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Thermal Effect Analysis of Hot flow Manifold Made for Industrial Automated Washing Machine

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Abstract : *Automated Manifold acting in component processing machine is developed with thermal effect assessment. Manifold to perform transfer of fluid and air through optimized inlet piping with pneumatically sliding whole assembly. Vertical and horizontal mounting feasibility for this assembly gives perfect solution to make transfer of fluid in any position. Non reachable geometrical surfaces and complex shapes are to be covered for washing and drying which are already with bur, oil and dirt. This manifold is to be installed in SPM washing machine. Heated air and heated fluid intake gives perfect required supply through output temperature in medium to perform cycle operations in SPM. Considered output temp of medium is at least 45°C. Manifold sliding design parameters are developed with considering all engineering terms. Manifold with optimized thermal effective solution to achieve minimum 45 ° C. Flow Analysis is performed with Rate of heat transfer through this dedicated manifold and heat fluxes on manifold body is validated in this work.*
Keywords: *Cylinder Block, Manifold, SPM (Special purpose Machine), Thermal analysis.*

I. Introduction

After performing machine operations on any component or for just cleaning purpose, the components have to be washed. Just after washing and before proceeding component to assembly level, it should be dried and free from water on the surface. But if they have some complex cavities (like oil galleries in Cylinder Block) it is not easy to dry or wash these kinds of complex profile areas. For this, a system of nozzle is used which is responsible for washing and drying such complex profile cavities within components. And these portion are processed with the help of automated manifold, Manifold are designed generally in pipe structures and bends of pipes welded, in this research the manifold is considered with sliding assembly. In assembly pipe is also sliding to reach the nozzles till object.

II. Automatic Washing Machine Specification

An automatic component washing machine is shown in the below images. This machine is a special purpose machine which is used to wash and dry various components.

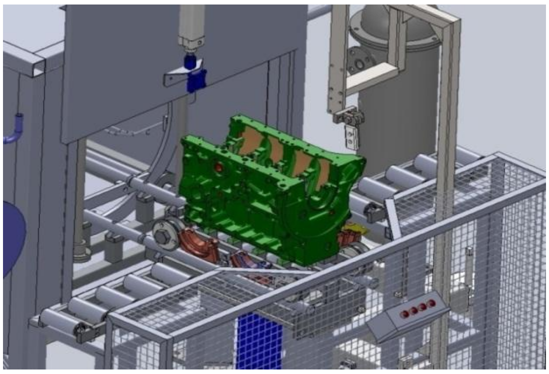


Figure 1: Component entering inside machine cabinet

1.1 Machine Specifications:-
Below table gives the specifications of automatic washing machine.

Utilities Required

Consumption in Machine		
1	Clean Tank	300 litters water with (3-5 % washing chemical)
2	Dirty Tank	550 litters water with (3-5 % washing chemical)
3	Compressed Air	90 CFM @ 4.0BAR
4	Power	40KW , 3PH
5	Compact band filter paper	600mm width paper, 20 Micron
6	Filter Bag	7”×20” filter bag, 10 Micron

Processes Parameters

Sr No	Process Parameter	Required Value	Checking Method
1	Spray Line Pressure	12-16 Bar	On Respective pressure guages
2	Transfer Line Pressure	0.5 – 2Bar	On Respective pressure guages
3	Air Pressure	4 – 4.5Bar	On Respective pressure guages
4	Clean tank Temp	55-65˚C	On Respective TIC
5	Dirty tank Temp	55-65˚C	On Respective TIC
6	Clean Tank water level	In green zone	On Respective TIC
7	Dirty Tank water level	In green Zone	On Respective TIC

III. Objective Of The Reserch

1.2 To Find out Solution to Maintain Temperature at the Outlet of the Manifold, so as to wash and dry the Component.
1.3 To Find out Effective Thermal Solution To Achieve Minimum 45˚C
1.4 To Optimize the Design of Manifold to Achieve Millipore value in Washing Machine.

IV. Implementation

In this chapter most of the technical aspects of the parts and materials used in this thesis, and the basic settings used on the simulations will be described. Firstly, a review on the Finite Element Method (FEM) will be performed so that the process followed in every simulation can be explained.

1.4.1 Working on Flow With FEM
1.4.2 Creation of 3D model: Preparation of the model before taking it into FEM software such as elimination of bad geometry, simplification of unnecessary parts and improvement of contact regions
1.4.3 Basic Inputs in ANSYS: This information allow the model to work properly during simulation and will define the behavior of the parts during the analysis
1.4.4 FEM Inputs: These parameters control the computational time and the accuracy of results in the simulation. A special analysis of factors is performed in order to define them.
1.4.5 Simulation is carried out by software's.

