

**Thermal Effect Analysis of Hot flow Manifold Made for Industrial Automated
Washing Machine**Pooja .G Ekade¹, Dr. Rachayya.R.Arakerimath²

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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.

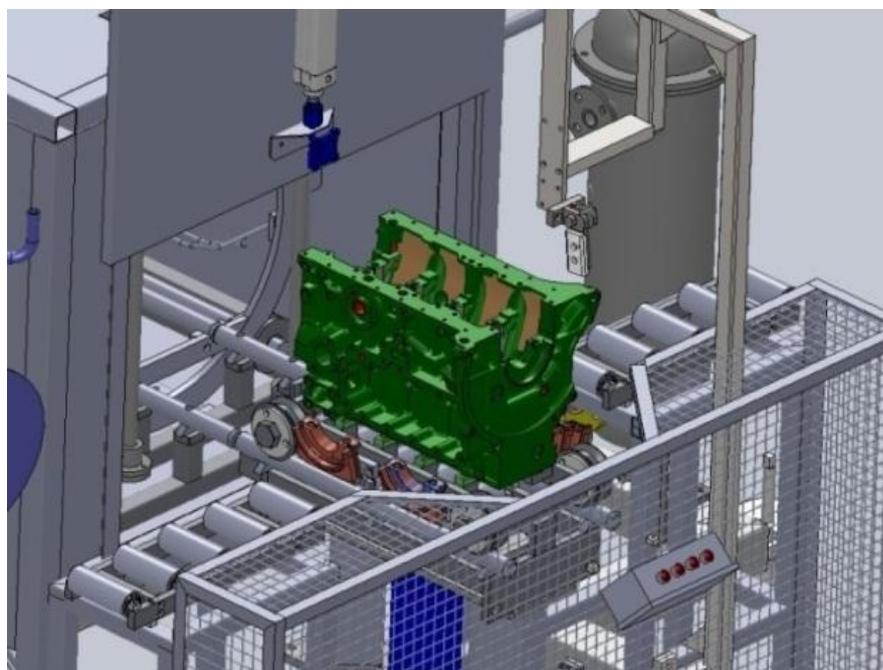


Figure 1: Component entering inside machine cabinet

A. Machine Specifications:-

Below table gives the specifications of automatic washing machine.

**Table 1: Utilities Required
Consumption in Machine**

Consumption in Machine		
1	Clean Tank	300 liters water with (3-5 % washing chemical)
2	Dirty Tank	550 liters 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

Table 2: Processes Parameter

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 RESEARCH

- A. To Find out Solution to Maintain Temperature at the Outlet of the Manifold, so as to wash and dry the component
- B. To Find out Effective Thermal Solution To Achieve Minimum 45°C
- C. 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.

A. Working on Flow With FEM

- 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
- 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
- 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. Simulation is carried out by software’s

