Thermal Performance Analysis and Design Modification of Natural Draft Wet Cooling Tower

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Abstract: *In thermal power plant one of the main parts is consider, which cools the refrigerant. When cooling the refrigerant, the cold water becomes the hot water. The hot water temperature is reduced by cooling towers. When hot water enters the induced draft cooling tower and sprayed by nozzles. So hot water is converted into cold water .The effective cooling of water depends upon the dry bulb temperature and wet bulb temperature, size, height of the cooling tower and velocity of air .The project deals with the performance study and analysis of induced draft cooling tower, which is one of the deciding factors used for increasing the power plant efficiency also modelling and analysis of flow using software .A cooling tower is an enclosed device for the evaporative cooling of water by contact with the air. We aim to address the modeling of cooling tower in solid works software. We measure performance of cooling tower and wish to achieve more cooling efficiency. The performance of the Induced draft cooling tower evaluated, and the structural analysis is carried out in solid works simulation tool by varying the materials namely galvanized steel, stainless steel, concrete and balsa wood.*

Keywords: Power Plant, Cooling Tower, Induced draft cooling tower, Air Inlet.

I. INTRODUCTION

A cooling tower is a heat rejection device, which extracts waste heat to the atmosphere though the cooling of a water stream to a lower temperature. Common applications for cooling towers are providing cooled water for air-conditioning, manufacturing and electric power generation. Cooling Tower is used in power plants, petroleum refineries, petrochemical plants, natural gas processing plants, food processing plants and many industries. Cooled water is needed for, for example, air conditioners, manufacturing processes or power generation. A cooling tower is equipment used to reduce the temperature of a water stream by extracting heat from water and emitting it to the atmosphere. Cooling towers make use of evaporation whereby some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere. As a result, the remainder of the water is cooled down significantly. Cooling towers can lower the water temperatures more than devices that use only air to reject heat, like the radiator in a car, and are therefore more cost-effective and energy efficient. Originally, cooling towers were constructed primarily with wood, including the frame, casing, louvers, fill and cold-water basin. Sometimes the cold-water basin was made of concrete. Today, manufacturers use a variety of materials to construct cooling towers. Materials are chosen to enhance corrosion resistance, reduce maintenance, and promote reliability and long service life. Galvanized steel, various grades of stainless steel, glass fiber, and concrete are widely used in tower construction, as well as aluminum and plastics for some components. There are two types of cooling tower Natural Draft Cooling Tower and Mechanical Draft Cooling Tower. The **natural draft or hyperbolic cooling tower** makes use of the difference in temperature between the ambient air and the hotter air inside the tower. As hot air moves upwards through the tower (because hot air rises), fresh cool air is drawn into the tower through an air inlet at the bottom. Due to the layout of the tower, no fan is required and there is almost no circulation of hot air that could affect the performance. Concrete is used for the tower shell with a height of up to 200 m. These cooling towers are mostly only for large heat duties because large concrete structures are expensive. There are two main types of natural draft towers: **Cross flow tower:** air is drawn across the falling water and the fill is located outside the tower. **Counter flow tower:** air is drawn up through the falling water and the fill is therefore located inside the tower, although design depends on specific site conditions. **Mechanical draft towers** have large fans to force or draw air through circulated water. The water falls downwards over fill surfaces, which help increase the contact time between the water and the air - this helps maximize heat transfer between the two. Cooling rates of mechanical draft towers depend upon various parameters such as fan diameter and speed of operation, fills for system resistance etc. Mechanical draft towers are available in a large range of capacities. Towers can be either factory built or field erected - for example concrete towers are only field erected.

Many towers are constructed so that they can be grouped together to achieve the desired capacity. Thus, many cooling towers are assemblies of two or more individual cooling towers or "cells." The number of cells they have, e.g. Eight-cell tower, often refers to such towers. Multiple-cell towers can be lineal, square, or round depending upon the shape of the individual cells and whether the air inlets are located on the sides or bottoms of the cells.

