The Unsteady Behavior of a Jet at Exit of a Tap

Shashank L[1], Laksmana Gowda B. H[2]
[1]Student, Department of mechanical Engineering, K.S.Institute of Technology, Bangalore-560109.
[2]Professor, Department of Applied Mechanics, I.I.T.Madras,
Chennai-600036(Retired)

Abstract **- The unsteady characteristics of a jet flow is studied in this paper. A simple device (kitchen tap) is used for this purpose. The exit of the tap is fitted with a mesh with a honeycomb structure. The parameter used in the study is the Reynolds Number based on the diameter of the tap at exit and the average exit velocity. It is observed that over a range of Reynolds number a bulb like structure is formed at the exit which exhibits unsteadiness. The length of this "bulb" varies with time; however, no regular periodicity is seen. A series of videos are taken to show the various features of this phenomenon at different Reynolds numbers.**

Keywords –Jjet; tap exit; unsteady

I. INTRODUCTION

The authors observed that the flow from the exit of the taps fitted with a mesh with honeycomb structure exhibited unsteadiness and caused bulb like structure to be formed. Such a phenomenon was not seen with taps without the mesh. This prompted the authors to systematically study this feature. The results of such a study is presented in this paper.

Jets and their characteristics are reported in detail by Abromovich in his book
[1]. The second author has investigated features of interaction of two two-dimensional jets in an enclosed space [2]. It was observed that the recirculation regions formed on the walls of the enclosure, exhibited unsteadiness in the extent of the zones. Both length and width of the recirculation zones varied with time. However, there was no regular periodicity in the variations. Further studies with an additional central jet between the two outer jets was also carried out [3]. The interesting influence of the central jet on the mixing process is reported. Vortex formation during draining from cylindrical vessels and the slowing down of the exit flow rate due to the vortex have been studied by the second author [4]. The influence of a mesh placed at the bottom of the cylindrical vessel in suppressing the vortex are investigated [5].

As mentioned earlier, the present study is the result of the observation of the authors in the flow from ordinary house taps. The bulb formation at the exit of the taps and their unsteadiness prompted the authors to carry out this study.

II. EXPERIMENTAL ARRANGEMENT

The results were obtained by using a common kitchen tap (Fig. 1a). The exit of the tap is fitted with a disk having honeycomb structure (Fig. 1b). The parameter used for the study is the Reynolds number based on the average exit velocity (at the tap exit), the diameter at exit. To obtain the average velocity, the exit area of the tap was obtained by using Fig. 1b. A 30% reduction in the area occurred due to the honeycomb structure. The actual diameter of the tap is 16 mm; after accounting for the reduction in area due to the honeycomb, the equivalent diameter was obtained as 13.3 mm. To obtain the average velocity, the flow from the tap (controlled by the tap knob) was collected in a graduated container of 1 litre capacity when full (Fig. 1a). The time for collecting this volume of flow was measured by a stop watch with a least count of 0.01 second. For each case, three runs were made and the average time taken for collection of 1 liter of water (i.e., when the container just full) for a particular operating position of the tap valve determined. The rate of flow is obtained by dividing the volume by the time of collection. The average velocity at exit is determined by using this rate of flow. The Reynolds number is calculated using the average velocity and the diameter equal to 13.3 mm. The value of kinematic velocity is taken as 10^{-6} m^2/s.

Results were obtained at several Reynolds number (Re) ranging from1500 to 8000. At each Re, the exit flow features were video graphed using a smart phone. The pictures were taken for sufficiently long duration (60 s for each case) to capture all the relevant features of the phenomenon like bulb formation (when it occurred), its unsteady behavior, formation of vena contracta etc.

III. RESULTS AND DISCUSSION

The results were obtained at Re values of 1729, 2288, 2410, 3201, 3531, 4519, 5274, 6629 and 7819. These values were obtained by careful and gradual control of the tap valve (Fig. 1a) increasing the flow rate gradually. At each setting of the valve, three runs were made as mentioned earlier. The video was taken for a typical setting at a particular valve opening and the features at the exit captured. Videos were taken at all the Reynolds numbers mentioned above. At low values of Re no bulb formation occurred. Same was the case at very high values of Re. In between Reynolds numbers, the formation of bulb, its growth and the unsteady behavior with time were captured. Though, as mentioned, the videos were taken at every Re, only typical cases are presented and discussed. In this paper still photos of the results are shown and discussed.

