한국추진공학회 2005년도 추계학술대회 논문집 pp.106~109 2005 KSPE Fall Conference

코안다 이젝터 유동에 관한 수치해석적 연구

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A Computational Study of Coanda Ejector Flows

G. Rajesh* · J. H. Lee** · H. D. Kim***

ABSTRACT

The Coanda effect has been used extensively in various aerodynamic applications to improve the system performance. The primary flow in Coanda ejectors is attached to the ejector wall and is expanded inducing a secondary flow. This will probably lead to the mixing of both primary and secondary flows at a down stream section. Very few works have been reported based on the optimization on such devices. The main objective of the present study is to numerically investigate the flow field on a typical Coanda ejector and validate the results with the available experimental data. Many configurations of the Coanda ejector have been analyzed. The effect of various geometric parameters of the device on the expanding mixing layer has also been obtained. The computed data agree fairly well with the experimental data available.

Key Words: Coanda Ejector(코안다 이젝터), Mixing Flow(혼합 유동) Flow Chocking(유동 초킹진), Mixing Layer (혼합층), Compressible Flow(압축성 유동)

1. Introduction

The Coanda effect has long been employed in the aerospace applications to improve the performances of various devices. This effect is the ability of a flow to follow a curved contour without separation. Even though the idea of a Coanda ejector is not new, only very few of investigations(1,4) have been conducted to optimize the performance of such devices. Ameri(1) and Guerriero, *et al*(2) have carried out the most important investigations about these kinds of devices. Ameri designed a numerical code for investigating the Coanda effect on ejectors. Even though his numerical model gave fairly good results, the boundary layer and turbulent effects had not been considered. Hence it is hardly possible to optimize the geometry using his results. Moreover, this model has such limitations as it considered isentropic primary flow conditions in between the reservoir and nozzle outlet, and it had been validated for two ejectors with close geometrical design.

On the other hand, in the parametric study

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conducted by Guerriero, *et al*, various geometries have been tested to optimize the Coanda ejector. Even though the experimental results are reasonable, there are large discrepancies between the numerical and experimental results. This is due to the fact that the Pitot tube used to measure the flow velocity might have perturbed the flow to a great extend, leading to possible errors.

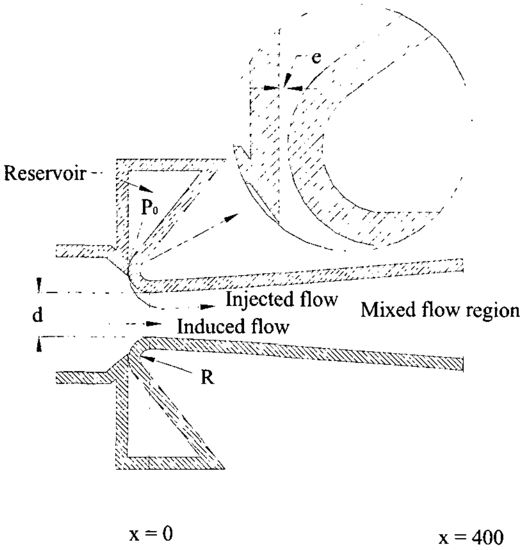

Fig. 1 Schematic of Coanda Ejector

Though there are few works$^{(3, 4)}$ which analyzed the basic mechanism by which the secondary flow is induced in the ejector, the semi-empirical relations able to give the mixing parameter in any configuration are not available yet. The main objective of this paper is thus to study numerically, the various flow patterns inside the Coanda ejector and the effect of various parameters on the mass flow rate of the induced flow. Efficiency analysis of the Coanda ejector is carried out based on a parameter which is defined as the ratio of the induced mass flow rate to the power of the inlet flow, calculated from the stagnation pressure and the volume flow rate of the primary flow.

2. Numerical Model

The two-dimensional compressible Navier-Stokes equations are solved using a finite volume computational fluid dynamics method. The equations are discretized using implicit volume method with the second order upwind scheme.

