IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Design And Analysis Of Compressor Impeller Blade.

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Abstract: Axial compressors are commonly employed in airplanes because they offer a higher flow capacity per unit frontal area, are very efficient, and are easy to stage. But they are expensive, hefty, and have a low pressure ratio per stage. Radial discharge centrifugal compressors (radial compressors) have short axial lengths and can produce larger pressure ratios per stage. Both have relatively low efficiency and a bigger frontal area than axial compressors. A centrifugal compressor is made up of blades positioned so that flow enters and exits radially. Centrifugal compressors are mostly employed in airplanes, freezers, and marine applications. They can be utilized to achieve higher pressure ratios. Centrifugal compressors have impellers with main and splitter blades, which help to increase the pressure ratio. Due to the high pressure ratios achieved, a high thrust is produced, resulting in axial and radial thrusts.

Index Terms – Compressor blade, Analysis

I. INTRODUCTION

A mixed flow compressor combines axial and radial components to form a diagonal flow unit. The exit mean radius is higher than at the inlet, but the flow exits axially rather than radially. This avoids the requirement for the comparatively large diameter exit diffuser associated with centrifugal compressors. The impeller can be machined from solid utilizing NC machines, just like a centrifugal compressor. The diagonal or mixed-flow compressor is essentially a cross between a centrifugal and an axial-flow compressor. Because these compressors combine both axial and radial velocity components, the term "diagonal-flow" is appropriate. The main advantage is that the exit diffuser has a smaller diameter than the similar centrifugal compressor. Axial compressors Figure shows an approximate comparison of radial and mixed flow compressors with the same mean impeller exit diameters in terms of frontal area Radial and mixed flow compressor design has not progressed as quickly as axial compressor design due to structural constraints, limited computing capability, and a limited experimental database in the past. However, in recent years, the design of radial and mixed flow compressors has advanced significantly due to rapid advances in computational tools, computational capacity, manufacturing capabilities, and a better knowledge of flow analysis. Mixed flow compressors are expected to have a wide range of applications in the future in compact gas turbine engines due to their high efficiency and ability to deliver high pressure with a small frontal area.

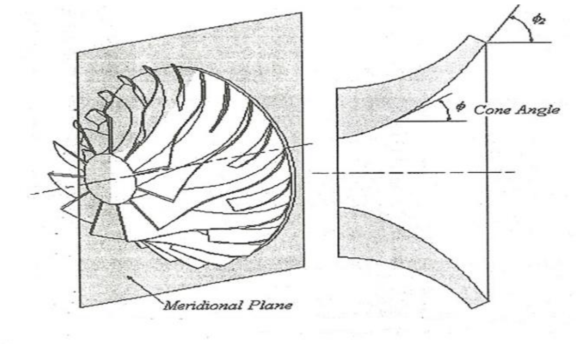

Fig 1 : Mixed flow turbine

As the bearings are supplied with lubricating oil, there is chance of oil leakage from the ends of bearing; seals are used with very close tolerances mounted in the stationary member. Mechanical seals are being used on both the ends of bearings to avoid the leakage of lubricating oil to the other ends. The other purpose of using the mechanical seals is to avoid the mixing of air with lubricating oil. Labyrinth seals are being used to avoid the leakage of air re-entering the impeller and are also used to obstruct the leakage of lubricating oil past the mechanical seal.

Factors Influencing the Critical Speed:

There are many factors, which many change the critical speed from the calculated value. Frequently the magnitude of their effect cannot be determined accurately. When special cases arise, in which they become important or in which it is necessary to account for discrepancies between test results and calculated values.

Bearing length: It is usually assumed that the shaft is simply supported and this assumption is justified if bearings are free to oscillate and adjust themselves to shaft deflections. Often the bearings are fixed and, if long compared to their diameter, they may tend to crate the effect of a fixed support. This decreases the shaft deflections and raises the critical speed.

As the shaft deflects, the center of the oil film is no longer at the bearing centerline but tends to move in towards the main mass.

Gyroscopic Effect of the Impeller: If the impellers are heavy and have a large diameter, they create a gyroscopic action and resist any change in the direction of their axis. When the shaft begins to whirl, the impeller raises the motion and tends to keep straight, thus reducing the deflection and raising the critical speed. This effect is greater for impellers nearer to the bearings where the slope of the shaft is greater.

