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CFD Analysis of Melting and Solidification of the Phase Changing Material using Turbulator

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***Abstract*—In this work, a cylinder with twisted tape inserts is analysed. This design is about significant increase of heat transfer enhancement by introducing a cylinder inserted with twisted tape with flow of varied velocities of air inside the cylinder. The analysis performed in this paper focuses on the heat transfer enhancement and the change in the boundary layer thickness with twisted tape and without twisted tape. After performing the necessary design methods the change in boundary layer temperature and boundary layer thickness is found by CFD simulation, whose thermo-physical characteristics are highly variable with temperature. Furthermore using air the changes occurring in the cylinder provided with inserts was investigated by CFD. The results are compared and verified with thickness in boundary layer varied by heat transfer enhancement and temperature change & solidification of pcm.**

Index Terms—Boundary layer, CFD, Heat transfer enhancement, Pcm, Twisted tape

I. Introduction

The heat transfer enhancement inside a cylinder is not very efficient, hence mechanical inserts are been used. They increase the efficiency of heat transfer enhancement operating upon the boundary layer by introducing a swirl motion and increasing the mixing of the air from the inlet to outlet. In this way an increase in the convective heat transfer coefficient is obtained.

In this paper, the thermal and aerodynamic properties of a flow within a cylinder, with which twisted tape inserts, were analysed through numerical CFD methods for varied velocities. In this study the cylinder wall was considered to have a constant heat flux. Moreover, in the CFD tool, the conditions of the cylinder and the twisted tape are analysed which is compared based on simulation results.

The analysis was conducted for a cylinder of length 660 mm. The analysis is conducted for the cylinder with twisted tape, with air as inlet in cylinder. The development of the hydrodynamic boundary layer was found and the cylinder with twisted tape and without twisted tape is found during the analysis together with varying the velocity of the air in the cylinder.

The insertion of this type of cylinder introduces a swirl motion, the boundary layer is modified by varying the velocity and temperature gradient [1].

Different velocities resolutions were compared for the same geometry. Also, in order to make a comparison, CFD analysis was applied to a cylinder with a length of 660 mm. The heat transfer enhancement is dimensioned and optimized using CFD software.

In order to increase the heat transfer enhancement value of the convective heat transfer coefficient by varying the velocity of the air and the chiller room temperature, the analysis concerned a cylinder with a length of 660 mm using air as the working air. CFD simulation results were finally compared with those of with cylinder and twisted tape.

II. Concentric cylinder

Their design also requires observation performances with the varied velocities of air using CFD software .The air flowing in the cylinder with varied velocities can induce changes in the temperature and the change of boundary layer thickness.

The enhancement surface or the convective heat transfer coefficient can be changed to increase the thermal power. Introducing, the variation in the boundary layer and desired boundary layer temperature can be achieved by varying the velocities of air flow from inlet to outlet. It results in a reduction of their thickness. The disorder can be obtained by using mechanical inserts which improve the heat transfer enhancement and thermal efficiency. The choice of the material of the cylinder is suggested by the flow of the air with which they are in contact. In general they are made of the same material as the cylinder so they are inserted [5].

Fig. 1. Twisted tape

The experimental studies conducted to check the thermal and hydraulic performance of these devices have shown that they lead to an improvement of the performance of heat exchangers, with an increase in pressure losses, caused by the same mechanisms that lead to the improvement of the heat transfer enhancement.

The most common types of twisted tapes are: Helical Twisted tape (Fig. 1), consisting of a metal wire wrapped which a metal matrix is formed; Twisted tape (Fig. 2), consisting of a twisted metal.

A) Twisted tape:

Twisted tapes are inserts of 660mm in length and , to which a torque is applied to impart the characteristic helical shape. The flow is fundamentally changed because the twisted tape induces a swirl motion that causes an increase in flow path. An increase in the axial velocity owing to the reduction of the hydraulic diameter, the generation of secondary motion components which improve the mixing of the air which allows the boundary layers to be modified by varying the velocity and temperature gradients. In this way, the resistance to heat transfer enhancement.

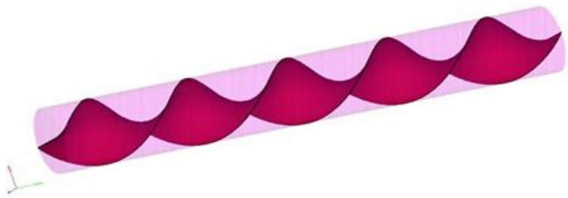

Fig. 2. Twisted tape inserts

Fig. 1 shows a sample of the twisted tape apparatus. In the initial part of the twisted tape there is a hole that is used to insert the twisted tape in the cylinder. The twisted tape can be easily pulled out of the cylinder and again reinserted to facilitate maintenance operations.

