Thermal Stress and Creep Analysis of Failed Tube of Secondary

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Abstract – Super heater is an inevitable component of any boiler system. Failure of super heater leads to breakdown of whole plant. This paper is aimed at thermal stress and creep damage analysis of secondary super heater tubes .Computational fluid dynamic analysis of secondary super heater block is carried out which shows disturbed flue gas flow pattern and overheating in some regions of super heater. Fairly high temperature values on bottom bends of tube panels are seen in conjugate heat transfer analysis. Affected tube panels are analyzed for thermo-structural stresses using ANSYS under combined as well as isolated pressure and temperature effect. The stresses are found within safe limits under isolated pressure and temperature loads however under combined loading larger values of thermal stresses are seen on affected bottom bends of the super heater panel. The flow modifications were carried out to get better heat transfer and uniform temperature on the super heater. Post flow modification stress analysis shows lower stresses in on bottom bends due to uniform flow and improved temperature profile on super heater. The failure regions of the super heater tubes are found out by high temperature areas and stress obtained from thermo structural analysis. These results are verified respectively with creep analysis of the failed tube and ground data.

Index Terms – Thermal Stress, Tube, Boiler, ANSYS.

1. INTRODUCTION

Sugar industry is the second largest traditional industry in India; The first one is textile industry. It is the large agro based industry. At present there are 380 sugar mills in India and this includes 34 factories from Tamilnadu, Agriculture contributes about 40% to the national income and provide over 70% of the job using only about 10% of total commercial energy.Aringnar Anna Sugar Mill-AASM is located at Kurungulam. The period from Nov-June is called as season. The other half period of the year is called as off season when cleaning, repairing are done.

There are four department in Aringnar Anna Sugar Mills they are

1. Administrative department
2. Cane department
3. Engineering department
4. Manufacturing department

1.1 MILLING UNITS

1.1.1 Activities of Various Equipment In Sugar Plant

Procurement of sugarcane from the fields.

- Weighing of sugarcanes using weigh bridge.
- The capacity of the weighing bridge is 25 tonnes.
- Number of Bridges in AASM is 3.
- Unloading of canes through un loaders.
- Capability of the sugarcane through cane un loader is 5 metric tonnes SWL.
- Number of cranes with long travel movement cross travel movement and hoist.

1.1.2. Feeder Table

The feeding of the sugarcane is done by the feeder table. The required space has been allocated for the feeder table. The height of the feeder table can be adjustable and is having variable speed. Owing to our quality oriented approach, we have attained a reputed place in the industry for providing high quality range of Feeder Table. The provided products are designed by the use of quality tested materials and high-tech machines. To ensure their superb quality, these products are strictly examined on various parameters by our quality controllers. Our customers can avail these products from us in different specifications as per their demands.

1.1.3. Cane Carrier

Conveying the sugarcanes to the mill is done by using cane carriers. It has various speed drive We are amongst the reliable names in the industry for providing highest quality range of Sugarcane Carrier. The offered products are highly demanded by our precious customers for their optimum quality and durability. The provided range is tested against varied parameters in order to deliver flawless range at clients' end. Apart from this, we deliver the whole range of these products at clients' end within the promised time frame.

1.1.4. Cane Cutter Rotor of a Sugar Plant

In order to satisfy various requirements of our valuable customers, we are providing a wide array of Cane Cutter. The offered products are manufactured by our experienced professionals utilizing contemporary technology and finest quality raw materials in line with set industrial standards. These cutters are highly appreciated by our clients for their high durability. We provide these products at most economical prices within the given time frame.

1.1.5. Cane Leveler

It having 48 no of knifes rotates with 600rpm through central shafts with a swing diameter of 1600mm.

1.1.6. Swing Hammer Cane Fibriser

We are successfully ranked amongst the eminent names in the industry for providing a complete range of Swing Hammer Cane Fibriser. Precisely manufactured utilizing matchless quality components and upgraded techniques, these products are widely demanded amongst our customers for their optimum quality and superb performance. Apart from this, the entire range can be availed by our customers at market leading prices.

1.1.7. Belt Conveyer

With the support of our qualified professionals, we are able to provide superior quality range of Belt Conveyer. The entire range of these conveyers is manufactured as per the clients' requirements using premium quality materials and sophisticated techniques. Our offered products are carefully tested by our quality experts in order to provide a high quality range to our customers. We offer these conveyers at very reasonable rates.

1.1.8. Feed Rake Carrier

It receives the prepared cane from the fibreser. We are involved in providing our clients qualitative range of Feed Rake Carrier. These products are precisely designed and manufactured by our dexterous professionals using superior quality materials and progressive technology at our advanced manufacturing unit. Our quality controllers strictly check the whole range against diverse parameters of quality in order to deliver the perfect range at customers' end. We offer these carriers at most economical rates.

1.2. Drives of The Mills

In a hot rolling mill the metalworking process occurs above the re-crystallization temperature of the material. During this process the material is rolled through a number of passes to form the desired shape. To achieve the desired tonnage per hour and the desired sizes and shaped there may be a variation in the number of passes, the size of input material and the speed at which the mill operates. All these factors have an effect on the separating force on the mill rolls, the torque and power required. In order to achieve smooth rolling it is very essential to have well engineered mill drives. The material being processed passes through a set of rolls which are fitted in a mill stand. These rolls are connected to a set of drive which consists of the motor, which is coupled to a gear box which is further coupled to a pinion stand which is coupled to the mill stand. Depending on the torque and power to be transmitted a flywheel may also be required.

