NUMERICAL INVESTIGATION OF FLOWTHROUGH CONICAL DIFFUSER WITH SWIRLGENERATOR

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Abstract: Swirlisatangentialvelocitycomponentofthefluidflowandisoftenpresentintheconicaldiffuserasaresultofrotatingmachineryintheupstream section. The present experimental work is dedicated to study theeffectof moderate swirlonwide angle conicaldiffuser performance andflow development. The numerical investigation were performed in ansyssoftware. There are two different diffusers having a cone angle ofand 21°(with area ratio 4.2) were selected for this investigation. The results showedthat the moderate swirl can significantly improve the stalled diffuser (21°coneangle)performance;however,ithasalittleeffectonthediffuser(13°cone angle) having incipient turbulent boundary layer separation. It wasconfirmed that the introduction of moderate swirl reduces the chances offlowseparationinwideangle conical diffusers.

Keywords:

Introduction

Flow control involving perforated plates and wire gauze screens in internal flows has been extensively investigated for more than 50 years [1]. Particular interest has been given to wide-angle diffusers because of their association in many applications, for example in electrostatic precipitators (ESPs) and wind tunnels. There is a natural tendency of a wide-angle diffuser to develop a highly non- uniform velocity distribution at the outlet. Therefore, there is a need to control the flow for industrial applications, such as ESPs. Many studies were concerned with the use of wire gauze and perforated plates as flow control devices [2–3]. They showed that flow is very sensitive to the nature of the screens involved and their positions within the diffuser. Space limitation in practical situations is an important issue, and diffusers used in ESP installations have area ratios greater than 6.Sahin and Ward–Smith [4] and et al. [5] studied flow control by perforated plates in wide-angle diffusers of ESPs with larger area ratios up to 10. In a systematic investigation of the flow distributions at the outlet of wide-angle diffusers with area ratio of 10, Ward–Smith et al. [6] showed that good flow uniformity can be achieved at the outlet by using only two perforated plates or wire gauze screens with appropriate porosities and locations. They proposed that two perforated plates with porosities of between 40% and 50% be used, with the first one placed at a location near one-third of the diffuser length from the inlet, and the other one at a location just prior to the diffuser exit. In the present study, the flow within a wide- angle diffuser, which can be schematically represented as half a classical pyramidal diffuser, is investigated. The inner wall is aligned with the flow and the outer wall has an opening angle of 45°. Miller [7] referred to this type of diffuser as asymmetric, but presented only a few data points since they have not been previously investigated. The purpose of this study is to investigate the effect of perforated plates on the flow distributions within this asymmetric wide-angle diffuser model. A combination of different perforated plates permitted the investigation of flow control, and the velocity distribution at the outlet of the diffuser.Mc Donald and Fox [1] conducted an experiment in a transparent conical diffuser using water as the flow medium. They concluded that the pressure recovery and effectiveness are independent of the inlet Reynolds number if is greater than 75,000.Okwuobi and Azad [2] conducted experiments to study the structure of turbulence in a conical diffuser with fully developed flow at entry. They reported that the rate of turbulent energy production reaches the maximum value at the edge of the wall layerKlein [3] reviewed thirty publication results in the subject of the effect of inlet conditions on the performance of conical diffuser flow. From the review results, he presented the optimum diffuser geometries for non- dimensional diffuser length.Azad [4] made an extensive research work in turbulent flow through an 8° cone angle diffuser. The measurement of fourth-order moments of turbulence fluctuations showed that the turbulent flow is symmetrical for all mean values in a conical diffuser.Mahalakshmi [5] studied experimentally the effect of wake type velocity distortions at the inlet of conical diffusers. They observed that the wake at inlet greatly affects the diffuser performance.VanDewoestine et al. [6] conducted experiments to study the effect of swirling inlet flow on the performance of conical diffusers. The results showed that the swirling inlet flow increases the performance of optimum diffuser compared to the uniform flow at the inlet.Senoo et al. [7] and Okhio et al. [8] suggest from their experimental study in a conical diffuser that the moderate swirl will delay the flow separation and increase the pressure recovery.Clausen and Wood [9] made detailed measurements of turbulence quantities for a 20° conical diffuser having swirl flow. A considerable amount of theoretical investigations has been done on conical diffusers Lai et al. [10] investigated the effect of the adverse pressure gradient in conical diffuser using $k - \varepsilon$ model. Jiang et al adopted DLR $k - \varepsilon$ model to study the internal turbulent flow in a conical diffuser.Armfield and Flecther [11] studied the swirl effect in a conical diffuser using $k - \varepsilon$ model and Reynolds stress model.Chou and Fletcher [12] concluded that their Algebraic Reynolds model predicts the swirl flow better than the $k- \varepsilon$ model.Okhio et al. [13] selected Prantl mixing length model to calculate the mean velocities in a wide-angle conical diffuser.C. S. From et al. [14] modeled turbulent swirling flow in a conical diffuser using the Explicit Algebraic Reynolds stress model. The present work is mainly concerned with the experimental study of the flow and boundary layer development in conical diffusers with the steady, uniform flow and moderate swirl type distorted flow at the entry of the diffuser. The experiments were conducted in a subsonic wind tunnel using a Constant temperature hot-wire anemometer (CTA) measurement system.