Bearing Elasticity: The usual assumption made in calculating the deflection curve is that the bearings are rigid and do not deflect. Actually every bearing will deflect somewhat because of the load on it. This will tend to lower the critical speed, since the deflection is greater than calculated, and may be as much as 25 to 50 percent. The bearings may deflect more in one direction than another resulting in two distinct critical speeds for the same shaft.

II. Literature on Suspension:

Delamination also lowers the buckling factor of the composite panels. Primary air craft components like wing, shear wall panels and skin area of the aircraft that are supported by ribs are designed for high buckling loads. The threat of delamination arising from in service loading has been one of the factors in limiting the adoption of laminated composite material in greater volume for primary structure. While other damage modes such as matrix cracks may occur first, delamination's result in larger stiffness drops and reduction in load bearing capabilities

S.P. Joshi has investigated the experimental data of the three dimensional problem of impact of a flat strip by a spherical impact are presented and interpreted qualitatively by comparison with a plane strain numerical analysis of an infinitely wide plate impacted by a cylindrical member. The role of transverse shear stresses in proximal and middle layer crack initiation is established.

Ronald Krueger developed a shell/3D modeling technique was developed for which a local solid finite element model is used only in the immediate vicinity of the delamination front. The goal was to combine the accuracy of the full three dimensional solution with the computational efficiency of a shell finite element model. Multipoint constraints provided a kinematically compatible interface between the local 3D model and the global structural model which has been meshed with shell finite elements.

D.M. Kim discussed the influence of inter-laminar shear stress on mode II free – edge Delamination at the free edge in composite laminate is studied experimentally and analytically. Delamaination tests are conducted under uni-axial compressive load to eliminate transverse cracking test laminates are designed to have compressive inter-laminar normal stress and various ratios of inter-laminar shear stresses at the interfaces of interest

H.V. Lakshminarayana presented numerical simulation of static indentation and lateral impact tests of laminated composite plates, using a commercial finite element system are presented. Extensive results from a parametric study are also provided to supplement the experimental result.

III. Mathematics of Rotating Disks of Uniform Thickness

The explanation for the rapid rate of work hardening rests on two effects. Forst, the coarse hared particles disturb the 'stream' of plastically flowing metal round them and produce a kind of turbulence in it. This complex deformation may result in the generation of dislocations on intersecting planes and cause rapid work hardening. Second, because the metal matrix deforms while hard particles do not, more of the applied load builds up on the particles. The hard particles carry more load than the matrix. In order to achieve efficient strengthening effect the particles should be small, properly distributed and of uniform size. While the better engineering properties of the strong particles are utilized in this way, the effect of some of their less desirable features, such as brittleness, is simultaneously mitigated by the presence of ductile matrix that binds them together. Normally the elastic modulus of the particulate composite follows the rule of mixture. Its value falls between the higher value given by equation. And the lower value given by equation.

The equations being:

$$E_c = V_m E_m + V_p E_p$$

$$E_c = \frac{E_m E_p}{E_p V_m + E_m V_p}$$

Where E is the elastic modulus,
V is the volume fraction;
Suffix, c, m and p represent the composite, matrix and particle respectively.

The proper combination of ceramic materials and metals could result in a material having the high temperature strength and oxidation resistance of ceramics together with the toughness and thermal shock resistance of metals. The composites comprising of ceramic material as reinforcement and a metal matrix are commonly known as cermet's.

IV PROBLEM DEFINITION:

Layered composites composed of two or more different layers (called lamina) or sheets bonded together. The layers can differ in material (as in clad metals and bimetallic materials), form (as in sandwich materials such as honeycombs in which the core and facing material may or may not differ in form), and orientation (as in plywood in which the layers are the same but have different orientation of fibers.

By proper combination of constituting layers one can achieve a balance of such properties as light weight, high strength, high stiffness, wear resistance, corrosion resistance, unusual thermal expansion characteristics, appearance, etc. Properties of layered composites tend to be anisotropic and may vary from one side of the composite to other. Each layer may perform separate and distinct function. In addition, layered composites can incorporate the advantages of other composites. For example, the properties that can be achieved from the combination of fibers or particulates with metal, ceramic or polymer matrix can be utilized in combination with other materials used in the construction of layered composites. The individual layer itself can be a reinforced composite which is bonded by another resin. Some properties of the layered composites along the lamellae are estimated from the rule of mixture with negligible error. These properties include density, elastic modulus, electrical and thermal conductivity.

