DESIGN AND ANALYSIS OF SUPPORT STRUCTURE FOR GYROTRON COMPONENTS

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DESIGN AND ANALYSIS OF SUPPORT STRUCTURE FOR GYROTRON COMPONENTS

Major Project Report

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology in Mechanical Engineering (Design Engineering)

By

Vatsal S Shah

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May 2012

Declaration

This is to certify that

1. The thesis comprises my original work towards the degree of Master of Technology in Mechanical Engineering (Design Engineering) at Nirma University and has not been submitted elsewhere for a degree.

2. Due acknowledgement has been made in the text to all other material used.

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Undertaking for Originality of the Work

I,**Vatsal S. Shah**, Roll. No. **10MMED16** , give undertaking that the Major Project entitled **"Design and Analysis of Support Structure for Gyrotron Components"** submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in Mechanical Engineering (Design Engineering) of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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This is to certify that the Major Project Report entitled **"Design and Analysis of Support Structure for Gyrotron Components"** submitted by **Mr Vatsal S Shah** (10MMED16), Towards the partial fulfillment of the requirements for the award of Degree of Master of Technology in Mechanical Engineering (Design Engineering) of Institute of Technology, Nirma University, Ahmadabad is the record of work carried out by him under our supervision and guidance. In our opinion, the submitted work has reached a level required for being accepted for examination. The result embodied in this major project, to the best of our knowledge, has not been submitted to any other University or Institution for award of any degree. The result embodied in this major project, to the best of our knowledge, has not been submitted to any other University or Institution for award of any degree or diploma during 4^{th}July,2011 to 6^{th}May,2012.

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Abstract

Gyrotron is one of the subassembly in Tokomak reactor use to heat plasmas in nuclear fusion research experiments. Now a days Gyrotron is considered as rapid heating tool for process industries also. It is highly desirable to provide proper support structure to the gyrotron components as it is working under high rotational speed, high pressure and temperature environment. The basic aim of the present work is to design and analyze the support structure for gyrotron Component to sustain the such dynamic loading.

The Basic requirement of support structure is to provide support to Gyro Component & accurate alignment to all the components like collector magnet, MIG magnet and gyro-tube of subassembly gyrotron .The Design of support structure is carried out with analytical solution techniques for each component's support structure. With the help of design calculations a support structure assembly modal is prepared which is used for further analysis.

The working enviroment demands for the structural analysis,seismic analysis and thermal analysis for the support structure components,To accomplish this task support strucutre assembly model is analized for the structural analysis,seismic analysis and thermal analysis with the help of standard FEA tool. Result of which are coming satisfactory and can be further utilized for the purpose of the preventive maintainance and to avoid accidents.

Keyword: *Gyrotron,MIG Magnet,Collector Magnet,Gyro tube,Support structure*

Contents

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Nomenclature

P Total applied Load

E Elasticity of Modulaus

L Length of Column

a Outer radius of Plate

b Inner radius of Plate

r Radial loacation of unit line loading

t Thickness of plate

L/K Slenderation Ratio

K Radius of Gyration

q Load per unit area

δ Deflection of plate

ν Possion'sRatio

S_y Yield Stress

D Flexural Rigidity

A Area

I Importance Factot

R Reducution Factor

A_h Design horizontal seismic coefficient

$\frac{S_a}{g}$ Average response acceleration coefficient

d_{c1}Diameter of column of collector magnet

d_{c2}Diameter of column of gyrotube

d_{c3}Diameter of column of MIG magnet

d_sDiameter of stud

Q Heat generation

k thermal conductivity of material

Chapter 1

Introduction

1.1 Background

The Gyrotron is long microwave tube, is based on the conversion of electron beam energy in to the RF radiation using a resonant cavity structure. An annular electron beam is produced using a magnetron injection gun (MIG) and travel through a resonant cavity, located at the centre of the superconducting magnet under the influence of a high DC magnetic field, the magnetic field causes the electron to gyrate with the angular velocity of cyclotron resonance. The unused electron beam leaves the cavity region and propagates to the collector.

The project aim is to design support structure of gyrotron components Now a day's Gyrotron is considered as rapid heating tool for process industries also. It is highly desirable to provide proper support structure to the gyrotron components as it is working under high rotational speed, high pressure and temperature environment.

1.2 Project Statement

Design and Analysis of support structure for gyrotron Components. The basic requirement of support structure is to provide support to gyrotron component and accurate alignment to all components like collector magnet,MIG magnet and gyrotube of sub-assembly gyrotron.The design of support structure is carried out with analytical solution techniques for each components support strucutre with the help of design calculations a support structure assembly model is prepared which is used further analysis.

1.3 Objective

Design and analysis of support structure for gyrotron components

Support structure are designed for

- collector magnet
- MIG Magnet
- Gyrotube

In analysis part doing Structural Analysis,Thermal Analysis and Seismic analysis.

Modelling Part is done in Catia,

Meshing Part is done in HYPERMESH

Analysis part is done in ANSYS

1.4 About Institute of Plasma Research

I have done this project in Institute for Plasma Research(IPR). Institute for Plasma Research (IPR) is working for the development of the fusion technology in INDIA. IPR is located in a peaceful and green campus on the bank of the Sabarmati River near Gandhinagar, Gujarat. It was established in 1986 with confined (Tokamak) plasmas, to promote industrial applications of plasma based India's first Tokamak, ADITYA, has been in operation since 1990, IPR is a erecting a new machine- the Steady state Superconducting Tokamak (SST-1). IPR has also set up a Facilitation Center for Indian industries. The term 'Plasma' refers to an ionized state of matter. The production, confinement and diagnosis of plasmas being truly multi-disciplinary activities, the IPR faculty consists of scientists and engineers from a wide range of disciplines engaged in research in:

- Electrical discharge phenomena
- Electrical discharge phenomena Plasma surface interaction
- Particle and energy transport in plasma
- Non-neutral, dusty and quark-gluon and such 'exotic' plasma
- Plasma heating by high power RF radiation and fast neutral beams
- Pulsed power technology
- Novel plasma diagnostic techniques

IPR is now internationally recognized for its contributions to be fundamental and applied research in plasma physics and associated technologies. It has a scientific and engineering manpower of 200 with core competency in theoretical plasma physics, computer modeling, super conducting magnets and cryogenics, ultra high vacuum, pulsed power, microwave and RF, computer-based control and data acquisition and industrial, environmental and strategic plasma applications.

1.4.1 ADITYA Tokamak IPR

ADITYA, a medium size Tokamak, is being operated for over a decade. It has a major radius of 0.75m and minor radius of the plasma 0.25m. A maximum of 1.2 T toroidal magnetic field is generated with the help of 20 toroidal field coils spaced symmetrically in the toroidal direction.

ADITYA is regularly being operated with the transformer-convertor power system. Pulses longer than 100 ms with 80-110 kA plasma current at toroidal field of about 0.9 T is being regularly produced for various experiments. During this period experiments on edge plasma fluctuation, turbulence and other related works have been conducted. Standard diagnostics have been employed during the measurements.

1.4.2 SST1 Tokamak at IPR

The Steady-state Superconducting Tokamak-1 (SST-1) belongs to a new generation of Tokamak with the major objective being steady state operation of advanced configuration plasma. Traditionally the Tokamak have operated with a Transformer action - with plasma acting as a secondary, thus having the vital 'self- generated' magnetic field on top of the 'externally-generated' (toroidal and equilibrium) fields. This is a pretty good scheme in which creation, current – drive and heating are neatly integrated and remained a choice of fusion community for many years until the stage came to heat the plasma to multi-keV temperatures. Heating was then accomplished separately by Radio Frequency (RF) waves and/or energetic Neutral Beam Injection (NBI)

Subsequently, excellent control got established in Tokamak plasma performance by controlling the plasma wall-interaction processes at the plasma boundary so the plasma duration was limited primarily by the 'transformer pulse length'. However, for relevance to future power reactors it is essential to operate these devices in a steady state mode. The very idea of steady state operation presents a series of physics and technology challenges. For example, the excellent plasma performance which has accomplished earlier was with the surrounding material wall acting as a good 'pump' of particles, a fact which may not be true in steady state.

1.5 About ITER

Scientists and engineers from India, China, Europe, Japan, Korea, Russia, and the United States are working in an unprecedented international collaboration on the next major step for the development of fusion – ITER (which means "the way" in Latin). ITER's mission is to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes. To do this, ITER will demonstrate moderate power multiplication, demonstrate essential fusion energy technologies in a system integrating the appropriate physics and technology, and test key elements required to use fusion as a practical energy. ITER will be the first fusion device to produce thermal energy at the level of an electricity-producing power station. It will provide the next major step for the advancement of fusion science and technology, and is the key element in the strategy to reach the following demonstration electricity-generating power plant (DEMO) in a single experimental step.

ITER is an experimental fusion reactor based on the "Tokamak" concept – a toroidal (doughnut shaped) magnetic configuration in which to create and maintain the condition for controlled fusion reactions. In ITER plant comprises the Tokamak, its auxiliaries, and supporting plant facilities. In ITER, super conducting magnet coils around a toroidal vessel confine and control a mix of charged particles – the "plasma" – and induce an electrical current through it.

Fusion reaction takes place when the plasma is hot enough, dense enough, and contained for long enough for the atomic nuclei in the plasma to start fusing together. ITER will test the entire main new feature needed for that device – high temperature-tolerant components, large scale reliable super conducting magnets, fuel-breeding blankets using high temperature coolants suitable foe efficient electricity generation, and safe remote handling and disposal of all irradiated components. ITER's operating condition are close to those that will be experienced in power reactor, and will show how they can be optimized, and how hardware design margins can be reduced to control cost.

- The plasma would be confined in a large vacuum vessel surrounded by a neutron absorbing breeding blanket. The breeding blanket has a dual function: it converts the energy of neutron into thermal energy and it 'breeds' new tritium from lithium to provide more reaction element.

- A large scale vacuum system is required to ensure an ultra high vacuum in the reactor vessel and to maintain the vacuum surrounding the Superconducting coils located outside the reactor vessel that provide the required strong magnetic field to confine the plasma away from the vessel walls.

- Cryogenics (circulating very low temperature liquids) are used to remove waste and impurities from the plasma, cool the superconducting magnet coils to allow them to operate, separate the waste gases into their different individual components for disposal or recycling, provide the cooling for RF heating sources pressure and control the gas pressure of neutral beam systems.

- Divertor system in the vacuum vessel extracts waste gases and power from the plasma and new deuterium and tritium is continuously injected into the plasma.

- **The next step: ITER**

ITER is a large scale, international experiment that should demonstrate the scientific and techno-logical feasibility of using fusion as an energy source on earth. ITER will allow the study of plasmas in conditions similar to those expected in a electricity-generating fusion power plant. It will also test a number of key technologies for fusion including the heating, control, diagnostic and remote maintenance that are expected to be needed for a real fusion power station. ITER started in the 80ies as an initiative of the former presidents Reagan and Gorbatsjov; the current partners in the project are the European Union, Japan, the Russian Federation, China, Korea, India, and the USA, which means that more than half of the global population is represented in the project.

ITER will be a machine of the tokamak type in which the torus-shaped fusion plasma is confined by strong magnetic fields (see illustration). Compared with current conceptual designs for future fusion power plants, ITER will include most of the necessary technology, but will be of slightly smaller dimensions and will operate at about one-fifth of the power output level. In June 2005, the partners in the project decided unanimously to choose the European site at Cadarache, in the South of France, as the location for the construction of ITER. The design of ITER is ready for the start of construction to begin, and the first plasma operation is expected in 2016. ITER is a unique project, which needs very advanced technology, and will ask the utmost from materials, scientific understanding, and international cooperation. For sure, ITER is one of the most complexes, Challenging and innovative project in the world today.

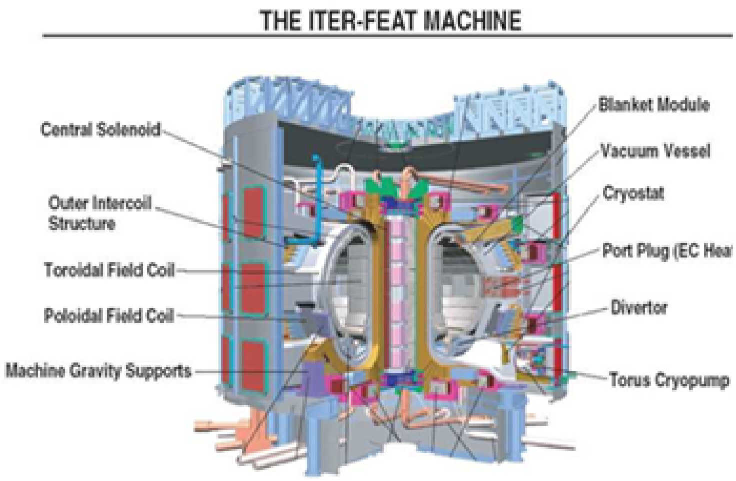


Figure 1.1: ITER

1.6 Introduction about Gyrotron

The Gyrotron is long microwave tube, is based on the conversion of electron beam energy in to the RF radiation using a resonant cavity structure. An annular electron beam is produced using a magnetron injection gun (MIG) and travel through a resonant cavity, located at the centre of the superconducting magnet under the influence of a high DC magnetic field, the magnetic field causes the electron to gyrate with the angular velocity of cyclotron resonance. The unused electron beam leaves the cavity region and propagates to the collector.

- **Function**

In a gyrotron, beams of electrons are accelerated toward a cavity where a strong magnetic field is applied. The interaction between the rotating (cyclotron) motion of the electrons and the magnetic field generate high-frequency radio waves that "travel" in a straight line, almost like an optical beam.

