CREEP DEFORMATION AND STRESS ANALYSIS IN ROTATING DISC OF COMPOSITE MATERIAL

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IN
CAD/CAM & ROBOTICS

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CERTIFICATE

This is to certify that the thesis titled, **“CREEP DEFORMATION AND STRESS ANALYSIS IN ROTATING DISC OF COMPOSITE MATERIAL”**, being submitted by **Mr. BARINDER SINGH** , in partial fulfillment of the requirement for the award of degree of **MASTER OF ENGINEERING (CAD/CAM & ROBOTICS)** at **Department of Mechanical Engineering, Thapar University , Patiala,** is a bonafide work carried out by him under our guidance and supervision and that no part of this seminar has been submitted for the award of any other degree.

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ABSTRACT

Creep is the tendency of a solid material to slowly move or deform permanently under the influence of stresses when subjected to high temperatures for long duration of time. So creep is one of the major considerations while analyzing the materials which are used for high temperature for long durations. Discs are used under high temperatures mainly in turbines, aero-engines, automobiles, pumps and compressors. So creep analysis of composite material disc has a wide scope for research.

In this research work the radial and circumferential stress analysis of the disc when subjected to Angular Velocity at high temperatures for long durations of time is done with the help of Ansys Software. The validation of the results is proved by matching the results with Hamid Jahed et al. [4]..

From the results obtained it is clear that they are in accordance with the results obtained by Hamid Jahed et al. [4]. In the study when we increase angular velocity the radial stress firstly increase and then decreases but circumferential stress decrease by increase in angular velocity. There for we can say that in a rotating disc the most stressed area near to the center.

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CHAPTER 1 INTRODUCTION

1.1 COMPOSITE MATERIAL [24]

The continuing quest for improved performance, specified in terms of weight reduction, high strength and low cost has led to develop a new class of materials called composite materials.

A composite material consists of combining two or more constituents called matrix and reinforcement. The constituents are combined at microscopic level and are not soluble to each other. Matrix phase materials are generally continuous while the reinforcing phase may be in the form of fibers, particles or flakes.

The composite materials possess characteristic properties, such as high stiffness, high strength, low weight, high temperature performance, good corrosion resistance, high hardness and conductivity that are not possible in any of its constituents alone. Analysis of these properties reveals that they depend on the following:

i) Properties of the individual constituents.

ii) Relative amounts of the constituents.

iii) Size and shape of the constituents (i.e. Morphology).

iv) Degree of bonding between constituents.

v) Orientation of the various constituents.

The composite materials possess high specific modulus and specific strength as compared to conventional materials. Specific Modulus is defined as the ratio of Young Modulus and density whereas Specific Strength is defined as the ratio of strength and density of materials. As an example the strength of a graphite/epoxy unidirectional composite material is same as that of steel but specific strength of this composite is three times that of steel thereby saving in cost of material and energy.

1.2 HISTORY OF COMPOSITES

One of the earliest known composite materials is adobe brick in which straw (a fibrous material) is mixed with mud or clay (an adhesive with strong compressive strength). The straw allows the water in the clay to evaporate and distribute cracks in the clay uniformly, greatly improving the strength of this early building material. Another form of a composite material is the ubiquitous construction material called plywood. Plywood (Fig.1.1) uses natural materials (thin slabs of wood) held together by a strong adhesive, making the structure stronger than just the wood itself. In nature, bamboo is often cited as an example of a wood composite structure, combining a cellulose fiber and lignin, with the lignin providing the adhesive to hold the fibers together.

Fig 1.1 Thin Slabs in Plywood

Reinforced concrete is a combination of two remarkable materials, concrete (a composite by itself) and steel that takes advantage of the strengths of each material to overcome their individual limitations in each. Steel has very high tensile strength, while concrete has very high compressive strength. In combination, they make a superior material for road and bridge construction. Today, when we speak of composite materials, or just ‘composites’, we are referring to the highly engineered combinations of polymer resins and reinforcing materials such as glass fibers. A fiberglass composite structure is a combination of glass fibers of various lengths and resins such as vinyl ester or polyester. The term FRP is often used, meaning Fiber Reinforced Plastic. FRP is a very general term for many different combinations of reinforcement materials and bonding resins. Thus, the term “composites” is used extremely broadly to describe many materials with many different properties targeted at an even larger number of applications. To show how composites have changed our world, look no further than under the hood of a modern car and realize that most of what we can see are components made of composite materials.

1.3 PARAMETERS FOR SELECTION OF COMPOSITES

For selecting a composite material for a particular application, the following parameters are to be considered:

i) Strength

ii) Toughness

iii) Formadibility

iv) Weldeability

v) Corrosion

vi) Wear Resistance

vii) Affordability**.**

1.4 FACTORS AFFECTING MECHANICAL PERFORMANCE

The mechanical performance of composite materials depends on number of factors such as:

i) Fiber factor

ii) Matrix factor

iii) Other factors (Fiber Matrix interface, etc.)

i) Fiber factor:

It involves the following four parameters.

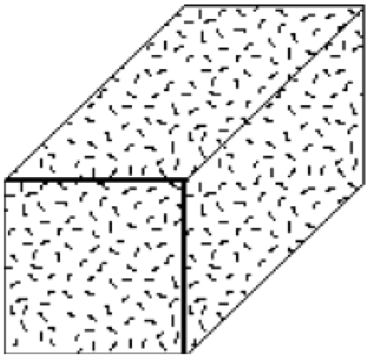
a) Length

b) Orientation

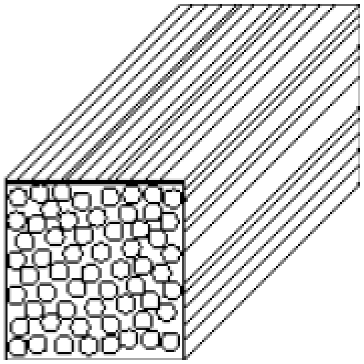
c) Shape

d) Material

a) Length: - Fiber can be either short or long in the length as shown in Fig.1.2 (a,b)



1.2 (a) Short Fiber Composite



1.2 (b) Long Fiber Composite

Long continuous fibers are easy to orient and process while short fibers cannot be fully controlled or oriented properly. Further, long fibers provide several benefits over short fibers including high impact resistance, low shrinkage, improved surface finish and dimensional stability. On the other hand, short fibers provide low cost, easy to work with and had fast cycle time fabrication procedures. Short fibers possess few flaws, therefore leading to higher strength.

b) Orientation: - The distribution of fiber in a matrix can be random or aligned in a specific direction to achieve very high stiffness and strength in that direction. If fibers are oriented in more than one direction in matrix, the composite will exhibit possess high stiffness and strength along these directions.

c) Shape: - The most common shape of fibers is circular because of ease of handling and manufacturing. Hexagonal and square-shaped fibers are possible but their advantages of strength and high packing factors do not out weigh the difficulty in handling and processing.

d) Material: - The material of fiber directly influences the mechanical performance of a composite. Fibers are generally expected to had high elastic modulus and strength. This expectation along with the low cost are the key factors that graphite, aramids and glass fibers dominate the fiber market for composites.

ii) Matrix Factors

Fibers are used as reinforcement to matrix. The matrix functions include binding of the fibers together, protecting fibers from environment, shielding from damage during handling and load transfer from matrix to fibers. In general, the matrix possesses inferior properties compared to fibers.

iii) Other Factors

Apart from fiber and matrix there are several other factors which can affect the mechanical performance of composite materials. The fiber-matrix interface is an important factor which determines how well the matrix transfers the loads to the fibers. The fiber-matrix interfacial bonding is of following three types:

a) Chemical Bonding

b) Mechanical Bonding

c) Reaction Bonding

a) Chemical Bonding:-Chemical bonding is formed between the fiber surface and the matrix. Some fibers bond naturally to the matrix while others do not. Coupling agents are often added to form a chemical bond.

b) Mechanical Bonding: - Natural roughness and etching of the fiber surface causing interlocking may form a mechanical bond between the fiber and the matrix. If the coefficient of thermal expansion of the matrix is higher than that of fiber, and the manufacturing temperatures are higher than the operating temperatures, the matrix will shrink more than the fiber, causing the compression of matrix around the fiber.

c) Reaction Bonding: - Reaction bonding occurs when atom or molecules of fiber and matrix diffuse into each other at interface. This inter diffusion often creates a distinct interfacial layer, which has different properties than that of fiber or matrix. Though, this thin layer helps to form a bond but it also forms micro cracks in the fiber. These micro-cracks reduce the strength of fiber which ultimately leads to poor strength of composite materials.

1.5 CLASSIFICATION OF COMPOSITE MATERIALS

Composites are classified by the geometry of the reinforcement as particulate, flake and fiber or by the type of matrix as polymer, metal, ceramic and carbon as shown in Fig.1.3

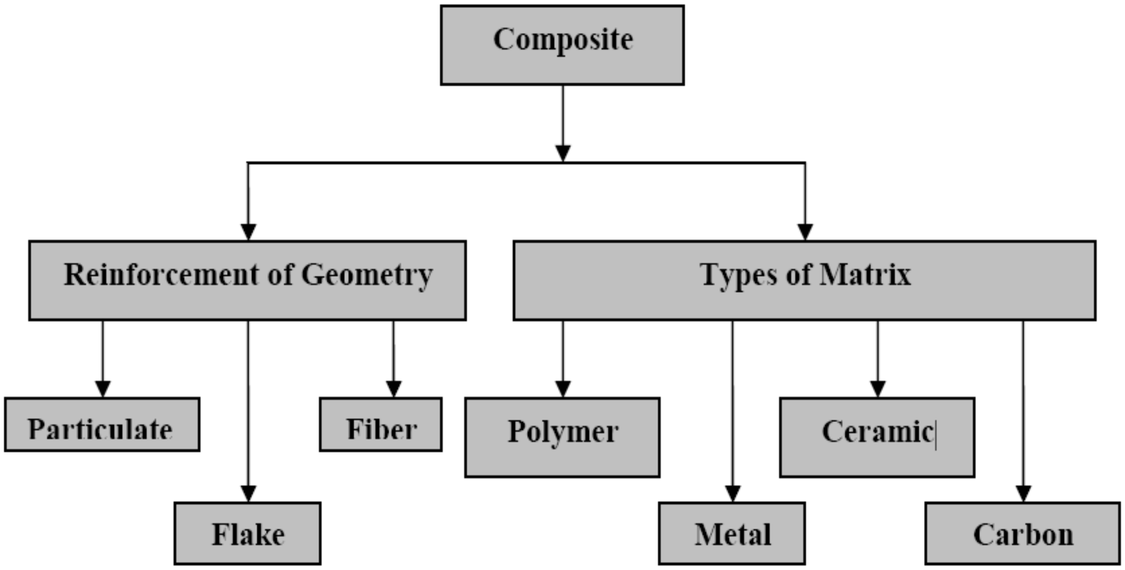


Fig 1.3. Classification of Composite Materials

1.6 CLASSIFICATION BASED ON REINFORCEMENT GEOMETRY

According to the reinforcement geometry, composites are classified into three groups namely:-

i) Particulate Composites

ii) Flake Composites

iii) Fiber Composite

i) Particulate Composites

It consists of particles reinforced in matrices such as alloy and ceramics as shown in Fig.1.4. They are usually isotropic since the particles are randomly distributed. Particulate composite has advantages such as improved strength, increased operating temperature and oxidation resistance etc. Examples include use of aluminum particles in rubber matrix, silicon particles in aluminum matrix etc.

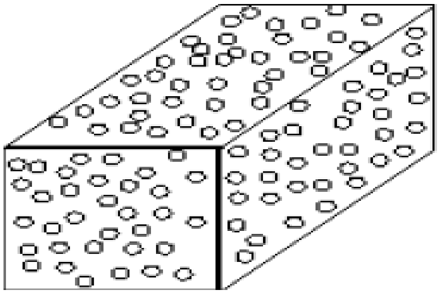


Fig.1.4 Particulate Composite

ii) Flake Composites

It consists of flake shaped reinforcement such as glass, mica, silica, silver etc in matrices as shown in Fig.1.5. Flake composites provide advantages such as high out of plane flexural modulus, higher strength and low cost. However, flakes can not be oriented easily therefore a limited number of materials are available for use.

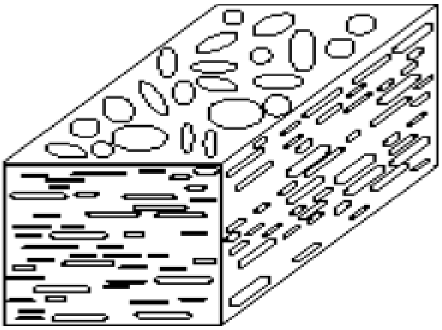


Fig.1.5 Flake Composite

iii) Fiber Composites

It consists of matrix reinforced by short (discontinuous) or long (continuous) fibers as shown in Fig.1.6 (a, b) Fibers are generally anisotropic. Typical examples of matrices are resins such as epoxy, metals such as aluminum and ceramics such as calcium-aliminosilicate.

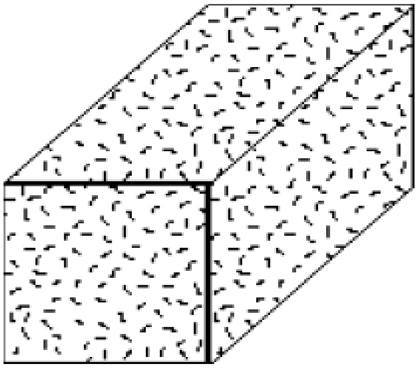


Fig 1.6 (a) Short Fiber Composite

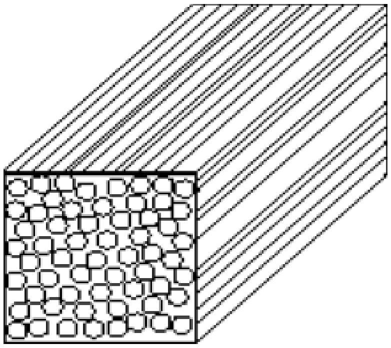


Fig 1.6 (b) Long Fiber Composite

1.7 CLASSIFICATION BASED ON MATRIX

Based on the type of matrix, Composites may be classified as:

i) Polymer Matrix Composite (PMC)

ii) Metal Matrix Composite (MMC)

iii) Ceramic Matrix Composite (CMC)

iv) Carbon–Carbon Composite

i) Polymer Matrix Composite (PMC)

These are the most common advanced composites consisting of polymer (epoxy, polyester, urethane etc) reinforced by thin diameter fibers (graphite, aramids, boron etc). Graphite/Epoxy composites are approximately five times stronger than steel on a weight for-weight basis. They are commonly employed due to their low cost, high strength and simple manufacturing. Main drawbacks of polymer Laminate Composites (PMCs) include low operating temperature, high coefficient of thermal and moisture expansion and low elastic properties in certain directions. However, their advantages are high strength, low cost, high chemical resistance and good insulating property.

ii) Metal Matrix Composite (MMC)

It consists of metal matrix such as aluminum, magnesium and titanium etc. reinforced with fibers such as carbon, silicon carbide etc. Metals are reinforced to increase or decrease their properties to suit the design needs. For example, the elastic stiffness and strength of metals can be increased, while large coefficients of thermal expansion and thermal and electric conductivities of metal can be reduced by addition of fibers such as silicon carbide. MMCs are mainly used to provide advantages over monolithic alloy/metals such as steel and aluminum. These advantages include higher specific strength and specific modulus achieved by incorporation of reinforcement in low density metal matrix such as aluminum and titanium. MMCs possesses several advantages over polymer matrix composite such as higher elastic properties, higher service temperature, insensitive to moisture, higher electric and thermal conductivity, better fatigue and flow resistance. However, the drawbacks of MMCs over PMCs include higher processing temperature and higher densities.

iii) Ceramic Matrix Composite (CMC)

Ceramic matrix composites (CMCs) have a ceramic matrix such as alumina, calciumalumino- silicate reinforced by fibers such as carbon or silicon carbide. Their main advantages include high strength and hardness, high service temperature, chemical inertness and low density. CMCs are finding extensive applications in high temperature areas where MMCs and PMCs cannot be used.

iv) Carbon–Carbon Composite

Carbon-carbon composites have carbon fiber reinforced in matrix of carbon. Carboncarbon composites are used in very high temperature environments up to 6000 °F (3315°C) and are 20 times stronger and 30% lighter than graphite fibers. Their advantages include ability to withstand high temperatures, low creep at high temperature, low density, good tensile and compressive strength, high fatigue resistance, high thermal conductivity and high coefficient of friction. Their disadvantages include high cost, low shear strength and susceptibility to oxidations at high temperature. These composites find application in space shuttle nose cone, aircraft brakes, mechanical fasteners etc.