1.2.1. Imbibition System

Imbibition is a special type of diffusion when water is absorbed by solids-colloids causing an enormous increase in volume. Examples include the absorption of water by seeds [1] and dry wood. If it were not for the pressure due to imbibition, seedlings would not have been able to emerge out of soil into the open; they probably would not have been able to establish. Imbibition is also diffusion since water movement is along a concentration gradient; the seeds and other such materials have almost no water hence they absorb water easily. Water potential gradient between the absorbent and the liquid imbibed is essential for imbibition. In addition, for any substance to imbibe any liquid, affinity between the adsorbant and the liquid is also a pre-requesite.

Imbibition occurs when a wetting fluid displaces a non-wetting fluid, contrary to drainage where a non-wetting phase displaces the wetting fluid. The two processes are governed by different mechanisms. One example of imbibition that is found in nature is the absorption of water by hydrophilic colloids. Matrix potential contributes significantly to water in such substances. Examples of plant material which exhibit imbibition are dry seeds before germination. Imbibition can also entrain the genetic clock that controls circadian rhythms in Arabidopsis thaliana and (probably) other plants. Another example is that of imbibition in the Amott test.Different types of organic substances have different imbibing capacities. Proteins have a very high imbibing capacity then starch less and cellulose least. That is why proteinaceous pea seeds swell more on imbibition than starchy wheat seeds. Imbibition of water increases the volume of the imbibing, which results in imbibition pressure. This pressure can be of tremendous magnitude. This fact can be demonstrated by the splitting of rocks by inserting dry wooden stalks in the crevices of the rocks and soaking them in water, a technique used by early Egyptians to cleave stone blocks. Skin grafts (split thickness and full thickness) receive oxygenation and nutrition via imbibition, maintaining cellular viability until the processes of inosculation and revascularization have re-established a new blood supply within these tissues.

1.3. BOILER

1.3.1. Type of Boiler Used In the Industry

1.3.1.1. Water Tube Boiler

A **water tube boiler** is such kind of boiler where the water is heated inside tubes and the hot gasses surround them. This is the basic definition of water tube boiler. Actually this boiler is just opposite of fire tube boiler where hot gasses are passed through tubes which are surrounded by water.

1.3.1.2. Advantages of Water Tube Boiler

There are many **advantages of water tube boiler** due to which these types of boiler are essentially used in large thermal power station.

1. Larger heating surface can be achieved by using more numbers of water tubes.
2. Due to convectional flow, movement of water is much faster than that of fire tube boiler, hence rate of heat transfer is high which results into higher efficiency.
3. Very high pressure in order of 140 kg/cm^2 can be obtained smoothly.

1.3.1.3. Working Principle of Water Tube Boiler

The working principle of water tube boiler is very interesting and simple. Let us draw a very basic diagram of water tube boiler. It consists of mainly two drums, one is upper drum called steam drum other is lower drum called mud drum. These upper drum and lower drum are connected with two tubes namely down-comer and riser tubes as shown in the picture.Water in the lower drum and in the riser connected to it, is heated and steam is produced in them which comes to the upper drums naturally. In the upper drum the steam is separated from water naturally and stored above the water surface. The colder water is fed from feed water inlet at upper drum and as this water is heavier than the hotter water of lower drum and that in the riser, the colder water push the hotter water upwards through the riser. So there is one convectional flow of water in the boiler system. More and more steam is produced the pressure of the closed system increases which obstructs this convectional flow of water and hence rate production of steam becomes slower proportionately. Again if the steam is taken trough steam outlet, the pressure inside the system falls and consequently the convectional flow of water becomes faster which result in faster steam production rate. In this way the water tube boiler can control its own pressure. Hence this type of boiler is referred as self-controlled machine.

1.3.2. Economizer

Economizer is a heat exchanger which takes heat from the flue gas, and increases the temperature of feed water coming from feed water common header to about the saturation temperature corresponding to the boiler pressure.Throwing away the flue gases of high temperature into the atmosphere involves a great deal of energy losses. By utilizing these gases in heating feed water, higher efficiency and better economy can be achieved, and hence the heat exchanger is called “Economizer”.

1.3.3. Super-Heaters

Super heater is another important part of Feed Water and Steam Circuit of Boiler Super-Heater is an important element of the feed water-steam circuit. It is basically a heat exchanger in which heat is transferred to the aturated steam to increase its temperature. In high pressure boilers more than 40% of the total heat is absorbed by the super heaters. The T-S diagram beside illustrates the heat absorbed by the super heater and is denoted by ‘Qsh’. Feed Water Steam Circuit .In super-heater the rate of heat absorption is more. Hence, in the modern water tube boilers there are more. Hence, in the modern water tube boilers there are more super heating surfaces.Super-heater tubes are exposed to the highest steam pressure and temperature on the inside and the maximum gas temperature on the outside. They are made of costliest alloys.

Functions of Super-Heater

An increase in inlet steam temperature gives a steady improvement in cycle efficiency. Hence, the function of super-heater is to raise the overall efficiency. In addition, it reduces the moisture content in the later stages of the turbine and thus increases the turbine internal efficiency.However; the increase in temperature is limited by the properties of the construction materials of boilers and turbines. Usually the optimum temperature of steam is maintained 450oC at the turbine inlet.

1.3.4. Clarification unit

- Cane receiving and unloading (receive the cane at the factory and unload it from the transport vehicles).
- Cane preparation (cutting and shredding cane to prepare it for juice extraction).
- Juice extraction (two technologies are in common use; milling or diffusion)
- Juice clarification (remove suspended solids from the juice, typically mud, waxes, fibres).
- Juice evaporation (to concentrate the juice to a thick syrup of about 65°brix)
- Syrup clarification (remove suspended solids from the syrup, typically colloid syze of mud, waxes, fibres, etc.)

