Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 54(3) (2022) 147-150
DOI: 10.22060/mej.2021.20112.7171

Investigating the Effect of Isothermal Channel Height on the Vibrational and Thermal Behavior of Elastically-Mounted Cylinder Affected by Unilateral and Bilateral Jet Flow

S. D. Farahani, A. M. Zakinia, A. H. Rabiee

Department of Mechanical Engineering, Arak University of Technology, Arak, Iran

ABSTRACT: In this paper, the active flow control of flow-induced vibration of a circular cylinder placed in the isothermal channel affected by jet injection is studied. The effect of flow injection on heat transfer inside the channel has also been examined. For this purpose, three slots are placed symmetrically in the upper and lower walls of the channel at distances 0, D, and 4D where D is the diameter of the cylinder from the side surface. The main innovation of the present study is to evaluate the effectiveness of the proposed flow control method in terms of channel height. For this purpose, 6 channels with heights of 5.5D, 6D, 7D, 8D, 9D, and 10D are considered to perform fluid-solid interaction simulations. The finite element method has been used to solve the flow and energy equations. For coupling the movement of the cylinder with the flow field, the dynamic mesh method is used. Numerical results show that for all channels with different heights, jet injection, either unilaterally or bilaterally, from slot 3, has no effect on displacement because the distance of the jet from the cylinder is large. By increasing the height of the channel, the injection velocity must be increased to completely reduce the oscillations of the cylinder.

Review History:

Received: Jun. 01, 2021
Revised: Oct. 15, 2021
Accepted: Nov. 04, 2021
Available Online: Nov. 04, 2021

Keywords:

Vortex-induced vibration
Jet flow
Flow control
Vortex shedding
Channel heat transfer

1- Introduction

Vortex-Induced Vibration (VIV) of structures is of practical interest to many fields of engineering. For example, it can cause vibrations in heat exchanger tubes; it influences the dynamics of riser tubes bringing oil from the seabed to the surface; it is important to the design of civil engineering structures such as bridges and chimney stacks, as well as to the design of marine and land vehicles; and it can cause large-amplitude vibrations of tethered structures in the ocean. These are a few examples out of a large number of problems where VIV is important. The practical significance of VIV has led to a large number of fundamental studies [1].

VIV control methods can be divided into two different aspects. From the first aspect, VIV reduction methods are classified into two methods: (1) passive control and (2) active control. From the second aspect, VIV reduction methods are classified into two methods: (1) direct control of structural vibrations and (2) flow control. In direct vibration control methods, which are mainly active control methods, control devices are connected directly to the cylinder and target structural oscillations. In flow control methods, the amplitude of VIV is indirectly reduced by making changes in the vortex sequence or in the process of vortex fall [2]. Numerous researchers have examined the effectiveness of this method in recent years.

The combination of the VIV problem and heat transfer is unavoidable in some engineering applications such as heat exchanger tubes [3]. They found that heat transfer from a vibrating cylinder increases by 13% in the range of the frequency matching region where the VIV frequency approaches the normal frequency of the oscillator.

According to previous literature, it can be seen that although much research has been done on VIV control by jet injection, heat transfer of fixed cylinders with different geometries, and also heat transfer of vibrating cylinders. But the effect of jet injection from the walls of the channel was not subject to the vibrations and heat transfer of the cylinder. Therefore, in this study, the effect of changing the channel height on the vibrational and thermal behavior of the cylinder inside the channel, which is affected by the jet flow through the walls, has been studied numerically. The finite volume method has been used to solve the equations governing the temperature and flow fields. The effect of single and double jet injection, the distance of the jet from the cylinder, and the change in channel height on the amplitude of the cylinder vibrations, the vortex-shedding pattern, and the Nusselt number have been investigated.