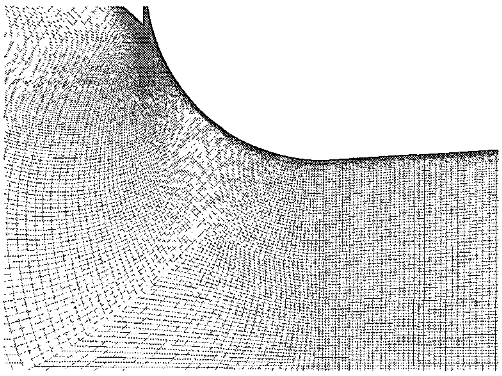

Fig. 2 Grid system near the ejector throat

Total pressure of 0.6 MPa and total temperature of 300 K are imposed at the reservoir inlet. The boundary conditions at the two ends of the ejector have been chosen to be pressure outlet with a total pressure of 0.10325 MPa.

The flow is considered steady with ideal gas properties. A coupled implicit axi-symmetric solver is used. A realizable k-ε model has been identified to be ideal for such problems. Grids near the boundary are fine enough to apply the near wall treatment. The grid system has been chosen as structured grids with quadrilateral cells with about 40,000 nodes for grid independency. Fig. 2 shows the grid system of the

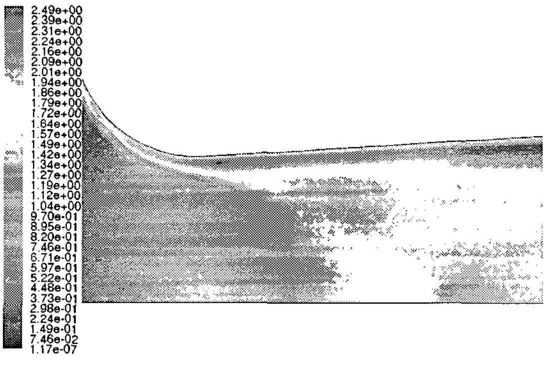

Fig. 3 Mach contours at the ejector throat upper half of the Coanda ejector used in the experiments done by Guerriero, *et al*[2].

3. Results and Discussion

Fig.3 shows the Mach contours for an axi-symmetric model of the Coanda ejector. Since there is a low pressure region generated by the supersonic primary flow expansion, the induced flow stagnates in this zone. The Mach contours clearly show the flow patterns of the primary and induced flows and how they mix in the divergent portion of the ejector.

The velocity profiles plotted against the dimensionless axis at two section of the Coanda ejector are shown in Figs. 4 and 5. The reservoir pressure is 0.6 MPa. From this plot, one can easily understand the degree of mixing between the primary and the induced flow.

On close observation of the velocity profiles, it can be seen that the graph can be split into two parts: the first part characterized by large velocity gradient with high velocities and a second part where the velocity gradient is small. The first part represents the primary flow while the second part is related to the induced flow. Meanwhile, the flat portion of the velocity profile indicates that the two flows are mixed completely.

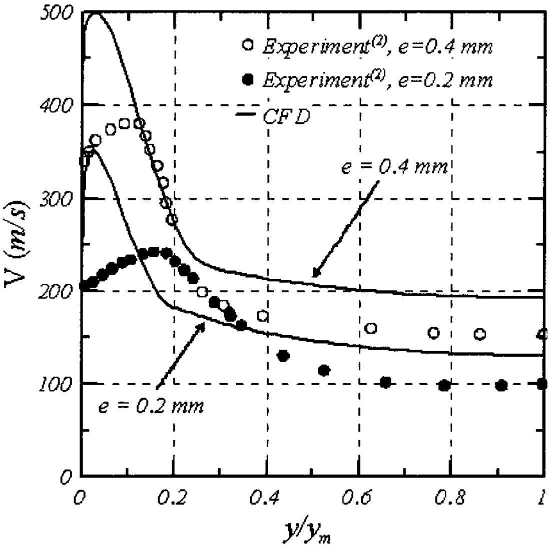

Fig. 4 Velocity profiles at section x=0 mm

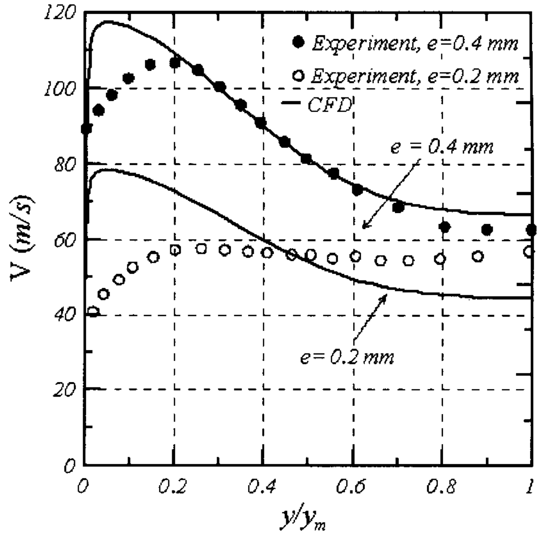

Fig. 5 Velocity profiles at section x=400 mm

Similar trend can be seen in Fig. 5 also, where the velocity profile at a section x = 400mm is plotted. Flow

