Design and Parametric Analysis of Helical Coil convective type Heat Exchanger

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Abstract

A heat exchanger is a mechanical device used for transfer of heat from one medium to another or from one fluid to other. The application of heat exchangers can be in the process of cooling and heating both. The applications of heat exchangers are in the field of textile industries, food processing industries, petrochemical industries, and medical industries. The requirement of the present manufacturing and production factories directs the researchers in finding a substitute system which should be effective in the most efficient way. From different types of heat exchangers the helical coil heat exchangers with double coil is to be under study. For making the helical coil heat exchanger for higher performance and efficiency at low manufacturing and maintenance cost in which maximum utilization of heat energy of flue gases is possible and also which is cheap and easy to accommodate by any industries for their operation. And to improve the working condition, life of device and decrease the losses by altering the type of material of tubes for given mechanical and thermal property for which the heat exchanger is to be designed.

Keywords — *Heat Exchanger, Helical coil pipe, Material analysis, Thermopac, CFD*

I. INTRODUCTION

A heat exchanger is a device used to transfer heat between one or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be indirect contact. They are widely used in space heating, refrigeration, air conditioning, power station, chemical plants and sewage treatment. Helical coil is type of heat exchanger in which, the coil of tubes is wounded in the form of a helix is called a helical tube heat exchanger.[2]It is one of the most efficient heat exchangers.

A “THERMOPAC” is a heat exchanging device, which consists of two helical coil heat exchangers arranged uses liquid as a heat transfer medium to put heat energy into a process. Thermal oil, furnace oil or water are common heating mediums that are used by being heated and circulated to heat energy users within a closed loop system.

The thermal oil circulates in a coil heated by the furnace flame and its resulting combustion gases. Further it is move from low pressure network to the various heat users. On the back circuit a de-aerator/expansion vessel, atmospheric or blanketed with inert gas, assure the remove of entrained air, vapour and light fractions before the thermal oil re-enters the heater. Effective expansion of fluid and de-aeration systems with thermal buffer, provide long term operation of thermal system.[4]

The circulating primary pump helps the flow of heat from the heater and transfers it to the desired use. Heat losses occurred to low levels of radiated heat from the well-insulated distribution pipe work.[7] The heat exchanger can be horizontal or vertical, single pass or multi-pass and any fuel can used to provide the heat from gas and oil to biomass products. Typical Specification of Thermopac is shown in Table

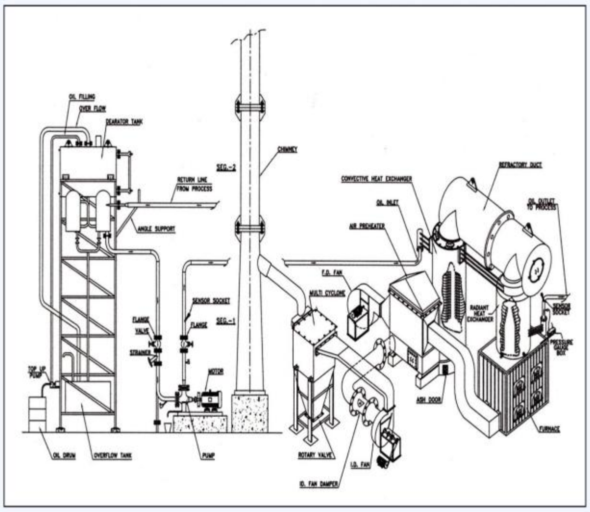


Fig.1: Heat transfer flow in Thermopac

II. MATERIAL ANALYSIS AND DESIGN

A. *Material analysis*

Different material have different properties like thermal conductivity, Heat transfer by conduction in helical coil depends on different properties of material and thickness of specific heat etc. Therefore, if the material of the tube is changed, it affects the heat transfer by conduction.[5] So, alternate materials are selected for helical coil instead of present material that will increase or decrease the heat transfer by conduction and also affect the thermal efficiency of radiant section and whole unit so alternate material ASTM A135 is selected instead of BS 3059**.**

In steel, different composition of the various elements such listed having different impact on the final product of the steel which defines the different grade of particular standard which having different properties.Some of the effects by various elements listed below (standard content in bracket):