1.5 Transient Thermal Analysis
A transient thermal analysis follows basically the same procedures as a steady-state thermal analysis. The main difference is that most applied loads in a transient analysis are functions of time.
1.6 Task in thermal Analysis
The procedure for performing thermal analysis involves building of model, applying loads and then reviewing results.

V. Methodology

1.7 To Design Conceptual Model
1.8 Proper Arrangements of Inlet and Outlet
1.9 Minimum Surface Area to Avoid Heat Losses
1.10 Effect of Medium Temperature on Manifold Body
1.11 Application Feasibility Checking
1.12 Effective heating medium supply calculations
1.13 Validation on Ansys , thermal fluxes simulation

VI. Designed Manifold Structure And Parts

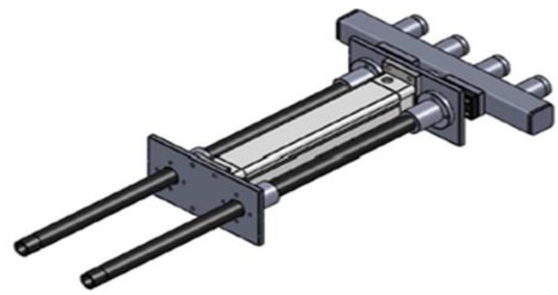


Fig 2: Pipe manifold with sliding assembly

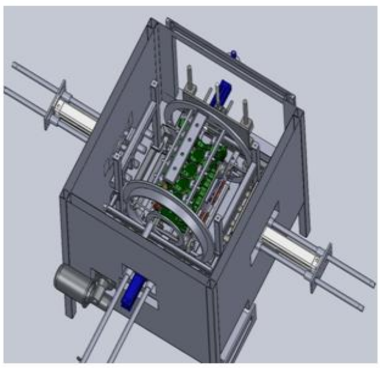


Fig 3: Installed manifold sliding assembly

VII. Working With ANSYS To Analyze Thermal Phenomenon

A thermal analysis calculates the temperature distribution and related thermal quantities in a systemor component. Typical thermal quantities of interest are:

1.14The temperature distributions
1.15The amount of heat lost or gained
1.16Thermal Gradients
1.17Thermal Fluxes

7.1.1 How ANSYS Treats Thermal Modelling:-

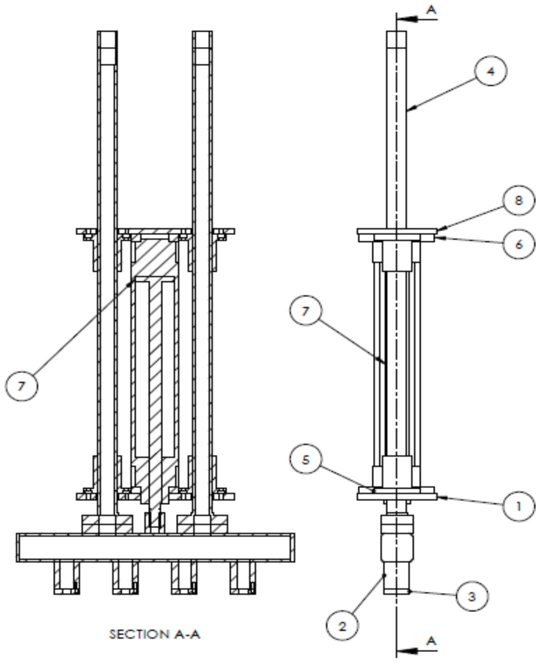
Only the ANSYS Multi-physics, ANSYS Mechanical, ANSYS Professional, and ANSYS FLOTRAN program support thermal analyses. The basis for thermal analysis in ANSYS is a heat balance equation obtained from the principle of conservation of energy. (For details, consult the Mechanical APDL Theory Reference.) The finite element solution we perform via Mechanical APDL calculates nodal temperatures, then uses the nodal temperatures to obtain other thermal quantities. The ANSYS program handles all three primary modes of heat transfer:

- Conduction,
- Convection,
- Radiation.

7.1.2 Tasks in Thermal Analysis:-

- Build the model.
- Apply loads and obtain the solution.
- Review the results.

