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New Method of Swirl Control in a Diffusing S-Duct

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Introduction

S-SHAPED intakes have been widely used in aircraft design. The investigation of curved ducts has received much attention. Previous papers by Guo and Seddon^{1,2} show that the bulk vortex occurs because of flow separation at the bottom wall near the throat of the duct, which results in a large swirl (i.e., rotational flow) at the engine face. The swirl will get stronger when the separation region becomes larger.

The purpose of the swirl investigation in an S-duct is to control or curb the swirl. In Refs. 1 and 2, the solid spoiler, blocking of 15% of entry width from the inside wall, reverses the sense of the final swirl. Stocks and Bussiger³ give swirl measurements for the tornado intake at 20-deg incidence for Mach 0.7 and at 3-deg incidence for Mach 1.8; the results also show the swirl reduction obtainable by the use of duct and curl fences. The authors⁴ present a new approach called the vortex reduced device (VRD) method to control the swirl and to improve the average total pressure coefficient in an S-duct. The bulk vortex at the exit can be diminished to a smaller region. In Seddon's paper,⁵ the sensitivities of swirl to fences are reported. In Vakili et al.'s paper,⁶ an airfoil vortex device and flow control rail are used to reduce a pair of contrarotating vortices in the flow after the second bend. Lin and Guo⁷ describe a vortex control device that decreases the swirl with increasing suction and even eliminates the bulk vortex if the suction is large enough.

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A new swirl control method, called the automatic adjustable blade (AAB) method, is described in this Note.

Experimental Description

An S-shaped diffuser was used, as shown in Figs. 1, consisting of five parts: lip, first bend, straight midsection, second bend, and straight rear section. The diffuser area ratio (exit area to throat area ratio) is 1.3095. Figures 1 also show the AAB device and its location on the model. The AAB has a NACA 0012-series profile, 110 mm long and 50 mm wide,

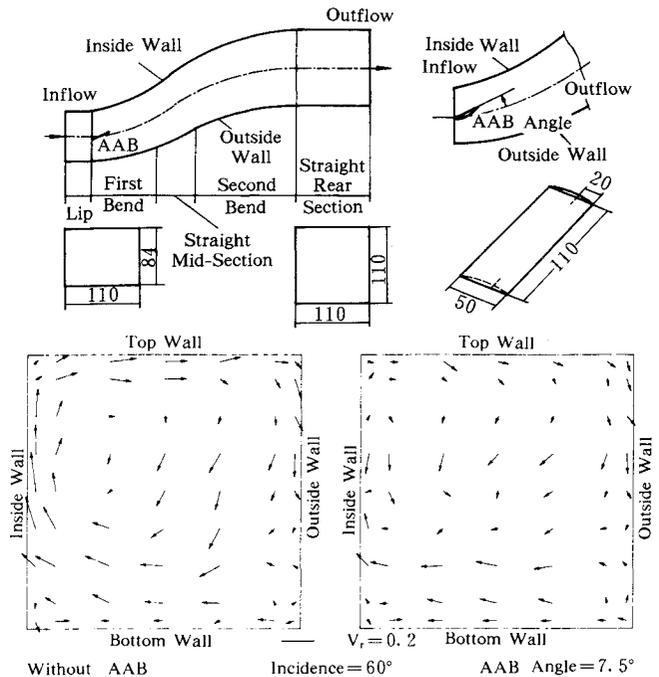


Fig. 1 Experimental model and exit velocity field.

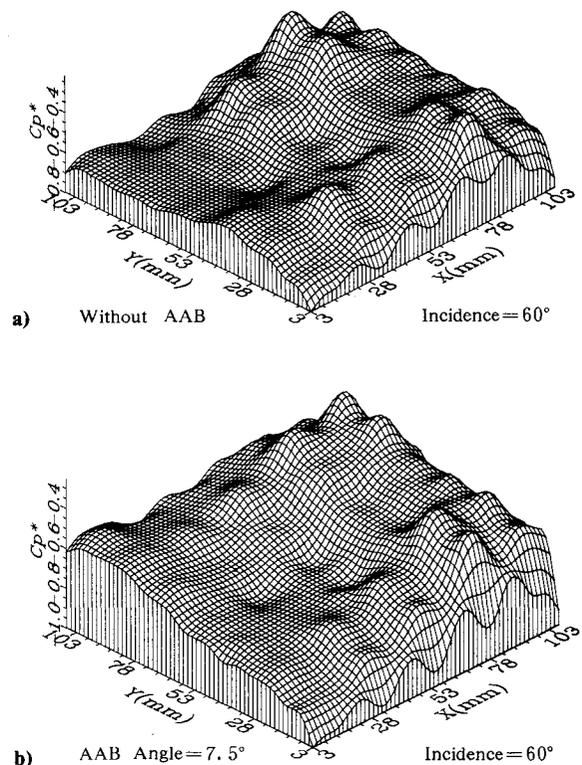


Fig. 2 Total pressure coefficient map: a) without AAB, incidence = 60 deg; b) AAB angle = 7.5 deg, incidence = 60 deg.

