FLOW BEHAVIOUR NEAR THE LEADING EDGE OF THE VANED DIFFUSER

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Measurements were carried out close to the leading edge of vane diffuser of a centrifugal impeller to study the flow behaviour from impeller outlet to throat at different flow coefficients. The flow behaviour is characterized in terms of pressure recovery coefficient from leading edge to throat and variation of Mach number and flow angle near throat. The unsteady static pressure variations at impeller outlet, leading edge and across the throat of vane diffuser were also measured to characterize the flow. Some salient features of the measurements are discussed in this paper.

1. INTRODUCTION

The flow coming out of the impeller has fluctuations in tangential and radial velocities as well as pressure in addition to changes in kinetic energy. The large kinetic energy at impeller outlet is converted to useful pressure energy by placing a vane-less or a vane diffuser. Vane-less diffuser requires large radius before the flow is brought to required level of Mach number acceptable in the combustion chamber. It was believed that flow fluctuations would die down as it passes through the vane-less diffuser and flow becomes uniform after reaching certain distance from the impeller. It is generally assumed that flow becomes uniform at a radius ratio of around 1.05. And a vane diffuser will be placed at this radius to achieve the required pressure recovery. Measurements in vane-less diffusers indicate that flow becomes uniform at radius ratio much higher than the above-mentioned value.

2. INSTRUMENTATION

Measurements were carried out close to leading edge of the vane diffuser of centrifugal impeller to study the behaviour of flow from impeller outlet to throat. Global pressure measurements were carried out using yaw probes and providing static pressure taps on the sidewall. The static pressure fluctuations were measured using high response Kulite transducers. The Transducer signals were triggered using a shaft pulse and acquired using a high-speed data acquisition card mounted in a Pentium computer. The transducer signals were conditioned using a programmable signal conditioner before feeding onto the data acquisition card.

3. RESULTS AND DISCUSSION

The geometrical area in the vane less portion from impeller outlet to diffuser leading edge increases. The supersonic flow at impeller outlet decelerates to subsonic value through a shock wave that is anchored near the leading edge of the diffuser. This deceleration in supersonic flow takes place through a series of shocks and provides some static pressure recovery. The pressure recovery in static pressure depends on the incidence to the diffuser. The variation of static pressure recovery with flow coefficient is shown in Figure-1. It is observed that from this figure nearly 50% of the pressure recovery occurs between inlet to throat of the diffuser for a range of flow coefficient. The maximum pressure recovery in the throat region occurs near optimum incidence to the diffuser.

In a classical design of vane diffuser it is assumed that the Mach number at the throat is unity and remains constant across the throat. Similarly it is also assumed that there is no variation in flow angle across the throat. The variation of Mach number and flow angle across the throat is shown in Figure-2 and Figure-3. It is observed from Figure-2 that there is a variation in Mach number across the throat and this variation is least at the large positive incidence to the diffuser. In an ideal flow situation without boundary layer the geometrical throat coincides with the actual throat, but due to the viscous of the flow the position of the actual throat gets changed. This position also gets varied depending on the incidence. Hence it is observed that the Mach number at the geometrical throat is slightly greater than unity. The actual throat is occurring down stream of the geometrical throat. Similarly it is observed from figure that the flow angle across the throat varies and the variation depends on the loading of the vane diffuser.

The variation of static pressure at five different locations is shown in Figure-4. These locations corresponds to impeller outlet, diffuser-leading edge, close to pressure surface near throat, throat center and close the suction surface near throat. The static pressure variations are shown with respect to time. These measurements were carried out at subsonic Mach number at impeller outlet. The flow behaviour at subsonic Mach number largely depends on the incidence to vane diffuser. It is observed from these figures that the static pressure fluctuations get amplified as the flow enters the diffuser at negative incidence to the diffuser. At negative incidence the static pressure fluctuations at throat near the pressure surface and center are larger as compared to suction surface of the throat. This is attributed to the fact that the flow is trying to get separated from the pressure side of the blade. Where as at positive incidence the blade loading increases and the flow tries to separate from the suction surface. The static pressure fluctuations amplify on the suction surface and in the mean time the flow fluctuations will diminish on the pressure surface. Even at zero incidence to the diffuser there exists pressure fluctuations at the throat. It is observed in the vane diffuser that pressure fluctuations build up within the diffuser depending on inlet conditions to the diffuser and are carried away to the exit of the diffuser. Such a phenomenon of flow fluctuations getting amplified is not seen in the case of diffuser without vanes. This leads to a reduction in surge margin of compressor with vane diffusers compared to ones fitted with vane-less diffuser.

4. CONCLUSIONS

Measurements very close to the leading edge of vane diffuser showed that the pressure recovery from leading edge to the throat is nearly half of the total pressure recovery achieved through the vane diffuser. This pressure recovery is achieved through supersonic diffusion trough shocks. The static pressure measurements in the subsonic flow regime showed that the flow fluctuations get amplified on the suction surface of the throat at positive incidence. These static pressure fluctuations are carried almost to the exit of the vane diffuser. These fluctuation leads to a reduction in surge margin of compressor with vane diffusers compared to ones fitted with vane-less diffuser.