II. RELATED WORK

T. Jagadeesh, Dr.K. Subba Reddy (2013) [1] conclude that by increasing the efficiency of cooling tower is built in non-coastal areas (Humidity is low) we can increase the cooling tower efficiency. The efficiency of cooling tower in winter season 78.92%. Efficiency of cooling tower in summer season = 63.82% the cooling tower efficiency difference between summer season and winter season is =15.10%.

Sachin Kulkarni & Prof A. V. Kulkarni (2014) [2] prove that by comparing all cooling towers (i.e. CT 1, CT 2, CT 3, CT 4, CT 5) in static analysis (self-weight of tower), CT 3 & CT 4 shows least maximum principal stress among all cooling towers and prove to be the optimum cooling towers for shell thickness of 200mm.

ALOK SINGH, SANJAY SONI, R. S. RANA (2014) [3] decide that by demonstrated that decreasing the nozzle height by 0.75 m instead of 1 m from trouble top significantly reduces the average moisture content of hot air leaving the tower. Increased effectiveness and decreased cold water temperature by 1.1 K generates 6-8 MW more power towards rated production of electricity. Average moisture content leaving the tower reduced by 8% in case of optimum injection height.

Priyank V. Dave (2014) [4] The CFX simulations are performed to study the contribution of the cooling tower on the overall performance of the power plants. For that in improvement in cooling tower operating parameters case should be taken throat height for the evaluation of better performance of thermal parameters. In which at throat height 91.12m 10 to 12% improvement in the cooling efficiency and 12 to 14% improvement in cooling range is observed.

S.Satheesh,G.Kumaresan(2016) [5] prove that the process of water cooling occurs mainly as the result of the evaporation of a small amount of cooled water to the air stream (transport of mass),making the use of the heat of phase transition (heat of vaporization), which is collected from the water stream and to a lesser extent as the result of convective heat transfer form water to air (heat transfer) Counter-current air flow in the cooling tower is inducted by the suction produced by the axial fan with a capacity adapted to the required cooling parameters.

J. Ashok & Dr. K. Karuppasamy (2016) [6] Analyse that Readings and Graphical result showing condenser performance will depends on the cooling tower water flow rate. Circulating water flow rate is low means condenser performance will be decreased. Condenser performance is most important for obtaining high efficiency of the thermal plant. Design and theoretical calculation of the zero head or ultra-head turbine efficiency obtained for 85%. Hydro power up to 75 KW. Design of ultra-head turbine is successfully done.

A.VIJAYARAGAVAN,S.ARUNRAJ,P.PARTHASARTHY,M.SUNDAR RAJ (2016) [7] conclude that Water outlet temperature of cooling tower decreases as the air inlet angle decreases. Hence the cooling efficiency and effectiveness of cooling tower increases. Out of selected three air inlet angles, angle of 150c leads to maximum efficiency and effectiveness for selected cooling tower.

B. RANJITH KUMAR, J. CHANDRAMOULI, C.SREEDHAR (2016) [8] find that As Ground acceleration increases the stresses developed in shell reaches maximum and the stresses developed in shell portion depends upon the SHELL thickness.

Pooja Rai, Irshad Ahmad Khan (2016) [9] find that Side Stream Filter to control total suspended solid particle, turbidity and free from chemicals. Above method for removal of fouling and scaling are concluded that side stream filter is best substitute of chemical dosing and ClO2 generator.

M.V.H. Satish Kumar (2016) [10] **proved that** The climatic conditions like air dry bulb and wet bulb temperature, relative humidity will affect the performance of the cooling tower.

III.PROPOSED WORK

Components of a cooling tower

The basic components of a cooling tower include the frame and casing, fill, cold-water basin, drift eliminators, air inlet, louvers, nozzles and fans. These are described below.