B. 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.

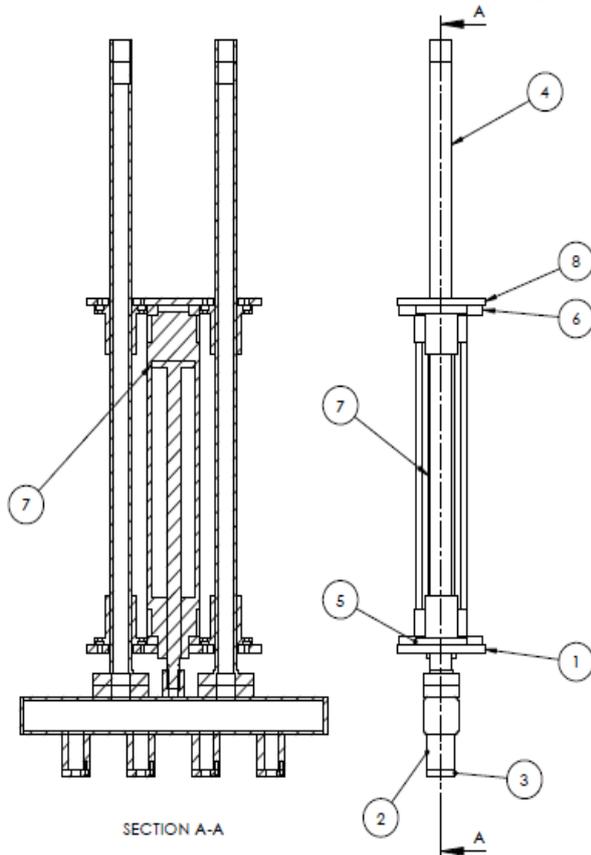
C. Task in Thermal Analysis

The procedure for performing thermal analysis involves building of model, applying loads and then reviewing results.

V. METHODOLOGY

- A. To Design Conceptual Model
- B. Proper Arrangements of Inlet and Outlet
- C. Minimum Surface Area to Avoid Heat Losses
- D. Effect of Medium Temperature on Manifold Body
- E. Application Feasibility Checking
- F. Effective heating medium supply calculations
- G. Validation on Ansys , thermal fluxes simulation

