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Numerical Study on Temperature Distribution in an Annular Diffuser Using Twisted Rectangular Hub / Pimpled Hub as Swirl Generators

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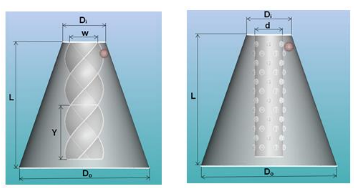
Graphical abstract



Abstract

Annular diffuser has very strong industrial significance. The existence of hub can guide the flow axially and radially outward. In this paper temperature distribution is numerically investigated in an annular diffuser fitted with two different hub geometries that include twisted rectangular hub and pimpled hub. These two hub shapes are studied and compared as swirl generators. Inlet boundary conditions and annular diffuser geometries for both hub configurations are kept constant with Reynolds number (Re = 4.2 x 10^4). The results indicate that using both twisted rectangular hub and pimpled hub will impose the flow to follow in a swirl motion and force the temperature to distribute in a helical direction. Temperature distribution will be enhanced as a result of increasing of swirl motion, however the results pointed out that pimpled hub inserts provide better distribution effect.

Keywords: Temperature distribution, annular diffuser, twisted hub, pimpled hub, swirl flow, CFD.

1.0 INTRODUCTION

Diffusers are used in many industrial engineering applications to reduce flow velocity and to increase flow pressure. According to the applications, they have been designed in different geometries (shapes and sizes). Annular diffuser is one of them. It is an essential component in many fluid systems. Annular diffusers are extensively used in gas turbine engines of high-speed aircraft, pumps, fans, wind tunnels, etc. Their performance depends on their geometry and the inlet conditions.

In combustion process and heat exchangers heat distribution is needed to be promoted. Therefore, swirl creator is used for this purpose. Because of the importance of internal swirl flow on heat distribution, Yang et al. [1] studied the heat transfer in the entry area of a convergent passage with the pre-swirl inserts. The experiments conducted with Reynolds number range from 7970 to 47820, and the swirl number from 0 to 1.2. They obtained that with the insertion of a swirl number equal to zero (that means no swirling flow), there was no considerable effect on the heat transfer, but after the generation of the swirling flow, the heat transfer increased with increasing the swirl number. As a conclusion, the helical motion and swirl velocity of the flow will caused the heat transfer to be increased.

Swirl can be produced by different processes such as twisted configuration [2,3], pimples [4], helical tape [5,6], and helical screw-tape [7,8], etc. Researchers studied different swirl configurations to reach more understanding for the swirling flow field. Ehan et al. [2,4] numerically simulated the influence of the twisted arrangement and the pimples as swirl creator to enhance the distribution of the temperature. An annular diffuser with twisted rectangular hub [2] and an annular diffuser with pimpled hub [4] are simulated. The results showed that the temperature distribution will be promoted with the use of twisted and pimpled hub. Since heat transfer enhancement technology plays an important role in many engineering applications, Hong et al. [3] studied the thermal flow characteristics in converging-diverging tubes (CDs) and converging-diverging tubes equipped with twin counter-swirling twisted tapes (CDTs) numerically. The obtained results detected that all geometric parameters had important effects on the thermal performance. Erdemir et al. [9] pointed out that increasing helical and swirling motion increased the heat transfer. They numerically investigated the internal flow fitted with dual twisted arrangements. Different diameter ratios (d/D) were examined and the results indicated that swirling motion enhanced the thermal flow properties.

Eiamsa et al. [10,11] experimentally investigated the co-swirl flow and the counter swirl generators effect through a round tube equipped with helical screw tape and twisted tape [10]. Experiment result obtained that the combined tapes in counter–swirl arrangement the heat transfer were 3.4% and 10% higher than those in co-swirl arrangement and helical tape alone. Moreover researchers studied the co-swirl flow generators that included twin counter twisted tapes and twin co-twisted tapes. Four different twist ratios (y/w = 2.5, 3.0, 3.5 and 4.0) were used for Reynolds numbers range between 3700 and 21,000 under uniform heat flux conditions [11]. The results confirmed that the counter-swirl tapes were more efficient than the co-swirl tapes and heat transfer, and friction factor increased as the twist ratio (y/w) decreased.

In the current study, an annular diffuser with twisted rectangular hub and an annular diffuser with pimpled hub are numerically simulated. The study conducted to show how the temperature is distributed inside the annular diffuser with two different hub configurations. They are simulated and analyzed by means of CFD software. The simulations are carried out at the same inlet conditions with Reynolds number around (Re = 4.2 x 10^4) based on the hydraulic diameter of the annular diffuser (Dh).