Frame and casing Most towers have structural frames that support the exterior enclosures (casings), motors, fans, and other components. With some smaller designs, such as some glass fiber units, the casing may essentially be the frame.

Fills Most towers employ fills (made of plastic or wood) to facilitate heat transfer by maximizing water and air contact. There are two types of fill: Splash fill: waterfalls over successive layers of horizontal splash bars, continuously breaking into smaller droplets, while also wetting the fill surface. Plastics plash fills promote better heat transfer than wood splash fills. Film fill: consists of thin, closely spaced plastic surfaces over which the water spreads, forming a thin film in contact with the air. These surfaces may be flat, corrugated, honeycombed, or other patterns. The film type of fill is the more efficient and provides same heat transfer in a smaller volume than the splash fill.

Cold-water basin The cold-water basin is located at or near the bottom of the tower, and it receives the cooled water that flows down through the tower and fills. The basin usually has a sump or low point for the cold-water discharge connection. In many tower designs, the cold-water basin is beneath the entire fill. In some forced draft counter flow design, however, the water at the bottom of the fill is channeled to a perimeter trough that functions as the cold-water basin. Propeller fans are mounted beneath the fill to blow the air up through the tower. With this design, the tower is mounted on legs, providing easy access to the fans and their motors.

Drift eliminator These capture water droplets entrapped in the air stream that otherwise would be lost to the atmosphere.

Air inlet This is the point of entry for the air entering a tower. The inlet may take up an entire side of a tower (cross-flow design) or be located low on the side or the bottom of the tower (counter-flow design).

Louvers Generally, cross-flow towers have inlet louvers. The purpose of louvers is to equalize air flow into the fill and retain the water within the tower. Many counter flow tower designs do not require louvers.

Nozzles These spray water to wet the fill. Uniform water distribution at the top of the fill is essential to achieve proper wetting of the entire fill surface. Nozzles can either be fixed and spray in a round or square pattern, or they can be part of a rotating assembly as found in some circular cross-section towers.

Fans Both axial (propeller type) and centrifugal fans are used in towers. Generally, propeller fans are used in induced draft towers and both propeller and centrifugal fans are found in forced draft towers. Depending upon their size, the type of propeller fans used is either fixed or variable pitch. A fan with non-automatic adjustable pitch blades can be used over a wide kW range because the fan can be adjusted to deliver the desired air flow at the lowest power consumption. Automatic variable pitch blades can vary air flow in response to changing load conditions.

Material CFD simulation using

- Galvanized steel: Galvanization is the process of applying a protective zinc coating to steel or iron, to prevent rusting
- Stainless steel: Cooling towers are excellent *applications* for *stainless steel use* because the clean aerated water flow maintains a protective layer of chromium oxide on the steel surfaces.
- Concrete: Even structures constructed of reinforced concrete require maintenance to continue to function as a critical foundation
- FRP (Fiber Reinforced Polyester): It has been *used* as a cooling tower casing material for some time.
- Balsa wood: It is low-density but high in strength, balsa is a very popular material for light, stiff structures in model bridge tests, model buildings, and for the construction of model aircraft, Cooling Tower.

Advantages of Cooling tower: Cooling towers operate on the stack effect which causes the hot air in the tower to rise (natural draft). Wet natural draft cooling towers are used mainly for electrical energy industry, but can be used for other industrial objects. Such towers allow the cooling of high water volumes and are designed both from concrete and metal structures.