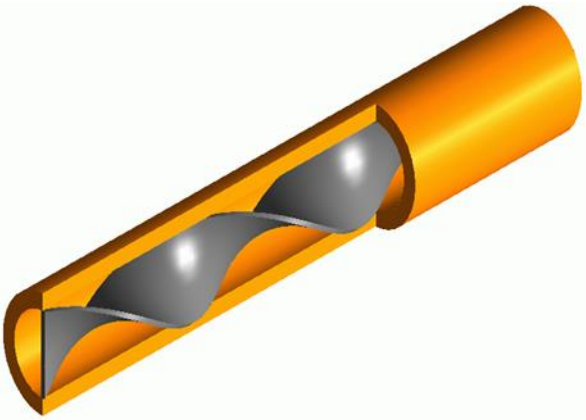

Fig. 3. Representation of a twisted tape inside a cylinder

III. DESCRIPTION OF THE PROBLEM

The increase in the heat transfer enhancement with the use of twisted tapes causes five effects [1]. These effects are: the increase in velocity due to the partitioning of the flow, the reduction of the hydraulic diameter, the increase of the flow path due to the presence of the tape, the generation of a secondary flow due to the spin induced by insert and, in the case of good contact between the insert and wall of cylinder.

The major influence on the increase of convective heat transfer coefficient is due to the strong mixing of the air for the occurrence of a swirl motion. This generates a vortex inside the flow and produces a tangential velocity component, negligible in the case of one-dimensional flow typical of a cylinder without insert, with the consequent increase in the velocity modulus, because of the complexity of the flow and temperature field it is necessary to use advanced numerical tools for the study of the problem. In the present work CFD fluent was used for solving the temperature variation and the boundary layer change with the change in the velocity of the air.

The change in the velocity of the air & the usage of the air as the desired flow inside the cylinder with and without the twisted tapes. The main aim is to achieve the swirl motion and increase in the heat Transfer enhancement along with the change in the boundary layer thickness.

In simulations aimed at the study of the influence of the twist ratio, air was employed as working air. Air is a very whose thermo-physical characteristics vary significantly with the temperature for the 660 mm cylinder, because of the small temperature difference between the inlet and outlet sections, the characteristics of the air have been assumed as constants and evaluated at an average temperature between the two sections. The velocity flow rate of 3m/s, 4m/s, 5m/s & 6m/s was used.

TABLE I
PROPERTIES OF COPPER AND ALUMINIUM

Material	Density	Specific heat	Thermal Conductiv
Copper	8978 kg/m^3	381 .0	387.6 W/m
Aluminium	2719 kg/m^3	871. 0	202.4W/m

The enhancement of heat transfer is the method of developing the performance of heat transfer to improve the enhancement of the heat transfer one is active method & another passive method and the main achievement of the experiment is to achieve the temperature change and change in boundary layer thickness The copper has uniform heat flux and uniform heat transfer [8].

The Table-1 confirmed from Orhan Keklikcioglu [2], Copper shows desired heat transfer enhancement and the usage of the same material of the twisted tape is same material used in the material of the cylinder. The copper shows better characteristics of thermal conductivity compared to aluminium. The material copper is used in the making of the cylinder and the same material of the cylinder is been used in making of the twisted tape in same length of the cylinder.

The geometry corresponding to the analysis, aimed at the study velocity of air in the 660 mm long cylinder, did not allow the use of a large number of volumes because of the extension of the physical and computational domain. In this case the rows belonging to the boundary layer were reduced.

The approach by which the behavior of the air with which the heat transfer enhancement without the inserts does not show the heat transfer enhancement the full length twisted tape is more effective than short length inserts [3].

The verification of the simulation correctness was performed in reverse order, i.e. starting from the results obtained from CFD analysis and compared them with those resulting from the application of temperature change and boundary layer is to be found.

IV. BOUNDARY CONDITIONS

Solid walls were designed with the wall-type boundary condition. On the lateral surface of the cylinder a constant heat flux is assigned, which determines a condition of the wall temperature variable along the axis of the cylinder. The circumferential heat flow through the cylinder where the boundary wall becomes significant for High value of Biot Number which induces variable conductive resistance [4] .The conditions of "mass flow inlet" in the input section and "outflow" at the output section were used for the air. The input condition is characterized by a constant mass flow rate.