2.0 Methodology

2.1 Annular Diffuser With Twisted Rectangular Hub Geometry

The annular diffuser with twisted rectangular hub geometry is shown in Fig. 1-a. Two different pitches (Y = 43 mm and Y = 32 mm) are numerically simulated. Twist can be calculated by counting the number of twists in length unit, therefore these two pitches will produce two types of twists includes 2-twists rotations and 3-twists rotations as shown in Fig. 2.

2.2 Annular Diffuser With Pimpled Hub Geometry

The annular diffuser with pimpled hub geometry is shown in Fig.1-b. Pimples with two different radiuses (R = 3.5 mm and R = 4.5 mm) with the same pitch (Y = 20 mm) are represented by configurations (c and d), respectively. CAD drawing is shown in Fig. 3. Table 1 displays the geometric dimensions of the tested diffuser for both hub designs.

2.3 Computational Simulation

In the present work numerical study is conducted in an annular diffuser fitted with twisted rectangular hub and an annular diffuser fitted with pimpled hub.

The commercial software Numeca Fine/Open v.3.1 is chosen as the CFD tool for this study. The standard k-ε model is applied as a turbulence model and the numerical analyses are performed in three dimensional domains. The turbulence kinetic energy k and its rate of dissipation ε calculations follow literature reference [12].

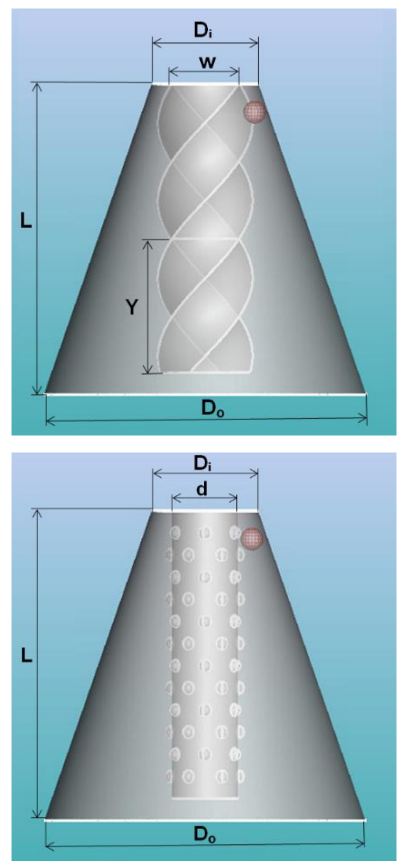


Figure 1 Annular diffuser fitted with, a: twisted rectanguar hub, b: with pimpled hub

Table 1 Tested diffuser dimensions

Parameters	Dimension [mm]
Inlet diameter, D_i	48
Outlet diameter, D_o	145
Length, L	140
Hub height, W	30
Hub diameter, d	30

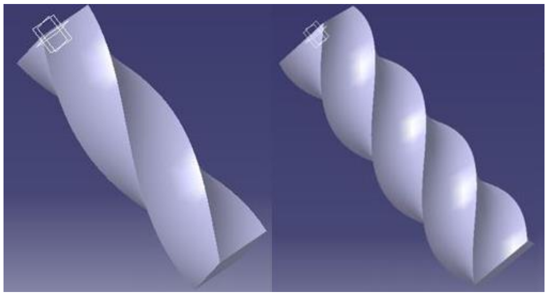


Figure 2 CAD drawing with twisted rectangular hub

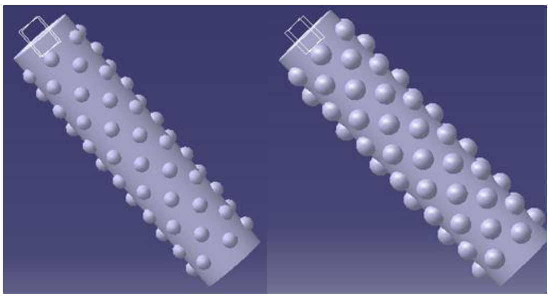
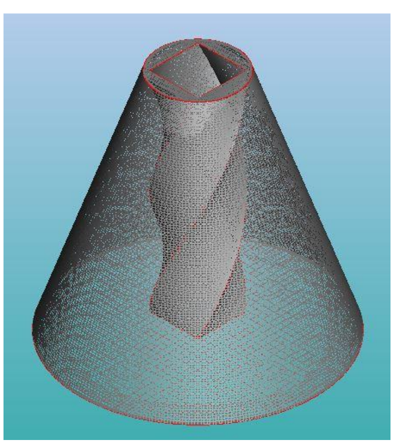


Figure 3 CAD drawing with pimpled hub

Fig. 4 (a-b) shows mesh generation of an annular diffuser fitted with twisted rectangular hub and pimpled hub respectively. Table 2 represents typical values of boundary conditions.