- No energy consumption for fans operation
- No recirculation
- Low costs of maintenance and spare parts
- Low thermal energy waste

Solid Work

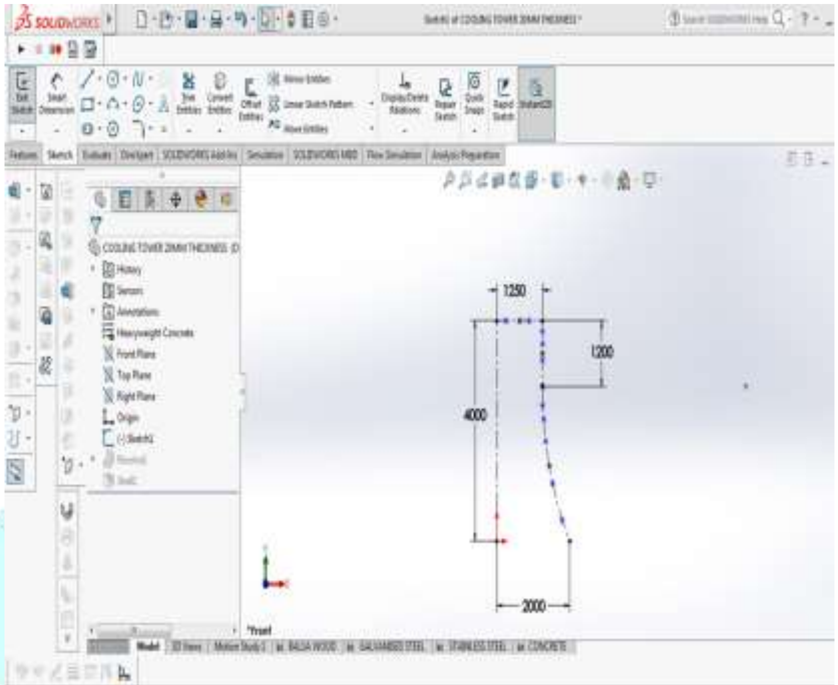


Fig 1 Key Points