VI. 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

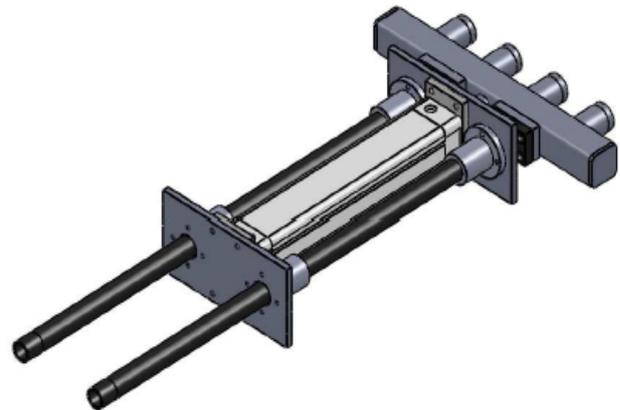


Figure 2: Details of proposed assembly

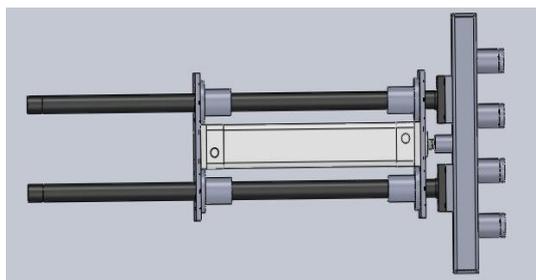


Figure 3: Closed inactive position

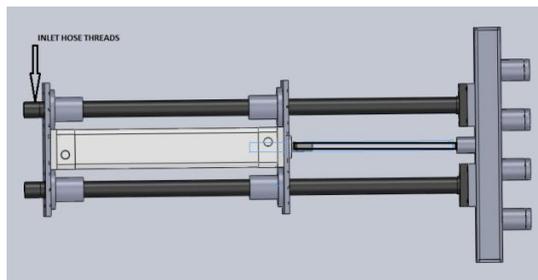


Figure 4: Open active position

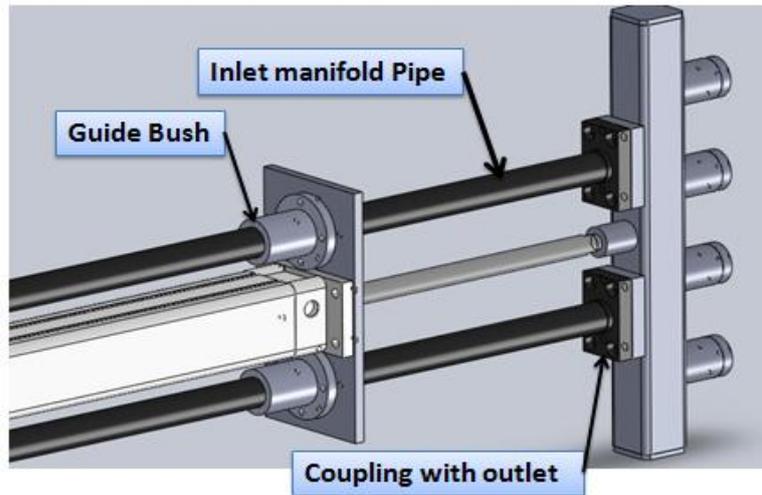


Figure 5: Inlet Pipe Connection

VII. ANALYTICAL ASSESSMENT OF MANIFOLD COMPONENT

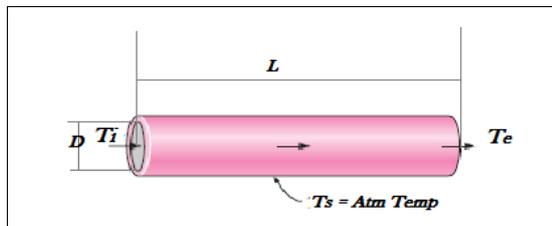


Figure 6: Analytical Design of Manifold

We have,

T_i = Inlet Temperature = 750C

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)

$$T_e = T_s - [(T_s - T_i) \exp(-hA_s / mC_p)] \dots \dots \dots (1)$$

Where,

T_s = Surrounding Temperature (atmospheric Temp) = Constant = 300C (Assumed)

h = Average heat transfer Coefficient (W/m²)

m = Mass flow rate (kg/s)

C_p = Specific heat of water (kJ/kg)

A_s = Surface Area = πDL (m²)

The fluid entering in to the manifold at 200 lit/min

$m = 3.4$ kg/s..... (as 1 lit/min = 0.017 kg/s)

$$A_s = \pi DL$$

$$= 0.104 \text{ m}^2$$

Now,

$$\text{We have, } Q = mC\Delta T$$

$$\text{Where } \Delta T = T_i - T_s = 75 - 30 = 450C$$

$$C = 40187 \text{ kJ/kg}$$

Hence,

$$Q = 640.61 \text{ kJ/s}$$

Also we have,

$$Q = hA_s(T_i - T_s)$$

Therefore,

$$h = 136.88 \text{ W/m}^2$$

Putting all these values in equation (i) for T_e , We get,

$$T_e = 46.660C \sim 470C$$

From the above Calculation We get the temperature at exit of the manifold is 47⁰C.

And the minimum required fluid temperature at the outlet side of the manifold is around 40⁰C – 45⁰C.

Now, the rate of heat transfer through the manifold,

$$Q = mCp\Delta T$$

$$Q = 3.4 \times 4.187 \times (75 - 47)$$

$$Q = 398.6 \text{ kJ/s}$$

Thermal Stresses

The thermal stresses acting on the manifold can be calculated by

$$\sigma = \epsilon E$$

$$= \Delta L E/L$$

Where,

$$\Delta L = \text{Amount of thermal expansion in length}$$

$$= \alpha \Delta T L$$

$$\alpha = \text{thermal expansion coefficient}$$

$$= 16 \times 10^{-6} / \text{K}$$

$$\Delta L = 0.0005\text{m,}$$

E = modulus of elasticity = 190 GPa

Hence thermal stresses

$$\sigma = 79.17 \text{ MPa}$$

Maximum uni-axial thermal stresses is given by,

E = 190000MPa

$\alpha = 16 \times 10^{-6} / \text{K}$

Maximum uni-axial thermal stresses is given by,

$$\sigma_x = \frac{E\alpha}{(1-\theta)} (T_i - T_e) \quad \theta = \text{Poissons ratio} = 0.3$$

