STRAIN ANALYSIS AND OPTIMIZATION OF STEAM TURBINE CASING

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A Project Report

Submitted by

L. Karthick - 71205402003

in partial fulfillment for the award of the degree
of

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COIMBATORE – 641 006

ANNA UNIVERSITY:: CHENNAI 600 025

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ANNA UNIVERSITY :: CHENNAI 600 025

BONAFIDE CERTIFICATE

Certified that this project report entitled **"Strain Analysis and Optimization of Steam Turbine Casing"** is the bonafide work of

Mr. L. Karthick - Register No. 71205402003

Who carried out the project work under my supervision.

Signature of the HOD

18/5/07.

Signature of the supervisor

Internal Examiner

4/7/07

External Examiner

DEPARTMENT OF MECHANICAL ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY

COIMBATORE 641 006

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A.C.College of Engineering and Technology
Karaikudi - 04, Tamil Nadu.

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Co-Authors :

Dr.A.Syed Abu Thaheer
Co-Ordinator

Prof. K.R.Viswanathan
Chairman

Dr.R.Sundararajan
Principal

MAHENDRA ENGINEERING COLLEGE

Mahendhirapuri, Mallasamudram (w), Vadugapalayam (Po),
Namakkal Dt., - 637 503.

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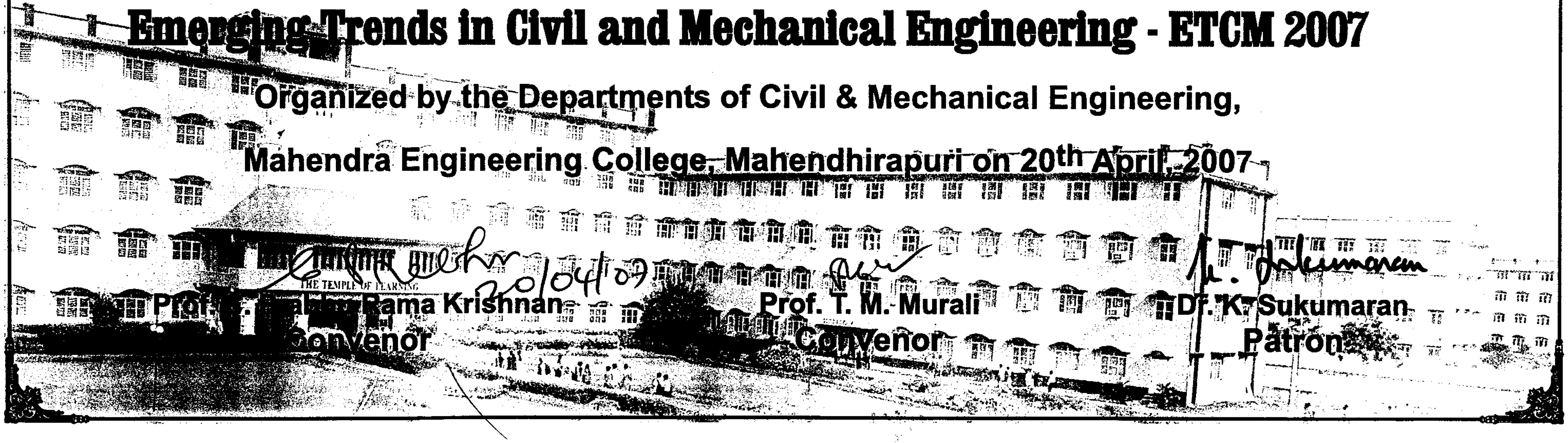

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ABSTRACT

The steam turbine is one of the most important power generating turbo machine. The operational performance of a turbine mainly depends on the clearance (flow area of steam) available between the turbine blades and the turbine casing. Normally each and every region of the turbine casing is subjected to different pressure and temperature. Due to this the clearance will be affected. The strain in the casing should be given maximum importance, since it is a factor which governs the optimum performance of every turbine. This project deals with the modeling of three different types of casing which covers all the possible types of turbine casing that includes impulse, reaction and combined impulse-reaction turbine. In this project the analysis of each turbine casing is done using Ansys software to predict the strain rate. The optimization is then carried out using design optimization tool in Ansys to improve the operational performance of the turbine. The results showed the turbine performance is significantly improved.

ஆய்வுச் சுருக்கம்

மின்சாரம் உற்பத்தி செய்யும் இயந்திரங்களில் நீராவி டர்பைன் மிகவும் முக்கியமான ஒன்றாகும். பொதுவாக டர்பைனுடைய செயல் திறனானது அதனுடைய இறக்கைக்கும், வெளி உறைக்கும் இடைப்பட்ட இடைவெளியையே மிகவும் சார்ந்துள்ளது. எப்பொழுதும் வெவ்வேறு அழுத்தமும், வெவ்வேறு வெப்பநிலையும் கொண்ட நீராவியானது டர்பைனுடைய வெளிஉறையின் உட்பரப்பின் மீது பட்டுக் கொண்டிருப்பதால் வெளிஉறையானது வெளிநோக்கி விரிவடையும். இதனால் இடைவெளியானது பாதிக்கப்படும். டர்பைனுடைய ஆப்டிமம் செயல் திறனை இந்த விரிவடைதல் பாதிப்பதால் இது மிகவும் முக்கியமான காரணியாக கருதப்படுகிறது. இந்த ஆய்வானது இம்பல்சு, ரியாக்ஷன் மற்றும் இரண்டும் இணைந்த இம்பல்சு - ரியாக்ஷன் ஆக மொத்தம் மூன்று வகையான டர்பைனுடைய வெளிஉறையினை வடிவமைத்தலும், அவைகளை “ஏன்சிஸ்” மென்பொருளைக் கொண்டு ஆய்வு செய்து விரிவடைதல் அளவை கண்டுபிடிப்பதுவும் ஆகும். பிறகு ஏன்சிஸ் மென்பொருளில் உள்ள ஆப்டிமைசேஷன் டூல்ஐ கொண்டு மூன்று வகையான வெளிஉறையினையும் ஆப்டிமைசேஷன் செய்து டர்பைனுடைய செயல் திறனை அதிகரிக்க செய்வதாகும். இந்த ஆய்வின் முடிவானது டர்பைனுடைய செயல் திறன் அதிகரித்து இருப்பதைக் காட்டுகிறது.

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LIST OF SYMBOLS & ABBREVATIONS

σ - Stress (N/m^2)

P - Force (N)

A_0 - Unit area (m^2)

e - Strain

δ - Deflection (m)

L_0 - Gage length (m)

σ_u - Ultimate stress (N/m^2)

σ_f - Fracture stress (N/m^2)

σ_y - Yield stress (N/m^2)

σ_{pl} - Proportionality limit (N/m^2)

FEA - Finite Element Analysis

GUI - Graphical User Interface

NGV_s - Nozzle Guide Vanes

LDV - Laser Doppler Velocimeter

JCG - Jacobean Conjugate Gradient

CHAPTER 1

INTRODUCTION

1.1 TURBINE:

A turbo machine is a power or head-generating machine, which employs the dynamic action of a rotating element – the rotor. The action of the rotor changes the energy level of the continuously flowing fluid through the turbo machine. The head generating turbo machines increase the head using external power supply. These machines are called compressors. The power generating turbo machines decrease the head or energy level of the working fluids passing through them. These machines are called turbines, e.g. steam, gas, hydro, wind, and solar turbines. They are coupled to power absorbing machines, such as electric generators, pumps, compressors, etc.

1.2 STEAM TURBINE:

The steam turbine stands as the most important prime mover in existence. It offers many advantages. From a thermodynamic point of view the steam turbine occupies a favorable position, as it can translate into mechanical work a relatively large fraction of the heat energy rendered available by the expansion of steam in the turbine. Its thermal economy is also fairly good, especially in turbines of large output and operating at fairly high pressures.

From the mechanical point of view, the steam turbine is ideal, because the propelling force is applied directly to the rotating element of the machine and has not, as in the reciprocating engine, to be transmitted through a system of connecting links which are necessary to transform efficiently a reciprocating motion into a rotary motion.

1.3 TURBINE CASING:

Turbine casing has complicated shape often varying in diameter along its length to incorporate the steam chambers for supply of steam to its various stages, to accommodate the rotor with growing diameter at its low pressure end and the exhaust piping as well as pass-out chambers or extraction points if any. The exhaust piping of large condensing turbines are especially noted to have large dimensions.

A casing must be sufficiently strong satisfying the strength and stiffness requirements under normal conditions of operation. The use of lugs, cylindrical ribs and the end covers increase the stiffness of the cylinder. The exhaust pipes for large-capacity turbines are provided with special ribs inside them in order to increase their stiffness. These ribs also act as guides for the steam flowing to the condenser thus reducing heat losses in exhaust piping.

1.4 IMPORTANCE OF THE PROJET:

The operational performance of an every turbine is mainly depends on the clearance that is a flow area of steam available between the blades and the casing. The operational performance of every turbine is indirectly proportional to the clearance value. Normally the inner surface of a turbine casing is subjected to high pressure and high temperature and also each and every region of the turbine casing is subjected to different pressure and different temperature. Due to this the clearance will be affected. So the operational performance also will affect. The main objective of this project is to improve the operational performance of every turbine by optimize the existing design of every turbine casing.

CHAPTER 2

LITERATURE SURVEY

Porreca, Behr, Kalpas, Abhari and Schlienger (2005), a unique comparative experimental and numerical investigation carried out on two test cases with shroud configurations, differing only in the labyrinth seal path, is presented in this paper. The blade geometry and tip clearance are identical in the two test cases. The geometries under investigation are representative of an axial turbine with a full and partial shroud, respectively. Global performance and flow field data were acquired and analyzed. Computational simulations were carried out to complement the investigation and to facilitate the analysis of the steady and unsteady flow measurements. A detailed comparison between the two test cases is presented in terms of flow field analysis and performance evaluation. The analysis focuses on the flow effects reflected on the overall performance in a multi-stage environment. Strong interaction between the cavity flow and the blade tip region of the rotor blades is observed up to the blade mid span. A marked effect of this interaction can be seen in the downstream second stator where different vortex structures are observed. Moreover, in the partial shroud test case, a strong tip leakage vortex is developed from the first rotor and transported through the downstream blade row. A measurable change in the second stage efficiency was observed between the two test cases. In low aspect ratio blades within a multi-stage environment, small changes in the cavity geometry can have a significant effect on the mainstream flow. The present analysis has shown that an integrated and matched blade-shroud aerodynamic design has to be adopted to reach optimal performances. The additional losses resulting from small variations of the sealing geometry could result in a gain of up to one point in the overall stage efficiency.

Graham Pullan., John Denton., and Eric Curtis (2006), the experimental data and numerical simulations are presented from a research turbine with low aspect ratio nozzle guide vanes (NGVs). The combined effects of mechanical and aerodynamic constraints on the NGV create very strong secondary flows. This paper describes three designs of NGV that have been tested in the turbine, using the same rotor row in each case. NGV 2 used three-dimensional design techniques in an attempt to improve the performance of the datum NGV 1 blade, but succeeded only in creating an intense vortex shed from the trailing edge (as previously reported) and lowering the measured stage efficiency by 1.1% points.

NGV 3 was produced to avoid the "shed vortex" while adopting a highly aft-loaded surface pressure distribution to reduce the influence of the secondary flows. The stage with NGV 3 had an efficiency 0.5% points greater than that with NGV 1. Detailed comparisons between experiment and computations, including predicted entropy generation rates, are used to highlight the areas where the loss reduction has occurred and hence to quantify the effects of employing highly aft-loaded NGVs.

Behr, Porreca, Mokulys, Kalfas, and Abhari (2006), this paper presents the outcome of a recent study in clocking-related flow features and multistage effects occurring in high-pressure turbine blade geometries. The current investigation deals with an experimentally based systematic analysis of the effects of both stator-stator and rotor-rotor clocking. Due to the low aspect ratio of the turbine geometry, the flow field is strongly three-dimensional and is dominated by secondary flow structures. The investigation aims to identify the flow interactions involved and the associated effects on performance improvement or degradation. Consequently a three dimensional numerical analysis has been undertaken to provide the numerical background to the test case considered. The experimental studies were performed in a two stage axial research turbine facility. The turbine provides a realistic multi-stage environment, in which both stator blade rows and the two rotors can be clocked relative to each other. All blade rows have the same blade number count, which tends to amplify clocking effects. Unsteady and steady measurements were obtained in the second stage using fast response aerodynamic probes and miniature pneumatic five-hole probes. The current comprehensive investigation has shown that multistage and unsteady flow effects of stator and rotor clocking in low aspect ratio turbines are combined in a nonlinear fashion caused by axial and radial redistribution of low energy fluid. The integral result of clocking on stage efficiency is compensated by competing loss generating mechanisms across the span.

Gottlich, Neumayer, Woisetschlager, Sanz, and Heitmeir (2004), the current paper presents steady and unsteady flow data of a transonic test turbine stage operating under flow conditions similar to modern highly loaded gas turbines. Measurements were performed between stator and rotor as well as downstream of the rotor in planes perpendicular to the rotor axis. Time-resolved axial and tangential velocities were measured by a two-component laser doppler velocimeter (LDV) to investigate unsteady phenomena, while time-averaged flow properties were measured by means of a pneumatic seven-hole probe for all three spatial directions. The time-resolved investigation done by LDV allows to present velocity fields, flow angles and turbulence data at different stator rotor positions during one blade passing period. Averaging these results enabled comparison with the pneumatic multi hole probe measurement.

Brian R.McAuliffe and Steen A.Sjolandar (2004), the paper presents mid-span measurements for a turbine cascade with active flow control. Steady blowing through an inclined plane wall jet has been used to control the separation characteristics of a high-lift low-pressure turbine airfoil at low Reynolds numbers. Measurements were made at design incidence for blowing ratios from approximately 0.25 to 2.0 (ratio of jet-to-local free stream velocity), for Reynolds numbers of 25,000 and 50,000 (based on axial chord and inlet velocity), and for free stream turbulence intensities of 0.4% and 4%. Detailed flow field measurements were made downstream of the cascade using a three-hole pressure probe, static pressure distributions were measured on the airfoil suction surface, and hot-wire measurements were made to characterize the interaction between the wall jet and boundary layer. The primary focus of the study is on the low-Reynolds number and low-free stream turbulence intensity cases, where the baseline airfoil stalls and high profile losses result. For low free stream turbulence (0.4%), the examined method of flow control was effective at preventing stall and reducing the profile losses. At a Reynolds number of 25,000, a blowing ratio greater than 1.0 was required to suppress stall. At a Reynolds number of 50,000, a closed separation bubble formed at a very low blowing ratio (0.25) resulting in a significant reduction in the profile loss. For high free stream turbulence intensity (4%), where the baseline airfoil has a closed separation bubble and low profile losses, blowing ratios below 1.0 resulted in a larger separation bubble and higher losses. The mechanism by which the wall jet affects the separation characteristics of the airfoil is examined through hot-wires traverse measurements in the vicinity of the slot.

Ray Beebe (2003), described many power generation steam turbine generators today are required in service well beyond their intended lifetimes. Dismantling for inspection is expensive, and owners need to consider all relevant information in making the decision. Application of condition monitoring in all the applicable methods are justified, with each showing different degradation modes. Performance analysis is less well publicized, yet unlike vibration analysis and oil debris analysis, it will show conditions which reduce machine efficiency and output, such as deposits on blades and erosion of internal clearances. Data obtained from tests before and after overhaul also reveal whether any restorative work achieved the expected improvements in performance. The paper outlines, with examples, some condition monitoring techniques that have contributed to retaining some large fossil machines in service for up to 17 years without opening high-pressure sections.

CHAPTER 3

STEAM TURBINE

3.1 INTRODUCTION:

The steam turbine is one of the most important power generating turbo machine. The steam turbine is a prime mover in which the potential energy of the steam is transformed into kinetic energy and the latter in its turn is transformed into mechanical energy of rotation of the turbine shaft.

The turbine shaft, directly, or with the help of a reduction gearing, is connected with the driven mechanism. Depending on the type of driven mechanism a steam turbine may be utilized in the most diverse fields of industry for power generation and for transport.

