ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 9, April 2017

MODAL ANALYSIS OF COOLING TOWER

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ABSTRACT

Natural Draught hyperbolic cooling towers are the characterizing land marks of power station. They contribute both to an efficient energy output & to a careful balance with our environment. These structures are most efficient measures for cooling thermal power plants by minimizing the need of water & avoiding thermal pollution of water bodies. This paper deals with the study of static and dynamic (model) analysis of hyperbolic cooling towers (i.e. self weight, static loads). The boundary conditions considered are Top end free and Bottom end fixed. The material used for cooling tower is concrete. Three different cooling towers will modeled by using SOLIDWORKS 2016 software i.e:CT1, CT2, CT3, in which CT1 & CT3 are existing Cooling towers and CT2 is newly design intermediate Cooling tower obtain between two existing cooling towers. Static and model analysis will perform by using ANSYS 16.0 work bench software on self load condition due to gravity , stresses and deformation will find out on cooling tower due to load as static analysis , and frequencies on different deformation mode shapes will find out as model analysis.

INTRODUCTION A **cooling tower** is a heat rejection device which rejects waste heat to the atmosphere through the cooling of a water stream to a lower temperature. Cooling towers may additionally both use the evaporation of water to put off system heat and cool the working fluid to near the moist-bulb air temperature or, within the case of closed circuit dry cooling towers, rely solely on air to cool the operating fluid to near the dry-bulb air temperature.

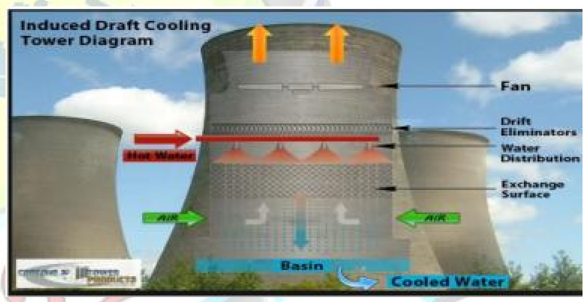


Fig: cooling tower and its working

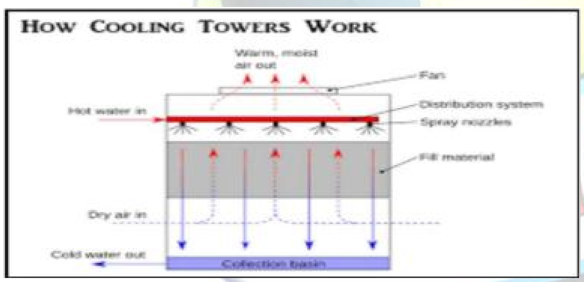
Common packages encompass cooling the circulating water utilized in oil refineries, petrochemical and different chemical plants, thermal energy stations and HVAC systems for cooling homes. The category is primarily based on the sort of air induction into the tower: the principle kinds of cooling towers are natural draft and induced draft cooling towers. Cooling towers vary in length from small roof-pinnacle units to very massive hyperboloid structures (as within the adjoining image) that can be up to two hundred meters (660 ft) tall and a hundred meters (330 ft) in diameter, or rectangular systems that can be over 40 meters (a hundred thirty feet) tall and eighty meters (260 toes) long. The hyperboloid cooling towers are regularly related to nuclear power plant, although they may be also used to a degree in some massive chemical and other industries. Although these big towers are very distinguished, the tremendous majority of cooling towers are much smaller, inclusive of many devices set up on or near homes to discharge warmness from air conditioning.

Fig: Cooling tower

Hyperbolic cooling towers are huge, skinny shell bolstered concrete structures which Contribute to energy generation performance, reliability and to environmental safety. Natural draft cooling tower is one of the maximum extensively used cooling among the air within the tower and outside the tower. Hyperbolic form of cooling tower is usually favored because of its electricity and stability and large available region at the base. Hyperbolic bolstered concrete cooling towers are correctly used for cooling huge quantities of water in thermal electricity stations, refineries, atomic strength vegetation, metallic plant life, aircon and other industrial plant life. Natural draughts cooling towers (NDCT) is the characterizing landmarks of strength stations and are used as warmness exchangers in nuclear strength vegetation. They contribute each to an green power output and to a cautious stability with our surroundings. These shell structures are subjected to environmental masses including Seismic and thermal gradients this is stochastic in nature. A collection of a hyperbolic cooling tower is as shown in Fig below.

Fig: natural draught cooling towers

Natural Draught cooling towers are most effective measures for cooling of thermal power plants by using minimizing the need of water and heading off thermal pollutants of natural water bodies. Thus they are able to balance environmental elements, investments and operating costs with demands of reliable strength supply. Reinforced concrete (RC) cooling towers, which incorporate of a thin concrete shell of revolution, are commonplace location in civil engineering infrastructure that is concerned with the technology of electric energy. Large reinforced concrete, natural draught cooling tower systems can be as tall as or even taller than many chimneys, but because of their design and feature, they've a completely a lot larger surface area, with a far decrease mass to surface area ratio. The modern hyperbolic cooling tower is super structures in view of their sheer length and complexities. The towers involve considerable amount of design work on structural aspect. The analysis of these towers is an interesting and challenging to any structural engineer in view in their size and shape. [2] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences. Elements and speed vectors were thought to be inaccessible, along these lines a NN eyewitness was intended to recoup the limitless states. At that point, a novel NN virtual control structure which permitted the craved translational speeds to be controlled utilizing the pitch and the move of the UAV. At long last, a NN was used in the figuring of the real control inputs for the UAV dynamic framework. Utilizing Lyapunov systems, it was demonstrated that the estimation blunders of each NN, the spectator, Virtual controller, and the position, introduction, and speed following mistakes were all SGUUB while unwinding the partition Principle.



CLASSIFICATIONS

Heating, ventilation and air conditioning (HVAC)

Fig: Two HVAC cooling towers on the rooftop of a shopping center (Germany)

An HVAC (heating, ventilating, and air conditioning) cooling tower is used to dispose of ("reject") unwanted heat from a chiller. Water-cooled chillers are normally more energy efficient than air-cooled chillers due to heat rejection to tower water at or near wet-bulb temperatures. Air-cooled chillers must reject heat at the higher dry-bulb temperature, and thus have a lower average reverse-Carnot cycle effectiveness.

