International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 9, 2019 (Special Issue)

Preliminary Design and Analysis of Water Boiling Domestic Chimney by Finite Element Analysis

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Abstract

A domestic chimney provides exit to the hot toxic gases. The large portion of heat was lost to the surrounding by the exhaust gases. The present study deals to recover this heat and make it for useful purposes. There are many methods to recover this heat but the most important method is a heat exchanger, which transfers the amount of heat to the receiving medium or object. In present study a CAD model of a heat exchanger type chimney was created in Catia and analyzed by Ansys. The model was tested for two different types of material for material optimization. The result was compare and analyzed on the bases of temperature and stress distribution due to thermal loading condition.

Keywords: Heat Exchanger chimney, CAD model, FEA, optimization.

Introduction

The population demand for the energy touches the new heights every year and the large portion of this demand is generally met through nonrenewable sources of energy. These non-renewable sources of energy are depleting quickly with time and these are also the causes for the emission of various hazardous gases like Co, CO_2 etc. Approximately 91% of worlds energy consumption demand is met through these resources and India's 92.93% of energy demand is fulfilled through non renewable resources. In 2017 worlds energy demand was raised by 2.1% and emissions of carbon were also raised for first time since 2014. It is more convenient to use more advance techniques of unconventional sources of energy. One of such techniques is to extract waste heat from domestic chimney, which can be used for various useful purposes. In domestic chimney large amount of heat is lost to the surrounding as waste heat. There are various methods of recovering this waste heat from the chimney. One of the most important methods is to install the fins. Fins increases surface for heat transfer so that large amount of lost heat can be recovered as useful heat. Many researchers contribute in extracting this heat by heat exchanger, double pipe heat exchanger and fins type heat exchangers.

Ram Thakar et al. [1] proposed that there are many heat losses associated with diesel engine. Among these all losses the exhaust heat losses contribute to 33 – 36%. This heat has been recovered by placing heat exchanger at the inlet and outlet of engine and this heat gain has been used to preheat the air. Haonan Cheng et al. [2] carried out the experimental study on shell and tube heat exchanger they carried out their experiment with and without use of circular fins. Their results have shown that circular fins improve heat transfer and they also found that the fuel charging time was significantly reduced. R.Senguptabet al. [3] had studied semicircular fins analytically for air preheated. They found that semicircular fin has more thermal efficiency than that of circular. C.C Fan et al. [4] carried out investigation on critical temperature and maximum heat transfer rate in boiling for circular finned tubes.

They carried out their analysis analytically by solving steady state heat conduction equation in two dimensional. They have found that varying the parameters like height, width and pitch can increase the heat transfer rate. Rasim Karabacak et al. [5] studied effect of holes on finned perforated heat exchanger. They placed holes on circular fins. They found that holes create turbulence on bottom of fin near heating tube surface which leads to increase in heat transfer rate. Tehmina et al**.** [6] studied effect on thermal performance by varying fin shape. They studied effect of using nanofluids for varying fin cross sections. They carried their investigation on three fin configurations hexagonal, circular and square. Their results show that circular fins give highest thermal performance fallowed by hexagonal and square fins. They found that for circular fin 44% enhancement in Nusselt number can be achieved. Sanjay Kumar Sharma et al. [7] studied maximizing heat transfer through fins using CFD. They analyzed heat transfer and air flow for automobile engine of light weight.

Figure 1 shows the working of Heat Exchanger type chimney. Which was made by two cylinders, the inner cylinder are in contact with heated exhaust gases whereas the outer cylinder holds the water.

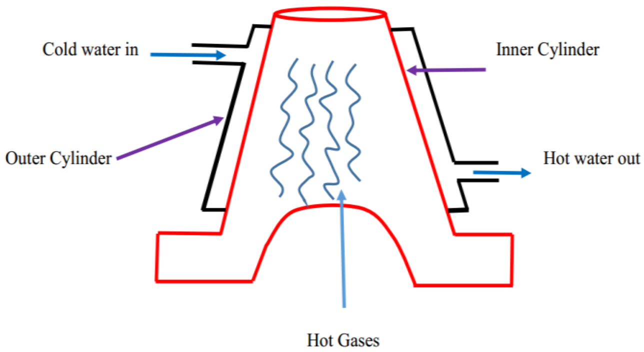

Figure 1: Heat Exchanger type Domestic Chimney

In order to increase the heat transfer rate circular fins are being used between two cylinders. When combustion of fuel takes place the inner cylinder gets heated up and then cold water is allowed to flow around the inner cylinder. The heat was exchanged by cold water; furthermore the heated water can be used for various useful purposes.

