World Academy of Science, Engineering and Technology
International Journal of Mechanical and Industrial Engineering
Vol:14, No:05, 2020

Experimental Investigation on the Effect of Cross Flow on Discharge Coefficient of an Orifice

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Abstract : Many fluid flow applications employ different types of orifices to control the flow rate or to reduce the pressure. Discharge coefficients generally vary from 0.6 to 0.95 depending on the type of the orifice. The tabulated value of discharge coefficients of various types of orifices available can be used in most common applications. The upstream and downstream flow condition of an orifice is hardly considered while choosing the discharge coefficient of an orifice. But literature shows that the discharge coefficient can be affected by the presence of cross flow. Cross flow is defined as the condition wherein; a fluid is injected nearly perpendicular to a flowing fluid. Most researchers have worked on water being injected into a cross-flow of water. The present work deals with water to gas systems in which water is injected in a normal direction into a flowing stream of gas. The test article used in the current work is called thermal regulator, which is used in a liquid rocket engine to reduce the temperature of hot gas tapped from the gas generator by injecting water into the hot gas so that a cooler gas can be supplied to the turbine. In a thermal regulator, water is injected through an orifice in a normal direction into the hot gas stream. But the injection orifice had been calibrated under backpressure by maintaining a stagnant gas medium at the downstream. The motivation of the present study aroused due to the observation of a lower Cd of the orifice in flight compared to the calibrated Cd. A systematic experimental investigation is carried out in this paper to study the effect of cross-flow on the discharge coefficient of an orifice in water to a gas system. The study reveals that there is an appreciable reduction in the discharge coefficient with cross flow compared to that without cross flow. It is found that the discharge coefficient greatly depends on the ratio of momentum of water injected to the momentum of the gas cross flow. The effective discharge coefficient of different orifices was normalized using the discharge coefficient without cross-flow and it is observed that normalized curves of effective discharge coefficient of different orifices with momentum ratio collapsing into a single curve. Further, an equation is formulated using the test data to predict the effective discharge coefficient with cross flow using the calibrated Cd value without cross flow.

Keywords : cross flow, discharge coefficient, orifice, momentum ratio
Conference Title : ICFM 2020 : International Conference on Fluid Mechanics
Conference Location : Berlin, Germany
Conference Dates : May 21-22, 2020