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NONLINEAR BIDIMENSIONAL SLOSHING SUPPRESSOR MODEL

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Abstract: In this work, a two-dimensional model of a submerged body in a rectangular tank partially filled with a fluid and excited horizontally is described by a set of nonlinear differential equations. The linear method was developed based on potential theory and uses the dimensions of the tank and the filling level to calculate the velocity of the fluid in the position where the object is located. By using the velocity, the dimensions and the drag coefficient of the body, the force due to sloshing can be calculated. With the nonlinear system we investigate the parameters to onset of chaos and its consequence for the mechanical system.

keywords: Applications in Engineering, sloshing, fluid dynamics, submerged solid.

1. INTRODUCTION

Sloshing is a phenomenon of great interest in the design of liquid container for fluid transportation by ship like fuel tanks. Usually longitudinal lateral structures is used to increase damping on the flow or longitudinal bulkheads is installed to change the resonance frequency. However, these solutions only work at a limited range of filling levels of the tank. One device, developed to reduce the undesirable sloshing for a wider range of filling level, is a dynamic buffer that is connected to the tank structure by springs [1, 2]. The analytical linear model was developed for a rectangular tank [3] from the connection of two mass-spring-damping system by a damping force, in which the first is the mechanical system that represents the submerged body with the springs connecting it to the tank and the second system is the sloshing motion of the liquid. The results of linear model show that the submerged body has small or almost no effect at low frequencies and near the resonance frequency of sloshing the amplitude declined due to the increase of damping, and for higher damping values the two masses behave as a singles body. The method provides a good approximation of the forces due to sloshing on the submerged body, and it contributes to better understanding of the phenomena. In this work, we propose a nonlinear model that is still in investigation for the mass-spring-damping system. The importance of this study is to investigate the applicability limits of the mass-spring model as a sloshing suppressor.

2. ANALYTICAL MODEL

The system considered consists of a tank partially filled with liquid and a submerged body connected to the tank structure by springs as shown in Figure 1. In the figure, m_s denotes the mass of the fluid, m_b the body's mass and k_b the spring constant. The tank is excited by a horizontal harmonic motion that results in sloshing motion.

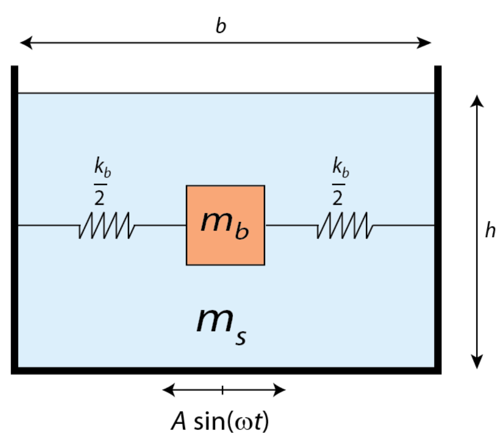

Figure 1 – Rectangular tank filled partially with a submerged body connected by horizontal springs.

This system can be interpreted as the composition of two different groups linked together by damping force. The first system is composed of the tank with fluid and the second is composed of the submerged body connected to the tank by springs as shown in Figure 2. The sloshing mass m_s is connected to the source of harmonic motion y_0 through spring with constant k_s and damping c_s, by the damping coefficient c_b. The sloshing mass m_s is also connected to the submerged body mass m_b, which is connected to y_0 by the spring k_b.

With this arrangement we build the set of nonlinear differential equation (Equation 1), following:

$$\begin{cases} m_s\ddot{y}_s = -k_s(y_s - y_0) - c_s(\dot{y}_s - \dot{y}_0) - c_b|(\dot{y}_s - \dot{y}_b)|(\dot{y}_s - \dot{y}_b) \\ m_b\ddot{y}_b = -k_b(y_b - y_0) - c_b|(\dot{y}_b - \dot{y}_s)|(\dot{y}_b - \dot{y}_s) \end{cases} \tag{1}$$

where $y_0 = A\sin(\omega t)$ and $\dot{y}_0 = A\omega\cos(\omega t)$. In the Figure 3 we show the time series of the center of mass of the fluid (in

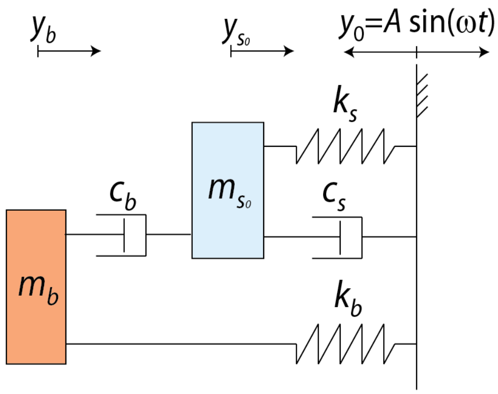

Figure 2 – Rearranged diagram of the mass-spring-damping system of the model.

blue) and the body (in red). In this situation the sloshing and the body follow the external perturbation and their motion are regular. For a set of parameters, our primary numerical

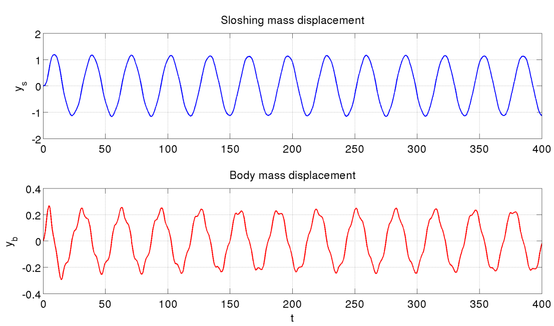

Figure 3 – The regular time series of the center of mass of the fluid and the submerged body.

results indicates that the system have a irregular behavior, as we can see in the Figure 4. It is important to notice that the amplitude of the sloshing and the body increases for the irregular motion.

3. CONCLUSION

We presented a nonlinear model to investigate the effects of the dynamics of a submerged body on the sloshing motion. When the motion is irregular the amplitude of the body and the fluid increases and may stress the container and the spring suppressor. Other important dynamical aspect of the nonlinear model, such as the attractor, are being researched.

ACKNOWLEDGMENTS

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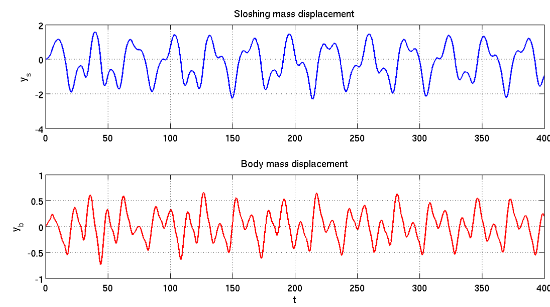

Figure 4 – The nonregular time series of the center of mass of the fluid and the submerged body.

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