Material properties and CAD model

Austenitic Stainless steel is wildly used material in high temperature application and provides excellent resistance to corrosion. It has, carbon, nickel and titanium additives, the titanium percentage helps in carbide precipitation at high temperature (427- 816 °C) [8]. The table 1 shows the mechanical properties of Austenitic Stainless steels 321 and 330.

Table 1: Mechanical property of stainless steel

Properties	Value	
	SS-321	**SS-330**
Density	9.01 g/cm^3	8 g/cm^3
Ultimate Tensile Strength	621 Mpa	550 Mpa
Yield Tensile Strength	276 Mpa	260 Mpa
Modulus of Elasticity	193 GPa	197 Gpa
Poisson's Ratio	0.24	0.27
Thermal Conductivity	14 W/m-k	13 W/m-k
Melting Point	1371 -1399 °C	1149-1177 °C

The cad model of the considered domestic chimney was design in Catia 2.0 and analyzed by Ansys 14. The cad model is of 10 fit high and contain two cylinders, between the two cylinders the water was filed. The performance of the heat exchanger is increase by providing the fins. So that fins was introduced between the two cylinders in such a way that, the water flow in parallel and counter way.

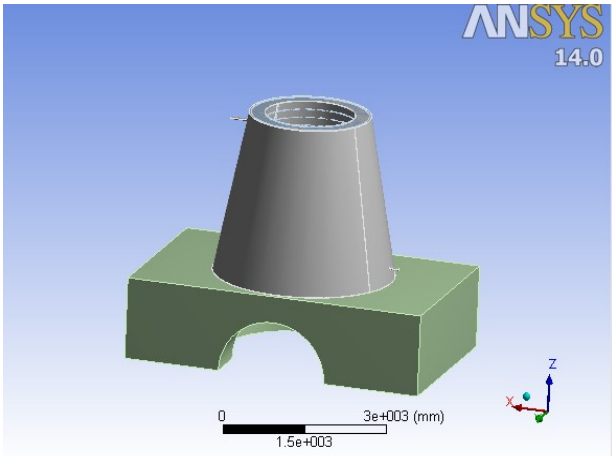

Figure 2: CAD model

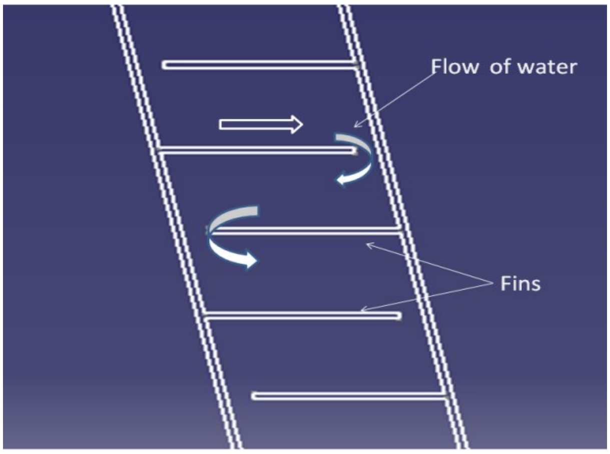

Figure 3: Front view of fins Layout

Figure 2 and 3 shows the Cad model and internal fins layout respectively. Figure 4 shows the mesh model which contains 195228 numbers of elements and 100995 numbers of nodes. The blue color shows the fixed support as shown in figure 5.