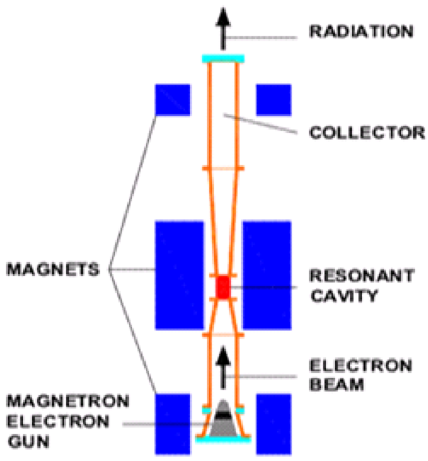


Figure 1.2: Schematic diagram of Gyrotron system

1.7 Motivation

The gyrotron is used in advanced technology like plasma, nuclear reactor etc. for generation of fusion power. As it has deal with varying pr. & temp. Condition along with high rotation speed it is essential to have rigid support structure for the components of gyrotron, this being an advanced technology. No literature directly suggests design procedure for the support structure of the gyrotron to achieve high performance rating of gyrotron. Subassembly designs with basic fundamentals are required to be done which should be followed by proper analysis like structural analysis, thermal analysis & seismic analysis.

1.8 Aim & Scope of work

Gyrotron is highly desirable to provide proper support structure to the gyrotron components as it is working under high rotational speed, high pressure and temperature environment. The basic aim of the present work is to design and analyze the support structure for gyrotron Component.

The Basic requirement of support structure is to provide support to Gyro Component & accurate alignment to all the components like collector magnet, MIG magnet and gyrotube of subassembly gyrotron .Here the Design of support structure is carried out with analytical solution techniques for each component's support structure individually. With the help of design calculations a support structure assembly modal is prepared to carry out further analysis.

1.9 Thesis organization

This thesis is divided into 5 chapters.

Chapter 1:Introductory information related to IPR, ITER, Gyrotron.Aim & Scope of Work and finally motivation of project is discussed in first chapter.

Chapter 2 covers literature review on Gyrotron system discription,Tokomak, Structural analysis,seismic analysis and Thermal analysis related papers.

Chapter 3 Analytical calculation related to support structure and assemble it.

Chapter 4 covers result and discussion related to structural analysis,seismic analysis and thermal analysis.

Chapter 5 Covers conclusion and future work.

Some reference tables are given in Appendix-A

Chapter 2

LITERATURE REVIEW

2.1 Tokamak

Gyrotron is one of the subassembly in Tokomak reactor use to heat plasmas in nuclear fusion research experiments. A Tokomaks is a device which uses a magnetic field to confine plasma in the shape of torus. Achieving stable plasma, magnetic field that move around the torus in a helical shape. Such a helical field can be generated by adding the toroidal field and Poloidal field as shown in figure. The toroidal field is produced by the electromagnets that surround the torus and Poloidal field is produced by the toroidal current that flows inside the plasma. This current is induced inside the plasma with the second set of electromagnet. As shown in the figure in the tokamak central solenoid works as a primary circuit of the transformer and plasma is the secondary circuit .

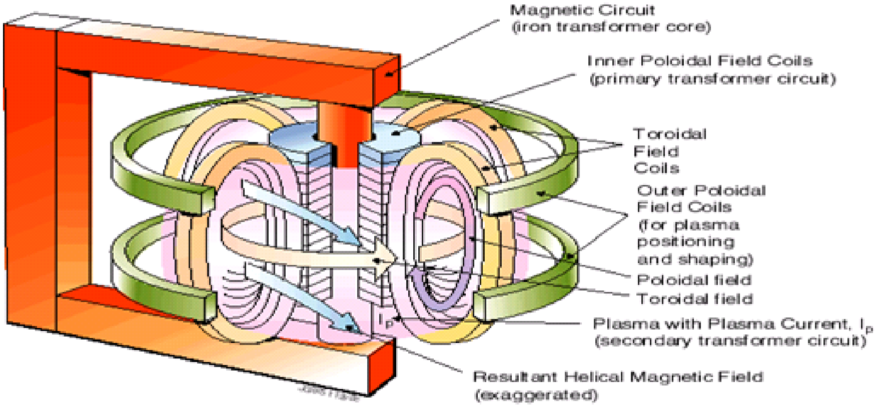


Figure 2.1: Tokamak currents and fields

The tokamak is the most developed magnetic confinement system and is the basis for the design of future fusion reactors using this method. It was invented in the Soviet Union during the 1960s and soon adopted by researchers around the world. The Joint European Torus (JET), located at Culham Centre for Fusion Energy, is the largest and most powerful tokamak currently operating. The main tokamak components and functions are as follows:

- The plasma is contained in a vacuum vessel. The vacuum is maintained by external pumps. The plasma is created by letting in a small puff of gas, which is then heated by driving a current through it.
- The hot plasma is contained by a magnetic field which keeps it away from the machine walls. The combination of two sets of magnetic coils - known as toroidal and Poloidal field coils -creates a field in both vertical and horizontal directions, acting as a magnetic 'cage' to hold and shape the plasma.
- Large power supplies are used to generate the magnetic fields and plasma currents.
- Plasma current is induced by a transformer, with the central magnetic coil acting as the primary winding and the plasma as the secondary winding. The heating provided by the plasma current (known as Ohmic heating) supplies up to a third of the 100 million degrees Celsius temperature required to make fusion occur.
- Additional plasma heating is provided by neutral beam injection. In this process, neutral hydrogen atoms are injected at high speed into the plasma, ionized and trapped by the magnetic field. As they are slowed down, they transfer their energy to the plasma and heat it.
- Radiofrequency heating is also used to heat the plasma. High-frequency oscillating currents are induced in the plasma by external coils or waveguides. The frequencies are chosen to match regions where the energy absorption is very high (resonances). In this way, large amounts of power may be transferred to the plasma.

2.2 Magnetic confinement

Magnetic confinement fusion is an approach to generating fusion power that uses magnetic fields to confine the hot fusion fuel in the form of plasma. Magnetic confinement is one of two major branches of fusion energy research, the other being inertial confinement fusion. The magnetic approach is more highly developed and is usually considered more promising for energy production. A 500-MW heat generating fusion plant using tokamak magnetic confinement geometry is currently being built in France.

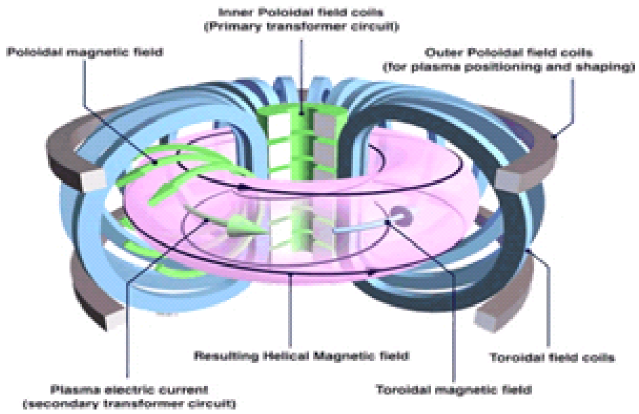


Figure 2.2: Magnetic confinement

2.3 System Description for Gyrotron

2.3.1 Magnetron Injection Gun

The triode type Magnetron Injection Gun (MIG)[1] is used as the gyrating electron beam source .Two design goals are considered in the MIG design i.e. High transverse velocity of electrons and minimum velocity spread. The initial MIG parameters which are essential for the modeling and the electron trajectory simulations are obtained by using the analytical tradeoff equations .

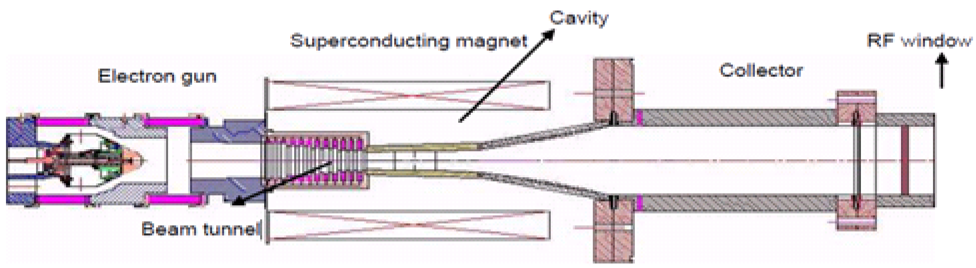


Figure 2.3: schematic diagram of 35 GHz gyrotron

2.3.2 Magnet System

In the present design, the magnet system consists of two magnet system coils,one is super conducting coil and other is gun coil. some other magnet coils are also used at the collector region for the efficient electron beam spreading. The superconducting coil mainly determines the magnetic field at the interaction cavity region. The gun coil is placed above the emitter and mainly controls the magnetic field distribution in the gun region for the efficent emisson and formation of electron beam.

2.3.3 Intrection Cavity

The beam wave intrection takes place at the middle section of the intrection cavity. The gyrating electron beam,emitted from the triode type electron gun,launched at the entrance of input taper section with the RF,present in the cavity in the form of TE03 mode, and get collected in the specially designed circular type sufficent beam-metal wall gap,the electron beam, is launched at the second radial maxima of the TE03 mode. MAGIC code is used for the beam-wave intreraction and efficiency computations.

2.3.4 RF window

The RF window is very critical part of any Gyrotron tube.This system separate the ultrahigh vacuum enviorment inside the tude (>10-7 torr) the external system located in the normal pressure the enviorment. Due to separation of two very opposite environments,the window material must be very good in case of mechanical strength and pressure gradient,Ideally the generated RF power should be transmitted through the window material without any reflection and absorption.considering all these aspects,various kind of dielectric materials like sapphire, SIN, CVD diamond , BN, Au doped silicon etc. have been studied by various research groups to fulfill the mechanical, thermal, and electrical properties required in the design of high power RF window.In this design study CVD diamond material is selected as the window material due to its very good mechanical properties. The CVD diamond also provides good compatibility with the brazing and the metallization process. Due to the very good thermal conductivity of CVD diamond and very weak dependency of the electrical parameters on temperature,edge cooled single disk design is selected from this gyrotron.

2.3.5 Beam tunnel

The beam tunnel is a lossy waveguide type of structure, used in the gyrotron to absorb the backward RF propagation towards the electron gun. The structure is made of the perodic arrangement of the lossy ceramic rings and the OFHC (Oxygen Free High Conductivity) copper rings. The spurious oscillation are the major problem in he design of beam tunnel and through analysis of these kinds of ocillations degrades the electron beam quality, which again affects the beam-wave interaction in the interaction cavity and output power performance.The lossy ceramic AIN-SIC is used in the 35 GHz beam tunnel to absorb the backward RF propagation and the suppress the spurious mode oscillations.

2.4 Working Procedure

Gyrotron is a essential device [3]. Once generated in the magnetic cavity, High-Frequency (HF) waves travel the length of a wave guide into an antenna that directs the beam into the plasma. The effect of the HF wave on the electrons in the plasma is to accelerate their motion - another way of saying that electrons are "heated" by the HF beam.

The energy that the electrons have acquired is then transferred, by way of ions, to the whole plasma. This heating technique is called Electron Cyclotron Resonance Heating (ECRH). In ITER, the ECRH system will be composed of more than 20 gyrotrons which will deliver a combined heating power of 24 MW.

"The area of the plasma that is impacted by the beams is rather small," explains Caroline Darbos, an engineer with the ECRH team, "but the energy spreads fast and evenly. The beams accelerate the electrons in the plasma, which, while generating current, communicate their newly acquired energy to the ions."

HF beams fulfill a second important role in fusion devices: when aimed precisely by way of a mobile mirror system, the current that is generated by the electrons can also suppress local instabilities in the plasma.

- **Application**

1. Gyrotron are used for many industrial and high technology heating application.
2. In plasma application,[3]Gyrotron used in nuclear fusion research experiments to heat plasmas.
3. In manufacturing industry as a rapid heating tool in processing glass, composites, and ceramic as well as for annealing (solar and semiconductor).

2.5 Structural Analysis

- **Column Buckling of structual Bamboo [5]**

This paper presents a research and development project for structural bamboo where the column buckling behaviour of two structural bamboo species, namely Bambusa pervariabilis (or Kao Jue) and Phyllostachys pubescens (or Mao Jue) were investigated.

A total of 72 column buckling tests with bamboo culms of typical dimensions and properties were executed to study the column buckling behaviour of structural bamboo. Furthermore, a limit state design method against column buckling of structural bamboo based on modified slenderness was established and carefully calibrated against test data. It is shown that for Kao Jue, the average model factors of the proposed design method are 1.63 and 1.86 for natural and wet conditions, respectively. Similarly, the average model factors of the proposed design method for Mao Jue are 1.48 and 1.67 for natural and wet conditions, respectively. Consequently, the proposed design method is shown to be adequate. With the availability of design data on the dimensions and the mechanical properties of structural bamboo together with the proposed column buckling design rule, structural engineers are encouraged to take the advantage offered by bamboo to build light and strong bamboo structures to achieve enhanced economy and buildability.

- Prposed Design Method

1. Basic section properties of a bamboo column are evaluated first.
2. The elastic critical buckling strength of the bamboo column.
3. The design compressive strength of the bamboo column.
4. The design compressive buckling strength of the bamboo column. Use this design procedure for a column.

- Design of column

Structural members which carry compressive loads may be divided into two broad categories depending on their relative lengths [7] and cross-sectional dimensions. Short, thick members are generally termed columns and these usually fail by crushing when the yield stress of the material in compression is exceeded. Long, slender columns or struts, however, fail by buckling some time before the yield stress in compression is reached.

The buckling Occurs owing to one or more of the following reasons:

1. The strut may not be perfectly straight initially;
2. The load may not be applied exactly along the axis of the strut;
3. One part of the material may yield in compression more readily than others owing to Some lack of uniformity in the material properties throughout the strut.

At values of load below the buckling load a strut will be in stable equilibrium where the displacement caused by any lateral disturbance will be totally recovered when the disturbance is removed. At the buckling load the strut is said to be in a state of neutral equilibrium, and theoretically it should then be possible to gently deflect the strut into a simple sine wave provided that the amplitude of the wave is kept small. This can be demonstrated quite simply using long thin strips of metal, e.g. a metal rule, and gentle application of compressive loads.

Theoretically, it is possible for struts to achieve a condition of unstable equilibrium with loads exceeding the buckling load, any slight lateral disturbance then causing failure by buckling; this condition is never achieved in practice under static load conditions.

Buckling occurs immediately at the point where the buckling load is reached owing to the reasons stated earlier.