VIII. Details Of Manifold Assembly



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	I20 MF 00 004	CABINET MOUNTING	1
2	I20 MF 00 001	MANIFOLD ASSEMBLY	1
3	I20 MF 00 002	NOZZLE	4
4	I20 MF 00 003	MANIFOLD HOLLOW PIPE /GUIDE ROD	2
5	LMF30	CYLINDER MOUNT	4
6	174 379 FNC-63	FNC - 63	2
7	163400 DNC-63-300-PPV-A	PN CYLINDER	1
8	I20 MF 00 005	MOUNT PLATE	1

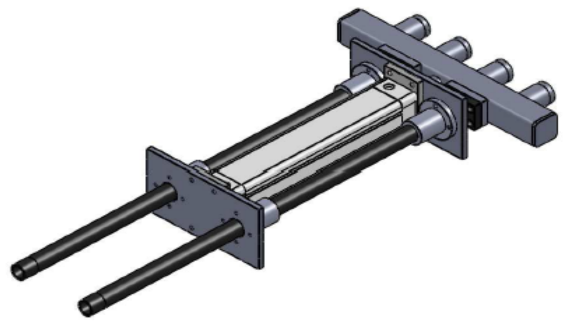


Fig 4: Details of proposed assembly

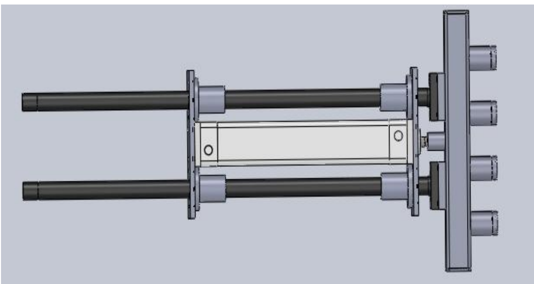


Fig 5: Closed inactive position

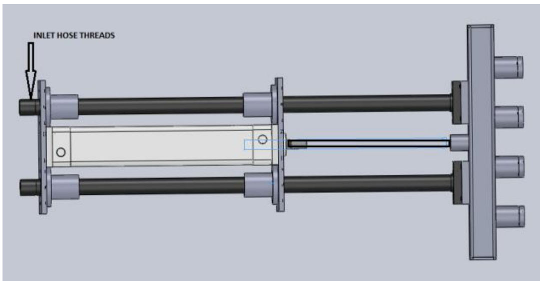


Fig 6: Open active position

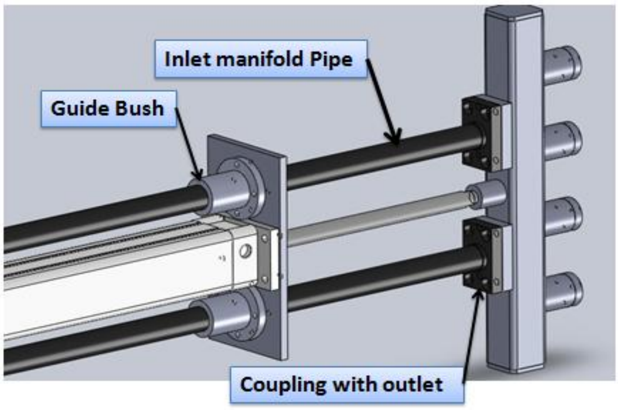


Fig 7: Inlet Pipe connection

IX. Analytical Assessment Of Manifold Component

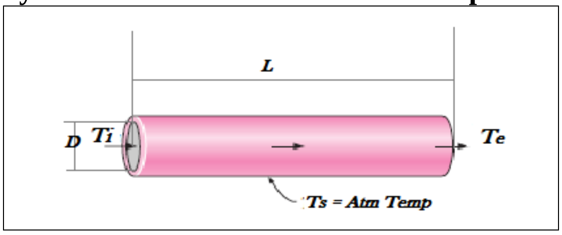


Fig 8: Analytical Design of Manifold

We have,
Ti = Inlet Temperature = 75^0C
L = Length of manifold = 1200mm
D = Inner Dia of manifold = 27.5mm
Material of Exhaust manifold is Stainless steel 304
The temperature at the exit of the manifold is given by)
$T_e = T_s - [(T_s - T_i) \exp(-hA_s /mC_p)]$..........................(1)
Where,
T_s = Surrounding Temperature (atmospheric Temp) = Constant = 30^0C (Assumed)
h = Average heat transfer Coefficient (W/m^2)
m = Mass flow rate (kg/s)
C_p = Specific heat of water (kJ/kg)
A_s = Surface Area = πDL (m^2)
The fluid entering in to the manifold at 200 lit/min
m = 3.4 kg/s.......................... (as 1 lit/min = 0.017 kg/s)
$A_s = \pi DL$
$= 0.104\ m^2$
Now,
We have, $Q = mC\Delta T$
Where $\Delta T = T_i - Ts = 75 - 30 = 45^0C$
C = 40187 kJ/kg
Hence,
Q = 640.61 kJ/s
Also we have,
$Q = hA_s(T_i - T_s)$
Therefore,
$h = 136.88\ W/m^2$
Putting all these values in equation (i) for T_e, We get,
$T_e = 46.66^0C \sim 47^0C$
From the above Calculation We get the temperature at exit of the manifold is 47^0C.
And the minimum required fluid temperature at the outlet side of the manifold is around $40^0C - 45^0C$.
Now, the rate of heat transfer through the manifold,
$Q = mC_p\Delta T$
$Q = 3.4 \times 4.187 \times (75 - 47)$
