

Force on piston (N)	
Max.	$6.097 \cdot 10^5$
Min.	2.285
Velocities (m/s)	
Max.	8.649
Min.	0.031

Total viscous drag force and velocity magnitude diagrams for case no. 2 are presented in Fig. 4-2 and values obtained are shown in Table 4-2.



a) Velocity magnitude

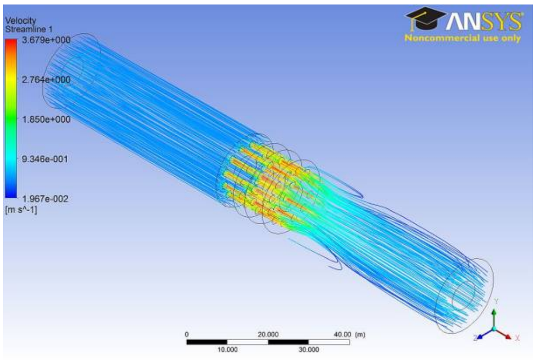


b) Viscous drag force

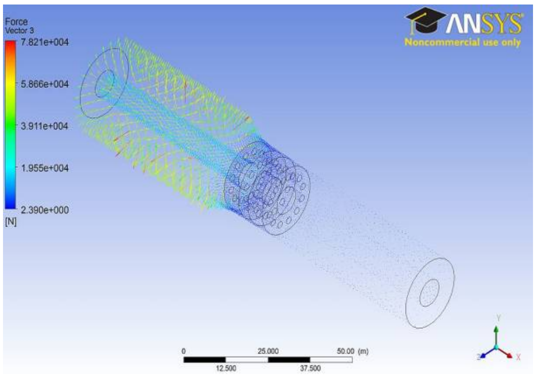
Fig. 4-2 Results for case 2

Table 4-2 Case 2 values

Force on piston (N)	
Max.	$2.192 \cdot 10^5$
Min.	5.904
Velocities (m/s)	
Max.	5.559
Min.	0.009



a) Velocity magnitude



b) Viscous drag force

Fig. 4-3 Results for case 3

Total viscous drag force and velocity magnitude diagrams for case no. 3 are presented in Fig. 4-3 and values obtained are shown in Table 4-3.

Table 4-3 Case 3 values

Force on piston (N)	
Max.	$0.782 \cdot 10^5$
Min.	2.390
Velocities (m/s)	
Max.	3.679
Min.	0.002

Table 4-4 Forces & velocities values estimation

v (m/s)	v^2 (m^2/s^2)	p (bar)	F (N)	Total orifices area (mm^2)
8.649	74.805	23.960	$6.097.10^5$	78.54
5.559	30.902	9.032	$2.192.10^5$	176.71
3.679	13.535	3.457	$0.782.10^5$	314.15

5. CONCLUDING REMARKS

The values we obtained for the damping force distribution relative to the square of the velocity of fluid forced to pass through the orifices range within acceptable limits for pressures under 100 bar.

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