Emulsion of oil in water was observed when the oil velocity was increased to 0.21 m/s. Wavy stratified flow pattern was found when the oil velocity was further increased to 0.26 m/s. Dispersion of water under the oil layer was found when velocities of both water and oil were 0.26 m/s.

Fig. 4 shows the values of pressure drop at various oil velocities. The velocity of oil was varied within the range of 0.04 to 0.3 m/s and water velocity was kept constant at 0.72 m/s. Pressure drop was found to be increasing with increase in oil velocity. When the oil velocity was increased from 0.04 to 0.3 m/s, there was nearly 25 % enhancement in pressure drop. This is due to the enhancement of inertial forces with increasing flow rates. Parity plots were plotted for pressure drop values measured from the present experiments against values predicted for single-phase flows in a coiled tube from correlations of Mishra and Gupta (1979) [28] and are shown in Fig. 5.

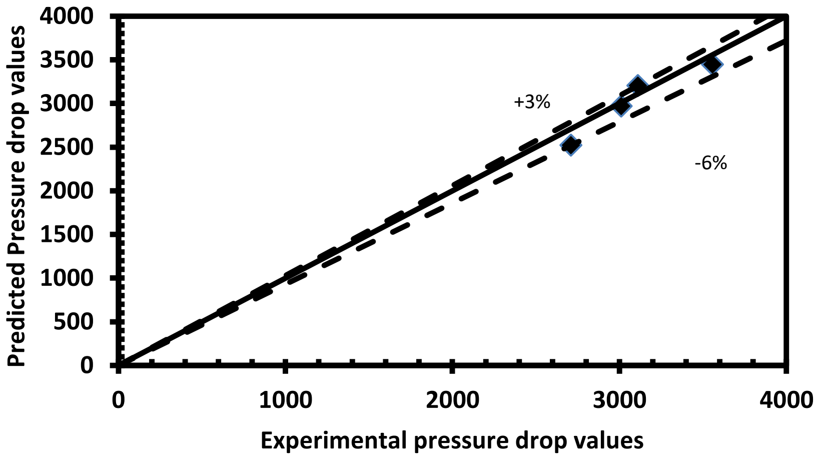

Fig. 5. Parity plot of experimental pressure drop values *vs*. predicted pressure drop values

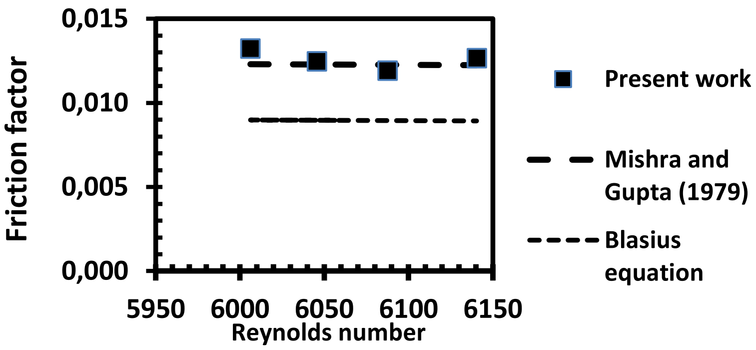

Fig. 6. Comparison of friction factor *vs*. Reynolds number with previous literature

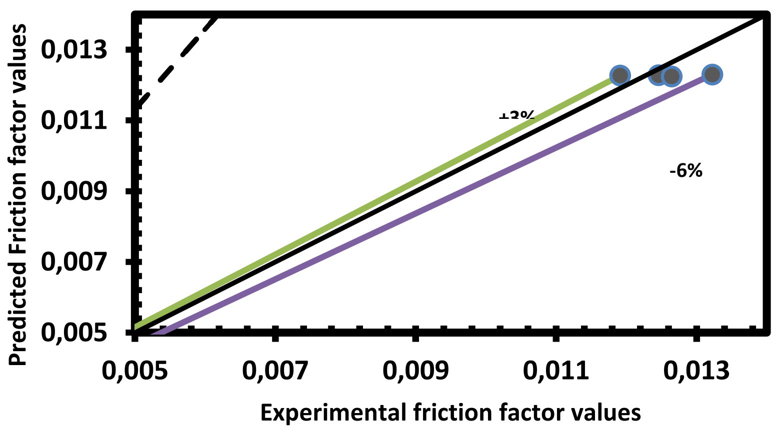

Fig. 7. Parity plot of experimental friction factor values *vs.* predicted friction factor values

The friction factor values were calculated for different Reynolds numbers and are reported in Fig. 6. The present data were compared with existing correlations previously reported for single-phase flows in a coiled tube, as well as in a straight tube by Mishra and Gupta (1979) [28] and by Blasius equation [29], respectively. It was found that under present flow conditions, the friction factor decreased with the increase in Reynolds number. Friction factor calculated from the present work was found to be by 24 to 32 % higher than that of Blasius equation proposed for a straight tube. Present experimental values were found to be in agreement with values predicted by correlation of Mishra and Gupta (1979) [28]. Fig. 7 shows the parity plot between friction factor values calculated from present experiments and values predicted from correlations of Mishra and Gupta (1979). Present experimental values are in agreement with predicted values and are within ±6 % error.