Q = 398.6 kJ/s

Thermal Stresses
The thermal stresses acting on the manifold can be calculated by
σ = ϵ E
= ΔL E/L
Where,
ΔL = Amount of thermal expansion in length
= α ΔT L
α = thermal expansion coefficient
= 16 x 10^{-6} / K
ΔL = 0.0005m,
E = modulus of elasticity = 190 GPa
Hence thermal stresses
σ = 79.17 MPa
Maximum uni-axial thermal stresses is given by,
E = 190000MPa
α= 16 x10^{-6} / K
Maximum uni-axial thermal stresses is given by,

$$\sigma_x = \frac{E\alpha}{(1-\vartheta)}(T_i - T_e$$

E = 190 GPa

ϑ = Poissions ratio = 0.3

α= 16 x10-6 / K
Hence,

$$\boldsymbol{\sigma_x = 115.80\ MPa}$$

1.18Heat Losses in conduction and convections

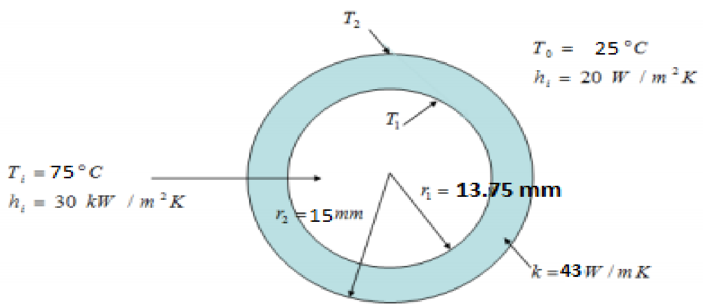


Fig 9: Cross section of manifold for analysis

$$Q = 2\pi r_1 L h_i (T_i - T_1)$$

Hence,

$$(T_i - T_1) = \frac{Q}{2\pi r_1 l} \text{--------- (1)}$$

Similarly,5

$$Q = 2\pi r_2 L h_o (T_2 - T_o)$$

Hence,

$$(T_2 - T_o) = \frac{Q}{2\pi r_2 L h_o} \text{--------- (2)}$$

Also

$$Q = \frac{2\pi L k (T_1 - T_2)}{\ln(r_2/r_1)}$$

Hence,

$$(T_2 - T_1) = \frac{Q}{2\pi LK/\ln(r_1/r_2)} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Adding three equations on right column eliminates the wall temperatures gives,

$$Q = \frac{2\pi L(T_i - T_o)}{\frac{1}{h_i r_1} + \frac{\ln(r_2/r_1)}{k} + \frac{1}{h_0 r_2}}$$

Hence heat loss per unit length

$$\frac{Q}{L} = \frac{2\pi(T_i - T_o)}{\frac{1}{h_i r_1} + \frac{\ln(r_2/r_1)}{k} + \frac{1}{h_0 r_2}}$$

$$\frac{Q}{L} = \frac{2\pi(75 - 25)}{\frac{1}{30000\ x\ 0.01375} + \frac{\ln(0.015/0.01375)}{43} + \frac{1}{20\ x\ 0.015}}$$

= 94.123 W/m

Hence heat loss per unit length is 94.123 W/m.
Hence,
Material of manifold – Stainless steel 304
Length – 1200mm
Diameter (Inner) – 27.5mm
Thermal expansion coefficient – 16 x10-6/K
Initial temperature – 750C
Final Temperature – 470C
Maximum Uni-axial thermal stresses – 115.80 MPa
Maximum thermal stresses acting on manifold – 79.17 MPa
Rate of heat transfer = 398.6 kJ/s
Heat loss per unit length = 94.123 W/m.