Constant Heat flux which determines a condition of the wall Temperature which determines the conditions of the wall Temperature along the axis of the cylinder. The inserts which is made of copper determines the partition of the flow and slight reduction of the cross section of the cylinder which the vortex is generated which determines the occurrence of the of tangential velocity increase with decrease in the twist ratio leads to the heat enhancement.

The swirl generated in a parallel direction to the cylinder axis which will not be more linear and ascending up to completely developed condition of the motion of the air. The Higher inlet velocity of the given conditions the higher heat transfer coefficient with corresponding inlet velocities with high heat flux and this enhances the cooling of the Phase change material along the walls of the cylinder [5].

The difference in the entrance region the decrease in local heat transfer enhancement of the constant cross section duct is faster than that of the divergent duct but slower than convergent, the convective heat transfer enhancement and the complete profile of temperature is achieved at the outlet of the cylinder [7], while the twisted tape enhance or deteriorate heat transfer depending on the comparison condition: for the identical mass flow rate, it can enhance heat.

V. CFD Analysis

A thermo and aerodynamic study of the different velocity flow of air was conducted through CFD simulation. The geometry of the turbulator was generated using CFD software, reproducing the geometric characteristics of the problem. The complexity of the geometry prevented use of a hexahedral grid because of volume intersections near the cylinder wall.

The smaller grid dimensions near the turbulator wall were performed using tetrahedral volumes. Being a turbulent flow, it was not necessary to use a particularly pushed thickening. For the gap present between the longitudinal end of the turbulator and the solid cylinder wall it was necessary to use a greater number of cells in order to study the behaviour of the air in this area with good accuracy.

The geometry corresponding to the analysis, aimed at the study of the behaviour of the air in the 660 mm long cylinder, did not allow the use of a large number of volumes because of the extension of the physical and computational domain. In this case the rows belonging to the boundary layer were reduced to two.

The approach by which the behaviour of the air in the cylinder without insert was studied, was completely different. The domain generated in this case, for obvious computational reasons, is two-dimensional, axisymmetric and periodic CFD fluent is used.

The verification of the simulation correctness was performed in reverse order, i.e. starting from the results obtained from CFD analysis and compared them with those resulting from the application of mass and energy balances.

For required results of the desired turbulent flow of the air then the inlet temperature of the air is around 30^0C which is first analysed without twisted tape and then the second step is to analyse the cylinder with twisted tape of 660mm with given dimensions of outer diameter of the cylinder is 75.4 mm & and the Internal diameter is 72.8 mm and the outlet temperature is to be cooled down which should prove that there is heat transfer enhancement on the cylinder which is the outlet Temperature and & turbulent flow.

A) CFD analysis on cylinder of air flow at various velocities:

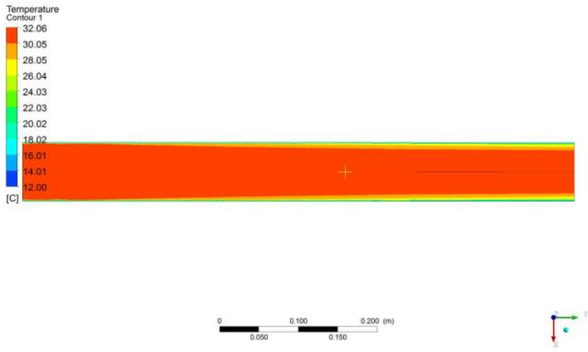

Fig. 4. Temperature and boundary layer

The above design shows the cylinder without twisted tape which they show the thickness of the boundary layer of the cylinder which has the less boundary layer thickness in observation .The cylinder without the twisted tape with the velocity 3m/s of the air as inlet with the inlet temperature of 30^0C the apparatus is placed in the chiller room where the outlet temperature is been Measured for all varied velocities.

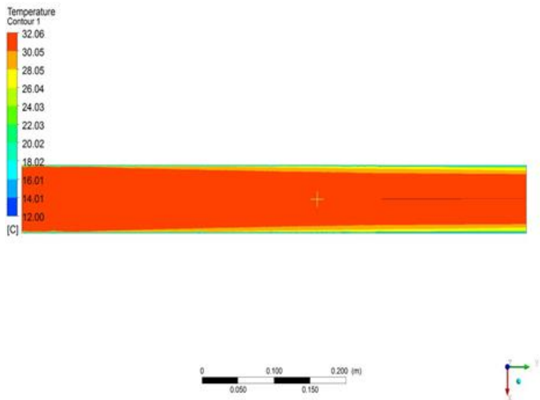

Fig. 5. 4m/s Temperature & Boundary layer

The analysed cylinder without twisted tapes is the main is temperature Inlet of 30^0C which is reduced to 12^0C which Results in the heat transfer Enhancement and boundary layer of the variation is not changed.