Preparing Existing Geometry for Analysis

CATIA models are usually intended to accurately represent the exact intents of the final designs and often lack additional features required for simulation. ANSYS DesignModeler provides these unique simulation features, such as splitting surfaces for applying loads, defining welds or creating regions around models that represent flow volumes for fluid flow analysis.

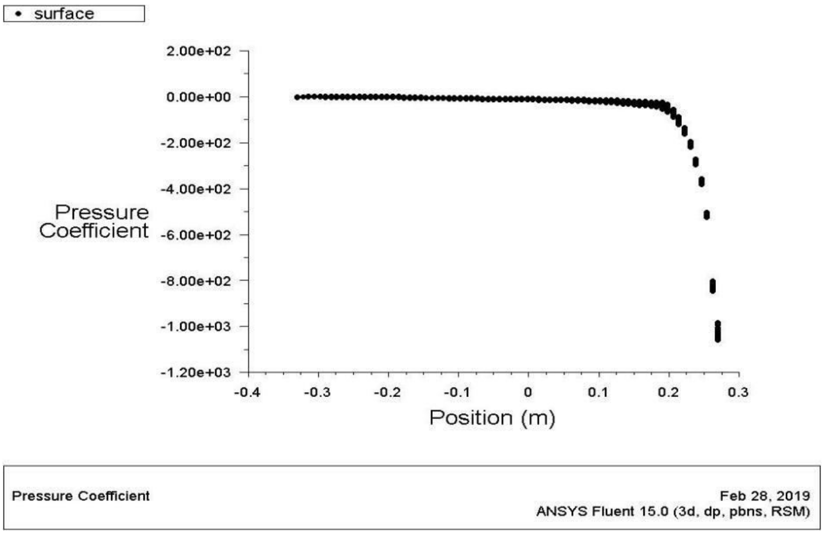
A CATIA model also may contain much more detail than the simulation process requires, or the detail may not be in the right form. ANSYS DesignModeler enables tasks like deleting CATIA features, extracting surfaces from a solid body, suppressing parts, merging multiple bodies into one, and grouping bodies to form a part.

ANSYS DesignModeler also provides several tools for shell/surface modeling. Face and edge merge operations can be used to easily simplify models by eliminating unnecessary features and boundaries, leading to improved meshes and faster solutions. Sew and connect operations can be used to ensure proper connectivity in model s with gaps and overlaps.

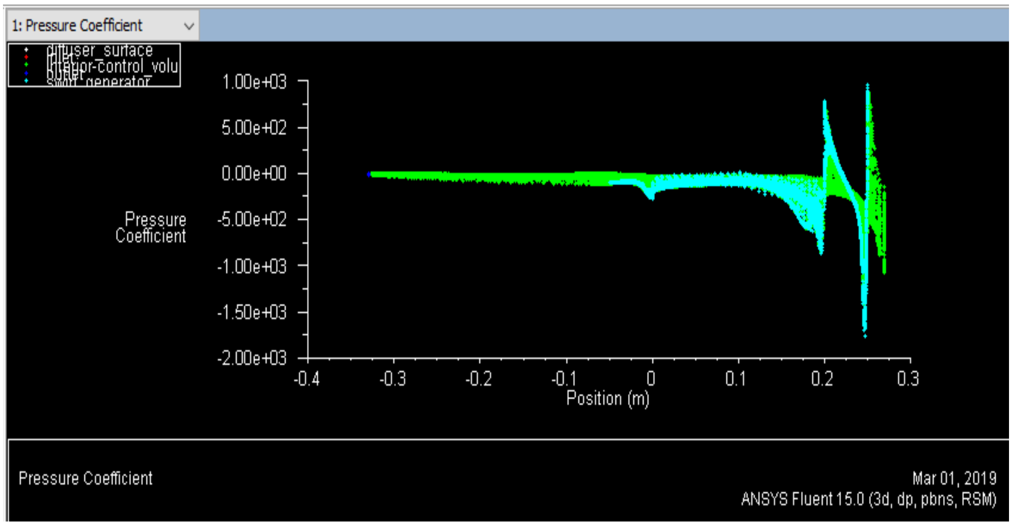
Similarly, the ability to select and extend groups of surfaces greatly simplifies the process of closing gaps between parts after midsurface extraction. This results in easier modeling of welds, for example. In addition, several features are available for beam modeling, including support of standard cross sections, user-defined offsets, user-defined cross sections, and tools for orientation control.