X. Steady State Thermal Analysis Of Supply Pipe

Following is the analysis on supply pipe and manifold guide.

Details of "Analysis Settings"

Step Controls	
Number Of Steps	4.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Radiosity Controls	
Flux Convergence	1.e-004
Maximum Iteration	1000.
Solver Tolerance	0.1
Over Relaxation	0.1
Hemicube Resolution	10.
Nonlinear Controls	
Heat Convergence	On
--Value	ANSYS Calculated
--Tolerance	0.5%
--Minimum Reference	1.e-006 W
Temperature Convergence	Program Controlled
Line Search	Program Controlled
Output Controls	
Calculate Thermal Flux	Yes
Calculate Results At	Equally Spaced Time Points
Number Of Time Points	1.

Fig 10. Analysis Setting

Details of "Mesh"

Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Si...	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge L...	1.57080 mm
Inflation	
Use Automatic Te...	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorit...	Pre
View Advanced ...	No
Advanced	
Shape Checking	Standard Mechanical
Element Midside ...	Program Controlled
Straight Sided El...	No
Number of Retries	Default (4)

Fig 11. Meshing Details

10.1 Material Taken Stainless Steel :-

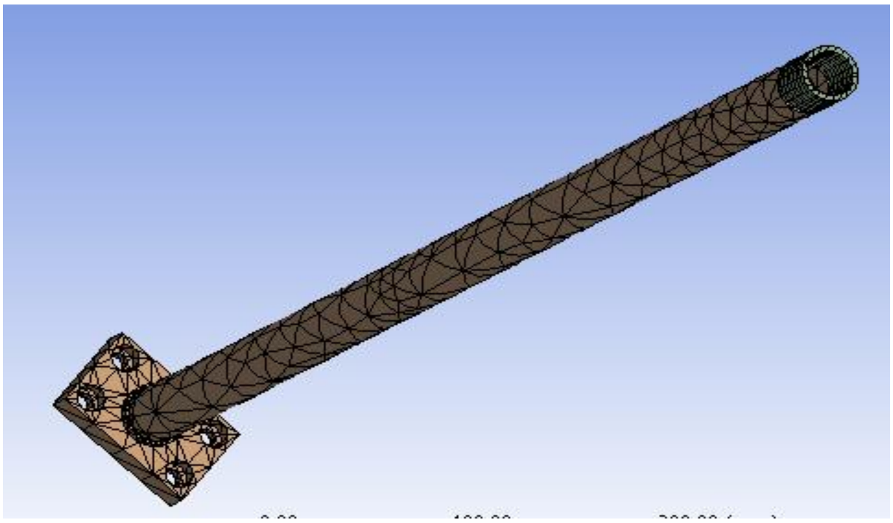


Fig 12. Analysis on Supply Pipe and manifold guide

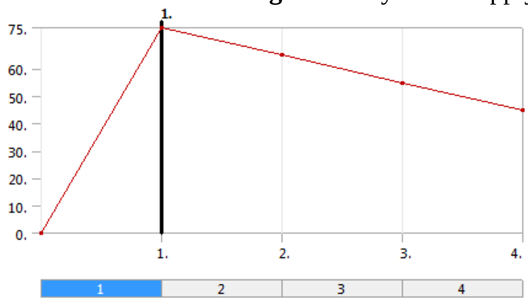


Fig 13 . Input Temprature Graph Against Stages

	Steps	Time [s]	Temperature [°C]
1	1	0.	0.
2	1	1.	75.
3	2	2.	65.
4	3	3.	55.
5	4	4.	45.
*			