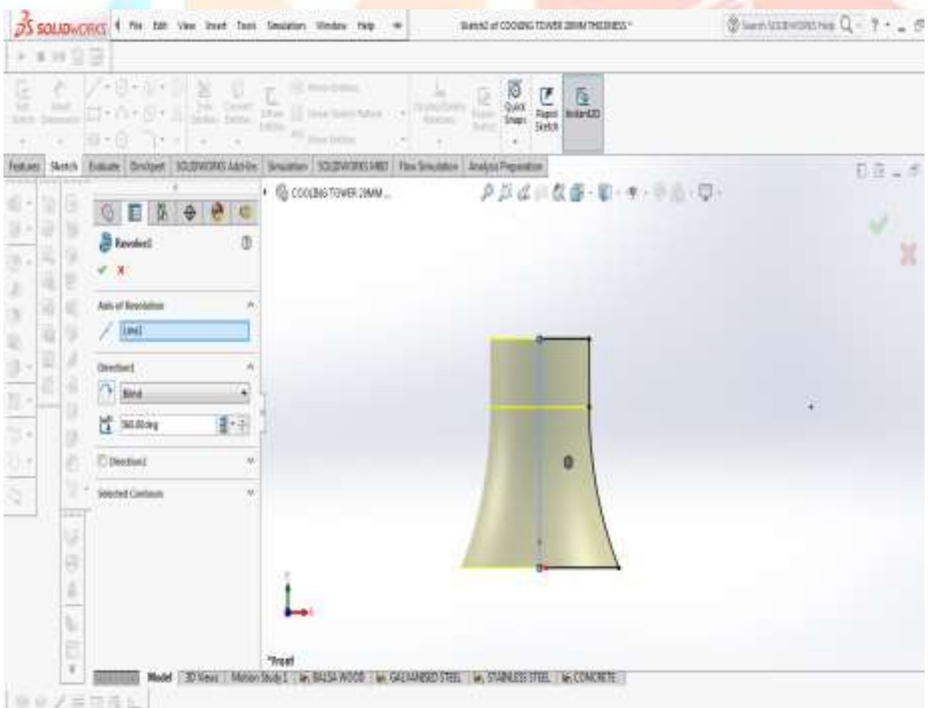


Fig 2: Revolve

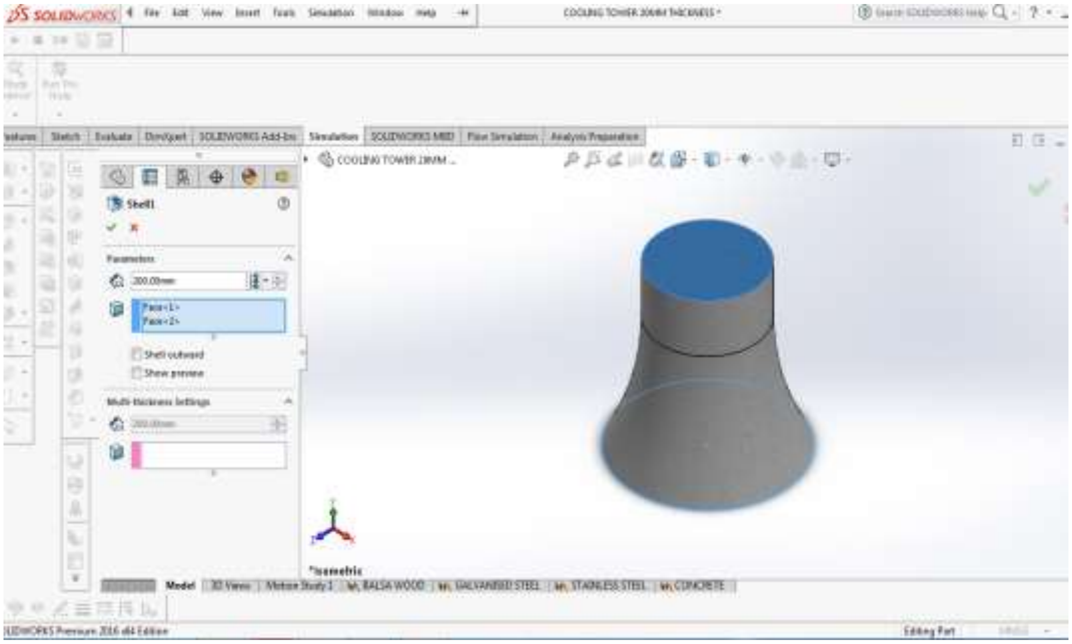


Fig 3: Creating shell

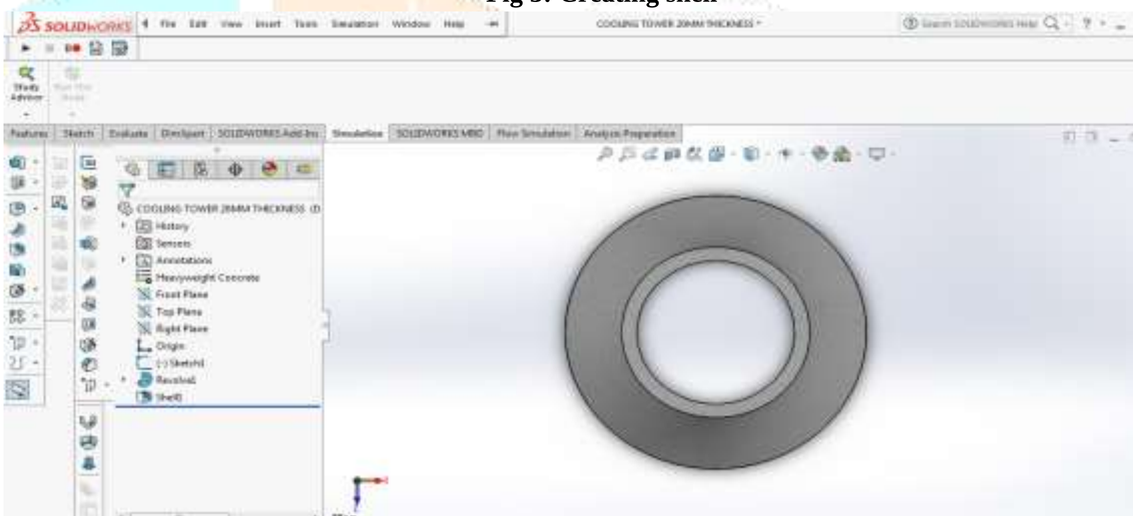


Fig 4: Top view

