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Study a Fluid Structure Interaction Mechanism to Find Its Impact on Flow Regime and the Effectiveness of This Novel Method on Declining Pressure Loss in Ducts

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Abstract. Using channels and tubes with a variety of shapes for fluids transportation is an epidemic approach which has been grown rampantly through recent years. In some cases obstacles which placed in the fluid flow act as a barrier and cause increase in pressure loss and accordingly enhance the need to more power in the entry as well as change flow patterns and produce vortexes that are not optimal. In this paper a method to suppress produced vortexes in two dimension channel that a fixed square cylinder placed in the middle of it in Re_D 200 in order to find a way to suppress vortexes are investigated. At first different length of splitter plates attached to square obstruction are studied to obtain the effects of length on flow pattern. Subsequently simulations have been conducted in three dimension to validate previous results as well as acquire better understanding about the selected approach. Simulations have done by Lagrangian Eulerian method, plates first assummed fix with length 1.5mm, 4mm and 7.5mm, and then flexible plates with the same length are studied. Young's modulus for flexible plate and blockage ratio were constant values of 2×10^6 and 0.25 in all simulations, respectively. Results indicate more vortexes would be suppressed when the length of splitter plate enhances.

1. Introduction

Transporting fluids using with high efficiency is an issue that has been inevitable nowadays due to conditions such as raising energy and equipment costs. Many companies in gas and oil industry try new kind of accessories, for example network of pipes with the least waste, to transport the raw material they required as well as their products with minimum cost and the least pressure loss in fluid flow beside maximum safety as the major goals of substance transportation. However using curve shapes in these systems, as said before, and subsequently vortex production because of facing fluids with walls or obstructions is unavoidable. Additionally, in many cases such as suspended bridges and also underwater structures vortex generation can be more harmful and cause numerous destructions, ruining Tacoma Narrow bridge because the blowing of a light wind is a good example to show the destructive effetc of this phenomenon. Thus finding a way to suppress vortices has became neccessary and various research groups from all over the world are trying to counteract this fact using a wide range of novel ideas.

In this paper our endeavours specifically allocated to study the vortex generation patterns and the impact of attending splitter plate on flow. Fixed plates' capabilites in destroying vortices are compared flexible plates with the same length and results presented in figures that are drawn by Ansys 16.2 simulator. Obstacle blockage ratio has obvious impression on flow patterns as well as vortex generation. So we picked 0.25 and selected square cylinder as these selections preferred to other

shapes and values by researchers because of their efficiency. The cylinder positioned with a 45 degree rotation into its center to cause less pressure loss.[1-5]
Besides, This point that flexible structure vibrations intensify while a fluid with the same or approximately same natural frequency flow over it has been proved by researchers[6-8], both experimentally and numerically. So there is two ways in order to decrease the volume of destructions; change in flow pattern and charactristicts which is not convenience in many situations, or detecting the best length of splitter plate to diminish the number of vortexes.

2. Model description

In this investigation a channel just like figure 1. With presented geometry and a flow of air with mentioned charactristics are studied. A developed profile for velocity, with the maximum value of 2.38 m/s in th middle of profile, has defined in order to make it easy to investigare the laminar flow. Properties of air presumed to be constant through simulations and viscous dissipation is omitted. Therefor, governing equations for laminar flow (1-2), velocity profile (3), young's modulus of flexible structure (4), and pressure loss (5) can be written as followings;

$$\nabla . V=0 \quad (1)$$

$$\rho(\partial v/\partial t) + \rho V. \nabla V = - \nabla P + \mu \nabla^2 V \quad (2)$$

$$\frac{u}{u_{max}} = (1-(1-\frac{2y}{w})^2) \quad (3)$$

$$E = 0.9465(\frac{mf^2}{b})(\frac{L^3}{t^3})(1+6.585(\frac{t}{L})^2) \quad (4)$$

$$f = (\Delta P) / (\rho u^2) (L/D_h) \quad (5)$$

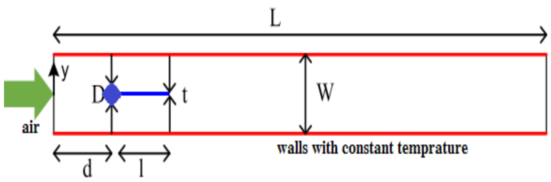

Figure 1. Shematic of channel with its attachments

Exact statictics about the geometry can be found in Table1. To mesh the fluid domain by picking Arbitrary Lagrangian Eulerian method as a renowned manner for its accuracy, the domain divided into 47814 cells. Furtheremore, the number of mesh in solid domain determined to be 1783 cell according to the feedbacks that we received from simulations. These simulations have conducted by coupling the Ansys fluent 16.2 and Ansys transient structural 16.2 while the time step for transfering data between the mentioned softwares was tuned to 0.01 second.