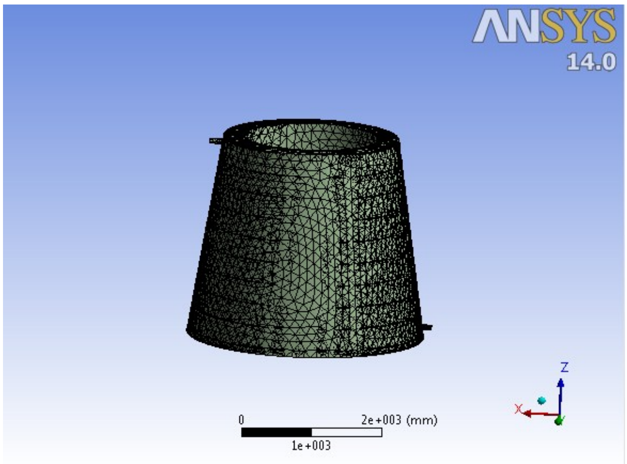

Figure 4: Mesh model

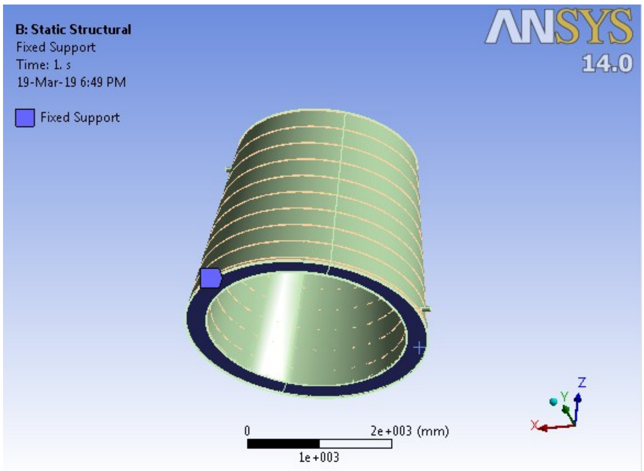

Figure 5: Fixed support

FEA simulation and Result

FEA is a wildly use method for solving the Structural, Fluid and thermal problems. FEA method also helps in optimizing and improvising the working model. The cad model of Chimney was imported to ansys workbench and a temperature of 600 °C was applied to the inner cylinder as shown in figure 6.

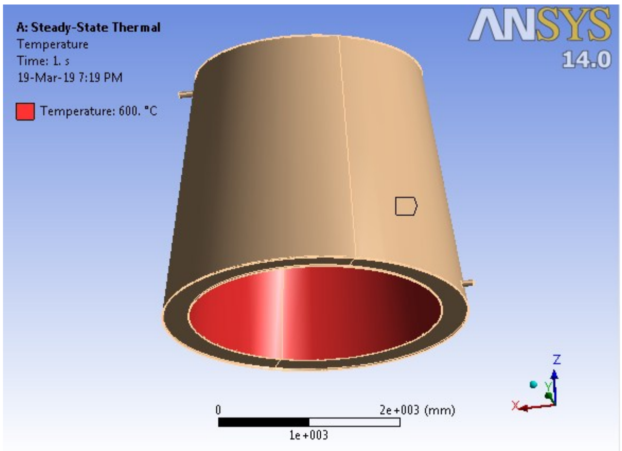

Figure 6: Boundary condition

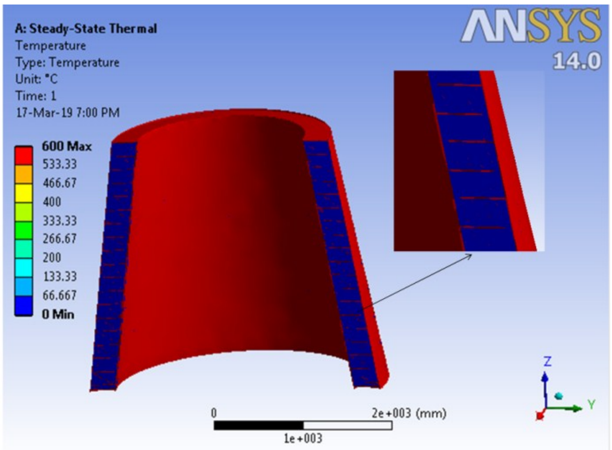

Figure 7: Temperature distributions for SS-321

Figure 7 and 8 shows the temperature variation in steady state condition for ss-321 and ss330 material. We can see that temperature of the fin is also in red color which shows that, the fins are at maximum temperature during steady state. Furthermore the temperature variations are same for both the material. The result of total deformation, stress, and strain for ss-321 and sss-330 material are shown in figure 9 to figure 14 respectively.