Industrial cooling tower

Fig: Industrial cooling towers for a power plant

Industrial cooling towers can be used to remove heat from various sources such as machinery or heated process material. The primary use of large, industrial cooling towers is to remove the heat absorbed in the circulating cooling water systems used in power plants,petroleum refineries, petrochemical plants, natural gas processing plants, food processing plants, semiconductor plants, and for other industrial facilities such as in condensers of distillation columns, for cooling liquid in crystallization, etc.. The world's tallest cooling tower is the 202 metres (663 ft) tall cooling tower of Kalisindh Thermal Power Station in Jhalawar, Rajasthan, India.

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Fig: Field erected cooling tower

Facilities such as power plants, steel processing plants, petroleum refineries, or petrochemical plants usually install field erected type cooling towers due to their greater capacity for heat rejection. Field erected towers are usually much larger in size compared to the package type cooling towers. A typical field erected cooling tower has a pultruded fiber-reinforced plastic (FRP) structure, FRP cladding, a mechanical unit for air draft, drift eliminator, and fill.

Heat Transfer Methods With respect to the heat transfer mechanism employed, the main types are:

• **Dry cooling towers** operate by heat transfer through a surface that separates the working fluid from ambient air, such as in a tube to air heat exchanger, utilizing convective heat transfer. They do not use evaporation.

• **Wet cooling towers** (or **open circuit cooling towers**) operate on the principle of evaporative cooling. The working fluid and the evaporated fluid (usually water) are one and the same.

• **Fluid coolers** (or **closed circuit cooling towers**) are hybrids that pass the working fluid through a tube bundle, upon which clean water is sprayed and a fan-induced draft applied. The resulting heat transfer performance is much closer to that of a wet cooling tower, with the advantage provided by a dry cooler of protecting the working fluid from environmental exposure and contamination.

Air flow generation methods

Fig: draft with stair case

Access stairs at the base of a massive hyperboloid cooling tower give a sense of its scale (UK)

With respect to drawing air through the tower, there are three types of cooling towers:

Natural draft — Utilizes buoyancy via a tall chimney. Warm, moist air naturally rises due to the density differential compared to the dry, cooler outside air. Warm moist air is less dense than drier air at the same pressure. This moist air buoyancy produces an upwards current of air through the tower.

Mechanical draught — uses power-driven fan motors to force or draw air through the tower.

Induced draught — A mechanical draft tower with a fan at the discharge (at the top) which pulls air up through the tower. The fan induces hot moist air out the discharge. This produces low entering and high exiting air velocities, reducing the possibility of recirculation in which discharged air flows back into the air intake. This fan/fin arrangement is also known as draw-through.

Forced a Forced draught — A mechanical draft tower with a blower type fan at the intake. The fan forces air into the tower, creating high entering and low exiting air velocities.

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Fan assisted natural draught — A hybrid type that appears like a natural draft setup, though airflow is assisted by a fan.

Categorization by air-to-water flow

Cross flow

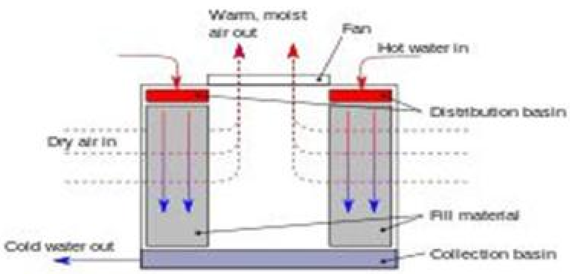

Fig: Cross flow working

Fig: Mechanical draft cross flow cooling tower used in an HVAC application

Cross flow is a design in which the air flow is directed perpendicular to the water flow (see diagram at left). Air flow enters one or more vertical faces of the cooling tower to meet the fill material. Water flows (perpendicular to the air) through the fill by gravity. The air continues through the fill and thus past the water flow into an open plenum volume. Lastly, a fan forces the air out into the atmosphere.

Advantages of the cross flow design

Gravity water distribution allows smaller pumps and maintenance while in use.

Non-pressurized spray simplifies variable flow.

Typically lower initial and long-term cost, mostly due to pump requirements.

Disadvantages of the cross flow design

More prone to freezing than counter flow designs.

Variable flow is useless in some conditions.

More prone to dirt buildup in the fill than counter flow designs, especially in dusty or sandy areas.

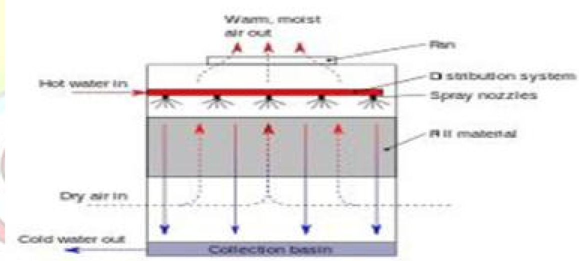

Fig: counter flow working

Fig: Forced draft counter flow package type cooling towers

In a counter flow design, the air flow is directly opposite to the water flow (see diagram at left). Air flow first enters an open area beneath the fill media, and is then drawn up vertically. The water is sprayed through pressurized nozzles near the top of the tower, and then flows downward through the fill, opposite to the air flow.

Advantages of the counter flow design

Spray water distribution makes the tower more freeze-resistant.

Breakup of water in spray makes heat transfer more efficient.

Disadvantages of the counter flow design

Typically higher initial and long-term cost, primarily due to pump requirements.

Difficult to use variable water flow, as spray characteristics may be negatively affected.

Typically noisier, due to the greater water fall height from the bottom of the fill into the cold water basin

Wet Cooling Tower Material Balance

Quantitatively, the material balance around a wet, evaporative cooling tower system is governed by the operational variables of make-up flow rate, evaporation and windage losses, draw-off rate, and the concentration cycles

In the adjacent diagram, water pumped from the tower basin is the cooling water routed through the process coolers and condensers in an industrial facility. The cool water absorbs heat from the hot process streams which need to be cooled or condensed, and the absorbed heat warms the circulating water (C). The warm water returns to the top of the cooling tower and trickles downward over the fill material inside the tower. As it trickles down, it contacts ambient air rising up through the tower either by natural draft or by forced draft using large fans in the tower. That contact causes a small amount of the water to be lost as windage/drift (W) and some of the water (E) to evaporate. The heat required to evaporate the water is derived from the water itself, which cools the water back to the original basin water temperature and the water is then ready to reticulate. The evaporated water leaves its dissolved salts behind in the bulk of the water which has not been evaporated, thus raising the salt concentration in the circulating cooling water. To prevent the salt concentration of the water from becoming too high, a portion of the water is drawn off/blown down (D) for disposal. Fresh water make-up (M) is supplied to the tower basin to compensate for the loss of evaporated water, the windage loss water and the draw-off water.

