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A Steady State Analysis on Axial Flow Compressor Subjected to Stresses and Deformation

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Abstract: ***Axial flow compressor in which helps in passing a high compressor air and is which can be alternate the air. In an axial flow compressor, air passes from one stage to the next, each stage rising the slightly. The energy level of air or gas flowing through it is increased by the action of the rotor blades which exert a torque on the fluid which is supplied by an electric motor or a steam or a gas turbine. In this thesis, an axial flow compressor is designed and modeled in 3D modeling software nx8.0 and Ansys 15.0 the present design has 30 blades, in this thesis it is replaced with 29 blades and to find the shear stresses, deformation of a compressor and a failure analysis through single blade. A single blade analysis is done for failure conditions. The present used material is Aluminum and magnesium alloy. Static Structural analysis is done on the compressor models to verify the strength of the compressor.***

Keywords: Axial Flow, Ansys, Compressor, NX8.0

1. Axial Compressor

An axial flow compressor is one of the mechanical devices it is continues pressurize the gases the device rotating in used air and oil based. The compressor works on the principle of the fluid in directional flow and parallel to the axis of rotation. The difference of rotating compressors such as centrifugal compressors, axial centrifugal compressors are mixed for a flow where the fluid flow will include a "radial component" through the compressor

2. Transonic Axial Compressor

Transonic axial flow compressors are today widely used in aircraft engines to obtain maximum pressure ratios per single-stage. High stage pressure ratios are important because they make it possible to reduce the engine weight and size and, therefore, investment and operational costs. The maturity in transonic compressors has reached at some regarding conditions where as to define the virtual forces influenced by the air oil aero design but the flow field in a compressor must varied due to some residual flow and the three-dimensional blade shape must be of some of some desired shape. Many conditions and several researches are done on the basis for design and theoretical analysis of axis flow compressor

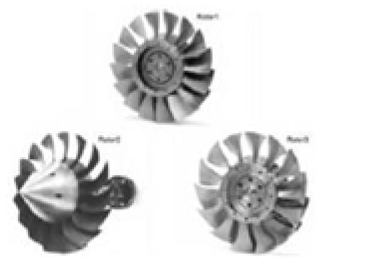

Figure 1: Transonic Compressor Test Rotors

3. Centrifugal Compressor Considerations

- Impellers with single and dual entry
- Acceleration of air radially outwards towards the hub.
- Relatively light weight design of the hub
- Efficiency of the large frontal area for the use of different stages.
- Sub-class of dynamic and axisymmetric in work absorbing turbo machinery.
- The idealized compressive and dynamic turbo machining achieves a dynamic pressure so that the kinetic energy or velocity for a continuous flow of fluid through the rotor is impeller is considered.
- A centrifugal compressor is a radial flow rot dynamic fluid machine that uses mostly air as the working fluid and utilizes the mechanical energy imparted to the machine from outside to increase the total internal energy of the fluid mainly in the form of increased static pressure head.