Fig 14 . Temprature Distribution

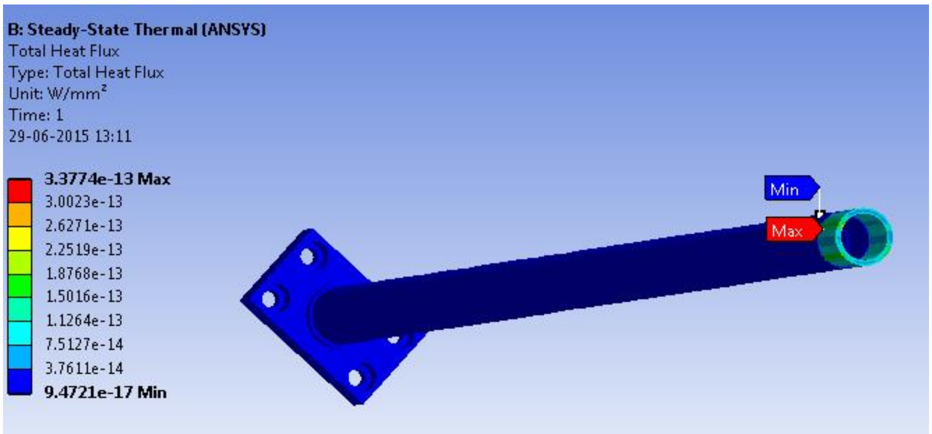


Fig 15 . Stedy State Total Heat Flux Analysis in ANSYS

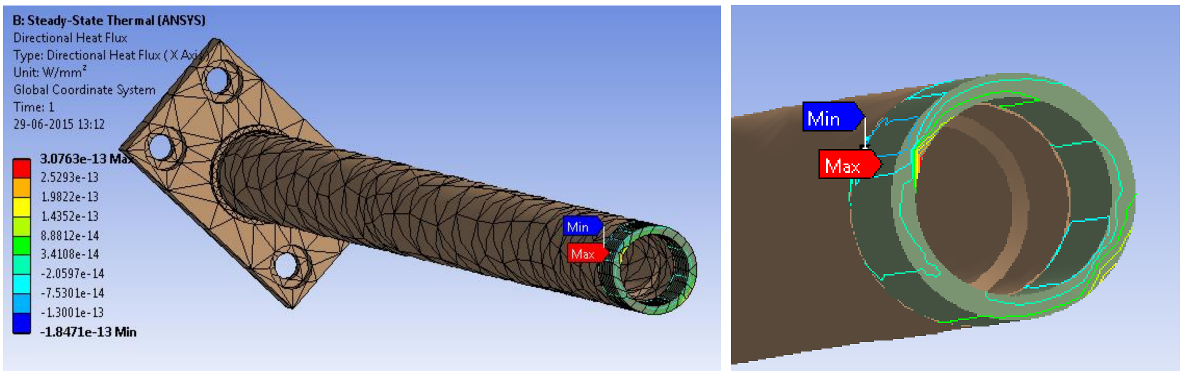


Fig. 16 Steady State Directional Heat Flux Analysis in ANSYS

10.2 Material Taken is Alluminium Alloy :-
So as to compare results we have taken Alluminium alloy as a material for supply pipes.

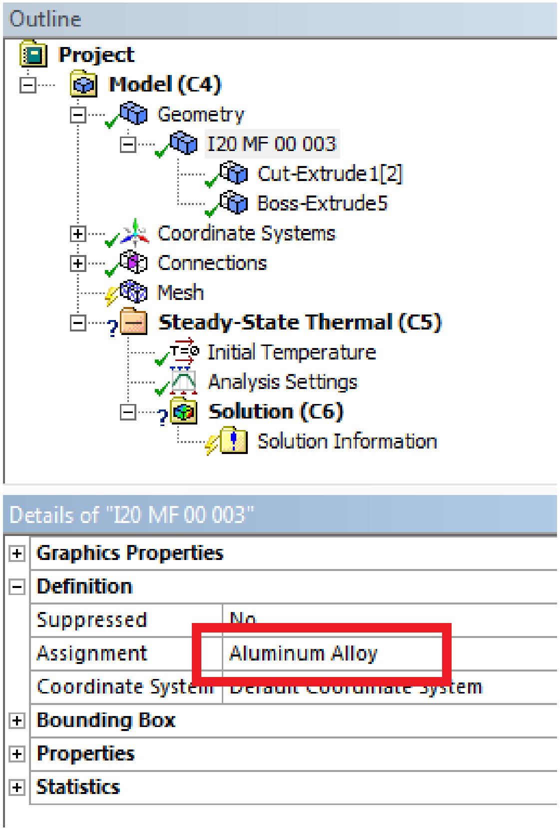
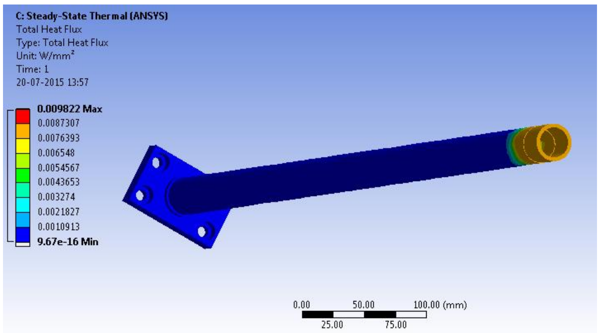