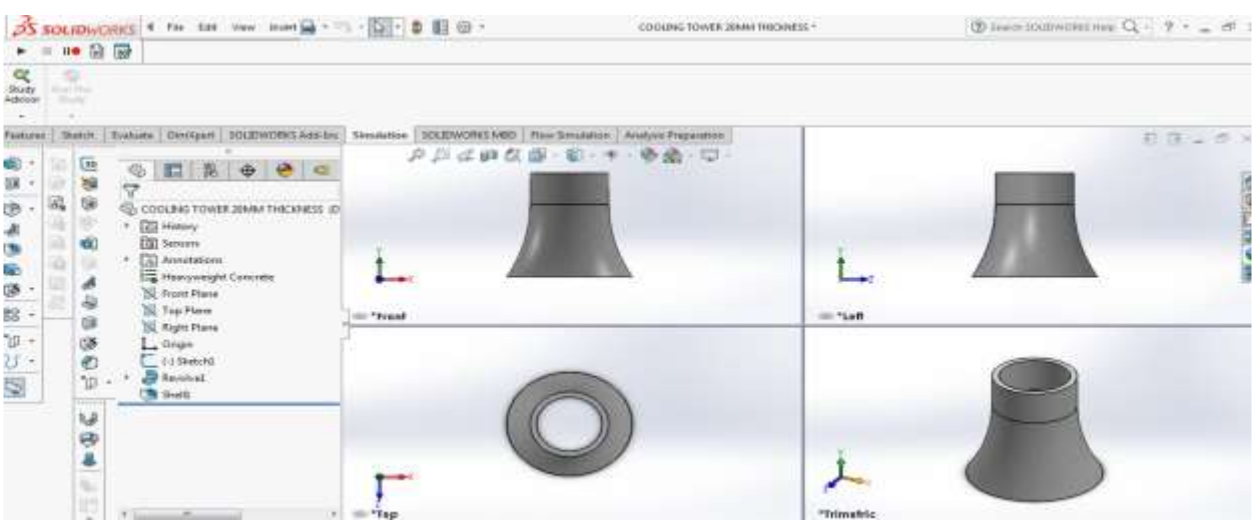


Fig 5: Different views of cooling tower

STUDY PROPERTIES

Study name	BALSA WOOD
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\Windows 10\Desktop \COOLING TOWER)