1.3.5. Crystallisation

Centrifugation (Separation of the sugar crystals from the mother liquor, done,```qa`Q1`by centrifugal machines).

1.3.6. Sugar drying

Packaging and delivery

These processing steps will produce a brown or raw sugar. Mill white sugar also known as plantation white sugar can be produced by introducing some form of colour removal process (often sulphitation) between the juice clarification and the juice evaporation stages mentioned above.[1] The raw sugar produced is often refined to produce white sugar. This sugar refining can be done either at a completely separate factory or at a back-end refinery which is attached to the raw sugar factory.

1.3.7. Juice extraction

1.3.7.1. Milling

Juice extraction by milling is the process of squeezing the juice from the cane under a set mills using high pressure between heavy iron rollers. Those mills can have from 3 up to 6 rolls; every set of mills are called tandem mill or mill train. For improve the milling extraction efficiency, imbibition water is added at each mill: Hot water is poured over the cane just before it enters the last mill in the milling train and is recirculated up to the reach the first mill. The juice squeezed from this cane is low in sugar concentration and is pumped to the preceding mill and poured onto the cane just before it enters the rollers, the juice from this mill is the same way pumped back up the milling train. Mixed juice (that is to say cane juice mixed with the water introduced at the last mill) is withdrawn from the first and second mills and is sent for further processing. Milling trains typically have four, five or six mills in the tandem. For improve the milling extraction performance before the cane reach the first mill, normally are used knife and shredder as preparation equipment.

1.3.7.2. Diffusion

Sugarcane diffusion is the process of extracting the sucrose from the cane with the use of imbibtion but without the squeezing by mills. Shredded cane is introduced into the diffuser at the feed end, Hot water is poured over the shredded cane just before the discharge end of the diffuser. The hot water percolates through the bed of cane and removes sucrose from the cane. This dilute juice is then collected in a compartment under the bed of cane and is pumped to a point a little closer to the feed end of the diffuser and this dilute juice is allowed to percolate through the bed of cane. At this point the concentration of sucrose in the cane is higher than the concentration of sucrose in the dilute juice just mentioned and so sucrose diffuses from the cane to the juice, this now slightly richer juice is pumped back up the diffuser and the process is repeated, typically, 12 to 15 times (compared with the four to six times for the milling process)

1.3.7.3. Juice clarification

Sugar cane juice has a pH of about 4.0 to 4.5 which is quite acidic. Calcium hydroxide, also known as Milk of lime or limewater, is added to the cane juice to adjust its pH to 7. The lime helps to prevent sucrose's decay into glucose and fructose. The limed juice is then heated to a temperature above its boiling point. The superheated limed juice is then allowed to flash to its saturation temperature: this process precipitates impurities which get held up in the calcium carbonate crystals.[4] The flashed juice is then transferred to a clarification tank which allows the suspended solids to settle. The supernatant, known as clear juice is drawn off of the clarifier and sent to the evaporators.

1.3.7.4. Juice evaporating

The clarified juice is concentrated in a multiple-effect evaporator to make a syrup of about 60 percent sucrose by weight.

Energy in the sugar mill

The remaining fibrous solids, called bagasse, are burned for fuel in the mill's steam boilers. These boilers produce high-pressure steam, which is passed through a turbine to generate electrical energy (cogeneration).The exhaust steam from the turbine is passed through the multiple effect evaporator station and used to heat vacuum pans in the crystallization stage as well as for other heating purposes in the sugar mill.Bagasse makes a sugar mill more than energy self-sufficient; surplus bagasse goes in animal feed, in paper manufacture, or to generate electricity for sale.

1.4. Power House

Bagasse is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice and is a by product generated in the process of manufacture of sugar. It can either be sold or be captively consumed for generation of steam. It is currently used as a biofuel and in the manufacture of pulp and paper products and building materials. The bagasse produced in a sugar factory is however used for generation of steam which in turn is used as a fuel source and the surplus generation is exported to the power grids of state governments. For each 10 tonnes of sugarcane crushed, a sugar factory produces nearly 3 tonnes of wet bagasse. Since bagasse is a by-product of the cane sugar industry, the quantity of production in a country is in line with the quantity of sugarcane produced. Bagasse when burned in quantity produces sufficient heat energy to supply all the needs of a typical sugar mill, with enough energy to spare. To this end, a secondary use for this waste product is in cogeneration, the use of a fuel source to provide both heat energy, used in the mill and the electricity which is typically sold on to the consumer through power grids. The power produced through co-generation substitutes the conventional thermal alternative and reduces greenhouse gas emissions. In India, interest in high-efficiency bagasse based cogeneration started in the 1980s when electricity supply started falling short of demand.

High-efficiency bagasse cogeneration was perceived as an attractive technology both in terms of its potential to produce carbon neutral electricity as well as its economic benefits to the sugar sector. In the present scenario, where fossil fuel prices are shooting up and there is a shortage and non-availability of coal, co-generation appears to be a promising development. The thrust on distributed generation and increasing awareness for cutting greenhouse gas emissions increases the need for cogeneration. Also it helps in controlling pollution from fossil fuels.

