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Validation of The Working Range of Inside to Outside Diameter Ratio of Pitot Probe

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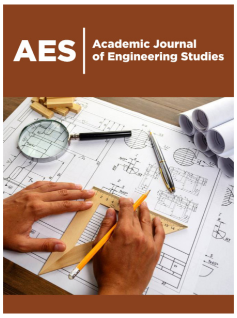

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Abstract

This note aims at validating the inside to outside diameter ratio of pitot probe for proper functioning of the probe. This ratio found by experience is in the range 0.5 to 0.75. But there is no systematic study reported on how this range is arrived at. This work addresses this geometrical aspect, using flow visualization studies in a simple water flow channel. The visualization demonstrates that, the flow will not pass through the probe if this ratio is less than 0.5, and flow separation caused by the wall thickness will not permit proper functioning of the probe if this ratio is more than 0.75.

Introduction

This note presents the validation of one of the vital geometrical issues associated with pitot probe. It is an accepted fact that the ratio of internal (ID) to external (OD) diameter of a pitot probe should be in the range 05-0.75 for proper functioning of the probe [1]. Though this speculation is found to work fine in practice, there is no physical verification for this important aspect of the geometrical ratio of the inner to outer diameter ratio of the pitot tube. This issue is addressed in this article. The Froude numbers of this study were 1.15, 1.30 and 1.45 and the Reynolds number ranged from 430 to 7626. The investigation was conducted for pitot probe ID by OD ratios of 0.25, 0.50 and 0.75.

Flow Visualization

To address the issue of ID/OD ratio for proper functioning of pitot probe, experiments were conducted in a water flow channel and hydraulic analogy was used to explain the flow physics behind the working range of diameter ratio of the pitot probe. The Froude numbers (Fr) of this study were 1.15, 1.30 and 1.45. The Reynolds number is in the range from 430 to 7626.

Two identical rectangular plates with square-edges were kept with the flat surface parallel to each other in the test-section of a water flow channel [2]. The flow passing through the uniform gap between the plates was visualized by injecting watercolor dye. In addition to the gap between the plates, for every gap the plate thickness was varied from 1mm to 3mm. Visualization was conducted with 1mm, 2mm and 3mm plates, by placing them with inner to outer distance ratio (ID/OD) of 0.25, 0.50 and 0.75. The wall thickness was taken as a parameter to identify the combination thickness and inner to outer distance ratio for proper function of the pitot probe. Visualizing the flow passing through the gap, without any separation, ensured the aspect of functioning.

All the visualizations were made at Froude number in the range from 1.15 to 1.476. Thus, it may be stated that, the equivalent flow speed in a gaseous medium is in the range of Mach 1.15 to 1.476. Visualization pictures for some combinations of the flow and geometrical parameters are shown in Figures 1(a)–1(e). It is seen from Figure 1(a) that, for plate thickness 1 mm and ID/OD = 0.5 flow passes through the gap smoothly, ensuring that this ID/OD ratio is suitable for proper function of pitot probe at Mach number 1.46. It is seen from Figure 1(b), plate thickness 1 mm, ID/OD = 0.75, Fr = 1.3 also lies in the proper working range. For these cases (Figure 1(a) and 1(b)) the Reynolds number is well above 500.

When the Reynolds number is less than 500 the viscous effect dominates and the flow is blocked from passing through the gap as seen in Figure 1(c), which is for plate thickness