The inlet temperature of the air at which shows no change in thickness of the boundary layer of which they are further subjected to vary inlet velocities and this is the constituents of checking the boundary layer condition with inserting Twisted Tape in cylinder.

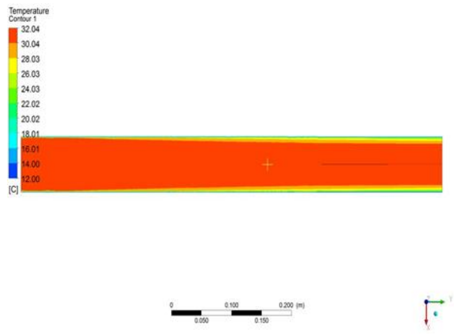

Fig. 6. 5m/s Temperature and boundary layer

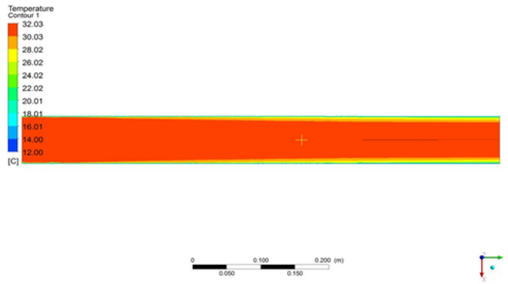

Fig. 7. 6m/s Temperature and boundary layer

VI. CFD Analysis of Twisted Tape

The twisted tape is made of copper material which is of the same material of the cylinder. The twisted tape inserted into the cylinder which the air flow of varied velocities is made to flow into inlet and the process of change in the temperature of the outlet and the thickness of the boundary layer and the temperature of the boundary layer around the walls of the cylinder is observed which implies the heat enhancement which they show changes in the heat enhancement of which is the desired temperature reduction and change in the thickness of boundary layer of the air in turbulent flow with the velocity of the air.

The heat Enhancement of the twisted tape inserts in the cylinder depends upon the velocity of the air initial flow of air and the change in the velocity of the air makes desired temperature changes in the cylinder and boundary layer thickness in the cylindrical walls.

The heat enhancement can be improved and swirl motion of the air in turbulent condition can be achieved with long twisted tapes inserts in the cylinder. The increase in velocity of the air can result in the desired heat enhancement and change in thickness of the boundary layer.

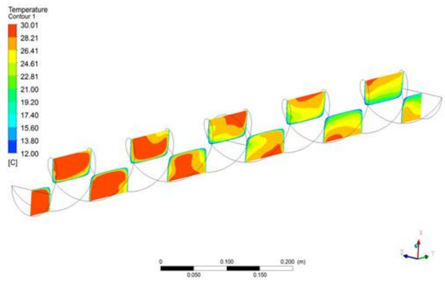

Fig. 8. 3m/s Temperature and boundary layer

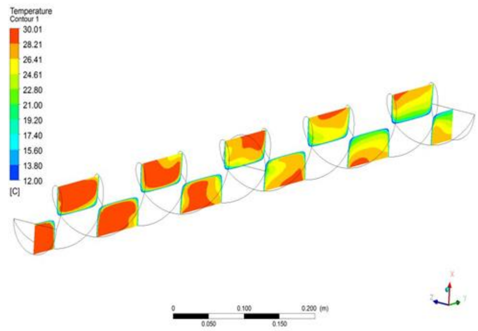

Fig. 9. 4m/s Temperature and boundary layer

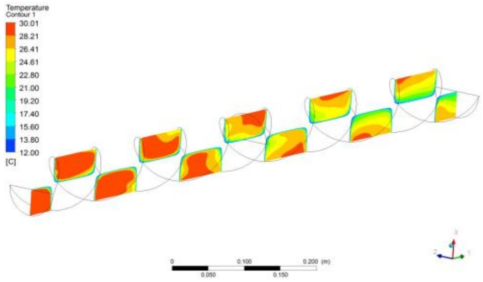

Fig. 10. 5m/s Temperature and boundary layer

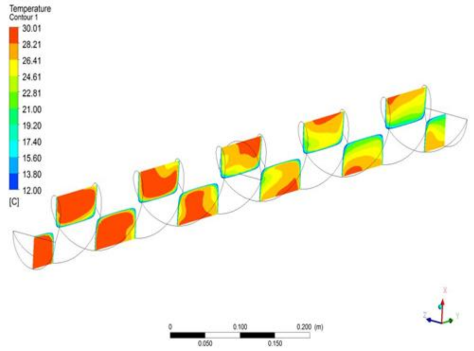

Fig. 11. 6m/s Temperature and boundary layer

VII. Results and Discussion

The Analysis of the concentric cylinder with and without twisted tapes are studied. The heat transfer enhancement is found to be efficient when the twisted tape is inserted in the cylinder. The cylinder with 660 mm is been analysed by the CFD where the heat transfer enhancement and change in the boundary layer is not observed without the inserts in the cylinder. The twisted tapes with full length of the cylinder which is inserted in the cylinder shows desired heat enhancement and desired boundary layer thickness change [3].