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

A. Heat Losses in conduction and convections

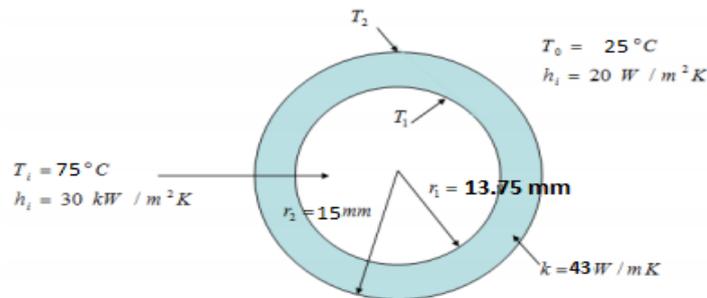


Figure 7: Cross section of manifold for analysis

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

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,

$$(T_2 - T_1) = \frac{Q}{2\pi L k / \ln(r_1/r_2)} \text{----- (3)}$$

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

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

Hence heat loss per unit length

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

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

$$= 94.123 \text{ W/m}$$

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 – $16 \times 10^{-6}/K$

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.

VIII. STEADY STATE THERMAL ANALYSIS OF SUPPLY PIPE

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.

Figure 8. 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)

Figure 9. Meshing Details

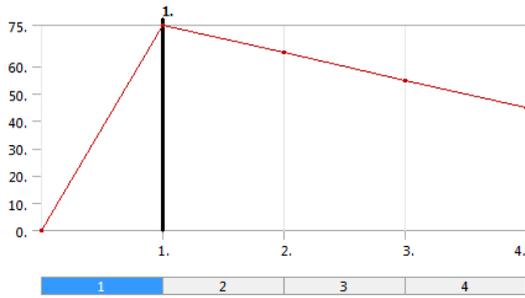


Figure 10 . Input Temperature Graph Against Stages

	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.
*			

Figure 11 . Temperature Distribution

A. Material Taken – Stainless Steel 304

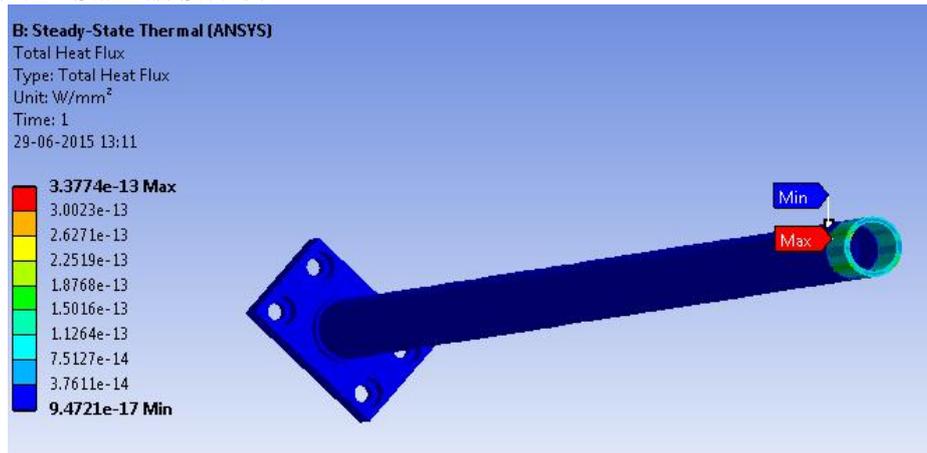


Figure 12 . Steady State Total Heat Flux Analysis in ANSYS

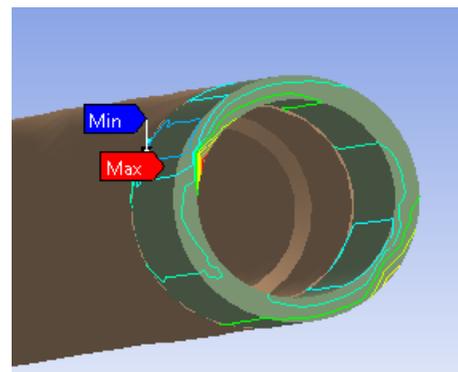
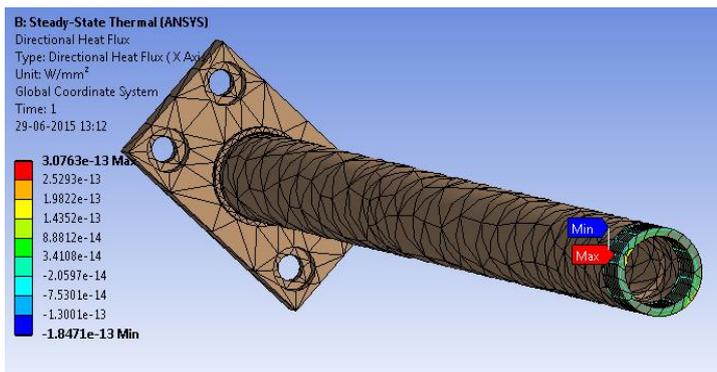