Fig. 8 shows the effect of oil fraction on pressure drop across the coiled tube with a curvature ratio dc/dt=7. Pressure drop increased with the increase in both oil fraction and velocity of oil-water. This was because of the enhancement of overall viscous forces and inertial forces. The percentage increase in pressure drop for the different velocities was 10 % at 0.3 oil fraction. However, this increment was 20 % for 0.5 oil fraction. The effect of curvature ratio on pressure drop at different oil fractions can be seen in Fig. 9. The curvature ratios were 7 and 28. The difference in pressure drop due to varying curvature at 0.41 oil fraction for 0.43 m/s was nearly 9 %. However, the increment increased to 25 % for v=0.52 m/s at oil fraction of 0.75.

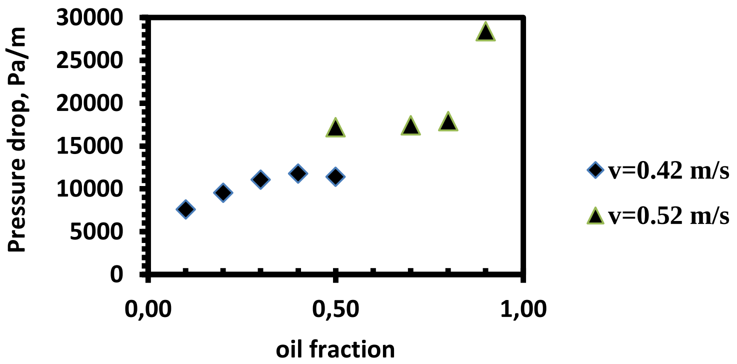

Fig. 8. Variation of pressure drop and oil fraction for different mixture velocities for d_t=0.007mm, λ=7

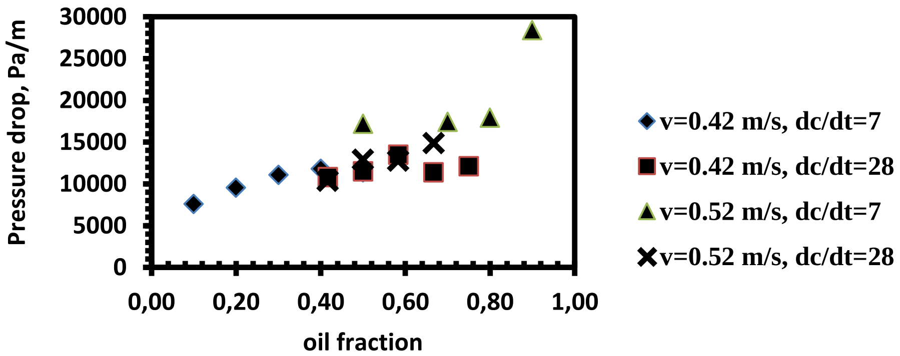

Fig. 9. Pressure drop *vs.* oil fraction for different curvature ratios

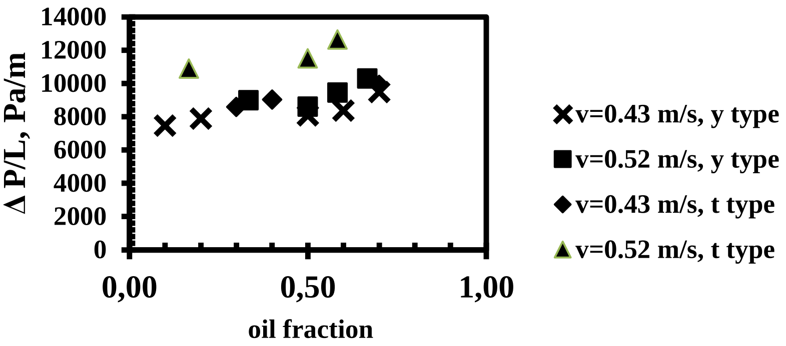

Fig. 10. Pressure drop *vs*. oil fraction for T-type mixer and Y- type mixer

This shows that the effect of curvature ratio on pressure drop was prominent at higher velocity. This was because of stronger development of secondary forces in a coiled tube at higher velocity.

Literature shows that the type of mixers has impact on the flow patterns of liquids flowing in micro tubes. The effect of two types of mixers (T type and Y type) on pressure drop was investigated and displayed in Fig. 10. In the present work, no significant effect was observed for lower velocity. However, pressure drop was found to increase for higher velocity (v=0.52 m/s) when the liquids flow through a T type mixer. Pressure drop value was by nearly 26 % higher in T type as compared to Y type mixer.

CONCLUSIONS

The present experimental study was carried out to gain insight on the hydrodynamics of oil-water flows through a coiled tube of diameter 7 mm. The study helped in identifying the various flow patterns of two immiscible liquids, i.e. kerosene and water. Various patterns of flow such as stratified, dispersed and annular flows were observed at different superficial velocities of water and oil. Flow pattern maps were plotted based on varying water and oil superficial velocities and reported for T type and Y type mixers. Effect of parameters such as velocity of oil, curvature ratio of coiled tube and oil fraction on pressure drop was observed. It was found that there was nearly a 25 % increment in pressure drop as the total oil–water flow velocity was increased from 0.76 m/s to 1.1 m/s. The influence of curvature of coiled tube on pressure drop was prominent at higher velocities. There was a pressure drop increment of 25 % for oil fraction of 0.75 at velocity 0.52 m/s. Increase in oil fraction lead to an increase in pressure drop due to enhancement of viscous forces. The significance of T or Y type mixer on pressure drop was observed for higher velocity. The T type mixer produced 26 % higher pressure drop for the oil-water flow with v=0.52 m/s in the coiled tube. This suggests that Y type mixers may be preferred to minimize energy losses for oil-water flows. Present study will be helpful in designing energy-efficient reactors and heat exchangers where immiscible liquids are used.

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