3.2 CLASSIFICATION OF STEAM TURBINE:

Steam turbines are broadly classified into three types, depending upon the way in which the transformation of potential energy into the kinetic energy of a steam jet is achieved.

- Impulse
- Reaction
- Combined (impulse-reaction)

3.2.1 Impulse Turbine:

The turbines in which the complete process of expansion of steam takes place only in stationary annals (nozzles), and the velocity energy is transformed into mechanical work on the turbine blades (without any further expansion taking place in them) are known as impulse turbines.

3.2.2 Reaction Turbine:

The turbines in which the complete process of expansion of steam takes place both in the stationary or guide blades and in the rotating or moving blades, so that the overall decrease in heat content in all the stages is more or less uniformly distributed between them are known as reaction turbines.

3.2.3 Impulse - Reaction Turbine:

The turbine in which the drop in pressure suffered by the steam during its flow through moving blades causes a further generation of kinetic energy within the blade and adds to the propelling force which is applied to the turbine rotor.

According to the direction of steam flow into the turbine, it can be classified into two types:

Axial flow turbine
Radial flow turbine

3.2.4 Axial flow Turbine:

Fluid flow occurs mainly in the axial direction, i.e. parallel to the axis of rotation. This is called as axial flow turbine. In an Axial flow turbine, the radial component of the fluid velocity is negligible. The change in radius between the entry and exit of the stage is small.

The turning of the fluid in axial stages is not too severe and the length of the blade passages is short. This leads to lower aerodynamic losses and higher stage efficiencies.

On account of the individual blade root figures the rotor of an axial stage has limited mechanical strength. This restricts the maximum permissible peripheral speed of the rotor.

3.2.5 Radial flow Turbine:

Fluid flow occurs mainly in the radial direction, i.e. perpendicular to the axis of rotation. This is called as radial flow turbine. Therefore, the change of radius between the entry and exit of the stage is finite. This causes the finite change in the energy level of the fluid due to the centrifugal energy.

Radial stage employs 'one piece' rotors in which the blades are an integral part of the main body. This makes a radial rotor mechanically stronger than an axial type in which the blades are separately fixed. Therefore radial machines can employ higher peripheral speeds.

On account of higher peripheral speeds and additional change in the energy level of the fluid caused due to centrifugal energy, much higher values of the pressure ratio per stage are obtained compared to the axial type.

3.3 COMPONENTS OF STEAM TURBINE:

3.3.1 Moving blade:

Moving blades in a turbine are meant for the conversion of the kinetic energy of the flowing steam into the mechanical work on the turbine shaft. The work done by steam is transmitted to the shaft through the disc on which the blades are mounted. Various methods are in use for the attachment of blades to the drum or discs of a turbine. Short blades having small centrifugal force are attached to the disc.

3.3.2 Fixed blade:

Fixed blades in a turbine are meant for same as the moving blades, that conversion of heat energy into kinetic energy due to expansion of steam and kinetic energy into mechanical work at the turbine shaft. But the velocity of steam increased in the fixed blade. The fixed blade is used in reaction turbine.

3.3.3 Nozzle:

Nozzle is a passage of varying cross sectional areas in which the potential energy of the steam is converted into kinetic energy. The increase in velocity of the steam at the exit of the nozzle is obtained due to the decrease in heat content of the steam. The nozzle is used only in impulse turbine.

3.3.4 Turbine stator (casing):

Turbine stator has complicated shape often varying in diameter along its length to incorporate the steam chambers for supply of steam to its various stages, to accommodate the rotor with growing diameter at its low pressure end and the exhaust piping as well as pass-out chambers or extraction points if any. The exhaust piping of large condensing turbines are especially noted to have large dimensions.

A stator must be sufficiently strong satisfying the strength and stiffness requirements under normal conditions of operation. The use of lugs, cylindrical ribs and the end covers increase the stiffness of the cylinder. The exhaust pipes for large-capacity turbines are provided with special ribs inside them in order to increase their stiffness. These ribs also act as guides for the steam flowing to the condenser thus reducing heat losses in exhaust piping.

CHAPTER 4

STRESS AND STRAIN

4.1. INTRODUCTION

Materials that we come across may be classified into elastic, plastic and rigid materials. An elastic materials that undergoes a deformation when subjected to an external loading such that the deformation disappears on the removal of the loading. A plastic material undergoes a continuous deformation during the period of loading and the deformation is permanent and the material does not regain its original dimensions on the removal of the loading. A rigid material does not undergo any deformation when subjected to an external loading.

A material when subjected to an external load system undergoes a deformation. Against this deformation the material will offer a resistance that lends to prevent the deformation. The material offers this resistance as long as the member is forced to remain in the deformed condition. The material by virtue of its strength offers this resistance. This is called as stress.

4.2 STRESS-STRAIN:

The stresses (σ), i.e., forces acting on a body, produce changes in their dimensions known as strains. The determination of the relationship between the external forces applied to a body and the stresses and strains within the body form the basis of this field of stress analysis.

$$\sigma = \frac{P}{A_0}$$

The force P also produces a stretching or elongation of the specimen. Since the stress is uniform throughout the gage length L_0 and on the basis that the material is perfectly homogeneous, it is assumed that this uniform stress will produce uniform total elongation. The elongation per unit of length e is called strain, and is expressed as

$$e = \frac{\delta}{L_0}$$

Strain may be defined as the change in unit length resulting from stress.

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Basic analytical stress solutions involve the stress-strain relationship of the material. The relationship differs for various materials and is determined by a simple tension or compression test of the material from which a stress strain diagram is plotted.

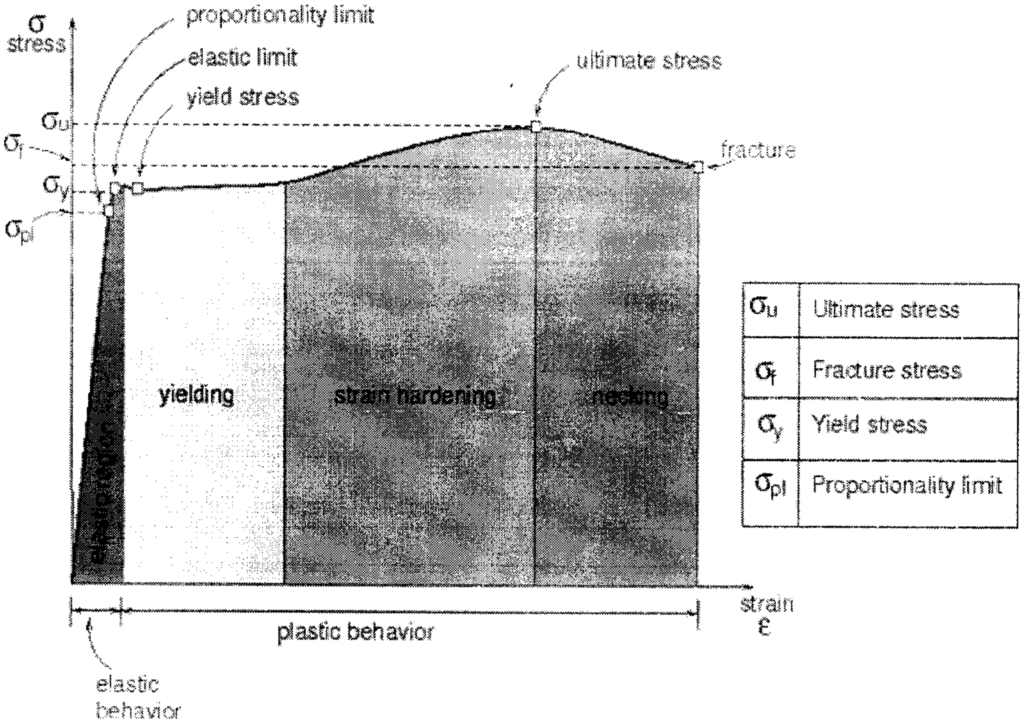


Fig. 4.1 Stress Strain curve

Elasticity is the property of a material to return to its original shape after removal of the load. The elastic range is the first stage of loading wherein the material returns to its original shape after unloading. Proportional limit is the greatest stress, as represented by point in fig. 2.1 that a material can withstand without deviating from the direct proportionality of stress to strain. Elastic limit is the maximum stress, as represented by point in fig 2.1, which a material is capable of withstanding without permanent deformation upon complete release of the stress. Yield point is the stress, represented by point in fig 2.1, at which there occurs a marked increase in strain without an increase in stress. This phenomenon of yielding is due to a sudden plastic flow of the material. Ultimate stress is the maximum stress which the material will withstand. This stress equals the maximum load divided by the original cross-sectional area of the specimen.

4.3 STRESSES IN TURBINE CASING:

There are two types of stresses acting on a turbine casing which cause the damage to the casing. The following are the two:

- Stress due to Pressure
- Thermal Stress

4.3.1 Stress due to Pressure:

Consider the steam turbine, in which the stress is created inside the surface of the turbine casing or stator due to the pressure of the steam that is flowing on the flow area available between the turbine blades and the turbine casing.

4.3.2 Thermal Stress:

When the temperature of a material changes there will be corresponding change in its dimensions. When a member is free to expand or contract due to the rise or fall of temperature, no stresses will be induced in the member. But, if the natural change in length due to rise or fall of temperature were prevented, stress will be offered. Stresses that result from restricting the natural growth or contraction of a material due to a temperature change are called thermal stresses.

4.4 MATERIALS FOR TURBINE CASINGS:

Steam turbine casings are typically large structures, with complex shapes that must provide the pressure containment for the steam turbine. Because turbine casing components are massive, their cost has a strong impact on the overall cost of the turbine. The materials used currently for inner and outer casings are the 1-2CrMo steels, usually as castings. The temperature limit of these alloys in this application is approximately 566°C, mainly due to their resistance to steam oxidation. For higher temperatures, cast 9Cr-1MoVNb alloys are considered to be adequate in terms of strength capabilities to 593°C, while the 12Cr steels in either cast or forged form currently appear to be limited to 650°C, assuming acceptable steam oxidation resistance. Casings made of cast martensitic/ferritic steels must still be heat-treated and tempered to produce the best combination of high temperature strength and ductile-to-brittle transition temperature (DBTT) behavior at low temperature. In our case the material selected is 12Cr steels to withstand the maximum pressure value of 120 bar and maximum temperature value of 640°C.

4.4.1 Properties of 12Cr Steels

- Modulus of Elasticity - 190 – 220 Gpa
- Density - 7700 Kg/m^3
- Thermal conductivity - 25 W/mK
- Specific heat capacity - 460 J/KgK
- Yield strength - 0.42x10^8 N/m^2
- Poisson ratio - 0.27

CHAPTER 5

FINITE ELEMENT ANALYSIS

5.1 INTRODUCTION:

Finite element analysis, the core of computer aided engineering dictate the modern mechanical industry and play a decisive role in cost cutting technology.

Finite element analysis is a technique to simulate loading condition on a design and determine the design's response to those conditions. The finite element model, which has a finite number of unknowns, can only approximate the response of the physical system, which has infinite unknowns.

Finite Element Analysis (FEA) enables engineers to perform the following tasks:

- Build computer models or transfer CAD models of structures, products, components, or systems.
- Apply operating loads or other design performance conditions.
- Study physical responses, such as stress levels, temperature distributions, or electro magnetic fields.
- Optimize a design in the development process to reduce production costs.
- Do prototype testing in environments where it otherwise would be undesirable or impossible (for example, biomedical applications).

The Finite Element Analysis (FEA) has a comprehensive graphical user interface (GUI) that gives users easy, interactive access to program functions, commands, documentation, and reference material. An intuitive menu system helps users navigate through the Finite Element Analysis (FEA).We can input data using a mouse, a keyboard or a combination of both.

5.2 ORGANIZATION OF FEA:

The Finite Element analysis (FEA) is organized into two basic levels:

- Begin level
- Processor (Routine) level

5.2.1 Begin Level:

The begin level acts as a gateway of the Finite Element Analysis (FEA). It is also used for certain global program controls such as changing the job name, clearing (zeroing out) the data base, and copying binary files. When we first enter the program, we are at the beginners level.

5.2.2 Processor level:

At the Processor level, several processors are available. Each processor is a set of functions that perform a specific analysis task. For example, the general preprocessor is where we build the model, the solution processor is where we apply loads and obtain the solution, and the general postprocessor is where we evaluate the results of a solution. An additional postprocessor enables us to evaluate solution results at specific points in the model as a function of time.

5.3 PERFORMING A TYPICAL FEA:

The Finite Element Analysis (FEA) has a ranging from simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis. The analysis packages are some specific procedures for performing analyses for different engineering disciplines. The next few section of this chapter covers general steps that are common to most analysis.

A typical analysis has three distinct steps:

- Build the model.
- Apply loads and obtain the solution.
- Review the results.

5.4 GENERAL PREPROCESSOR:

The ultimate purpose of a finite element analysis is to recreate mathematically the behaviors of an actual engineering system. In other words, the analysis must be an accurate mathematical model of a physical prototype. In the broadest sense, this model comprises all the nodes, elements, material properties, real constants, boundary conditions, and other features that are used to represent the physical system.

5.4.1 Model Generation:

In FEA terminology, the term model generation usually takes on the narrower meaning of generating the nodes and elements that represent the spatial volume and connectivity of the actual system. Thus model generation means the process of defining the geometric configuration of the model's nodes and elements.

The Finite Element Analysis (FEA) offers the following approaches to model generation:

- Creating a solid model within FEA package.
- Using direct generation.
- Importing a model created in a Computer Aided Design (CAD) system.

5.4.2 Meshing:

The procedure for generating a mesh of nodes and elements consists of three main steps:

- Set the element attributes.
- Select Free or Mapped meshing.
- Generate the mesh.

Before generate a mesh of nodes and elements, the appropriate element attributes must be defined. That is the following must be specified.

- Element type (for example PLANE 42, PLANE 55, etc.,)
- Real constant set (usually comprising the element's geometric properties such as thickness or cross–sectional area)
- Material properties set (such as Young's modulus, thermal conductivity, etc.,)

Before meshing the model and even before building the model, it is important to think about whether a free mesh or a mapped mesh is appropriate for the analysis. A free mesh has no restrictions in terms of element shapes, and has no specified pattern applied to it.

Compared to a free mesh, a mapped mesh is restricted in terms of the element shape it contains and the pattern of the mesh. A mapped area mesh contains either only quadrilateral or only triangular elements, while a mapped volume mesh contains only hexahedron elements. In addition, a mapped mesh typically has a regular pattern, with obvious rows of elements. If we want this type of mesh, we must build the geometry as a serious of fairly regular volumes and/or areas that can accept a mapped mesh.

5.4.3 Loading Overview:

The main goal of a Finite Element Analysis is to examine how a structure or component responds to certain loading conditions. Specifying the proper loading conditions is, therefore, a key step in the analysis. We can apply loads on the model in a variety of ways in the analysis.

The word loads includes boundary conditions and externally or internally applied forcing functions.

Examples of loads in different disciplines are:

Structural : displacements, forces, pressures, gravity.
Thermal : temperatures, heat flow rates, convections, internal heat generation.
Magnetic : magnetic potentials, magnetic flux, magnetic current segments, source current density.

Electric : electric potentials, electric current, electric charges, charge densities.
Fluid : velocities, pressures.

5.5 SOLUTION PROCESSOR:

Two methods of solution are available in the finite element analysis, Frontal solution and Jacobean Conjugate Gradient {JCG) solution. We can choose any of this method. The main feature of the Frontal solver is that it does not assemble complete global matrix, instead the assembly and solution steps are performed simultaneously as each element is progressed by the solver. The JCG solve also starts with element matrix formulation but the reaming steps are different. The JCG solver is best suited for 1-D scalar field analysis.

5.6 GENERAL POSTPROCESSOR:

After building the model and obtaining the solution, one required for answers some critical questions: Will the design really work when put to use? How high are the stresses in this region? How does the temperature of this part vary with time? What is the heat loss across this face of my model? How does the magnetic flux flow through this device? How does the placement of this object affect fluid flow? The postprocessors can help for these types of questions and others.