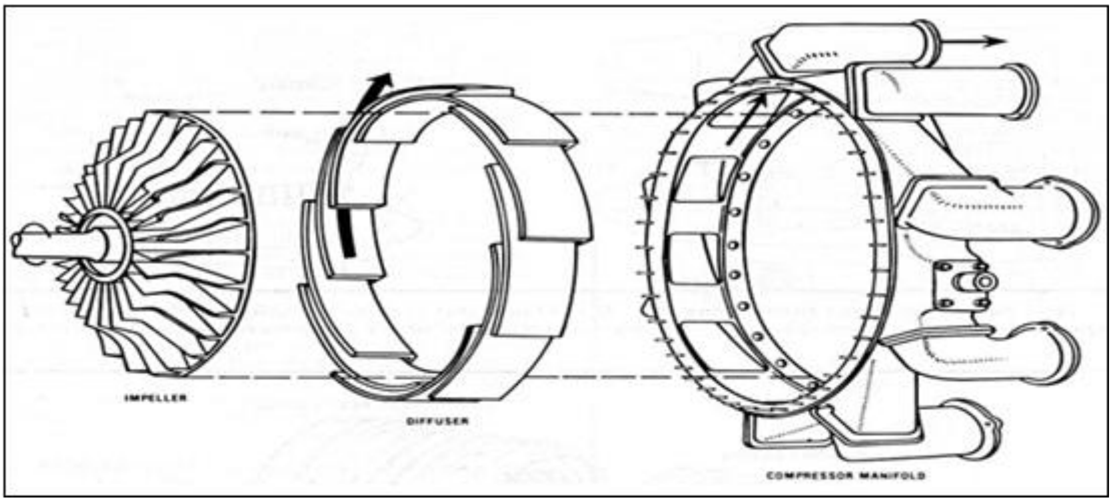

Figure 2: Centrifugal compressor components

The course of turbo machinery history splitter vanes have been used extensively in centrifugal compressors. Axial compressor rotors with splitter blades have been studied and shown potential for producing desirable performance characteristics (high stage pressure ratios and efficiencies), but have failed to gain traction due to perceived negative performance characteristics such as narrow mass flow operating ranges. Starting in the late 1980s, three different engine companies have explored the concept with contemporary CFD tools and have tested some prototypes. Some of these results showed great promise. None of this work has been published openly yet, but this approach does appear to offer prospects for good diffusion factors on the order of 0.5 to 0.7 and possibly higher. The key to successful application will be the development of a splitter-vane design procedure that balances and optimizes the pressure distributions in the two passages created by the splitter vane. An important component of this will be a viscous CFD code that handles shock waves, high diffusion, and separated regions well. This study revisited axial compressor rotors with splitter blades by the design, build, test, and evaluation of a non-axisymmetric rotor with splitter blades that retains the positive performance characteristics while addressing the previously identified deficiencies. Axial compressor rotors with splitter blades will be desirable in large and smaller gas turbine applications such as helicopters and unmanned aerial vehicles. Winner storm Supersonic Axial Compressor Stage Incorporating Splitter Vanes Starting in and co-workers at the Fluid Dynamics Research Laboratory, Aerospace Research Laboratories, Wright-Patterson Air Force Base, Ohio designed and tested a variant of a supersonic axial compressor stage that incorporated splitter vanes in the aft section of the rotor passage. This study resulted in a rotor that contained 30 main blades and 30 splitter blades depicted.

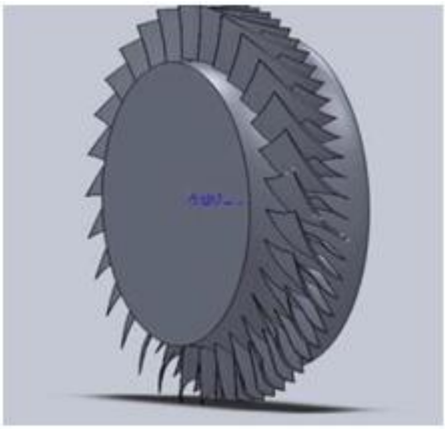

Figure 3: Wennerstrom's transonic axial compressor splattered rotor

The splitter blade camber line duplicated the camber line of the main blades and was circumferentially positioned exactly midway between main blades. The splitter blades extended the full radial span and their leading edges were placed halfway between the inlet and exit planes of the rotor. Additionally, the trailing edges of the splitter blades were in the same axial plane as the trailing edges of the main blades as shown in At 100 percent design speed, Wennerstrom's rotor achieved an experimentally measured peak total-to-total pressure ratio of 3.47 and a peak total-to-total isentropic efficiency of 85 percent. Detracting from theses impressive results was a very narrow mass flow rate range of 3 percent.

