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Influence of Pair of Vortex Generators on the Hydraulic Performance for Air Flow through a Rectangular Duct

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Abstract

The influence of a pair of delta wing vortex generators on the hydraulic performance has been experimentally studied. Pair of vortex generators is glued on the surface of rectangular duct the geometrical parameters of the vortex generator are varied systematically and effect of different size and shape of the vortex generators on the friction factor has been studied. The values of friction factors are noted down for different flow rates, Reynolds number based on the hydraulic diameter being varied from 8000-24000. Friction factors are reported for 0.1 e/Dh 0.5, 4 p/e 16, in rectangular duct having aspect ratio AR = 0.5.The values of the friction factors obtained for smooth pipes are compared with the values estimated from correlations proposed by Blasius.

***Key Words*:**Duct; Friction factor; Reynolds number; Pair of vortex generator; Hydraulic performance.

1 Introduction

Some methods are known to improve convective heat transfer. Turbulent promoters or vortex generators are often used to process the flow and to positively influence the thermal performance. There are many applications in the technical industry those are needed to enhance the heat transfer. The improvement of the heat transfer coefficient and the reduction of pressure drop are essential in all of these applications. In many technical applications, such as heat exchangers, high-temperature gas turbines and electronic equipment, heat transfer is very important. For this reason, many researchers are working to enhance the heat transfer in non-circular channels, such as rectangular, rectangular, trapezoidal, polygonal and triangular. In these channels hydrodynamics and thermal fields are closely linked. This paper presents the experimental results of hydrodynamics within a rectangular tube. Rectangular channels are well suitable in the turbine blade because we can easily construct the rectangular channels compare to other circular and non circular channels and also these channels provide the complex geometry due to this complex geometry turbulence of flow will increase the turbulence increases heat transfer also will increases. Ingalagi, M.R et al. (2016) there are many methods for increasing the heat transfer coefficients, which are classified as active method, passive method and compound method. The active method requires external power, such as electrical or acoustic fields, mechanical devices or surface vibrations, but passive method does not require external power, but this method requires a special geometric surface. The combination of both active and passive method technique is used in the compound method. Only passive techniques are discussed here. The passive method for heat transfer is based on two main strategies those are disturbing thermal barrier and creating turbulence flow. The destruction and restart of the boundary layer ensures that increase of heat transfer, making boundary layers instead of the constant limits. To do this Vortex generators can be used such as ribs, ridges, dimples or edges.

2 DESCRIPTION OF EXPERIMENTAL SET-UP

Different experiments are conducted in an experimental set-up as depicted in Fig. 1.(a) [1] The experimental system consists of a rectangular channel of hydraulic diameter 30mm and length 900mm. Blower sucks the air, air enters into the test section through a valve, which regulates the flow through the test section. flow rate is measured by using orificemeter which is placed about 25mm pipe diameters A simple U-tube manometer is used for the measurement of differential pressure head across the orificemeter. A micro differential manometer with a combination of water and benzyl alcohol (specific gravity = 1.046) as the manometric fluids is connected across the test section to measure the pressure drop across the test section. Two pressure taps give value of pressure of the test section where pressure measurement is required. The axial distance between the pressure taps for the differential manometer is 850 mm. And channel roughened with pair of delta wing vortex generators shown in Fig-1. In this the pair of delta wing vortex generators are attached on the bottom surface of the rectangular channel for conducting the experiment. These pair of delta wing vortex generators are made up of 0.5mm thick aluminium sheet and having different aspect ratios (ar=2b/c=1.6) also other geometrical parameters of pair of delta wing vortex generators are systematically varied

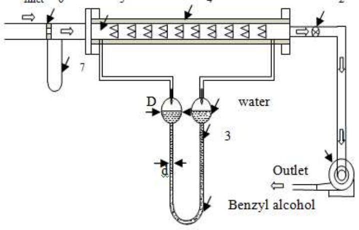

Figure 1 (a) Experimental Set-up
1. Air Blower

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2.Controle Valve
3 .Micro Deferential Manometer
4.Square duct
5.Pressure tap
6.orificemeter
7.U tube Manometer

A. Geometry and computational details

A delta-shaped pair of vortex generators are mounted on the lower surface of this channel to analyze the fluid flow characteristics in the rectangular closed duct. the rectangular duct sides are labeled L, H and W, and the channel aspect ratio (A) is W / H. other geometric parameters of the pair of delta wing vortex generator are , shown in Fig.1 and Fig.2 .