1. Aluminium (0.95-1.30%): A deoxidizer. Used to limit growth of austenite grains.
2. Boron (0.001-0.003%): Boron used to be added in killed steel but needs to be added in very small quantities to provide hardening effect, small amount of boron is effective in low carbon steels, Although it is a harden ability agent that increase deformability.
3. Chromium (0.5-18%): A relevant component of stainless steels. At over 12 per cent content, chromium significantly improves corrosion resistance. The metal also enhances hardenability, strength, reply to heat treatment and wear resistance.
4. Cobalt*:* At high temp & magnetic permeability enriches the strength.
5. Copper (0.1-0.4%): In steel copper is a residual agent and it provides hardening properties within improve corrosion resistance.
6. Lead: In solid steel it is insoluble within addition of lead carbon steels dispersed during pouring and improve mach inability.
7. Manganese (0.25-13%): Improves strength at higher temperatures by removing the formation of sulphides of iron, manganese enriches ductility and wear resistance.
8. Molybdenum (0.2-5.0%): It found in little quantities in stainless steels, which increases strength, at particular at high temperatures. Moreover used in austenitic steels, it protects against pitting corrosion causes by sulphur and chlorides.
9. Nickel (2-20%): Nickel mainly impacted on strength, toughness which increases resistance to corrosion additionally small amount of nickel increases toughness at low temperature. when added in small amounts at low temperature.
10. Niobium*:* Niobium improves tensile strength of steel additionally medium precipitation strengthening affect.
11. Nitrogen: Nitrogen improves increases yield strength and increases austenitic Stability of steel.
12. Phosphorus: Phosphorus adds strength and increases corrosion resistance and more over adding with sulphur increases machinability in low alloy steels.
13. Selenium: Improve machinability.
14. Silicon (0.2-2.0%): This metalloid improves strength, elasticity, acid resistance and results in larger grain sizes, thereby, leading to greater magnetic permeability.
15. Sulphur (0.08-0.15%): Added in small amounts, sulphur improves machinability without resulting in hot shortness. With the addition of manganese hot shortness is further reduced due to the fact that manganese sulphide has a higher melting point than iron sulphide.
16. Titanium: Carbon combines with titanium allowing chromium to resist oxidization and remain under boundaries and this occurs at 0.3-0.6 per cent titanium.
17. Tungsten: It gives increase in hardness and produce carbide which is stable, especially at high temperature.
18. Vanadium (0.15%): It also can produce carbides which are stable especially at high temperature and improves strength, as like niobium and titanium. Upgrading grain structure ductility can be withheld.

B. BS3059 specifications:

Sr. No.	**Content**	**Result**
1	O.D. (mm)	63.52
2	Thickness (mm)	3.63
3	Area (mm2)	683
5	Yield Stress (N/mm2)	215
6	Tensile Stress (N/mm2)	360-400
7	% of Elongation	36

Table.1: Material specification of BS3059

Material	%C	%Mn	%S	%P	%Si
BS 3059	0.14	033	0.04	0.04	0.37
	0.09	0.53	0.010	0.018	0.160

C. ASTM A135 Specifications

Chemical Requirement	Mnmax% Pmax% Smax% Cmax% 0.95 0.05 0.06 0.25
Tensile Requirement	Grade A Tensile strength, psi 48000 Yield strength ,psi 3000
Grade A	Two grades of electric resistance welded steel pipe, Grade A is adapted for flanging and bending and is suitable welding.
Permissible variations in wall thickness	Minimum wall thickness at any points shall not be more than 12.5% under the nominal wall thickness specified
Lengths	Pipe shall be furnished in 38^0 with minimum of 20 ft.
Steel	Open hearth Electric furnace

permitted pipe material	basic oxygen

Table.2: Specification of ASTM135

1) Materials Details

Material details are required for transferring the heat through conduction and its properties with data of constant values are calculated by LaGrange Interpolation formula as listed in Table 9.1 and 10.1 from Two Materials" tables listed in previous chapter

1. BS-3059 Part-1
2. ASTM A-135

BS-3059 Part-1

Property	Thermal conductivity	Specific heat capacity
A	3.927979505	361.6310305
B	0.518424151	0.350197833
C	$-1.599045*10^{-03}$	-2.365 □$10^{□04}$
D	$2.02899*10^{-6}$	$1.66667*10^{-6}$
E	$-9.53947*10^{-10}$	

Table.3: Data Constant for Property

Property = $A + B \times T + C \times T^2 + D \times T^3 + E \times T^4$

From above equation, necessary property values can be calculated as follows for temperature ranges of 273 to 673 K

ASTM A-135

Property	Thermal conductivity
A	120.5474121
B	0.699429378
C	$2.677481*10^{-3}$
D	$-5.41642*10^{-6}$
E	4.97972810^{-9}
F	$-1.861828*10^{-12}$

Table.4: Data Constant for Property

Property = $A + B \times T + C \times T^2 + D \times T^3 + E \times T^4 + F \times T^5$

From above equation, necessary property values can be calculated as follows for temperature ranges of 294 to 672 K.

