Effect of Swirl Producing Turbine Type Inserts on Heat Transfer Enhancement using Passive Method: A Review

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Abstract— Heat transfer enhancement techniques play a vital role in various engineering applications such as heat exchangers, air conditioning systems, boiler, chemical reactor and refrigeration systems. Heat transfer enhancement techniques are mainly divided into passive techniques and active techniques. Swirl flow generating insert is one of the new type of insert used for heat transfer enhancement. Swirl flow generating insert can be of active or passive type but this paper mainly focusing on heat transfer enhancement using passive type of swirl flow generating inserts. In passive technique without external power supply heat transfer rate is increased but the main precaution is taken to control the pressure loss.

Key words: Heat Transfer Enhancement, Swirl Flow, Passive Techniques

I. INTRODUCTION

Swirl/vortex flow has wide range of application in swirl burner, swirl vortex combustor, vortex tube refrigeration, heat exchanger, thermal power plant, automobiles, etc., Heart transfer enhancement techniques are mainly classified into three types; active, passive, and compound technique.In active techniques heat transfer rate is improved with the help of additional power supply, where as in case of passive technique heat transfer rate is improved at the cost of pressure drop of fluid flow without supplying additional power supply. In case of compound techniques both active and passive techniques are combined to increase heat transfer rate.In this review paper specifically those papers are considered in which swirl flow is generated with the help of twisted blade/baffle rotors, twisted fins, etc. Due to blade angle swirl flow is generated which diminishes after travelling certain distance, this length of swirl region mainly depends upon velocity of flow, blade angle of rotor, width of rotor, viscosity of fluid, etc.

II. LITERATURE REVIEW

A. Khalil et al. [1]In this paper experimental study has been done on the effect of sudden expansion ratio of pipe with differentswirl angles. Effect of different vane angle, swirl generator location, sudden expansion ratio and Reynolds number on heat transfer and pressure drop were examined. Reynolds number used in this experiment was in the range of 9000 to 41,000. Swirl generator propeller having vane angle of 15º,30º,45º and 60º are inserted in the test section at distance S=H, 3H, 5H, 10H, and 40H from its entrance (H is the step height, H=0.5(D-d)). Combine effect of swirl generator and sudden expansion pipe were studied in this experiment, sudden expansion ratio used were d/D=0.32, 0.46 and 0.61 (D- test section pipe diameter, d-upstream pipe diameter).For the same Reynolds number the Nusselt number increases as d/D decreases.It was found that, maximum Nusselt number shifted towards inlet with increase in sudden expansion ratio. For the small vane angles local Nusselt number increases with the distance S (the distance between sudden expansion and swirl generator), whereas for high vane angle Nusselt number increases as distance S decreases.

Fig. 1: Photograph of a swirl generator. [1]

Smith Eiamsa-ard et al. [2] The paper presents the effect of propeller having different number of blades with variable blade angle on heat transfer, enhancement efficiency and pressure loss. In this experiment study has been done for Reynolds number ranging from 4000 to 21,000. The experiments were also carried out for different propeller blade number (N=4, 6 & 8 blades).

Parameter	Values
Blade angles, θ	30°, 45° and 60°
Pitch ratio, PR=l/D	5, 7 and 10
Number of blades, N	4, 6 and 8 blades
Reynolds number, Re	4000 to 21,000

Table1: Experimental conditions used in the present investigation are[2]

Nusselt number and friction factor obtained for the plain tube from this experiment were compared with the Dittus-Boelter equation for the Nusselt number and Blasius equation for the friction factor. For the pitch ratio of 5, 7 and 10 increased in heat transfer rate were 113%, 90% and 73% respectively. In this experiment authors observed that with the increase of blade number(N) and the blade angle(θ) the heat transfer rate and enhancement efficiency both increase, but for the increase in pitch ratio enhancement efficiency and heat transfer rate both decrease. For higher Reynolds number swirl generator is found to be more effective.