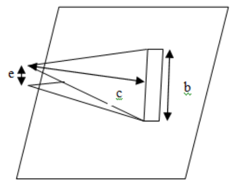

Figure 1(b) Active delta wing

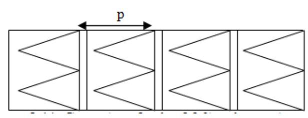

Figure 1 (c) Geometry of pair of delta wing vortex generators

Vortex Generator Base (b): The span of the vortex generator used to attach it to the wall surface is the base. Length of chord (c): The distance of the tip of the vortex generator from its base is Length of chord.

B. The non-dimensional parameters are

Ratio of height of vortex generator tip to hydraulic diameter of rectangular duct (e / Dh): the height of tip of the delta wing vortex generators can measured from measuring the distance between tip of the delta wing vortex generator to surface of rectangular duct where it glued and Dh is the hydraulic diameter of the channel ratio of these two parameter become the Ratio of height of vortex generator tip to hydraulic diameter of rectangular duct. Pitch to

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Height ratio (p / e): Pitch to Height ratio is the ratio axial distance between the two equal points of the pair of delta wing Vortex generator to tip of the vortex generator. Aspect ratio (ar): this indicates the size and shape of the delta wing vortex generator which is given as [ar = 2b / c].

The dimensionless friction factor is defined as (ff / ffs), where ffs is the friction factor measured in smooth rectangular duct and ff is friction factor measured when pair of vortex generators are attached inside the rectangular duct. The Reynolds number is defined as Re = v * Dh / , where v is the velocity of the air in a channel and is the viscosity of air which is flowing through the channel.

C. Governing equations

$$\Delta P = \rho_2 gh[1 - (\frac{\rho_1}{\rho_2} + \frac{a}{A} * \frac{\rho_1}{\rho_2})] \quad (1)$$

$$fforffa = \frac{\Delta p}{\frac{4L}{D_H} \frac{p_a V^2}{2}} \quad (2)$$

$$fft = 0.046 Re^{-0.2} \quad (3)$$

A micro differential manometer connected to pressure taps which measures the pressure drop across the rectangular duct. The schematic arrangement and dimensional details of the micro differential manometer are shown in Fig. 1 (a). The measurement of pressure drop was done at the atmospheric temperature condition. [2]In a fully developed duct flow using equation (1). The friction factor was determined in terms of pressure drop across the rectangular eq(2).The friction factor of the present study was validated by the friction factor for fully developed turbulent flow in smooth duct (l04¡ Re ¡ 106) proposed by Blasius as eq(3).

3 RESULTS AND DISCUSSION

Fig. 2 (a) Is the graph of friction factor vs. Reynolds number for the smooth rectangular channel ffa means actual friction factor obtained from the experiment fft is the friction factor obtained from the Blasius equation for the smooth channels. From this graph we can say that the experimental results for friction factor in smooth rectangular duct reasonably agree well within 7% and 4% values estimated from correlation proposed by Blasius.

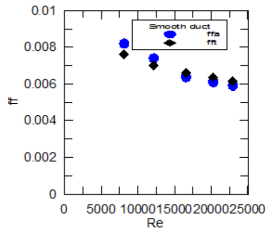

Figure 2(a) Results obtained from smooth duct.