2) Fluid Details

After the conduction, heat is passed inside the fluid and it is heated due to convective heat transfer and for that condition, fluid should fulfil the following properties with properties mentioned for the ideal thermal fluid which is as follows:

- Fluid Name: Shell Heat Transfer Oil S2X
- Previous Name: Shell Thermia C
- Manufacturer: Shell Lubricants

Typical fluid properties are as follows:

Properties	Shell heat transfer oil S2X
Density	865
Flash point	260
Pour point	-6
Water content	<0.1
Viscosity index	96

Table.5: Typical fluid properties

B. Design data of Helical Coil Convective type heat exchanger in Thermopac

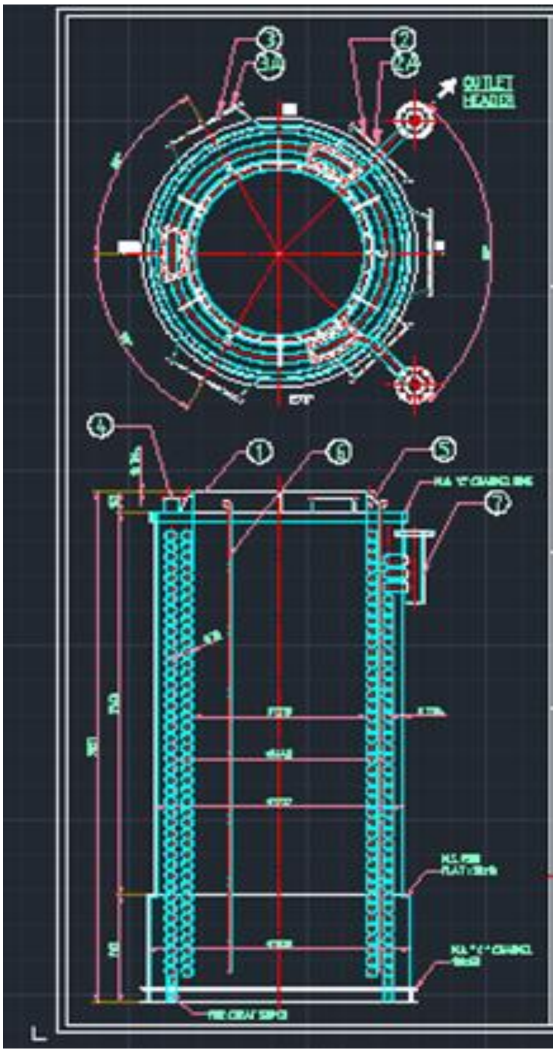
Particulars	HIL-1200 U-VTA
Heat Load	12,00,000
Design code for film temp calculation	DIN 4754
Design Temperature	300
Design Pressure	10
Temp rise across thermic fluid heater	30
Pressure Drop across thermic fluid heater	2
Furnace Draft type	Balanced
Type of installation	Outdoor with covered shed
FUEL CONSUMPTION & EFFICEINCY	
Type of Fuel	Coal/Wood/briquette
Consumption at full load of fuel	
Coal (GCV - 4000 Kcal/kg)	405
Wood (GCV - 3000 Kcal/kg)	556 4.8
Briquettes (GCV - 3800 Kcal/kg)	426
Efficiency of fuel	74 $\pm$ 2

Thermic fluid heat exchangers (Convective coils) features	
Total effective Heat transfer area	120 M^2
Oil hold up	1490 liters
Size Of Convective heat exchanger	63.5/3.66
MOC of jacket shall of convective heat exchanger	IS 2062 GR A/B

Table.6: Specification of Heat exchanger

1) 2D Design of helical coil convective type heat exchanger in thermopac

The following design is done under AUTOCAD which shows the front, rear view and top view of heat exchanger and the other is the assembly of part of the thermopac heat exchanger.



