4. Heat transfer enhancement of twisted tape inserts using TiO_2-Water Nano fluids in micro finned tube

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Abstract.

This work studies the experimental evaluation of TiO_2nano fluids in enhancing the heat transfer rate and friction factor on a micro finned tube fitted with twisted tape inserts. Results show that the enhancement in heat transfer and pumping power completely depends on the concentration ratio of nano particles, pitch ratio and the type of pitch. Comparisons were made with the previous study with different operating parameters such as twist ratio and twist type. Viscosity of nano fluid increases with an increase in the concentration which leads to increased pressure drop and pumping power. For the Reynolds number (Re=4000), the maximum performance ratio was found as 2.1, 2, for concentration of 0.1 and 0.05 respectively. The addition of micro fin arrangement inside the circular tube enhanced the performance ratio with minimum concentration of TiO_2nano fluid.

In the present study, the effect of TiO_2nano particles on Nusselt number, friction factor and performance ratio are experimentally analyzed using different twist ratio in straight and Left-Right (LR) twisted tapes under turbulent flow regime. There is no study till date with the use of Left-Right twist in micro finned tube with titanium oxide nano particles.

1. Micro-fin tube, Twisted Tapes and experimental setup

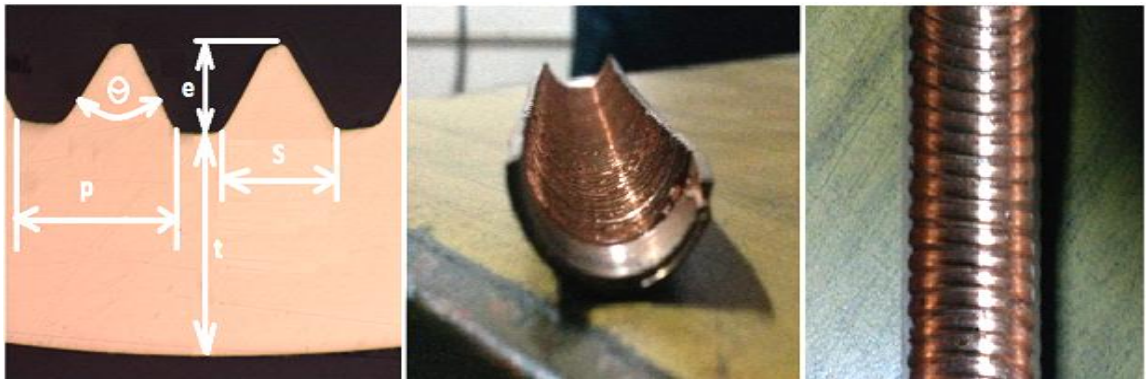

Fig. 1.Micro-fin tube used in present work

The experimental setup consists of a pump, 30 liter capacity inlet tank, turbine flow meter, rotameter, and calming section, test section, mixing chamber, riser section and an air cooled radiator. A self-priming, centrifugal regenerative pump of 51 kW and 2880 rpm is used which has a maximum discharge of 800 lph. A suction filter is attached to suction hose of 25 mm diameter connected to the pump which takes the incoming water through the rotameter to the calming section. Two calibrated rotameter with flow ranging from 0.1 to 1 lpm and 1 to 10 lpm to cover both laminar and turbulent flow. A turbine flow meter along with Flow Transducer (FT) is attached to the delivery hose of the pump, which shows the exact flow rate value digitally.

Water enters the calming section of 16 mm OD and 12.5 mm ID, 500 mm in length, made of stainless steel is provided before the test section in order to eliminate the entrance effect. The test section is a micro-fin copper tube 1000 mm long with 16 mm OD and 12.5 mm ID. Two copper reducers, one from the calming section to the inlet test section and the other from the outlet test section to the mixing camber is attached in order to link the three sections. Two pressure tapes are provided, one just before the test section and the other after the test section and connected to a pressure transducer to measure the pressure difference between the fluid flows. A pressure display is attached to the pressure transducer to note the exact pressure difference. The outside surface of the test section is covered with a glass fiber tape in order to insulate the copper tube from the current produced. A Ni-Cr wire is then wound around the glass fiber tape which is in turn covered with ceramic beads as an insulating medium. This Ni-Cr wire is connected to the auto transformer which

is used to change the heat flux produced by varying the voltage manually. Four layers of glass fiber wool with a total thickness of 67 mm covers the entire test section across 1000 mm. One layer of glass fiber tape is then wound over the glass fiber wool across the test section. The test section is made as per TEMA standards. Thermowells are designed as per ASME standards and brazed over the test section [52].Seven calibrated thermocouples – type K (T_2 to T_8), is inserted through a vertical projected thermo-well to measure the wall temperature are made in contact with the surface of the copper tube and two thermo couples (T_1 and T_2) are made in contact with water inside the copper tube (at the inlet and the outlet temperature junction). The vertical thermo-well through which the thermocouples are inserted has 10mm OD and 8mm ID. The thermocouples, flow meter, pressure transducer is connected to the Data Acquisition System (DAQ) which is connected to a Personal Computer for easy interpretation of the experimental data.