Layered composites are broadly grouped into two categories:

(i) Laminated or laminar
(ii) Sandwich composites

Laminar composite materials also include very thin coatings, thicker protective surfaces, claddings, bimetallics and many others. Laminates are generally produced by joining sheets or layers through an adhesive. Some important laminate composites include plywood, safety glass, Arall, and capacitor in which alternate conductor and insulator layers are bonded together.

Ultimate strength is an attribute directly related to a material, rather than just specific specimen of the material, and as such is quoted force per unit of cross section area (N/m^2). For e.g., the ultimate tensile strength (σu) of AISI 1018 Steel is 440 MN/m^2.

In general, the SI unit of stress is the Pascal,
Where,
1 Pa = 1 N/m^2.Factor of safety is a design constraint that an engineered component or structure must achieve.

$FS = \sigma u$

Where FS: The Factor of Safety,
σ: The allowable stress, and
σu: The ultimate stress

Margin of Safety is also sometimes used to as design constraint. It is defined
MS=Factor of safety – 1.

V.RESULTS FOR ANALYSIS

Analysis Results:

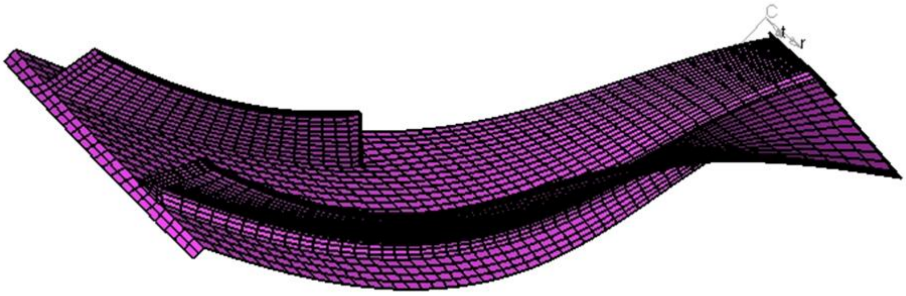

Fig :2 Shell element formation for composite layer representation

Figure 2 depicts an overall displacement plot in the problem. The maximum displacement is approximately 0.6mm at the inlet main blades. The key reason for this is the blade's height. It is almost like a cantilever configuration, with the highest deflection occurring at the main blade.

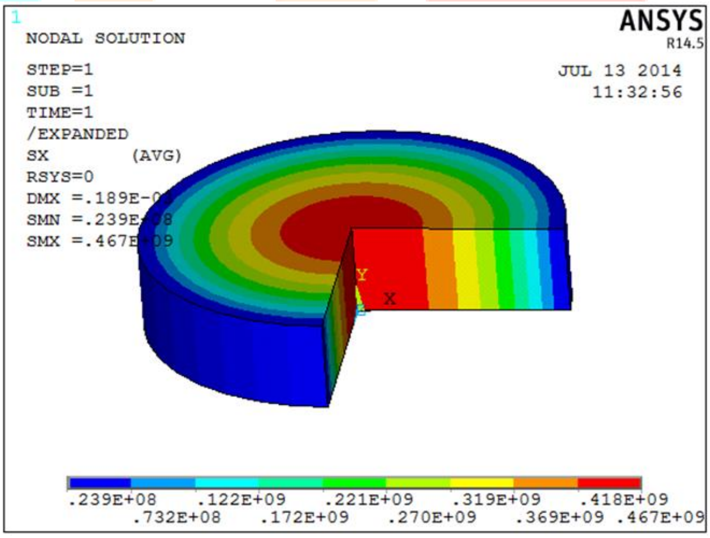

Fig :3 Temperature plot

The results shows finite element estimates for both radial and hoop stresses are 467 and 468Mpa. When compared with theoretical solution an error of 3.7% can be observed. This shows matching of finite element solution with theoretical solutions. Still finite element solution better then theoretical solution, as they consider stress concentration and material nonlinear effects.