2.4 Heat Source

For this research, a spherical heat source of 0.005 m radius is located at 24 mm from the radial axis, 22 mm downstream of the diffuser inlet section. It is with the beginning of the twist configuration and the pimples as shown in Fig. 1. The unsymmetrical location is purposely chosen in order to better observe the helical motion. The objective is to investigate temperature distribution during the flow, so to simplify, 10 kW heat source is selected for this purpose.



(a)

(b)

Figure 4 Mesh generation of an annular diffuser fitted with, (a) twisted rectangular hub, (b) pimpled hub

Table 2 Typical values of boundary conditions

Parameters/Properties	Value
Inlet pressure , *Pi*	289000 [Pa]
Inlet Temperature, *Ti*	870.266 [K]
Kinematic Viscosity, v	3.4077×10^{-5} [m^2/s]
Reynolds Number, Re	4.2×10^4
Inlet velocity of air, *Vi*	80.68 [m/s]

3.0 RESULTS AND DISCUSSION

The temperature distribution in an annular diffuser with twisted rectangular hub and pimpled hub are numerically studied and the simulation results are compared in both configurations.

3.1 Cutting Sections:

Three planes relative to the inlet for both configurations along the radial direction of the annular diffuser are discussed. The three planes include 30 mm (section 1-1), 80 mm (section 2-2), and 135 mm (section 3-3) respectively from the inlet section, presented in Figs 5 and 6.

3.2 Effect Of Twisted Rectangular Hub:

The effect of twist configuration is shown in Fig.5. It shows the temperature distribution inside the annular diffuser with two pitches. The temperature range for both analyses is set consistent from 480 K (light blue) to 2000 K (red). Section 1-1 in Fig. 5-a, represents the temperature behavior, it starts to distribute due to the twisted configuration effects. In section 2-2 the circular motion forced the temperature to be distributed in the radial direction as well. And in section 3-3, the distribution area becomes wider. From Fig. 5-b, it can be noticed that the behavior of the temperature distribution seems to be the same with a little improvement.

3.3 Effect Of Pimpled Hub:

Results of pimpled hub with different radius shown in Fig. 6, the temperature range is presented from 480 K (light blue) to 2000 K (red). Fig. 6-c shows the temperature distribution for pimple radius (R = 3.5 mm). In section 1-1, maximum temperature is at the heat source location. The insert of the pimples force the temperature to be distributed in a circular motion. Distribution area becomes wider in section 2-2 and in section 3-3. The effect of pimple radius (R = 4.5 mm) is represented in Fig. 6-d, the temperature starts to distribute in the both radial direction and in the direction of flow from section 1-1 until section 3-3. It can be seen that the phenomenon appears to be similar.

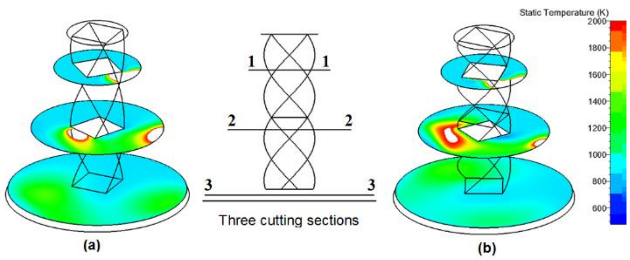


Figure 5 Temperature distribution at the three plans for an annular diffuser fitted to twisted rectangular hub for two different pitches, (a) Y = 43 mm, (b) Y = 32 mm

3.4 Comparison Of The Effect Of An Annular Diffuser Fitted With Both Twisted Rectangular Hub And Pimpled Hub:

In Fig. 5-a, and Fig. 6-c show clearly that the temperature start to distribute in both hub configuration started from section 1-1 to section 3-3. However the pimpled hub has a better effect. In Fig. 5-b, and Fig. 6-d, pimpled hub configuration prevents good temperature distribution.