1.8 ADVANTAGES OF USING COMPOSITES OVER CONVENTIONAL MATERIALS (METALS)

i) Very high specific strength. Which means very high strength and low weight

ii) Great freedom of shape. Double curved and complex parts can be simple produced.

iii) High degree of integration possible. Which means simple integration of stiffeners, inserts, cores, and production of self supporting structures in one or two production cycles?

iv) Material can be tailored. Which means fit for the loads / performance the end product has to perform during its lifetime

v) Excellent fatigue endurance concerning number of load cycles (many times higher than with metals) and residual fatigue strength (aramide and carbon epoxy laminates retain more than 60% of their residual static strength, which is far more higher than is possible with metals.)

vi) Excellent chemical resistance against acids, chemicals etc.

vii) Excellent weather/water resistance. Material has almost no corrosion, takes on little water which leads to low maintenance cost especially on the long run.

viii) Composites have excellent RAM features (Radar absorbing materials). It's also possible to make special laminates which are radar and sonar transparent.

ix) Excellent impact habits

x) Excellent electrical habits, concerning isolation but also conduction, dielectric habits, EMS shielding etc. Structures can be tailored on RF transparency but can also be made RF reflecting. Great for telecom especially UMTS frequencies.

xi) Great thermal isolation habits, fire retardant habits, and high temperature performance.

1.9 USES OF COMPOSITE MATERIALS

i) Extensively used in space technology and production of Aerospace components (tails, wings, fuselages, propellers).

ii) Used in the production of sport goods e.g. racing car bodies and bicycle frames etc.

iii) Used for general industrial and engineering structures**.**

iv) Used in high speed and fuel efficient transport vehicles.

v) The shell composed of Cosmolite, a thermoplastic fibre-reinforced composite and the exterior surface Spectralite which incorporates DuPont Surlyn, an impact-resistant coating found on *golf balls.*

vi) Carbon composite is a key material in today's launch vehicles and spacecraft. It is widely used in solar panel substrates, antenna reflectors and yokes of spacecraft. It is also used in payload adapters, inter-stage structures and heat shields of launch vehicles.

1.10 CREEP

It is the tendency of a solid material to slowly move or deform permanently under the influence of stresses. It occurs as a result of long term exposure to levels of stress that are below the yield strength of the material. Creep is more severe in materials that are subjected to heat for long periods, and near the melting point. Creep always increases with temperature.

The rate of this deformation is a function of the material properties, exposure time, exposure temperature and the applied structural load. Depending on the magnitude of the applied stress and its duration, the deformation may become so large that a component can no longer perform its function — for example creep of a turbine blade will cause the blade to contact the casing, resulting in the failure of the blade. Creep is usually of concern to engineers and metallurgists when evaluating components that operate under high stresses or high temperatures. Creep is a deformation mechanism that may or may not constitute a failure mode. Moderate creep in concrete is sometimes welcomed because it relieves tensile stresses that might otherwise lead to cracking. Unlike brittle fracture, creep deformation does not occur suddenly upon the application of stress. Instead, strain accumulates as a result of long-term stress. Creep deformation is "time-dependent" deformation.

The temperature range in which creep deformation may occur differs in various materials. For example, Tungsten requires a temperature in the thousands of degrees before creep deformation can occur while ice formations will creep in freezing temperatures. As a rule of thumb, the effects of creep deformation generally become noticeable at approximately 30% of the melting point for metals and 40–50% of melting point for ceramics. Virtually any material will creep upon approaching its melting temperature. Since the minimum temperature is relative to melting point, creep can be seen at relatively low temperatures for some materials. Plastics and low-melting-temperature metals, including many solders, creep at room temperature as can be seen markedly in old lead hot-water pipes.

1.11 GENERAL CREEP EQUATION

The general creep equation is:

$$\frac{d\in}{dt} = \frac{C\sigma^m}{d^b} e^{\frac{-Q}{kT}}$$

where ε is the creep strain, *C* is a constant dependent on the material and the particular creep mechanism, *m* and *b* are exponents dependent on the creep mechanism, *Q* is the activation energy of the creep mechanism, σ is the applied stress, *d* is the grain size of the material, *k* is boltzmann's constant and *T* is the absolute temperature.

To determine the engineering creep curve of a metal, a constant load is applied to a tensile specimen maintained at a constant temperature and the strain (extension) is determined as a function of time.

1.12 Failure of Material at High Temperature

The strength of material decrease with increasing temperature. Since the mobility of atoms increase rapidly with temperature, it can be appreciated that diffusion-controlled processes can have a very significant effect on high-temperature mechanical properties. High temperature will also result in greater mobility of dislocation by the mechanism of climb. The equilibrium concentration of vacancies likewise increase with temperature. New deformation mechanisms may come into play at elevated temperatures. Deformation at grain boundaries becomes an added possibility in the high-temperature deformation of metals.

An important characteristic of high-temperature strength is that it must always be considered with respect to some time scale. The tensile properties of most engineering metals at room temperature are independent of time, for practical purposes1 It makes little difference in the results if the loading rate of a tension test is such that it requires 2 h or 2 min to complete the test. However, at elevated temperature the strength becomes very dependent on both strain rate and time of exposure. A number of metals under these conditions behave in many respects like viscoelastic materials. A metal subjected to a constant tensile load at an elevated temperature will creep and undergo a time-dependent increase in length.

A strong time dependence of strength becomes important in different materials at different temperatures. What is high temperature for one material may not be so high for another. To compensate for this, temperature often is expressed as a homologous temperature, i.e., the ratio of the test temperature to the melting temperature on an absolute temperature scale. Generally, creep becomes of engineering significance at a homogeneous temperature greater than 0.5.

The tests which are used to measure elevated-temperature strength must he selected on the basis of the time scale of the service which the material must withstand. Thus, an elevated-temperature tension test can provide useful information about the high-temperature performance of a short-lived item, such as a rocket engine or missile nose cone, but it will give only the most meager information about the high-temperature performance of a steam pipeline which is required to withstand 100,000 h (= 3.6 x 108 s) of elevated-temperature service. Therefore, special tests are required to evaluate the performance of materials in different kinds of high-temperature service. The creep rest measures the dimensional changes which occur from elevated-temperature exposure, while the stress- rupture test measures the effect of temperature on the long-time load-bearing characteristics. Other tests may be used to measure special properties such as thermal shock resistance and stress relaxation.

1. 12 Time − Dependent Mechanical Behavior of Metals

Creep is one important manifestation of anelastic behavior. In metals anelastic effects usually are very small at room temperature, but they can be large in the same temperature region for polymeric materials. There is internal friction, which arises from a variety of anelastic effects in crystalline solids.

Elastic strain was a single-valued function of stress. This is a valid assumption for the engineering analysis of metals by the theory of elasticity. However, under certain circumstances there is a time dependence to elastic strain which is called anelasticity. In Fig.1.8 , an elastic strain e_1 is applied to an anelastic material. With increasing time the strain gradually increases to a value e_2, the completely relaxed strain. The amount of anelastic strain is e_2 — e_1. If the load is suddenly removed at $t = t_1$, the material undergoes an immediate elastic contraction equal in magnitude to e_1 and with the passage of time the strain decays to zero. This behavior is known as an elastic aftereffect.

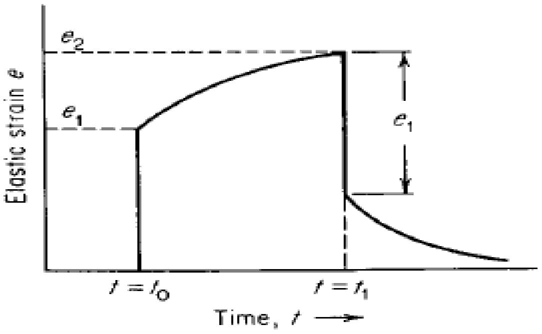


Fig 1.7 Anelastic Behavior and Elastic After-Effect.

It is important to be able to extrapolate creep or stress-rupture data into regions where data is not available. Therefore, the common methods of plotting creep data are based on plots which yield reasonable straight lines. Fig1.9 shows the common method of presenting the influence of stress on the steady-state or minimum creep rate. Note that a log-log plot is used, so that extrapolation of one log-cycle represents a tenfold change. A change in slope of the line will sometimes occur.

The value of the minimum creep rate depends on the length of time the creep test has been carried out.

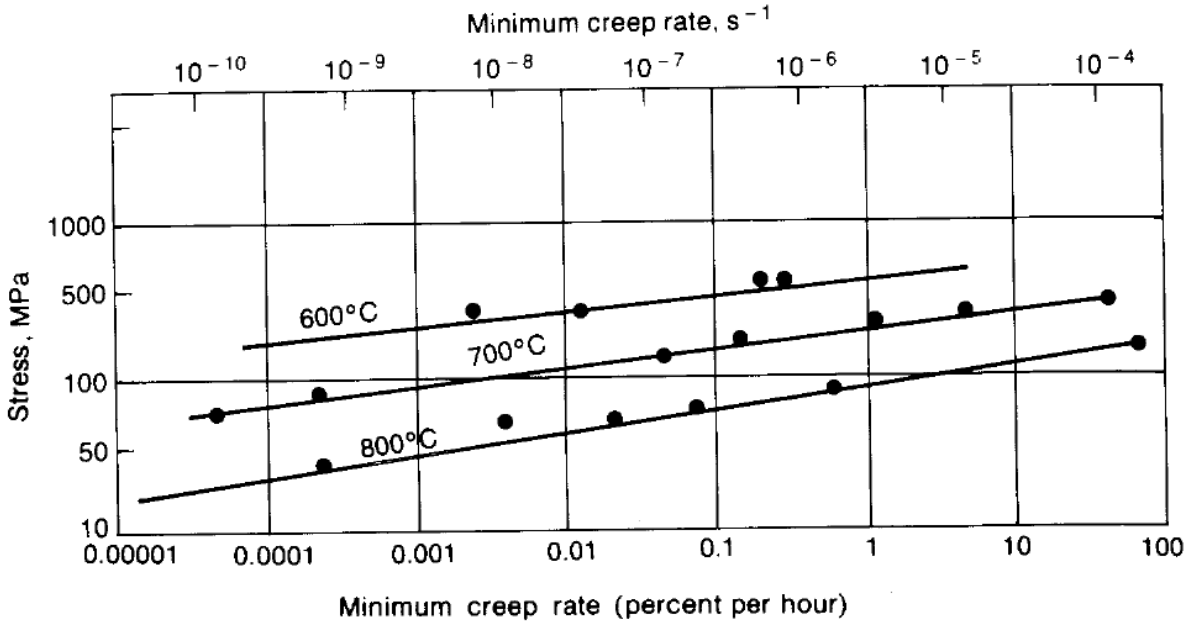


Fig 1.8 Stress and Minimum Creep

Another method of presenting creep data is a plot of stress vs. the time to produce different amounts of total strain (instantaneous strain plus creep strain). The uppermost curve in Fig.1.10 is the stress-rupture curve. The percentages beside each data point are the percentage reduction of area at failure.

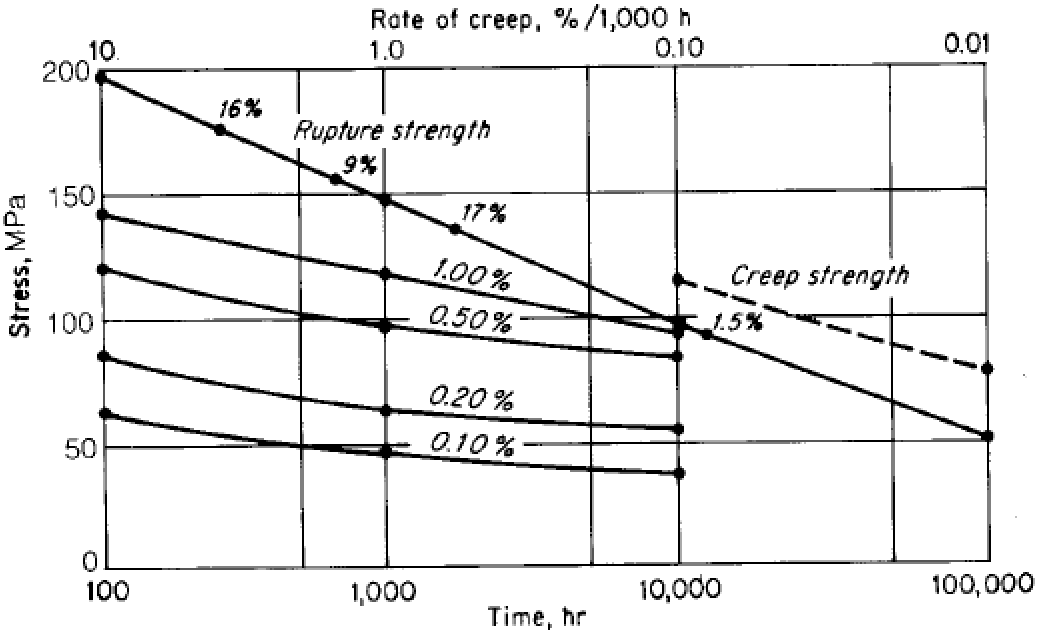


Fig 1.9 Stress Rupture

For short-time high-temperature applications (such as in missiles and high- speed aircraft), data are needed at higher temperatures and stresses and at shorter times than are usually determined for creep tests. From a set of creep curves at constant temperature and various stresses. it is possible to construct stress-strain curves by drawing lines at fixed times. The resulting fictitious stress-strain curves are called isochronous stress-strain curves. It often is cheaper and more convenient to conduct stress-rupture tests than creep tests, and it would be very useful if creep strength could be estimated from rupture strength with sufficient accuracy for design purposes.