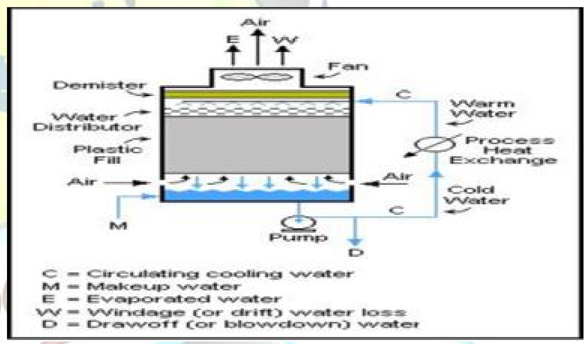

Fig: Fan-induced draft, counter-flow cooling tower

Using these flow rates and concentration dimensional units:

M = Make-up water in m³/h

C = Circulating water in m³/h

D = Draw-off water in m³/h

E = Evaporated water in m³/h

W = Windage loss of water in m³/h

X = Concentration in ppmw (of any completely soluble salts … usually chlorides)

XM = Concentration of chlorides in make-up water (M), in ppmw

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

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XC = Concentration of chlorides in circulating water (C), in ppmw

Cycles = Cycles of concentration = XC / XM (dimensionless)

ppmw = parts per million by weight

A water balance around the entire system is then:

M = E + D + W

Since the evaporated water (E) has no salts, a chloride balance around the system is:

$$MX_M = DX_C + WX_C = X_C(D + W)$$

and, therefore:

From a simplified heat balance around the cooling tower:

$$E = \frac{C \Delta T c_p}{H_V}$$

Where:

HV = latent heat of vaporization of water = 2260 kJ / kg

ΔT = water temperature difference from tower top to tower bottom, in °C

cp = specific heat of water = 4.184 kJ / (kg °C)

Windage (or drift) losses (W) are the amount of total tower water flow that is evaporated into the atmosphere. From large-scale industrial cooling towers, in the absence of manufacturer's data, it may be assumed to be:

W = 0.3 to 1.0 percent of C for a natural draft cooling tower without windage drift eliminators

W = 0.1 to 0.3 percent of C for an induced draft cooling tower without windage drift eliminators

W = about 0.005 percent of C (or less) if the cooling tower has windage drift eliminators

W = about 0.0005 percent of C (or less) if the cooling tower has windage drift eliminators and uses sea water as make-up water.

INTRODUCTION TO DYNAMIC (modal) ANALYSIS

Earthquakes are caused by faulting, a sudden lateral or vertical movement of rock along a rupture (break) surface. The surface of the Earth is continuous slow motion. This is plate tectonics--the motion of immense rigid plates at the surface of the Earth in response to flow of rock within the Earth. The plates cover the entire surface of the globe. Since they are all moving they rub against each other in some places, sink beneath each other in others, or spread apart from each other. At such places the motion isn't smooth the plates are stuck together at the edges but the rest of each plate is continuing to move, so the rocks along the edges are distorted (what we call "strain"). As the motion continues, the strain builds up to the point where the rock can't withstand any more bending. With a lurch, the rock breaks and the two sides move. An earthquake is the shaking that radiates out from the breaking rock. Unfortunately, timing of this natural phenomenon cannot be predicted scientifically. Historical records reveal the tendency of earthquakes to revisit regions after an interval of time. This random time interval is called RETURN PERIOD. This is the basis of the seismic conation. There are four zones in the country and they are denoted as II, III, IV and V. Zone I which existed in the earlier versions of the code, has been upgraded to Zone II or higher. The higher the zone,

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the more vulnerable is that region to a major earthquake. The size of an earthquake is measured by the strain energy released along the fault. It is expressed as MAGNITUDE. The commonly used scale for expressing the magnitude is the Richter scale. Every unit increase in magnitude implies an increase of about 31 times the energy. Dynamic analysis may be performed either by the Time History Method or by the Response Spectrum Method. For cases where a more refined design analysis is desired, response spectra are used as the means for determining lateral forces. A Response spectrum for a particular earthquake shows in a relatively simple way the dynamic characteristics of a given earthquake.

INTRODUCTION TO SOLID WORKS

Solid works mechanical design automation software is a feature-based, parametric solid modeling design tool which advantage of the easy to learn windows ™ graphical user interface. We can create fully associate 3-D solid models with or without while utilizing automatic or user defined relations to capture design intent.

MODELING OF COOLING TOWER

Geometry of cooling tower

Bellary thermal power station (BTPS) is a power generating unit near Kudatini village in Bellary district, Karnataka state. India. Two existing cooling towers are considered as case study as Shown in Fig 1 & 2. BTPS is geographically located at 15º11'58" N latitude and 76º43'23" E longitude.

Details of existing cooling towers

1) The total height of the tower is 143.5 m. The tower has a base, throat and top radii of 55 m, 30.5 m and 31.85 m respectively, with the throat located 107.75 m above the base. (Unit No- 2 Cooling tower in BTPS)

2) The total height of the tower is 175.5 m. The tower has a base, throat and top radii of 61 m, 34.375m and 41.00m respectively, with the throat located 131.60 m above the base (Unit No- 3 cooling tower in BTPS).

The geometry of the Hyperboloid revolution

$$\frac{R_o^2}{a_o^2} - \frac{Y^2}{b^2} = 1$$

In which Ro horizontal radius at any vertical coordinate, Y origin of coordinates being defined by the center of the tower throat, ao radius of the throat, and b is some characteristic dimension of the hyperboloid.

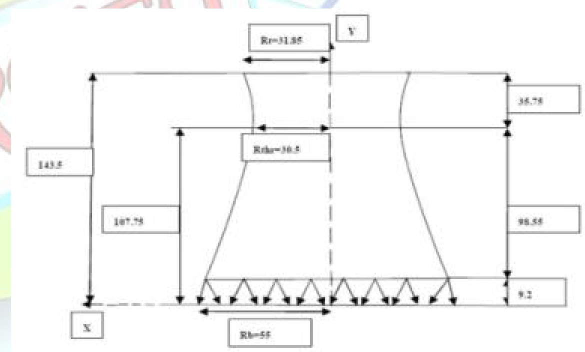

Fig: Geometry of existing cooling tower (BTPS)

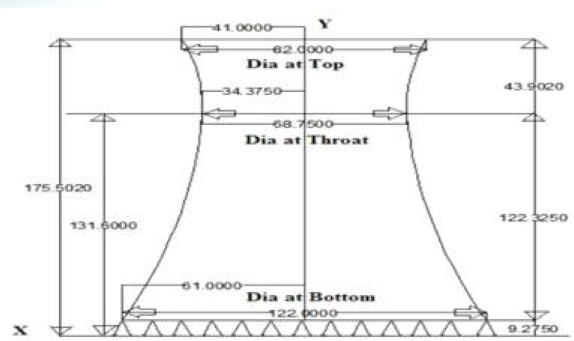

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Fig: Geometry of existing cooling tower (BTPS)