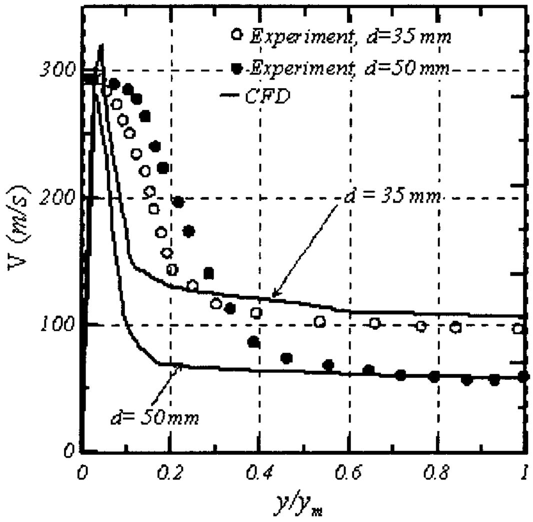

Fig. 6 Velocity profiles at section x=0 mm

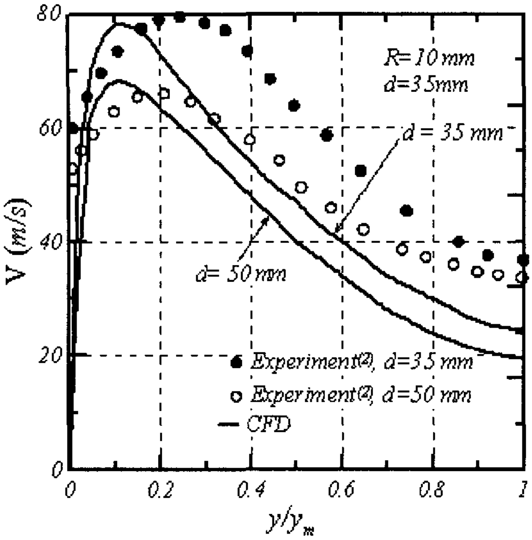

Fig. 7 Velocity profiles at section x=400 mm

velocity is low and the mixing percentage is higher here.

It can be deduced from the plots that increasing the sonic throat will induce more flow into the device. This is because the primary flow through an increased sonic throat is able to transfer more momentum to the induced flow. From an energetic point of view, the ratio of the induced mass flow rate to the injected power termed as ω, will be an important parameter to measure the Coanda ejector performance.

Figs. 6 & 7 illustrate the flow velocities for two diameters of the Coanda ejector. Even though the area of cross section of ejector is considerably increased, the increment in mass flow rate is quite low. The performance factor ω is nearly constant (3.2×10^{-5} kg/s.$W^{-1}$for d = 50 mm and 3.32×10^{-5} kg/s.W^{-1} for d = 35 mm) in both the cases as the critical geometry is hardly modified. For nearly same induced mass flow rates, the velocity of the induced flow at x=0 for d=35 mm is larger and hence the pressure imposed on the primary flow is small. This causes slower expansion rate of the mixing layer as the Mach number is lowered.

Based on the computational results, it is seen that the throat gap and the diameter of the Coanda ejector are the two critical parameters which have a great influence on the performance of the Coanda ejector.

4. Conclusions

A computational study has been performed to investigate the performance of the Coanda ejector. The effect of various geometric parameters the performance of the Coanda ejector have been analyzed and the obtained results are compared with the available experimental data. The throat gap of the primary nozzle has a strong influence on the ratio of mass flow rates of the induced flow and the primary flow and the mixing length as well. The ejector throat size does not seem to have a strong influence on the performance of the ejector. The agreement between the computed and the measured values is poor, possibly due to the experimental errors.

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