Figure 4: Wennerstrom's tip section blade and passage geometry

An axial compressor is a compressor that can continuously pressurize gases. It is a rotating, airfoil-based compressor in which the gas or working fluid principally flows parallel to the axis of rotation, or axially. This differs from other rotating compressors such as centrifugal compressors, axi-centrifugal compressors and mixed-flow compressors where the fluid flow will include a "radial component" through the compressor. The energy level of the fluid increases as it flows through the compressor due to the action of the rotor blades which exert a torque on the fluid. The stationary blades slow the fluid, converting the circumferential component of flow into pressure. Compressors are typically driven by an electric motor or a steam or a gas turbine. Axial flow compressors produce a continuous flow of compressed gas, and have the benefits of high efficiency and large mass flow rate, particularly in relation to their size and cross-section. They do, however, require several rows of airfoils to achieve a large pressure rise, making them complex and expensive relative to other designs (e.g. centrifugal compressors).

4. Working Principal of Axial Flow Compressor

As the fluid enters and leaves in the axial direction, the centrifugal component in the energy equation does not come into play. Here the compression is fully based on diffusing action of the passages. The diffusing action in stator converts absolute kinetic head of the fluid into rise in pressure. The relative kinetic head in the energy equation is a term that exists only because of the rotation of the rotor. The rotor reduces the relative kinetic head of the fluid and adds it to the absolute kinetic head of the fluid i.e., the impact of the rotor on the fluid particles increases its velocity (absolute) and thereby reduces the relative velocity between the fluid and the rotor. In short, the rotor increases the absolute velocity of the fluid and the stator converts this into pressure rise. Designing the rotor passage with a diffusing capability can produce a pressure rise in addition to its normal functioning. This produces greater pressure rise per stage which constitutes a stator and a rotor together. This is the reaction principle in turbo machines. If 50% of the pressure rise in a stage is obtained at the rotor section, it is said to have a 50% reaction.

Axial flow compressors are typically used at applications with low differential pressure (head) requirements and high flow rates. A typical axial compressor consists of a drum, to which blades of specific geometry are attached. Typical applications of big-size axial compressors are those used to compress the air intake of gas turbines. These are typically multistage axial compressors, consisting of several stages. Each stage typically consists of a rotor and a stator. A rotor is a set or rotating blades, whose role is to accelerate the gas flow. A stator is a set of stationary blades whose role is to convert the velocity energy gained in the rotor to pressure energy, similar to the impeller – diffuser combination used in the centrifugal compressors.

5. Design Optimization of Axial Flow Compressor

Basic steps involved in the project

- Design of axial flow compressor is done by using Nx 8.0
- The design process goes on with respected dimensions.
- The analysis gets carried out by using a ANSYS version 15.0
- The Analysis carried out by using materials
- Analysis of the component static, structural and shear strain ,shear stress

The geometry supplied for the compressor with a flow in axial direction and the compressor design at a geometric altered for the maximum efficiency at a design point. By applying the analysis having a dimension for a single stage and making the assumptions such as:

- Constant axial velocity C x
- Constant mean radius r m = 1/2(r h + r t).
- Identical velocity vectors C1 and C3 at entry to and exit from the stage at the mean radius rm. The efficiency ἡ t of this stage is dependent upon the following variables,

T

he variables having a thermodynamic staganation with an enthalpy rise to find the greater stage models of signifies stage loading to specify the enthalpy of h1, h2, h3 which are modeled to transfer the energy through the stages.

$$\eta_{tt} = f\left(\phi, \psi, R, \frac{W_1}{U}, \frac{C_2}{U}, M_1, M_2, R_{em}, \zeta_R, \zeta_s\right)$$

Where M1 and M2 are the rotor and stator exit Mach numbers that are defined as

$$\left.\begin{aligned} M_1 &= \frac{W_1}{a_1} \\ M_2 &= \frac{C_2}{a_2} \end{aligned}\right\}$$