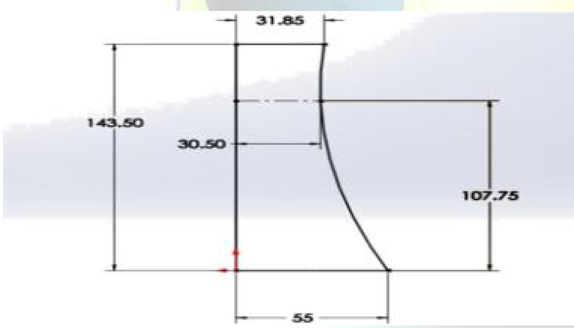
SL NO	DESCRIPTION	SYMBOLS	PARAMETRIC VALUES		
			CT 1 Existing CT(Reference)	CT 2	CT 3 Existing CT
1	Total Height	H	143.5m	157.85m	175.50m
2	Height of throat	Hthr	107.75m	118.525m	13160m
3	Diameter at top	Dt	63.6m	69.96m	82.00m
4	Diameter at bottom	Db	110m	121.00m	122.00m
5	Diameter at throat level	Dthr	61.0m	67.10m	68.750m
6	Column Height	Hc	9.20m	10.12m	9.275m

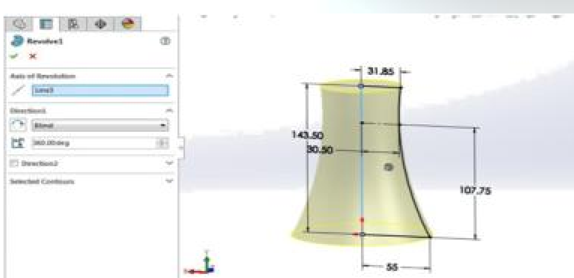
Table: Geometric Details of Cooling Towers

Above Table shows geometric details of cooling towers. CT2 is intermediate cooling towers obtained between two existing cooling towers i.e. CT1 & CT3. CT 2 is obtained by increasing 10%, all the dimensions of CT 1, which is considered as reference cooling tower. Thickness is varied from 500, 550, and 600 respectively.

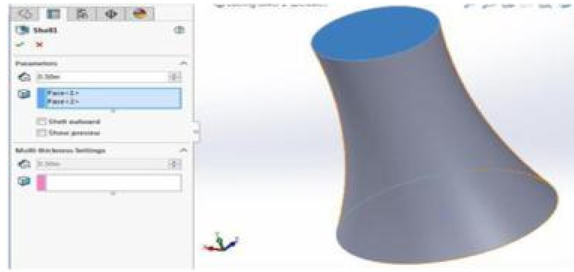
Modeling of CT1:

Sketch as follow and revolve to generate solid part.





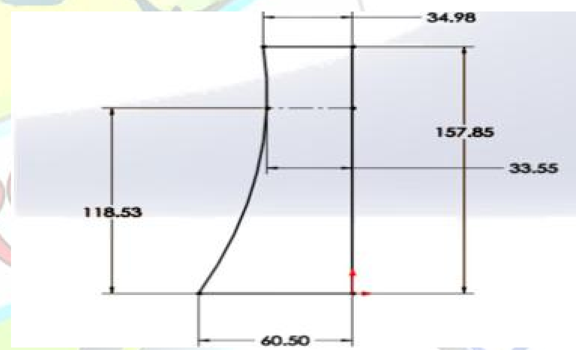
Use shell command to make hollow Cooling tower section and give the thickness as 500mm

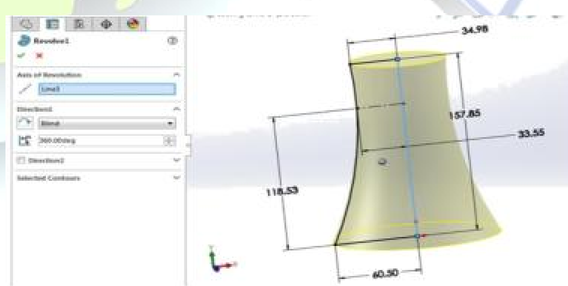


Model cooling tower1

Modeling of CT2:

Sketch as follow and revolve to generate solid part.





Use shell command to make hollow Cooling tower section and give the thickness as 550mm

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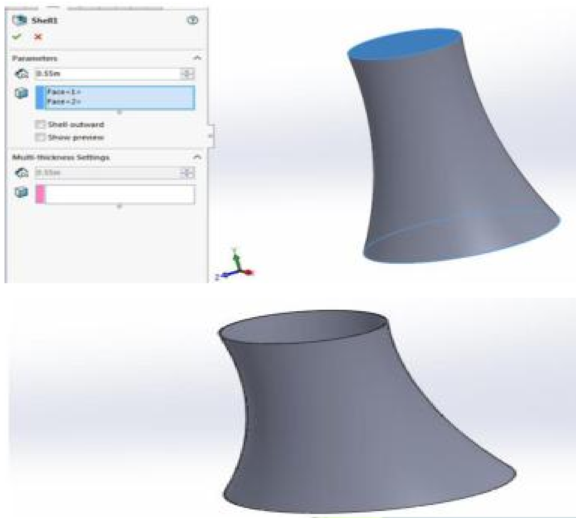
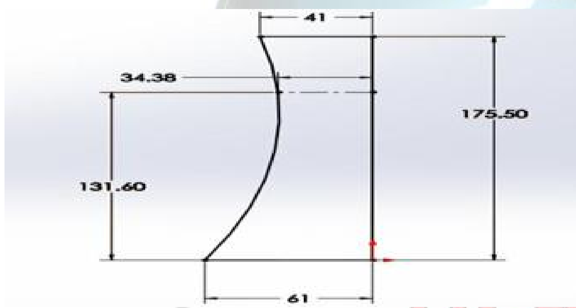
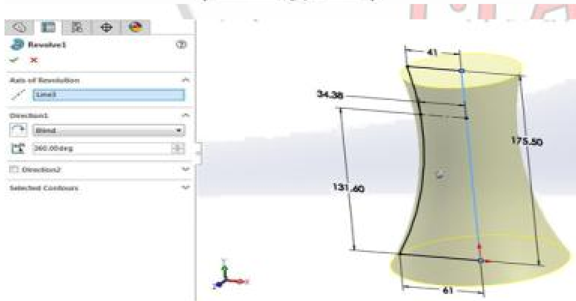