Table 1. Dimensions (mm) of the channel and structure

Lenghth of channel (L)	50mm	Diameter of square cylinder	1.5mm
Width of channel (w)	6mm	Distance between cylinder center and channel entrance	6mm
Thickness of Plate (t)	1mm	Angle between the square side and the channel surface	45^0
Length of plate (l)	1/5, 4 and, 7.5mm		

Nomenclature

ρ (Kg/m^3)..... Density	D (mm)........................... Diameter of cylinder
u(m/s)............ Fluid velocity	D_h (mm)..........................Hydrolic diameter
E(Pa)............. Young's modulus	m (kg)............................. weight
f(N)................ Friction	b (mm)........................... Depth
Re.................. Reynolds Number	Pr......................... .... Prandtl Number
ΔP.................. Pressure drop	L (mm)........................... Length of channel
W (mm)........Width of chan	t (mm)............................. Thikness of plate
d (mm)..........Distance from cylinder axis	l (mm)................................ length of plate

3. Results and Discussion

When the flow pass over the cylinder, or any kind of other obstructions, different kind of vortexes depend on Re number and other fluid features generate. To make this issue more clear and compare the attendance of fixed plate with different lengths, vorticity contours for fixed plates as well as emtpy channel and channel with fixed cylinder presented. Figure 3 illustrate this points clearly that attending splitter plate decrease number of vortices in fluid domain and this phenomenon intensify by increasing the length of plate.

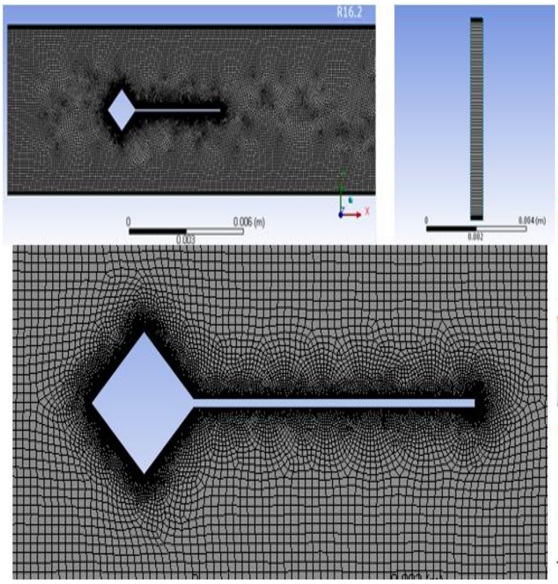

Figure 2. Fluid mesh

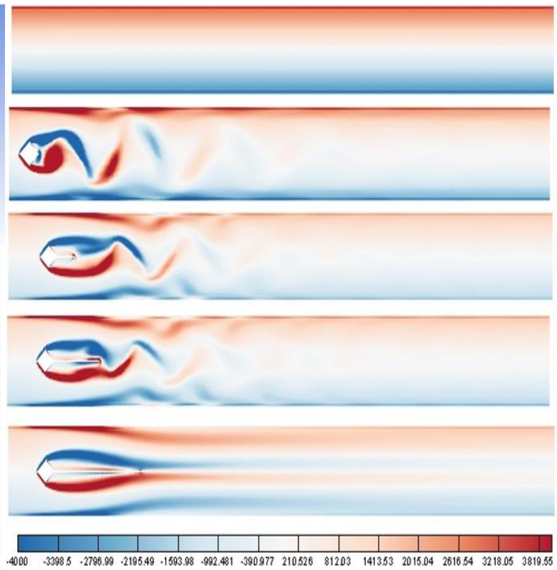

Figure 3. vorticity shematic for empty chnnel, Channel with cylinder, 1.5mm fixed plate, 4mm fixed plate, and 7.5mm fixed plate attached to cylinder

Pressure disturbution for 1.5mm, 4mm, and 7.5mm is drawn in figure 4. It shows that flexible plate has similar function to fixed plate in change flow regim as a splitter. While the length of plate growed we saw that vortexes declined. Another phonomenon that detected along with increase in the length of plate was vorex induced by vibrations of plate that were initialized by interactions between flexible plate and generated vortexes. This fact was amplitude by reactions of flexible plate to vortices. However, by enhancing the length of splitter the mentioned effect dwindled and the effect of length was dominant. The peak of vortex induced vibrations impacts diagnosed in flexible plate with 4mm length.

In the same way, drag and lift forces are compared for flexible plates in Table 3 and Table 4 respectively. As it can be viewed brightly, drag force has reverse correlation with the rise in the length of plate. Although the Lift force situation is a bit different and its quantity enhance simultaneously by length to 4mm, after this length the Lift declines constantly by increase in length of splitter plate. This is another evidence that proved the effect of attendance of flexible plate in quieting the flow regime.