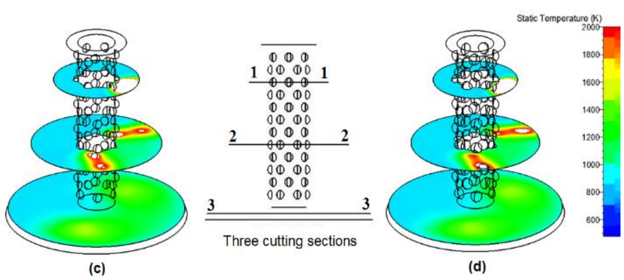


Figure 6 Temperature distribution at the three plans for an annular diffuser fitted to pimpled hub for two different pimples radius , (c) *R* = 3.5 mm, (d) *R* = 4.5 mm

4.0 CONCLUSION

Numerical simulations have been carried out to investigate the temperature distribution in an annular diffuser fitted with two different hub geometries using heat source. The results have been made according to twisted rectangular hub with two different pitches and pimpled hub with two different radiuses. Therefore the following conclusions can be made from the numerical simulation study:

1) The results indicate clearly that the temperature will follow helical and circular motion due to the present of twisted hub and the pimples inserts.
2) Different pitches for twisted rectangular hub will enhance the distribution and the results indicate that pitch (Y = 32 mm) has a better effect than pitch (Y = 43 mm).
3) Simulation results showed that the pimpled hub inserts provide better distribution effect.

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References

[1] Yang, C. S., Jeng, D. Z., Yang, Y. J., Chen, H. R. And Gau, C. 2011. Experimental study of pre-swirl flow effect on the heat transfer process in the entry region of a convergent pipe. *Experimental Thermal and Fluid Science*. 35: 73–81.

[2] Shukri, E. S., Wisnoe, W. And Zailani, R. 2014. Numerical Investigation of the Heat Distribution in an Annular Diffuser Equipped with Twisted Rectangular Hub. *Applied Mechanics and Materials*. 465-466: 582-586.

[3] Yuxiang, H., Xianhe, D. and Lianshan, Z. 2012. 3D Numerical study on compound heat transfer enhancement of converging diverging tubes equipped with twin twisted tapes. *Chinese Journal of Chemical Engineering*. 20: 589-601.

[4] Shukri, E. S., Wisnoe, W. and Zailani, R. 2014. Heat Distribution in an Annular Diffuser Equipped with Pimples. *IEEE Xplore*.

[5] Wisnoe, W., Shukri, E. S., Zailani, R., Che Mi, M. H. and Zakaria, M. F. 2013. Numerical Investigation of Temperature Distribution in a Diffuser Equipped with Helical Tape. *Applied Mechanics and Materials*. 393: 793-798.

[6] Gül, H. and Evinb, D. 2007. Heat transfer enhancement in circular tubes using helical swirl generator insert at the entrance. *International Journal of Thermal Sciences*. 46: 1297–1303.

[7] Zhang, X., Liu, Z. and Liu, W. 2013. Numerical studies on heat transfer and friction factor characteristics of a tube fitted with helical screw-tape without core-rod inserts. *International Journal of Heat and Mass Transfer*. 60: 490–498.

[8] Eiamsa-Ard, S. and Promvonge, P. 2007. Heat transfer characteristics in a tube fitted with helical screw-tape with/without core-rod inserts. *International Communications in Heat and Mass Transfer*. 34: 176–185.

[9] Erdemir, D., Gunes, S., Ozceyhan, V. and Altuntop, N. 2013. Numerical Investigation of Heat Transfer Enhancement and Pressure Drop in Heat Exchanger Tube fitted with Dual Twisted Tape Elements. *World Scientific and Engineering Academy and Society (WSEAS)*. ISSN: 2227-4596.

[10] Eiamsa-ard, S., Yongsiri, K., Nanan, K. and Thianpong, 2013. Thermo hydraulic of co/counter swirl flow through a round tube fitted with helical screw tape and twisted tape. *Indian Journal of Chemical Technology*. 20: 145-155.

[11] Eiamsa-ard, S., Thianpong, C. and Eiamsa ard, P. 2010. Turbulent heat transfer enhancement by counter/co-swirling flow in a tube fitted with twin twisted tapes. *Experimental Thermal and Fluid Science*. 34: 53–62.

[12] Mohd Jaafar, M. N., Jusoff, K., Osman, M. S. and Ishak, M.S.A. 2011. Combustor aerodynamic using radial swirler. *International Journal of the Physical Sciences*. 6: 3091-3098.