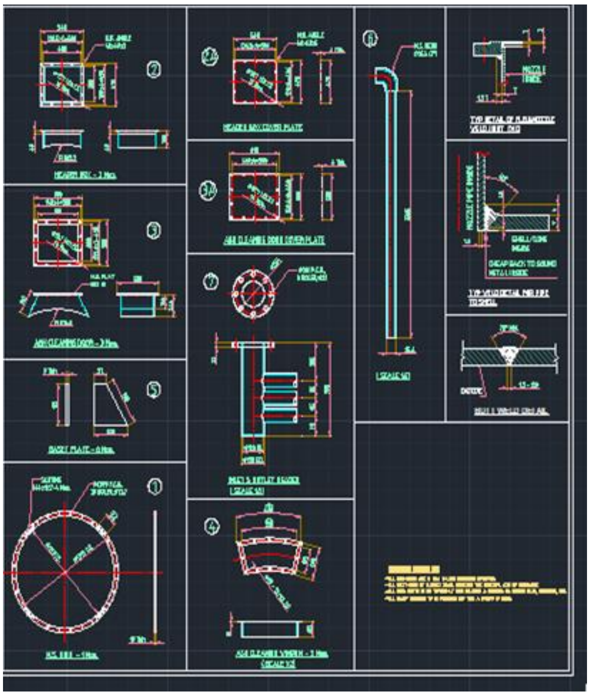


Fig.2 Helical coil convective type Heat exchanger

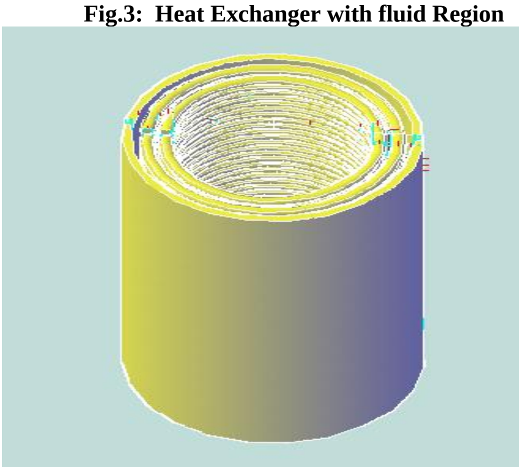
III. CFD

Computational fluid dynamics (CFD) uses different numerical methods and a number of computerized algorithms in order to solve and analysed problem that involve the flow of the fluid. CFD is the field of solving complex non-linear differential equation governing fluid flow using computer

A. Geometry and Model

Radiant heat exchanger is built in two phases of AutoCAD and ANSYS workbench design module.

Fig.3: Heat Exchanger with fluid Region



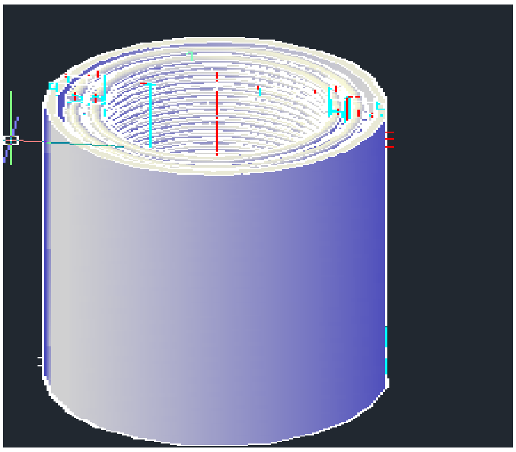


Fig.4: Heat Exchanger with fluid and flue Gases Region

B. Mesh

Initially, a relatively coarser mesh is generated. This mesh contained mixed shells having both triangular and quadrilateral faces at the boundaries. Later on, a fine mesh is generated. For this fine mesh, the edges and regions of high temperature and pressure gradients are finely meshed.

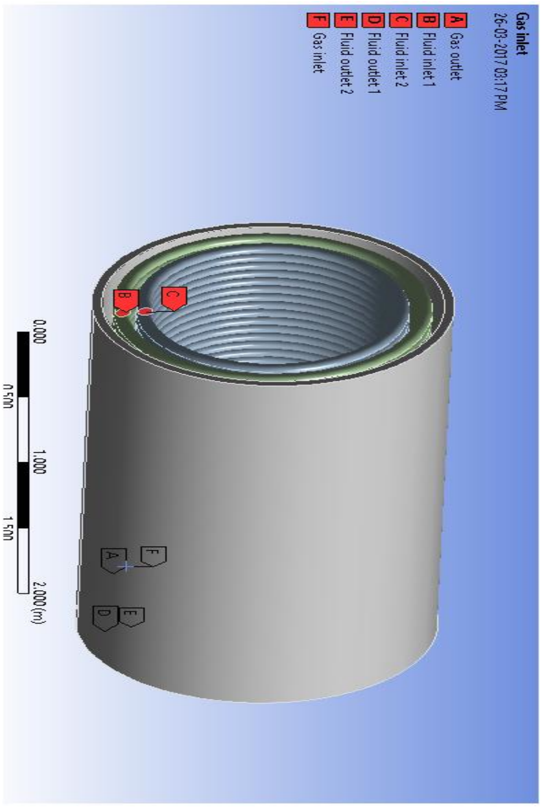


Fig.5: Named section of the geometry

C. Boundary conditions

Boundary conditions are used according to the need of the model. There are different five zones like flue gases inlet, flue gases outlet, fluid inlet, fluid outlet and wall outer. In which different values of different parameters like inlet temperature, emissivity, mass flow rate, velocity etc. have to be defined. Velocity of fluid is taken as 6.714 m/s and mass flow rate of flue gases is taken as 1.324 kg/s. Different values of different parameters are given in Table