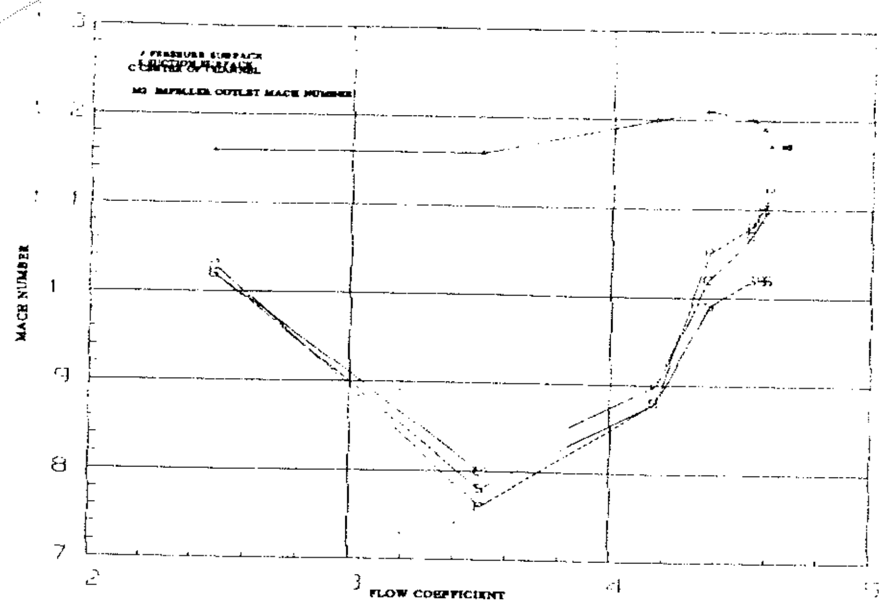

Fig. 1 MACH NUMBER VARIATION NEAR THROAT

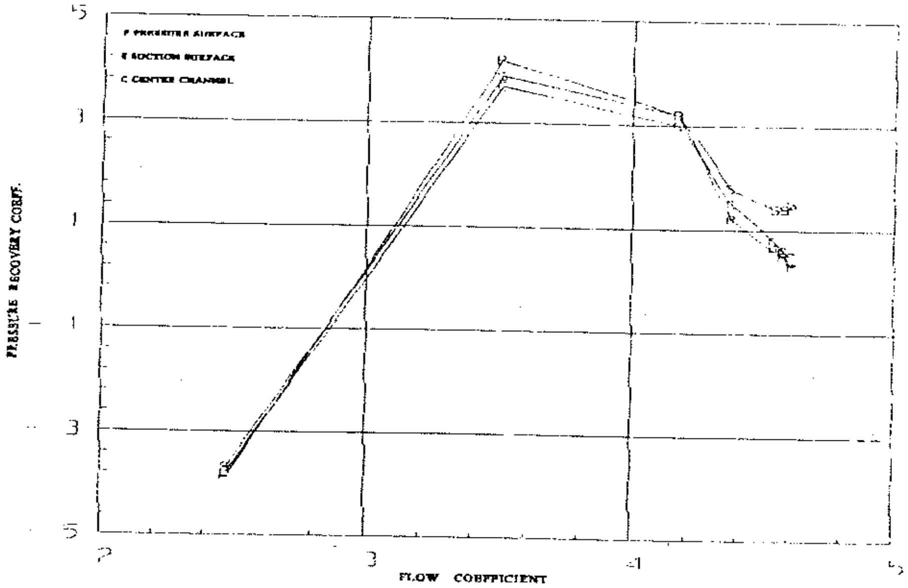

Fig. 2 PRESSURE RECOVERY COEFFICIENT