1. Fixed ends Consider the strut.(2.4)

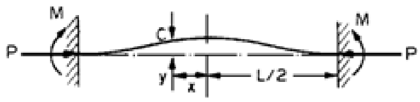


Figure 2.4: Strut with fixed end

Euler's theory

$$P_e = \frac{4\pi^2 EI}{L^2}$$

——(2.1)

Here L is the length of the strut and the term L/k is known as the slenderness ratio.

Rankine or Rankine-Gordon formula

Rankine stress

$$\sigma_R = \frac{\sigma_y}{1 + a\left(\frac{L}{K}\right)^2}$$

——(2..2)

Where$a = \frac{\sigma_y}{\pi^2 E}$, Theoretically, but having a value normally found by experiment for various materials. This will take into account other types of end condition. Therefore Rankine load

$$P_R = \frac{\sigma_y A}{1 + a\left(\frac{L}{K}\right)^2}$$

——(2.3)

End condition	Fixed-free	Pinned-pinned	Fixed-pinned	Fixed-fixed
Euler load	$\frac{\pi^2 EI}{L^2}$	$\frac{\pi^2}{EI}$	$\frac{2\pi^2 EI}{L^2}$	$\frac{4\pi^2 EI}{L^2}$
P_e	Or,I=Ak^2,Where K=radius of gyration			
Eulerstress	$\frac{\pi^2 EA}{4\left(\frac{L}{K}\right)^2}$	$\frac{\pi^2 EA}{\left(\frac{L}{K}\right)^2}$	$\frac{2\pi^2 EA}{\left(\frac{L}{K}\right)^2}$	$\frac{4\pi^2 EA}{\left(\frac{L}{K}\right)^2}$
σ_e	$\frac{\pi^2 E}{4\left(\frac{L}{K}\right)^2}$	$\frac{\pi^2 E}{\left(\frac{L}{K}\right)^2}$	$\frac{2\pi^2 E}{\left(\frac{L}{K}\right)^2}$	$\frac{4\pi^2 E}{\left(\frac{L}{K}\right)^2}$

Table 2.1: Different fix condition

2.6 Seismic Analysis

T. Tsunematsu a,, H. Namba b, Y. Akutsu a, Y. Ohkawa a, A. Yagenji a, M. Takeda b, K. Yajima b, Y. Nitta b, K. Kobayashi c, I. Maeda c, Y. Takenaka

The support structure of the International Thermonuclear Experimental Reactor (ITER) is suggested to have appropriate stiffness that accommodates both thermal distortion of the system and a maximum ground acceleration of 0.2 G due to earthquakes. For a site with earthquakes more severe than 0.2 G, the seismic isolation design is a possible candidate for keeping the seismic input low enough. The present design of ITER assumes that only the Tokamak pit portion is isolated, due to the whole building being very large and complex. In this study, dynamic analyses of the whole Tokamak building with a base-isolated Tokamak pit were carried out, and the effect of the isolation of the pit structure was evaluated.

G. Mazzonea, G.Sannazzaroa, T.Schiolera, V.Sorinb

The structural performance of the ITER Main Components it is important to take into accounts not only mutual dynamic interaction among the mduringa seismic event but also their interactions with the Tokamak Buildings (TB) complex. The seismic behaviour of the TB is affected by the large dimensions of the building, the concrete basemat thickness that obe sufficiently rigid to support the weight of the Tokamak, the presence of anti-seismic bearing (ASB) under the basemat, and the distribution of heavy equipment at higher levels. These factors require that the soil- structural interaction must be studied in detail, taking into account the specific effect such as the excavation inuence and the building rocking motion due to seismic wave- propagation. The study of the seismic behaviour has been carried out using two different linear dynamic methodologies: power spectral density (PSD) and spectral analyses. The paper illustrates the main results of the seismic analyses and gives the seismic design input for the Tokamak component in terms of support loads, accelerations and displacements.

V.M. Sorin, P. Barabaschi, G. Sannazzaro [12]

A coupled spectrum seismic analysis of the ITER tokamak-building-basemat- soil system has been performed. Soil structure interaction (SSI) is modelled as a set of springs and dampers. A new method is proposed to replace the detailed finite- element model of the building by an equivalent set of parallel oscillators having the same natural frequencies, modal effective masses and height as the building and creating the same shearing force and overturning moment. The response of the ITER tokamak is found versus different soil parameters. For some particular soil conditions, the natural frequency of the building is very close to that of the tokamak and critical resonance effects may take place.

S Tado , K Kitamura, Y Itou, K Koizumi, E Tada, T Tsunematsu [9]

The ITER tokamak machine has a relatively flexible support structure against horizontal loads as from an earthquake. Modal analyses and modal transient analyses have been carried out by using the finite element analysis code NASTRAN. To assess the response of the tokamak driven by a horizontal seismic load with the ITER design response spectra. Two types of three-dimensional models and a simplified mass/spring model have been used as structural models. The three-dimensional models have been used for modal analyses and modal transient analyses. The simplified mass/spring model has been used for parameter surveying of the transient response.

2.7 Thermal analysis

Jyotirmoy Koner, A.k.Sinha[15]

Gyro-devices like gyrotrons are used in the TOKOMAK system for plasma heating. Hence thermal temperature distribution of Gyrotron is so important. The operating mode TE03 Generated inner cavity wall due to cavity Ohmic wall loss has been cooled using liquid turbulent flow 290K.Water has been used as coolant liquid for cooling purposes. After cooling of the cavity thermal distributions along with cavity less than critical limit.

C.B.Baxi ,R.W.Callis,I.A.Gorelov,J.lohr[16]

During 2004 and 2005 collectors on three of the gyrotrons used at DIII-D failed due to stress cracks.In order to investigate reasons for these failures a nonlinear elastic plastic thermal stress analysis of the collector/design was undertaken.The thermal stress analysis results indiated the effective strain for oxygen free high conductivity copper material under the operating condition limited the cycle life of the collector due to fatigue resulting in failure.The desired service life of more than 10^5thermal cycles can be obtained by (1)Operating changes,Such as increasing the frequency and amplitude of sweeping to reduce the healt flux(2) Design changes,such as increasing the height and diameter of collector,enhancing the heat transfer coefficient by roughening the coolant channel walls(3)changing the material of the collector to dispersion strengthended copper such as Glidcop.

Chapter 3

DESIGN OF SUPPORT STRUCTURE FOR COMPONENTS

- In Gyrotron system basically main three components are in it.
  1.Collector magnet
  2.Gyrotube
  3.MIG magnet

Design Methodology

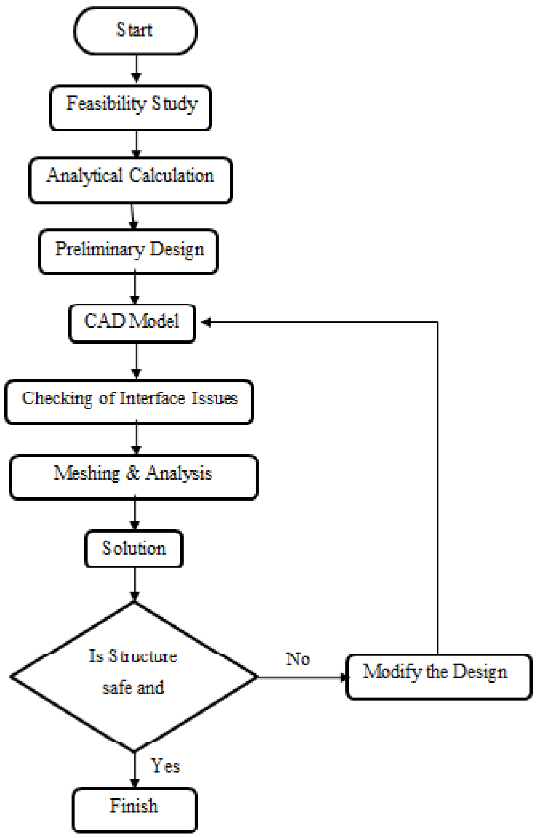


Figure 3.1: Design Methodology

Thickness of plate

Component	Parameter	thickness of plate in mm
Collector Magnet	Plate	20
Gyrotube	Plate	20
MIG Magnet	Bottom Plate	30
	Top Plate	25

Table 3.1: Thickness of plate for support Structure

3.1 Support structure for collector magnet

- **Design of Column**

Rankine Formula

$$\frac{P}{A} = \frac{S_y}{1 + a\left(\frac{L_c}{K}\right)^2}$$

Both ends fixed
Total applied load on a plate P=500kg
Yield stress S_y =253.33N/mm^2
Length of Column L_c=155mm
Radius of Gyration K=d/4
A=Area
Radius of Gyration K=d/4

$$A = \frac{\pi}{4}d^2$$

$$a = \frac{S_y}{\pi^2 E}$$

Figure 3.2: Load act on a Column

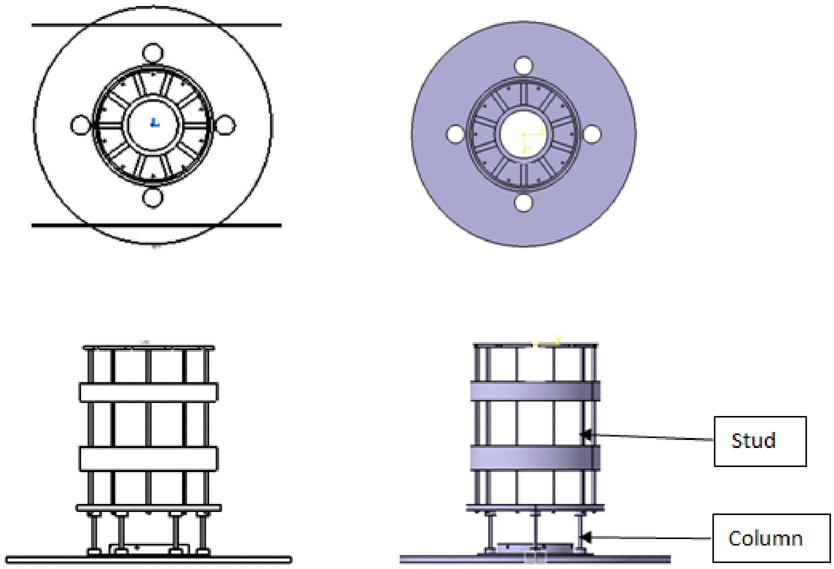


Figure 3.3: Support structure for collector magnet

Diameter of column $\mathbf{d_{c1}=8.91mm}$

As per standard $\mathbf{d_{c1}=10mm}$

Checking for Buckling

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

Buckling Strength Formula

$$= \mathbf{684.126\ kg}$$

Apply load is 500 kg on column, which is less than Buckling load

so,column design is safe.

- **Design of stud**

$$\frac{P}{A} = \frac{S_y}{1 + a\left(\frac{L_s}{K}\right)^2}$$

Where,
Total applied load on a plate P=5886N (Consider FOS 2)
Yield stress S_y =253.33N/mm^2

Length of Column L_s=520mm
Radius of Gyration K=d/4
A=Area
L=520mm

$$a = \frac{S_y}{\pi^2 E}$$

Diameter of a stud d_s=13mm

Checking for Buckling
Buckling Strength Formula

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

=398 kg

Apply load is 300 kg on stud, which is less than Buckling load.

So,Stud design is safe.

Deflection of plate
Total applied Load P=950kg
Elasticity of Modulaus E=2e5Mpa
Possion Ratioν=0.3
Inner radius of Plate b=‘130mm
Outer radius of plate a=255mm
Radial location of unit line loading r=55mm
Thickness of plate t=20mm
Flexural Rigidity D=146520147

Figure 3.4: Outer edge fixed inner edge free of plate for support structure plate

$$Y_b = -\frac{qa^4}{D}\left(\frac{C_1 L_{14}}{C_4} - L_{11}\right)$$

$$L_{14} = \frac{1}{16}\left[1 - 4\left(\frac{r_0}{a}\right)^2\right]$$

$$C_4 = \frac{1}{2}\left[(1+\nu)\frac{b}{a} + (1-\nu)\frac{a}{b}\right]$$

$$C_1 = \frac{1+\nu}{2}\frac{b}{a}ln\frac{a}{b} + \frac{1-\nu}{4}\left(\frac{a}{b} - \frac{b}{a}\right)$$

$$L_{11} = \frac{1}{64}\left\{1 + 4\left(\frac{r_0}{a}\right)^2 - 5\left(\frac{r_0}{a}\right)^4 - 4\left(\frac{r_0}{a}\right)^2\left[2 + \left(\frac{r_0}{a}\right)^2 ln\frac{a}{r_0}\right]\right\}$$

Deflection of pate is 0.12mm

Moment of Plate

Total applied Load P=350kg

Elasticity of Modulaus E=2e5Mpa

Possion Ratioν=0.3

Inner radius of Plate b=‘130mm

Outer radius of plate a=255mm

Radial location of unit line loading r=55mm

Thickness of plate t=20mm

Flexural Rigidity D=146520147

$$M_{ra} = -qa^2\left(L_{17} - \frac{C_7}{C_4}\right)$$

$$L_{14} = \frac{1}{16}\left[1 - 4\left(\frac{r_0}{a}\right)^2 ln\frac{a}{r_o}\right]$$

$$C_7 = \frac{1}{2}\left(1-\nu^2\right)\left(\frac{a}{b} - \frac{b}{a}\right)$$

$$C_4 = \frac{1}{2}\left[(1+\nu)\frac{b}{a} + (1-\nu)\frac{a}{b}\right]$$

$$L_{17} = \frac{1}{4}\left\{1 - \frac{1-\nu}{4}\left[1 - \left(\frac{r_0}{a}\right)^4\right] - \left(\frac{r_0}{a}\right)^2\left[1 + (1+\nu)\, ln\frac{a}{r_0}\right]\right\}$$

Bending moment of plate is -1.17Nm

3.2 Support structure for Gyrotube

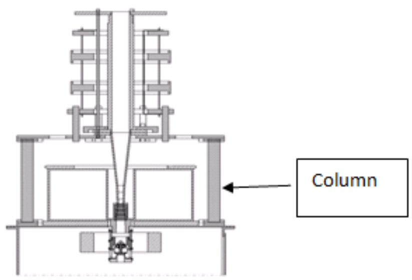


Figure 3.5: Support structure for Gyrotube

Design of column

$$\frac{P}{A} = \frac{S_y}{1 + a\left(\frac{L_c}{K}\right)^2}$$

Where,
Total applied load on a plate P=600kg
Yield stress S_y =253.33N/mm^2
Length of Column L_c=558mm
Radius of Gyration K=d/4
A=Area

$$a = \frac{S_y}{\pi^2 E}$$

Diameter of column $\mathbf{d_{c2}=16mm}$

Checking for Buckling
Buckling Strength formula,

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

=787.19kg

Apply load is 600kg, which is less than buckling load.