Model cooling tower 2

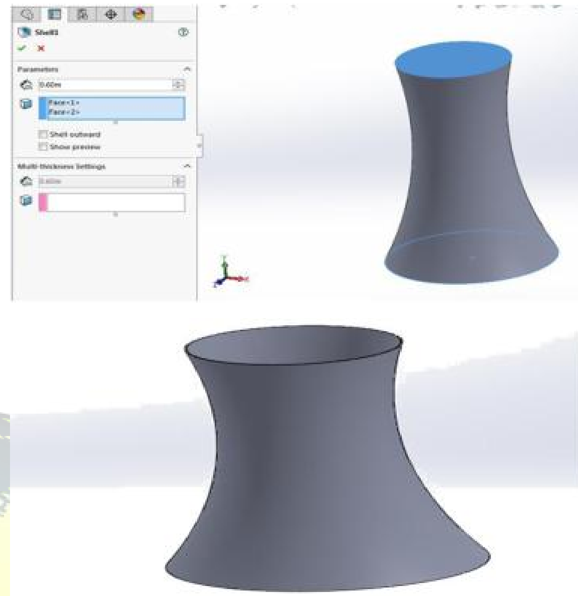
Modeling of CT3:

Sketch as follow and revolve to generate solid part.





Use shell command to make hollow Cooling tower section and give the thickness as 600mm



Model cooling tower 3

INTRODUCTION TO SIMULATION

Simulation is a design analysis system. Simulation provides simulation solutions for linear and nonlinear static, frequency, buckling, thermal, fatigue, pressure vessel, drop test, linear and nonlinear dynamic, and optimization analyses.

Basic concepts of analysis

The software uses the finite element method (fem). Fem is a numerical technique for analyzing engineering designs. Fem is accepted as the standard analysis method due to its generality and suitability for computer implementation. Fem divides the model into many small pieces of simple shapes called elements effectively replacing a complex problem by many simple problems that need to be solved simultaneously.

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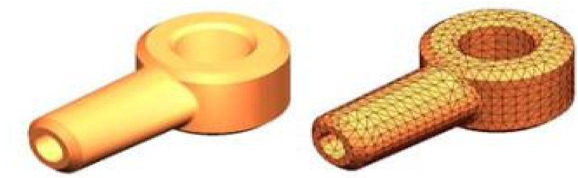

Fig: cad model of a par & model subdivided into small pieces (elements)

Elements share common points called nodes. The process of dividing the model into small pieces is called meshing.

Introduction to ANSYS

ANSYS 14.5 delivers innovative, dramatic simulation technology advances in every major Physics discipline, along with improvements in computing speed and enhancements to enabling technologies such as geometry handling, meshing and post-processing. These advancements alone represent a major step ahead on the path forward in Simulation

Table: the software offers the following types of studies:

Study type	Study icon		
Static		Modal time history	
Frequency		Harmonic	
Buckling		Random vibration	
Thermal		Response spectrum	
Design study		Drop test	
Nonlinear static		Fatigue	
Nonlinear dynamic		Pressure vessel design	

Static analyses

Static analysis deals with the conditions of equilibrium of the bodies acted upon by forces. A static analysis can be either linear or non-linear. All types of non-linearities are allowed such as large deformations, plasticity, creep, stress stiffening, contact elements etc. This chapter focuses on static analysis. A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those carried by time varying loads. A static analysis is used to determine the displacements, stresses, strains and forces in structures or components caused by loads.

Modal analyses

When an elastic system free from external forces is disturbed from its equilibrium position it vibrates under the influence of inherent forces and is said to be in the state of free vibration. It will vibrate at its natural frequency and its amplitude will gradually become smaller with time due to energy being dissipated by motion. The main parameters of interest in free vibration are natural frequency and the amplitude. The natural frequencies 45 and the mode shapes are important parameters in the design of a structure for dynamic loading conditions. Modal analysis is used to determine the vibration characteristics such as natural frequencies and mode shapes of a structure or a machine component while it is being designed.

ANALYSIS

Concrete material properties

Density	2.3e-006 kg mm^-3
Coefficient of Thermal Expansion	1.4e-005 C^-1
Specific Heat	7.8e+005 mJ kg^-1 C^-1
Thermal Conductivity	7.2e-004 W mm^-1 C^-1

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	30000	0.18	15625	12712

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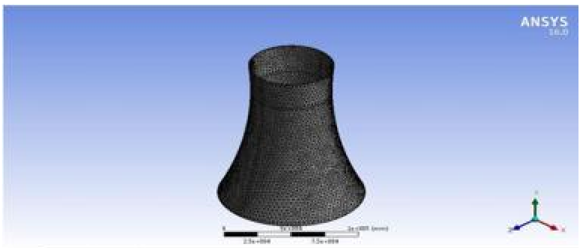
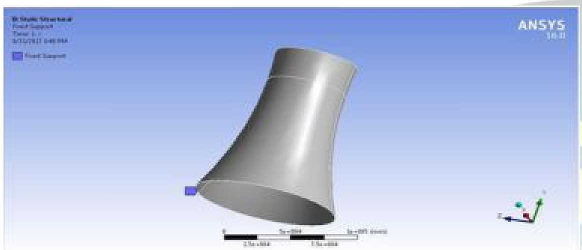
Cooling tower - 1 analysis

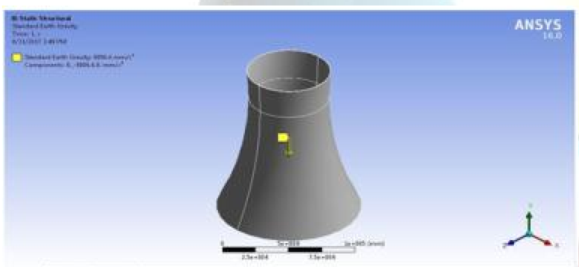
Meshing



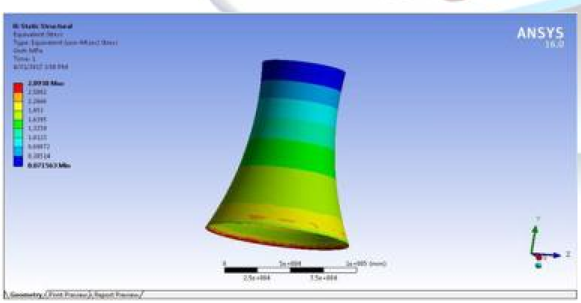
Fixed support



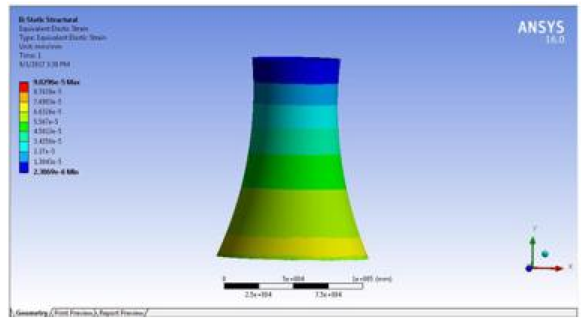
Self Load Condition (Due To Gravity)