Fig 17. Analysis Inputs



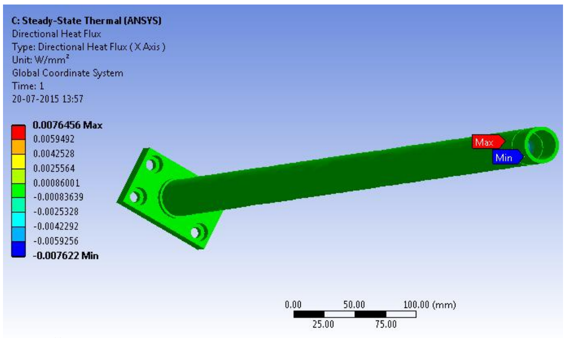
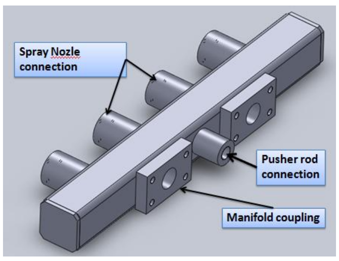
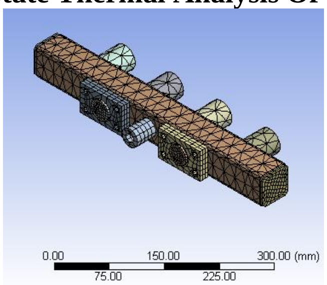


Fig 18 . Stedy State Total Heat Flux Analysis in ANSYS **Fig 19**. Steady State Directional Heat Flux Analysis in ANSYS

XI. Steady State Thermal Analysis Of Distributor In Manifold





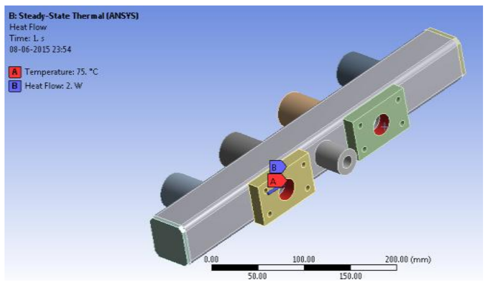


Fig 20 . Extension distributor **Fig 21** . Steady-State Thermal Analysis **Fig 22** . Boundry Condition applied