Post processing means that, reviewing the results of an analysis. It is probably the important step in the analysis, because we are trying to understand how the applied loads affect our design, how good our finite element mesh is, and so on.

5.6.1 Data for Post processing:

The solution phase calculates two types of result data:

- Primary data consists of the degree of freedom solution calculated at each node: displacements in a structural analysis, temperatures in a thermal analysis, and so on. These are also known as nodal solution data.
- Derived data are those results calculated from the primary data such as stresses and strains in a structural analysis, thermal gradients and fluxes in a thermal analysis, magnetic fluxes in a magnetic analysis, and the like. These are typically calculated for each element and may be reported at any of the following locations: at all nodes of each element, at all integration points of each element, or at the centroid of each element. Derived data are also known as element solution data, except when these are averaged at the nodes. In such cases, they become nodal solution data.

5.1 Primary and Derived data for Different Disciplines

Discipline	**Primary data**	**Derived data**
Structural	Displacement	Stress, strain, reaction, etc,
Thermal	Temperature	Thermal flux, thermal gradient, etc,
Magnetic	Magnetic potential	Magnetic flux, current density, etc,
Electric	Electric scalar potential	Electric field, flux density, etc,
Fluid	Velocity, pressure	Pressure gradient, heat flux, etc,

5.7 DESIGN OPTIMIZATION

Design optimization is a technique that seeks to determine an optimization design. By "optimum design", we mean one that meets all specified requirements but with a minimum expense of certain factors such as weight, surface area, volume, stress, cost, etc. In other words, the optimum design is usually one that is effective as possible.

Virtually any aspect of our design can be optimized: dimensions (such as thickness), shape (such as fillet radii), placement of supports, cost of fabrication, natural frequency, material property, and so on. Actually, any analysis item that can be expressed in terms of parameters can be subjected to design optimization.

The analysis program offers two optimization methods to accommodate a wide range of optimization problems. The sub problem approximation method is an advanced zero-order method that can be efficiently applied to most engineering problems. The first order method is based on design sensitivities and is more suitable for problems that require high accuracy.

For both the sub problem approximation and first order methods, the program performs a series of analysis-evaluation-modification cycles. That is, an analysis of the initial design is performed, the results are evaluated against specified design criteria, and the design is modified as necessary. This process is repeated until all specified criteria are met.

In addition to the two-optimization techniques available, the Analysis program offers a set of strategic tools that can be used to enhance the efficiency of the design process. For example, a number of random design iterations can be performed. The initial data points from the random design calculations can serve as starting points to feed the optimization methods mentioned above.

5.8 ABOUT ANSYS:

ANSYS the leading FEM simulation software, with its robust capabilities guides the engineering to arrive at a perfect design solution. It is applicable for fields like structural, thermal .electrical etc. ANSYS was first released in 1970,IBM mainframe computer which as much less powerful than today's PC's can solve 5000*5000 matrix in few minutes, instead of days as in the past. Accuracy of results is better than packages. Many consulting firms and hundreds of universities use ANSYS for analysis, research, and education use. ANSYS is recognizing world wide as one of the cost widely used and capable programs of its type.

5.8.1 Steps involved in preprocessor:

A common modeling session might follow the general outline (detailed information on italicized subjects can be found elsewhere in this guide):

- Begin by planning your approach: Determine our objectives, decide what basic form our model will take, choose appropriate element types, and consider how we will establish an appropriate mesh density. We will typically do this general planning before we initiate our ANSYS session.

- Enter the preprocessor (PREP7) to initiate our model-building session. Most often, we will build our model using solid modeling procedures.

- Generate basic geometric features using primitives and Boolean operators.

- Activate the appropriate coordinate system.

- Generate other solid model features from the bottom up. That is, create key points, and then define lines, areas, and volumes as needed.

- Use more boolean operators or number controls to join separate solid model regions together as appropriate.

- Create tables of element attributes (element types, real constants, material properties, and element coordinate system).

- Set element attributes pointers.

- Set meshing controls to establish our desired mesh density if desired. This step is not always required because default element sizes exist when we enter the program.

- Create nodes and elements by meshing our solid model.

- After we have generated nodes and elements, and features such as surface to-surface contact elements, coupled degrees of freedom and constraint equations.

- Save our model to Jobname ..DB.

- Exit the preprocessor.

As an alternative to creating our solid models within ANSYS, we create the model in our favorite CAD system and then import it into ANSYS for analysis, by saving the model in the IGES file format or in a file format supported by an ANSYS Connection product. Creating a model using a CAD package has the following advantages:

- Avoid a duplication of effort by existing CAD models to generate solid models for analysis.
- Use more familiar tools to create models.

However, models imported from CAD systems may require extensive repair if the models are not of suitable quality for meshing.

5.8.2 Steps involved in solution:

Solution step involve in defining the components boundary condition and the various load acted upon the component. This helps us to understand how the component will subject to various loads.

5.8.3 Steps involved in postprocessor:

Post processing means reviewing the results of an analysis. It is probably the most important step in the analysis, because to understand how the applied loads affect the design, how well the finite elements mesh, and so on. The various analyses are explained below:

Structural analysis:

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies and machine housings, as well as mechanical components such as pistons, machine parts, and tools. The primary unknowns (nodal degrees of freedom) calculated in a structural analysis are displacements. Other quantities, such as strains, stresses, and reaction forces, are derived form the nodal displacements.

Thermal analysis:

A thermal analysis calculates the temperatures distribution and related thermal quantities in a system or component. Typical thermal quantities of interest are:

- The temperature distributions.
- The amount of heat lost or gained.
- Thermal gradients.
- Thermal fluxes.

Thermal simulations play an important role in the design of many engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronics components. In many cases, engineers follow a thermal analysis with a stress analysis to calculate thermal (that is, caused by the thermal expansions or contractions.)

Coupled-Field analysis:

A coupled-field analysis is an analysis that takes into account interaction (coupling) between two or more disciplines (fields) of engineering. A piezoelectric analysis, for example, handles the interaction between the structural and electric fields: it solves for the voltage distribution due to applied displacements, or vice versa. Other examples of coupled-field analysis are thermal-stresses analysis, thermal-stress analysis, and fluid –structure analysis.

Some of the applications in which coupled-field analysis may be required are pressure vessels (thermal-stress analysis), fluid flow constrictions (fluid-structure analysis), induction heating (magnetic-thermal analysis), ultrasonic transducers (piezoelectric analysis), magnetic forming (magneto-structural analysis), and micro-electrochemical systems(MEMS).

CHAPTER 6

STRUCTURAL ANALYSIS

6. STRUCTURAL ANALYSIS

6.1 PREPROCESSOR STAGE:

Step 1: Create the model of the casings in Pro/E package and then save the model in the IGES file format.

Step 2: Open a new file in the ANSYS and set the preference as Structural Analysis.

Step 3: Import the model into the ANSYS. The created model can be generated in an active coordinate system.

Step 4: Save the model as jobname.db.

Step 5: Choose the element type as plane 42.

Step 6: Enter the Material property of the casing

Step 7: Create nodes and elements by meshing the model.

Step 8: Save model with the meshing as some other file as meshing.db.

6.2 PROCESSOR STAGE:

Step 9: Degrees of freedom to be constrained for the Structural Analysis.

Step 10: Apply the Boundary condition, i.e. pressure acting on the surface of the casing.

Step 11: Save the model with the load as load.db.

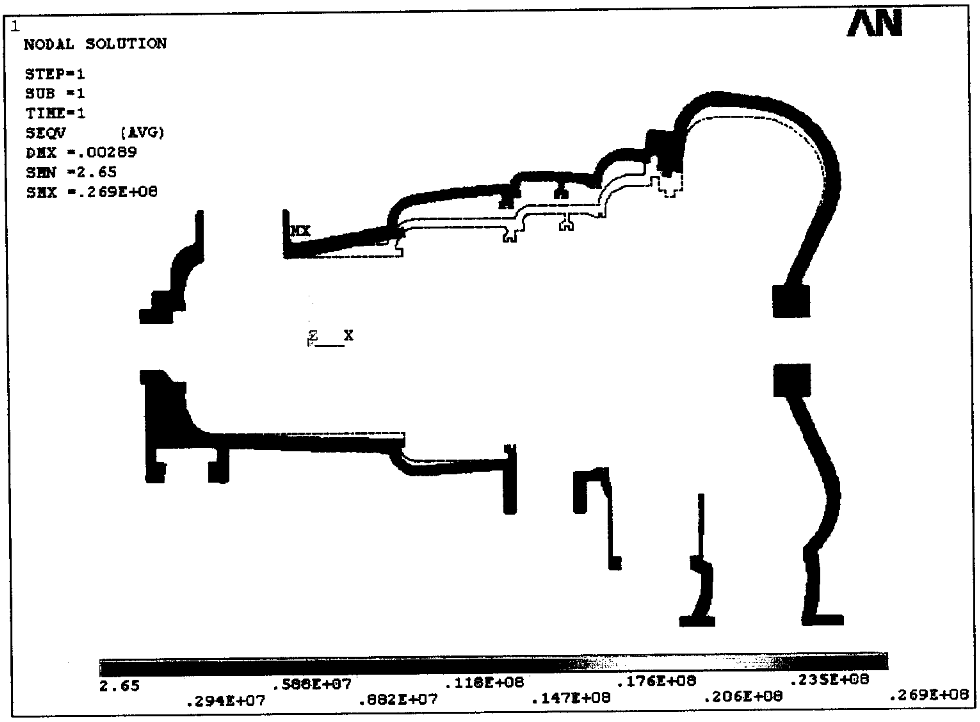
Step 12: Solve the model.

6.3 POSTPROCESSOR STAGE:

Step 13: Review the results of the analysis through graphical display.

Step 14: In results, get the deflection value as well as maximum stress value.

6.1 IMPULSE TURBINE CASING:



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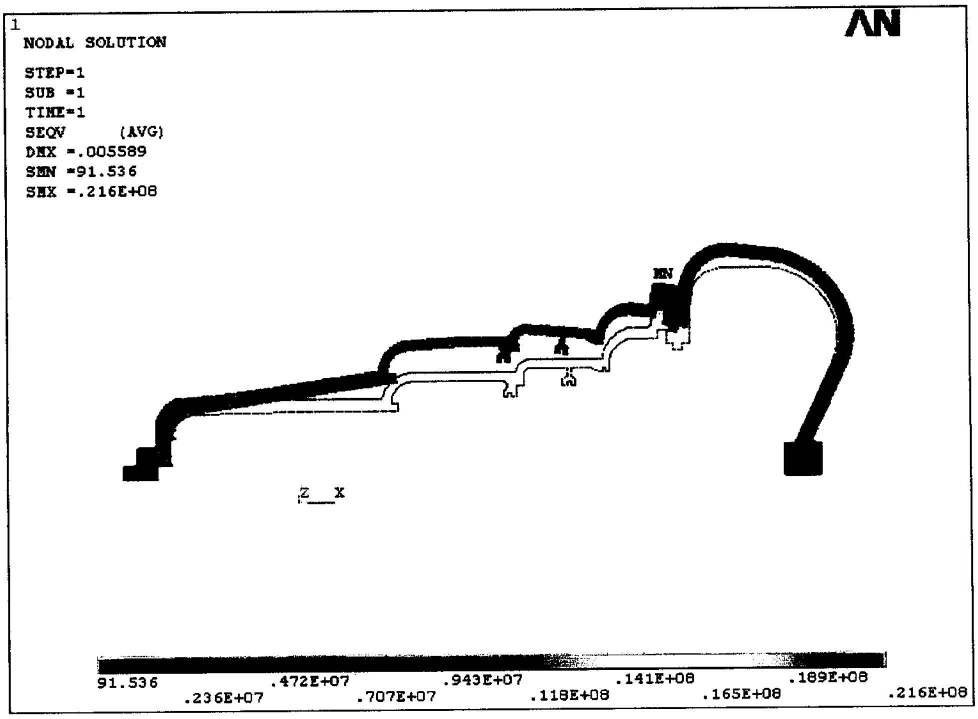

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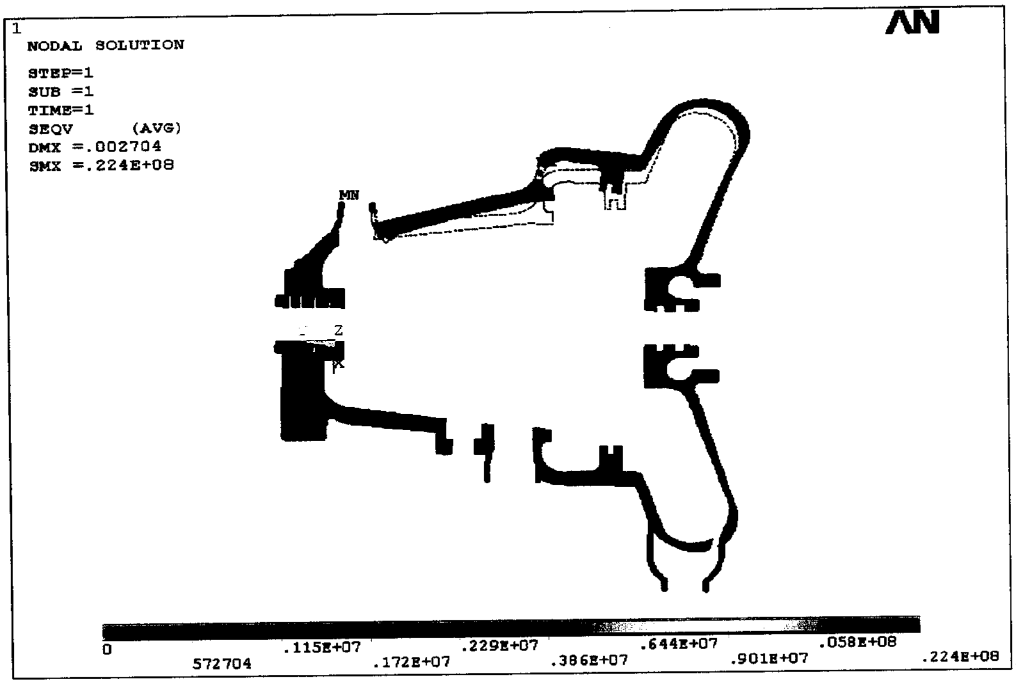

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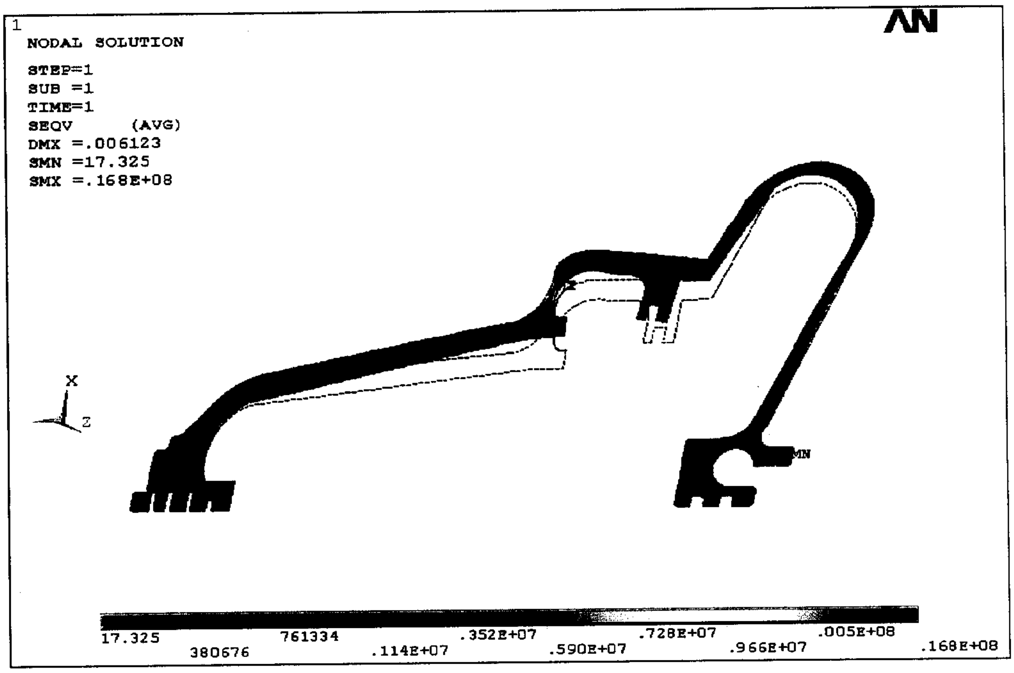