2. LITERATURE REVIEW

[1] William Yang et .al (1986), A CFD model of a 375 MW tangentially-fired furnace located in Australia's Latrobe Valley has been developed. Coal feed rates, air flow rates, coal particle size distribution and coal properties, obtained from plant data, are taken as input conditions in the CFD simulation. A level of confidence in the current CFD model has been established by carrying out a mesh independence test and comparing simulated results against power plant measurements. Performance of two turbulence models, standard k-ε model and SST model, are compared. The effect of particle dispersion on predicted results is found to be insignificant. The validated CFD model is then used to simulate several brown coal combustion cases at full load with different out-of-service firing groups.A CFD model of a 375 MW tangentially fired furnace at Yallourn W power plant has been developed. A substantial amount of work has been undertaken to validate the CFD model against measured operating data and to gain an understanding of the sensitivity of CFD results to modelling parameters. To this end two turbulence models, the standard k-ε model and SST model, are used to model gas phase turbulence. Both turbulence models provide similar predictions that are in good agreement with the plant data. The effect of the particle dispersion on the CFD prediction is found to be insignificant. This is consistent with the observation of Truelove (1986) who found the particle dispersion has little effect on the high-volatile coal combustion. This validated model is then employed to investigate brown coal combustion at full load with various firing groups out-of-service. It is found that the values of total boiler heat supply for case 4 and case 5 are slightly higher than those of other cases.

[2]TSUNG-FENG WU et .al (1989), The failure analysis of the leakage of the Super heater tube of the waste heat boiler in the energy factory is investigated in this study. The experimental methods included metallurgical and mechanical properties examination, XRD analyses of the corrosion products, and fractural observation of the failed tube. The results show that although the material and mechanical properties of the failed tube, were inferior to those of the new one, most of them were still satisfactory to the criterion requirement. From SEM observation, it is clear that the crack initiated in the outer surface and propagated toward the inner surface of the tube. The fracture, through the entire thickness of the tube, was identified to be intergranular. The crack formation is not dominated by overall degradation in the tube, but might result from a combination with the decrease in the toughness. The toughness degradation in the grain boundary of the Super heater tube must have taken place during the fin welding process.

[3] Hemant S. Farkade2 et .al (1992), This paper presents a simulation of the Super heater zone, which allows for the condition of the shell-side flow and tube-side and tube-wall, thermal fields, and of the shell-tube heat-exchange. Selection of the Super heater zone from the thermal power plant only because, it is found trends of failure that the Super heater is the zone where the leakages are found more. The maximum number of cause of failure in Super heater unit is due to flue gas erosion.

[4]Albert J. Depman III et. al (1999), In this work, updated models based on a previously existing Unit 10 stoker boiler model were created and used to run simulations testing various boundary conditions, flow models, and energy balance methods. Boundary condition modifications included modifying the geometry and mesh grid, matching wall temperatures to actual operating conditions, updating the coal proximate and ultimate analyses, and varying secondary air inlet velocities.The realizable $k - \varepsilon$ turbulence model and the P1 radiation model, also used in previous simulations by Zhang, were determined to be the most accurate models for this specific boiler model.

[5]Shahabaz Khan et .al (2007), Boiler can also be called as "the Burner".The main Function of the Boiler is to Burn the Fuel and Make Combustion possible. In this project we are going to study how coal is pulverized and burnt in order to gain more heat. Most coal fired power station boilers use pulverized coal.

3. SUPER HEATER

A Super heater is a mechanical device which is used as a heat exchanger by preheating a fluid to reduce energy consumption. In a steam boiler, it is a heat ex-changer device that heats up fluids or recovers residual heat from the combustion product i.e. flue gases in thermal power plant before being released through the chimney. Flue gases are the combustion exhaust gases produced at power plants consist of mostly nitrogen, carbon dioxide, water vapor, soot carbon monoxide etc. Hence, the Super heater in thermal power plants**,** is used to economise the process of electrical power generation, as the name of the device is suggestive of. The recovered heat is in turn used to preheat the boiler feed water, that will eventually be converted to super-heated steam. Thus, saving on fuel consumption and economizing the process to a large extent, as we are essentially gathering the waste heat and applying it to, where it is required. Nowadays however, in addition to that, the heat available in the exhaust flue gases can be economically recovered using air pre-heater which are essential in all pulverized coal fired boiler.

Figure 3.1 Board Mills boiler house

3.1. Working Principle of Super heater

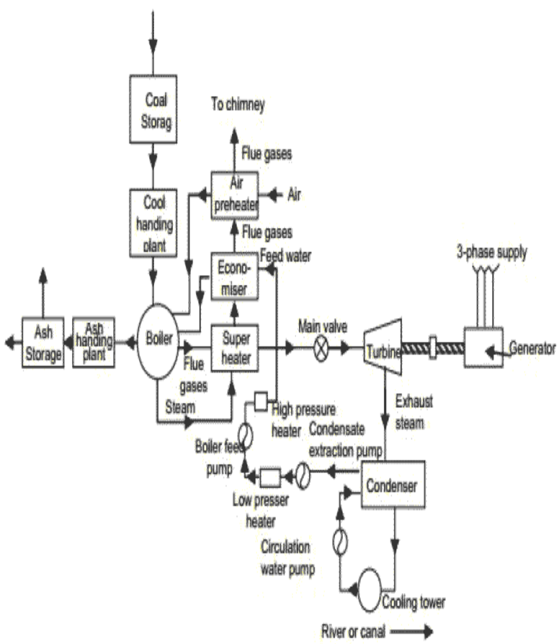

Figure 3.2.1 Working principle of super heater

As shown in the figure above, the flue gases coming out of the steam boiler furnace carry a lot of heat. Function of Super heater in thermal power plant is to recover some of the heat from the heat carried away in the flue gases up the chimney and utilize for heating the feed water to the boiler. It is simply a heat ex-changer with hot flue gas on shell side and water on tube side with extended heating surface like Fins or Gills. Super heaters in thermal power plant must be sized for the volume and temperature of flue gas, the maximum pressure drop passed the stack, what kind of fuel is used in the boiler and how much energy needs to be recovered. When the water is boiled in steam boiler, the steam is produced which is then super-heated after which it is passed to the turbines. Then the exhausted steam from turbine blades, is passed through steam condenser of turbine in which the steam is condensed and this condensed water then is pre warmed first in feed water heater then in it before re-feeding in boiler. It is placed in the passage of flue gases in between the exit from the boiler and the entry to the chimney. In this a large number of small diameter thin walled tubes are placed between two headers. The flue gases flow outside the tubes usually in counter flow.