1.14 STAGES OF CREEP

The progressive deformation of a material at constant stress is called creep. To determine the engineering creep curve of a metal, a constant load is applied to a tensile specimen maintained at a constant temperature, and the strain (extension) of the specimen is determined as a function of time. Although the measurement of creep resistance is quite simple in principle, in practice it requires considerable laboratory equipment. The elapsed time of such tests may extend to several months, while some tests have been run for more than 10 years.

Curve A in Fig.1.11 illustrates the idealized shape of a creep curve. The slope of this curve (de/dt or e) is referred to as the creep rate. Following an initial rapid elongation of the specimen, ε_0, the creep rate decreases with time, then reaches essentially a steady state in which the creep rate changes little with time, and finally the creep rate increases rapidly with time until fracture occurs. Thus, it is natural to discuss the creep curve in terms of its three stages. It should be noted, however, that the degree to which these three stages are readily distinguishable depends strongly on the applied stress and temperature.

In making an engineering creep test, it is usual practice to maintain the load constant throughout the test. Thus, as the specimen elongates and decreases in cross-sectional area, the axial stress increases. The initial stress which was applied to the specimen is usually the reported value of stress. Methods of compensating for the change in dimensions of the specimen so as to carry out the creep test under constant-stress conditions have been developed. When constant-stress tests are made it is found that the onset of stage III is greatly delayed.

The dashed line (curve B) shows the shape of a constant-stress creep curve. In engineering situations it is usually the load not the stress that is maintained constant, so a constant-load creep test is more important. However, fundamental studies of the mechanism of creep should be carried out under constant-stress conditions.

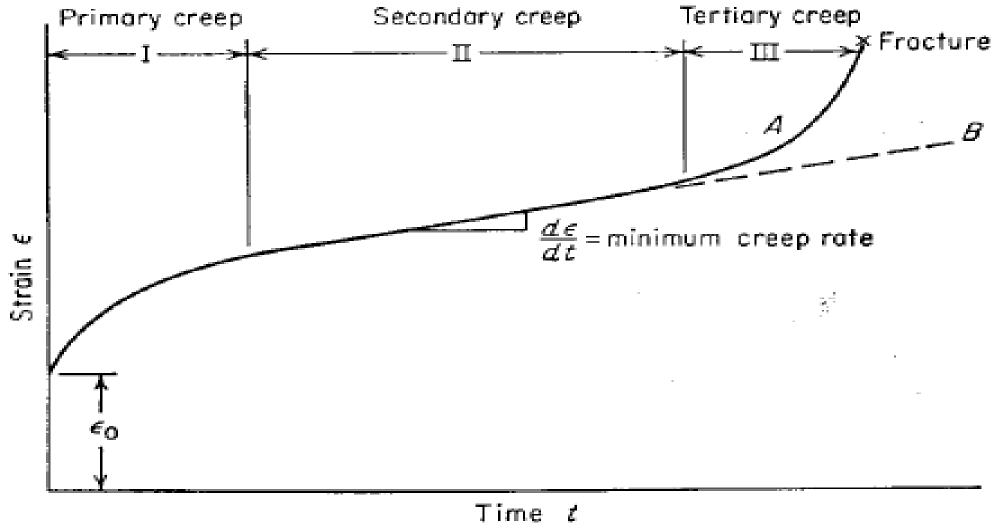


Fig 1.10 Creep curve

Andrade’s pioneering work’ on creep had considerable influence on the thinking on this subject. He considered that the constant-stress creep curve represents the superposition of two separate creep processes which occur after the sudden strain which results from applying the load. The

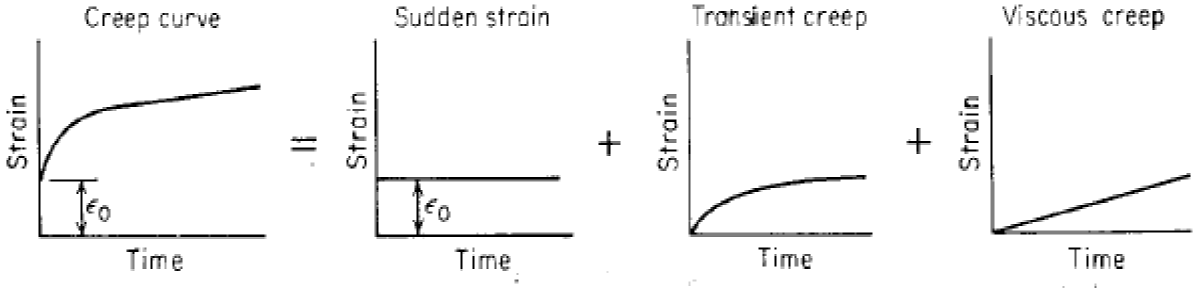


Fig 1.12 Andrade’s Analysis

first component of the creep curve is a transient creep with a creep rate decreasing with time. Added to this is a constant-rate viscous creep component.

The effect of applied stress on the creep curve at constant temperature It is apparent that a creep curve with three well-defined stages will be found for only certain combinations of stress and temperature. A similar family of curves is obtained for creep at constant stress for different temperature. The higher the temperature , the greater the creep rate.

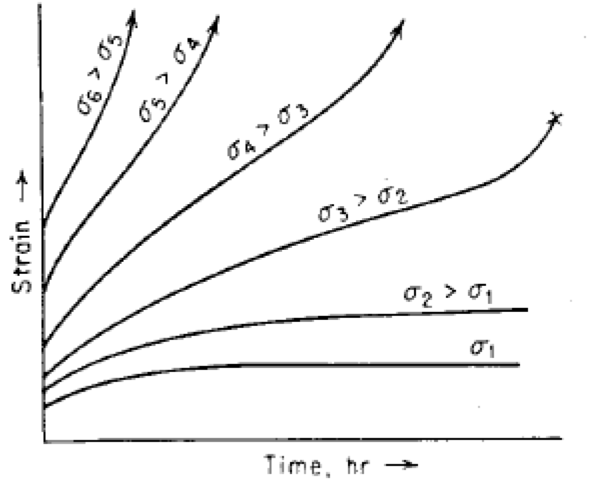


Fig. 1.12 Effect of Stress on Creep Curves at Constant Temp.

1.15 STRUCTURE CHANGE DURING CREEP

If we plot the slope of a creep curve (Fig.1.9) vs. strain, we obtain a curve of creep rate vs. total strain (Fig.1.12). This curve dramatically illustrates the large change in creep rate which occurs during the creep test. Since the stress and temperature are constant, this variation in creep rate is the result of changes in the internal structure of the material with creep strain and time.

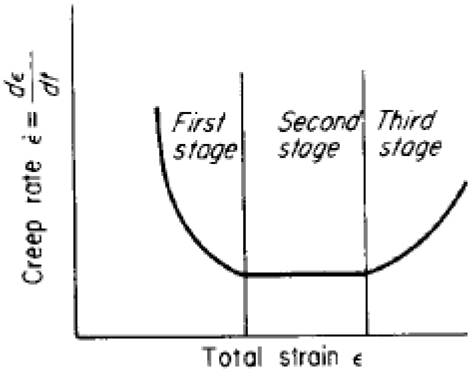


Fig 1.13 Structure Change During Creep

The principal deformation processes at elevated temperature are slip, sub- grain formation, and grain-boundary sliding. High-temperature deformation is characterized by extreme inhomogeneity. Measurements of local creep elongation’ at various locations in a creep specimen have shown that the local strain undergoes many periodic changes with time that are not recorded in the changes- in strain of the total gage length of the specimen. In large-grained specimens. local regions may undergo lattice rotations which produce areas of misorientation.

1.17 MECHANISMS OF CREEP DEFORMATION [25]

A great deal of research has gone into developing mechanisms for creep deformation. The various methods are:

i) Dislocation glide
ii) Dislocation creep
iii) Diffusion creep
iv) Grain boundary sliding

i) Dislocation Glide

It involves dislocation moving along slip planes and overcoming barriers by thermal activation. This mechanism occurs at high stress levels $\sigma/G > 0.01$ which are high relative to those normally considered in creep deformation. The creep rate is establish by the ease with which dislocations are impeded by obstacles such as precipitates, solute atoms and other dislocations.

ii) Dislocation Creep

Dislocation creep occurs by dislocation glide aided by vacancy diffusion. The frame work on which the various theories are hung is the idea of Orowan and Bailey that the steady state creep rate represents a balance between the competing factors of rate of strain hardening $h = ð\sigma/ð\varepsilon$ and the rate of thermal recovery by rearrangement and annihilation of dislocations $r = -ð\sigma/ðt$.

$$\acute{\varepsilon}_{s} = \frac{r}{h} = -\frac{\frac{\partial\sigma}{\partial t}}{\frac{\partial\sigma}{\partial\epsilon}}$$

A steady-state creep condition occurs when the rate of recovery is fast enough and the rate of strain hardening is slow enough that a balance is reached between these competing factors.

iii) Diffusion Creep

Diffusion creep becomes the controlling mechanism at high temperatures and relatively low stresses. $\sigma/G < .0001$. Naharro and Herring proposed that the creep process was controlled by stress-directed atomic diffusion. Stress changes the chemical potential of the atoms on the surfaces of the grains in a polycrystal in such a way that there is a flow of vacancies from grain boundaries experiencing tensile stresses to those which have compressive stresses. Simultaneously, there is a corresponding flow of atoms in the opposite direction, and this leads to elongation of the grain.

(iv) Grain Boundary Sliding

While grain boundary sliding does not contribute significantly to steady state creep, it is important in initiating in intergranular fracture. However it has been shown that grain boundary sliding must be present to maintain grain continuity during diffusional flow mechanism.

1.18 DISC

The study proposed in the current work would lead to draw important conclusions in the context of creep behaviour in a rotating disc made of light weight aluminium based composite materials. The analysis carried out will help to develop better understanding of the materials and process parameters, and the impact of different disc geometry on the distribution of stresses and strains in a rotating disc operating under elevated temperature. The problem investigated in this work may help the designers to explore the possibility of application of different types of disc on the basis of their creep behaviour and to generate a more reliable design.

CHAPTER 2 LITERATURE REVIEW

2.1 REVIEW OF LITERATURE

Rotating disc provides an area of research and studies intensively pursued due to their vast utilization in rotating machinery namely turbine rotors, compressors, flywheels, disc brakes of automobiles and railway vehicles, gears, computer disc drives etc. Optimal and more reliable design of rotating discs has long been an important issue in engineering design. By suitably changing the geometrical parameters and physical properties, the optimal and more reliable design of a rotating disc under given operating conditions (*i.e.* load, speed, operating temperature) can be achieved. The general parameters varied in the optimization process are the geometrical parameters like the mean radius and thickness, and material properties such as density, elastic modulus and Poisson's ratio.

An extensive literature review has been conducted in line with the titled research plan to find out the current level of research and identify the gaps in the study. The salient features of the most relevant research works are presented in the following text.

Horgan *et al* [1] (1999) formulated axisymmetric problem of a solid circular disk (or cylinder) rotating about its central axis with a constant angular velocity and traction-free on its surface. The body was composed of a linearly elastic inhomogeneous isotropic material with material properties that vary only in the radial direction. An exact solution was obtained for a special class of inhomogeneous materials, namely those with a constant Poisson's ratio and a Young's modulus with power-law dependence on the radial coordinate. They considered the case where the Young's modulus increases monotonically with radial distance from the centre, so that the power-law exponent n is positive. This stress response was radically different from that of the homogeneous case (n = 0) where both stresses reach their maxima at the centre. Thus, there was an abrupt transition in the stress response at the centre as one departs from material inhomogeneity. A similar situation was encountered in the analysis of the analogous problem for homogeneous circumferentially orthotropic materials, where even slight anisotropy radically alters the stress response from the isotropic case.

Orcean *et al* [2] (2002) described the distribution of stress, displacement and plastic strain in a rotating elastic–plastic solid disk of variable thickness in a power function form. The analysis was based on Tresca's yield condition, its associated flow rule and linear strain hardening material behaviour. An analytical solution was obtained and numerical results were presented for different values of the geometric parameters. The validity of the solution was demonstrated by comparing the results with those for a uniform thickness disk.

Singh.S.B *et al* [3] (2003) investigated the steady state creep response in an isotropic FGM rotating disc of Al–SiC particulate composites with composition gradient along the radial direction using Norton's law. The results so obtained had been compared with those in an isotropic disc had the same average particle gradient at the same temperature.

Hamid jahed *et al* [4] 2003 reviewed the governing equations of axisymmetric problems (e.g. rotating discs and pressure vessels). Rate type governing equations based on the rate of displacement are then derived and a general solution for uniform members is presented. A method for consideration of inhomogeneouity due to temperature gradients and no uniformity of members is proposed. Different numerical examples of a rotating disc are solved and compared to available results. Creep of the pressure vessel is also studied.

Tahani *et al* [5] (2005) described that the stress field was three-dimensional in regions of geometrical or material discontinuities. This study deals with a semi-analytical solution of 3-D stress field in disks constructed with nested circumferentially fiber-reinforced composite rings. It was assumed that at the inner boundary the plate was fixed (or free) and at the outer boundary was free of stress. To obtain accurate results, a layerwise theory (LWT) was used to model the problem. The results obtained from this theory will be compared with those obtained by using the finite element method. It was found that because of discontinuity of material properties, the stress field was three-dimensional at the interface of two rings.

You *et al* [6] 2007 described that the Functionally graded materials (FGMs) were composite materials where the composition or the microstructure was varied so that certain variation of material properties was achieved. Taking material parameters involved in Norton's law to be the functions of the radial coordinate, a simple and accurate method was developed from the strain rate–stress relations, Norton's law, deformation compatibility condition and equilibrium equation of axisymmetric , plane strain problems. The proposed approach was employed to calculate stresses and creep strain rates in the thick-walled cylindrical vessels.

Zhang *et al* [7] 2007 described a closed form solution of rotating annular disks made of functionally graded materials subject to a uniform temperature change, and to investigate the effects of material properties, different temperature changes, geometric sizes and each of material coefficients on deformations and stresses in the disks.

Vullo *et al* [8] 2007 described that the analysis was elastic and the proposed procedure was quite general and valid for rotating conical disks, either convergent or divergent, also subjected to thermal load and having density variation along its radius. As concerns rotating disk was constant density and non subjected to thermal load, only analytical developments concerning the solution of homogeneous differential equation of convergent conical disks were reported; nevertheless the procedure which uses a simple variable change and extends the subject to divergent conical disk was indicated and the correlated final results were reported. As concerns the solution of the hyper geometric differential equation brought about by the rotating conical disk under elastic loading, it was proposed to directly use its two independent integrals in lieu of the two linear combinations showing the advantages as compared to the latter approach, and validating its results by comparing with those obtained by means of FEA. Moreover this approach was general and it does not present the limits of the procedures found in up-to-date literature.

