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FLOW VISUALISATION IN COMPRESSORS

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Flow visualisation techniques for axial and radial compressors are described

(i) low speed compressors : smoke injection, models using water with air bubble or colorant injection, free surface watertables for radial compressor models, water table for cascade studies (fixed or moving linear cascades);

(ii) high speed compressors : shadowgraphs, schlieren pictures, laser holography.

1.- Flow visualisation techniques for low speed compressors.

1.1 - Smoke injection in a low speed flow

Visualisation of the streamlines in a low speed compressor can be obtained by means of smoke filaments. This technique is well suited either for axial or radial compressors.

a) Preparation of the smoke . Kerosene vapour seems the best suited for smoke injection. Temperature of the kerosene vapour has to be maintained in a narrow range of temperature (250 - 280 K) in order to have a dense vapour without condensation. Argon is used as the driving gas to avoid ignition hazards. Pressure of the kerosene vapour is controlled by means of a manometer and a security valve.

b) Smoke visualisation in a radial compressor . Smoke injection is mostly used for the determination of separation zones in the impeller. Smoke is injected in therotating impeller; a separation bubble appears on the blade pressure side and extends progressively as the mass flow decreases. (Fig.1). Flow patterns during the rotating stall regime can also be visualized.

c) Flow visualisation in axial compressors . Both the absolute and the relative streamlines can be recorded. For the absolute flow streamlines the smoke is injected in front of the blade row, through regularly disposed holes. This test set up is well suited for the analysis of steady flow and rotating stall (Fig.2).

Analysis of the flow field in the relative reference frames requires the use of a mirror that rotates at half the rotor speed. Flow separation from the blade suction side.can be investigated by this method.

1.2. - Water compressor studies

Compressor models using water have been tested in many laboratories.

a) Through flow models . The compressor has a transparent casing or a metal casing with visualisation windows. Streamline visualisation is obtained by means of coloured filament injection or by means of bubbles (air or hydrogen). The absolute streamlines are observed by direct photography of the set-up, visualization of the relative streamlines necessitates a rotating mirror. Fig.3 shows an example of the absolute streamlines in a water compressor.

b) Free surface models. Another type of flow visualisation in compressors uses a free surface water table. It applies mainly to radial compressors (impeller or diffuser studies). An example of flow in a radial compressor visualized on a free surface water table is given on Fig.4.

c) Cascade flow investigations. Free surface water table can also be used for blade cascade flow investigations. Secondary vortices and leading edge flow separation can be visualized (Fig.5).

Using compressor blades mounted on a belt, flow in a moving linear cascade can be visualized (Fig.6). Such test set up is very convenient for blade row interaction studies.

2.- High speed flow visualizations

2.1 - Cascade flows

Flow visualisation in conventional two-dimensional linear blade cascades is well known and no reference will be made of them.

The conventional shadograph and schlieren techniques can be easily applied to annular cascades. The only requirement is a well polished hub acting as a cylindrical mirror and reflecting the incident light beam. Since in annular cascades the hub to tip ratio

is very high, the schlieren technique gives better results. Conventional knives give black and white schlieren pictures. To obtain coloured schlieren pictures coloured screens are used instead of the knives. This technique gives the constant pressure lines. An example of flow visualisation in a supersonic blade cascade is given in fig.7.

These visualisations show suction side flow separations as the back pressure increases. Injecting water through midspan pressure holes, a direct visualisation of the separated flow regions is obtained. In this experiment the water vapourizes as soon as it leaves the injection hole and fills up the separated flow regions. The presence of vapour can be detected by direct observation of the flow.

2.2 - Rotating blade cascade

As an intermediary step between fixed annular cascades and actual compressors with long, twisted blades, rotating cascades can be used. These have non-twisted blades and a cylindrical configuration well suited for optical measurements. High speed schlieren systems are required for sharp pictures. These systems are usually laser controlled and can be fitted with:

an electronic camera, the flow is then visualized on a TV screen or recorded on magnetic tapes;

or with a conventional movie camera that is triggered by the spark.

This visualization technique is mainly used for shock wave pattern studies (Fig.8). Flow separation from the blade surfaces can also be detected.

2.3.- Shock wave configurations in an actual supersonic compressor

Flow visualisation in an axial supersonic compressor, with long, twisted blades and a converging hub is possible when the outer casing is cylindrical. A visualisation window has to be fit on the outer casing. Reflecting material is fixed on the hub surface. A conventional shadowgraph technique is used, with a laser controlled strobo-flash. (Fig.9)

Using either two cameras triggered simultaneously or a single camera that takes two images with a slight delay, 3-D pictures can also be obtained. This technique situates the shock wave along the blade span.