3.2. Process of Heat Transfer in Super heater, Evaporator and Super heater

Heat transfer to water in steam generator takes place in 3 different regimes, as shown in the figure below. Water is at first pre-heated sensibly in the **S**uper heater in liquid phase at a certain pressure from state 4 to state 5 (refer to the diagram below) till it becomes a saturated liquid. It is then send to the evaporator, where this saturated liquid is boiled associating a change of phase from 5 to 6 by absorbing the latent heat of vaporization, at that particular pressure.

Now this saturated vapor in state 6 is further heated in the super-heater, to bring it to state 1, i.e. in gaseous or vapor form. For unit mass of fluid, the heat transfer equation in the 3 types of heat ex-changers are given by, $Q_{Super\ heater} = h_5 - h_4$ $Q_{Evaporator} = h_6 - h_5$ $Q_{Superheater} = h_1 - h_6$ Out, of these 3 major heat ex-changer components, only the Super heater operates with, zero fuel consumption, and thus it is one of the most vital and economical equipment in a thermal power plant.

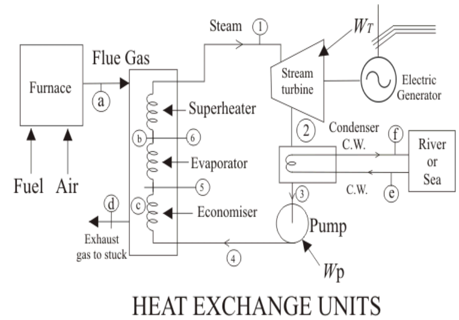

Figure 3.2.2 Heat Exchange Units

3.3. Types of Super heater

3.3.1. CI Gilled Tube Super heater

The gilled tube Super heaters are made up of cast iron which are fabricated using graded cast iron fins, have following features,

1. High optimum efficiency due to proper contact of gills with tubes.
2. Commonly used in plants where intoxicated flue gas is generated due to the quality of fuel burnt.

3.3.2. Round Gilled Tube Super heater

This is made by mild steel fabricated with square and round fins, welded on carbon steel seamless tubes, have the feature,

1. Proper contact between the tubes and fins are ensured for optimum efficiency.

3.3.3. Coiled Tube Type Super heater

These are used mostly in thermal power plants and large processing units. These coiled tube type Super heaters are fabricated out of carbon steel seamless, have following features,

1. These are very efficient in recovering the heat from gases.
2. Occupy very little space.

3.3.4. Horizontal Finned Tube Super heater

In this is carbon steel seamless tube sealed – welded with horizontal fins to make a complete assembly of Super heater for heat transfer, have following features,

1. Proper care is taken for making the contact of fins with tubes for perfect heat transfer.
2. These are used mainly used by Thermal Power Plants.

3.4. Types of Super heaters Based on Boiler Efficiency

Throughout this article, we have been having a qualitative discussion on the economical aspect of the Super heater, let us now see how the different types of Super heaters can be judicially assembled along with the boiler, in order to perceive maximum boiler efficiency. They are broadly classified into two types, as has been described below.

3.4.1. Non - condensing Super heater

The most widely used one, in a thermal power plant is the non-condensing Super heater. These are basically heat ex-changer coils, that are finned around in the form of a spiral and are located inside the flue gas duct near the exit region of the boiler. They have the ability to reduces the fuel requirements of a boiler by transferring heat from the exit flue gas to the steam boiler feed water. It is used in the case of coal-fired boilers, where the lowest temperature to which flue gas can be cooled is about 250° F (120°C).

You can well understand form the discussion above that, cooling the flue gas below 250° F and transferring that additional heat to the boiler feed water would have resulted in greater efficiency, but in a coal fired power plant, this should not be done, since coal as a fuel contains sulphur in a very large extent as impurity. And the flue gas thus formed by burning this coal, results in the formation of sulphurous compounds as by product. Now if this flue gas is allowed to cool below 250° F, condensation of the gaseous compounds result in the formation of sulphuric acid, which is considered extremely corrosive against the metal surface. Since the installation and maintenance cost of a power plant is huge, it is note-worthy that a non-condensing Super heater be installed to limit the cooling capacity of the flue gas to about 250° F, i.e above the condensation temperature and increase the overall boiler efficiency by about 3 to 6 %.

Figure 3.3.1 Non Condensing super heater

3.4.2. Condensing Super heater

The condensing Super heaters are mainly used in natural gas fired thermal power plants, as they have the ability to improve the waste heat recovery by cooling the flue gas below its condensation temperature, which is about 80° F (25°C). This particular variant of Super heaters result in greater efficiency of around 10 to 15% and more economical operation as it reclaims both sensible heat from the flue gas and latent heat by condensing water vapor present in the flue gas. This is contradictory to the conventional non-condensing Super heaters as they increase the efficiency to only about 5 %. But the condensing variant with greater value of efficiency can only be used, when the flue gas does not contain any sulphurous, nitrate or other corrosive compounds.