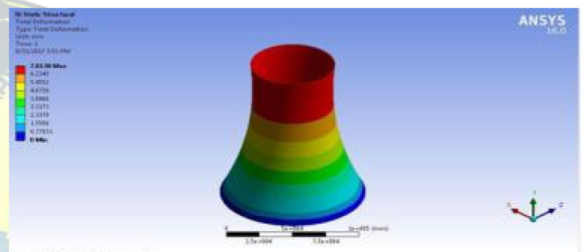
Stress



Strain



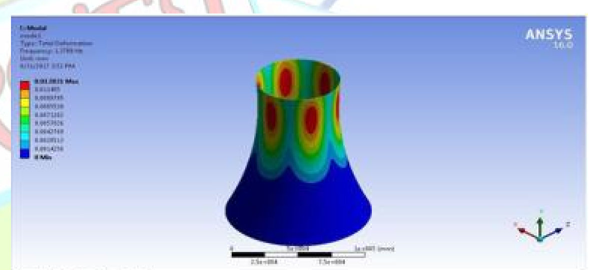
Deformation



MODAL ANALYSIS

Modal analysis CT-1

Mode1



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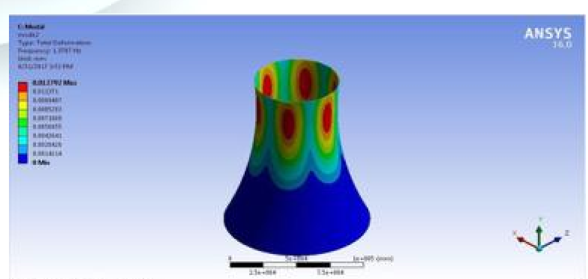

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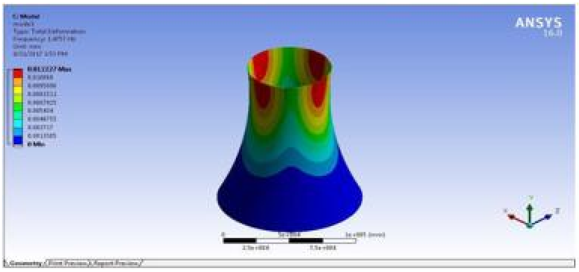

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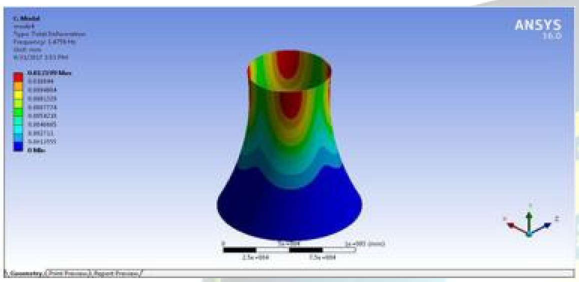

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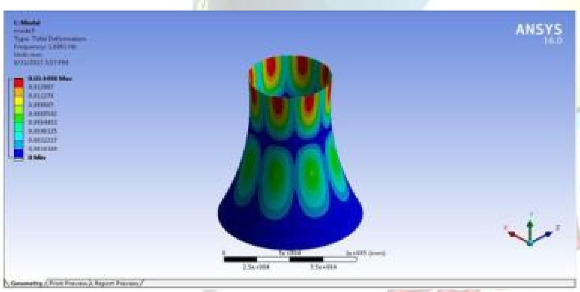
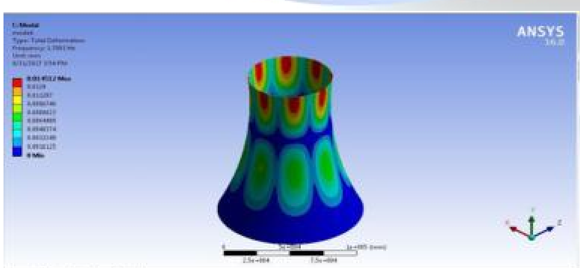
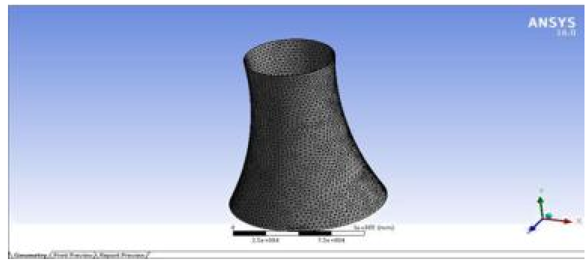


Mode6

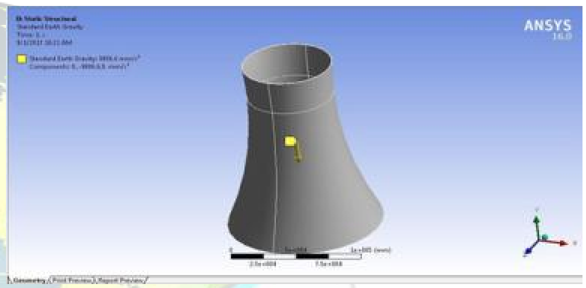


Cooling tower - 2 analysis

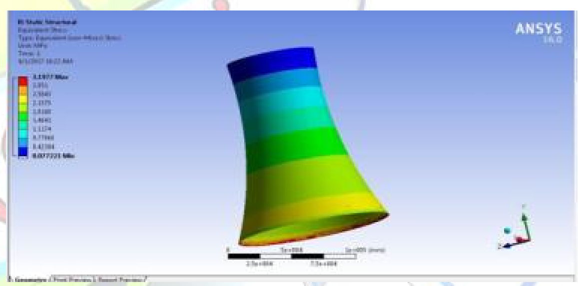
Meshing



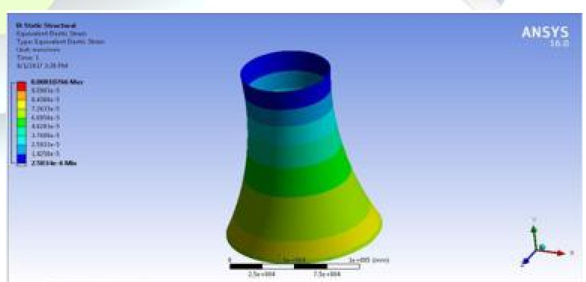
Self Load Condition (Due To Gravity)