UNITS

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

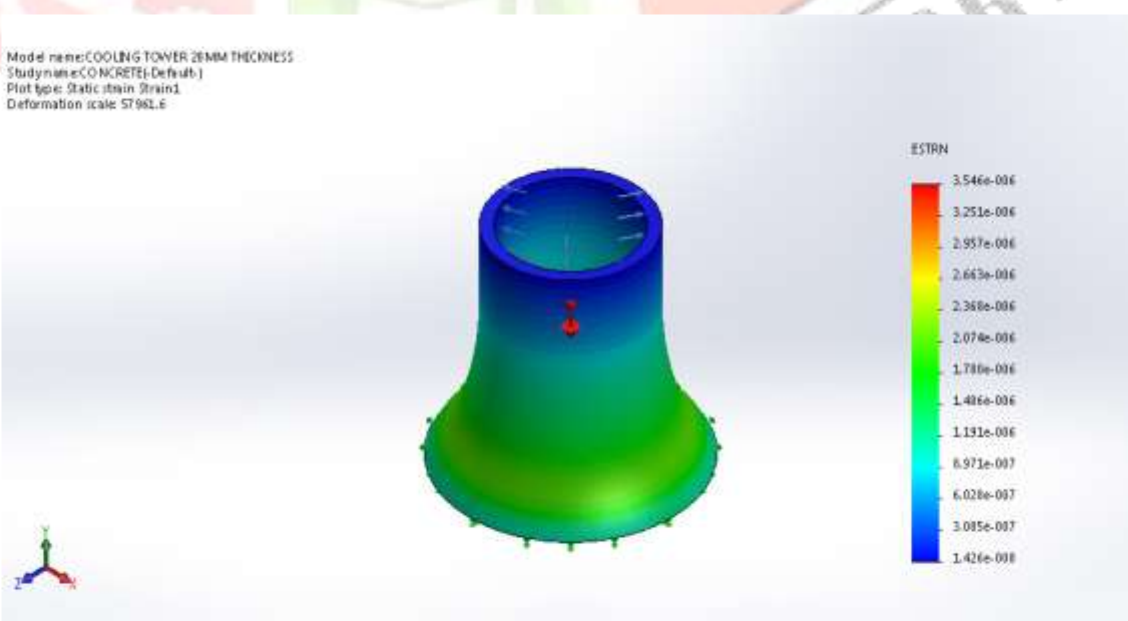
MATERIAL PROPERTIES

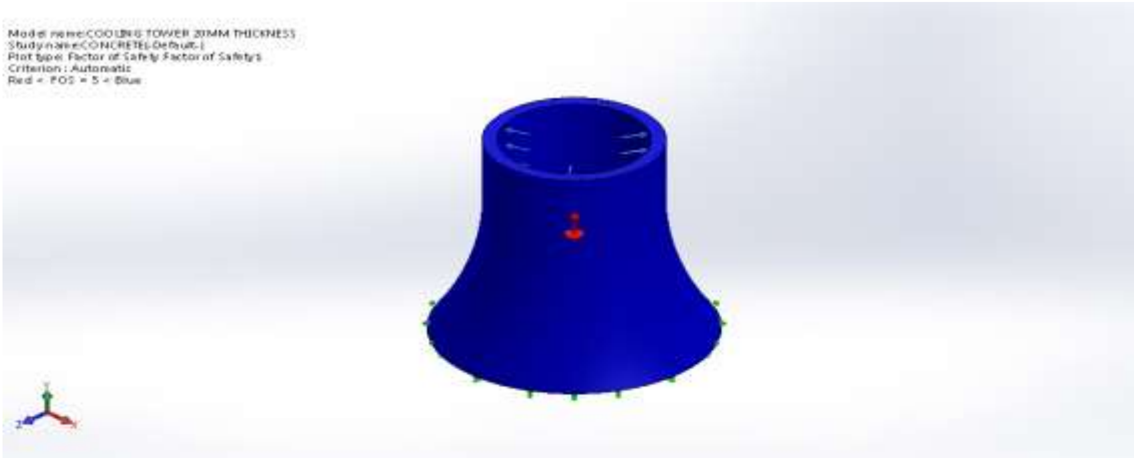
Model Reference	Properties
	Name: **Balsa** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **2e+007 N/m^2** Elastic modulus: **3e+009 N/m^2** Poisson's ratio: **0.29** Mass density: **159.99 kg/m^3** Shear modulus: **3e+008 N/m^2**

LOADS AND FIXTURES

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

Load name	Load Image	Load Details
Gravity-1		**Reference:** Top Plane **Values:** 0 0 -9.81 **Units:** SI
Pressure-1		**Entities:** 2 face(s) **Type:** Normal to selected face **Value:** 100 **Units:** N/mm^2 (MPa) **Phase Angle:** 0 **Units:** deg





RESULTS AND DISCUSSIONS

The structural analysis is carried out for cooling tower by applying balsa wood, galvanized steel, stainless steel and concrete materials the results are as follows:

Results	Balsa wood	Galvanized steel	Stainless steel	concrete
Von misses stresses(N/m2)	7192.9	353823	353933	107743
Total deformation(mm)	0.00385212	0.00284232	0.00283294	0.00690113
strain	2.00576e-006	1.47997e-006	1.47328e-006	3.5456e-006

Results and Discussion

The **Von Mises** yield criterion (also known as the maximum distortion energy criterion) suggests that yielding of a ductile material begins when the second deviatory **stress** invariant reaches a critical value. It is part of plasticity theory that applies best to ductile materials, such as some metals.