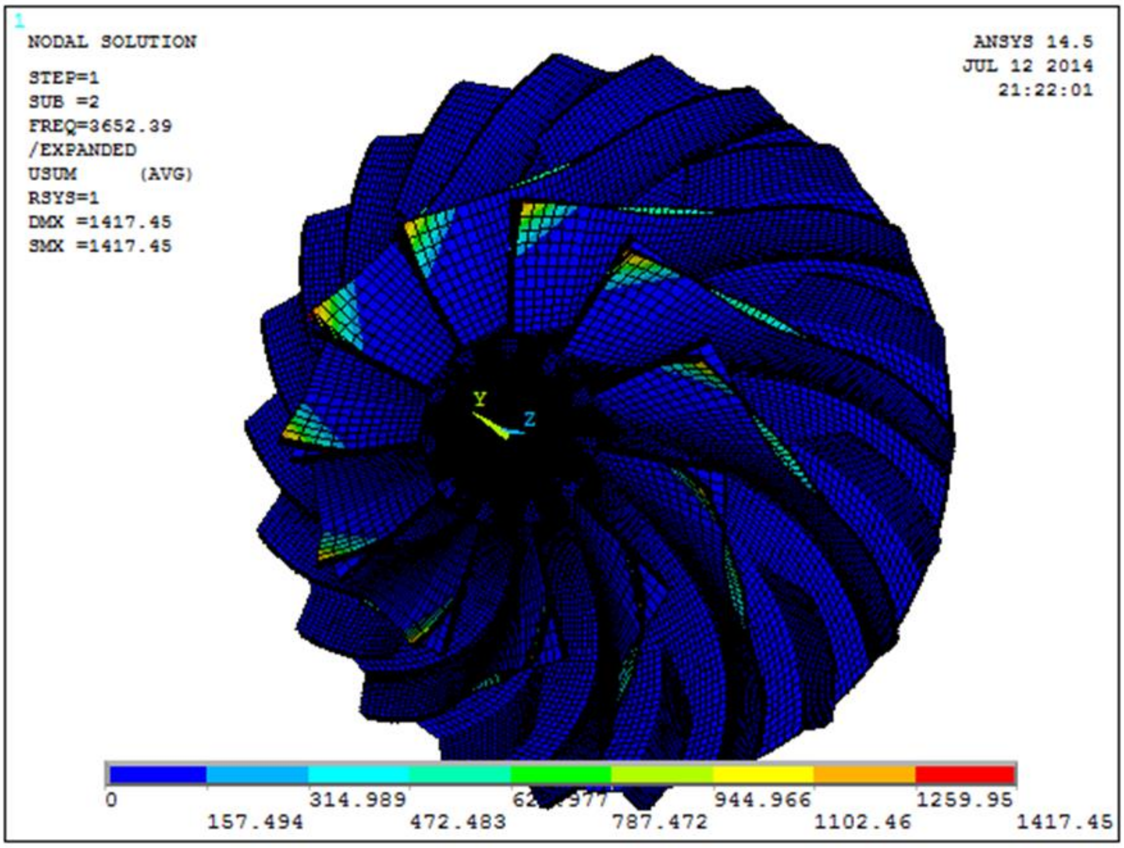

Fig: 4 Mode Shape corresponding to second frequency 3652.39Hz

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For hallow Rotor:

Outer Diameter d2 : 0.2m(200mm)

Outer Radius of the disc b=d/2=0.1m

Inner Diameter d1=0.1m

Inner Radius a=0.05m

Density ρ= 4500kg/m^3.(Titanimum material)

Angular velocity ω= 4921.8 (Corresponding to 47000 rpm of impeller)

As per the theoretical formulas for rotating discs hoop stress and radial stress is calculated as

$(\sigma_r)_{max}= \{(3+\gamma)/8\}\rho\omega^2(b-a)^2$ = 112.4 Mpa

$(\sigma_\theta)_{max}= \{(3+\gamma)/4\}\rho\omega^2\{b^2+(1+\gamma)/(3+\gamma)a^2\}$ =947Mpa

