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Numerical investigations on swirl intensity decay rate for turbulent swirling flow in a fixed pipe

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ABSTRACT

Due to the importance of predicting the SIDR[1] associated with engineering problems such as combustion chambers, draft tube of the Francis and Kaplan turbines, heat exchanger tubes, separators and so forth, in this research the trend of SIDR and its affecting factors, through a turbulent swirl decay pipe flow have been investigated. The swirling flow is created by means of a rotating honeycomb which produces solid body rotation at the inlet of a fixed pipe. First of all, turbulent swirling decay flow has been numerically surveyed using different flow conditions at the pipe inlet. The numerical results have been validated and compared with the existing experimental data and mathematical relations, showing satisfactory coincide. The obtained results show that, the SIDR depends mainly on the Reynolds number of the passing flow. On this basis, correlations have been proposed in order to improve the predictions of swirl intensity decay rate at upstream regions as well as those with high swirl intensity. In addition, conducted analyses demonstrates (analyses have been made to demonstrate) that the previous developed correlations for predicting swirl intensity decay rate, agree with those provided in this study only for regions far enough from downstream having the low swirl intensity. This implies that the swirl intensity decay rate should be a function of the type of swirl generator at the pipe inlet.

1. Introduction

Swirling flow, which is one of the well recognized configurations of the flow in the industrial equipments, is accentuated for its various applications as well as its sophisticated scientific basis. This type of flow field, often appearing as turbulent flow, not only does occur in equipments, whose application conditions requires the existence of such flows such as separators, combustion chambers and heat exchangers, but also in many other equipments like the draft tube of Francis and Kaplan turbines. In separators, swirl is the major factor leading to the separation of particles as a result of the centrifugal forces. In combustors, the swirl also contributes to nurturing combustion process by faster mixing of the reacting components, and creates recirculation zones where the temperature of the species are maintained sufficiently high for a long period of time [1]. It is the vortex breakdown phenomenon and studied by [2–5]. Likewise, swirling flow may improve thermal efficiency in heat exchanger tubes by increasing the fluid flow capacity of convection heat transfer [6].

In the draft tube of the Francis and Kaplan turbines, this type of flow may occur when these turbines operate beyond their designed operating points. This may cause a decline in efficiency of the turbine proceeding through the wakes of reduction of draft tube recovery factor [7]. However, divergent as draft tube is, the presence of a marginal swirl in passing flow can partly preclude separation of flow by producing appropriate pressure gradient [6]. This type of flow which is a combination of a vortex flow and an axial velocity one causes the fluid particles to move in spiral trajectories where the velocities vary continuously with respect to the axial and radial coordinates. It is worth mentioning that the presence of swirl in a flow field can change the flow shape as well as the turbulence properties, which have their own respective ambiguities. Owing to the importance of swirling flows, studying and comprehending the behavior of such flow fields and their effects on the performance of the aforementioned equipments have been always of the great interest to researchers.

Although the swirling flow field may occur in different types and shapes depending on the kind of fluid devices, previous conceptual studies were mostly focused on internal swirling flows (i.e. flows inside a pipe). A pipe flow has been used as a benchmark or a tool to describe concepts of internal flows for many years, for instance, Prandtl's mixing length theory [8], dating back to 70 years ago, or comprehensive measurements of the fully developed turbulent structures of flow inside a pipe by Lauffer [9].

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[1] Swirl Intensity Decay Rate.

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