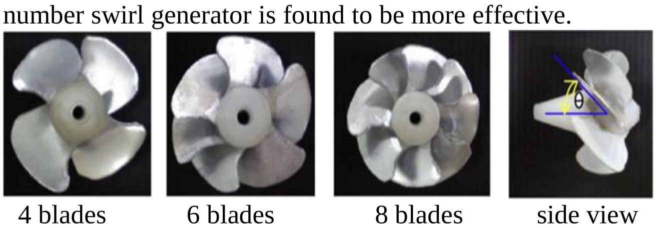


Fig. 2: various propeller type [2]

Weerapun Duagthongsuk et al. [3]In this paper experimental investigation has been done on the effect of RTSG (rotating turbine type swirl generator)on heat transfer rate and pressure drop. Test section used is of stainless steel tube having 9.2mm ID, 0.4mm thickness and 3.2m in length. 2cm long aluminium made RTSG was used with twist angle of 60o. Total five number of RTSG inserts were mounted in test pipe at X/L= 0.0, 0.2, 0.4, 0.6, and 0.8 respectively.

Study has been done for Reynolds number ranging from 4500 to 9500. The results obtained for plain tube were compared with values obtained from Gnielinski equation and Colebrook equation to validate experimental setup. Experimental result shows that the average heat transfer coefficients of the RTSG insert were nearly 35-37% higher than that of the plain tube. Pressure drop in RTSG inserts were nearly 2.5 times more than that of plain tube. Results were compared with plain tube and it was found that the heat transfer rate and pressure drop were increased due to RTSG insert.The maximum local heat transfer coefficient were observed to be just after RTSG insert.

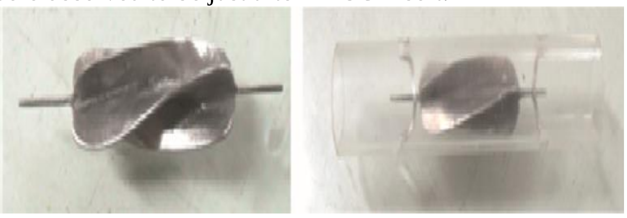


Fig. 3: Bare RTSG insert and RTSG insert installed in acrylic pipe [3]

Weerapun Duagthongsuk et al. [4]The authors have done research on the effect of FTSG (fixed turbine type swirl generator)and RTSG(rotating turbine type swirl generator)on heat transfer and friction characteristics. From the experimental analysis it is clear that, the heat transfer rate is more after FTSG and RTSG. Test section of 9.2mm ID, 10mm OD and length of 2.3m is used. De ionized (DI) water is used as testing fluid, study has been done for the range Reynolds number range 4500 to 9500and constant heat flux conditions were used. Effect of both FTSG and RTSG were studied separately by placing 5 pieces in test section and were located at X/L= 0.0, 0.2, 0.4, 0.6, and 0.8 respectively. From the experimental data it is demonstrated that the temperature of the wall in case of RTSG is slightly lower than that of FTSG insert, this shows that heat transfer performance is higher for RTSG than FTSG by 6.3% and 56% higher than plain tube.

Betul Ayhan Sarac, Tulin Bali [5]experimentally studied the effect of vane angle of vortex generator on heat transfer and friction factor and the authors conclude that with the increase in vane angle of vortex generator heat transfer decreases. Also they examined the effect of different position of vortex generator in test section on heat transfer and pressure drop and they found that the heat transfer and friction factor is large at x=L/4 than x=0 and x=L/2. Reynolds number range used in this experiment was 5000 to 30,000.

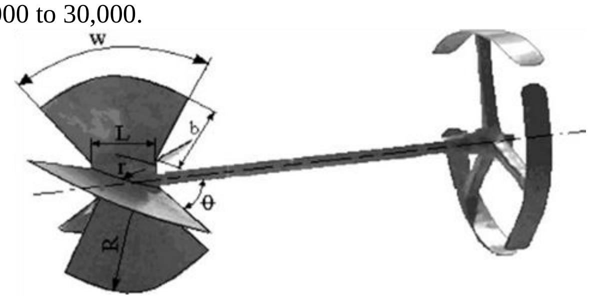
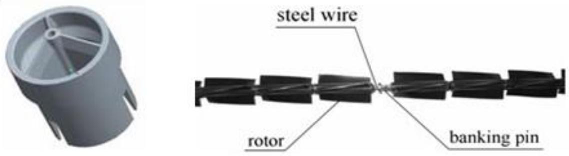


Fig. 4: The geometry of the propeller-type swirl generator [5]

Lin Guang-Yi et al.[6]The study has been done on the performance of heat exchanger with the insert of 19-100 specification (i.e. 19 mm diameter and 100 mm lead) rotors increases above smooth tube values. Also it is clearly mentioned in the paper that with the increase in flow velocity heat transfer rate increases to some level and starts align i.e. it has some optimum flow rate velocity at which maximum heat transfer is observed.