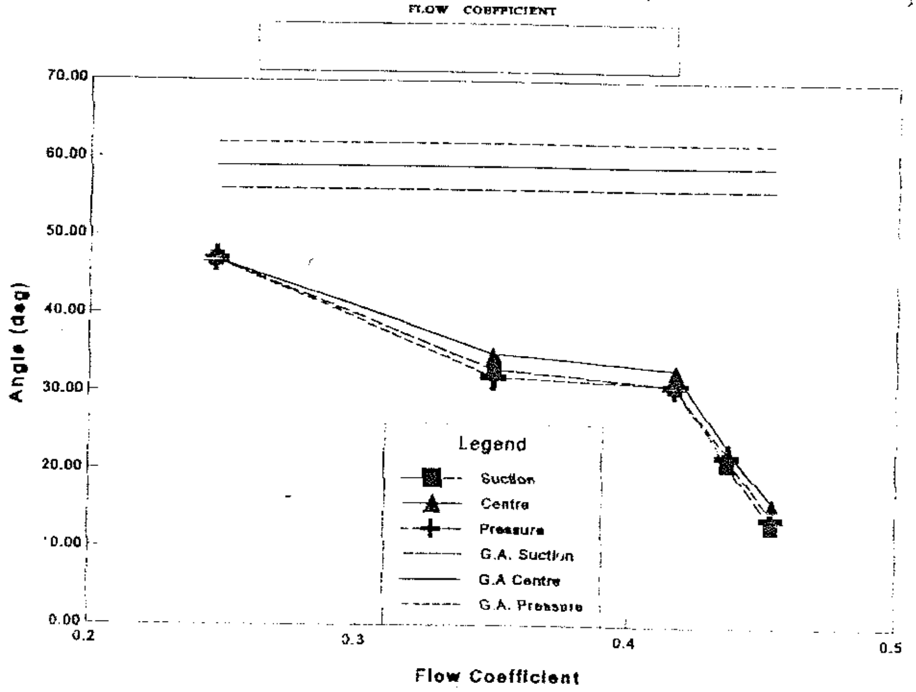

Fig. 3 FLOW ANGLE VARIATION

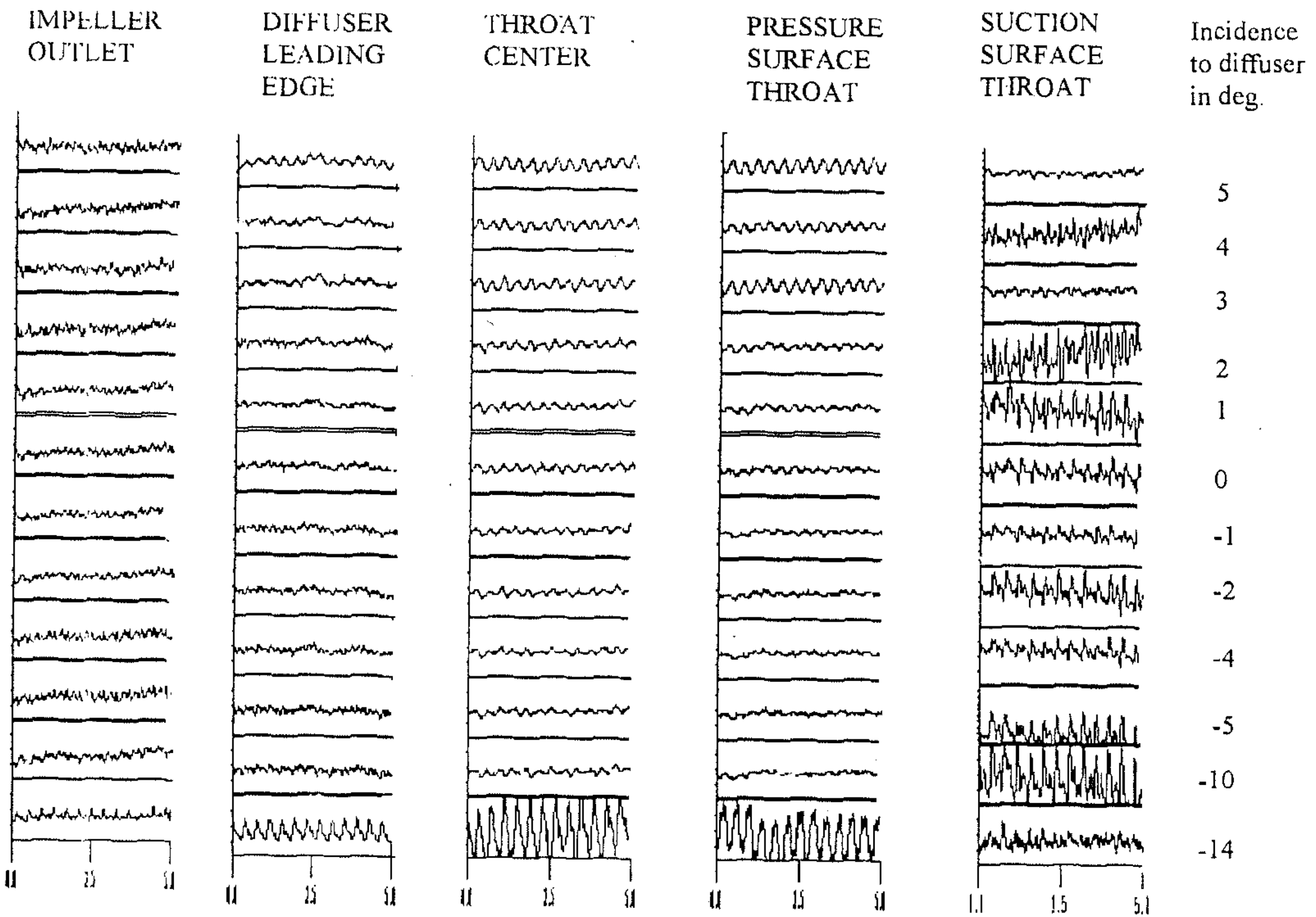

Fig. 4 STATIC PRESSURE VARIATION NEAR LEADING EDGE OF VANED DIFFUSER