Sahari *et al* [9] (2008) described a variable thickness FG disk which was subjected to thermal, body and bending loads .The mechanical loading was obtained by having bending load in the z direction, thermal and centrifugal loads in the radial direction. The material properties of the constituent components of the disk were assumed to be represented by a power law distribution along the radial direction of the disk. This work aims to investigate the effects of some basic factors such as material property gradation, the thickness profile of the disk and boundary conditions on the displacement and stress fields .Solid disk with roller-support at the outer edge and the hollow disk with clamped support at the inner edge and free at outer edge were considered .In both cases, semi-analytical solutions for the normalized displacement and force resultant components were obtained. In the semi-analytical method, the radial domain was divided into some virtual sub-domains in which the mechanical property was assumed to be constant. This assumption yields the governing equations in each sub-domain as ordinary differential equations with constant coefficients whose general solution can be written involving certain unknowns .These unknowns can be determined as solution of a set of linear algebraic equations imposing the continuity condition of displacement and radial stress at the interface of the adjacent sub-domains together with global conditions. Increasing the number of sub-domains (divisions) in the radial direction increases the accuracy of the solution.

Singh.T. *et al* [10] 2008 investigated the steady state creep in a cylinder made of Al- SiCP composite and subjected to high pressure and high temperature. A mathematical model had been developed to describe the steady creep behavior of the composite cylinder. The model developed was used to investigate the effect of material parameters viz particle size and particle content, and operating temperatures on the steady state creep response of the composite cylinder.

You *et al* [11] 2008 described a linear variations of Young’s modulus and Poisson’s ratio, and developed an accurate analytical solution to determine deformations and stresses in annular disks made of functionally graded materials subjected to external and/or internal pressure. Taking mechanical properties of the materials of circular disks to be linear variations, the governing equation was derived from basic equations of axisymmetric, plane stress problems in elasticity. By transforming the governing equation into a hyper geometric equation, an accurate analytical solution of deformations and stresses in circular disks was obtained. The comparison with the numerical solution indicates that both approaches give very agreeable results, indicating correctness of the proposed analytical solution. The obtained analytical solution was employed to determine the radial displacement and stresses in circular disks subjected to external pressure and internal pressure.

Hamouda *et al* [12] 2008 described the analysis of a variable thickness FG disk subjected to centrifugal loading due to constant angular velocity . The thickness of the disk was assumed to be sufficiently small compared to its diameter and plane stress condition was applied. The symmetry with respect to the rotational axis and the mid-plane was assumed. This work aims to investigate the effect of property gradation and the geometry of the disk on stresses and displacements in hollow disks under free and fixed boundary conditions and solid disk under free boundary condition. In the case of hollow disk, the non-dimensional stress, strain and displacement components in the radial direction were given using both analytical and semi-analytical methods based on the form of the power-law distribution for the mechanical properties of the constituent components and the thickness profile function. An exact elastic solution for the rotating FG disk with special material properties and thickness profile is also given. For the solid disk, only semi-analytical solution was presented. To implement the semi-analytical method in numerical studies, the radial domain of the disk was divided into some virtual sub-domains where, in each sub-domain, the mechanical property was assumed to be constant. This assumption yields the governing equilibrium equations in each sub-domain as ordinary differential equations with constant coefficients whose general solution can be written involving certain unknowns. These unknowns can be determined as solution of system of linear algebraic equations obtained by imposing the continuity conditions at the interface of the adjacent sub-domains together with global conditions. Increasing the number of sub-domains (divisions) in the radial direction increases the accuracy in the solution.

Gupta *et al* [13] 2008 considered a cylinder which was made of composite containing silicon carbide particles in a matrix of pure aluminum. The effect of imposing linear particle gradient on the distribution of stresses and strain rates in the composite cylinder had been investigated. The study reveals that for the assumed linear particle distribution, the radial stress decreases throughout the cylinder with increase in particle gradient, whereas the tangential, axial and effective stresses increases significantly near the inner radius but show significant decrease towards the outer radius. The strain rates in the composite cylinder could be reduced significantly by employing gradient in the distribution of reinforcement.

Saleem *et al* [14] 2008 described that a variable thickness FG disk subjected to centrifugal body and thermal loading was considered. Plane stress condition and the symmetry with respect to the axis and the mid-plane were assumed. The main aim of this investigation was to enhance the understanding of the elastic behaviour of hollow and solid FG disks subjected to thermo mechanical loading and relate this behaviour to some basic factors such as material property gradation and the geometry of the disks under appropriate boundary conditions. This study also investigates the question how did grading and geometry of the disks relate to their weight and hence to their optimum design. Based on the form of the power-law distribution for the mechanical properties of the constituent components and the thickness profile function, semi-analytical method was employed in this paper to obtain the thermo elastic solutions for the non-dimensional temperature distribution and the displacement field in the disks. In semi-analytical method, the radial domain of the disk was divided into some virtual sub-domains where, in each sub-domain, the mechanical property was assumed to be constant. This assumption yields the governing equilibrium equations in each sub-domain as ordinary differential equations with constant coefficients whose general solution can be written involving certain unknowns. These unknowns determined as solution of system of linear algebraic equations obtained by imposing the continuity conditions at the interface of the adjacent sub-domains together with global conditions. Increasing the number of subdomains (divisions) in the radial direction increases the accuracy in the solution.

Mondali *et al* [15] 2008 described that analytical solution for prediction of the steady state creep behavior of short fiber composites based on shear-lag theory was offered. An axisymmetric unit cell representing a fiber with its surrounding matrix as two coaxial cylinders was assumed. It should be highlighted that the proposed solution technique in contrary to the previous studies satisfies all the equilibrium and the constitutive equations along with all the existing boundary conditions. This model was capable of providing the stress state inside the composite, i.e. radial, circumferential, axial and shear stress components, as well as the radial and axial displacement rates as functions of r and z coordinates. For verification of the solution method, the SiC/6061Al composite was selected as a case study and the results will be compared with the FEM, analytical, and experimental available results. It will be shown that this simple axisymmetric cell model was capable of predicting the creep behavior of the whole composite in low range externally applied stresses when appropriate boundary conditions were applied and more consistent assumptions were assumed. The results obtained here and also the results in indicate that with the assumption of fiber/matrix perfect bond, the exponential creep law can produce acceptable results under low stresses. However, under large stresses, the available voids and cracks in the matrix cause some sort of fiber/matrix debonding in the composite that the length of debonding depends on the amount of the applied external stress. Therefore, including of debonding to the present model was an essential assumption since the FEM studies had shown the mentioned defect can improve the results, compared to the experimental results, to a great extent. It was necessary to use the imaginary fiber technique which dictates solving the problem with perfect bond.

Deepak *et al* [16] 2008 described that a detailed analysis of the published creep data for aluminum-based composites suggests that constitutive creep model was untenable because it leads to consistently higher values of activation energy for creep compared with those anticipated for lattice self-diffusion in aluminum . It was also suggested that creep behavior of aluminum and aluminum alloy matrix composites could be analysed in a better way by assuming the flow to be controlled by creep of the matrix material. With these considerations, it was decided to analyse the impact of the stress exponent on the steady state creep behavior of a rotating disc made of Al–SiCp composite. The creep stresses and creep rates in the disc had been calculated by assuming the values of the stress exponent appearing in creep law . The results obtained had been compared in order to investigate the impact of the stress exponent on creep performance of the composite disc.

Zenkour *et al* [17] 2009 described that the composite structures were composed of three-layer sandwich solid disks with faces made of different isotropic materials and core made of FGM .The relative influence of property gradation on the radial displacement and stresses in FG rotating solid disks. The radial domain was divided into three subdomains, in which the mechanical properties were assumed to be FG through the core subdomain. Two composite structures of FGM solid disks were considered. The inside subdomain of Structure 1 was made of a metal material and the outside subdomain was made of a ceramic material. The core subdomain of Structure 1 is made of a metal-rich surface at the first interface and a ceramic-rich surface at the second interface, between these two surfaces material properties vary according to a simple gradation relation. Structure 2 was considered by rearranging the material properties of metal and ceramic. The problem of rotating such FGM solid disks subjected to free or clamped-edge conditions was considered. The exponential variation of Young’s modulus and density allows exact solution for the problem. At the end of the present work, some numerical results for deformation and stresses were presented and some discussions were carried out.

Dham *et al* [18] 2009 described that it was decided to carry out analysis of steady state creep in rotating disc had different thickness profile. The disc was assumed to be made of composite consisting of silicon carbide particles embedded in aluminum matrix. The creep behavior of the composite had been described by threshold stress based creep law with a stress exponent . The creep stresses and creep rates had been estimated in different composite discs having linearly varying thickness and hyperbolically varying thickness. The results obtained had been compared with those estimated for constant thickness disc to investigate the impact of disc profile on creep performance of the composite disc.

Bayet *et al* [19] 2009 made attempts to incorporate both body and bending forces in the analysis of FG rotating disks. FG annular rotating disk with inner radius, outer radius, and thickness, axisymmetric with respect to z axis and subjected to mechanical loading was considered. The mechanical loading was obtained by having pressure load in the z direction and centrifugal load in the radial direction. The material properties of the constituent components of the disk were assumed to be represented by a power law distribution along the radial direction in the disk. The first order shear deformation theory was used. To be more specific, this work aims to investigate the effect of some basic factors such as material property gradation and the mechanical loading on displacement and stress fields in the solid disk with roller supported boundary conditions and in an annular disk with boundary conditions with clamped support at the inner edge and free or roller supported at outer edge. A semi-analytical solution for displacement field was given for small deflection. Numerical results for normalized displacement and stress resultant components along the radius and thickness of the disk were presented. In the semi-analytical method, the radial domain was divided into some virtual sub-domains where in each sub-domain, the mechanical property was assumed to be constant. This assumption yields the governing equations in each sub-domain as ODE with constant coefficients. Imposing the continuity at the interface of the adjacent sub-domains together with global conditions, a set of linear algebraic equations was derived. Increasing the number of sub-domains (divisions) in the radial direction increases the accuracy in the solution.

Tutuncu *et al* [20] 2009 described that the linear elastic analysis of isotropic pressure vessels with axisymmetric conditions essentially results in a two-point boundary value problem. The governing differential equation will had variable coefficients which were functions of material properties. A novel approach will be attempted to obtain displacements, strains and stresses in a simple and efficient manner, the Complementary Functions method will be infused into the analysis to convert the problem to an initial-value problem which can efficiently be solved. The fifth-order Runge–Kutta method (RK5) with great accuracy. Material properties for typical FGMs made from a mixture of ceramic and metal will be used in the analysis. The ceramic constituent was able to withstand high temperature environments due to its better thermal resistance, while the metal constituent provides stronger mechanical performance. Three material models will be used: (a) simple power law with constant Poisson's ratio for which case analytical benchmark solutions were available, (b) exponentially-varying properties, and (c) volume fractions of the constituents varying according to a power law . It should be emphasized once again that the solution procedure was not confined to any particular choice of material model; it was equally suitable for arbitrary functions defining the gradient variation of material properties.

Singh *et al* [21] 2009 described that a steady-state creep in a thick-walled FG cylinder consisting of SiCp particles embedded in an Al matrix and subjected to high pressure and high temperature. FG cylinders in which the content of SiCp in the Al matrix had been assumed to vary linearly with the maximum amount at the inner radius and the minimum at the outer radius of cylinder. As a result of this, the creep parameters in the FG cylinders will be a function of radial distance, which would otherwise remain constant in uniform composite cylinders. A mathematical model had been developed to describe the steady-creep behavior of composite cylinders made of FGM. The model developed was used to investigate the effect of gradient in distribution of SiCp on the steady-state creep response of the composite cylinder.

Batra *et al* [22] 2009 described a infinitesimal deformations of a rotating disk composed of an isotropic linear thermoelastic FGM when the shear modulus was an arbitrary smooth function of r. For a few specific variations of the shear modulus, they provide exact solutions, and for a general smooth variation they solve the problem numerically by the differential quadrature method (DQM). Furthermore, they study the material tailoring problem and find either the shear modulus or the thermal expansion coefficient as a function of r to achieve a desired radial variation of stresses. For plane strain axisymmetric deformations of an FG cylinder composed of an orthotropic compressible material, they assumed that all material moduli were proportional to each other and found their spatial variation so to make either the hoop stress or the shear stress uniform in the cylinder. they used a higher-order shear and normal deformable plate theory to find the spatial variation along the axial and the thickness directions of the two constituents in a FG cantilever plate to optimize the fundamental frequency. The through-the-thickness variation of the fiber orientation angle in a fiber-reinforced laminated composite plate to optimize one of the first five lowest frequencies of a rectangular plate under different boundary conditions and the axial variation of the shear modulus to control the angle of twist per unit length for the torsion of a FG cylinder . They had derived a higher-order plate theory for FGIM plates, and an exact solution for frequencies of a simply supported plate made of an incompressible material was provided.

Payten *et al* [23] 2009 described a specifically interested in an analytical formulation which could be applied a wide range of pipe geometries and temperature conditions relevant to power stations components, but simple enough to be easy implemented and used as a screening process for feasible ramp rates. The thermal cycle that occurs during start-up and operation can be described by a compressive stress on the inside surface of the component as the station ramps up, thermal balance at operating temperature as the unit synchronizes, and a tensile stress on the inside surface during operation as a result of the pressure stress. The creep dwell therefore occurs at the tensile locus tip.

2.2 PROBLEM DESCRIPTION

It is quite evident from the literature reported that the problem of determination of elastic stresses and deformations in a rotating disc made of monolithic material has been dealt by several workers but the studies pertaining to creep deformations in a rotating disc, that too of composite materials, are rather scant.

- In view of the potential applications of FGMs to operate under severe thermo-mechanical loadings, it has been decided to investigate creep behavior of rotating disc made of composite material. The creep response of the rotating disc will be analyzed with the help of Finite Element Analysis. In this an attempt will be made to obtain the distributions of stresses and strains in the disc.
- Values of material parameters from experimental study:-

In order to get close results, we can also associate some other variables, like diameter of disc, different cross sections etc along with these three variables.

The study proposed in the current work would lead to draw important conclusions in the context of creep behaviour in a rotating disc made composite materials . The analysis carried out will help to develop better understanding of the materials and process parameters, and the impact of different disc geometry on the distribution of stresses and strains in a rotating disc operating under elevated temperature. The problem investigated in this work may help the designers to explore the possibility of application of different types of disc on the basis of their creep behaviour and to generate a more reliable design.

CHAPTER 3 FINITE ELEMENT ANALYSIS

3.1 INTRODUCTION

The finite element method is numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in almost every industry. In more and more engineering situations today, we find that it is necessary to obtain approximate solutions to problem rather than exact closed form solution. It is not possible to obtain analytical mathematical solutions for many engineering problems. An analytical solutions is a mathematical expression that gives the values of the desired unknown quantity at any location in the body, as consequence it is valid for infinite number of location in the body. For problems involving complex material properties and boundary conditions, the engineer resorts to numerical methods that provide approximate, but acceptable solutions. The finite element method has become a powerful tool for the numerical solutions of a wide range of engineering problems. It has been developed simultaneously with the increasing use of the high- speed electronic digital computers and with the growing emphasis on numerical methods for engineering analysis. This method started as a generalization of the structural idea to some problems of elastic continuum problem, started in terms of different equations.