Figure. 13 Steady State Directional Heat Flux Analysis in ANSYS

B. Material Taken – Alluminium Alloy

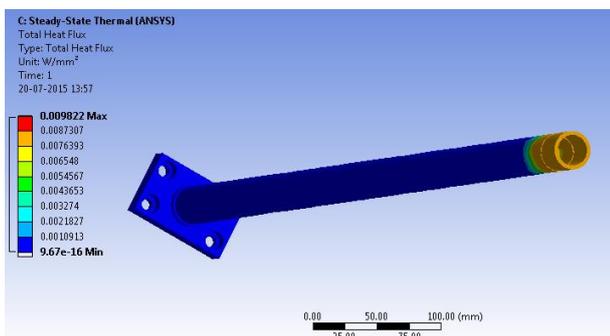


Figure 14 . Steady State Total Heat Flux Analysis in ANSYS

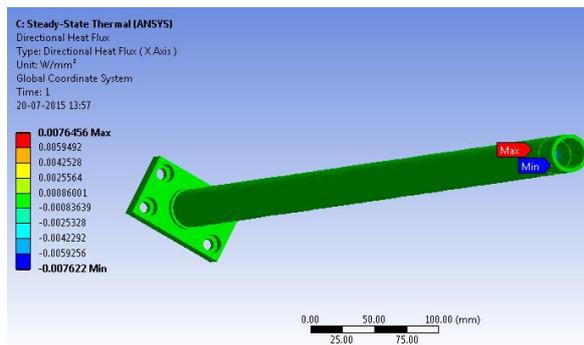


Figure 15. Steady State Directional Heat Flux Analysis

IX. STEADY STATE THERMAL ANALYSIS OF DISTRIBUTOR IN MANIFOLD

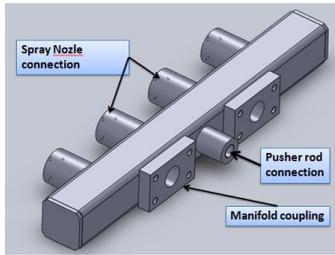


Figure 16 . Extension distributor

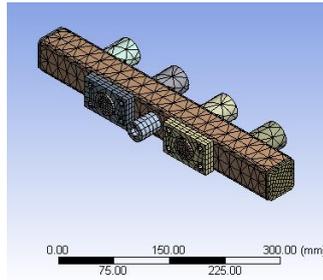


Figure 17 . Steady-State Thermal Analysis

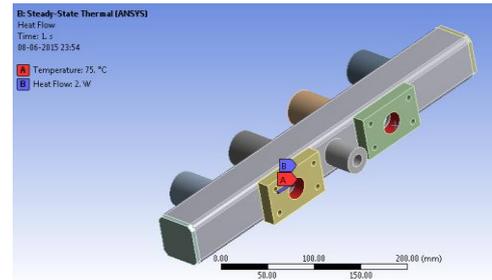


Figure 18 . Boundry Condition

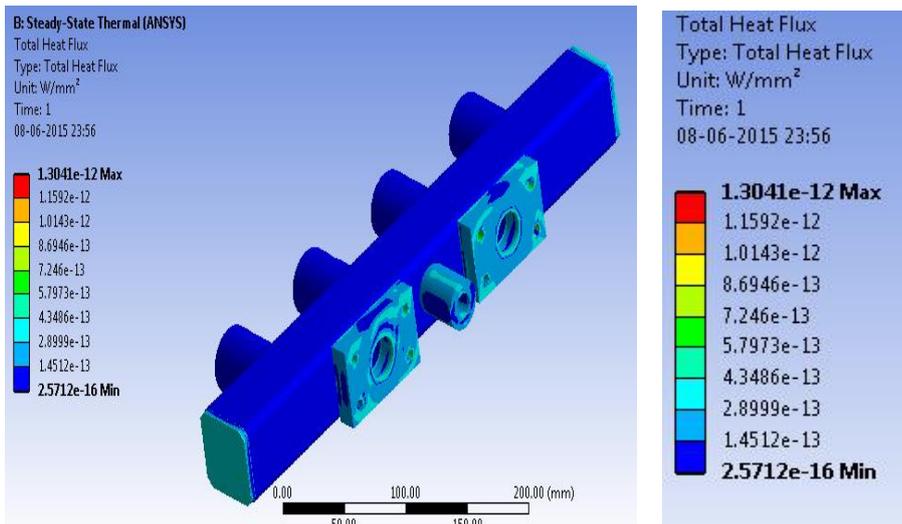


Figure 19 . Total Heat Flux in Distributor

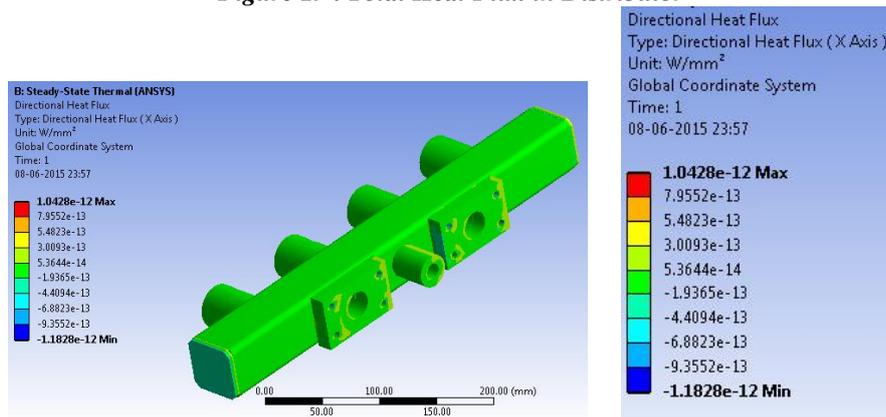


Figure 20 . Directional Heat Flux in Distributor

X. 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

Solid (Manifold)	
Material : - Steel	
Thermal conductivity (ks)	43 W/m.K
Thermal expansion coefficient (a)	$16 \times 10^{-6} / K$
Modulus of elasticity (E)	190 GPa
Poisson's ratio (ν)	0.3
Flow	
Flow fluid : - Water	
Thermal conductivity (ks)	0.597 W/mK
Density (ρ)	1000 kg/m ³
Specific heat(Cp)	4181.8 J/KgK
Kinematic viscosity (ν)	$1.006 \times 10^{-6} \text{ m}^2 / \text{s}$

Manifold Specifications	
Material of manifold	Stainless steel 304
Length	1200mm
Diameter (Inner)	27.5mm
Thermal expansion coefficient	$16 \times 10^{-6}/K$
Initial temperature	75 ⁰ C
Final Temperature	47 ⁰ C
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

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

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