DEVELOPING VORTICAL SWEEPS OVER UPSTREAM OF A TUBE AT LOW REYNOLDS NUMBER

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ABSTRACT

A series of experiments were conducted in water tunnel for Reynolds number between 500 and 3500 for the visualization of flow structures around a tube. The aim was to break the laminar boundary layer over the upstream half of the tube thereby to augment the heat transfer from this portion. To achieve objective, various flow visualization were investigated keeping a smaller diameter tube before the main tube and varying its spacing. Two smaller tubesof diameters 2.5 mm and 4mm which were called as vortex generator were investigated. From the investigation it was found out that at Re=745 with smaller tube of diameter 2.5mm and spacing ratio of 1.82, the most effective vortical sweepsover the main cylinder was observed. The experiment was then conducted in wind tunnel to test the heat transfer from the main cylinder under the same spacing ratio, diameter ratio and Reynolds number which confirmed the Reynolds number, spacing ratio and diameter ratio providing the augmented heat transfer.

Keywords: Circular tube, flow visualization,low Re, spacing ratio,Vortical sweep.

I. INTRODUCTION

In cross-flow heat exchangers circular tubes are used with usually air as the cooling medium. From the various literatures and experiments conducted, it has been found out that the over its upstream half of the tube and till the separation point the flow is attached exhibiting a laminar boundary layer flow. However, the growth of the boundary adds thermal resistance and decreases heat transfer from the front stagnation point till the separation point. Thus, if this laminar boundary layer is distorted the heat transfer from the upstream half of the tube may be augmented.Yoo et al. [1] have investigated fin-flat tube and fin-circular tube and showed that the aaverage heat transfer coefficients of fin-flat tube without vortex generator are much lower than those of fin-circular. On the other hand, fin-flat tube with vortex generators has muchhigher heat transfer value than conventional fin-circular tube. Prabhakar et al [2] have shown that the longitudinal vortices generated by the winglets located away from the tube wall are stronger and last longer.The strength of the horseshoe vortex system is much less than thatof the longitudinal vortices generated by the winglets. Far winglet heat transfer is more than nearwinglet. Solov'yov et al. [3] have shown that the dependence of the diffusing substance flow is not only on the concentration gradients, but also on the vorticity of the liquid.The concept offers a new glimpse on natural and technical effects such as the tornado and the Ranque effect. Jurgens and Kaltenbach [4] in their investigation have found out that the stream wise vortices in the buffer layer were swept by the bubble swarm but brought to the backside of the swarm to survive until the swarm passed by increase of the sweep angle effects a shortening of the reattachment length. Jin and Tasaka [5] have shown that by means of the wave forcing a relative reduction in the reattachment length of upto 29% is achieved for sweep angles upto 40^o, with a forcing amplitude of only 1% of the free-stream velocity.

II. METHODOLOGY

- Generation of the vortical sweep around the tubes and optimizing it.
- Generating vortical sweep for different spacing ratio (L/D) and comparing them.
- Measurement of pressure drop across a cylindrical body.
- Variation of logarithmic temperature difference with time plotting them on graph.
- Testing of heated tubes for heat transfer analysis.

The present work deals with the experimental investigation of convective heat transfer from the surface of a three-dimensional circular cylinder. The augmentation of heat transfer from the heated tube is thought off by placing a tube as vortex generator before the heated tube on the upstream side.

To achieve this at first this experiment was carried out in water tunnel. Three aluminium tubes of diameter 31.5mm, 11mm, 9mm were used as the main tube whose laminar boundary was to be disrupted by generating vortices from the vortex generator tubes and sweeping over the upstream portion of the main tube. Two vortex generator tubes were investigated of diameter 2.5mm and 4mm. The vortex generator tube was placed at various centre to centrespacing from the main tube to achieve effective vortical sweep.