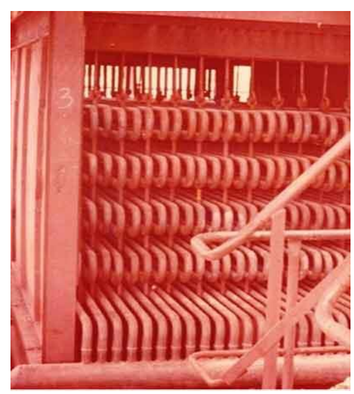

Figure 3.4 condensing super heater

3.5. Applications of Super heater

It is used in all modern plants. The use of Super heater results in saving fuel consumption, increases steaming rate and boiler efficiency.

Some of the common applications of Super heater are given below, In steam power plants it captures the waste heat from boiler stack gases (flue gases) and transfers it to the boiler feed water. Air-side Super heaters HVAC (Heating, Ventilation and Air Condition) can save energy in buildings by using cool outside air as a means of cooling the indoor space. Refrigeration : This is commonly used in industrial refrigeration where vapor compression refrigeration is essential. Systems with Super heaters aim to produce part of the refrigeration work on high pressures, condition in which gas compressors are normally more efficient.

3.6. Advantages And Benefits of Super Heater

1. It recovers more heat of flue gases which normal air pre-heater can not do.
2. Due increase in fuel prices, all power plants are facing pressure for increasing boiler efficiency. So by using Super heater, this pressure can be minimized.
3. Power plants where it is not used, large quantity of water is required to cool the flue gas before desulphurization which is minimized by using Super heaters.
4. The efficiency of power plant reduced when steam air pre-heater required steam.

4 PRINCIPAL EFFECTS OF MAJOR ALLOYING ELEMENTS FOR STEEL

TABLE4.1 Principal effects of major alloying elements for steel

Principal effects of major alloying elements for steel		
Element	**Percentage**	**Primary function**
Aluminium	0.95–1.30	Alloying element in nitriding steels
Bismuth	-	Improves machinability
Boron	0.001–0.003	A powerful hardenability agent
Chromium	0.5–2	Increases hardenability
	4–18	Increases corrosion resistance
Copper	0.1–0.4	Corrosion resistance
Lead	-	Improved machinability
Manganese	0.25–0.40	Combines with sulfur and with phosphorus to reduce the brittleness. Also helps to remove excess oxygen from molten steel.
	>1	Increases hardenability by lowering transformation points and causing transformations to be sluggish
Molybdenum	0.2–5	Stable carbides; inhibits grain growth. Increases the toughness of steel, thus making molybdenum a very valuable alloy metal for making the cutting parts of machine tools and also the turbine blades of turbojet engines. Also used in rocket motors.
Nickel	2–5	Toughened
	12–20	Increases corrosion resistance

Silicon	0.2–0.7	Increases strength
	2.0	Spring steels
	Higher percentages	Improves magnetic properties
Sulfur	0.08–0.15	Free-machining properties
Titanium	-	Fixes carbon in inert particles; reduces martensitic hardness in chromium steels
Tungsten	-	Also increases the melting point.
Vanadium	0.15	Stable carbides; increases strength while retaining ductility;

5. MATERIAL SELECTION

Nowadays Carbon Steels are used to manufacture Super heater tubes. Even though carbon steels have good thermal properties,Super heater failure occurs frequently in boilers. Some disadvantages of using carbon steel as Super heater tubes as follows,

1.Low strength in high temperatures .
2. Low resistance to corrosion and oxidation at high temperatures.
3.Low,hardenability.
4. Significant drop of hardness on tempering after hardening

To overcome such drawbacks and to broaden their usefulness, alloy steels have been developed by deliberately adding alloying elements (chemical elements) to steels. Therefore, most of the steels, actually all the steels, used in severe conditions are alloy steels today. E.g: Highly fatigue resistant alloys have been developed for high speed applications like motor vehicle shafts called HSS (High Speed Steels).

Pure iron is relatively soft and adding small amounts of carbon hardens the 'carbon steel' by affecting solid crystals. Larger amounts of carbon (cast iron) will make the metal even harder but relatively brittle. Other alloying agents (often in addition to the correct amount of carbon) will provide desirable properties. For example, leaded steel is more easily machined. Nickel may be added to enhance magnetic properties. Chrome may be added to reduce corrosion (stainless steels).

In addition to the amount of carbon used in steels, heat treatment can produce desirable properties. Heating the steel helps dissolve the carbon and quenching (rapid cooling) keeps the carbon evenly distributed. Slow cooling will allow crystals to grow pushing the excess carbon to the final grain boundaries and the characteristics of the steel will depend upon grain sizes and strength of the grain boundaries. However, generally alloying induces some brittleness into steels which may be identified as their weakness. But, many remedies have been introduced to avoid this situation and better alloys have been developed. Therefore, there's hardly any disadvantage (may be the cost) in Alloys over carbon steels.

5.1. Carbon Steel

Carbon steel is steel in which the main interstitial alloying constituent is carbon in the range of 0.12–2.0%. The American Iron and Steel Institute (AISI) definition says:

Steel is considered to be carbon steel when:

- No minimum content is specified or required for chromium, cobalt, molybdenum, nickel, niobium, t itanium, tungsten, vanadium or zirconium, or any other element to be added to obtain a desired alloying effect;
- The specified minimum for copper does not exceed 0.40 percent;
- The maximum content specified for any of the following elements does not exceed the percentages noted: manganese 1.65, silicon 0.60, copper 0.60.So me generally used carbon steels are SA192, SA 210 Gr A1,SA 210 Gr C,SA 106 Gr B,SA 106 Gr C . Among them SA Gr 210 A1 is widely used as a Super heater tube.