A. Effect of Pitch to height ratio (p/e) on friction factor ratio (f/fs) for given Reynolds numbers.

Fig. 2(b) to Fig. 2(e) shows the effect of pitch to height ratio on friction factor ratio (f/fs) for different Reynolds number and p/e=4,8,12,16 in a rectangular duct. The friction factor ratio increases with reducing pitch to height ratio shown in Fig 4 for different Reynolds numbers. The smaller p/e ratio provides shorter axial distance before flow gets obstructed by the axially placed next pair of vortex generator which results in a higher friction factor ratio. The increased overall mixing of the flow at lower p/e ratios also contributes to the increased pressure drop. In this figure results are compared and it was found that the value of friction factor ratio for the lower value of p/e (p/e=8) is 38% higher than the larger value of p/e (p/e=16) similar trend is continue in the Fig. 2. b,c,d,e.

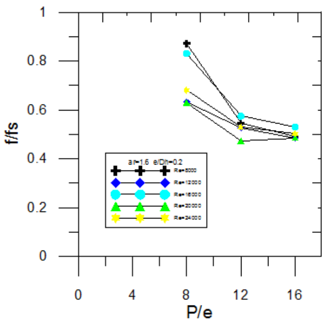

Figure 2 (b)Variation in f/fs with p/e(ar=1.6,e/Dh=0.2)

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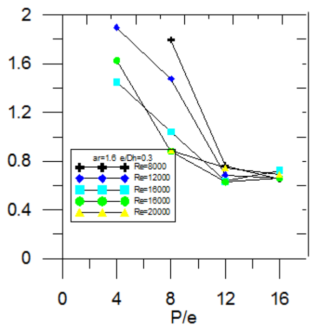

Figure 2(c)Variation in f/fs with p/e(ar=1.6,e/Dh=0.3)

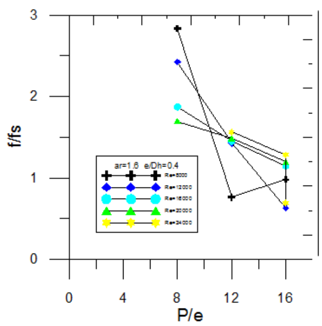

Figure 2 (d)Variation in f/fs with p/e(ar=1.6,e/Dh=0.4)

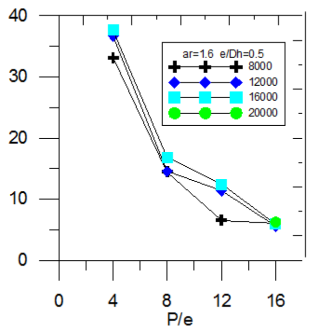

Figure 2(e) Variation in f/fs with p/e(ar=1.6,e/Dh=0.5)

4 Conculation

In this paper an experimental study has been performed to obtain pressure loss or friction factor for an air flow in rectangular channel. The vortices are produced by the insertion of pair of wing vortex generators with delta wing type geometry. From the experimental results, it can be concluded as follows:

For the air flow in the rectangular channel, the friction factor ratio decreases with the increase in Pitch to height ratio (p/e). Because if p/e increases the distance between two adjacent pair of wings also increase and therefore disturbance in the channel is reduced.

Comparing all the graphs which are obtained from the experiment carried out in rectangular duct having pair of delta wing vortex generator and the graph obtained from the smooth duct experiment, friction5factor ratio is decreasing with increasing Reynolds number in smooth channel, but in case of graphs obtained from rectangular duct having pair of wing vortex generator the friction factor ratio is increasing with Increasing Reynolds number because in these ducts better mixing of air takes place and also the pair of wing vortex generators blocks more amount of air in ducts which may affect the boundary layer thickness at higher Reynolds number.

References

[1] Katti, Vadiraj V., Malipatil, Anandkumar S., Ingalagi, Mahesh R.,. Experimental Investigation of Flow Characteris-tics in a Square Duct With Delta-Wing Vortex Generators.Paper No. GTINDIA2013-3773., pp.295-309,http: //dx.doi.org /10.1115 /GTINDIA 2013-3773, pp. V001T04A013; 10 pages.

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