Rem is the stage Reynolds number based on mean radius

$$R_{em} = \frac{U r_m}{\upsilon}$$

$$\left.\begin{aligned} \zeta_R &= \frac{\Delta p_{oR}}{\frac{1}{2}\rho W_1^2} \\ \zeta_s &= \frac{\Delta p_{os}}{\frac{1}{2}\rho C_2^2} \end{aligned}\right\}$$

φ , ψ are the flow and work coefficients defined as

$$\left.\begin{aligned} \phi &= \frac{C_x}{U} \\ \psi &= \frac{\Delta h_o}{U} \end{aligned}\right\}$$

By an effecting an experimental cascade test show that the loss coefficient. Affecting (ηtt) Experimental cascade tests show that the loss coefficients R s, are themselves dependent upon blade row Reynolds number and inlet Mach number. We would also expect that loss levels to be directly influenced by the velocity triangle environment within which the blades have to operate and hence to depend up on φ , ψ and R. We can express this through

$$\left.\begin{aligned} \zeta_R &= f_1(\phi, \psi, R, \mathrm{Re}_R, M_1) \\ \zeta_s &= f_2(\phi, \psi, R, \mathrm{Re}_s, M_2) \end{aligned}\right\}$$

Where, the blade row Reynolds numbers ReR and Res are based on rotor and stator blade chords lR and ls.

$$\mathrm{Re}_R = \frac{W_1 l_R}{\upsilon}$$

$$\mathrm{Re}_s = \frac{C_2 l_s}{\upsilon}$$

$$\eta_{tt} = f(\phi, \psi, R,, \zeta_R, \zeta_s)$$

Thus, the efficiency of an axial-compressor stage depends upon five dimensionless parameters which are sufficient to account for all the 15 items listed in 50Of these parameters, just three may be independently selected by the designer, namely φ,ψ and R. The loss coefficients themselves are also dependent upon the duty parameters φ ,ψ and R but in addition are influenced by Reynolds number and Mach number.

Simple analytical formulation for the total to total efficiency of a compressor stage

The can be converted into a more useful analytical form. By assuming for the moment a fixed reaction value R = 0.5. Defining the stagnation enthalpy loss due to irreversibility into

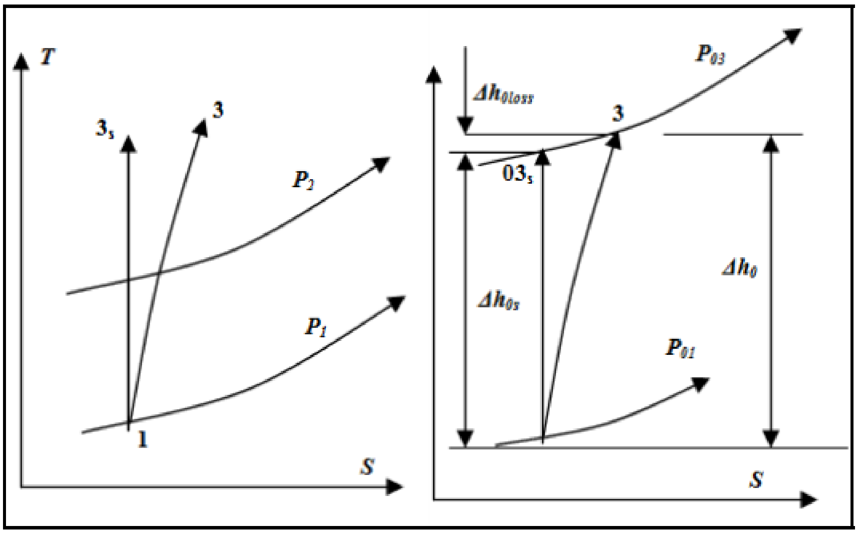

Figure 4: T-S and h0-S diagrams for an axial-compressor stage

$$\eta_{tt} = \frac{h_{03s} - h_{01}}{h_{03} - h_{01}} = 1 - \frac{(\Delta h_0)_{loss}}{\Delta h_0}$$