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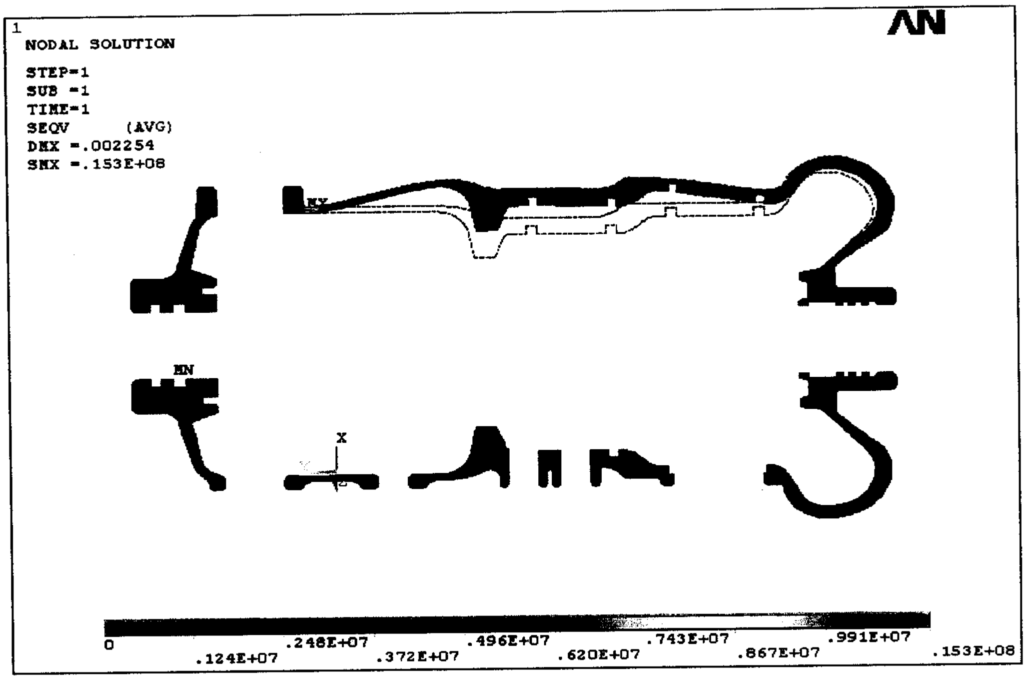
6.3 IMPULSE-REACTION TURBINE CASING:



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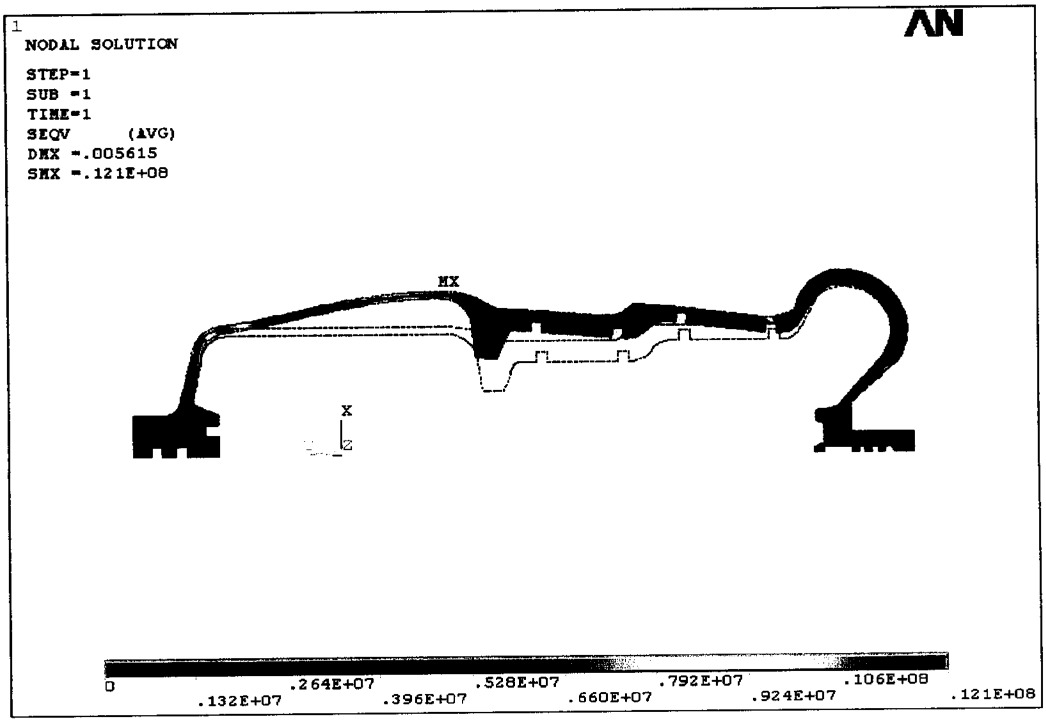

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6.4 INFERENCE FROM STRUCTURAL ANALYSIS:

6.1 Results of Structural Analysis at the Opened region

Turbine Casings	Strain value (mm)	Maximum Stress value (N/mm^2)
Impulse turbine	2.89	26.9×10^6
Reaction turbine	2.704	22.4×10^6
Impulse-Reaction turbine	2.254	15.3×10^6

6.2 Results of Structural Analysis at the Closed region

Turbine Casings	Strain value (mm)	Maximum Stress value (N/mm^2)
Impulse turbine	5.589	21.6×10^6
Reaction turbine	6.123	16.8×10^6
Impulse-Reaction turbine	5.615	12.1×10^6

From the Structural analysis, we know that the deformation does not occur at the ends. The reason is that the resistance offered by the ends of the casing is too high for deformation. The value of the stress is found maximum at the edges and areas of minimum thickness.

CHAPTER 7

THERMAL ANALYSIS

7. THERMAL ANALYSIS

7.1 PREPROCESSOR STAGE:

Step 1: Create the model of the casings in Pro/E package and then save the model in the IGES file format.

Step 2: Open a new file in the ANSYS and set the preference as Structural Analysis.

Step 3: Import the model into the ANSYS. The created model can be generated in an active coordinate system.

Step 4: Save the model as jobname.db.

Step 5: Choose the element type as plane 55 according to the usage.

Step 6: Enter the Material property of the casing

Step 7: Create nodes and elements by meshing the model.

Step 8: Save model with the meshing as some other file as meshing.db.

7.2 PROCESSOR STAGE:

Step 9: Apply the Boundary condition, i.e. temperature in the surface of the casing.

Step 10: Save the model with the load as load.db.

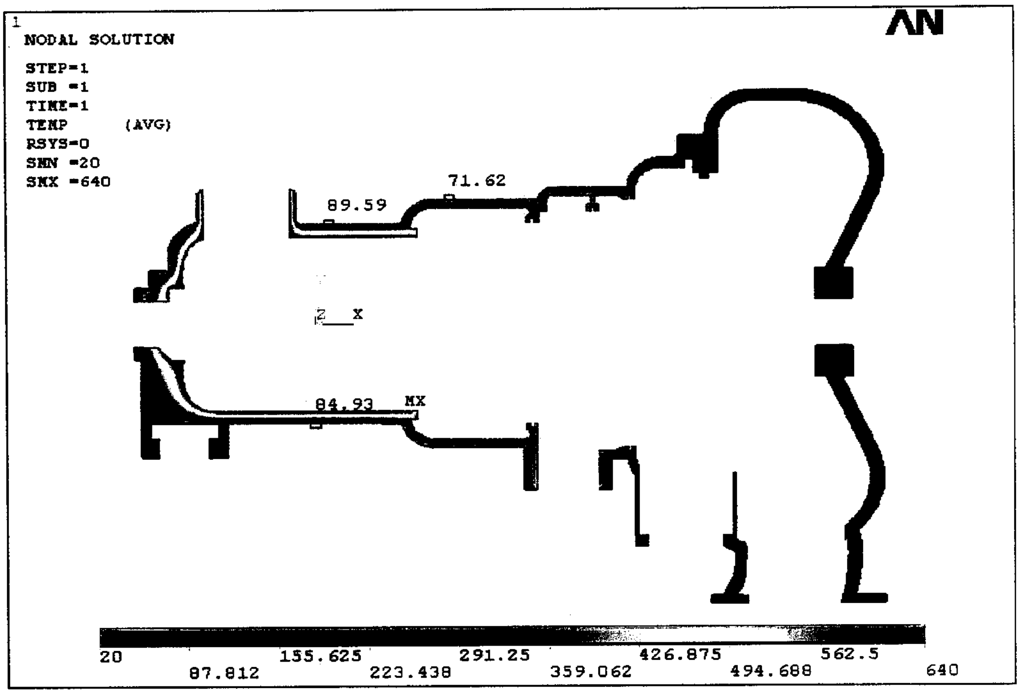
Step 11: Solve the model.

7.3 POSTPROCESSOR STAGE:

Step 12: Review the results of the analysis through graphical display.

Step 13: In results, get the temperature distribution of the casing.

7.1 IMPULSE TURBINE CASING:



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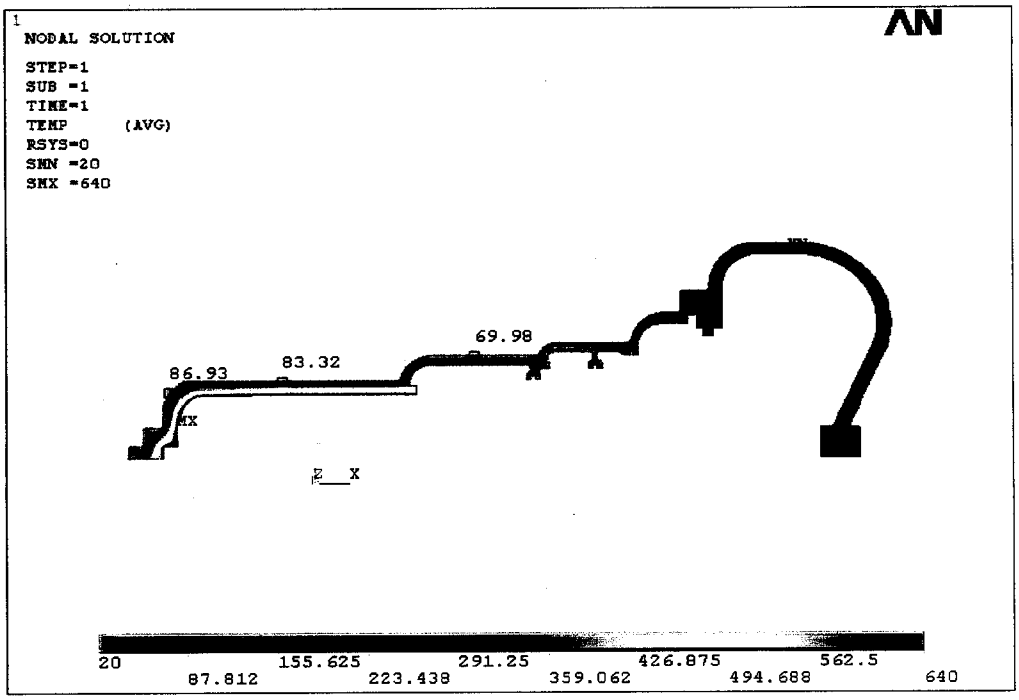

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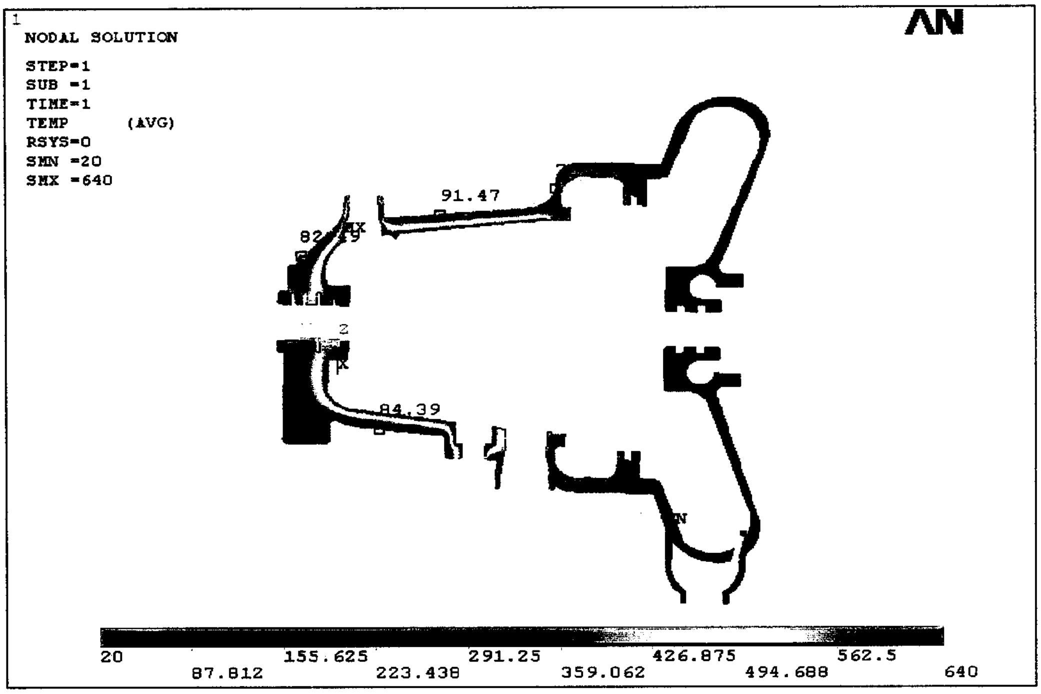
7.2 REACTION TURBINE CASING:



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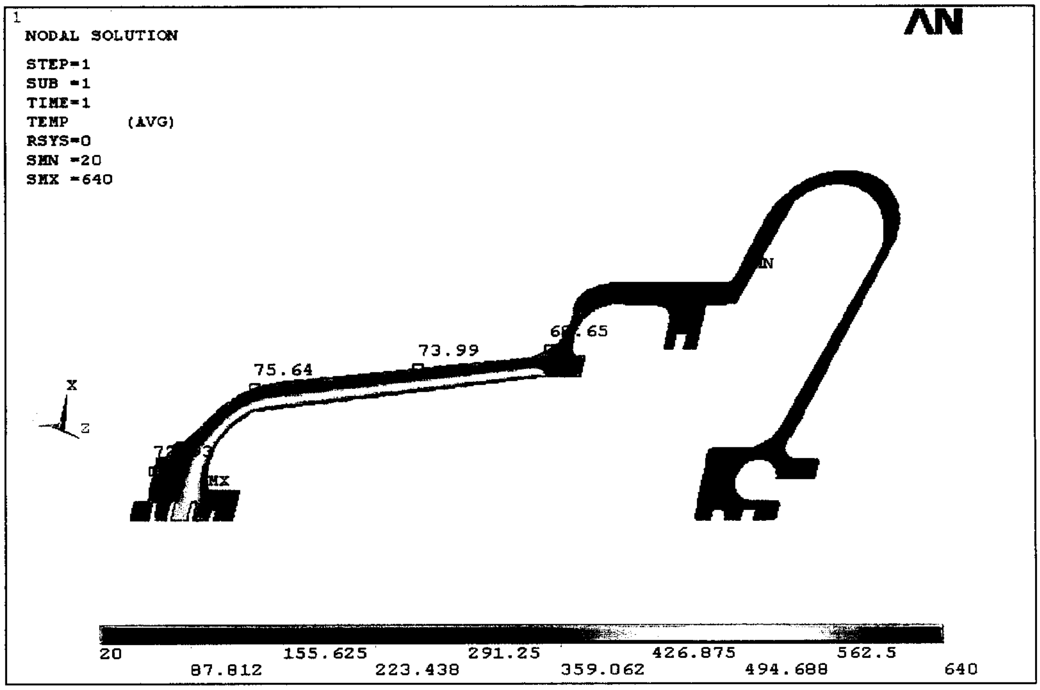