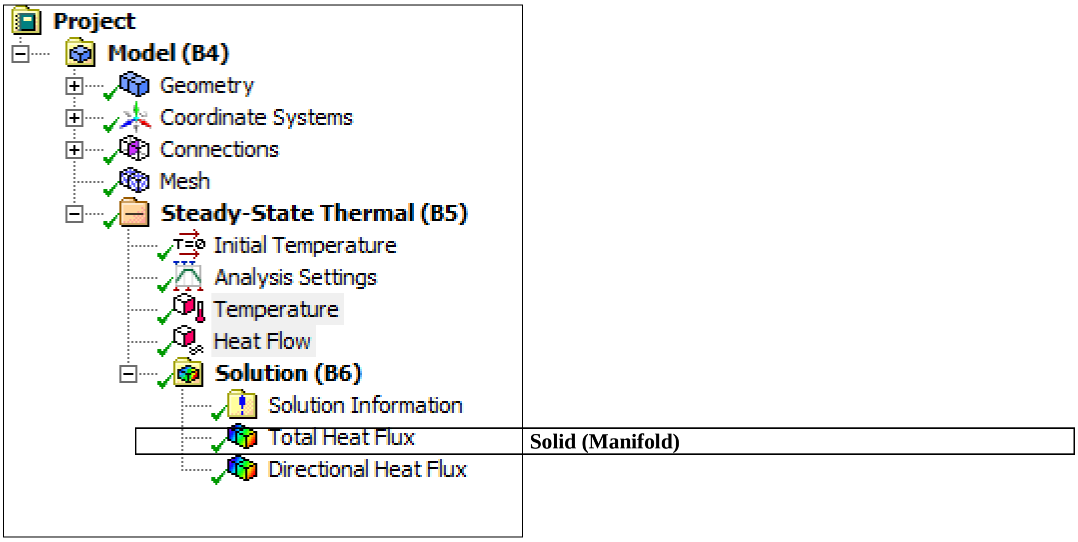


Fig 23 . Parameter Applied

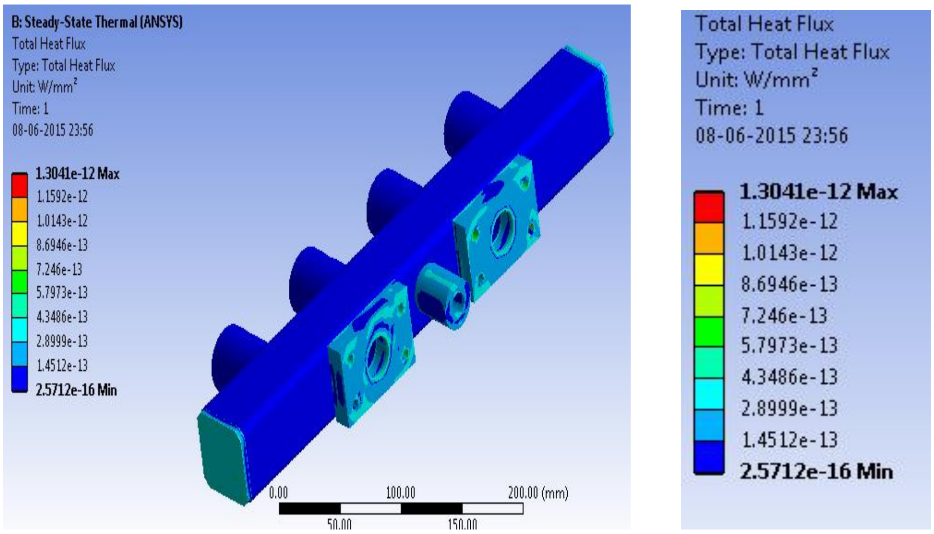


Fig 24 . Total Heat Flux in Distributor

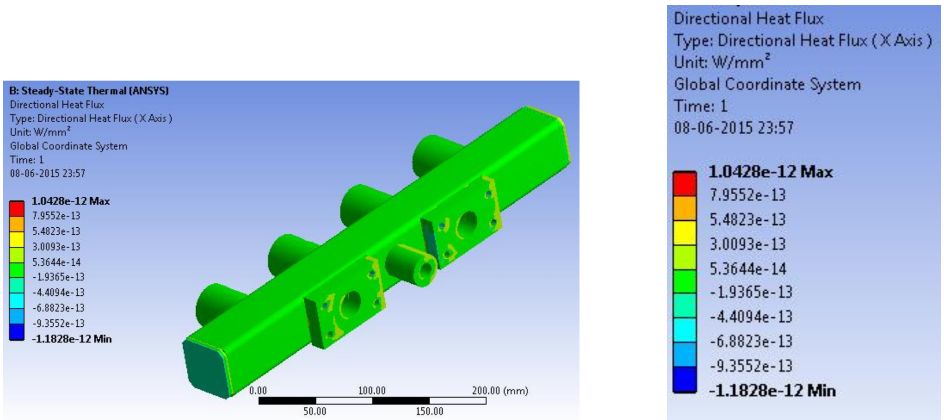


Fig 25 . Directional Heat Flux in Distributor

XII. Results

The results of this study about thermal stresses in thick-walled pipes (manifold) subjected to fully developed internal flows are given and analysed in this section. The properties of the solids (manifolds) and fluid used in this study are presented in following table

Material : - Steel	
Thermal conductivity (ks)	43 W/m.K
Thermal expansion coefficient (a)	16 x 10^{-6} / K
Modulus of elasticity (E)	190 GPa
Poisson's ratio (v)	0.3
Flow	
Flow fluid : - Water	
Thermal conductivity (ks)	0.597 W/mK
Density (p)	1000 kg/m^3
Specific heat(Cp)	4181.8 J/KgK
Kinematic viscosity *{jj/p)*	1.006 xl0^{-6} m^2 / s
Manifold Specifications	
Material of manifold	Stainless steel 304
Length	1200mm
Diameter (Inner)	27.5mm
Thermal expansion coefficient	16 x10^{-6}/K
Initial temperature	75^0C
Final Temperature	47^0C
Maximum Uni-axial thermal stresses	**115.80 MPa**
Maximum thermal stresses acting on manifold –	**79.17 MPa**
Rate of heat transfer	**398.6 kJ/s**
Heat loss	**94.123 W/m**

XIII. Conclusion

From the study of the result mentioned as above. After performing the calculation the output temperature is 45 °C, which is near to the value mentioned output temperature of requirement for washing purpose. This type of Manifold can be installed in industrial washing machine for maintaining temperature difference between input temperature and output temperature

Acknowledgements

I express my deep sense of gratitude to Dr Rachayya.R.Arakerimath for his valuable guidance.

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