The flow pattern at the exit is shown in Fig.2 Re = 1729). As can be seen there is no 'bulb' formation at exit at this low Re and the pattern is wavy for some distance from exit. At an increased flow rate i.e., increased Reynolds number, Re = 2768 (Fig.3), the exit flow pattern has changed, but still no bulb like structure is seen at exit. However, at Re = 3201 (Fig. 4), a distinct change can be observed. The exit flow contracts to a minimum area and then slightly expands and the flow continues. At a Re = 3201 (Fig.5), the formation of the bulb (or tulip) like shape is clearly seen. The veena contracta is also clearly visible. As the Reynolds number is further increased gradually (Fig.6), the length of the bulb like shape increases with the formation of the veena contracta. At slightly higher flow rates i.e., increased Re values (Re = 4519, Fig.7a and Re = 5274, Fig.8) some nominal changes in the length of the bulb occurs. It was found that the flow exhibits unsteadiness at these Reynolds number with the length of the bulb at exit decreasing and increasing. It is like flexing a muscle to different degrees. No regular periodicity is observed in these variations. The videos at these Re values clearly bring out these features of unsteadiness. (The conditions at another instant for Re=4519 is shown in Fig.7b to bring out the unsteady nature.) As the Re is further increased, the bulb length decreases (Fig.9, Re = 6629) and at still higher values of Re, it disappears (Fig.10, Re = 7819).

The results presented above reveal that the exit jet flow can vary with the flow rate. At low flow rates i.e., at low Reynolds numbers normal flow occurs. However, with gradual increase in flow rate interesting features occur. A bulb or tulip like shape occurs at exit which exhibits unsteady behavior. As mentioned, this unsteady behavior is well captured in the videos at various flow rates (Reynolds numbers). Obviously the question arises why such flow behavior is seen. The honey comb shaped mesh appears to be the main reason for the phenomena seen. The flow passes through this honey comb mesh and forms several small jets. The interaction between these jets appear to be the main reason for the observed features. It is not clear how the interaction between these jets give rise to the hollow bulb like structure and also the unsteady behavior at increased flow rates. Further, the features disappear when the flow rate increases beyond a limit. The formation of the bulb and the unsteady behavior were not observed when there was no mesh at the exit or when square shaped meshes were used at exit. Hence the role of the honey comb shape appears to play a important role on the features observed.

CONCLUDING REMARKS

It is seen that exit mesh shape at the end of a pipe plays an important role in deciding the flow conditions at exit. Depending on the flow rate, there can be normal flow, formation of a bulb whose size and shape depends on the flow rate. Also, the exit flow can exhibit unsteady behaviour. At higher flow rates these feature disappear.

The results presented in this study indicate fascinating features of a simple phenomenon which we come across almost daily in our houses or outside. As indicated, if observed closely several interesting features can be seen and questions which require further probing result. Use of different shaped meshes, size of mesh etc. may be looked into. Application of CFD to explain the observed features can be thought of.

Fig.1a Experimental Arrangement

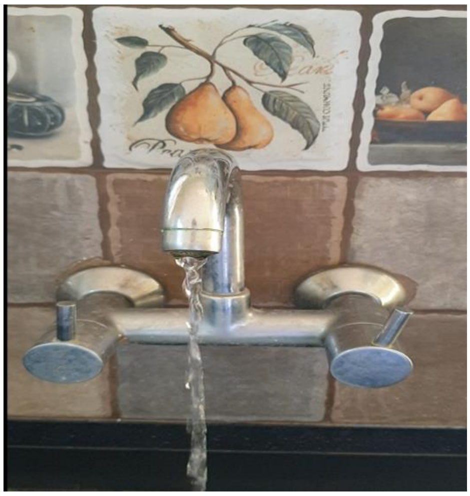

Fig.2. Flow pattern at Re=1729

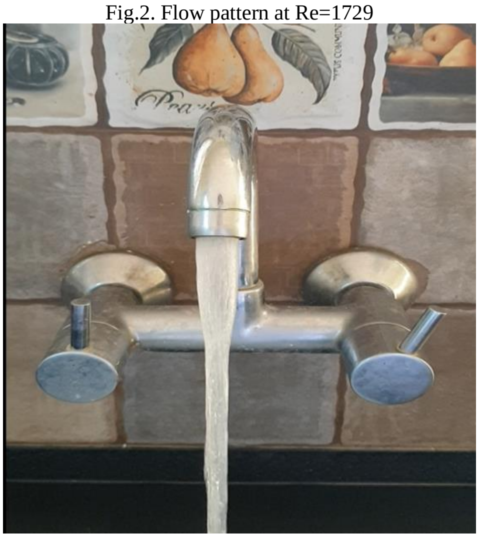

Fig.4. Flow pattern at Re=2914

Fig.1b Honey comb structure

Fig.3. Flow pattern at Re=2768

Fig.5.Flow pattern at Re=3201

Fig.6.Flow pattern at Re=3513

Fig.7b.Flow pattern at Re=4519

Fig.9.Flow pattern at Re=6629

Fig.7a.Flow pattern at Re=4519

Fig.8.Flow pattern at Re=5274

Fig.10.Flow pattern at Re=7819

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