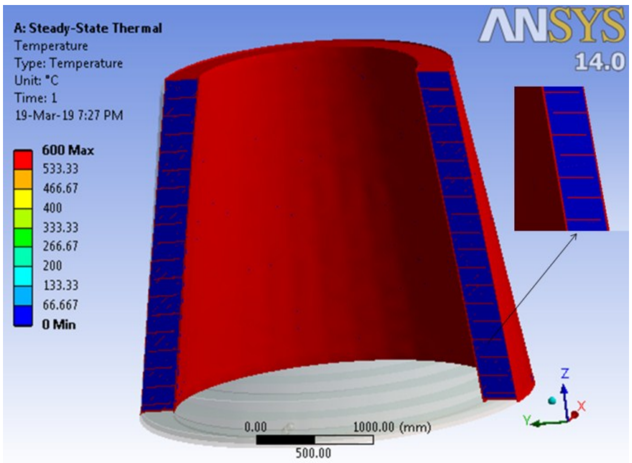

Figure 8: temperature distributions for SS-330

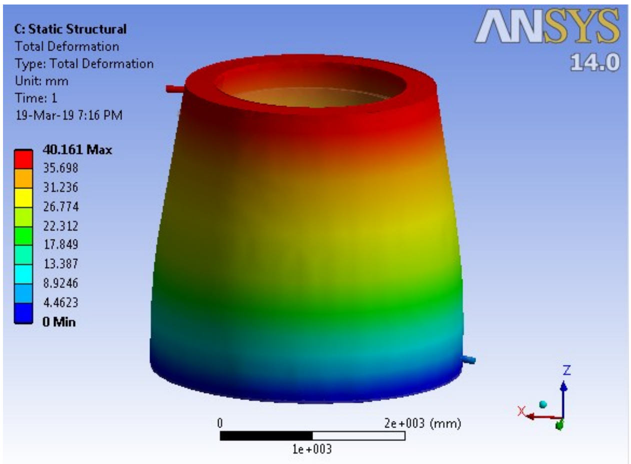

Figure 9: Total Deformation for SS-321

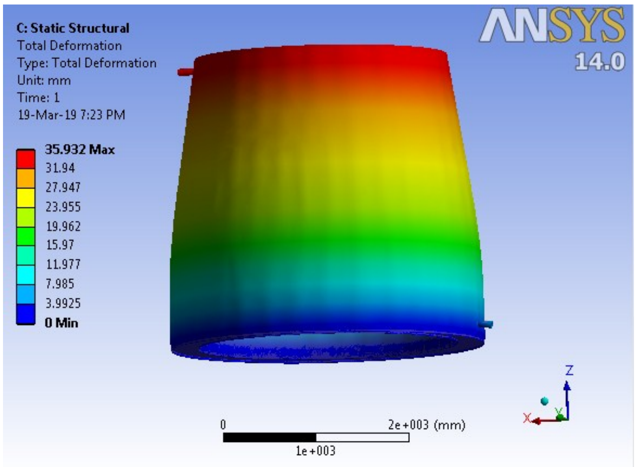

Figure 10: Total Deformation for SS-330

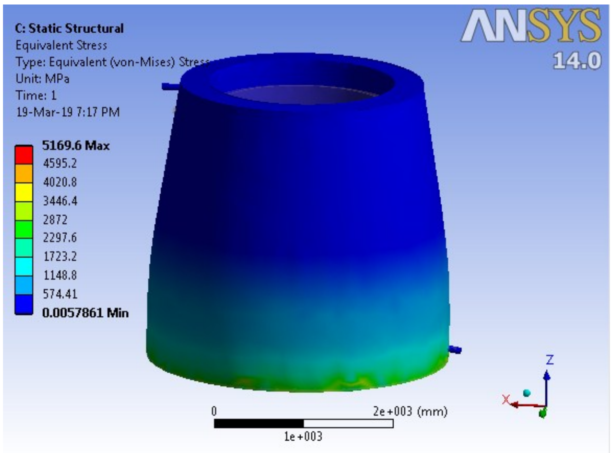

Figure 11: Equivalent stress for SS-321

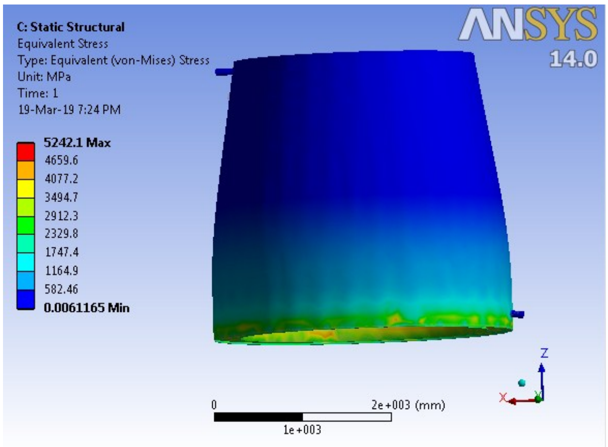

Figure 12: Equivalent stress for SS-330

In figure 7 and 8 the temperature variation was same for both the materials, but the Deformation was different as shown in figure 15. We can see that the deformation in ss-330 is less as compare to the ss-321 material. So that ss-330 material is the best suited material for domestic chimney.

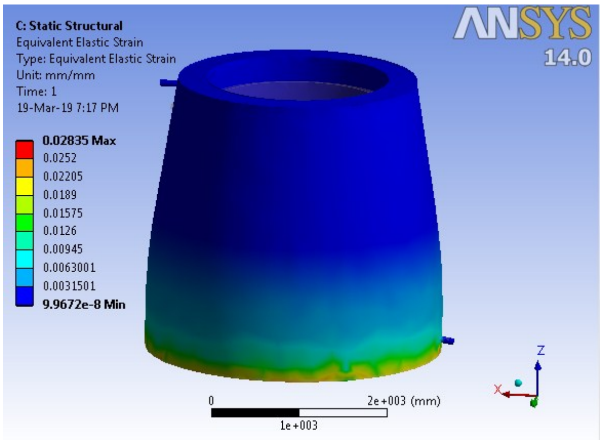

Figure 13: Equivalent strain for SS-321

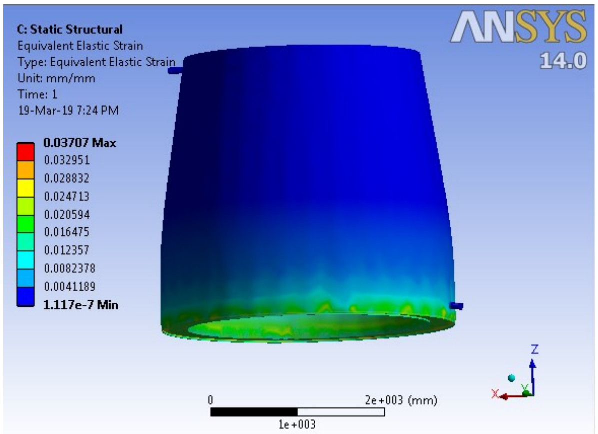

Figure 14: Equivalent strain for SS-330

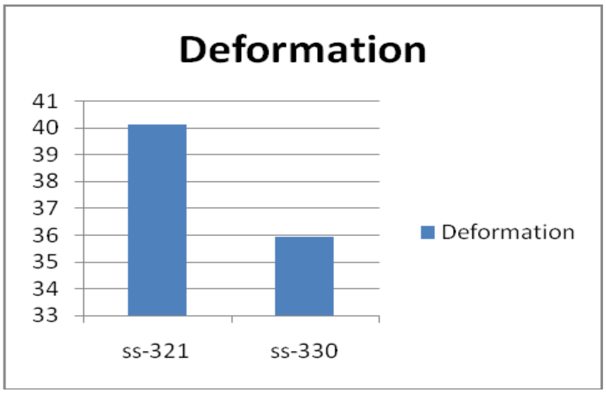

Figure 15: Deformation comparison

Conclusion

The present study demonstrates the use of waste heat for water boiling. The model was explained by design and analysis. Fins are design in such a manner that the water follows the rule of parallel and counter flow approach. The chimney was optimized by material to improve the performance. And both the materials having the same temperature distribution that's way the model was optimized by deformation induce in chimney. The simulation shows that fin temperature are relatively same as inner cylinder, which will increase the rate of water boiling. Furthermore we can see that the values of stress, strain and deformation are under satisfactory conditions.

Future Scope

Since the demand for the energy touches the new heights every year and the non renewable sources of energy are also depleting with time. So in future it is interesting to recover the waste heat from the chimney experimentally and use it for various useful purposes. Furthermore it is also interesting to check the performance of the considered chimney at different flow rate at different fins profile.

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