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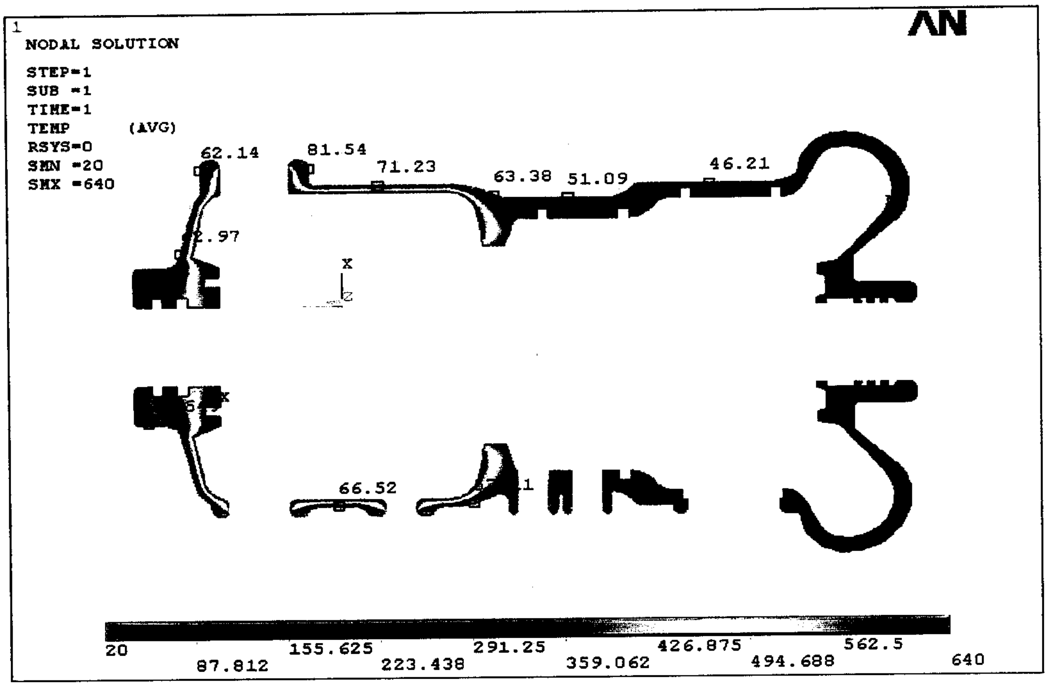
7.3 IMPULSE-REACTION TURBINE CASING:



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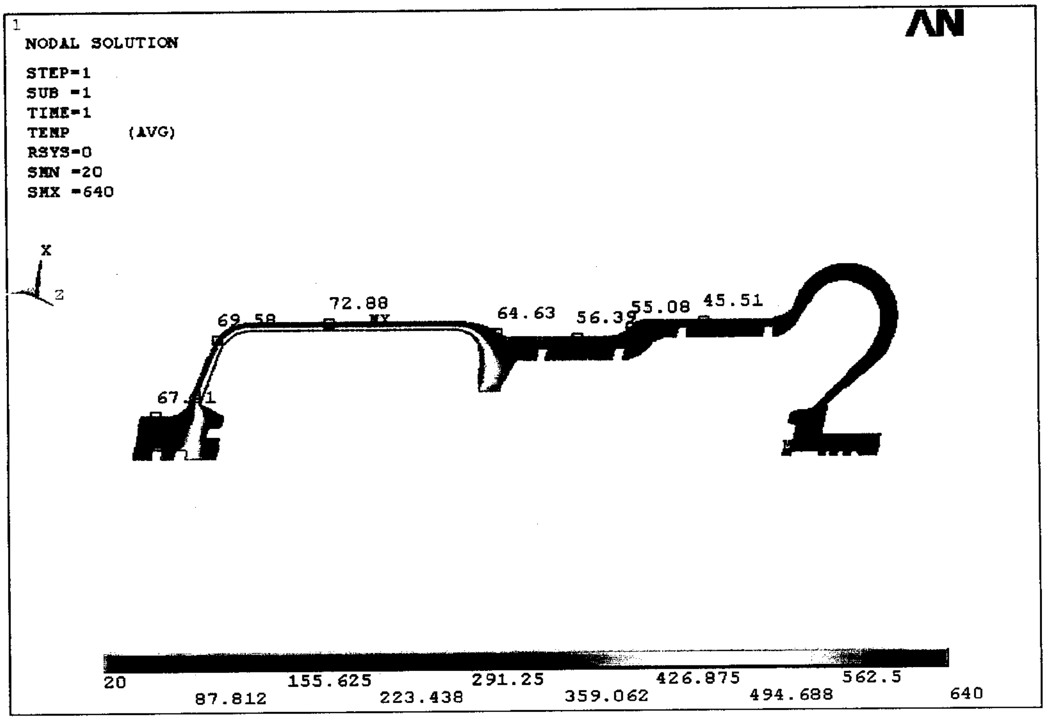

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7.4 INFERENCE FROM THERMAL ANALYSIS:

From the thermal analysis, we found that the failure occurs in turbine casings. The reason for the failure is that the heat loss to the surrounding environment is nearly 80°C. In order to reduce these losses to improve the performance of the turbines, the turbines have to be optimized with proper thermal insulation.

CHAPTER 8

THERMAL INSULATION

8.1 INTRODUCTION:

Thermal insulations are materials or combinations of materials that are used primarily to provide resistance to heat flow. Most insulation is heterogeneous materials made of low thermal conductivity materials.

Temperature difference is the driving force for heat flow, and the greater the temperature difference, the larger the rate of heat transfer. We can slow down the heat flow between two mediums at different temperatures by putting "barriers" on the path of heat flow. Thermal insulations serve as such barriers, and they play a major role in the design and manufacture of all energy efficient devices or systems, and they are usually the corner stones of all energy conservation projects.

8.2 REASON FOR INSULATING:

The use of insulation is not limited to energy conservation. Varies reasons for using insulation can be summarized as follows:

8.2.1 Energy conservation:

Conserving energy by reducing the rate of heat flow is the primary reason for insulating surfaces. Insulation materials that will perform satisfactorily in the temperature range of -268°C to 1000°C are widely available.

8.2.2 Personnel protection and Comfort:

A surface that is too hot poses a danger to people who are working in that area of accidentally touching the hot surface and burning themselves. To prevent this danger, the temperatures of hot surfaces should be reduced to below 60C by insulating them. Also the excessive heat coming off the hot surfaces creates an unpleasant environment in which to work, that adversely affects the performance or productivity of the workers, especially in summer months.

8.2.3 Maintaining process temperature:

Some processes in chemical industry are temperature – sensitive, and it may become necessary to insulate the process tanks and flow sections heavily to maintain the same temperature throughout.

8.2.4 Reducing temperature variations and fluctuations:

The temperature in an enclosure may vary greatly between the midsection and the edges if the enclosure is not insulated. For example, the temperature near the walls of a poorly insulated house is much lower than the temperature at midsection. Also the temperature in a non-insulated enclosure will follow the temperature changes in the environment closely and fluctuate. Insulation minimizes temperature no uniformity in an enclosure and slows down fluctuations.

8.3 SELECTING THE PROPER INSULATION:

There are several considerations in the selection of insulation for an application, and the first step in selecting the right insulation understands the nature of the application. Once the requirements of the application are determined, the task becomes selecting the most economical insulation among those that meet these requirements.

Here are the main considerations in the selection of insulation:

8.3.1 Purpose:

First we need to know the primary reason for insulating a surface. Most likely it is to conserve energy, but the purpose may also be to reduce the surface temperature for safety reasons. If the purpose is to reduce the temperature of hot surfaces below 60°C to meet a safety requirement, for example, we will use as much insulation as it takes to satisfy the requirement.

8.3.2 Special requirements:

Each insulation job has its own requirements, and they must be identified before a selection can be made. For example, rigid boards cannot be used for pipe insulation. Here the choice is between flexible insulation and performed rigid pipe insulation at a fixed diameter.

8.3.3 Environment:

The environment to which the insulation will be exposed may severely limit the choices. The insulation for the underground steam pipes will be quite different than the insulation for the steam pipes hanging inside the production facilities.

8.3.4 Easy of Handling and installation:

Some insulation has special requirements during storage prior to installation; others do not. The plant personnel can install some; others may require specialists. Some permit easy one step installation; others require cutting, wrapping, painting, and so forth, and are more involved.

8.3.5 Cost:

The final selection among the insulations that meet the requirements is made on the basis of lowest cost. Once the choices are narrowed to a few, an economic analysis is performed to identify the one with the minimum total cost. The thickness of insulation is also determined on the basis of minimum cost.

Other considerations for the selection of insulation include freedom from harmful chemicals (such as asbestos, which is no longer used because it is carcinogenic) and local availability.

The insulation material currently used for turbine casings is Calcium silicate because of its low thermal conductivity and the added strength to the casing.

8.4 PROPERTIES OF CALCIUM SILICATE:

Density	-	190 Kg/m^3
Thermal conductivity	-	0.063 W/mK
Modulus of Elasticity	-	110 – 125 GPa

CHAPTER 9

THERMAL ANALYSIS WITH INSULATION

9. THERMAL ANALYSIS WITH INSULATION

9.1 PREPROCESSOR STAGE:

Step 1: Create the model of the casings in Pro/E package and then save the model in the IGES file format.

Step 2: Open a new file in the ANSYS and set the preference as Structural Analysis.

Step 3: Import the model into the ANSYS. The created model can be generated in an active coordinate system.

Step 4: Save the model as jobname.db.

Step 5: Choose the element type as plane 55 according to the usage.

Step 6: Enter the Material property of the casing and the property of the insulation material.

Step 7: Create nodes and elements by meshing the model.

Step 8: Save model with the meshing as some other file as meshing.db.

9.2 PROCESSOR STAGE:

Step 9: Apply the Boundary condition, i.e. temperature in the surface of the casing.

Step 10: Save the model with the load as load.db.

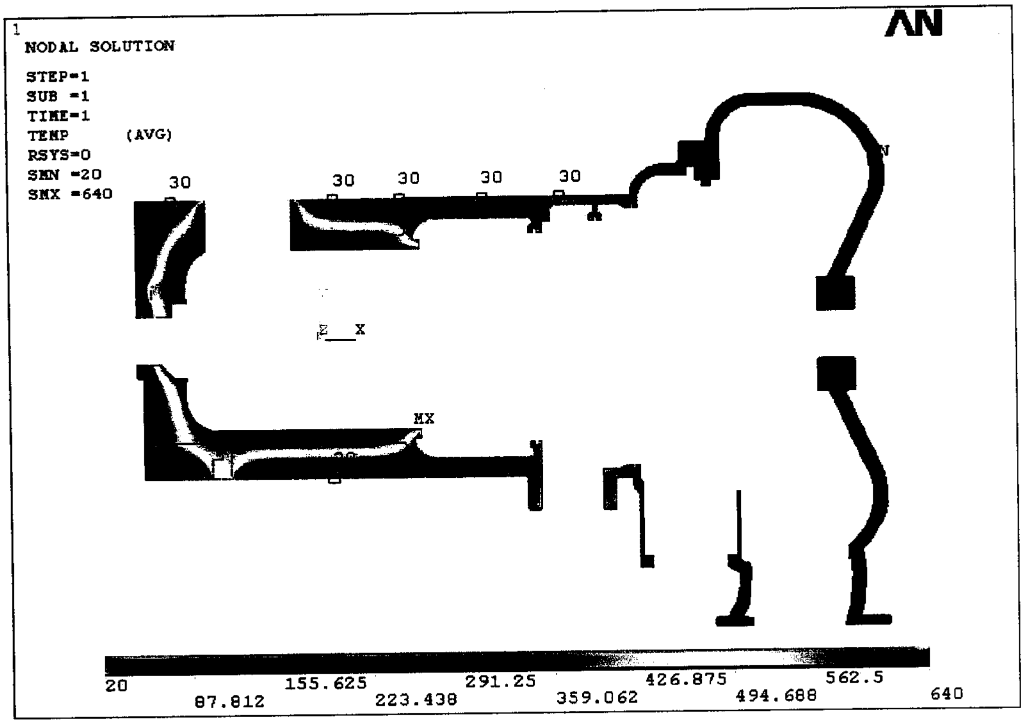
Step 11: Solve the model.

9.3 POSTPROCESSOR STAGE:

Step 12: Review the results of the analysis through graphical display.

Step 13: In results, get the temperature distribution of the casing in the Thermal Analysis.

9.1 IMPULSE TURBINE CASING:



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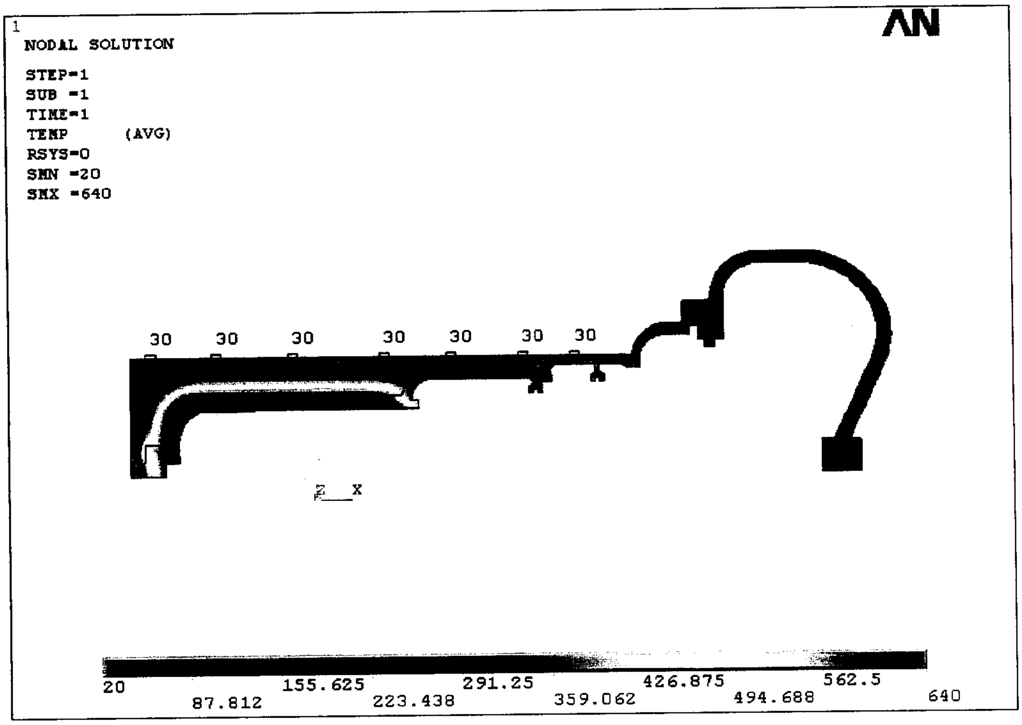