3.2 PROCEDURE FOR ANSYS ANALYSIS

Static analysis is used to determine the displacements stresses, stains and forces in structures or components due to loads that do not induce significant inertia and damping effects. Steady loading in response conditions are assumed. The kinds of loading that can be applied in a static analysis include externally applied forces and pressures, steady state inertial forces such as gravity or rotational velocity imposed (non-zero) displacements, temperatures (for thermal strain). A static analysis can be either linear or non linear. In our present work we consider linear static analysis.

The procedure for static analysis consists of these main steps

i) Building the model

ii) Obtaining the solution

iii) Reviewing the results.

3.3 BUILD THE MODEL

In this step we specify the job name and analysis title use PREP7 to define the element types, element real constants, material properties and model geometry element type both linear and non- linear structural elements are allowed. The ANSYS elements library contains over 80 different element types. A unique number and prefix identify each element type.

E.g. BEAM 94, PLANE 71, SOLID 96 and PIPE 16

3.4 MATERIAL PROPERTIES

Young's modulus must be defined for a static analysis. If we plan to apply inertia loads (such as gravity) we define mass properties such as density (DENS). Similarly if we plan to apply thermal loads (temperatures) we define coefficient of thermal expansion (ALPX).

3.5 SOLUTION

In this step we define the analysis type and options, apply loads and initiate the finite element solution. This involves three phases:

i) Pre-processor phase

ii) Solution phase

iii) Post-processor phase

i) Pre-processor:

Pre processor has been developed so that the same program is available on micro, mini, super-mini and mainframe computer system. This slows easy transfer of models one system to other.

The following Table 3.1 shows the brief description of steps followed in each phase:

PREPROCESSOR PHASE	**SOLUTION PHASE**	**POST-PROCESSOR PHASE**
GEOMETRY DEFINITIONS	**ELEMENTMATRIX FORMULATION**	**POST SOLUTION OPERATIONS**
MESH GENERATION	**OVERALL MATRIX TRIANGULARIZATION**	**POST DATA PRINT OUT (FOR REPORTS)**
MATERIAL	**(WAVE FRONT)**	**POST DATA**
DEFINITIONS		**SCANNING POST DATA DISPLAY**
CONSTRAINT DEFINITIONS	**DISPLACEMENT, STRESS, ETC.**	
LOAD DEFINITION	**CALCULATION**	
MODEL DISPLAY		

Pre processor is an interactive model builder to prepare the FE (finite element) model and input data. The solution phase utilizes the input data developed by the pre processor, and prepares the solution according to the problem definition. It creates input files to the temperature etc. on the screen in the form of contours.

Geometrical definitions:

There are four different geometric entities in pre processor namely key points, lines, area and volumes. These entities can be used to obtain the geometric representation of the structure. All the entities are independent of other and have unique identification labels.

Model Generations:

Two different methods are used to generate a model:

i)Direct generation.

ii) Solid modeling

With solid modeling we can describe the geometric boundaries of the model, establish controls over the size and desired shape of the elements and then instruct ANSYS program to generate all the nodes and elements automatically. By contrast, with the direct generation method, we determine the location of every node and size shape and connectivity of every element prior to defining these entities in the ANSYS model. Although, some automatic data generation is possible (by using commands such as FILL, NGEN, EGEN etc) the direct generation method essentially a hands on numerical method that requires us to keep track of all the node numbers as we develop the finite element mesh. This detailed book keeping can become difficult for large models, giving scope for modeling errors. Solid modeling is usually more powerful and versatile than direct generation and is commonly preferred method of generating a model.

Mesh generation:

In the finite element analysis the basic concept is to analyze the structure, which is an assemblage of discrete pieces called elements, which are connected, together at a finite number of points called Nodes. Loading boundary conditions are then applied to these elements and nodes. A network of these elements is known as Mesh.

Finite element generation:

The maximum amount of time in a finite element analysis is spent on generating elements and nodal data. Pre processor allows the user to generate nodes and elements automatically at the same time allowing control over size and number of elements. There are various types of elements that can be mapped or generated on various geometric entities.

The elements developed by various automatic element generation capabilities of pre processor can be checked element characteristics that may need to be verified before the finite element analysis for connectivity, distortion-index etc. Generally, automatic mesh generating capabilities of pre processor are used rather than defining the nodes individually. If required nodes can be defined easily by defining the allocations or by translating the existing nodes. Also on one can plot, delete, or search nodes.

Boundary conditions and loading:

After completion of the finite element model it has to constrain and load has to be applied to the model. User can define constraints and loads in various ways. All constraints and loads are assigned set ID. This helps the user to keep track of load cases.

Model display:

During the construction and verification stages of the model it may be necessary to view it from different angles. It is useful to rotate the model with respect to the global system and view it from different angles. Pre processor offers this capabilities. By windowing feature pre processor allows the user to enlarge a specific area of the model for clarity and details. Pre processor also provides features like smoothness, scaling, regions, active set, etc for efficient model viewing and editing.

Material defections:

All elements are defined by nodes, which have only their location defined. In the case of plate and shell elements there is no indication of thickness. This thickness can be given as element property. Property tables for a particular property set 1-D have to be input. Different types of elements have different properties for e.g.

Beams: Cross sectional area, moment of inertia etc
i)Shell: Thickness
ii)Springs: Stiffness
iii)Solids: None

The user also needs to define material properties of the elements. For linear static analysis, modules of elasticity and Poisson.s ratio need to be provided. For heat transfer, coefficient of thermal expansion, densities etc. are required. They can be given to the elements by the material property set to 1-D.

ii) Solution:

The solution phase deals with the solution of the problem according to the problem definitions. All the tedious work of formulating and assembling of matrices are done by the computer and finally displacements are stress values are given as output. Some of the capabilities of the ANSYS are linear static analysis, non linear static analysis, transient dynamic analysis, etc.

iii) Post- processor:

It is a powerful user- friendly post- processing program using interactive colour graphics.It has extensive plotting features for displaying the results obtained from the finite element analysis. One picture of the analysis results (i.e. the results in a visual form) can often reveal in seconds what would take an engineer hour to assess from a numerical output, say in tabular form. The engineer may also see the important aspects of the results that could be easily missed in a stack of numerical data. Employing state of art image enhancement techniques, facilities viewing of:

i) Contours of stresses, displacements, temperatures, etc.
ii) Deform geometric plots
iii) Animated deformed shapes
iv) Time-history plots
v) Solid sectioning
vi) Hidden line plot
vii)Light source shaded plot
viii) Boundary line plot etc.

The entire range of post processing options of different types of analysis can be accessed through the command/menu mode there by giving the user added flexibility and convenience.

CHAPTER 4 MODELING AND ANALYSIS

4.1 MODELING AND ANALYSIS OF ROTATING DISC

Following steps have been followed to model the rotating disc.

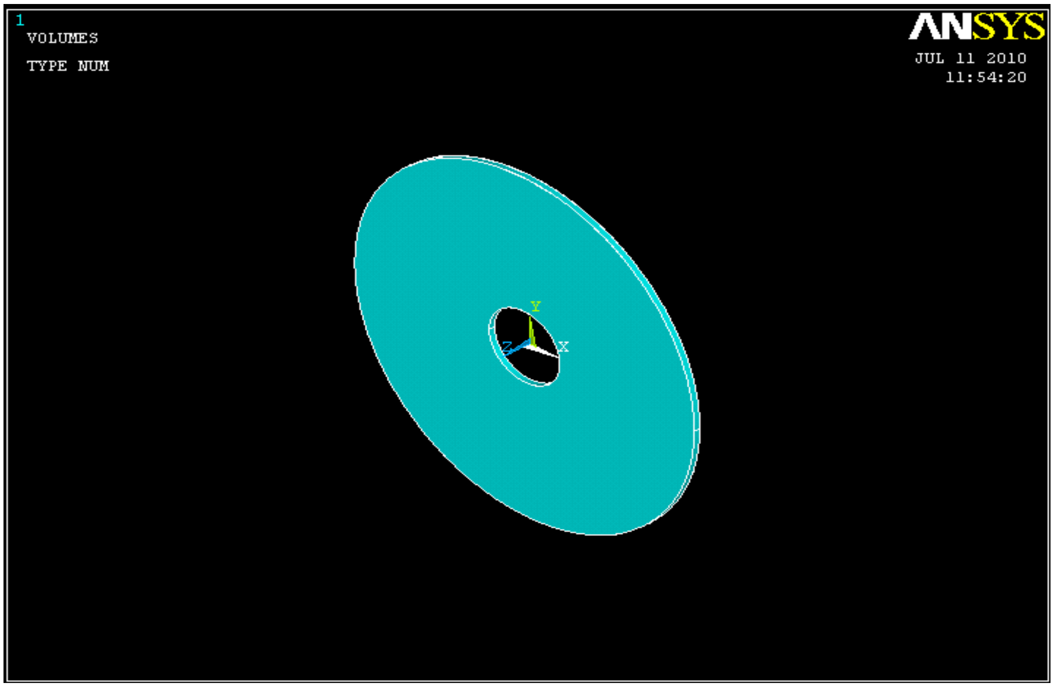
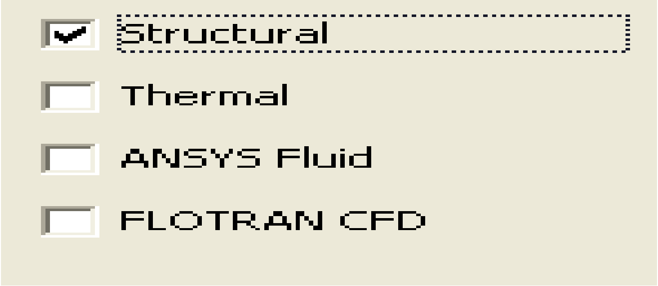


Fig 4.1 Disc model

Step 1:- To select the type of analysis under preferences.

- Select ‘structural’ from the menu as shown in figure 4.2.



☑ Structural

☐ Thermal

☐ ANSYS Fluid

☐ FLOTRAN CFD

Fig 4.2 Selecting the Type of Analysis

Step 2:- To decide the finite element for the geometry.

- Select ‘8node82’ element as shown in figure 4.3.
- Select element behavior as ‘axis symmetric’.

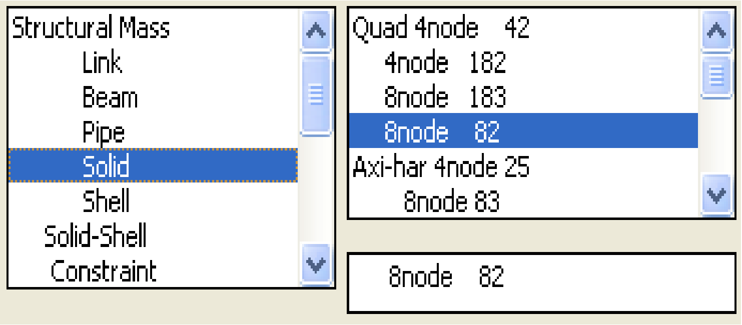


Fig 4.3 Selecting the Type of Element

Step 3:- Deciding the material properties.

- Give the values of Young modulus, Poisson ratio, Creep exponent as given in table .

Young modulus	Poisson ratio	Creep exponent
15×10^8N/mm^2	0.3	6

Table 4.1 Materials Values

Step 4:- Modeling

- Select a rectangular section from a disc of given dimensions as shown in figure 4.4 and then model it in Ansys as shown in figure 4.5.

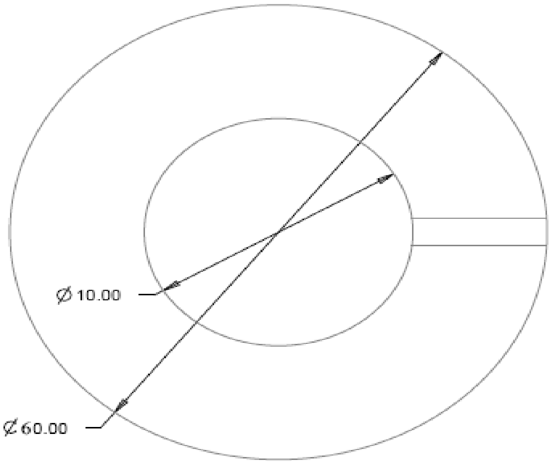


Fig 4.4 Rectangular section taken from disc section

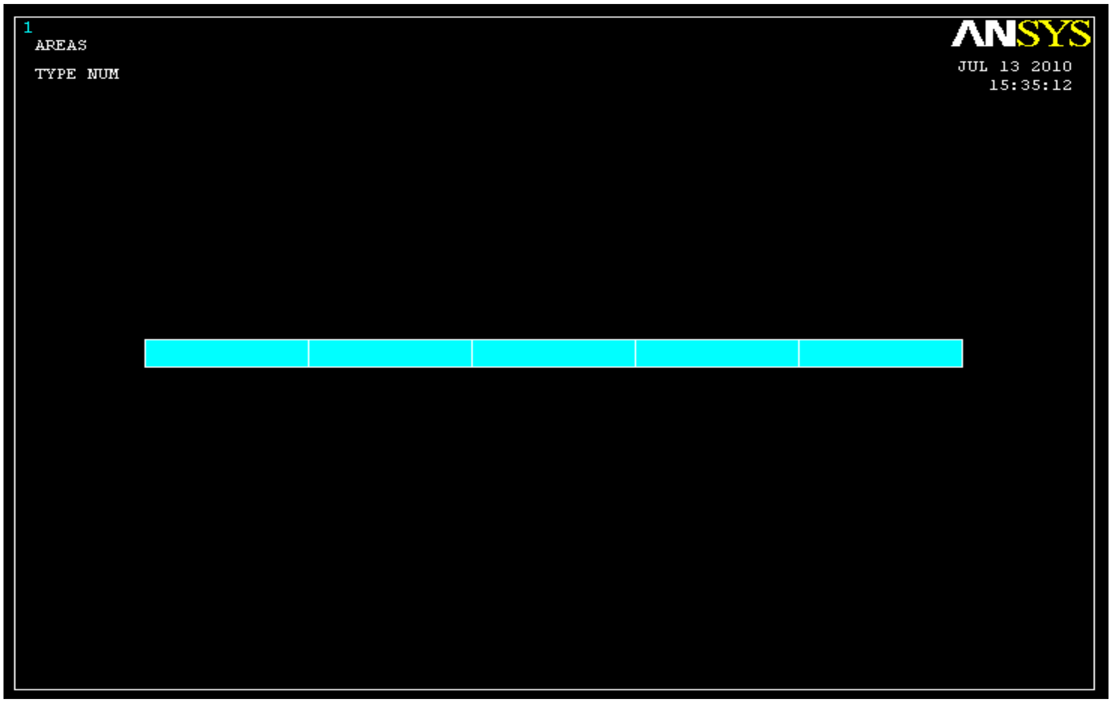


Fig 4.5 Modeling of Different Areas

Step 5:- Meshing

- Mesh the section by taking the Elements defined above.