So,Column design is safe.

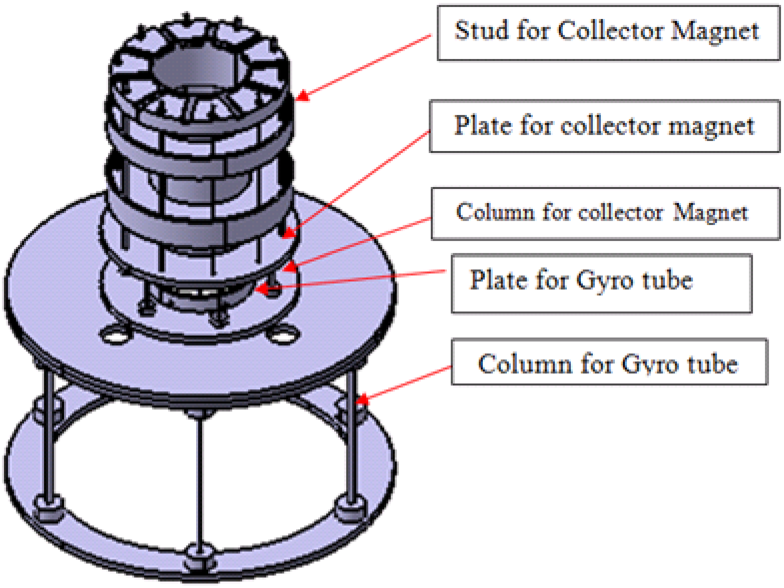


Figure 3.6: Support structure for collector Magnet & Gyro tube

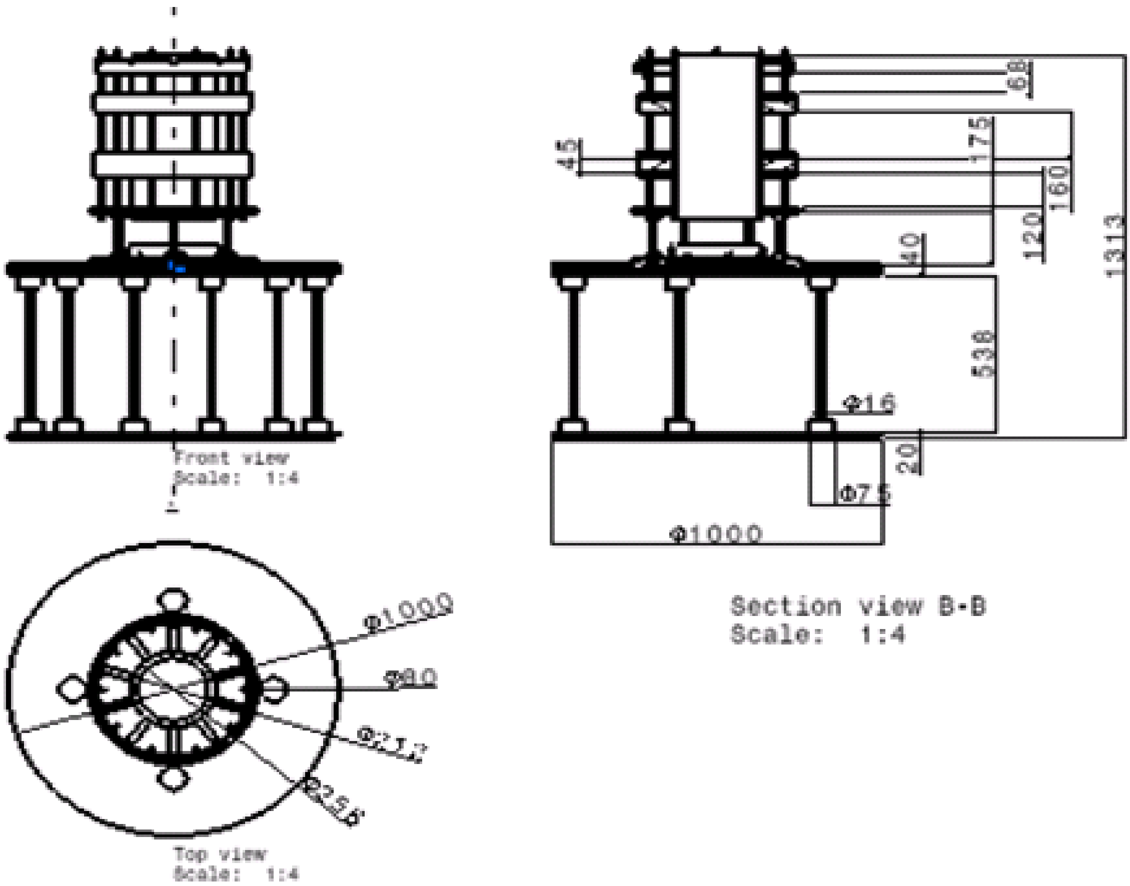


Figure 3.7: Discriptive Drawing of Support structure for collector Magnet and Gyrotube

3.3 Support Structure for aMIG magnet

Design of Column

$$\frac{P}{A} = \frac{S_y}{1 + a\left(\frac{L}{K}\right)^2}$$

Where,

Total applied load on a plate P=140kg

Yield stress S_y =253.33N/mm^2

Length of Column L_c=145mm

Radius of Gyration K=d/4

A=Area

$$a = \frac{S_y}{\pi^2 E}$$

Diameter of column d_{C3}=5.68mm

As per standard $\mathbf{d_{c3}=6mm}$

Checking for Buckling

Buckling Strength Formula

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

=781.777kg

Apply load is 140 kg, which is less than buckling load

So,Column design is safe.

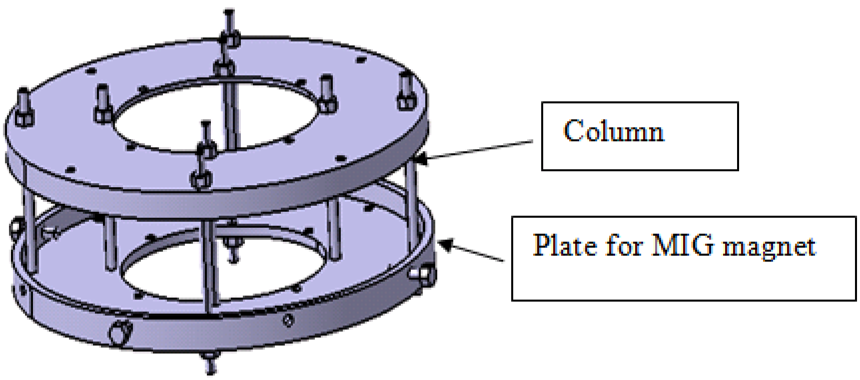


Figure 3.8: Support structure for MIG magnet

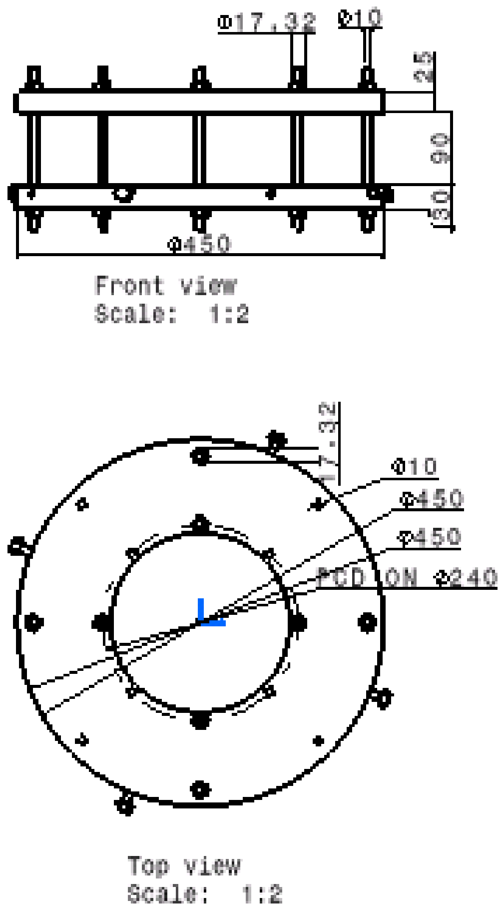


Figure 3.9: Discriptive Drawing of Support structure for MIG magnet

3.4 Tank

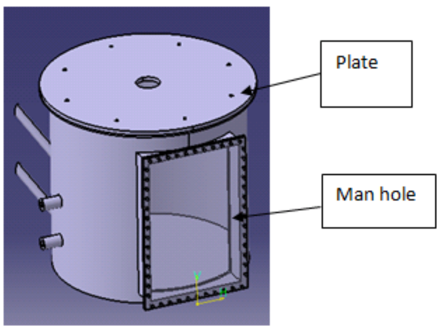


Figure 3.10: Tank

Tank is fabricated for the 200kW Gyrotron system.The length of the gyrotrons required that the tanks be of a low profile in order that the assembly of tank-magnet-gyrotronconvertor fit within the building celiling limit.This low profile puts a considerable constraint on the packaging of the electronics that must reside in the floating at the cathode voltage.

Problem associated with tank

1. The steel in the building floor supports created unacceptable perturbations in the gyrotron magnetic field profile. The tanks had to be supported 14 in. from the floor to reduce this perturbation.

2. Tight packaging of the electronic packages has lead to several fiber optic failures and has made access for maintenance more difficult.

Recommendations

1. The need for maintenance should be factored in during the design phase.

2. More protection from voltage transients during sparkdowns should be included in the electronics design.

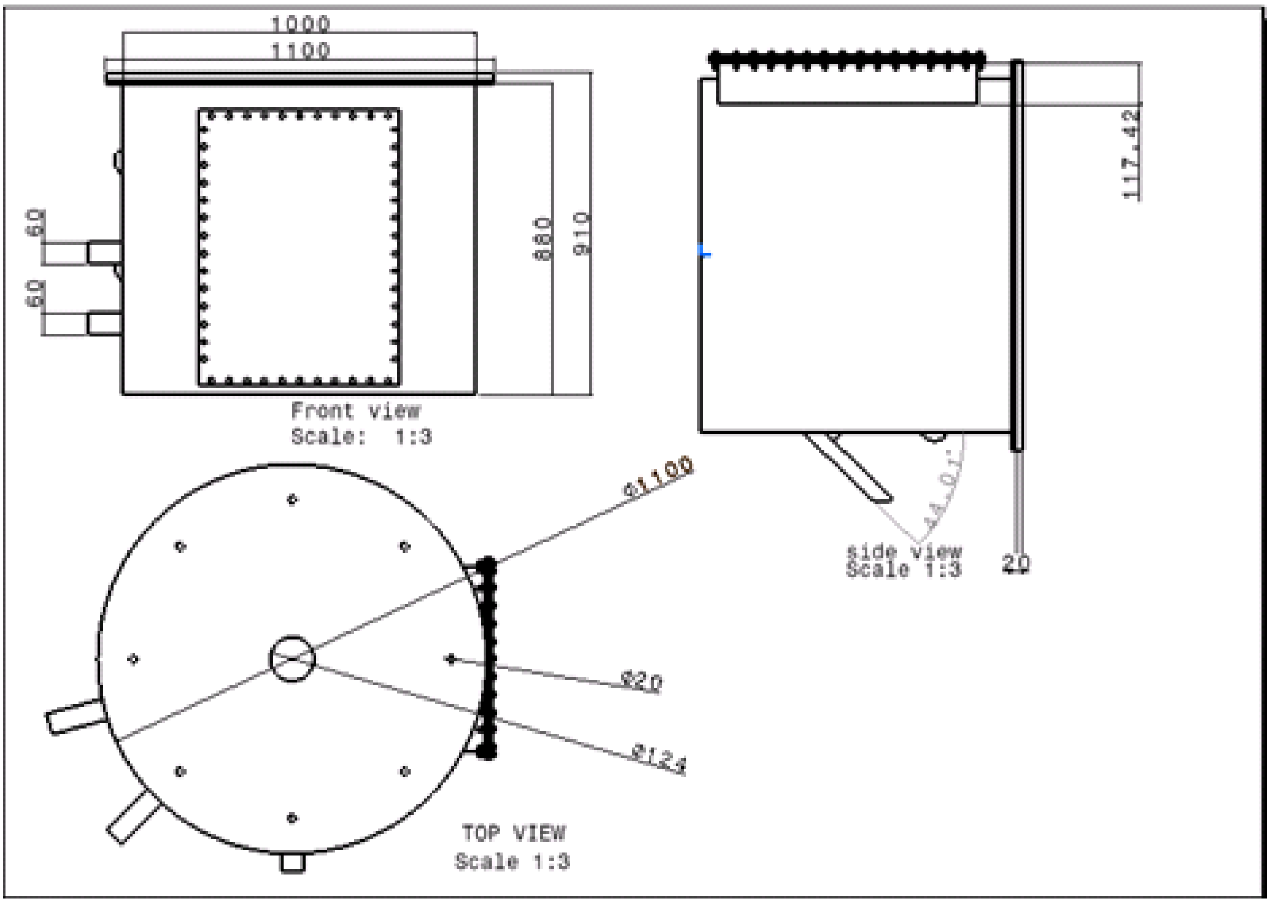


Figure 3.11: Discriptive Drawing of Tank

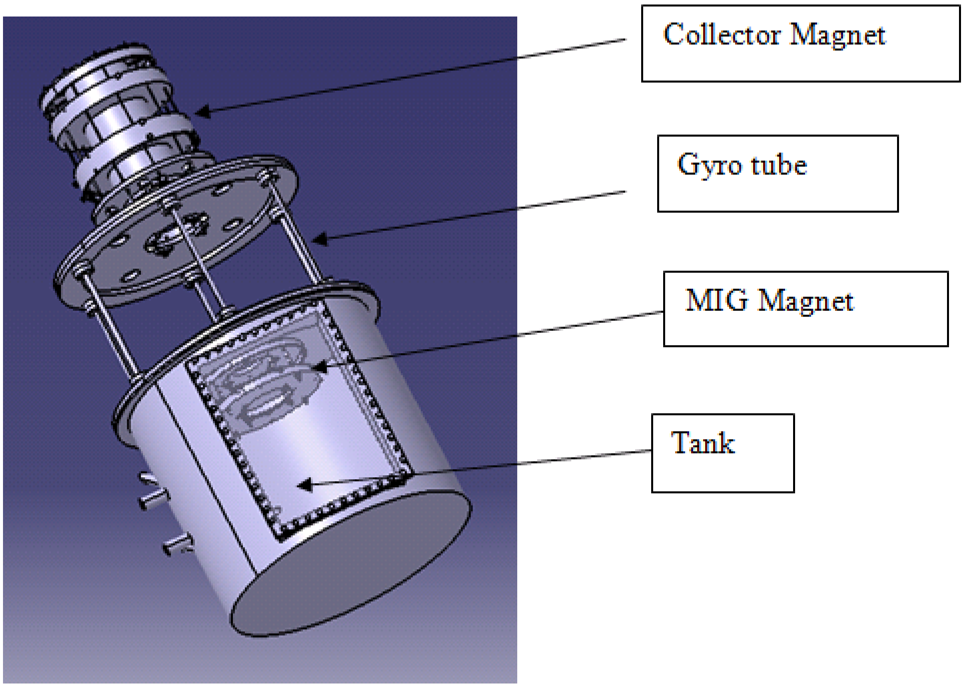


Figure 3.12: Assembly

3.5 Seismic Analysis

Seismic Analysis is a subset of structural analysis and is the calculation of the response of a building (or nonbuilding) structure to earthquakes.