1mm, ID/OD = 0.25, Fr =1.476. This result validates the fact, the viscous effects will result in the growth of boundary layer inside the gap leading to the filling of the tube and thus prevent the flow from passing through [2]. Another aspect, which might make the flow to separate is the wall thickness. This aspect is captured in the visualization picture shown in Figure 1(d), which is for plate thickness 2mm, ID/OD = 0.5, Fr = 1.15. Similarly, for plate thickness 3mm, ID/OD = 0.75, Fr = 1.45 also, flow separation caused by the plate thickness is clearly seen, in Figure 1(d). Similar results of separation caused by wall thickness is seen in Figures 1(e) and 1(f), which are for plate thickness 3mm, ID/OD = 0.5, Fr = 1.15 and plate thickness 3mm, ID/OD = 0.75, Fr = 1.45, respectively. The results in Figures 1(d) to 1(f) show that even though the ID/OD ratio is in the working range of 0.5 to 0.75, the flow separates at the face of the flow. This demonstrates that it is not only the ID/OD ratio, but also the combination of this ratio and the wall thickness should be in a proper range for the proper functioning of pitot probe.

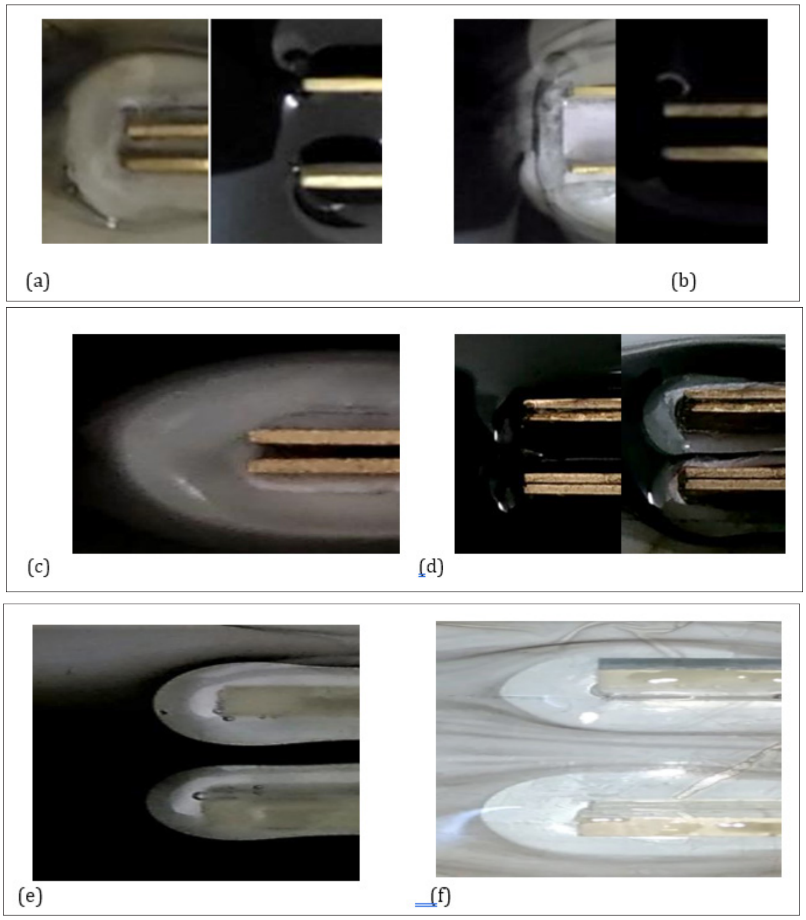

Figure 1: Flow passing through the gap between the plates for different combinations of the flow and geometrical parameters.

Conclusion

It was found that for ID by OD ratio 0.25 and Reynolds number 430 (see figure 1(c)), flow enters the gap, but does not pass through the probe in accordance with the viscous theory that for proper functioning of pitot probe the Reynolds number should be more than 500. As seen, for Re <500, flow doesn't pass through the probe, while for all other cases the flow passed through the probe. For probe wall thickness of 2mm and 3mm, flow experiences a sudden turning and a detached shock if formed. This shock would generate entropy at the probe inlet. The combined effect of the detached shock, which would introduce irreversibility flow and the flow separation, will result in the enhancement of the error in the pressure measured by the probe [1]. The maximum possible probe wall thickness for proper functioning was found to be between 1mm and 2mm.

References

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2. Rathakrishnan E (2017) Instrumentation, measurements and experiments in fluids.