Stress



Strain



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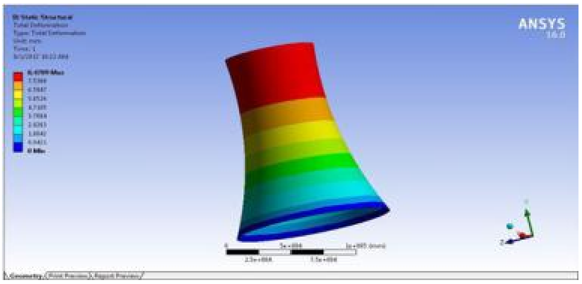
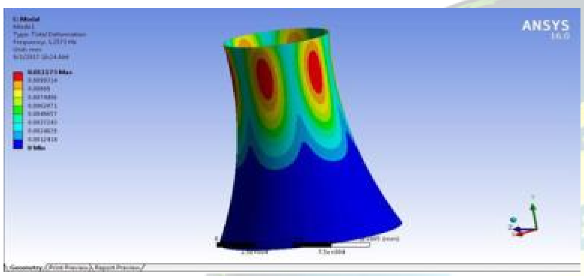
Deformation



Modal analysis CT-2

Mode1



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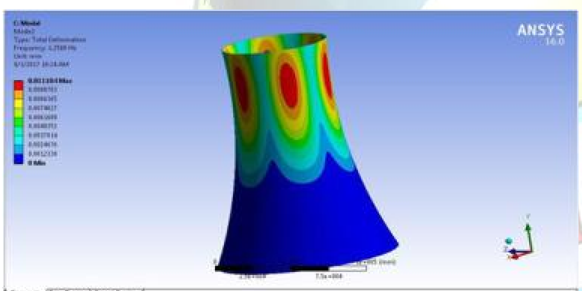

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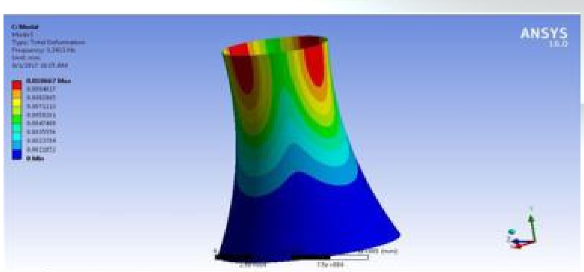

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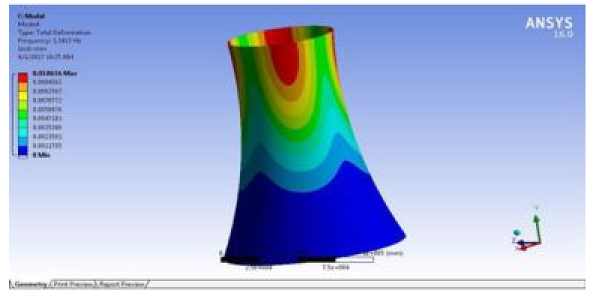

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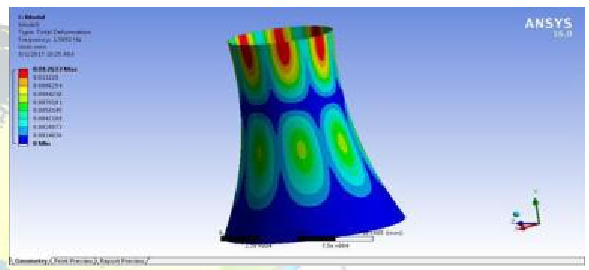
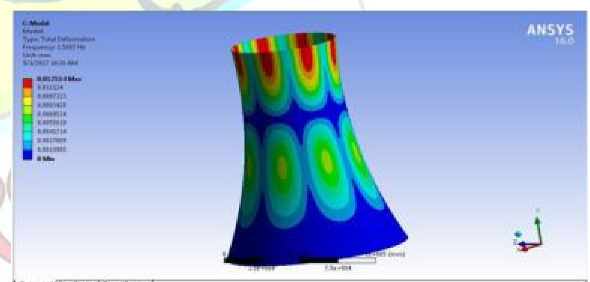
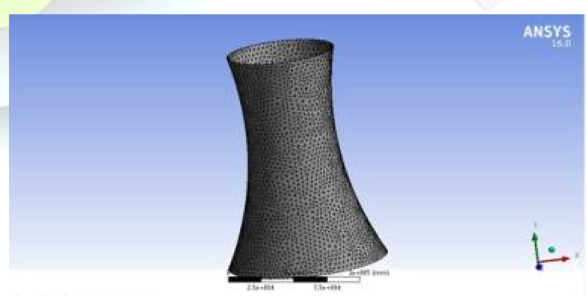


Mode6



Cooling tower - 3 analysis

Meshing



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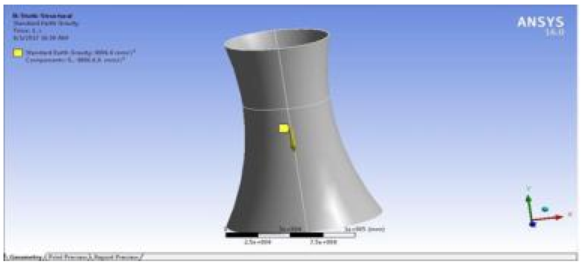
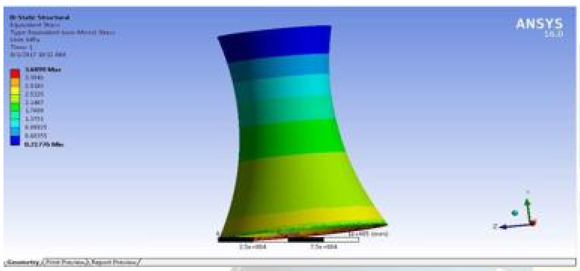
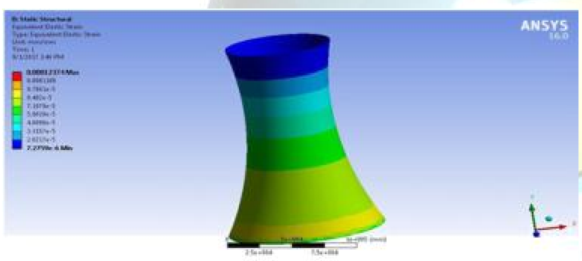
Self Load Condition (Due To Gravity)



