Aspects Regarding Fluid Viscous Anchoring Systems Used for Vibration Mitigation at Bridge Structures

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Abstract: *During the last period are increasingly used hydraulic devices attached to building structures in order to achieve energy dissipation during earthquakes but also as anchoring systems being interposed between structural frameworks. An anchoring system is a hydraulic device consisting of a cylinder with piston having inside a working fluid with special viscosity properties. The anchor device can be connected to both ends making a connection between the bridge pier and superstructure. This special positioning between structural frames is made in order to ensure vibrations mitigation and increased stability at high stress requests. The device piston can perform translation displacements inside the cylinder by means of a hydraulic circuit which allow working fluid flow between the two chambers of the cylinder. Due to high viscosity values of the working fluid and small diameter of crossing orifices, the relative slow movements between structural frameworks are allowed, but when a dynamic request of major intensity occurs the system becomes rigid assuring the safety connections between structural frameworks. This article shows a method of modelling a three-dimensional model for a hydraulic anchoring system and numerical analysis to highlight the working principle for such a device.*

Keywords: *fluid device, anchoring, structural system, bridge, vibration mitigation, energy dissipation*

1. Introduction

Special mechanical systems are used at the construction of new bridge or viaduct structural types or rehabilitation of existing ones, that work as anchoring safety connections between structural elements (pier and superstructure) when significant dynamic requests are occurring. Such safety systems are based on a hydraulic fluid having special properties in terms of viscosity.
In the absence of active control equipment are considered passive systems, being velocity dependent, because they respond to relative movements between the structural frames where they are located. In the event of an earthquake there is a tendency of relative motion between frameworks, but by changing the anchoring systems rigidity it is ensured a rigid connection between the superstructure and bridge pier.
The working fluid used is a high viscosity silicone oil which can be used in a wide temperature range $\left(40 \div 50^{0} C \right)$ and showing no change in properties over time.

2. Modeling aspects for viscous fluid anchoring system

A viscous fluid anchoring system is composed of a cylinder with a piston that divides the interior of the cylinder body in two chambers. The interior volume of the cylinder body is filled with fluid and the movement of the piston is made possible by a special circuit that allows the fluid flow.
Due to the diameter value of the passage orifices, low-velocity movements are allowed for the piston but when a dynamic request occur the hydraulic system is activated acting as a safety device. Increasing rigidity is ensured based on the working fluid due to their high viscosity value but also to valve system that can be adjusted to face high levels of forces arising from the dynamic requests.
A three-dimensional model for viscous fluid anchoring device was developed and presented in Figure 1.

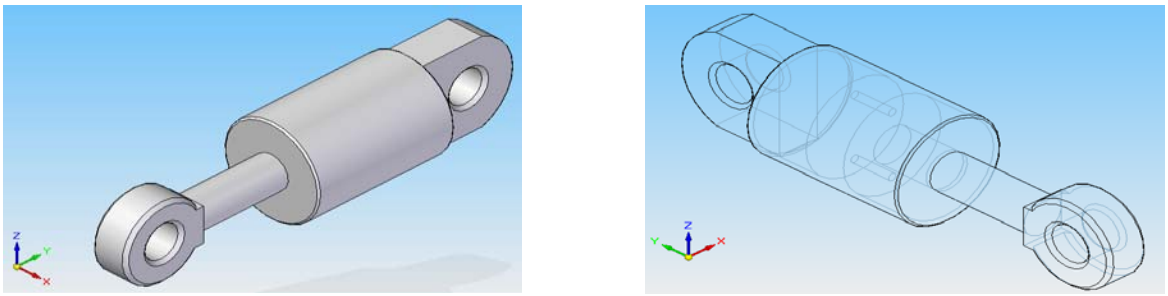


Fig. 1 Fluid viscous anchoring device model assembly

3. Theoretical approaches regarding fluid dynamics inside the anchoring system

The fluid viscous anchoring system is connected to the resistance structure of a bridge or viaduct by means of clamping flanges at both ends being positioned between the superstructure and the support pier. In normal working conditions when the system receives small oscillations due to traffic conditions, the piston movement within the cylinder is relatively free without forced circulation of the working fluid within the orifices.