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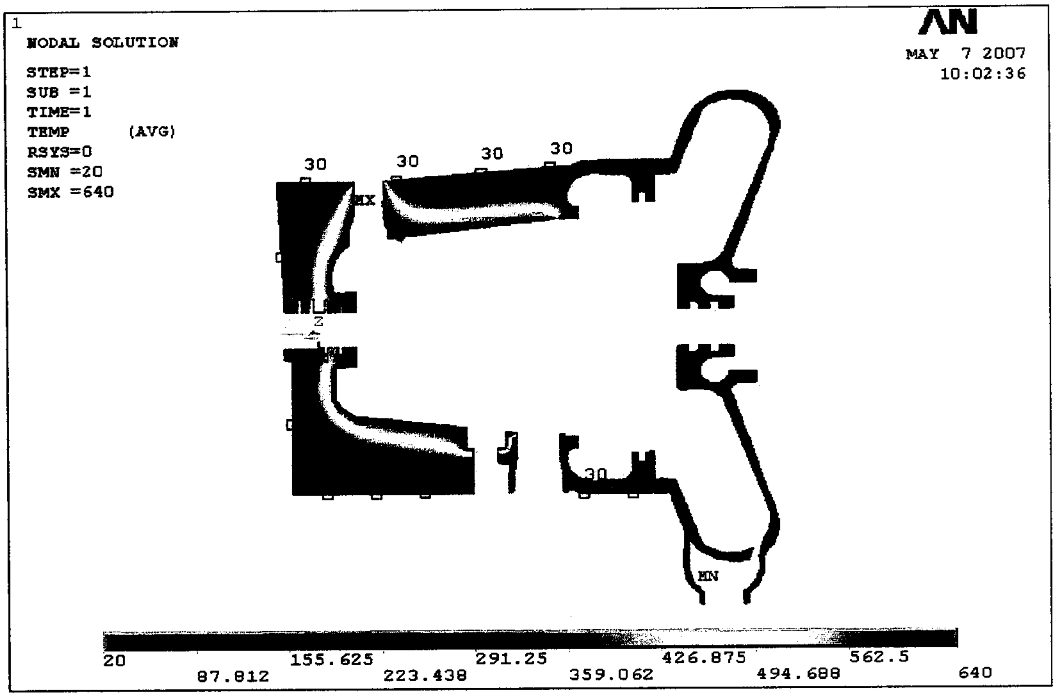
9.2 REACTION TURBINE CASING:



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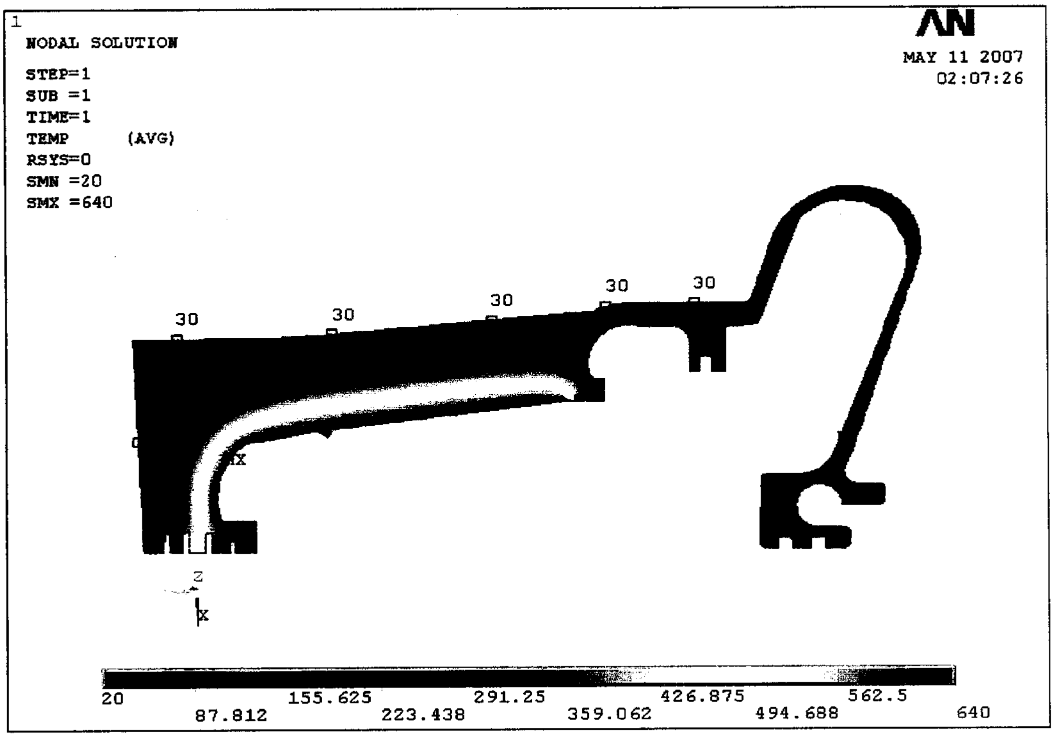

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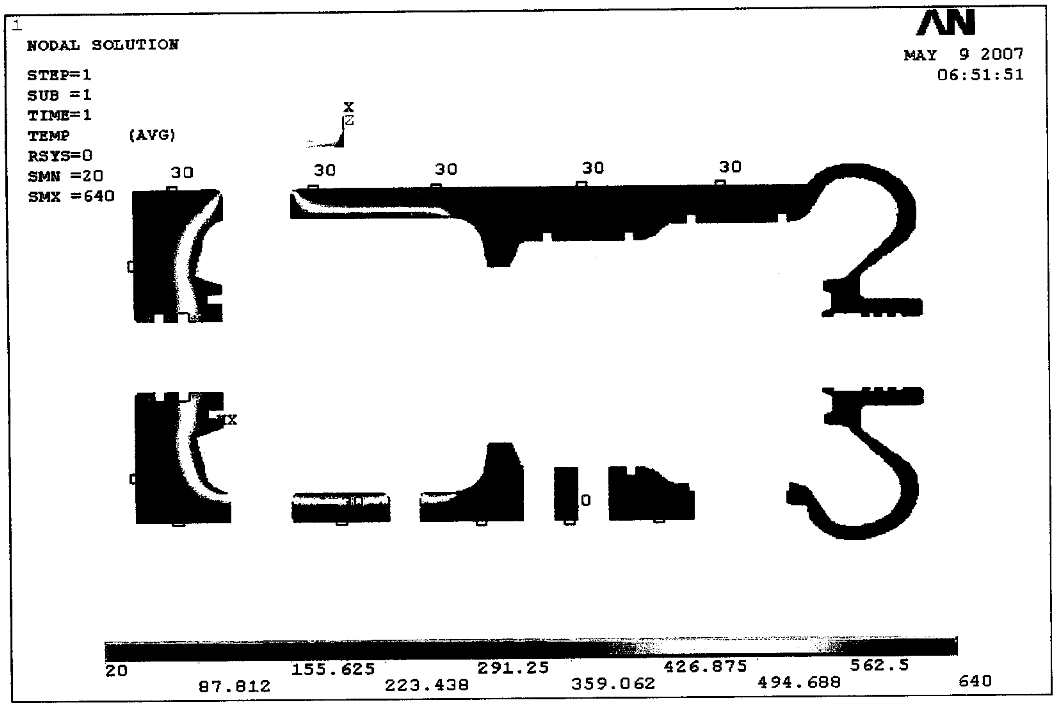
9.3 IMPULSE-REACTION TURBINE CASING:



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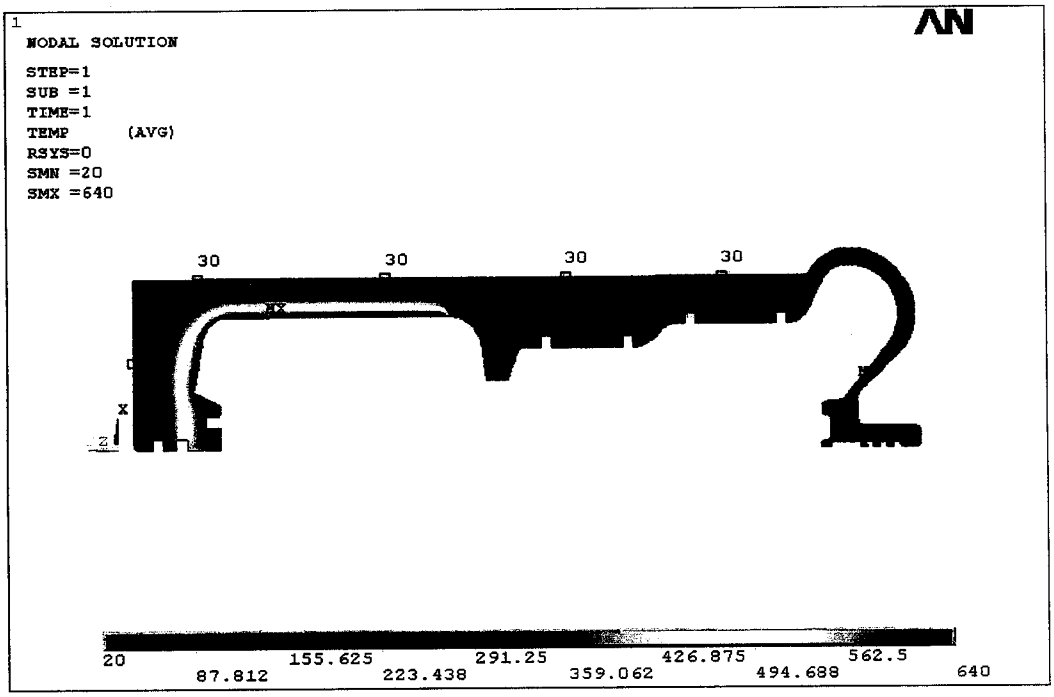


Closed region

9.4 INFERENCE FROM THERMAL ANALYSIS WITH INSULATION:

From the thermal analysis of optimized turbine casings, the insulation around the turbine casings minimizes the heat loss to the surroundings. Moreover an insulated model has more durability when compared with a non- insulated model and hence it has longer life.

CHAPTER 10

COUPLE FIELD ANALYSIS

10. COUPLE-FIELD ANALYSIS

10.1 PREPROCESSOR STAGE FOR THERMAL ANALYSIS:

Step 1: Open a new file in the ANSYS and set the preference as Structural Analysis.

Step 2: Import the model into the ANSYS. The created model can be generated in an active coordinate system.

Step 3: Save the model as jobname.db.

Step 4: Choose the element type as plane 42 according to the usage.

Step 5: Enter the Material property of the casing

Step 6: Create nodes and elements by meshing the model.

Step 7: Save model with the meshing as some other file as meshing.db.

10.2 PROCESSOR STAGE FOR THERMAL ANALYSIS:

Step 8: Apply the Boundary condition, i.e. temperature in the surface of the casing.

Step 9: Save the model with the load as load.db.

Step 10: Solve the model.

10.3 POSTPROCESSOR STAGE FOR THERMAL ANALYSIS:

Step 11: Review the results of the analysis through graphical display.

Step 12: In results, get the temperature distribution of the casing in the Thermal Analysis.

After finishing the Thermal Analysis, take the result and implies into the Structural Analysis.

10.4 PREPROCESSOR STAGE FOR STRUCTURAL ANALYSIS:

Step 13: In the model, remove the boundary condition used in Thermal Analysis.

Step 14: Switch over the element to Structural Analysis.

10.5 PROCESSOR STAGE FOR STRUCTURAL ANALYSIS:

Step 15: Apply the Boundary condition, i.e. pressure in the surface of the casing.

Step 16: Result of thermal analysis is taken from the file (jobname.rth).

Step 17: Save the model with the load.

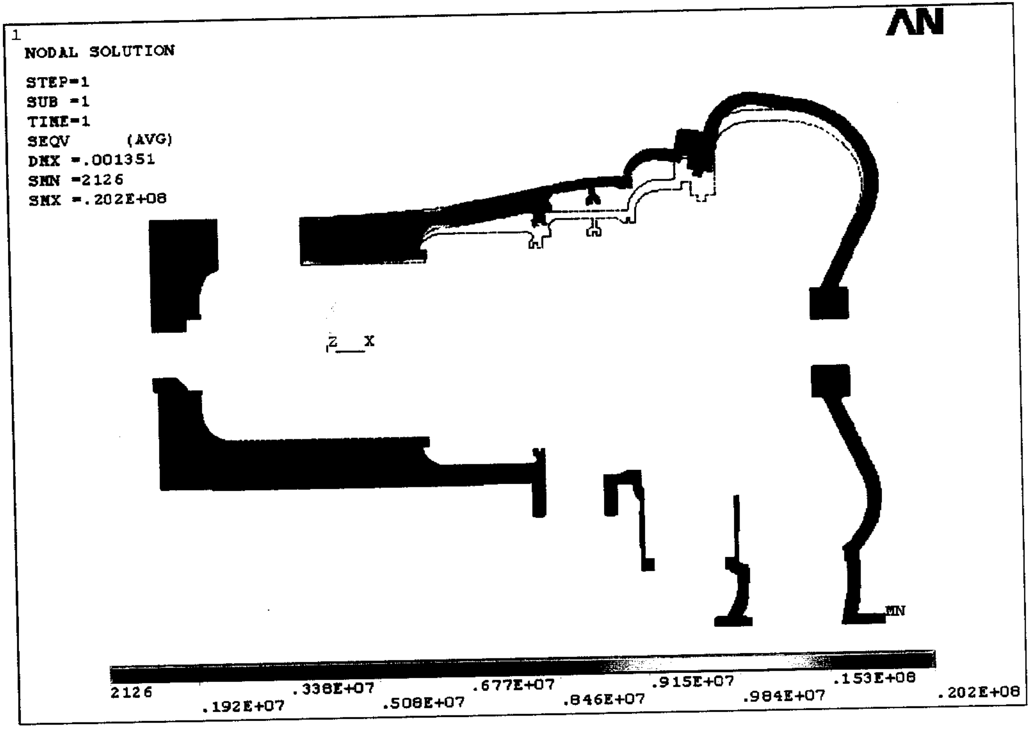
Step 18: Solve the model.

10.6 POSTPROCESSOR STAGE:

Step 19: Review the results of the analysis through graphical display.

Step 20: In results, get the deflection value as well as maximum stress value.

10.1 IMPULSE TURBINE CASING:



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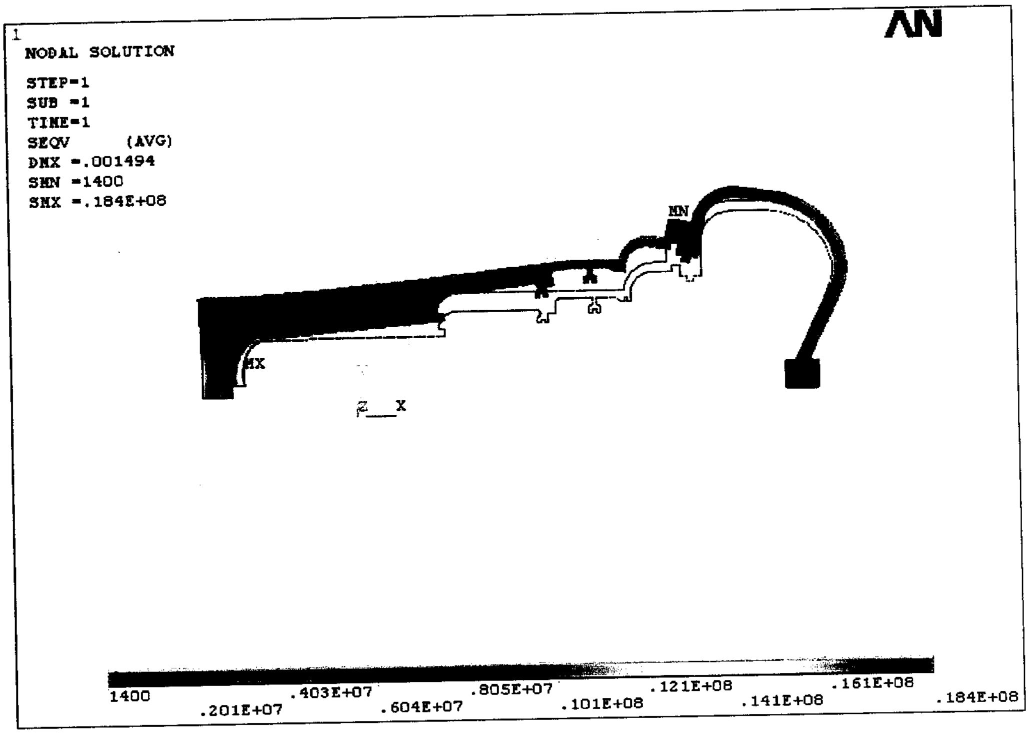
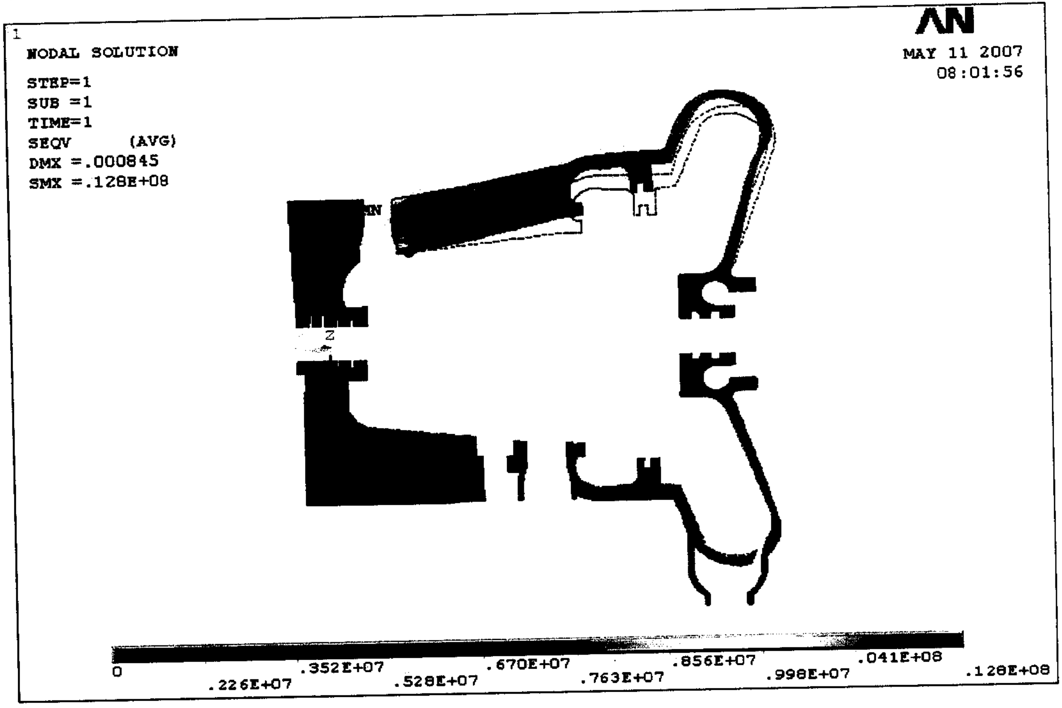