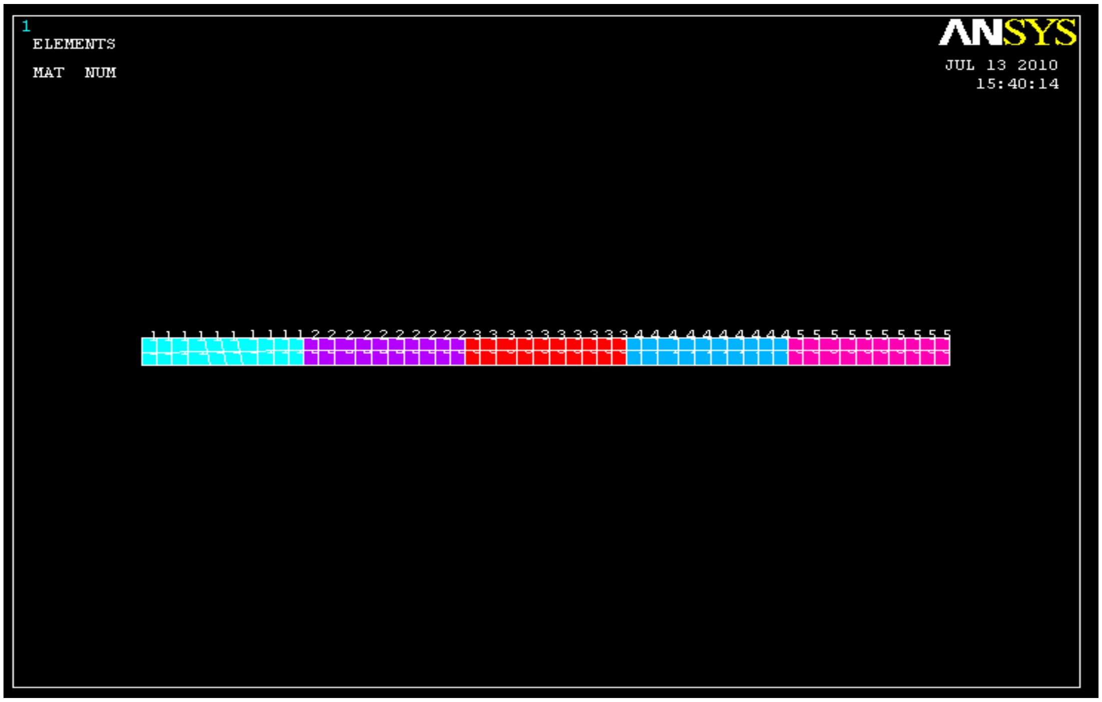


Fig 4.6 Meshed Area

Step 6:- Angular Velocity and Boundary Conditions

- Apply constraint on the lower edge in y-direction as shown in the figure 4.7.
- Now apply Angular Velocity to elements.

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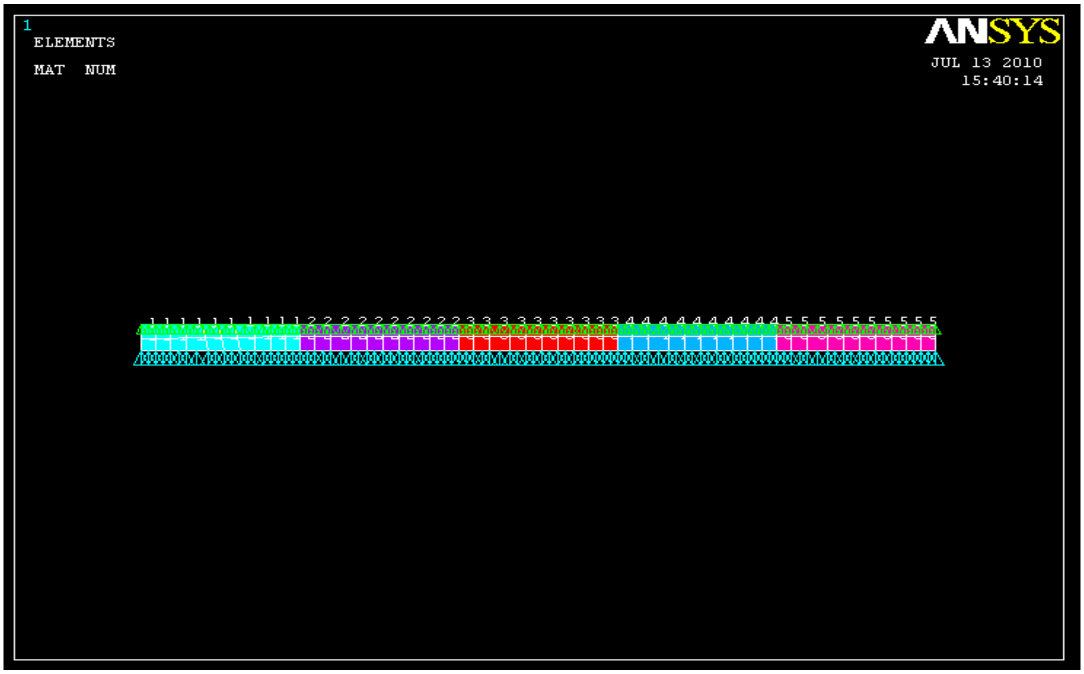

Fig 4.7 Angular Velocity and Boundary Condition

Step 7:- Solution

- Go to solution and select solve to get the desired results.
- Display the nodal solutions.
- Display the graphical solutions.

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CHAPTER 5 RESULTS AND DISCUSSIONS

The results have been obtained by Modeling and Analysis in Ansys software for the problem which had undertaken by Hamid Jahed et al**. [4].**In his work he had mathematically modeled for the radial and circumferential stresses by giving the rotation to the disc. The results of the present work are obtained by the Ansys Software. The dimensions of the disc used are internal radius of 5cm and external radius of 30cm. The angular velocity given the disc is 837.76 rad/sec.

5.1 VALIDATION OF RESULTS FOR RADIAL STRESSES WHEN DISC SUBJECTED TO ROTATION

The results obtained by Hamid Jahed [4] are in the Graphical form as shown below:

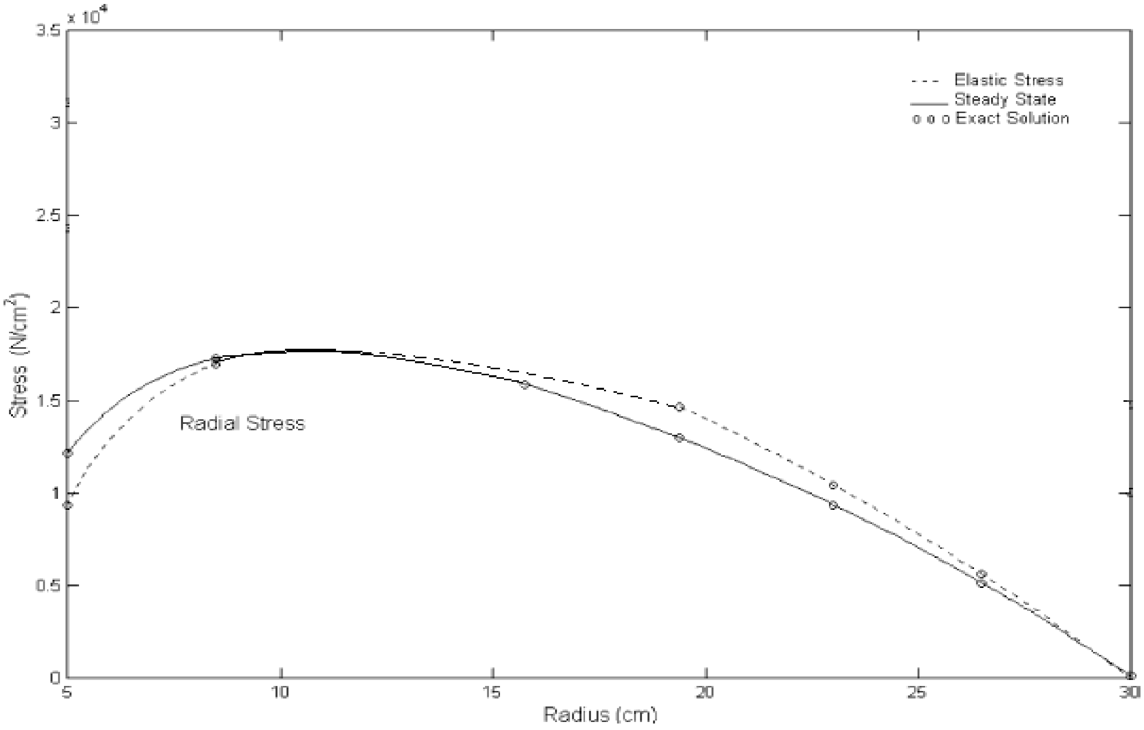
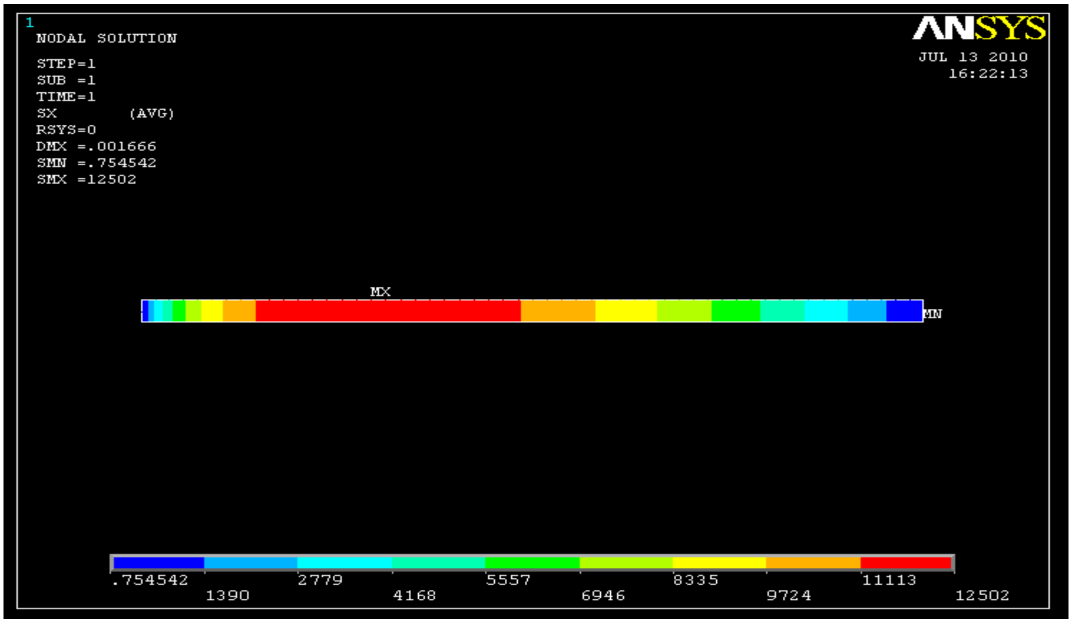


Fig. 5.1 Graph Showing Results of Hamid Jahed [4] for Radial Stresses

In the Fig. 5.1 the horizontal axis shows the radius of disc and vertical axis shows the radial stresses. It is clear from the fig. 5.1 that in the disc as we move outside along the radius the radial stresses firstly increases to their maximum value at a radius very near to center and then they decreases along the radius reaching their minimum value at the outer periphery of the disc. In his work he had shown the results for Angular Velocity ω = 837.76 rad/s.



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SMX =12502
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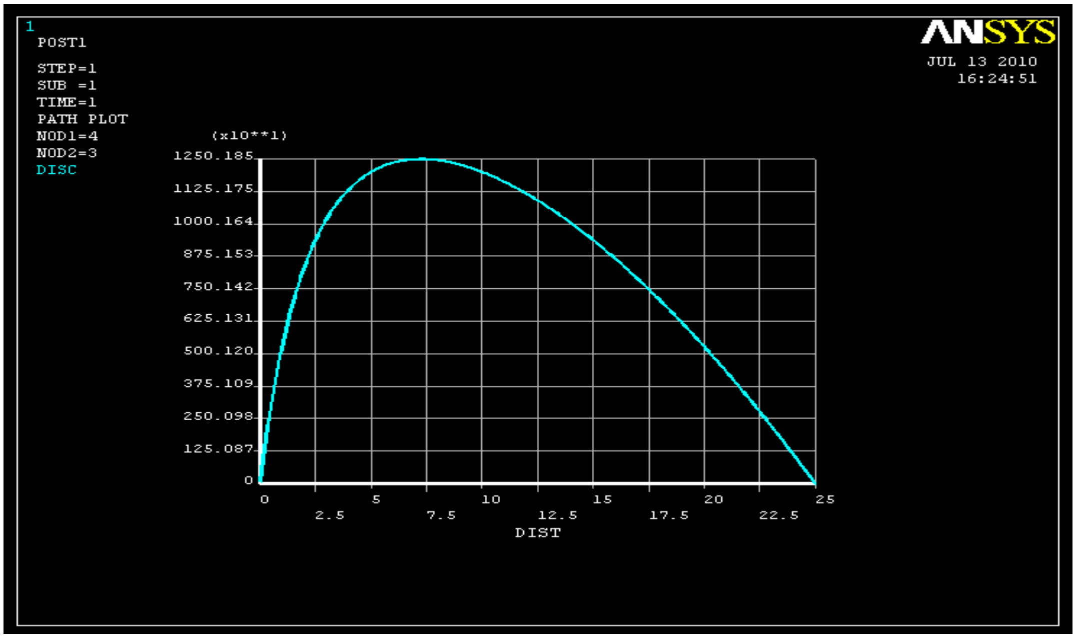
Fig. 5.2 Variation of Radial Stresses along the Radius