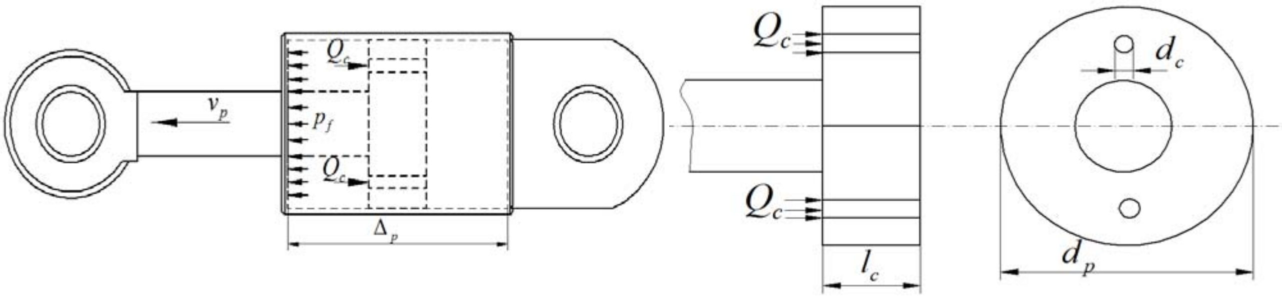


Fig. 2 Anchoring model efforts distribution

When a seismic event is occuring, the anchoring system is activated by the forced relative movement achieved at the device ends, while the piston is moved inside the cylinder by forcing the viscous fluid to pass through the orifices made inside the piston head. The efforts distribution created in this situation it is presented in Fig. 2. The fluid flow rate that is circulated through the orifices can be calculated using the folowing relation:

$$Q_c = \pi \frac{d_c^2}{4} v \tag{1}$$

Where:
- Q_c - fluid flow rate;
- d_c - orifices diameter;
- v - piston velocity.

The pressure created inside cylinder, performing piston motion braking can be assumed by the relation:

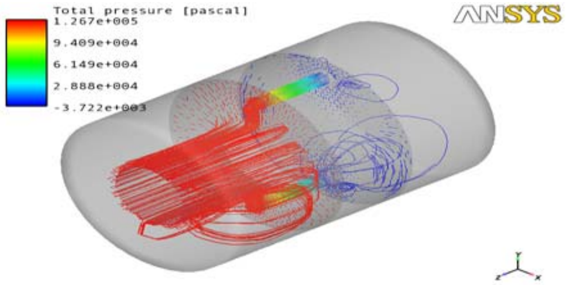
$$p = \frac{\xi \rho}{2} \left(\frac{A}{a_d} \right)^2 .v^2 \tag{2}$$

Where:
- p - pressure;
- ρ - fluid density;
- A - piston area;
- a_d - orifice area.

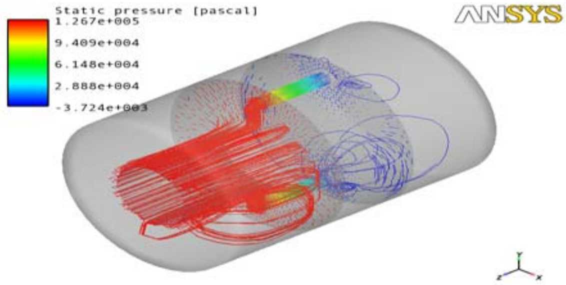
From pressure relation shall be deducted that the braking pressure is even higher as the momentary piston velocity is higher and the orifices opening area is smaller.

4. Computation fluid dynamics analysis for anchoring model

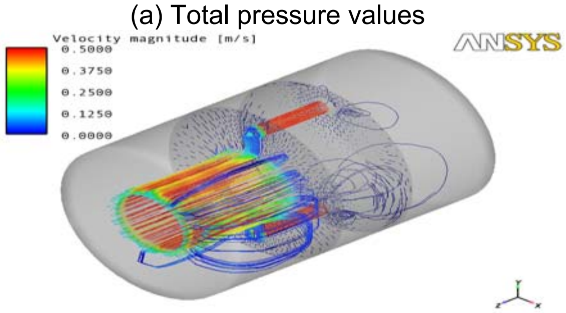
Two different cases were analyzed for the fluid viscous anchoring system three-dimensional model. In the first case it has been considered two circulation orifices for the fluid having a diameter of 20 mm and for the second case the orifices diameter has been reduced to 10 mm. The working fluid is silicone oil having characteristics which remain constant when are changes in temperature or over time. The results are shown in the following, (Fig. 3, Fig. 4).