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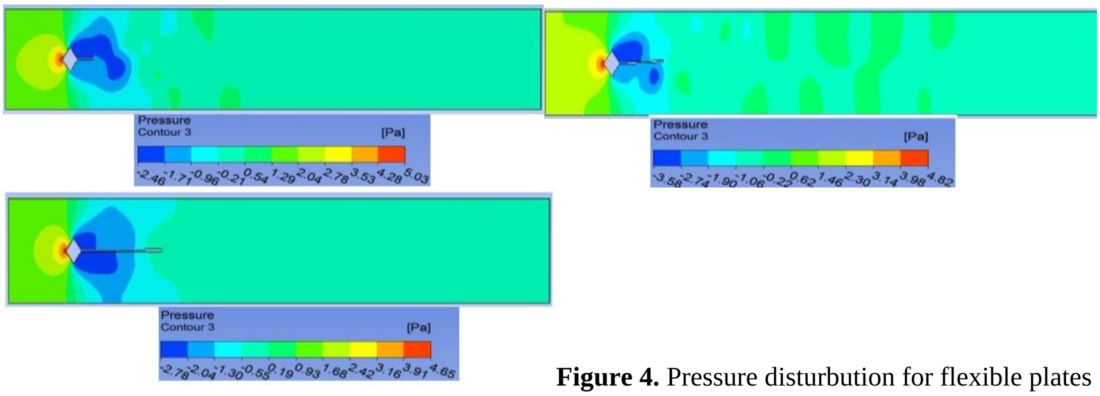

Figure 4. Pressure disturbution for flexible plates

Table 2. Drag for flexible plates

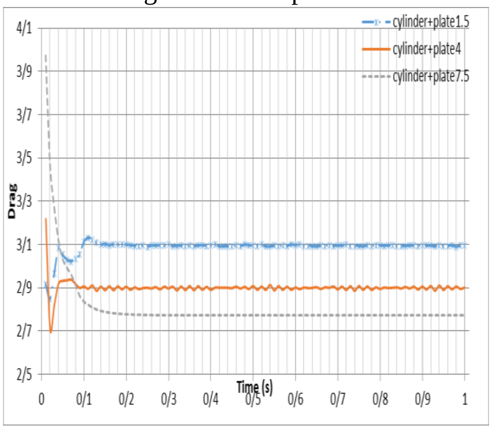

Table 3. Lift for flexible plates

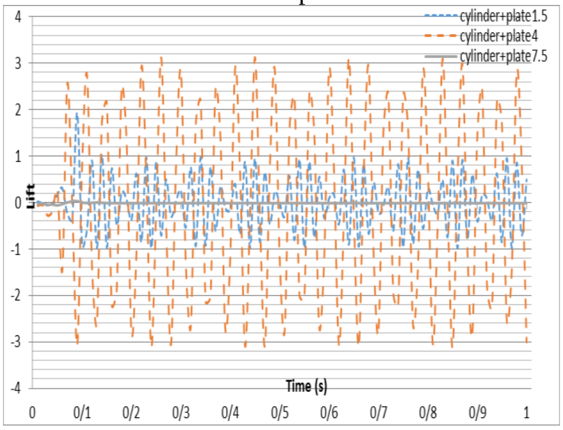

Table 4. Displacements of flexible plate in every second

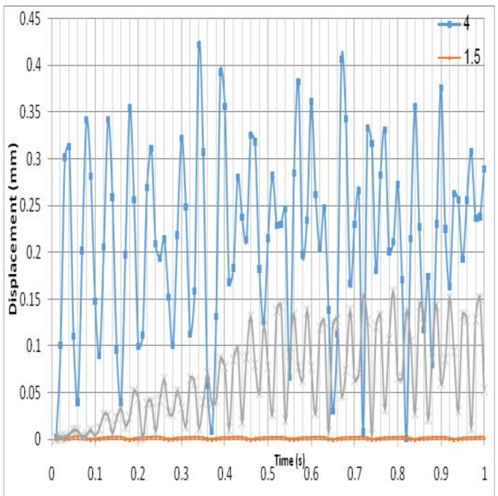

Table 5. Pressure loss comparison

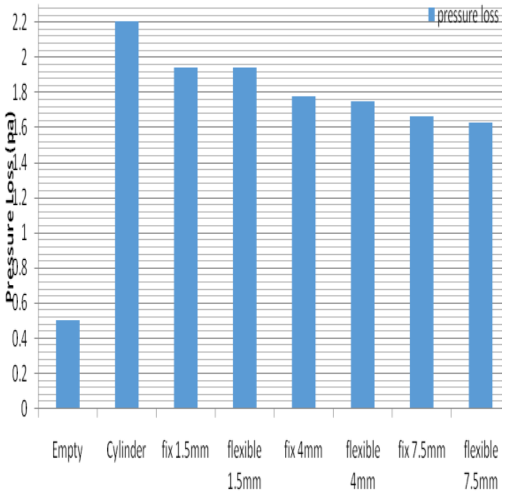

Table 4 illustrate the displacements of flexible plates in millimeter. Flexible plate with 4mm length had the most movements. The smallest plate was approximately fixed and had very little displacement.

The longest plate under investigation had movements less than 4mm plate but they were restricted and without any jump.

4. Conclusion
consequently pressure loss in all cases have been compared in Table 5. The biggest dissipation occurred in channel with cylinder situation. Attaching a plate, regardless to be flexible or fix, both make flow quiet and this effect strengthened by increase in the length of the plate. Flexible longer plates have better performance in relation to shorter ones. This phenomenon could be seen obviously in 7.5mm plate that its movement cause suppressing the vortexes.

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