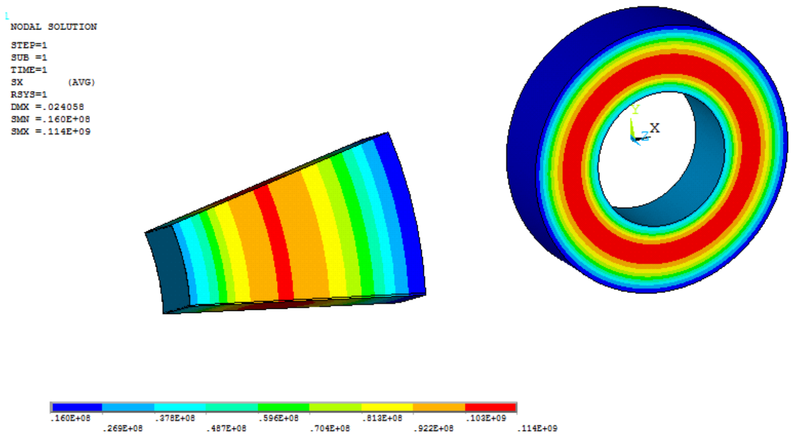

Fig:5 Finite element solution for radial stress through cyclic symmetry

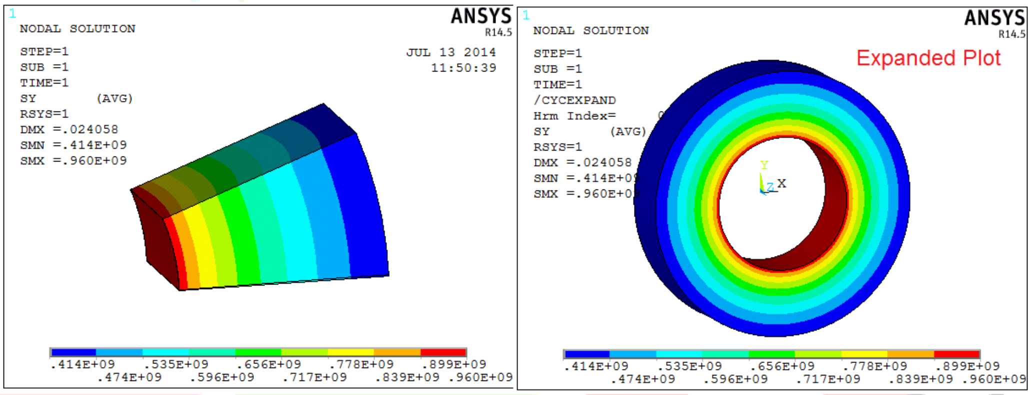

Fig:6 Hoop Stress plot through cyclic symmetry

Description	**Theoretical**	**FEM**	**% Error**
Radial	112.4	114	1.4
Hoop	947	960	1.37

Table 4.3 Comparison of Theoritical and Finite element Solution

The table shows negligible difference between theoretical and finite element solutions. So finite element solutions can be considered an alternative to complex theoretical solutions for complex problems.

VI Conclusion:

Thermal coatings are applied to the main and splinter blades to assess their impact on structural safety. The results reveal an improvement in structural integrity as stresses and deflections are significantly decreased. The materials' lower thermal expansion and density are primarily responsible for this phenomenon. Composites can minimize impeller stress and increase load carrying capability. Further dynamic analysis is performed to determine the resonant situation. Modal analysis is the initial phase in dynamic analysis. It is useful in determining the resonant frequencies. Once resonant frequencies have been identified, operational frequencies can be fixed by avoiding these frequencies. Mode forms are also formed. The results demonstrate that the obtained natural frequency value of 1332 Hz is significantly higher than the operational frequency value of 783 Hz. The impeller is completely safe and provides dynamic stability.

References

[1]. Robert L. Norton, " Machine design an integrated approach" second edition PEARSON Education publication, page No 588-591.
[2]. Joseph E Shigley and Charles R Mischke "Mechanical Engineering Design," sixth edition, TATA Mc GRAW HILL Publication, page No 1102.
[3]. P.L Srinivasa Murthy and J.B.K Das, "Design of Machine Elements I and II", fourth revised edition April 2009.
[4]. K.Lingaiah, "Machine Design Data Hand Book," Volume I and II.