3.5.1 Seismic analysis and design verication

Structures are usually designed for gravity loads and checked for earthquake loading. In conformity with the design philosophy, this check consists of two steps - the rst ensures elastic response under moderate earthquakes and the second ensures that collapse is precluded under a severe earthquake. Due to the uncertainties asso- ciated in predicting the inelastic response, the second check may be dispensed with, by providing adequate ductility and energy dissipation capacity. In this section, the various methods of performing these checks are described.

The important factors, which in uence earthquake resistant design are, the geographical location of the structure, the site soil and foundation condition, the importance of the structure, the dynamic characteristics of the structure such asthe natural periods and the properties of the structure such as strength, stiness, ductility, and energy dissipation capacity. These factors are considered directly or indirectly in all the methods of analysis.

3.6 Elastic Response Analysis

Elastic response analysis[13] is invariably performed as a part of the usual design procedure. The primary aim of elastic analysis is to ensure serviceability under mod- erate earthquakes. For simple and regular structures, the seismic coecient method is normally used. Structures such as multi-storeyed buildings, overhead water tanks and bridge piers are usually designed by the response spectrum method while for more important structures such as nuclear reactors, time-history response analysis is usually adopted. In what follows the seismic coecient method is explained in detail while the response spectrum method and time history analysis are described brie y since understanding of these methods requires some knowledge of structural dynamics.

- Seismic coecient method (static).
- Response spectrum method (dynamic).

3.7 Seismic coefficient Method

This is the simplest of the available methods and is applicable to structures, which are simple, symmetric, and regular. In this method, the seismic load is idealized as a system of equivalent static loads, which is applied to the structure and an elastic analysis is performed to ensure that the stresses are within allowable limits. The sum of the equivalent static loads is proportional to the total weight of the structure and the constant of proportionality, known as the seismic coecient, is taken as the product of various factors,which is influnce the design and are specified in the code IS:1893-2002

3.7.1 Theoretical calculation for seismic coefficient value

For,Seismic coefficient value,[14]

$$A_h = \frac{ZIS_a}{2Rg}$$

I= 1.5 From Importance factor depending upon functional
use of the strucutres characterized bt hazards consequences
of its failure,post-earthquake functional needs historical value
or economic importance from tableA.2
R= 3 From Reduction factor depending on the preceived seismic
damage performance of the strucutre,charactersied by ductile or
brittle deformantions. However the ratio $\left(\frac{I}{R}\right)$ shall not be greater

than 1.0.from table A.3
$\frac{S_a}{g}$= Average response acceleration coefficient for rock or soil site as given by fig and table based on appropriate natural periods and damping of the strucutre.
A_h=It is horizontal acceleration coefficient that shall used for design of structures.
Z=seismic zone factorA.1

For Hard soil,

$$\frac{S_a}{g} = \begin{cases} 1 + 15T, 0.00 \leq T \leq 0.10 \\ 2.50, 0.10 \leq T \leq 0.40 \\ 1.00/T, 0.40 \leq T \leq 4.00 \end{cases}$$

For Medium soil,

$$\frac{S_a}{g} = \begin{cases} 1 + 15T, 0.00 \leq T \leq 0.10 \\ 2.50, 0.10 \leq T \leq 0.55 \\ 1.36/T, 0.55 \leq T \leq 4.00 \end{cases}$$

For Soft soil,

$$\frac{S_a}{g} = \begin{cases} 1 + 15T, 0.00 \leq T \leq 0.10 \\ 2.50, 0.10 \leq T \leq 0.67 \\ 1.67/T, 0.67 \leq T \leq 4.00 \end{cases}$$

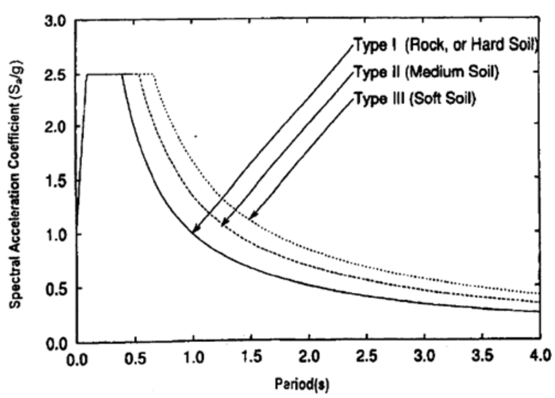


Figure 3.13: Response spectra for Rock and soil site for 5 percent Damping

For accurate value first range is divided into four parts
other two range is divided into ten parts.
seismic coefficient value is carried out **0.28.**

Chapter 4

RESULT AND DISCUSSION

Support Structure to check the stress & deflection and study the structural stiffness to the dead weight. Based on the result, the dimension of structure has been optimized. Further, the Static equivalent seismic analysis has been carried out to study the seismic behavior of the support structure and also behavior of Gyro system.

Component	Parameter	Diameter in mm
Collector Magnet	Column	10
	Stud	13
Gyrotube	Column	16
MIG Magnet (Self wt.)	Column	10

Table 4.1: Design Parameter of support structure

4.1 Structural Analysis

1. Structural Analysis: Finally design was made with 6 tie rod to support structure.It is mounted on a tank.

Collector magnet and support structure is 500 kg,which is act on a circular plate.

Structural analysis was carried out three kinds of loads.

1. Vertical Load
2. Load act by 5 degree inclined to vertical.
3. Load act by 10 degree inclined to vertical.

4.1.1 Vertical Load

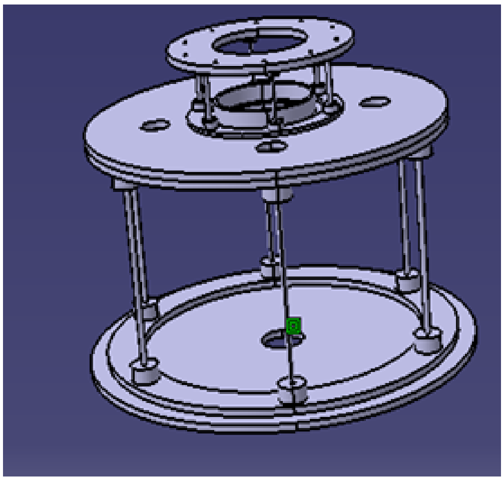


Figure 4.1: Model

Meshed model

Support structure has been meshed with tri element

Element Type: Solid185

No of Elements: 33674

No of Nodes: 10771

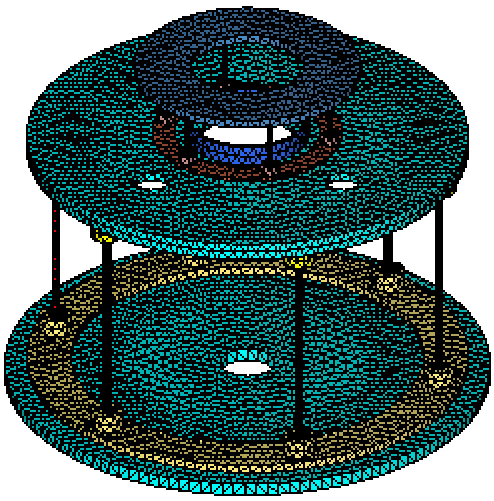


Figure 4.2: Meshing Model

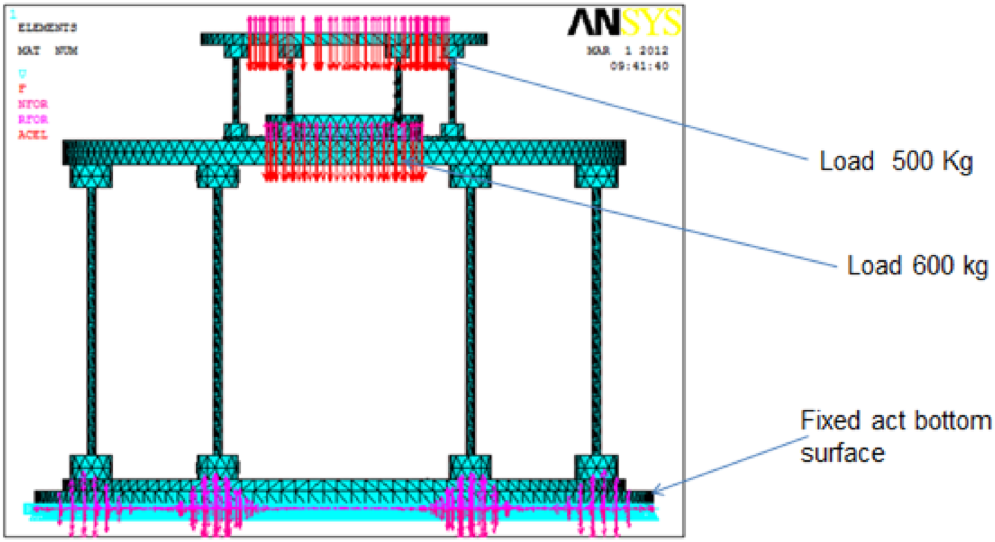
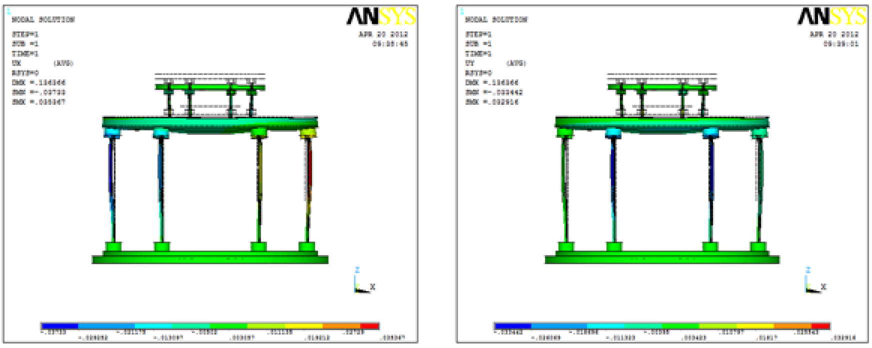
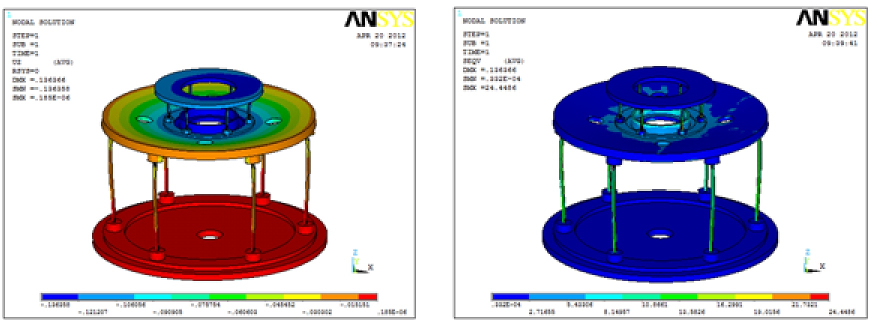


Figure 4.3: Apply vertical load



X - Displacement = -0.35mm **Y -Displacement= -0.32mm**

Figure 4.4: X and Y Displacement of vertical load



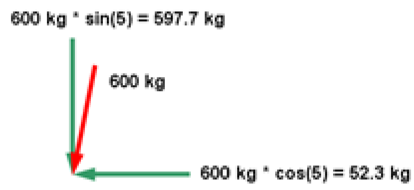
Z –Displacement= 0.136mm **Von-Mises Stress=24.45Mpa**

Figure 4.5: Z Displacement and von mises stress of vertical load

Here, When vertical load is appied on a gyrotron assembly at that time displacement is coming 0.13mm and von-mises stress is coming 24.45Mpa.

