CHAPTER 1

INTRODUCTION

1.1 GENERAL

Suddenly expanded flow fields find application in many interesting problems of practical importance such as combustors and combustion chambers, propulsion system, parallel diffusers and so on. In Supersonic combustion flow fields, the recirculation region formed behind the step is the main flame holding mechanism. For the case of supersonic upstream flow, injecting fuel transversely behind a rearward facing step enables the jet to penetrate well into the locally low speed flow before being turned by supersonic cross flow. A prime example of this is provided by the case of the ballistic missile during the re-entry phase, where much of the drag and hence the trajectory, is determined by the pressure acting on the base.

Flow separation at the base of aerodynamic vehicles such as missiles, rockets, projectiles and after bodies of fighter aircraft leads to the formation of a low speed recirculation region near the base. The pressure in this region is generally significantly lower than the free stream atmospheric pressure. Base drag caused by this difference in pressures can be up to two thirds of the total drag on a body of revolution. Large scale unsteadiness, often associated with a turbulent separated flow, can cause additional problems like base buffeting which are undesirable. The need of controlling such flow fields has initiated studies on control of these flows.
Sudden expansion of flow both in subsonic and supersonic regimes of flow has been extensively studied because of its wide range of applicability.

1.2 PHENOMENON OF SUDDEN EXPANSION

Axi-symmetric sudden expansion phenomenon can be characterized by flow separation, flow re-circulation and reattachment. Such a flow field is divided by a shear layer, into two main regions, one being the flow recirculation region and the other the main flow region. The point at which the dividing streamline strikes the wall is called the reattachment point. The base corner was thought of as a sump with two supplies of mass. The first was the boundary layer flow around the corner and the second was the back flow in the boundary layer along the wall of expanded section. This back flow occurred because of the pressure difference across the shock wave originating where the jet strikes the wall. It was concluded by Wick (1955), after observing all this phenomenon experimentally, that the mechanism of internal and external flow was principally the same and base pressure phenomenon in external flow could be studied relatively easily by experiments with internal flow.

The experimental study of sudden expansion with internal flows has the following advantages over the external flows. The volume of air supply needed is greatly reduced by eliminating the need for tunnel with large enough cross section so that certain flow disturbing features like wall interference are avoided. ‘Stings’ and other support mechanisms required for external flow tests are also eliminated in the internal flows. The most important advantage of an internal flow apparatus is that complete static pressure and surface temperature measurements can be made not only along the entrance
Figure 1.1 Schematic Sketch of Sudden Expansion

Section to the expansion (analogous to a body of projectile) but also in the wake region. These measurements are particularly valuable if one wants to test theoretical prediction adequately.

1.3 FLOW CONTROLS FOR DRAG REDUCTION

All types of flow controls for drag reduction can be broadly classified into active and passive controls. In active control, an auxiliary power source is used to control the drag on the body. In passive control the controlling energy is drawn directly from the flow to be controlled. Both active and passive controls mainly aim at modifying the flow characteristics to get the desired reduction of drag. But passive controls have the advantage of not using extra source of energy.

1.3.1 Active Control

Active control methods use energy from external source. Previously studies on base flow investigation with active control in the form of micro-jets to control base pressure level have been demonstrated. An extra settling chamber was used to blow through the control holes of the base. Although the flows with active controls produced certain interesting results as in the case of micro-jets it requires additional source of energy to be carried on flying vehicle.
1.3.2 Passive Control

The passive controls are made inherent controls which do not require additional source of energy. Studies on suddenly expanded flows in the past, employed control in the form of grooves, cavities and ribs. For drag reduction in supersonic and hypersonic regime, different kinds of passive controls are in application. For nose drag reduction, spike at the nose, spike with different tipped bodies, sharp nose of different fineness ratio, straight and conical cavity at the nose are used. For base drag reduction boat-tailed base, step base, cavity at the base are mainly common in use.

The present study also employs passive control in the form of a rib to investigate the base pressure and wall pressure distribution along the enlarged duct.

1.4 OUTLINE OF THE THESIS

Suddenly expanded flows with passive controls in the form of annular ribs have been investigated, laying emphasis on the base pressure reduction and enlarged duct pressure field. Experiments were conducted over the subsonic, sonic correctly expanded and underexpanded flows, and Mach 1.4, 1.6, 1.8 and 2 supersonic flows at overexpanded and underexpanded states. Suddenly expanded flow with four different passive control aspect ratios of 0.45, 0.64, 0.84, 1.25, and six different enlarged duct lengths of 2D, 3D, 4D, 5D, 6D and 10D, their combinations with rib at different locations for each enlarged duct length were studied in detail. The present study aims at providing an idea for predicting the optimum geometries of controls with respect to enlarged duct length, for the desired base pressure, without causing severe oscillations of wall pressure field.