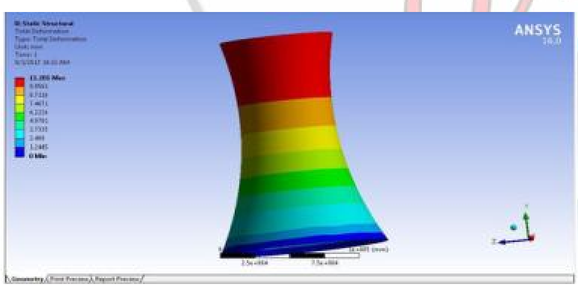
Stress



Strain

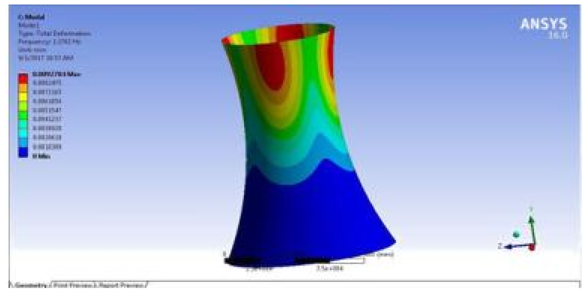


Deformation



Modal analysis CT-3

Mode1



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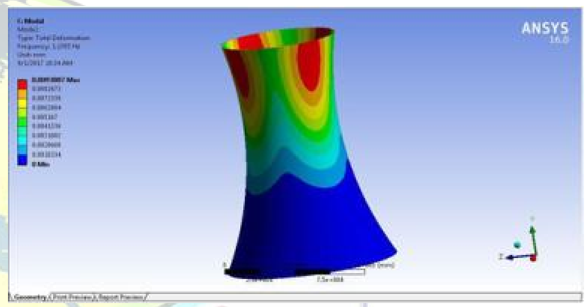

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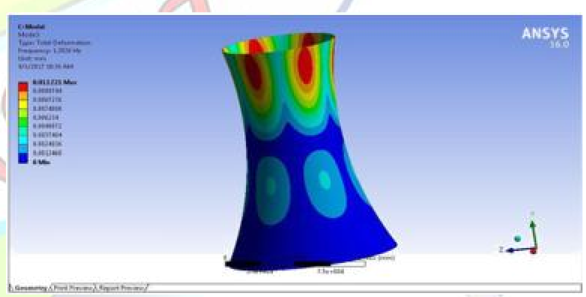

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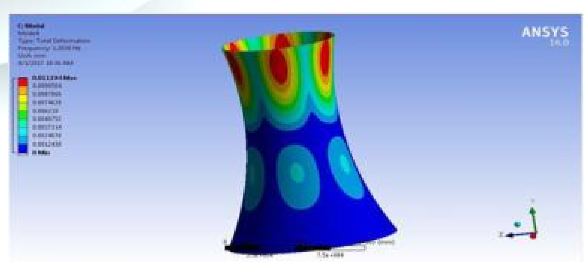

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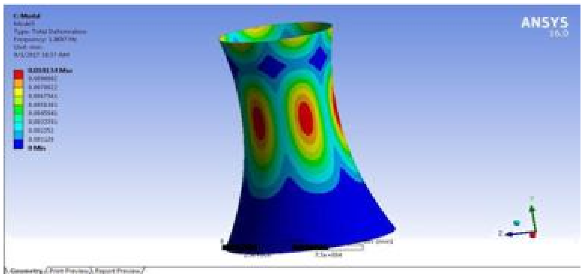
Mode5



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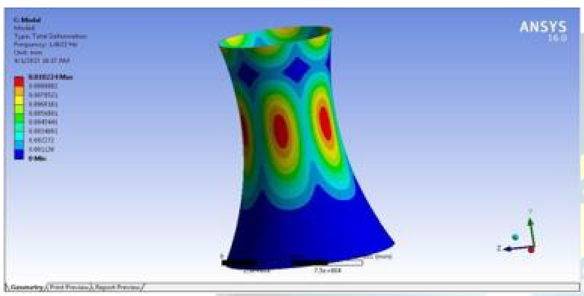

RESULTS TABLES

Table: Static structural Result

SL NO	STRESS (mpa)	DEFORMATION (mm)	STRAIN
CT1	2.8938	7.0138	9.8296e-6
CT2	3.1977	8.4789	0.00010766
CT3	3.6899	11.201	0.00012374

Table: Modal Analysis Result

		CT1	CT2	CT3
MODE 1	FREQUENCY (Hz)	1.3789	1.2573	1.1762
	DEFORMATION (mm)	0.0128931	0.011173	0.0092784
MODE 2	FREQUENCY (Hz)	1.3797	1.2588	1.1765
	DEFORMATION (mm)	0.012792	0.011104	0.0093007
MODE 3	FREQUENCY (Hz)	1.4757	1.3411	1.2026
	DEFORMATION (mm)	0.012227	0.010667	0.011221
MODE 4	FREQUENCY (Hz)	1.4759	1.3413	1.2039
	DEFORMATION (mm)	0.012199	0.010616	0.011194
MODE 5	FREQUENCY (Hz)	1.6981	1.5692	1.4607
	DEFORMATION (mm)	0.014498	0.012633	0.010134
MODE 6	FREQUENCY (Hz)	1.7001	1.5697	1.4622
	DEFORMATION (mm)	0.014512	0.012514	0.010224

CONCLUSION:

- Design and analysis of cooling tower is done.
- Brief study about cooling tower , its applications and types is done in this project
- Modeling of cooling tower is done in solid works 2016 design software by using different commands and tools.
- Three different geometrical cooling towers (CT1, CT2, and CT3) are modeled of different heights and thicknesses.
- The models are saved as IGES (neutral) files to import in ansys.
- Concrete is selected as the material for cooling tower
- Static structural analysis is performed by applying self weight of the cooling tower i.e.: due to gravity, stress, strain and deformation due to load is obtained for each cooling tower.
- MODAL analysis is performed on cooling tower by fixing it with ground , 6 different deformation modes shapes with respective frequencies are obtained as the result for each cooling tower.
- Stresses, strain, deformation values and frequencies are noted and tabulated.

- From the static result table we can conclude that as the height increases the stress are also increases.
- From the modal analysis table we can conclude that as the height of the cooling tower increase the natural frequency will decrease.

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