Closed region

10.2 REACTION TURBINE CASING:



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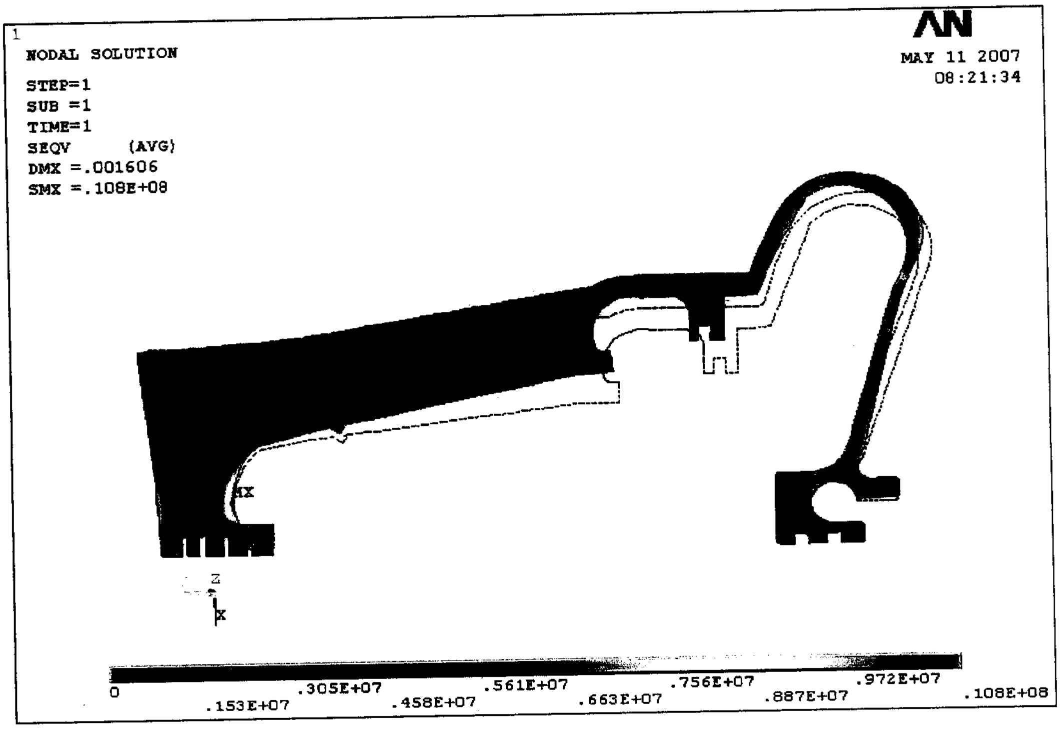
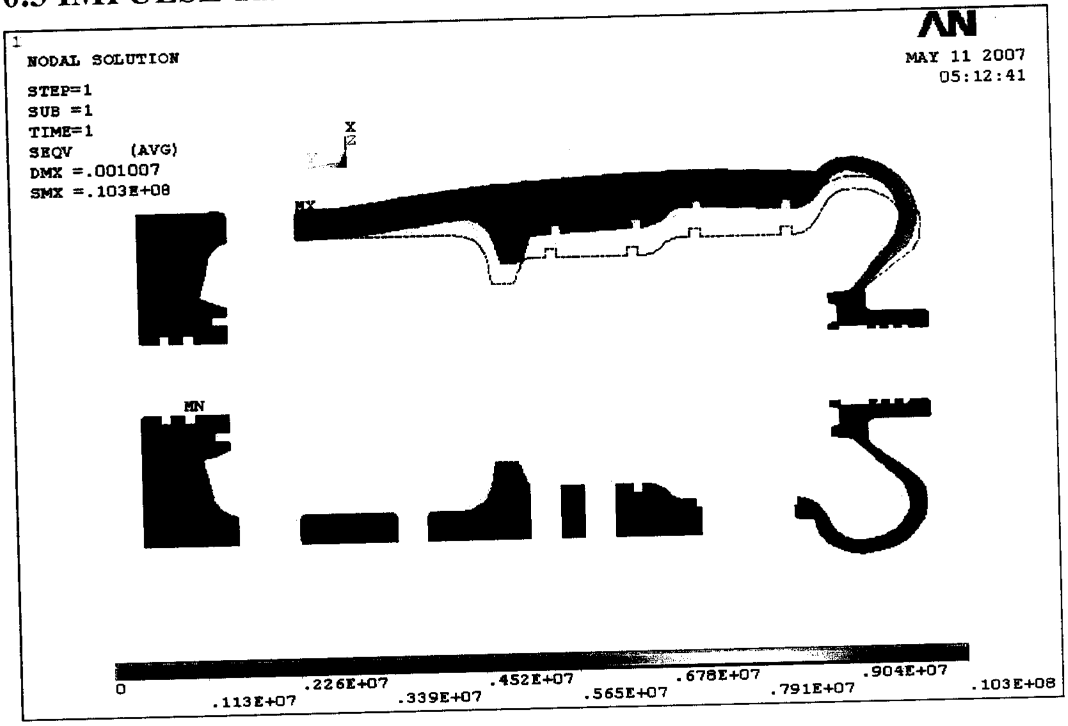


Closed region

10.3 IMPULSE-REACTION TURBINE CASING:



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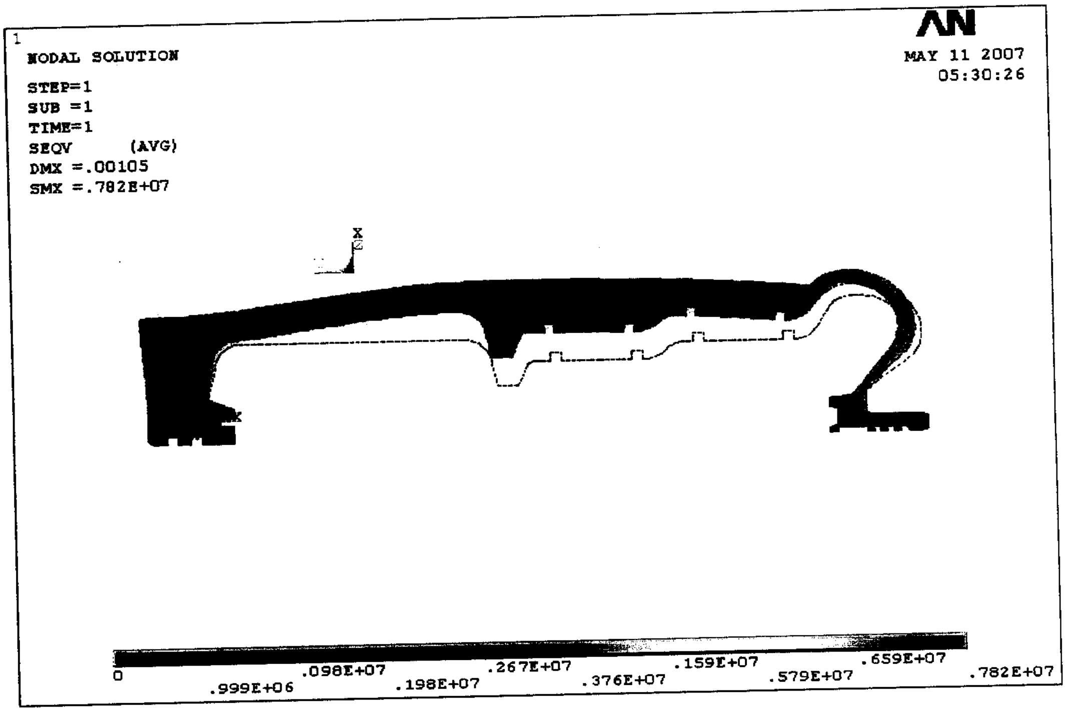


Closed region

10.7 INFERENCE FROM COUPLE FIELD ANALYSIS:

10.1 Results of Couple Field Analysis at the Opened region

Turbine Casings	**Strain value (mm)**	**Maximum Stress value (N/mm^2)**
Impulse turbine	1.351	20.2×10^6
Reaction turbine	0.845	12.8×10^6
Impulse-Reaction turbine	1.007	10.3×10^6

10.2 Results of Couple Field Analysis at the Closed region

Turbine Casings	**Strain value (mm)**	**Maximum Stress value (N/mm^2)**
Impulse turbine	1.494	18.4×10^6
Reaction turbine	1.606	10.8×10^6
Impulse-Reaction turbine	1.050	7.82×10^6

From the couple field analysis of the optimized turbine casings, we found that the deflection value and the maximum stress value are significantly reduced when compared with the results of structural analysis.

CHAPTER 11

CONCLUTION

11. CONCLUSION

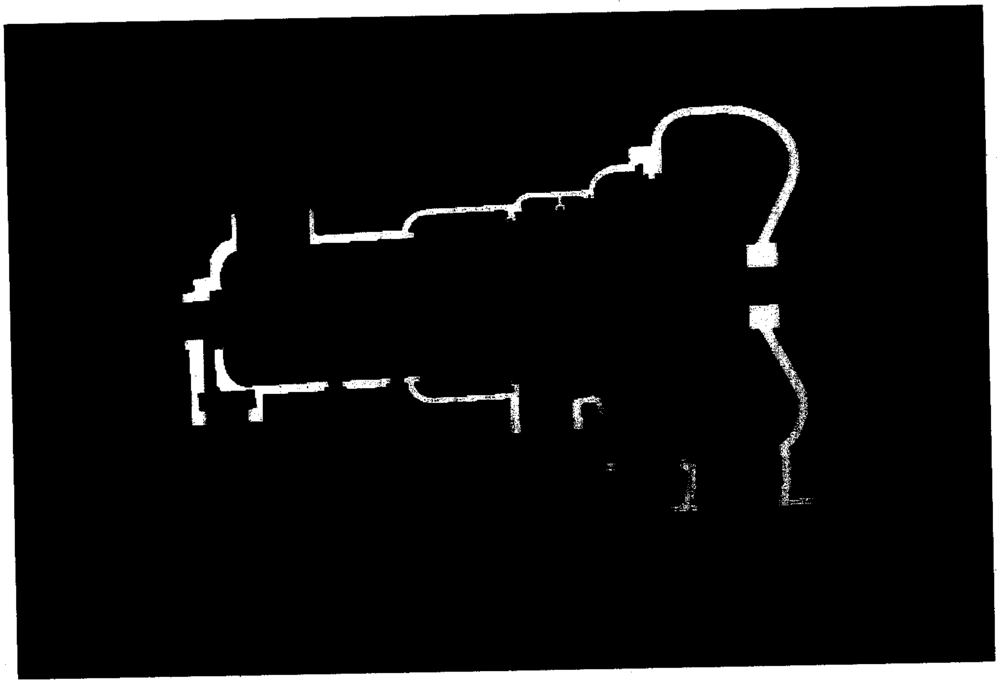
The axial turbine casings are analyzed using ANSYS software. Three type of analysis are performed. They are structural analysis, thermal analysis, and couple field analysis.

Structural analysis performed for turbine casings is to find out the values of strain as well as maximum stress. The stress value is found out to check whether the casing can withstand the existing stress value. Thermal analysis performed for non insulated turbine casing showed that the heat transmitted from the casings to the surroundings is nearly 80°C. So in order to reduce the heat loss, the turbine casings were optimized by insulation. Thermal analysis of optimized turbine casing shows that the heat transmitted from the casing to the surroundings is reduced to room temperature (30°C).

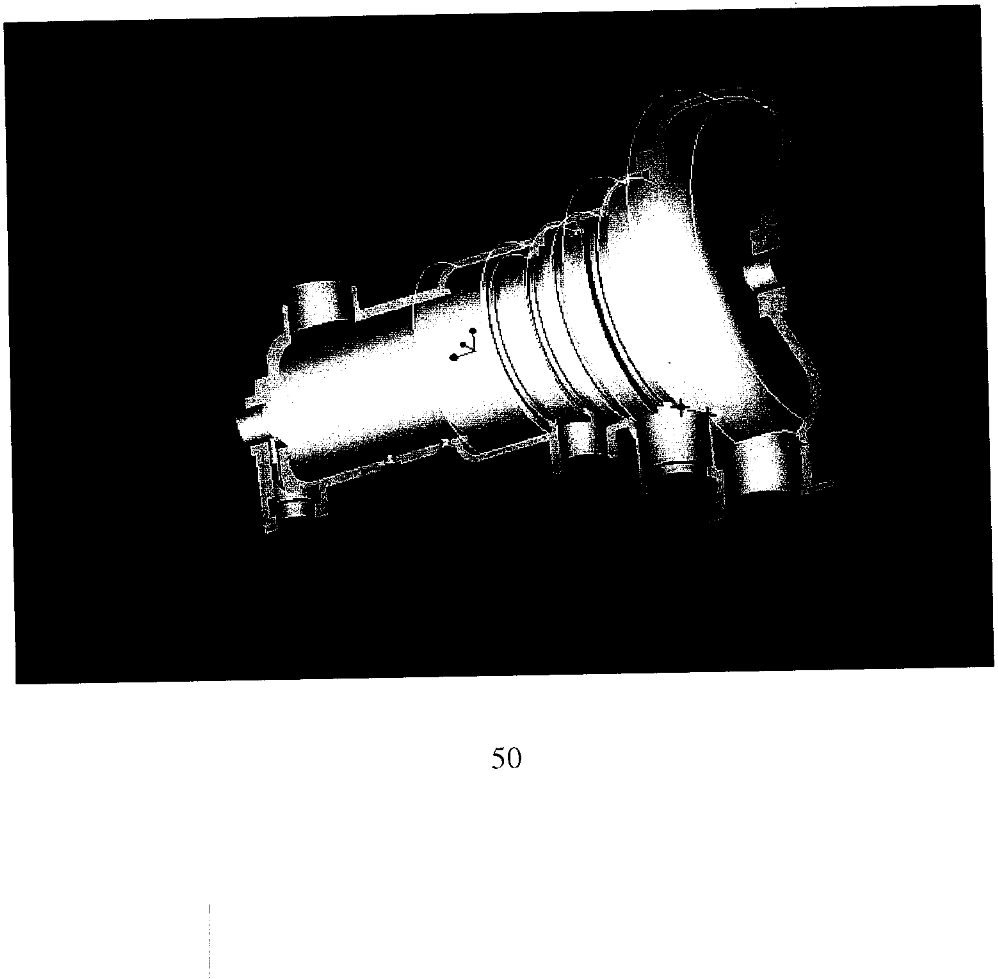
The couple field analysis of optimized turbine casings shows that the deflection values and the stress values are significantly reduced. So the operational performance also improved.