4.1.2 Load act by 5 degree inclined to vertical.

Total load is resolved on a plate in here verical direction z- direction and horizontal X-direction



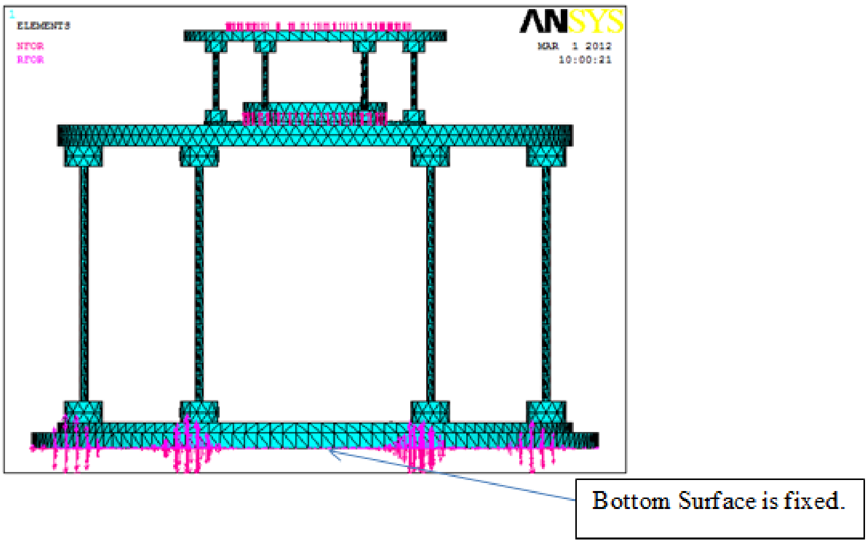


Figure 4.6: Gyrotorn assembly incliend by 5 degree

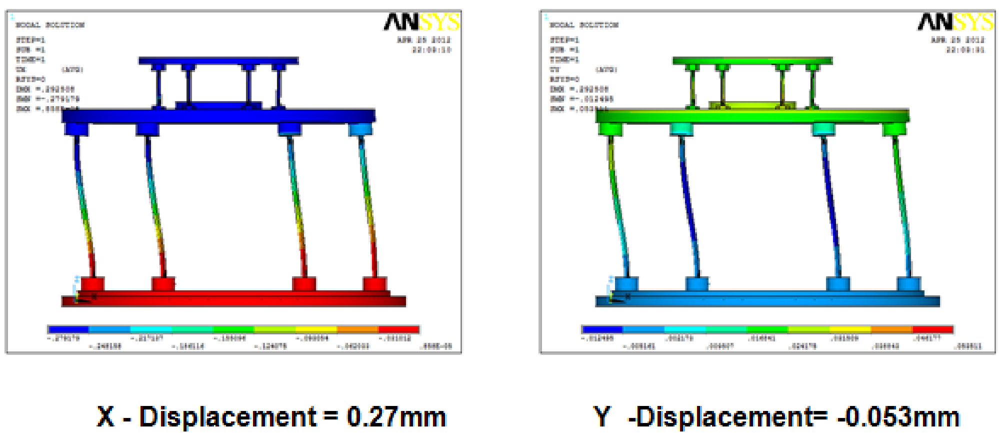
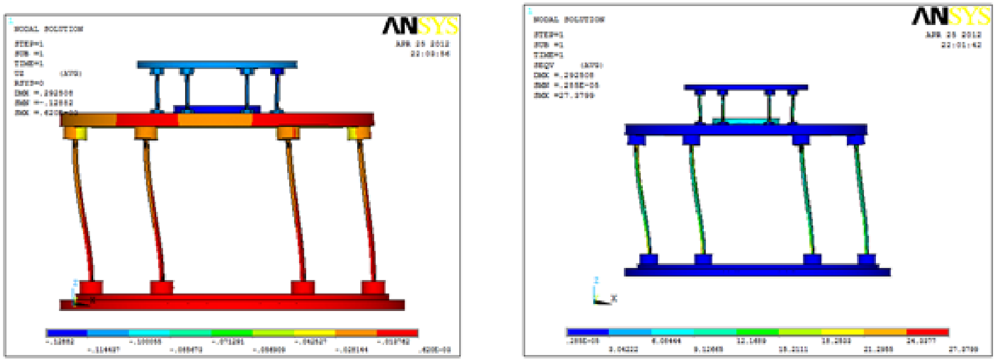


Figure 4.7: X and Y Displacement of 5 degree inclined gyrotron assembly load



Z –Displacement= 0.128mm   Von-Mises Stress=27.37Mpa

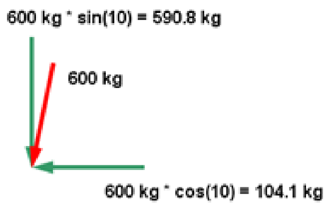
Figure 4.8: Z Displacement and von mises stress of 5 degree inclined gyrotron assembly load

Here, When inclnied 5 degree load is appied on a gyrotron assembly at that time displacement is coming 0.128mm

and von-mises stress is coming 27.37Mpa.

4.1.3 Load act by 10 degree inclined to vertical.

Total load is resolved on a plate in here verical direction z- direction and horizontal X-direction



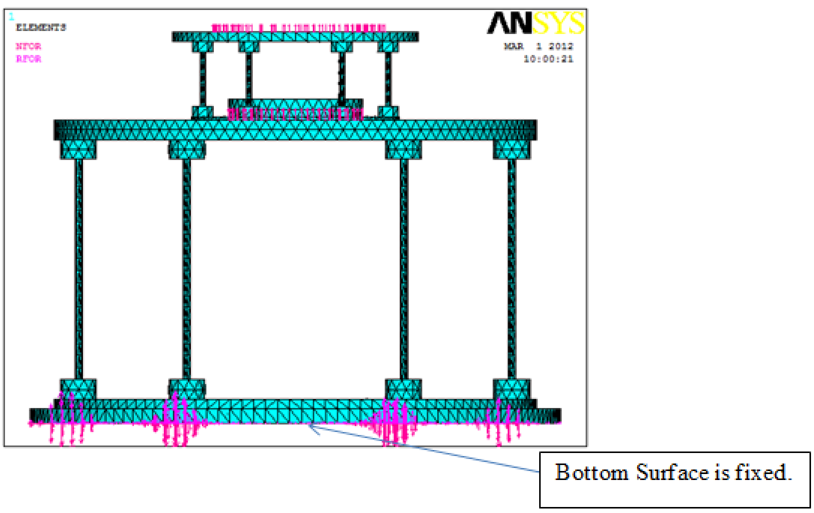


Figure 4.9: Gyrotorn assemblyincliend by 10 degree

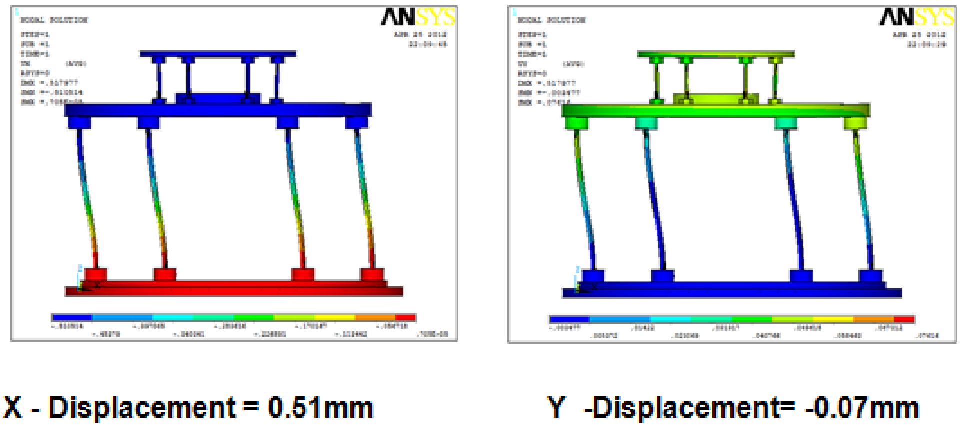


Figure 4.10: X and Y Displacement of 10 degree inclined gyrotron assembly load

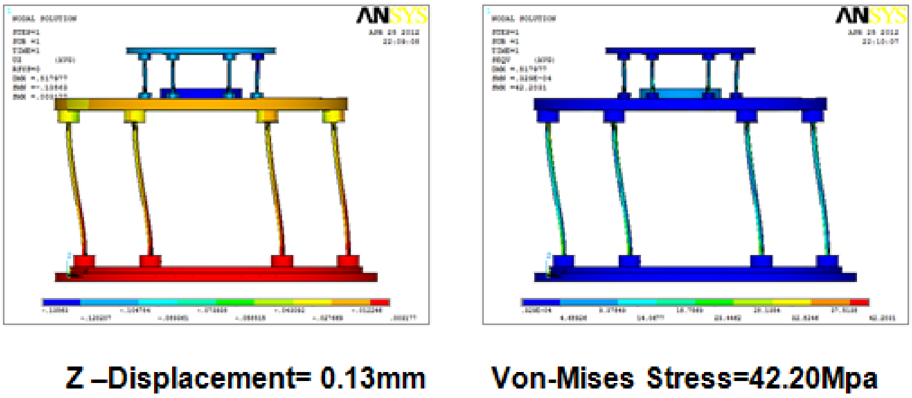


Figure 4.11: Z Displacement and von mises stress of 10 degree inclined gyrotron assembly load

Here, When inclnied 10 degree load is appied on a gyrotron assembly at that time displacement is coming 0.13mm

and von-mises stress is coming 42.20Mpa.

Degree	Displacement in mm	Permissible displacement in mm	Stress in Mpa	Permissible stress inMpa	Remarks
0	0.1369	1	24.45	253	Safe
5	0.2925	1	27.37	253	Safe
10	0.5179	1	42.20	253	Safe

Table 4.2: Structural Analysis Result Comparison

4.2 Structural analysis of Tank

The tank is designed to take the weight of the complete support structure assembly and the weight gyrotron assembly. Structural analysis has been carried out for to the check stress and deflection.

No of total load apply on a tank

1. Collector Magnet weight (240kg)
2. Gyrotron assembly weight (600kg) Fos 2
3. Gun magnet weight (70kg)
4. Cryostat magnet weight (700kg)
5. Support structure assembly weight (373kg)

Also apply Gravitational force in vertical direction 9810N.

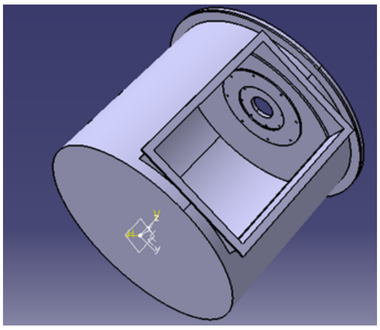


Figure 4.12: Model of Tank

Meshed Model Tank has been meshed with tri element.
Element Type: Solid185
No of Elements: 172710
No of Nodes: 53647

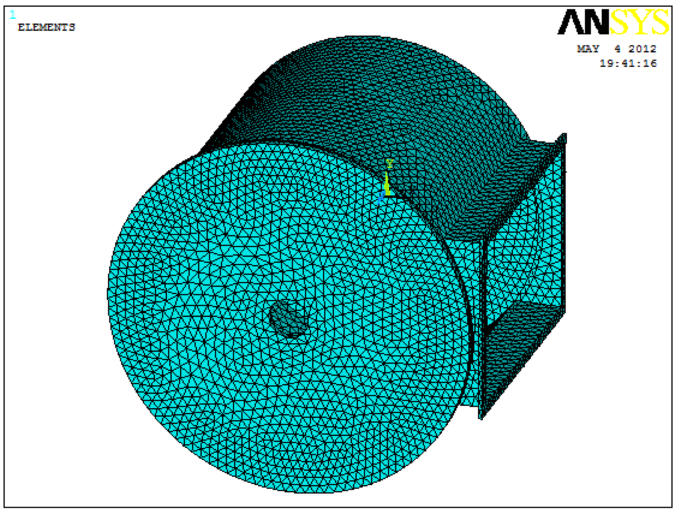


Figure 4.13: Meshing model of Tank

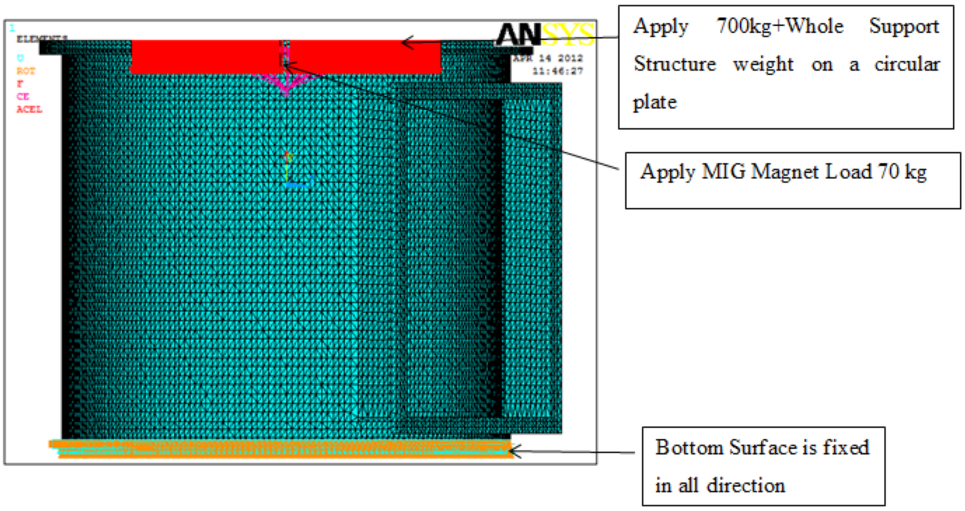
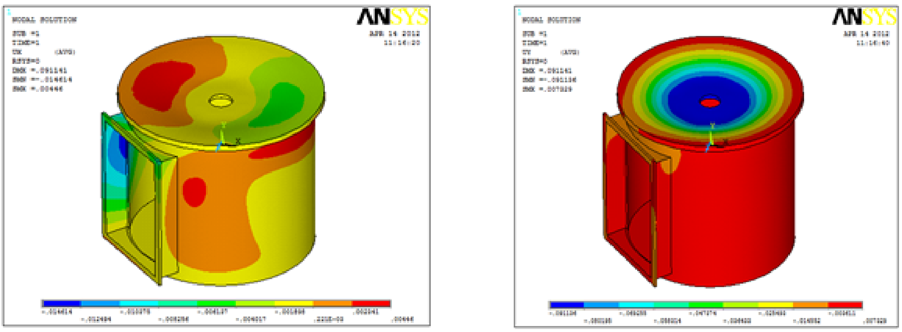
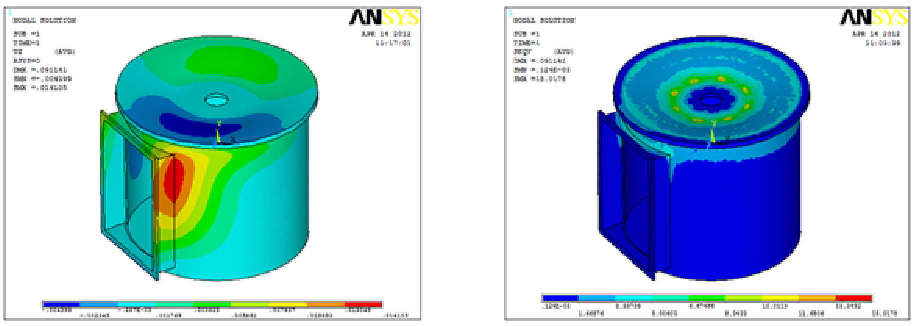


Figure 4.14: Apply Loading condition on a tank



X- Displacement=0.0044mm **Y-Displacement=0.0073mm**

Figure 4.15: Xand Y displacement of Tank



Z-Displacement=0.0141mm **Von-mises stress=15.01Mpa**

Figure 4.16: Z-displacement and Von-Mises Stress of Tank

When load is applied on a circular tank plate the load becomes 15.01Mpa. Which is less than yeild strength so,tank design is safe.