$$= 1 - \frac{(\Delta p_0)_{loss}}{\rho \Delta h_0} = 1 - \frac{1}{\psi}\left(\frac{(\Delta p_0)_{loss}}{\rho U^2}\right)$$

$$\eta_{tt} = 1 - \frac{1}{2\psi}\left(\phi^2 + \frac{1}{4}(1+\psi)^2\right)(\zeta_R + \zeta_s)$$

is equivalent to the parametric derived from the dimensional analysis for a 50% reaction. But it is in the much more useful explicit form of an analytical relationship which shows how ηtt depends upon the various dimensionless groups. From this, we can deduce that the efficiency of a 50% axial-compressor stage is dependent upon two main factors: 1. The stage duty coefficients (φ , ψ). 2. The blade-row loss-coefficients R and s. The initial selection of the stage duty coefficients (φ, ψ) is crucial. R and S are normally used to represent cascade loss coefficient. We need to pin into all other frictional losses such as tip leakage and secondary losses related to rotor and stator from the stage performance analysis the inherent aerodynamic loss charater tips of the blades can be summarized coefficients (φ , ψ) velocity triangles environment into which the blade summarised

6. Results

29-BLADES ANALYSIS: -ALUMINUM:

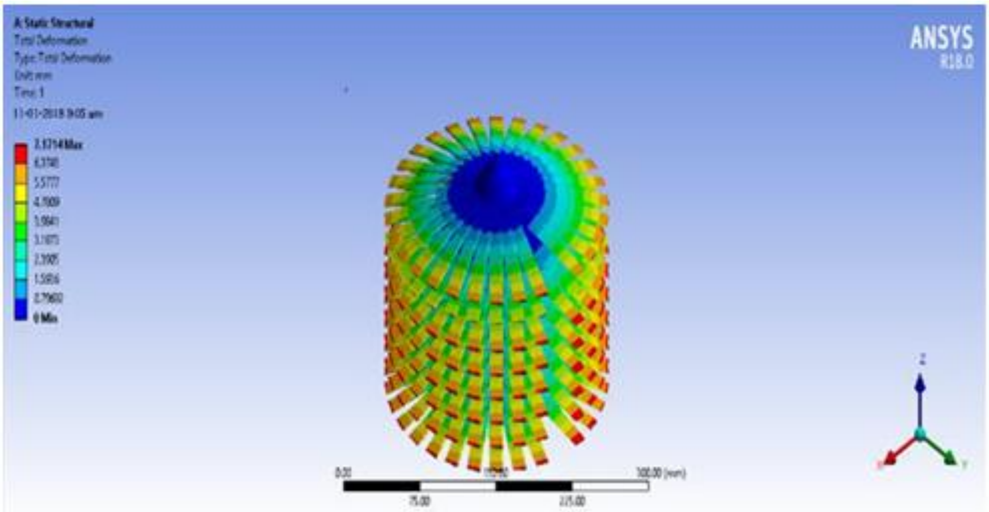

Figure 5: Total deformations of 29-blades of aluminum

Analysis is done by using ANSYS and the parameters such as deformation and the equivalent stresses are obtained for both the materials and are compared. Here we have done the analysis for a single blade finding the failure analysis of blades.

So using stainless steel for compressor blade decreases the strength of the compressor Structural analysis is done on the compressor models to verify strength of the compressor to verify the strength of the compressor.

By use of 29 blades stress using 29 blades the stresses are increasing, but are within the limits. Static structural analysis is done to verify the flow of air. The outlet velocity is increasing for 29 blades, pressure is more for 30 blades and mass flow rate is more for 29 blades. So it concluded that using magnesium than stainless steel for 29 blades is better for compressor.

Here we have also found the periodicity for a single blade analysis for finding the quality and failure analysis of the compressor. The Blade profile has been generated two rotors and stator analytically. The calculation spread sheet is made so by input the values one can get the required parameters to generate the blade coordinates. While comparing both design results of materials, it is observed that the static structural analysis result shares in agreement within acceptable range in both the materials.

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