2- Methodology

In this study, the effect of jet injection from the lower and upper walls of the channel on induced vibrations and heat transfer from the channel with different heights of 5.5*D*, 6*D*, 7*D*, 8*D*, 9*D,* and 10*D*, where *D* is the diameter of the cylinder, is investigated. A schematic of the problem is shown in Fig. 1. As can be seen, a channel with a constant temperature

*Corresponding author's email:rabiee@arakut.ac.ir

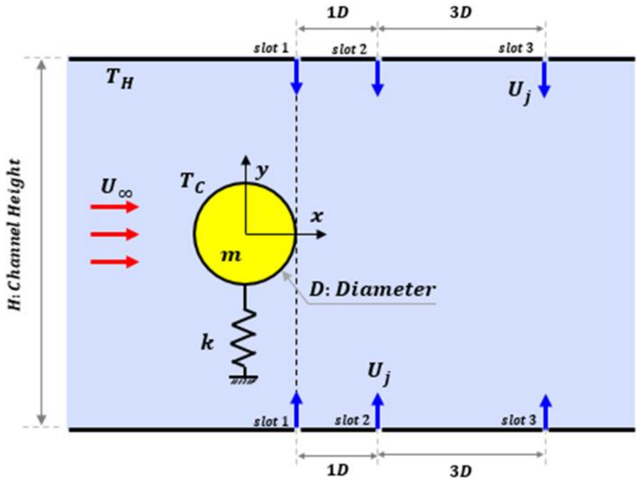

Fig. 1. Schematic of the present problem

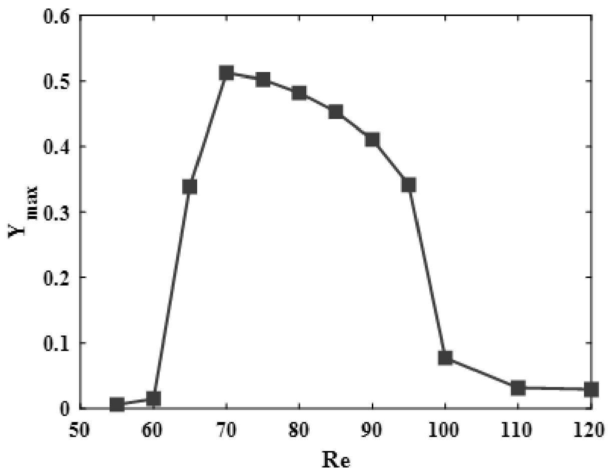

Fig. 2. Uncontrolled cylinder response in a 7D height channel in terms of Reynolds number

boundary condition is considered. The cylinder can fluctuate freely in the y (transverse) direction due to the collision of the flow and the fall of the vortices. The slots are located on the lower and upper wall of the channel at distances 0, *D*, and 4*D* from the side of the cylinder (see Fig. 1).

The two-dimensional flow field is considered. The fluid is Newtonian. The flow regime is laminar and incompressible. There are no external forces such as electric and magnetic forces. The equations of continuity, momentum, and energy for a Newtonian incompressible fluid, regardless of viscosity heat loss, are expressed as follows:

$$\nabla V = 0 \tag{1}$$

$$\rho(\frac{\partial \vec{V}}{\partial t} + \vec{V}.\nabla\vec{V}) = -\nabla P + \mu\nabla^2\vec{V} \tag{2}$$

$$\rho C_p(\frac{\partial T}{\partial t} + \vec{V}.\nabla T) = \nabla.(\lambda\nabla T). \tag{3}$$

where ρ, T, t, P, μ, V, C_p, and λ are fluid density, temperature, time, static pressure, dynamic viscosity, velocity, heat capacity at constant pressure, and thermal conductivity, respectively. If the cylinder is placed on an elastic substrate, it will vibrate as the fluid flows. In this study, the movement of the circular cylinder is in the *y*-direction. For the modeling of cylinder vibrations, the classical mass-spring-damper model with second-order differential equation can be used as follows:

$$m\ddot{y} + c\dot{y} + ky = F_L \tag{4}$$

Where m, c, k and F_L are the mass of cylinder, damping ratio, spring stiffness, and lift force. The finite volume method has been used to solve the governing equations and the dynamic mesh has been used to model the rigid motion of the cylinder.