4.3 Seismic Analysis

4.3.1 Modal analysis

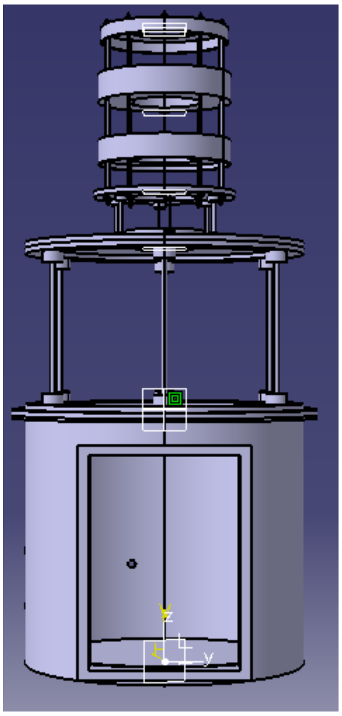


Figure 4.17: Support Strucutre assembly Model

Meshed Model Support structure has been meshed with tri element.

Element Type: Solid185

No of Elements: 94963

No of Nodes: 34576

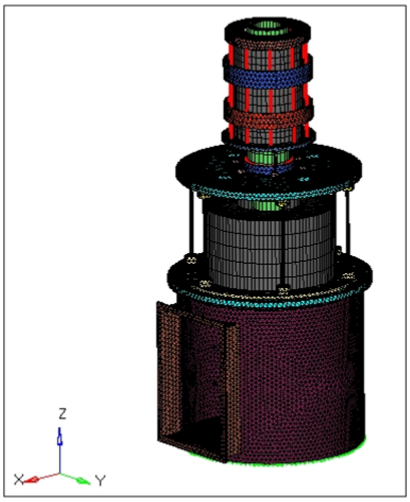


Figure 4.18: Mesh model

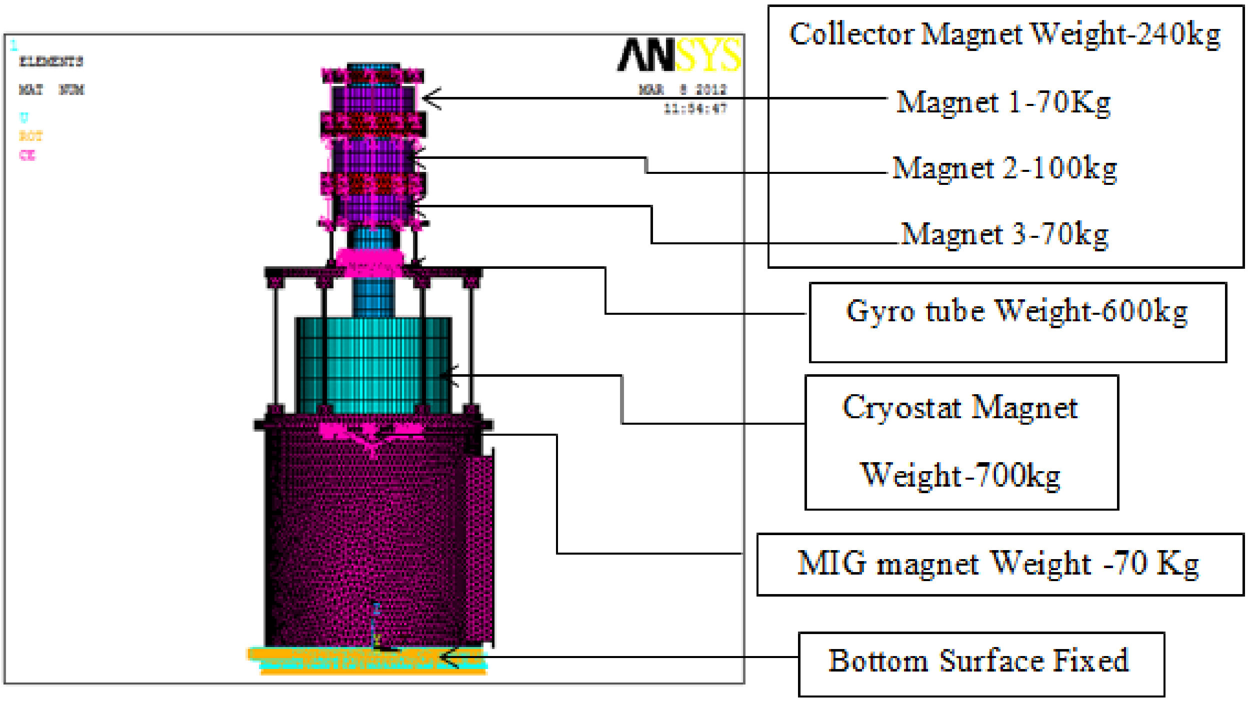


Figure 4.19: Loading condition on Model.

Ten modes were extracted from the modal analysis are listed below

Mode no.	Frequency (Hz)
1	9.805
2	10.739
3	18.733
4	78.188
5	79.788
6	82.564
7	89.691
8	119.75
9	128.18
10	128.86

Table 4.3: Natural frequency

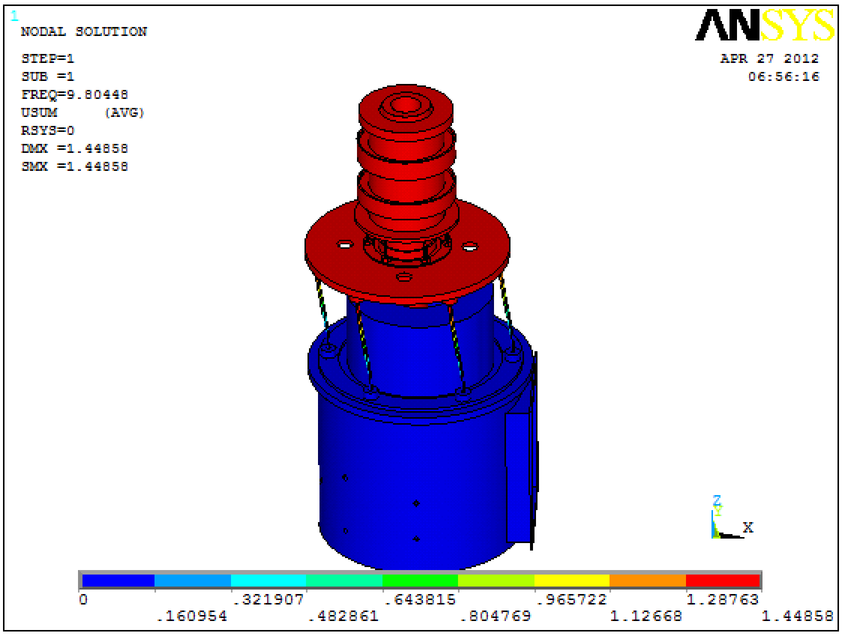


Figure 4.20: 1^{st}Mode Natural frequency

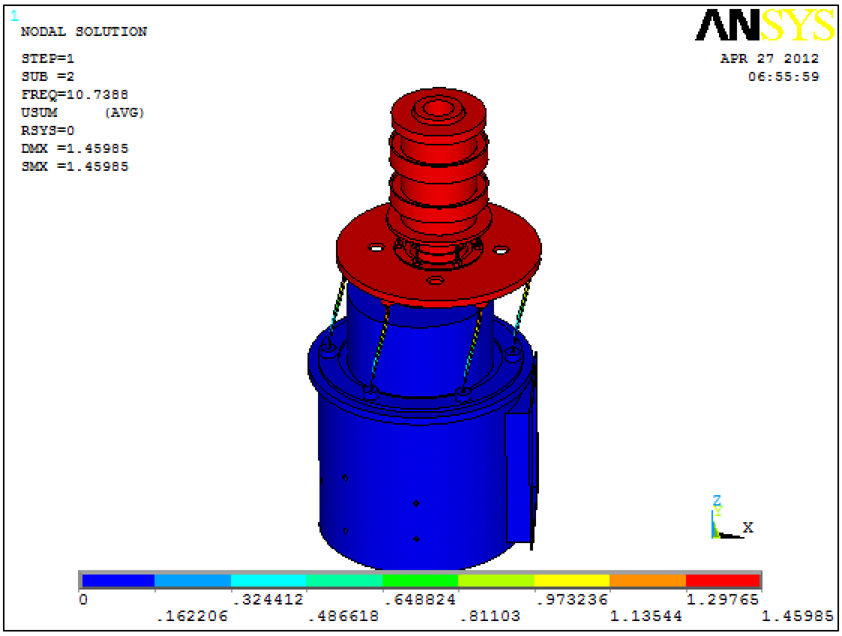


Figure 4.21: 2^{nd}mode Natural frequency

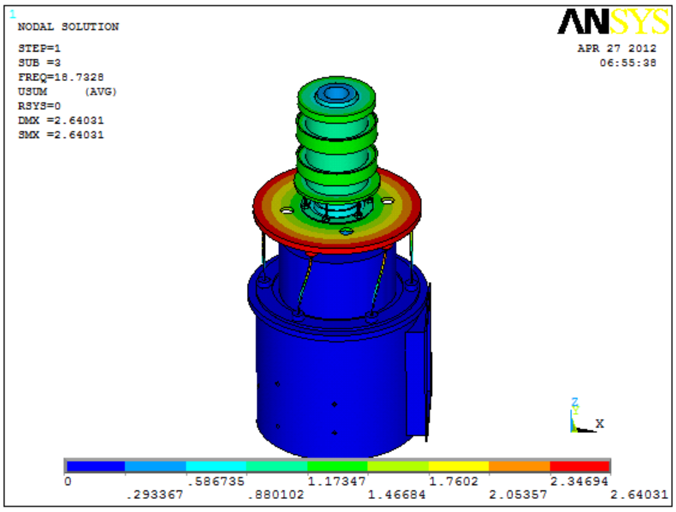


Figure 4.22: 3^{rd}mode natural frequency

As per the ITER design criteria and based on the experience of experts, frequency value of the system around 10 Hz is acceptable .

Use this first mode natural frequency for find out the seismic coefficient value

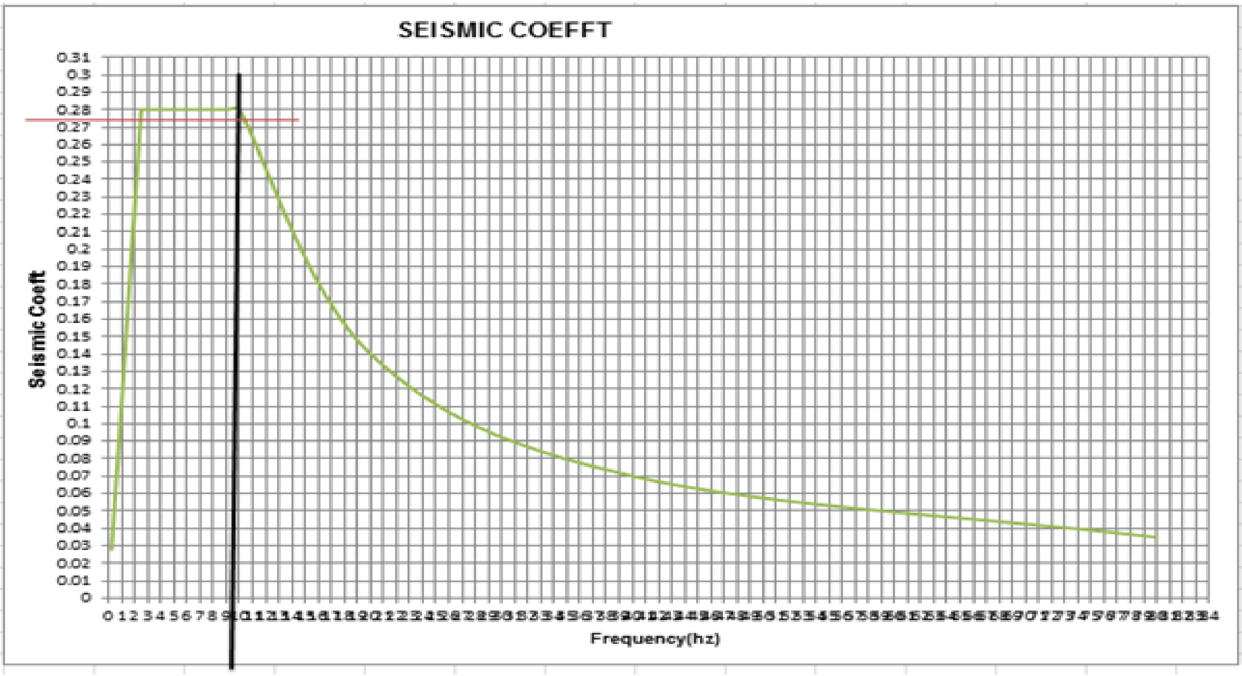


Figure 4.23: Graph seismic coeffcient vs Frequency

4.3.2 Static equivalent seismic analysis

From IS: 1893-2002 standard Ahmadabad is under zone-3 where the seismic intensity is moderate with zone factor of 0.16. The Seismic Coefficient value is 0.28(from theoretical calculation).for the analysis purpose seismic coefficient value is taken 0.3.Lateral acceleration will be 0.3G.