5.2. Alloy Steel

Alloy steel is steel that is alloyed with a variety of elements in total amounts between 1.0% and 50% by weight to improve its mechanical properties. Alloy steels are broken down into two groups: low-alloy steels and high-alloy steels. The difference between the two is somewhat arbitrary: Smith and Hashemi define the difference at 4.0%, while Degarmo, et al., define it at 8.0%.[1][2] Most commonly, the phrase "alloy steel" refers to low-alloy steels.

Strictly speaking, every steel is an alloy, but not all steels are called "alloy steels". The simplest steels are iron (Fe) alloyed with carbon (C) (about 0.1% to 1%, depending on type). However, the term "alloy steel" is the standard term referring to steels with other alloying elements added deliberately in addition to the carbon. Common alloyants include manganese (the most common one), nickel, chromium, molybdenum, vanadium, silicon, and boron. Less common alloy,include aluminum, cobalt, copper, cerium, niobium, tita nium, tungsten, tin, zinc, lead, and zirconium.

Some generally used alloy steels are SA 209 T1,SA 213 T11,SA 213 T12,SA 213 T22,SA 213 T23,SA 213 T91,SA 213 T92. In our project we used SA 209 T1 as a Super heater seamless tube.

5.3. Conventional Super heater Tube (SA 213 T-11)

TABLE 5.3.1 Chemical Composition

Elements	**Percentage**
Carbon	0.27
Manganese	0.93max
Potassium	0.035
Sulfur	0.035
Silicon	0.10

TABLE 5.3.2 Mechanical Properties

Tensile Strength	414 MPa
Yield Strength	183 MPa
Young's Modulus	1.72E5 MPa
Max Rockwell Hardness	79

5.4 Our Alternative MaterialASTM SA 335 P5

TABLE 5.4.1 Chemical Composition

Elements	**Percentage**
Carbon	0.12
Manganese	0.60max
Potassium	0.02
Sulfur	0.01
Silicon	0.50

TABLE 5.4.2 Mechanical Properties

Tensile Strength	483 MPa
Yield Strength	276 MPa
Max Rockwell Hardness	89

6. SOFTWARES USED

6.1. Introduction to CREO

CREO is a computer graphics system for modeling various mechanical designs and for performing related design and manufacturing operations. The system uses a 3D solid modeling system as the core, and applies the feature-based, parametric modeling method. In short, CREO is a feature-based, parametric solid and surface modeling system with many extended design and manufacturing applications.

CREO is the first commercial CAD system entirely based upon the feature-based design and parametric modeling philosophy. Today most software producers have recognized the advantage of this approach and changed their products onto this platform. Some of the features are:

- Ease of Use
- Full Associativity
- Parametric, Feature-Based Modelling
- Robustness
- Change Management
- Hardware Independence

6.2. Pro/ENGINEER/ CREO

(commonly referred to as Pro/E or CREO) is a 3D CAD parametric feature solid modelling software created by Parametric Technology Corporation (PTC). Its direct competitors are UGS-NX, CATIA, Solid Works, Autodesk Inventor and Solid Edge. It runs on several UNIX flavours, Linux and Microsoft Windows, and provides solid modelling, assembly modelling and drafting functionality for mechanical Engineers.

Overview

CREO is an integrated 3D CAD/CAM/CAE solution for mechanical engineering and design which was created by Dr. Samuel P. Geisberg in the mid-1980. It pioneered the CAD industry by introducing the concept of Parametric, Feature-based Solid Modeling. Models are driven by parameters and intelligent features, rather than simple dimensional values. CREO outputs consist of solid model data for tooling and rapid prototyping, CNC manufacturing, and finite element analysis.

A product and its entire bill of materials (BOM) can be modeled accurately with fully associative engineering drawings, and revision control information. It is compatible with Windows and Unix-variants.

6.2.1. Competition

From the era of early Windows based PC's, CREO solidified its hold in the 3D CAD market. Since then, many users trying to switch to CREO from other comparable software find it difficult to learn many of its intricate commands. Luckily, tutorial books have been written on the topic spanning from the beginner to the advanced power user.

6.2.2. Modules

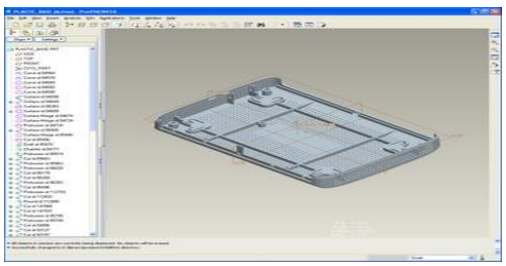

Fig. 6.2 Pro/E Wildfire 2.0 screenshot

A typical CREO software package is made up of different modules, customizable to the customer's specific needs. In the past years some of the modules like Pro/SURFACE and Pro/SHEETMETAL have been integrated into the basic Pro/E offerings. The modules serve different needs, for example, the Pro/CABLING and Pro/HARNESS-MFG modules are used for the design of wire harnesses for the automotive industry. Likewise, free form surfacing is done via the ISDX package.