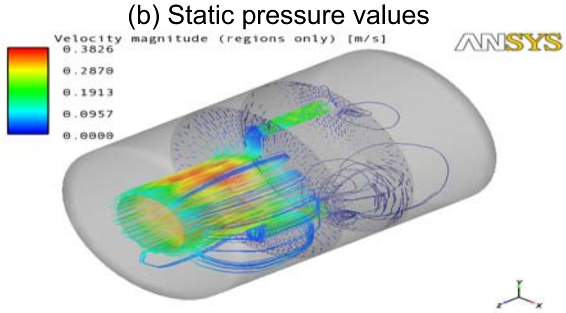
(a) Total pressure values



(b) Static pressure values

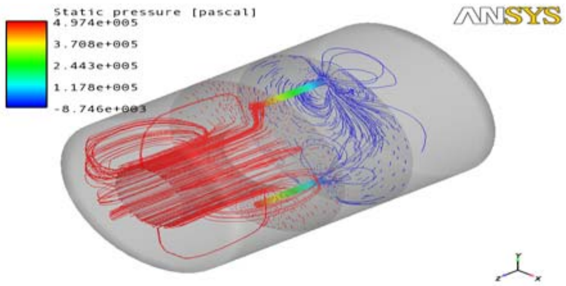


(c) Fluid velocity values

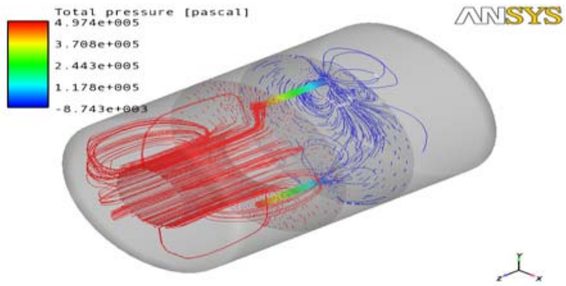


(d) Fluid velocity values on regions

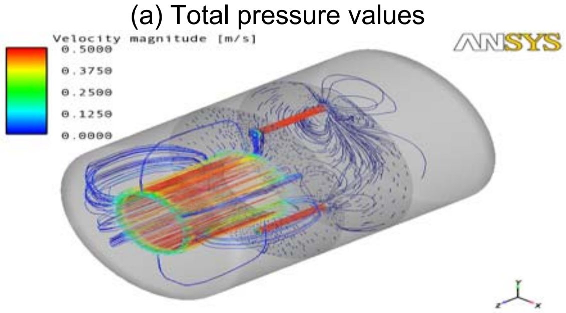
Fig. 3 The obtained results for anchoring model having diameter orifices of 20 mm (case 1)



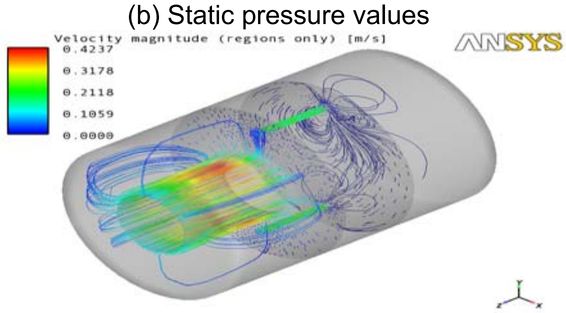
(a) Total pressure values



(b) Static pressure values



(c) Fluid velocity values

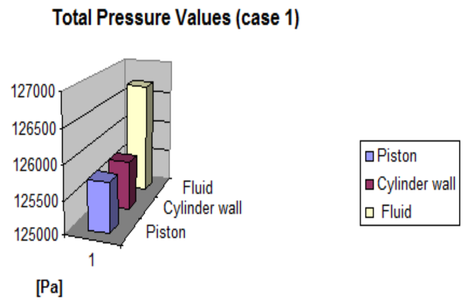
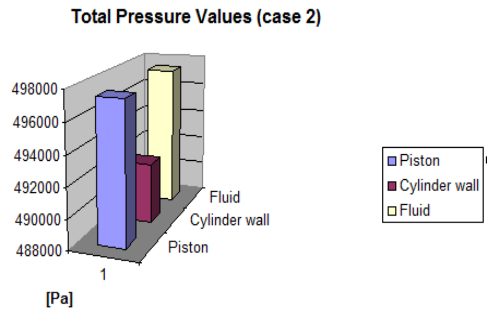


(d) Fluid velocity values on regions

Fig. 4 The obtained results for anchoring model having orifices diameter of 10 mm (case 2)

The values obtained for the force at piston rod and total pressure for the two analyzed cases are presented in TABLE 1.

TABLE 1 Result values obtained for total pressure and force

Case 1 – 20 [mm]		Case 2 -10 [mm]	
Force [N]		Force [N]	
Boundary	Z-Component	Boundary	Z-Component
Piston	5575.33	Piston	22171.65
Net	5575.33	Net	22171.65
Pressures (Total) [Pa]		Pressures (Total) [Pa]	
Boundary or Region	Maximum	Boundary or Region	Maximum
Piston	125744.54	Piston	497369.64
Cylinder wall	125744.54	Cylinder wall	491981.75
Fluid	126692.76	Fluid	497369.64
			

5. Conclusions

The fluid viscous anchoring system are considered as dissipation devices acting on the passive principle that reacts at relative movements between the structural frames where they are mounted and behave like real safety devices for the bridge or viaduct structural types where there are attached. At this kind of structures the vehicle emergency braking and also the seismic actions can determine the entry into operation of the anchoring devices and make a stiff connection between structural frameworks.
The use of these special fluid viscous anchoring systems shows benefits regarding the high efforts transferred and proper distribution of seismic forces in horizontal plane in the same time with displacement limitation resulted from earthquakes of considerable magnitude.
Following the analysis results made for the three-dimensional model it can be said that while reducing the diameter for the passage orifices with 50% it is obtained an increase in pressure and force values at the piston of nearly four times (400 %), when using silicon oil having a medium value for kinetic viscosity of 30 [cSt] as working fluid.

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