3- Results and Discussion

In this study, the effect of flow injection from the upper and lower walls as well as the change in channel height on the vibration/thermal behavior of the vibrating cylinder was investigated. Three slots are placed at close, medium, and far distances from the cylinder.

Fig. 2 shows the maximum displacement changes of the cylinder located in the channel with height *7D* in terms of Reynolds number. It can be seen that as the Reynolds number increases, the displacement of the cylinder increases abruptly due to the frequency matching in the locked region. In this regard, the transverse displacement at $Re = 70$ has reached its maximum value ($Y_{max} = 0.52$). Fig. 3 shows the maximum transverse displacement for the cylinder located in the channel with height $H = 5.5D$ in terms of jet velocity. Injecting the jet, either unilaterally or bilaterally, from slot 3 has no effect on displacement because the distance of the jet from the cylinder is relatively large. On the other hand, by increasing the injection velocity of slots 1 and 2 in both single and double, the maximum displacement of the cylinder is drastically reduced. It can be seen that the reduction in displacement for slot1 compared to slot 2 occurs at a lower jet. Also, the effectiveness of double jets is much higher than a single jet

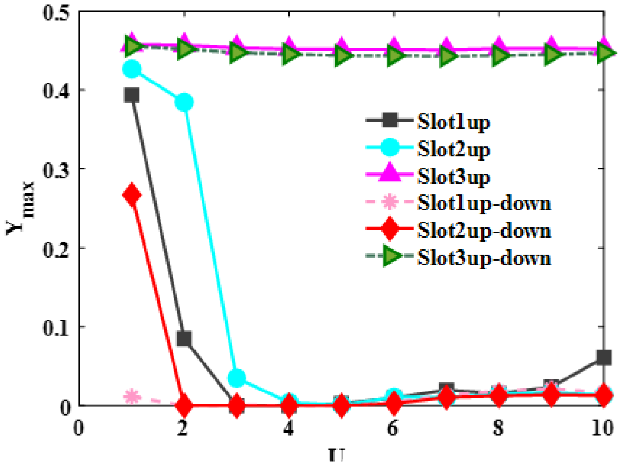

Fig. 3. Changes in cylinder displacement for a channel with a height $H = 5.5D$

4- Conclusion

In this paper, the ability of the jet injection method, either unilaterally or bilaterally, from the upper and lower slots of the channel, which are placed at different distances from the cylinder, has been investigated according to the height of the channel. The findings of this study are summarized below:

1. It can be seen that with increasing the height of the channel, the maximum displacement of the cylinder also increases so that with increasing the height of the channel from $H = 5.5D$ to $H = 10D$, the maximum displacement has increased by 15%.

2. For low-altitude channels ($H = 5.5D, 6D$), a complete reduction in displacement for slot 1 compared to slot 2, either as a single jet or as double jets, occurs at a lower jet velocity.

3. The amount of heat transfer increases with increasing jet injection velocity and decreasing channel height. The amount of heat transfer in double jet mode is more than a single jet.

References

[1] P. Bearman, On vortex street wakes, Journal of Fluid Mechanics, 28(04) (1967) 625-641.

[2] A.H. Rabiee, Numerical Study on Vibration Attenuation of Cylinder using Active Rotary Oscillating Controller, International Journal of Engineering, 34(1) (2021) 202-211.

[3] E. Izadpanah, A. Ashouri, M. Liravi, Y. Amini, Effect of vortex-induced vibration of finned cylinders on heat transfer enhancement, Physics of Fluids, 31(7) (2019) 073604.

HOW TO CITE THIS ARTICLE

S. D. Farahani, A. M. Zakinia, A. H. Rabiee , Investigating the Effect of Isothermal Channel Height on the Vibrational and Thermal Behavior of Elastically-Mounted Cylinder Affected by Unilateral and Bilateral Jet Flow, Amirkabir J. Mech Eng., 54(3) (2022) 147-150.

DOI: 10.22060/mej.2021.20112.7171