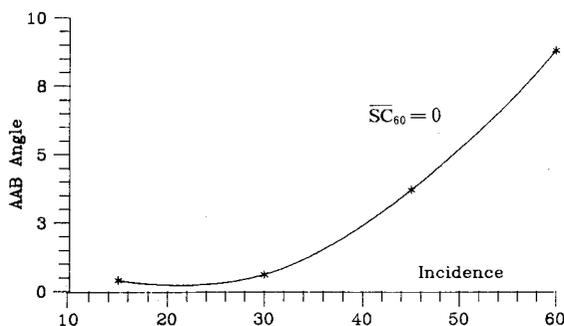


Fig. 3 Relationship between incidence and optimized AAB angle.

mounted near the diffuser entry. This blade could revolve freely around an axis 20 mm behind the leading edge. Installation of the AAB appears to create two inlets. The measurements consisted of static pressure taps along the model walls, measurements of the crossflow velocities and the total pressures at the duct exit at 0-, 5-, 10-, 15-, 30-, 45-, and 60-deg incidences and comparisons with those of no AAB. Details about data processing are described in Ref. 4.

Results and Discussion

The tests in a diffusing S-duct model with the AAB installed showed that the automatically rotating blade experiences no resultant aerodynamic moment at AAB angles of 15 and -12 deg. This physical phenomenon is caused by the bulk vortex because of the flow separation near the inlet and the influence of the blade. Moreover, the swirls at the duct exit have different senses of rotation when the blade is held at these two different angles. The result implies that the large swirl could be reduced only if the AAB is mounted at an angle between these two values.

To find the optimized AAB angle that produces zero swirl, experiments were made at 2.5-deg steps between these two angles. Figure 1 shows that the exit swirl varies with the AAB angle at 60-deg incidence. It is well known that without the AAB the swirl rotates clockwise because of the bulk vortex caused by a large separated flow region near the bottom lip. The results show that the swirl has changed its rotation from clockwise to counterclockwise with increasing AAB angle. The presence of the AAB affects the pressure distribution near the entry, and the bulk swirl could be reduced to the point of elimination at about 7.5-deg AAB angle.

The results also show the static pressure distributions along the model walls at 7.5-deg AAB angle with 60-deg incidence and compared with those of no AAB. It is obvious that both of them are quite similar and that the presence of the AAB does not influence the pressure distribution along the walls. Figures 2 show total pressure coefficient maps at the exit of the curved duct. Clearly, because of the large separated flow near the inlet and the bulk swirl, there is a severely distorted total pressure field at the exit of 60-deg incidence (see Fig. 2a). The low-energy flow region with the lower C_p^* value moves clockwise from the bottom lip at the inlet to the inside wall under the effect of the swirl. The presence of the AAB does not substantially affect this distorted total pressure field, although there is a small drop in the C_p^* value, as shown in Fig. 2b. If this pressure loss is acceptable, the AAB method is an effective means of swirl control in aircraft inlet design.

Figure 3 shows that the relation between the incidence and the optimized AAB angle at which the swirl disappears is nearly an exponential function of the incidence. Hence, the optimized AAB angles for zero swirl coefficient can be determined at any incidence, which may be helpful for aircraft inlet design.

Conclusions

In this Note, a new approach of swirl control in an S-shaped diffuser, called the AAB method, is presented. Several conclusions could be drawn as follows.

1) Two angular positions have been found where the AAB experiences no resultant aerodynamic moment, i.e., 15 and -12 deg.

2) The optimized AAB angle is found between these two positions.

3) The swirl at the duct exit (i.e., the engine face position) can be reduced or eliminated by the AAB method. The relationship between the incidence and the optimized AAB angle at which swirl disappears has been established.

4) The AAB method offers an effective swirl control approach at the expense of an acceptable total pressure loss.

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Breakup of a Liquid Jet in Supersonic Crossflow

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I. Introduction

CONSIDERABLE attention has been given to the physical process of transverse liquid jet breakup and its role in the control of the rate and/or completeness of combustion.¹⁻⁴ The jet-breakup location divides the combustion process into two fundamental stages (see, for example, Fig. 1). Before breakup, the transverse liquid fuel jet evaporates and reacts with the oxidizer in the gas-phase boundary layer at the surface of a coherent, curved liquid column. After breakup, the liquid fuel droplets interact with the gas stream (and, under some circumstances, each other), and burn either as individual particles or as droplet clusters.⁵ Thus, the determination of jet-breakup location is a first step in the overall understanding of combustion in the transverse liquid fuel jet.

Schetz et al.¹ first observed that the local sonic point associated with a sharp wave crest is a rather good indicator for the beginning of jet breakup. The liquid jet column fractures shortly behind the local sonic point, where the jet body has

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