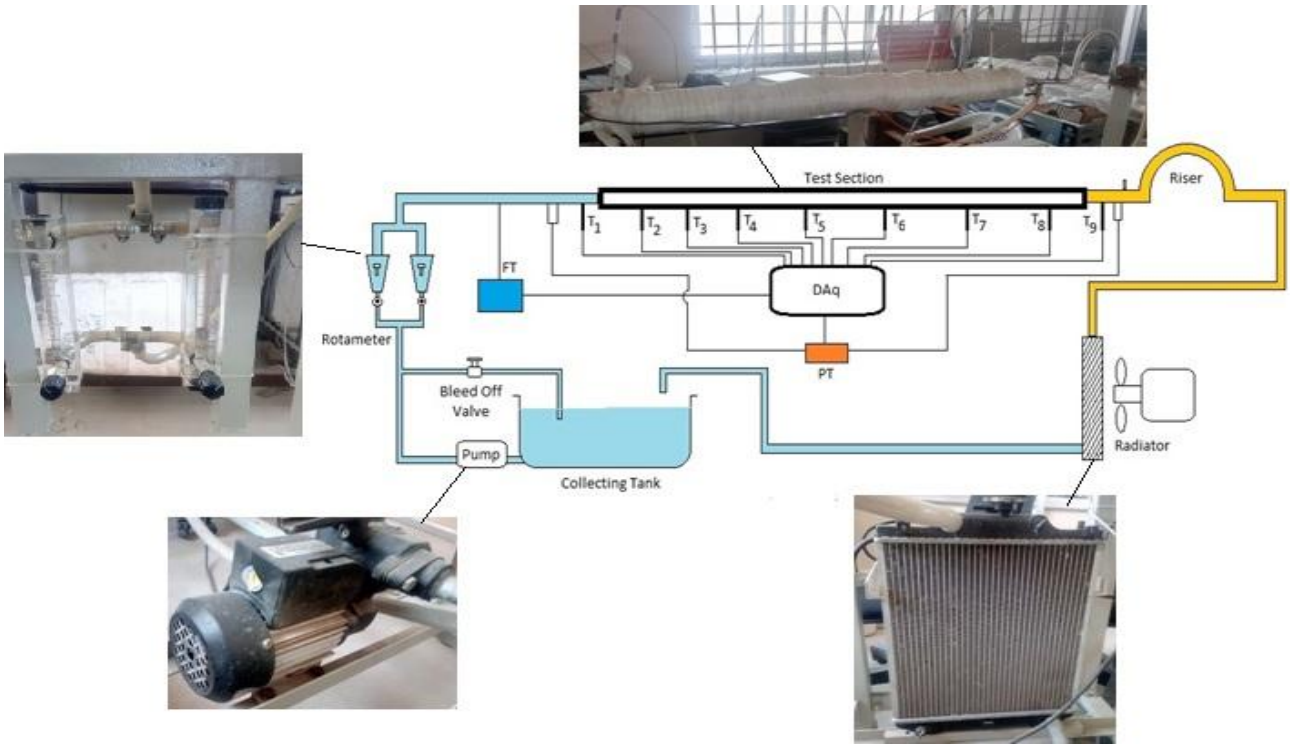

Fig. 2. Schematic diagram of heat transfer apparatus

A mixing chamber is introduced at a distance of 33 mm after the test section and the hot water from the test section and cold water from the pressure transducer are properly mixed. To ensure the

fully developed flow condition a riser section with 150mm height is provided at the end of the test section. To remove the heat from the hot fluid an air cooled radiator is used. The cooled water is then discharged to the collecting tank through the outlet of the radiator and the cycle continues. The experimental setup is shown in the Fig. 2.

In the present study, a combination of two different twisted tapes was used in the micro fin tube (Straight twist and LR twist). With respect to the flow direction the straight twisted tapes and direction of fins are arranged so that the fluid flow is in counter direction. Whereas, for an LR combination of twist tapes there is no specific direction as the fluid flows through the alternate direction of twist tape. The geometries of straight and left right twisted tape is shown in Fig. 3 and also listed in Table 2. In the present study three different twist ratio were chosen ((y/d) = 6, 8, and 10).