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TIME=1
PATH PLOT
NOD1=4
NOD2=3
DISC
```

Fig. 5.3 Graph for Radial Stresses along the Radius

The results obtained in the present work by using Ansys software with Angular Velocity of 837.76 rad/s on a disc of internal radius 5 cm and external radius of 30 cm. The stress variation diagram for the radial stresses is shown in Fig. 5.2 and the graphical plot of the results is shown in Fig. 5.3. From the above discussion it is clear that our results are in accordance with the results of the Hamid Jahed [4].

5.2 VALIDATION OF RESULTS FOR CIRCUMFRENTIAL STRESSES

The results obtained by Hamid Jahed [4] are in the graphical form as shown below:

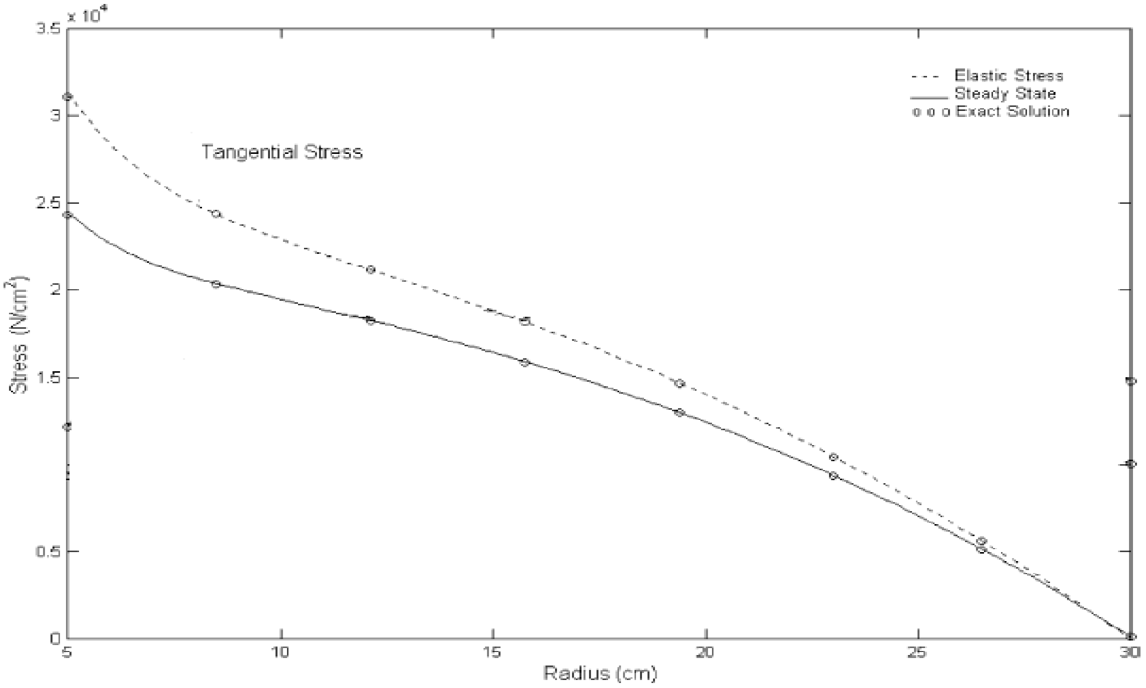


Fig. 5.4 Graph Showing the Results Hamid Jahed [4] for Circumferential Stresses

In the Fig. 5.4 Hamid Jahed [4] showed the results for circumferential stresses. The horizontal axis varies the radius of disc and vertical axis shows the circumferential stresses. It is clear from the graph that the circumferential stresses (σ_θ) are proportional to radius (r). He applied Angular velocity ω= 837.76 rad/s.

The results obtained in the present work by using Ansys software are shown in Fig. 5.5 and Fig. 5.6. It is clear in the both the figure that as the radius increase i.e. as we move from inner radius to outer radius the circumferential stresses get decreased. The circumferential stresses are maximum near the center of the disc which they decreases gradually as we move along the radius to their minimum value. From the above discussion it is clear that our results are in accordance with the results of the Hamid Jahed [4].

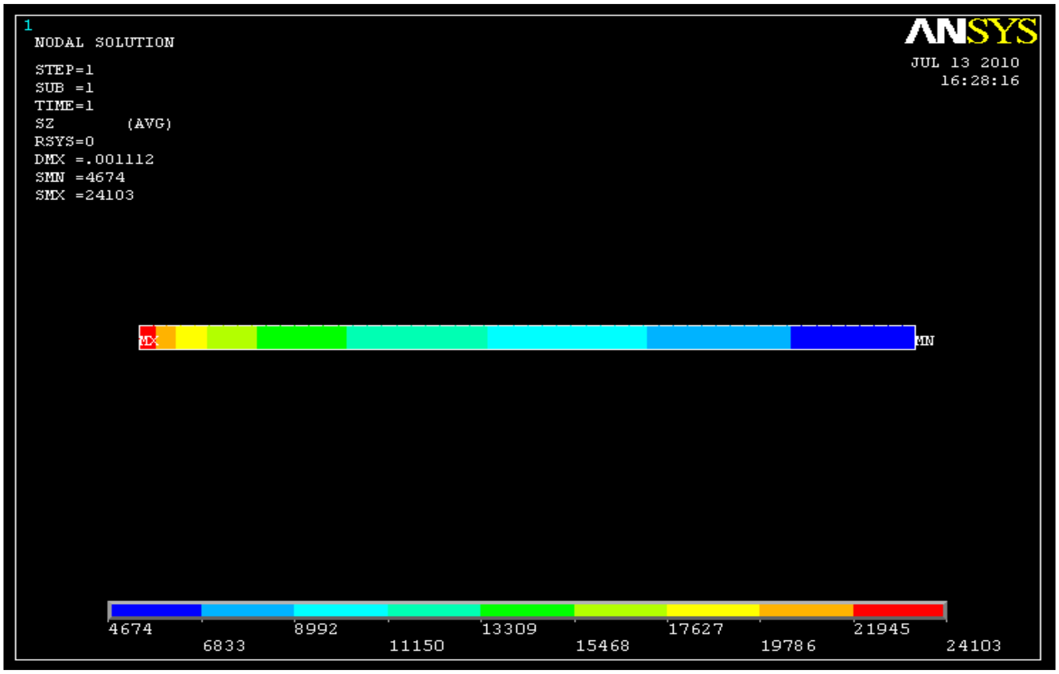


Fig. 5.5 Variation of Circumferential Stresses along the Radius

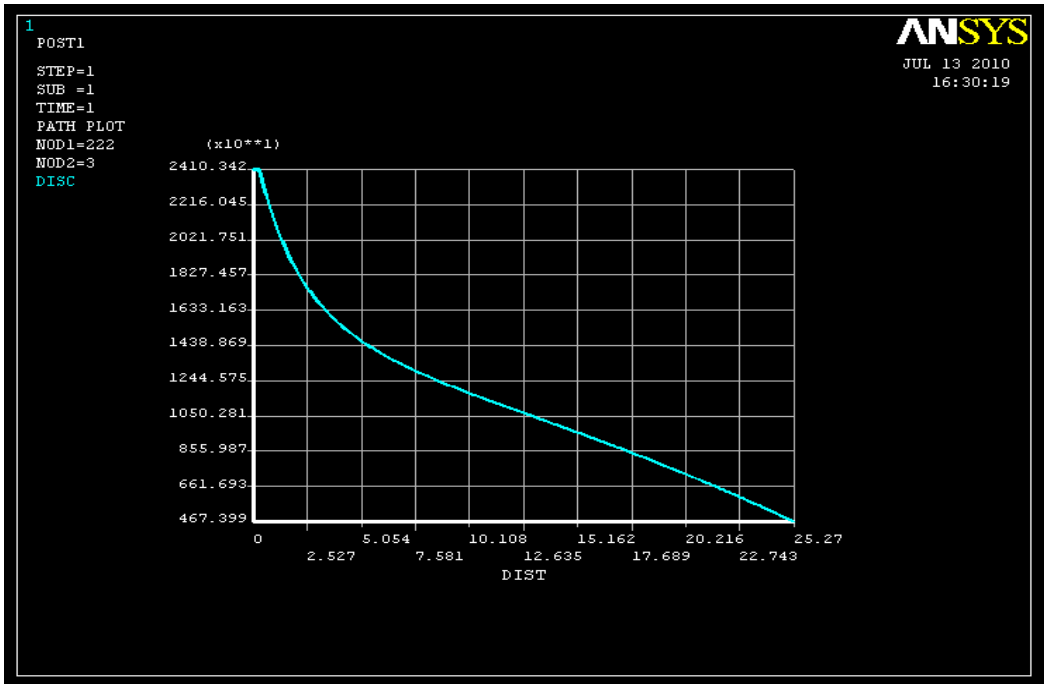
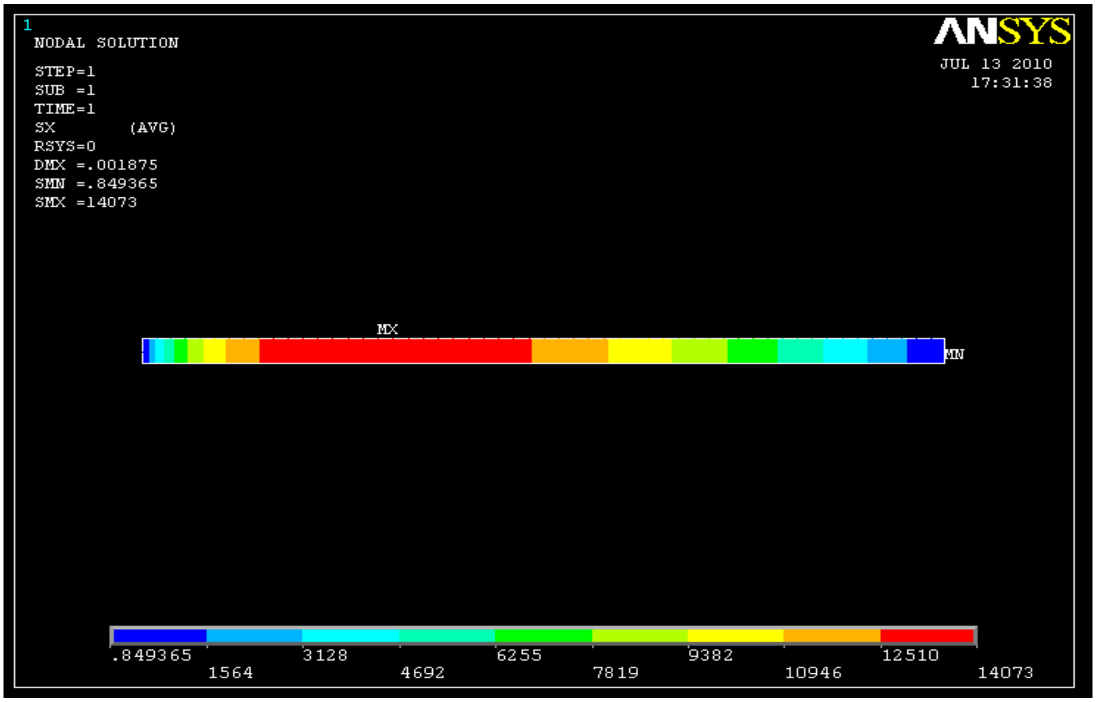


Fig. 5.6 Graph for Circumferential Stresses along the Radius

5.3 ANALYSIS FOR RADIAL STRESSES WHEN DISC SUBJECTED TO HIGHER ANGULAR VELOCITES.

In this study further the effect of increasing the angular velocity on the radial stresses is observed. In the Fig. 5.7 and Fig. 5.8 the variation for radial stresses is shown in the form of stress variation diagram and in graphical form respectively for the angular velocity of 887.37 rad/sec. Similarly the results for radial stresses are shown in Fig. 5.9 and Fig. 5.10 for angular velocity of 937.37 rad/sec. Horizontal axis shows the radius of cylinder and vertical axis shows the radial stresses. It is clear from the Fig. 5.7, Fig. 5.8, Fig. 5.9 and Fig. 5.10 that when we move from internal radius to outer radius the stresses are increased to maximum value at the radius very close to the center but as we move further towards the outer periphery the radial stresses decreases gradually.

It is observed that at each and every point the intensity radial stress is directly proportional to the angular velocity but their variation along the radius remains the same..



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JUL 13 2010
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Fig. 5.7 Variation of Radial Stresses along the Radius at 887.37 rad/sec