PROPOSSED SYSTEM

14 DEGREE WITHOUT SWIRL

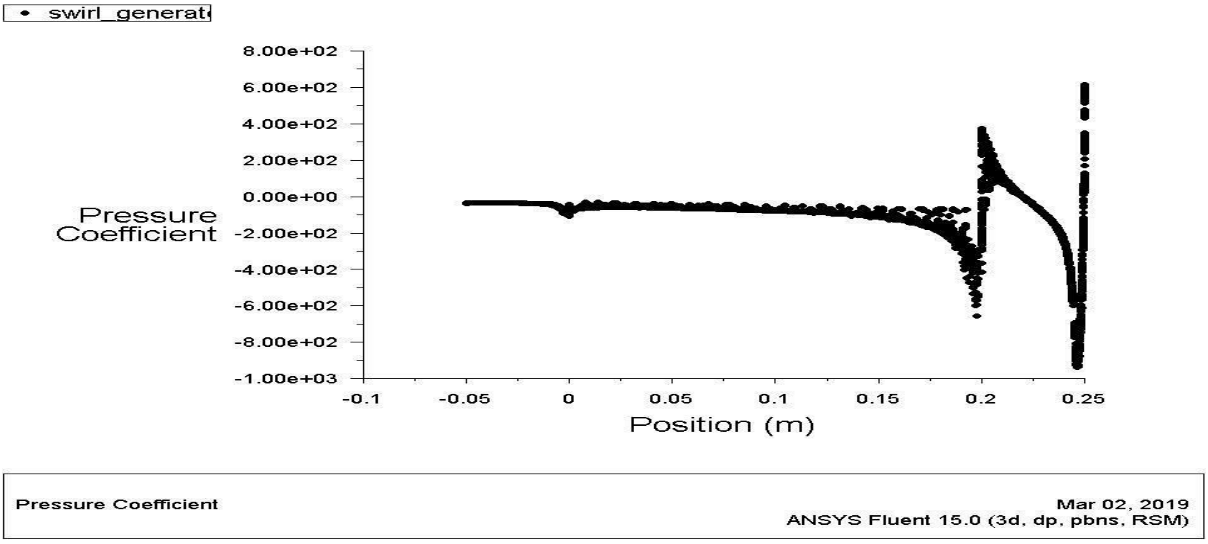


WITH SWIRL

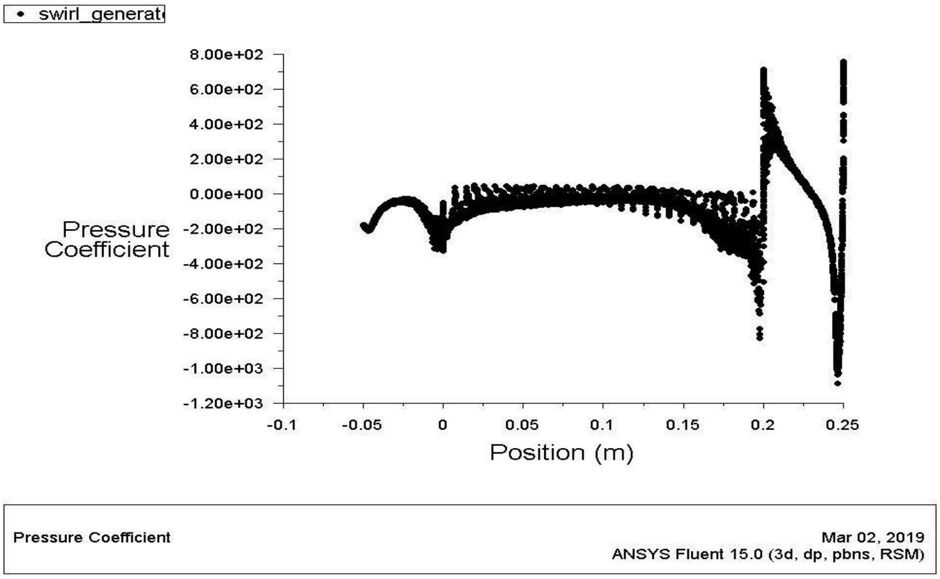


EXPOSSED SYSTEM

21 DEGREE



13DEGREE



Results and discussion

Performance

Generally, the diffuser performance is stated by a pressure recovery coefficient (Cp). It indicates the diffuser ability of the diffuser to convert kinetic energy into pressure energy. The pressure recovery coefficient can be calculated as

$$CP=PX-PA/qA$$

where Px is the average static pressure at each station, Pa is the atmospheric pressure and qx is the dynamic head of the respective station. The static pressure at each station is measured using eight-hole pitot-static tube with digital manometerread out, by traversing probe at an interval of 4 mm. The measurements of static pressure are made relative to the atmospheric pressure exposing one of the leads of the manometer to the atmosphere. Figure 6 illustrates the performance of the conical diffusers with uniform velocity and swirl at the inlet. It can be noticed that there is a marginal increase in pressure recovery in the case of flow with swirl when compared to uniform flow for the diffusers. It is also observed from the figures that 50 % of pressure recovery takes place within the first 40 % length of the diffuser.

CONCLUSION

The present experimental investigations of wide angle conical diffusers with uniform flow and swirl flow lead to the conclusion that:

- The introduction of a moderate swirl improves the performance of the stalled 21°cone angle diffuser diffuser, compare to 140cone angle diffuser.
- For the diffuser (13°cone angle diffuser) having incipient turbulent boundary layer separation, the addition of moderate swirl has a little effect on the diffuser performance.

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