Fig. 5: The shape of rotor[6]

XIE Pengcheng et al. [7]The purpose of this experimental investigation was to study the performance of shell-and-tube heat exchanger with inserts. Rotor assembled strands were inserted into the circular tube to study the effect of inserts on heat transfer rate also the inserts are placed such that they should provide online automatic cleaning. Rotor-assembled strand consist steel wire, banking pin, rotors and fixed mounts. Fixed mounts are used to stretch the steel wire at both ends. With increase in Reynolds number and Nusselt number increases. Nusselt number for the tube inserted with rotor assembly is 101.6% more than that of the plain tube for the same Reynolds number. Friction factor was found to be more for rotor assembled tube than that of smooth tube. Also the Reynolds number and Prandtl number dependency were studied. The overall heat transfer coefficient was increased by 58.1%-67.4% for the range of Reynolds number 20,000 to 36,000. Friction factor increased by 52.25 to 84.25 for the same range of Reynolds number. In this experiment it was observed that the Nusselt number for the tube with rotor-assembeled strand is 101.65 more than that of smooth tube for Reynolds number of 20,000, whereas for Reynolds number 36000 Nusselt number is 106.6% more than that of smooth tube.



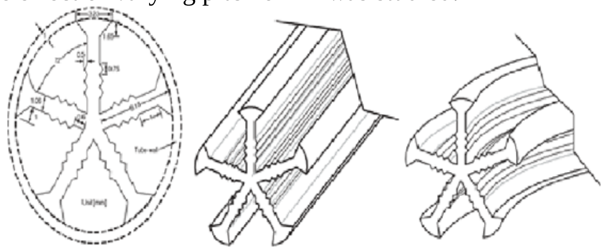
a) Fixed mount b) Insert

Fig. 6: picture of rotor assembly strand component [7]

HAN Changgang et al. [8] Study was carried out to understand the effect of rotor assembled strand on performance of shell tube heat exchangers. As compared to the plain tube theNusselt number increases was more than 200% for tube inserted with rotor assembled strand for same Reynolds number. Friction factor is also increased more than 200% for the same range of Reynolds number.

H. Gul, D. Evin [9]Analysis was done on the effect of helical tapes on heat transfer.In this experiment different type of helical tapes with different helical angles were mounted at the entrance of the test section. Momentum ratio (M_h/M_T) was used to calculate swirl intensity. The increase in heat transfer was found to be the function of M_h/M_T(tangential momentum of the helical fluid /axial momentum of the total flow) and Reynolds number. There was not much effect of helical angle (α) and helical channels (N_h) on heat transfer. Heat transfer coefficients were found to be more for swirl flow compared to non-swirl flow. Local heat transfer coefficient is 300% more for swirl flow as compared to the non-swirlflow. Reynolds number for experiment is 5000 to 30,000. Nearly 20% net energy gain was observed for highest momentum ratio.

Leonard D. Tijing et al. [10] Investigated the effect of star-shape internal aluminium straight and twisted fin on the heat transfer coefficient and pressure drop. Heat exchanger used for this investigation was counter flow heat exchanger. It was also observed that pressure drop is more in case of twisted internal fin than straight internal fin. Also the effect of varying pitch of fin was studied.



(i) (ii) (iii)

Fig. 7: Internal fin configurations: (i) cross-sectional view of star-shape fin and circular copper tube; (ii) straight fin; (iii) twisted fin.[10]

III. CONCLUSION

In this review paper the research papers which are reviewed are working on passive technique of heat transfer, also the main focus is turbine type of swirl generating devices. Heat transfer rate and friction factor is affected by type of swirl generator. In rotating type of swirl generator heat transfer rate is more than fixed type of swirl generator also the friction factor is less for rotating swirl generator as compared to fixed swirl generator. Location of swirl generator, angle of baffles/blades, number of baffles, and length of the swirl generator are the factor which affect the effectiveness of heat exchanger. With increase in blade angle friction factor, Reynolds number and pressure drop increases resulting to increase in Nusselt number.

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