Zone	Type	Inlet temperature (k)	Internal emissivity
Flue gases inlet	Mass flow rate	1140	0.6
Flue gases outlet	Pressure outlet	-	0.6
Fluid inlet	Velocity inlet	225	0.6
Fluid outlet	Pressure outlet	-	0.6

Table.7: Flue gases and fluid boundary conditions

IV. RESULTS AND DISCUSSION

The analysis on the ANSYS 15.0, results are obtained in the form of the numerical data and the various types of contours heat exchanger data from it and all the detailed results are discussed below

Mass flow rate and Total heat Transfer rate

The mass flow rate and total heat transfer rate for various conditions given in Table

(kg/s)	Fluid Fixed Property	Fluid Variable Property	Fluid Fixed Property	Fluid Variable Property
Fluid Inlet	11.8966	10.710684	11.89662	10.710684
Fluid Outlet	-11.6733	10.799312	11.80344	9.350066
Flue gas inlet	1.324	1.324	1.324	1.324
Flue Gases Outlet	-1.19039	-0.89958	-1.253240	-1.2936992

Table.8: Mass flow rate

Total heat transfer rate(w)	BS3059		ASTM A-135	
	Fluid fixed property	Fluid variable property	Fluid Fixed property	Fluid variable property
Fluid inlet	2697325.9	2734787	2697325.9	2734819.9
Fluid outlet	-3944798	3697056	3953362.9	-3710175
Net	-1347472	962269.46	-1356037	-975355.5
Wall	1140136.8	865037.23	1140224.7	1270089.9

Table. 9: Total heat transfer rate

Temp (K)	BS3059		ASTM A-135	
	Fluid fixed property	Fluid Variable property	Fluid fixed property	Fluid variable property
Fluid inlet	405	405	405	405
Fluid outlet	452.231	439.034	447.047	448.058

Table. 10: Temperature data for various conditions

Vectors of static temperature

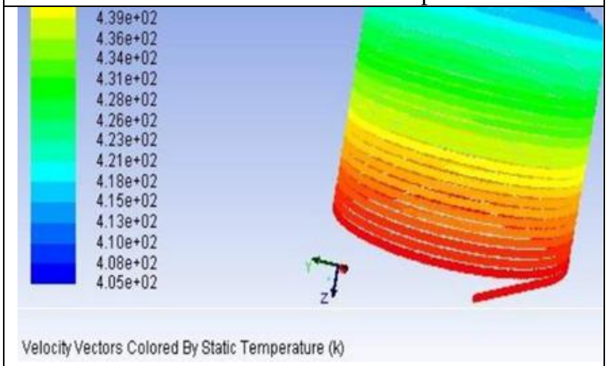


Fig.6: Vectors of fluid Static Temperature in BS 3059

Vectors of static temperature

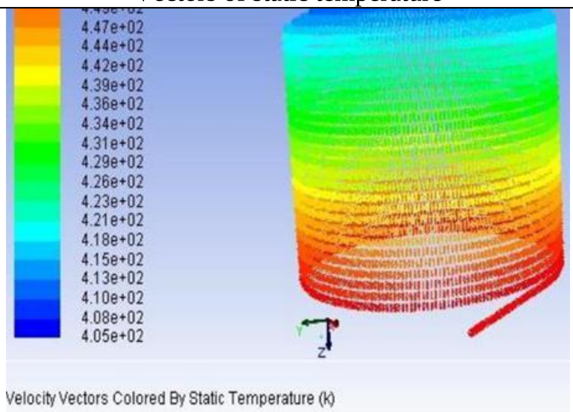


Fig.7:Vectors of fluid Static Temperature in ASTM A-135

V. CONCLUSION

From the above experiment, we have concluded a list of conclusions by altering the conventional material to the new one that is ASTM A135. From the analysis we came to know that the rate of heat transfer of ASTM A135 is slightly better than the conventional material that Is BS309, although specific heat of ASTM A135 is lesser than the BS3059. Thus amount of heat required to raise temperature by one Celsius, Is Less for ASTM A135. Additional To That Fluid outlet Temperature of BS3059 is higher than compared with the ASTM A135 Which didn't affect the working condition of thermopac. The life of Helical Coil made with ASTM A135 is much more than the BS3059 because carbon percentage and manganese percentage are higher which increases the strength and fouling resistance of the coil.

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