The increase in the velocity of the air can enhance the swirl motion and enhance the heat transfer which the change in the boundary layer can be observed in desired. Variations of the increase in velocity change of the inlet in the cylinder with twisted tape.

From the inlet and the twisted tapes inserts are to be made in full length types of inserts which inserts further heat enhancement and the thermal efficiency and the required boundary layer change is obtained by the variation of velocity of the air flow from the inlet and the temperature in the outer surrounding of the cylinder.

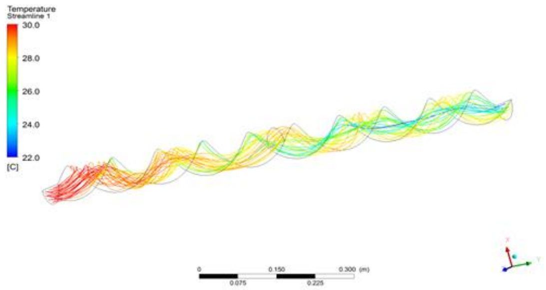

Fig. 12. 3m/s Temperature stream line profile

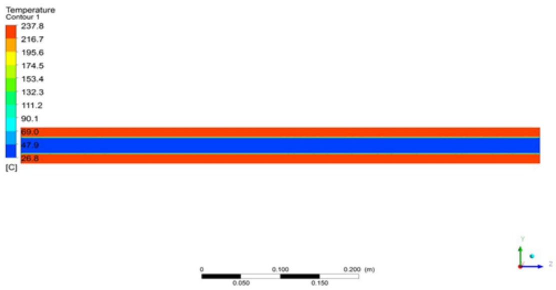

Fig. 13. Temperature of solidification of pcm

The above figures show the variation of temperature shows the change in the Temperature inside the cylinder is observed, which induces friction flow and enhances heat transfer with the velocity streamline difference for the change in velocities of the air.

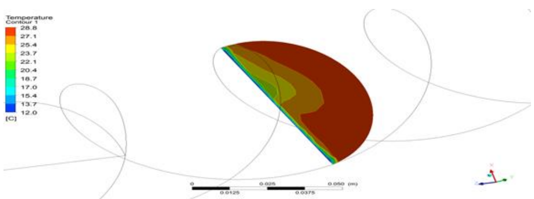

Fig. 14. 3m/s Temperature stream line profile

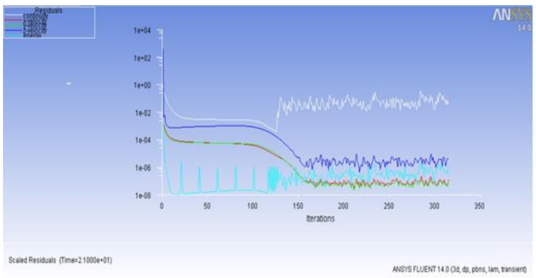

Fig. 15. 6m/s Temperature variation and boundary layer

The above figure shows the change in the increase of the temperature reduction and the walls of the twisted tape shows the change in the Boundary layer of the twisted tape with increase in velocity of the air.

Thus the increase in the velocity of the air flow and the inserting of the full length twisted tape of the material of the same material of the cylinder shows the increase in heat transfer enhancement the change in Temperature profile and boundary layer thickness of the twisted tape can be achieved.

VIII. Conclusion

Thus the concentric cylinder which is inserted with the full length twisted tape induces temperature variation and the change of boundary layer in the cylinder is found to be decreased by 0.20%. By the orderly increase of the velocity of air in the inlet of the cylinder with enhancing the solidification of the phase change material.

Nomenclature

- D - Width of the cylinder, mm.
- h - Heat transfer coefficient $Wm^{-2}K^{-1}$
- L - Length of the cylinder mm
- K - Thermal conductivity $Wm^{-1}K^{-1}$
- Nu - Nusselt Number , dimensionless
- T - Temperature ^{0} C
- C - specific heat J, Kg^{-1} K^{-1}

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