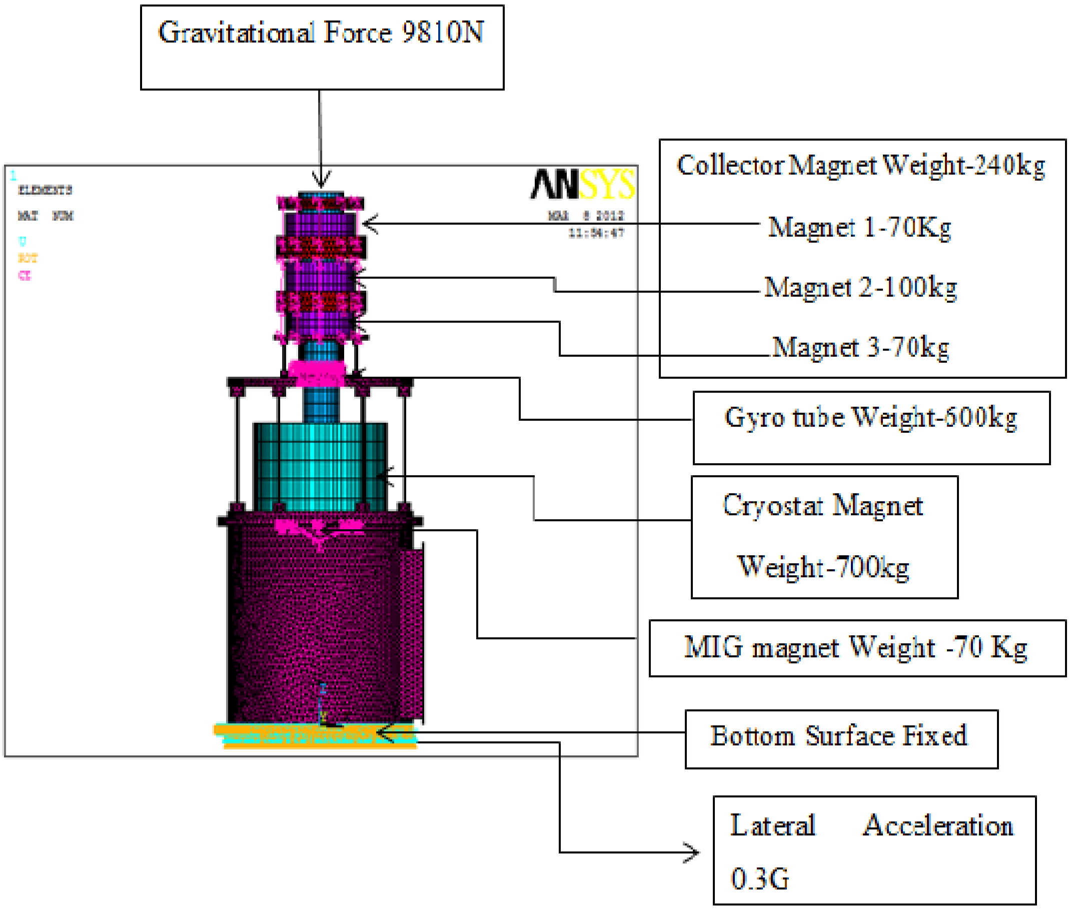
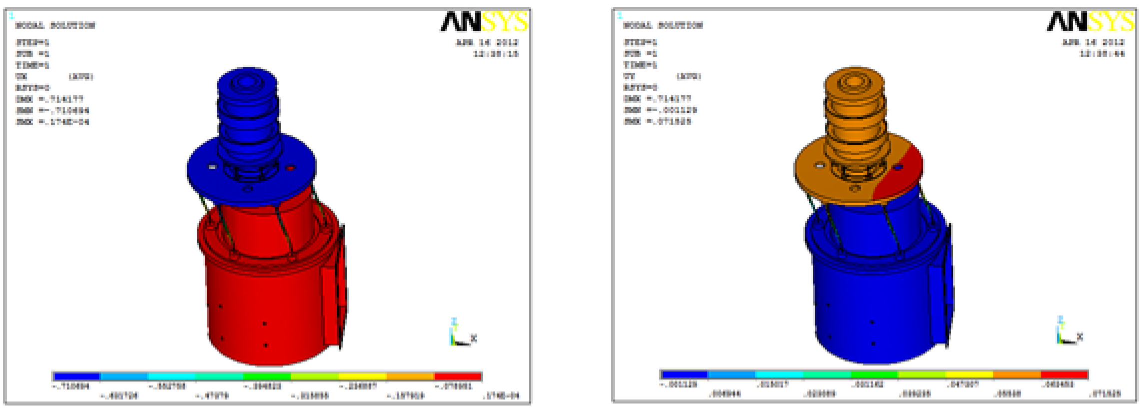
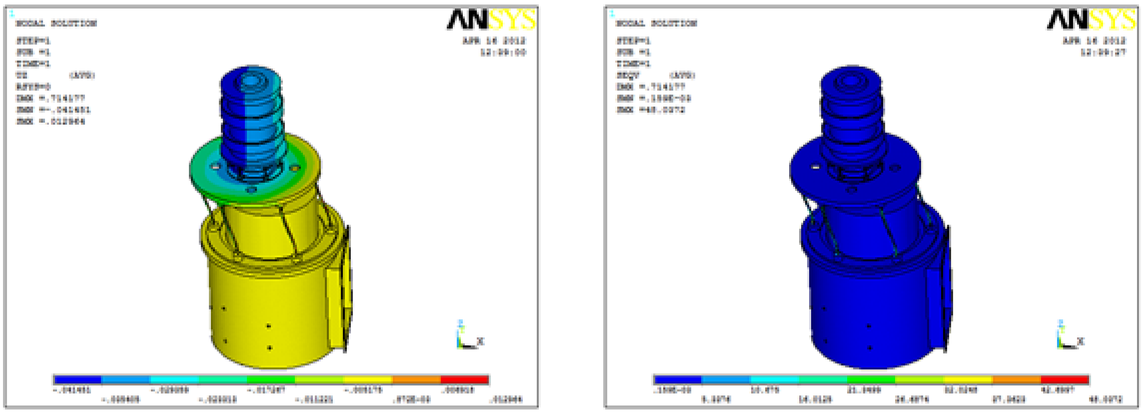


Figure 4.24: seismic loading condition



X-Displacement= -0.71mm **Y-Displacement= -0.0112mm**

Figure 4.25: X- Displacedment and Y-displacement Plot for seismic condition



Z-Displacement=0.012mm **Von-mises stress=48.03Mpa**

Figure 4.26: Z-Displcement and Von-Mises Stress for seismic condition

Max displacement observed in the structure 0.71(x-direction) which is lateral direction.

Max-von mises stress observed ont the strucutre 48.03Mpa and which is well within the yeild limit of the material strength.

So,Design is safe.

4.4 Thermal Analysis

In tank MIG magnet is produced 7500 watt heat,assume that this heat is directly 100% transfer tothe outer wall

outer wall temperature is considered room temperature.thermal conductivity of metal is 20w/mk.

Meshed Model Support structure has been meshed with tri element.

Element Type: Solid70

No of Elements: 33741

No of Nodes: 11384

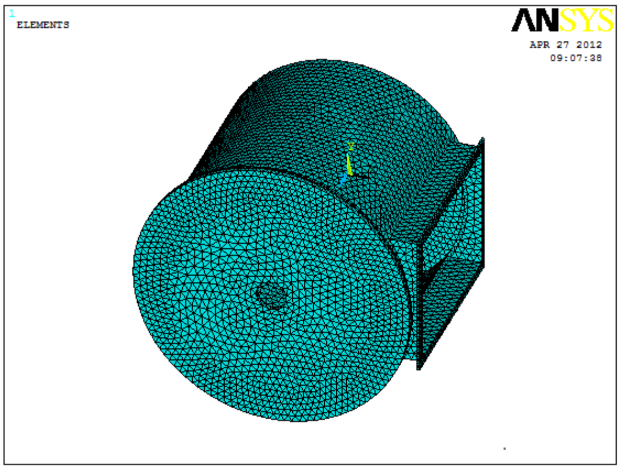


Figure 4.27: mesh tank model

From MIG mangnt heat is gnereated inside the wall as shown in below fig4.28

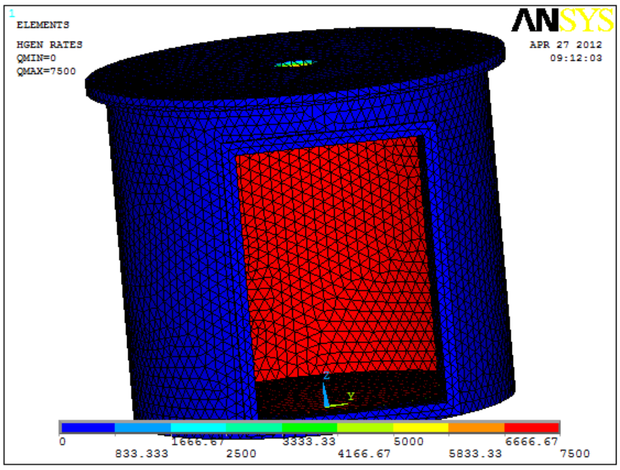


Figure 4.28: Heat genration inside wall

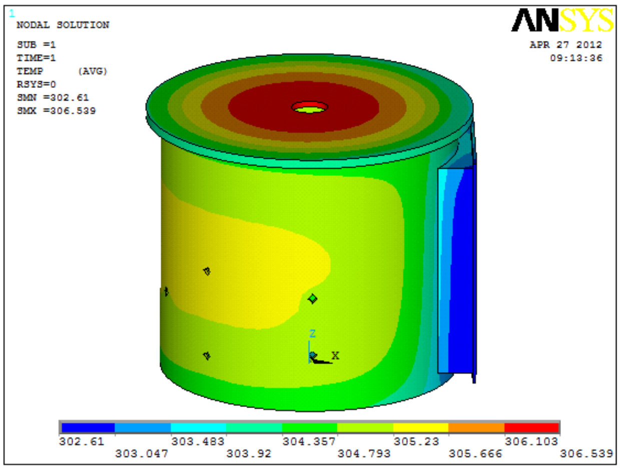


Figure 4.29: Temprature distribution in a tank

As shown in fig4.29 temperature distribution in a tank.

In inital condition temperature is 300k,but when in working condition maximum temperature is 306.53k.

4.5 Results

Component	Parameter	Diameter in mm
Collector Magnet	Column	10
	Stud	13
Gyrotube	Column	16
MIG Magnet (Self wt.)	Column	10

Structural Analysis

Degree	Displacement in mm	Permissible displacement in mm	Stress in Mpa	Permissible stress in Mpa	Remarks
0	0.1369	1	24.45	253	Safe
5	0.2925	1	27.37	253	Safe
10	0.5179	1	42.20	253	Safe

Structural analysis of Tank

Component	Displacement in mm	Permissible displacement in mm	Stress in Mpa	Permissible stress in Mpa	Remarks
Tank	0.091	1	15.01	253	Safe

Seismic analysis of Gyrotron system

Component	X-displacement in mm	Y-displacement in mm	Z-displacement in mm	Stress in Mpa
Gyrotron system	-0.71	-0.0112	0.012	48.03

Table 4.4: Result

As per the table4.4 all results are coming with in limit,so support structure design is safe.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

Design of support structure for gyrotron is done using standard analytical solution,for each components individually design is done and also they are analyzed individually for structural analysis,thermal analysis and seismic analysis with the help of FEA tool.Result obtained from the adopted procedure are coming with in safe limits.As the results are satisfactory,The adopted procedure can be useful for such analysis.

5.2 Future Work

- Response spectrum method is other method for seismic analysis.,use this method we can find out the displacement and acceleration graph.
- Tank is fill up with oil. so, heat genration is not directly 100% transfer to the outer wall.so CFD analysis can be done.
- Optimization can be done for a support structure gyrotron component.

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Appendix A

Tables for seismic coefficient values

This tables are taken from the book Indian Standard Critical for Earthquake Resistant Design of Structure, Part 1general Pprovisions and Buildings,Fifth Revision.which is based on IS::1893-2002

Seismic Zone	II	III	IV	V
Seismic intensity	Low	Moderate	severe	Very severe
Z	0.10	0.16	0.24	0.36

Table A.1: Zone factor(Z)

SI No (1)	Structure (2)	Importance factor (I)
1	Important service and community buildings, such as hospitals; schools; monumental structures; emergency buildings like telephone exchange, television stations, ratio stations, railway stations, fire station buildings, large community halls like cinemas, assembly halls and subway stations, power station	1.5
2	All other building	1
	Notes 1. The design engineer may choose values of importance factor l greater than those mentioned above.	
	2. Buildings not covered in SI No. (i) and (ii) above may be designed for higher value of l ,depending on economy, strategy considerations like multi-storey buildings having several residential units. 3.This does not apply to temporary structure like excavations, scaffolding etc of short duration.	

Table A.2: Importance factor I

SI No (1)	Lateral Load Resisting system (2)	R (3)
	Building Frame Systems	
(i)	Ordinary RC moment-resisting frame(OMRF)[2)]	3.0
(ii)	Special RC moment-resisting frame (SMRF)[3)]	5.0
(iii)	Steel frame with	
	(a) Concentric braces	4.0
	(b) Eccentric braces	5.0
(iv)	Steel moment resisting frame designed as per SP 6 (6) Building with shear Walls[4)]	5.0
(v)	Load bearing masonry wall building[5)]	
	a)Unreinforced	1.5
	b)Reinforced with horizontal RC bands	2.5
	c)Reinforced with horizontal RC bands and vertical bars at corners of rooms and jambs of openings	3.0
(vi)	Ordinary reinforced concrete shear walls[6)]	3.0
(vii)	Ductile shear walls[7)] Building with dual Systems[8)]	4.0
(viii)	Ordinary shear wall with OMRF	3.0
(ix)	Ordinary shear wall with SMRF	4.0
(x)	Duplicate shear wall with OMRF	4.5
(xi)	Duplicate shear wall with SMRF	5.0

Table A.3: Response Reduction factor R