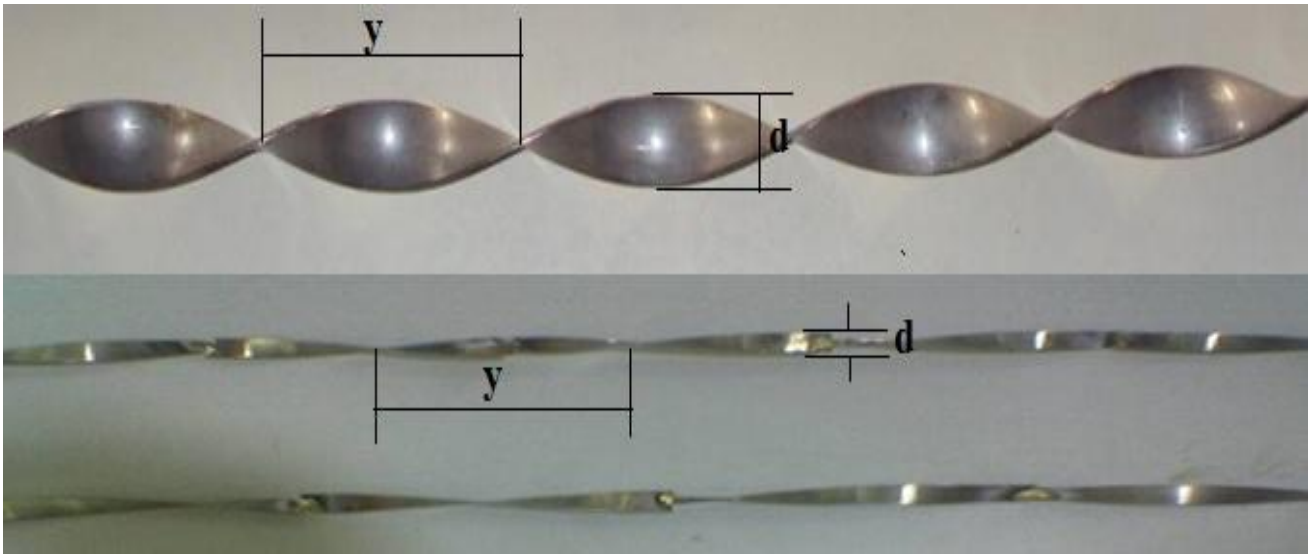

Fig. 3. Straight and Left-Right twisted tapes used in present work

1. Conclusions

The present investigation studied has provided valuable information on the enhancement of friction and heat transfer in micro finned tube with different concentration of nanoparticles in the fluid and the following conclusions are arrived.

- The performance ratio is higher in the case of nano fluid with a concentration of 0.1% nano particle by volume. And the performance is higher in the case of LR twisted tape with a pitch to diameter ratio of 6.
- Similarly, the improvement in Nusselt number is found as 20% in the case of 0.2% concentration which is higher than base fluid without any nano particles in the fluid.
- The increase in concentration of nano particles increased the effect of clogging and pumps power and thus results in poor performance.
- Viscosity of nano fluids decreases with an increase in concentration of nano fluid at room temperature.
- The zeta potential of TiO_2nano fluids is stable for almost 12 days and has a good stability without adding any surfactant.

CENTRE FOR EXCELLENCE IN ENERGY AND NANO TECHNOLOGY

Academic Year 2014-2015

PROJECT MEMBERS DETAIL:

S.No	Name of The Project	Lab Utilization	Student Participated in the Project
1	Experimental Investigation On Augmenting The Heat Transfer And Friction On Plane And Microfinned Tube Using CNT +Al2O3 Nanofluids	Sonication, PTC test rig, solar power meter, temperature sensors, anemometer, calibrated flask	**(ACY 2016-17)** R Praveen Kumar N Rajesh D Vignesh Vishwakumar V
2	Experimental Investigation on Augmenting the Heat Transfer and Friction on Plain and Micro fined tube using CNT Nano Fluids		**(ACY 2016-17)** P. Deepak Fernando M. Manoraj S. Madhan Kumar R. Dinesh Babu

PROJECT OUTCOME:

Paper Published

1. Sasidharan, S.J.K., Krishnamurthy, N.P., Mamat, R., Loganathan, V.D. and Sathyamurthy, R., 2017. Synthesis, characterisation and thermo-physical investigations on magnesia nanoparticles dispersed in ethylene glycol–DI water (50: 50). Micro and Nano Letters
2. Babu, D.M., Nagarajan, P.K., Madhu, B. and Ravishankar, S., 2017. Experimental evaluation of friction factor and heat transfer enhancement of twisted tape inserts using TiO2–water nanofluids. *Journal of Engineering Thermophysics*, *26*(4), pp.567-579.
3. MageshBabu, D., P. K. Nagarajan, Ravishankar Sathyamurthy, and S. Suseel Jai Krishnan. "Enhancing the thermal performance of AL2O3/DI water nanofluids in micro-fin tube equipped with straight and left-right twisted tapes in turbulent flow regime." *Experimental Heat Transfer* 30, no. 4 (2017): 267-283.