III. RESULTS AND DISCUSSION

L/D = 3.14

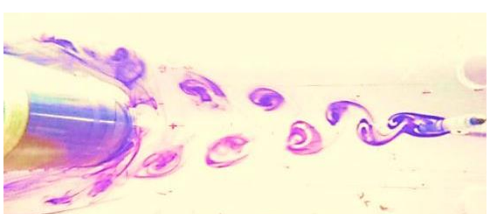

Fig.1 Flow structure at Re=1748

L/D = 1.34

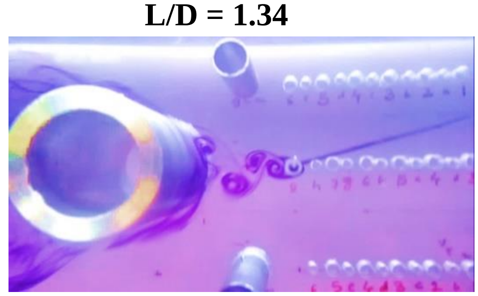

Fig.2Flow structure at Re= 2134

As shown in Fig.1at Re=1748, a combination of main tube of diameter D = 31.5 mm, vortex generator tube of diameter d = 2.5mm and spacing ratio L/D = 3.14 has been utilized. The vortices shedding from the vortex generator tube collides and sweeps the main tube on its upstream part in a clear and distinct manner, however, the spacing ratio L/D = 3.14 is too large as far as the compactness of the heat exchanger is concerned and due to this reason this spacing is not suitable and advised. Similarly, as shown in Fig.2 the Re = 2134, a combination of main tube of diameter D = 31.5 mm, vortex generator tube of diameter d = 4 mm and spacing ratio L/D = 1.34 has been utilized. Strong vortex shedding was formed by vortex generator tube. However, the vortex did not sweep through the front side of the main tube as a result of which required heat transfer is not expected to be achieved.

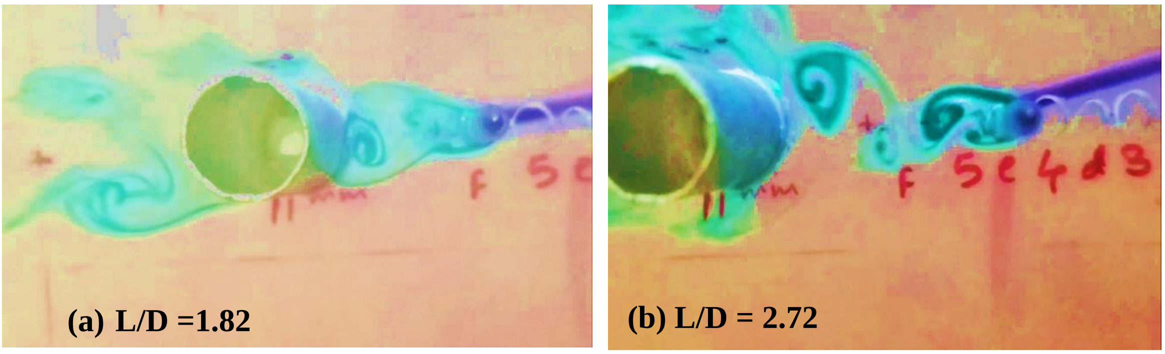

Fig.3 Flow structure at Re=745

As shown in Fig.3 (a) at Re=745, a combination of D = 11mm and d = 2.5mm along with L/D = 1.82 was utilized. In this case a clear and distinct vortex shedding has been formed that interacted to upstream portion of the main tube and moves ahead sweeping its top and bottom surface. As shown in Fig.3 (b) at Re=745, a combination of D = 11mm and d = 2.5mm along with L/D = 2.72 was utilized. Here, in this case the vortices shedding from the the vortex generated tube sweeps only over the top and the bottom surface of main tube without interacting the front surface of the main tube.

After the spacing has been most effective and favourable spacing of L/D = 1.82 had been achieved together with the combination Re=745, D = 11mm and d = 2.5mm, the diameter ratio D/d = 4.4, Re=745 and L/D = 1.82 was maintained to test the heat transfer from the main tube in the wind tunnel. Heat transfer was estimated by Lumped heat capacity method have shown the heat transfer augmented by 47% over the upstreamportion of the main tube.

IV. CONCLUSIONS

Various flow visualization were investigatedina water tunnel for different spacing ratiosand Reynolds number with two different vortex generator tubes of diameter 2.5 mm and 4 mm. from the investigation it has been found out that a combination of Re=745, D = 11mm, d = 2.5mm and L/D = 1.82 have shown a clear and distinct vortex shedding that interacted to upstream portion of the main tube and moved ahead sweeping firmly its top and bottom surface. Experiment conducted in the wind tunnel has approved the combibation of main and vortex generator tubes for the heat transfer augmentation.

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