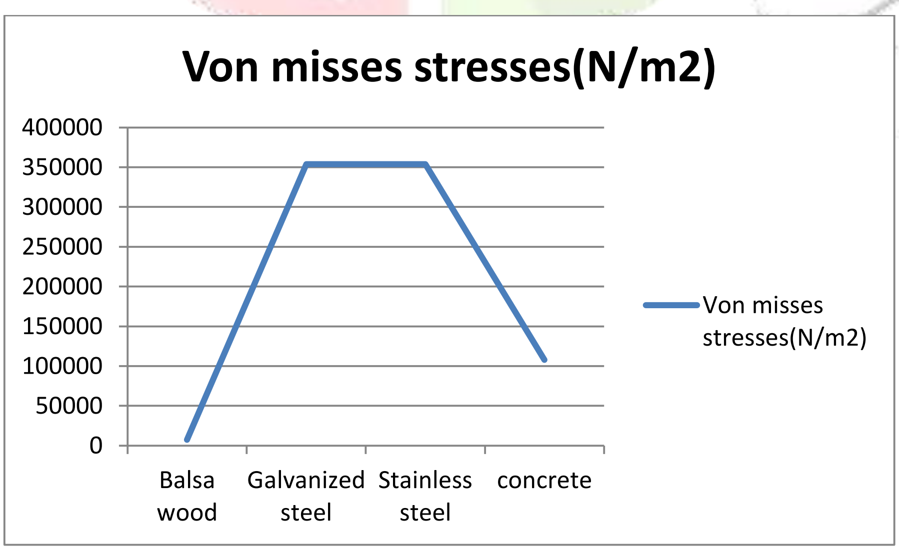


Fig 6: von misses stress

CONCLUSION

In thermal power plant one of the main parts is consider, which cools the refrigerant. When cooling the refrigerant, the cold water becomes the hot water. The hot water temperature is reduced by cooling towers. When hot water enters into the induced draft cooling tower and sprayed by nozzles. So hot water is converted into cold water. The effective cooling of water depends upon the dry bulb temperature and wet bulb temperature, size, height of the cooling tower and velocity of air. The project deals with the performance study and analysis of induced draft cooling tower, which is one of the deciding factors used for increasing the power plant efficiency also modelling and analysis of flow using software. A cooling tower is an enclosed device for the evaporative cooling of water by contact with the air. Cooling tower is a heat rejection device. Common application includes cooling the circulating water used in oil refineries, petrochemical, and other chemical plants, thermal power stations and HVAC system for cooling buildings. The efficiency and effectiveness of cooling tower depends on number of parameter like inlet air angle, inlet and outlet temperature of air and water, fill materials, fan speed etc. The project is directed towards the modeling of cooling tower in solid works software. The structural analysis is carried out in solid works simulation tool by varying the materials namely galvanized steel, stainless steel, concrete and balsa wood. By comparing the above results the von misses' stresses developed by Balsa wood is less compared to galvanized steel, stainless steel and concrete. But displacement generated by galvanized steel is less compared to balsa wood, stainless steel and concrete. The cut plots and flow trajectories of pressure and velocity variation over the cooling tower has been displayed. Finally, the best suitable material is selected for cooling tower by comparing the results is balsa wood. In last phase of our dissertation, we wish to implement the proposed work on simulated environment, we will have carried out CFD analysis for cooling tower the pressure variation and velocity variation over the cooling tower. Finally, the best suitable material will select for cooling tower by comparing the results.

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