6..2.3 Advanced modules

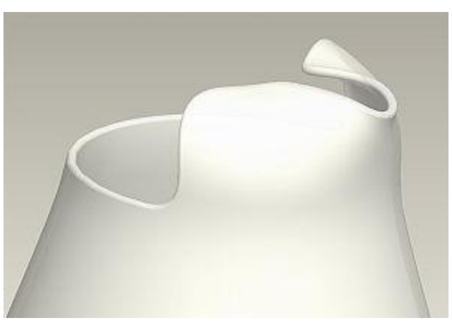

Fig. 6.2 Module

CREOWF2.0 created using the ISDX - free form surfacing extension module

- Basic Hull
- Structural Hull
- BehavioralModeler
- Design Animation
- Expert Machinist
- Import Data Doctor
- Mechanism Design
- Model CHECK
- Pro/ASSEMBLY (Advanced)
- Pro/CABLE
- ROUTED SYSTEM DESIGNER or RSD
- Pro/CMM
- Pro/COMPOSITE
- Pro/DIAGRAM
- Pro/DIEFACE
- Pro/HARNESS-MFG
- Pro/MOLDESIGN and Pro/CASTING
- Pro/NC
- Pro/NC-SHEETMETAL
- Pro/PIPING (Specification-Driven Design Mode)
- Pro/PIPING (Non Specification-Driven Design Mode)
- Pro/PROCESS for Assemblies
- Pro/PROCESS for MFG
- Pro/REVIEW
- Pro/SCAN-TOOLS
- Restyle - reverse Engineering module
- Pro/SURFACE
- ISDX (Interactive Surfacing Design extension)

wide range of simulation options for controlling the complexity of both modeling and analysis of a system. Similarly, the desired level of accuracy required and associated computational time requirements can be managed simultaneously to address most engineering applications. FEM allows entire designs to be constructed, refined, and optimized before the design is manufactured.

6.4. GEOMETRIC MODELING OF SECONDARY COIL

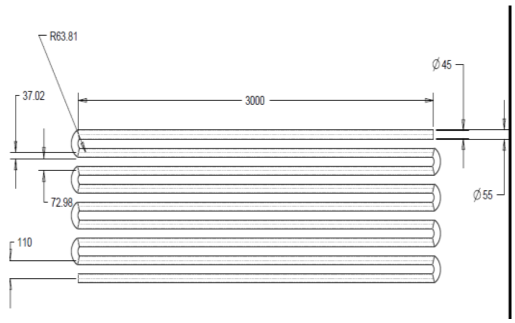

Fig 6.4 GEOMETRIC MODELING OF SECONDARY COIL

6.5. SOLID MODELING OF TUBE

Fig 6.5.1Solid modeling of tube

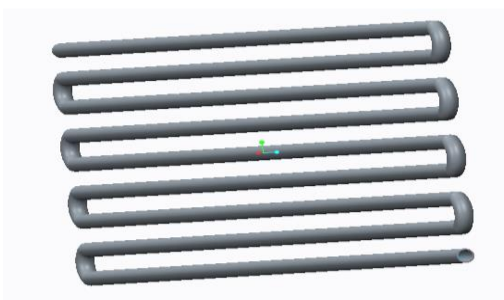

Fig 6.5.2 solid modeling of tube

ANALYSIS OF SECONDARY COIL TUBE

RESULT

6.10.1 Thermo Structural Analysis of Existing Coil

Equivalent Stress of Coil

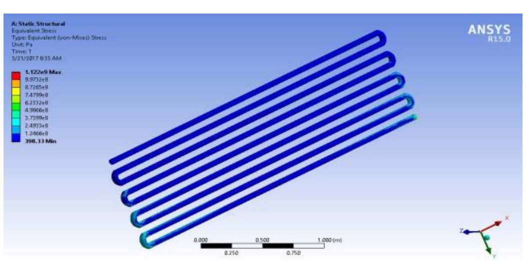

Fig 6.10.1 Equivalent stress of coil

6.10.2. Total Deformation of Coil

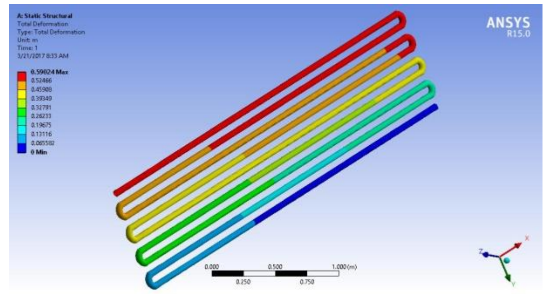

Fig 6.10.2 Total deformation of coil

6.11. Thermal Analysis of Coil

6.11.1. Temperature of Coil

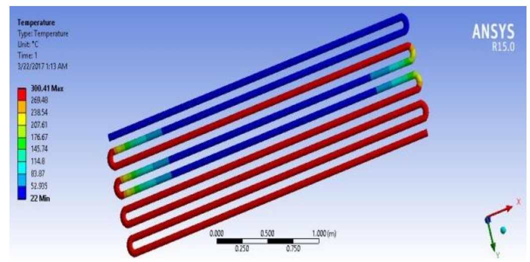

Fig 6.11.1 Temperature of coil

Total Heat Flux of coil

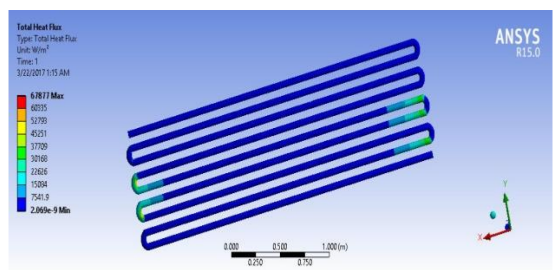

Fig 6.11.2 total heat flux of coil

7. CONCULUSION

Since the invention of new material in secondary coil tube which has more efficient then the conventional material our alternative material in super heater results in saving fuel consumption, increases steaming rate and boiler efficiency.

Some of the common applications of Super heater are given below, In steam power plants it captures the waste heat from boiler stack gases (flue gases) and transfers it to the boiler feed water. Air-side Super heaters HVAC (Heating, Ventilation and Air Condition) can save energy in buildings by using cool outside air as a means of cooling the indoor space. Refrigeration : This is commonly used in industrial refrigeration where vapor compression refrigeration is essential. Systems with Super heaters aim to produce part of the refrigeration work on high pressures, condition in which gas compressors are normally more efficient.

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