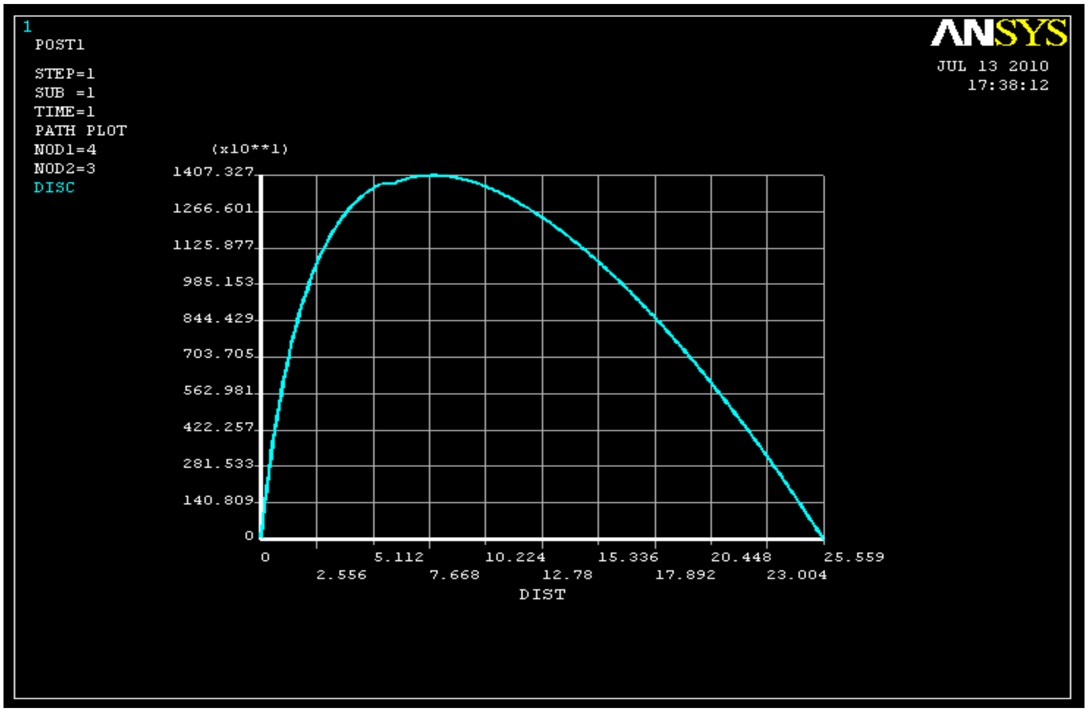

Fig. 5.8 Graph for Radial Stresses along the Radius for 887.37 rad/sec

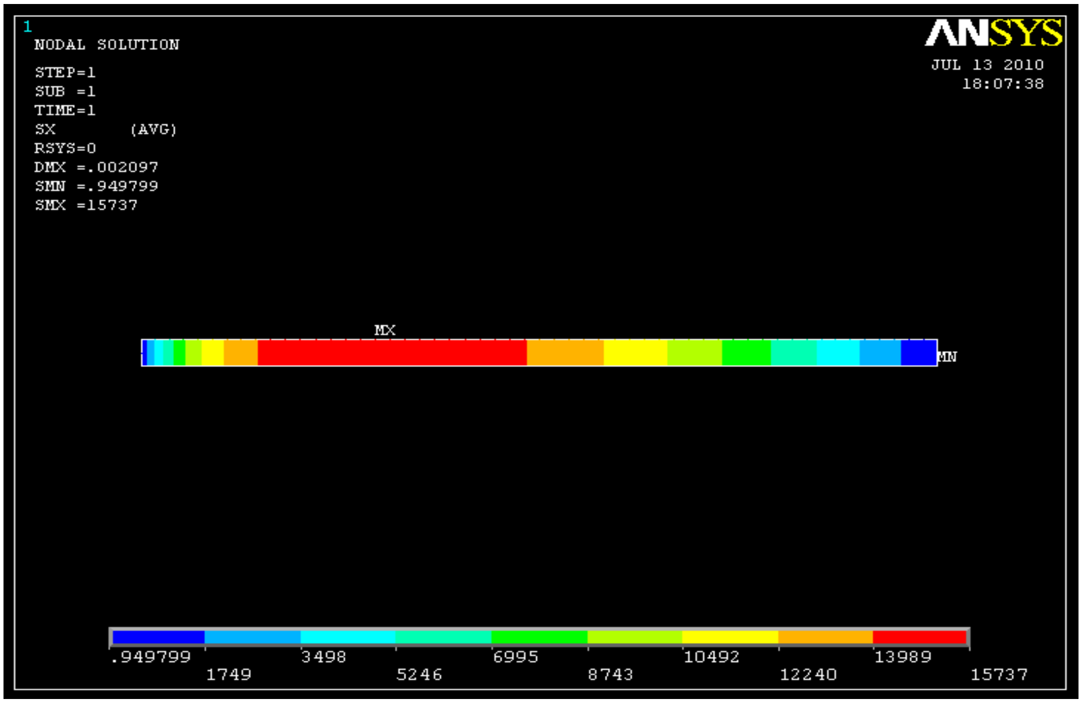

Fig.5.9 Variation of Radial Stresses along the Radius at 937.37 rad/sec

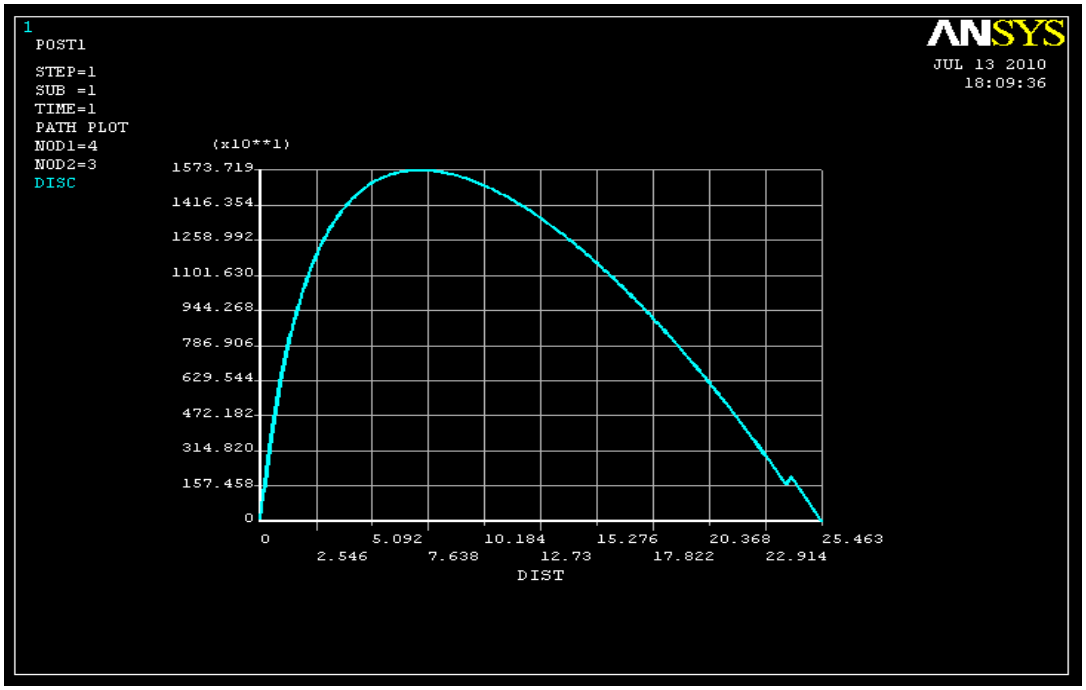

Fig.5.10 Graph for Radial Stresses along the Radius for 937.37 rad/sec

5.4 ANALYSIS FOR CIRCUMFERENTIAL STRESSES WHEN DISC SUBJECTED TO HIGHER ANGULAR VELOCITES.

In this study further the effect of increasing the angular velocity on the circumferential stresses is observed. In the Fig. 5.11 and Fig. 5.12 the variation for circumferential stresses is shown in the form of stress variation diagram and in graphical form respectively for the angular velocity of 887.37 rad/sec. Similarly the results for circumferential stresses are shown in Fig. 5.13 and Fig. 5.14 for angular velocity of 937.37 rad/sec. Horizontal axis shows the radius of cylinder and vertical axis shows the circumferential stresses. It is clear from the Fig. 5.11, Fig. 5.12, Fig. 5.13 and Fig. 5.14 that when we move from internal radius to outer radius the circumferential stresses are decreased as we move towards outer periphery to its minimum value at the outer periphery.

It is observed that at each and every point the intensity of circumferential stress is directly proportional to the angular velocity but their variation along the radius remains the same.

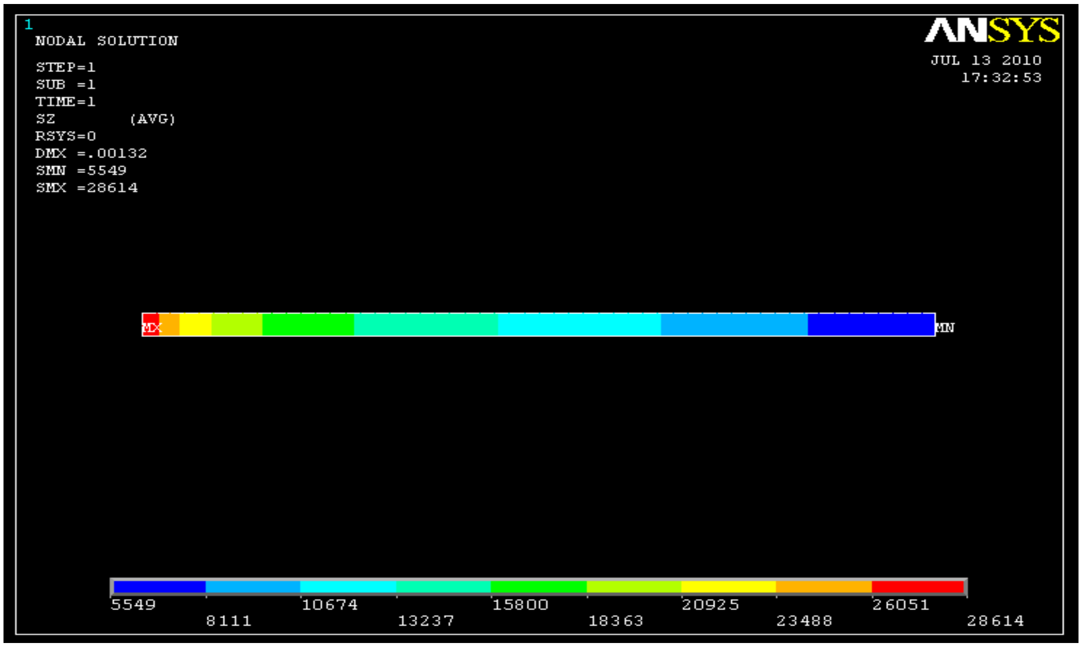

Fig. 5.11 Variation of Circumferential Stresses along the Radius at 887.37 rad/sec

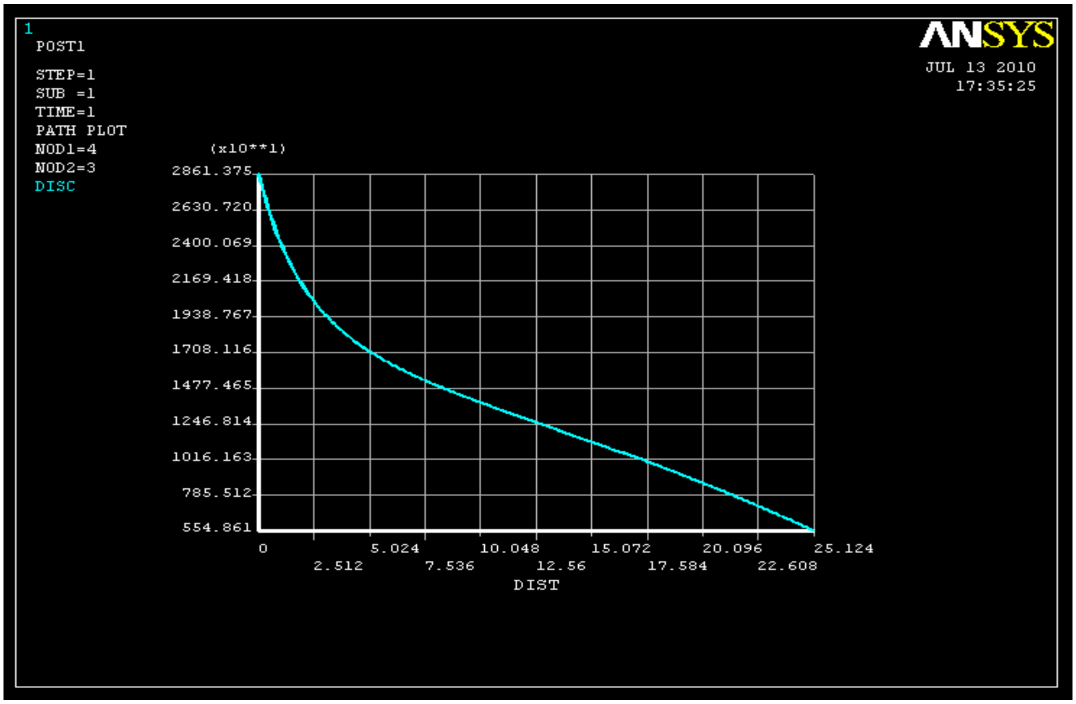

Fig. 5.12 Graph for Circumferential Stresses along the Radius for 887.37 rad/sec

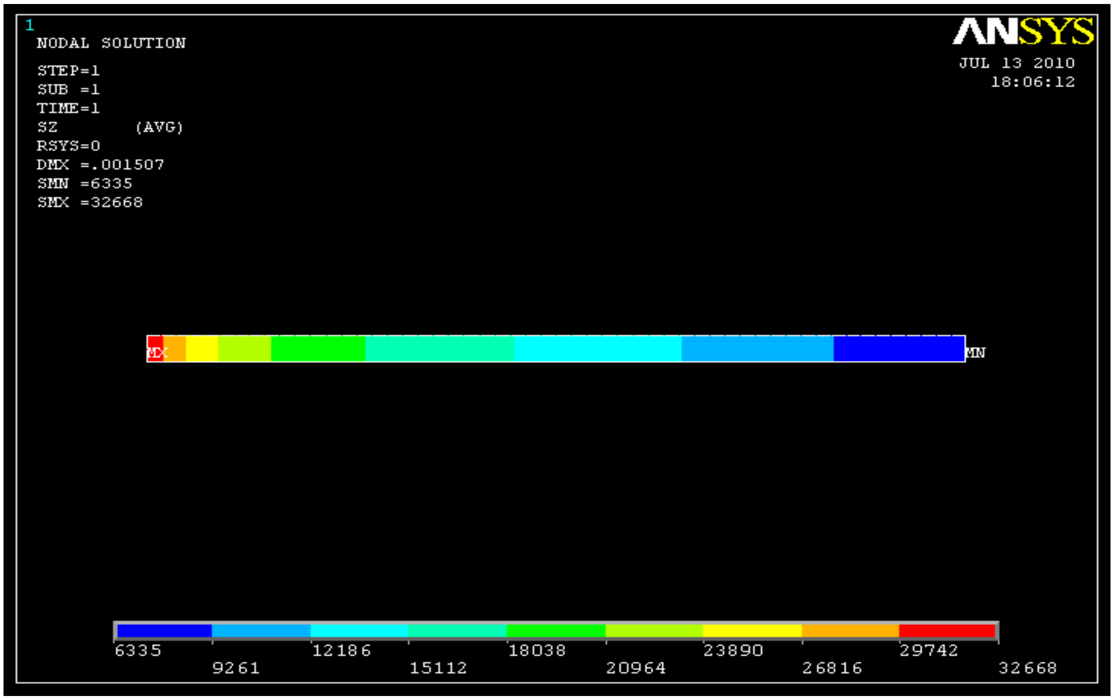

Fig. 5.13 Variation of Circumferential Stresses along the Radius at 937.37 rad/sec

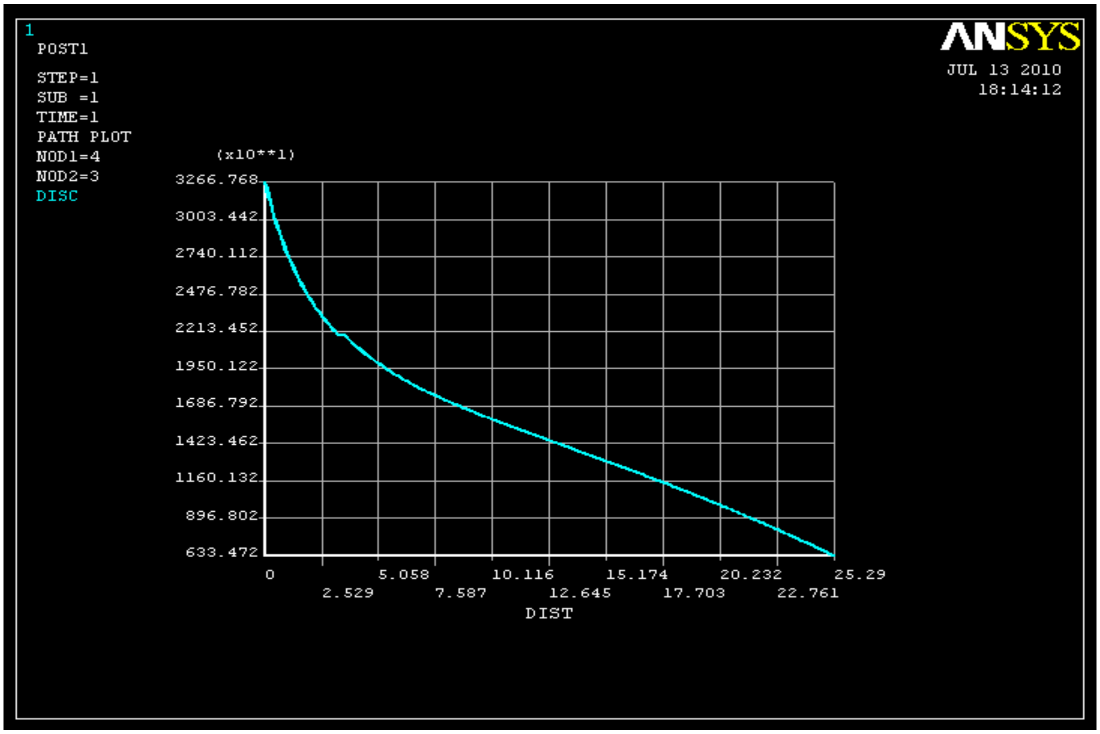

Fig. 5.14 Graph for Circumferential Stresses along the Radius for 937.37 rad/sec.

5.5 CONCLUSION

In present study I had undergone the analysis of rotating disc, for the radial and circumferential stress. The result obtain are quite satisfactory and are validated with Hamid Jahed. The modeling and analysis is done in ansys software.

The effect of increasing the angular velocity on the radial and circumferential stress is observed. In the study when we increase angular velocity the radial stress firstly increase and then decreases but circumferential stress decrease by increase in angular velocity. There for we can say that in a rotating disc the most stressed area near to the center.

So we can conclude that Ansys is a very powerful software which can be used for modeling and analyzing different mechanical engineering problems.

5.6 SCOPE FOR FURTHER STUDY

i) Ansys is power full software for modeling and analysis. There for there is the scope for time dependent analysis and steady state analysis of the rotating discs for creep.

ii) There is scope for work in turbo industry in the ansys for rotating parts like turbine, pump and rotors.

iii) In the upcoming time we can extend our study for defects and stress levels at different points within the discs which could be helpful in enhancing the life of the disces.

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