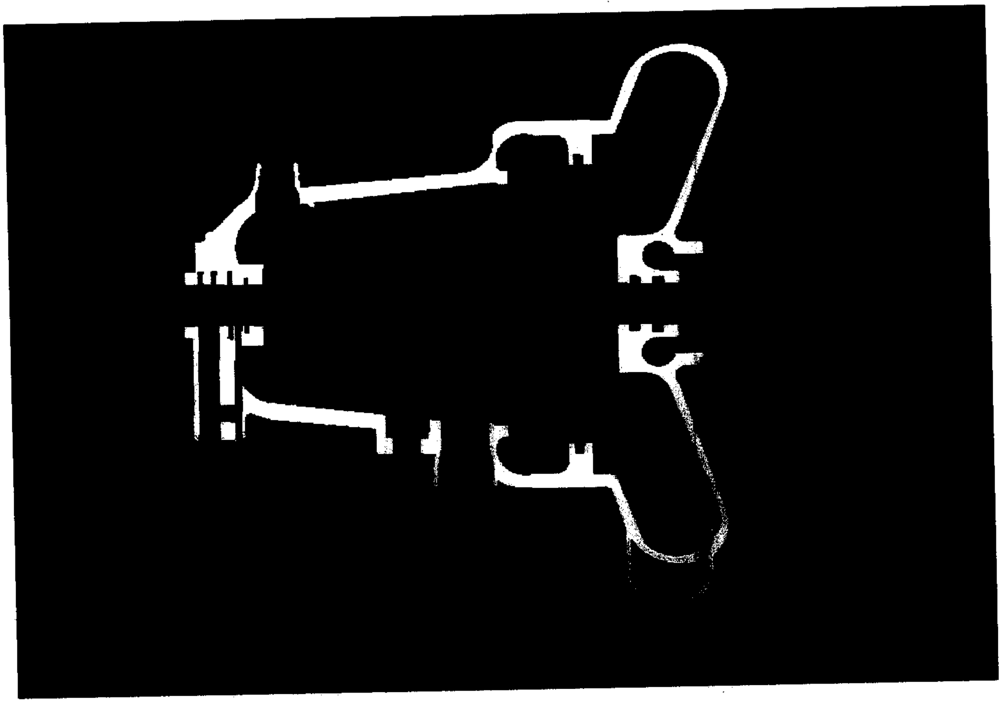
APPENDIX A

Appendix A
MODELS OF TURBINE CASING

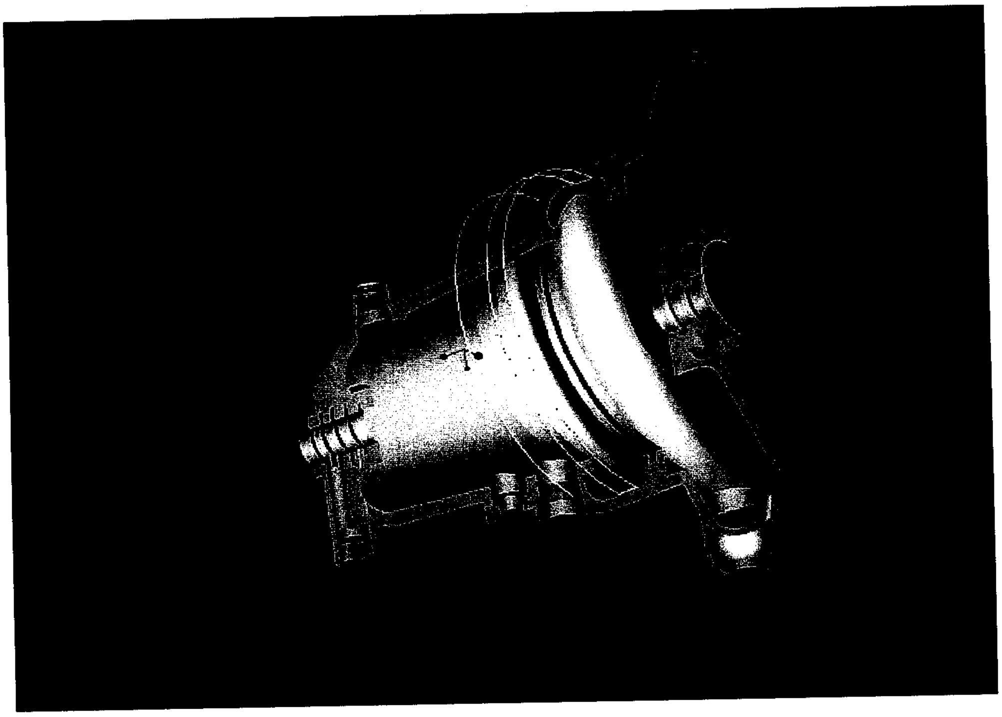


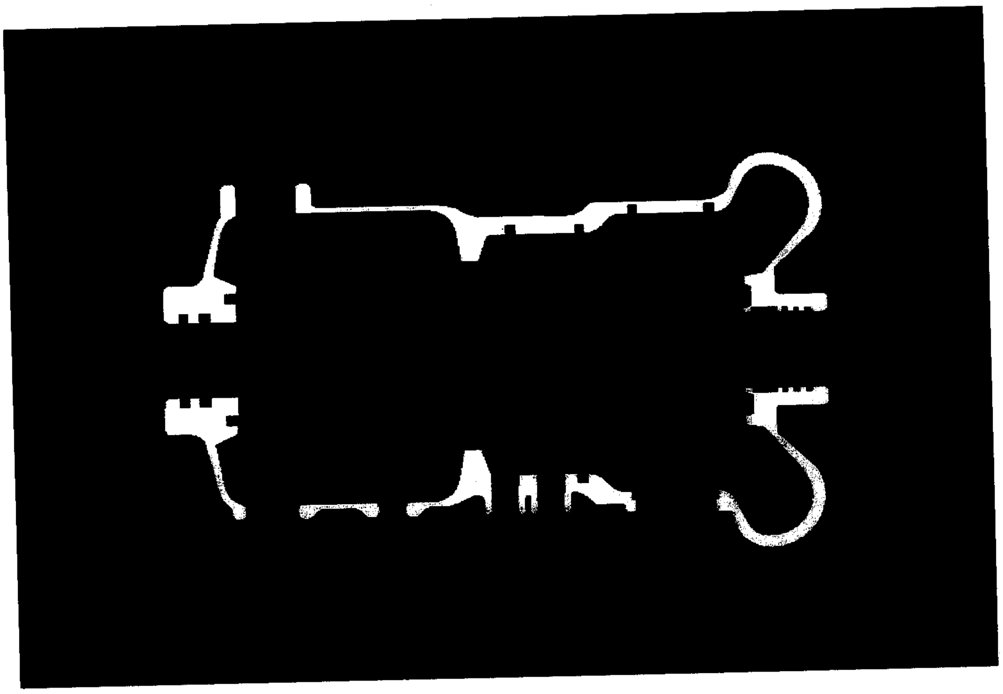
Model 1 - Impulse Turbine Casing



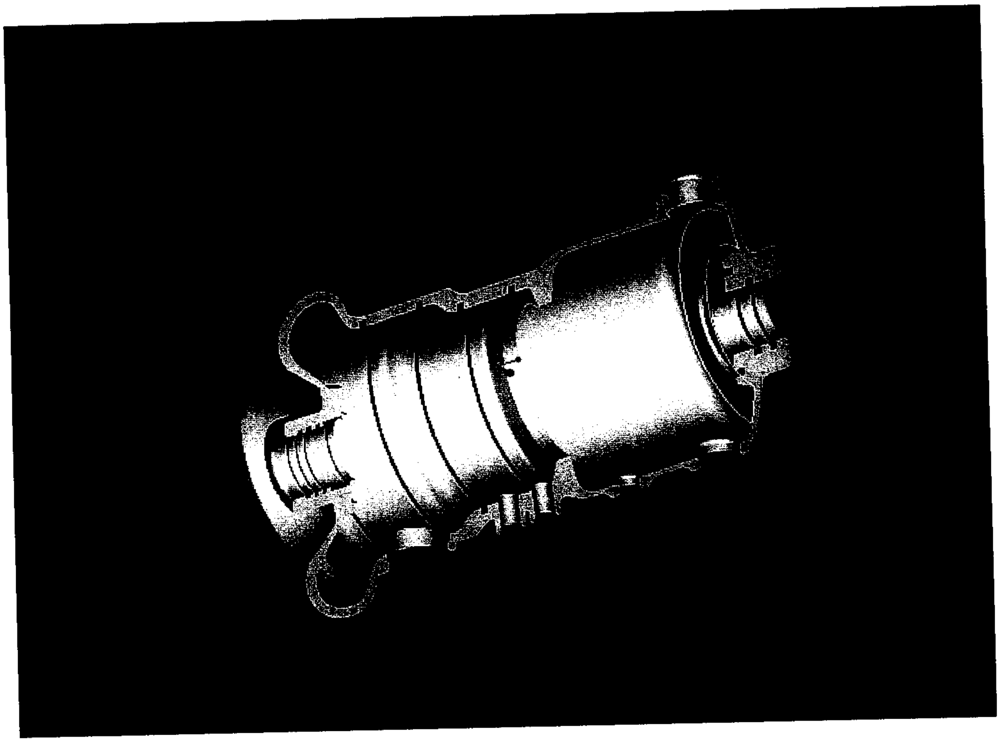


Model 2 – Reaction Turbine Casing





Model 3 – Impulse-Reaction Turbine Casing



APPENDIX B

Appendix B
DIAGRAM OF TURBINE CASINGS

IMPULSE TURBINE

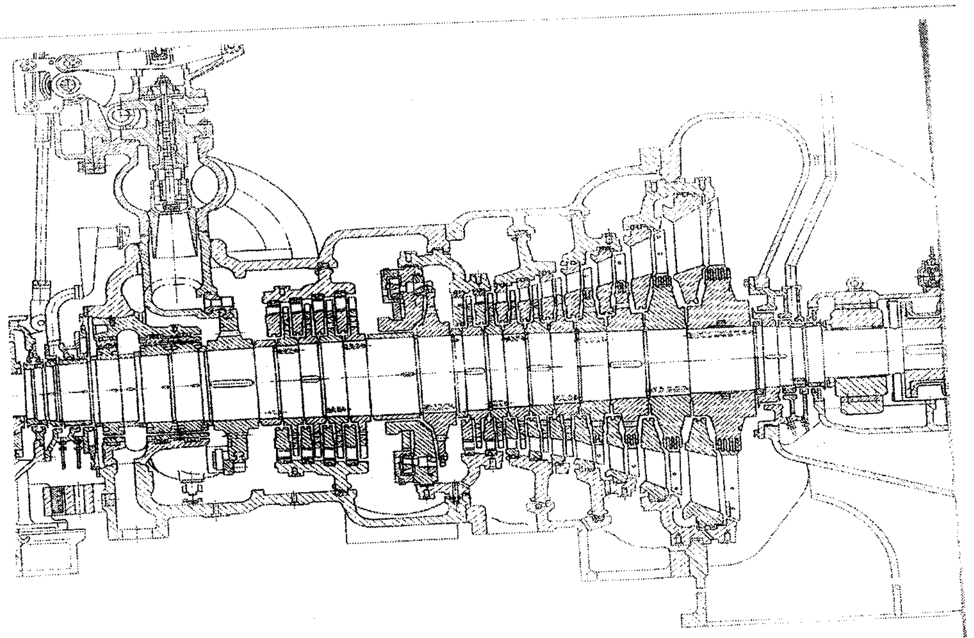
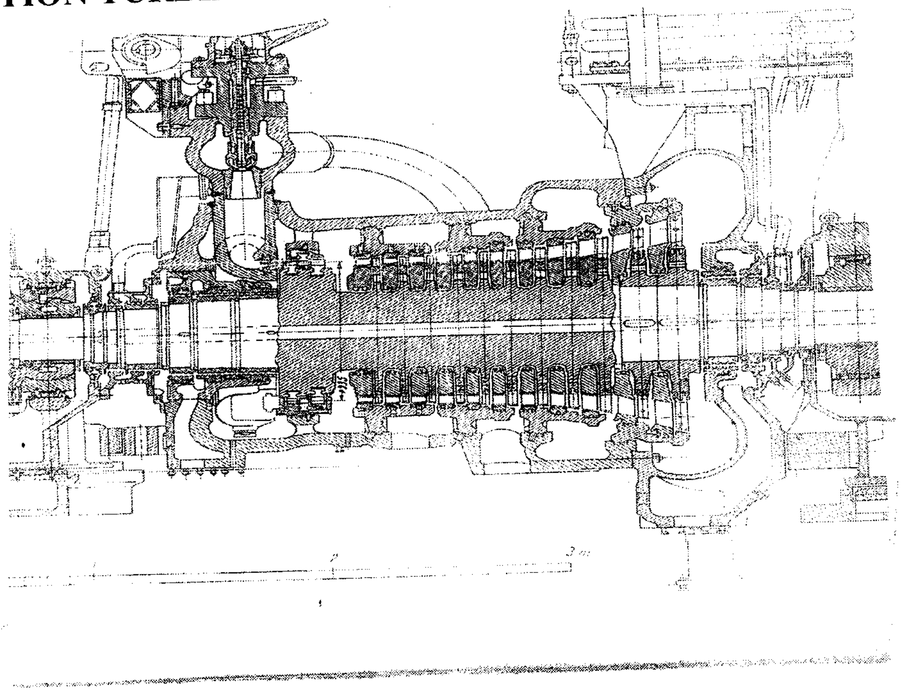


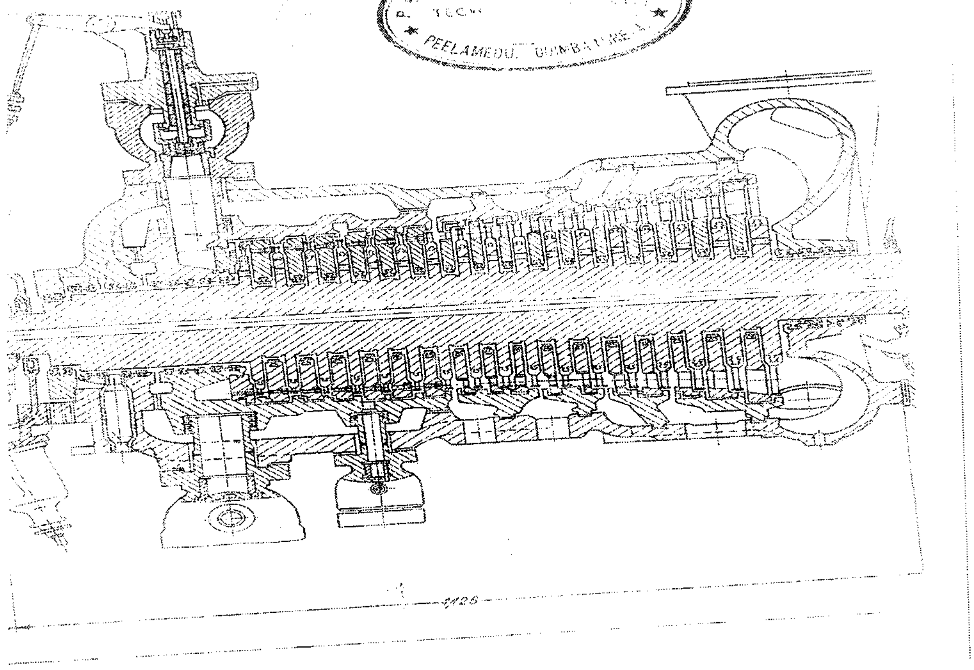
Fig. 11-76. Turbine AP 25-2 (L. M. W.)

REACTION TURBINE



IMPULSE – REACTION TURBINE

PEELAMEDU, COIMBATORE



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