2581-4575
International Journal For Recent Developments in Science & Technology
Crossref
A Peer Reviewed Research Journal

THERMAL ANALYSIS OF A NUCLEAR POWER PLANT'S HEATPIPE HEAT EXCHANGER USING CFD METHOD

D. Ajay Babu[1], D Sharath kumar[2],Dr. J. Krishna[3]

[1], Student, Department of Mechanical Engineering of RISE KRISHNA SAI PRAKASAM GROUP OF INSTITUTIONS Vallur, AP.

[2], Assistant Professor ,[3]Professor Department of Mechanical of EngineeringRISE KRISHNA SAI PRAKASAM GROUP OF INSTITUTIONS, Vallur, AP.

ABSTRACT

In a thermal electricity station, heat exchangers count on a pivotal component in transferring depth from the atomic reactor to the non-obligatory frameworks that create strength. These intensity exchangers are essential for transferring the nuclear energy delivered via the atomic splitting interplay into valuable systems, like steam, without allowing direct contact among radioactive liquids and non-radioactive frameworks. The reason for this study is the plan and Warm Analysis of intensity pipes and the primary intensity exchanger of the energy plant. The reactor's nuclear power is 5 MW and its intensity is moved to carbon dioxide as the functioning liquid in the intensity exchanger by way of 192 potassium warmness pipes. The Computational Liquid Elements (CFD) method is applied for Warm Investigation. Ansys workbench, that's an elite presentation and reliable tool, is also utilized for reenactment. In this gift situation, our results exhibit that these obstacles altogether have an effect on the exhibition of depth pipes. The evaluation indicates that the temperature and anxiety within the depth strains and depth exchanger are critical for the framework's exhibition. Utilizing the proper materials and breaking down the framework with ANSYS Workbench allows ensure the depth pipes move warmth efficiently. The material involved here for the investigation is Copper composite, Primary Steel, Aluminium Compound. Its Warm investigation utilizing ANSYS programming. The evaluation tests three substances: Copper Combination, Primary Steel, and aluminium Compound, which might be picked for his or her capacity to cope with excessive temperatures and direct intensity nicely out.

INTRODUCTION

INTRODUCTION OF NUCLEAR POWER PLANT HEAT EXCHANGER

In a thermal electricity station, warmth exchangers assume an essential element in transferring depth from the atomic reactor to theauxiliary frameworks that create strength. These depth exchangers are fundamental for moving the nuclear electricity introduced with the aid of the atomic splitting interaction into treasured systems, like steam, without permitting direct contact between radioactive drinks and non-radioactive frameworks.

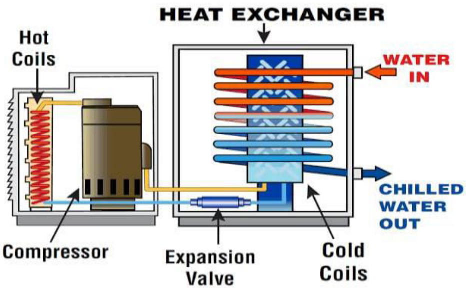


Fig 2.2: Heat Exchanger

Working Principle of Nuclear Power Plant Heat exchanger

The intensity comprised of atomic splitting is moved via the crucial coolant (normally water or gasoline), which guides through the reactor middle. This crucial coolant keeps the depth created by splitting and later on needs to transport that depth to the optional aspect, that may power a steam turbine. Heat exchangers are the important thing component that works with this trade.

Key Concepts & Formulas

1. Heat Transfer Rate (Q):

The rate at which heat is transferred in a heat exchanger is given by:

$Q=U \cdot A \cdot \Delta T$

Where:

- QQQ = Heat transfer rate (W or kW)
- UUU = Overall heat transfer coefficient ($W/m^2 \cdot K$)
- AAA = Heat transfer surface area (m^2)
- ΔT\Delta TΔT = Temperature difference between the two fluids (°C or K)

2. Log Mean Temperature Difference (LMTD):

The **temperature difference** between the hot and cold fluids varies along the length of the heat exchanger. The average temperature difference is given by the

Log Mean Temperature Difference (LMTD):

ΔTlm=ln(ΔT2ΔT1) (ΔT1−ΔT2)

Ln(ΔT1)ΔT2

ΔT1 = Temperature difference at one end of the heat exchanger.

LATERATURE REVIEW

Lakhi et al. (2023) A DPHE and a shell and cylinder warmth exchanger's time constants were researched. The goal of this look at has been to apprehend the highlights of the intensity exchangers in a temporary kingdom, specially where surprising varieties in channel speeds are considered. A version containing barriers of time deferral and time consistent became applied to direct this exploration. Thus, it is essential that the logical time period was determined utilising the energy balance situation. Besides, it appeared to be that the mathematical facts were authorised making use of an exploratory methodology, with the most extreme recorded inconsistency being below 10%.

Aicher and Kim (2023) the effect of counter circulates with in spout piece of a DPHE introduced upon that shell aspect wall had been investigated. The counter circulation with in spout section ended up having a significant effect on warmness circulate or strain decline. It turned into moreover resolved that once the intensity exchanger was little and the proportion of loose cross section areas became sufficiently low, the effect is greater recognizable. Analysts likewise exhibited trial relationships for looking ahead to the tempo of depth pass in tempestuous circulation.

METHODALOGY

DESIGN SPECIFICATIONS

S. No	Parameter	Value
1	Heat pipe vapour core diameter(mm)	137
2	Heat pipe wick thickness(mm)	20
3	Heat pipe wall thickness(mm)	20
4	Heat pipe vapour core length(mm)	137
5	Heat exchanger tube diameter(mm)	50
6	Heat exchanger tube length(mm)	558
7	Heat pipe diameter(mm)	177

Table 5.1: DESIGN SPECIFICATIONS

5.2. MATERIAL DATA

1. STEUCTURAL STEEL

TABLE 13
Structural Steel > Constants

Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m

2.Aluminium Alloy

TABLE 13
Aluminium Alloy > Constants

Density	2770 kg m^-3
Isotropic Secant Coefficient of Thermal Expansion	2.3e-005 C^-1
Specific Heat Constant Pressure	875 J kg^-1 C^-1

5. Boundary Conditions for CFD Simulation

Delta Liquid Temperature and Stream Rate: Characterizes the start states of the liquid entering the depth exchanger and the depth pipe.

Outlet Liquid Temperature and Tension: The circumstances at the exit of the depth exchanger.

Heat Age from Reactor Center: Characterizes how tons depth the depth exchanger is supposed to deal with, in light of the atomic reactor's end result.

Wall Temperature and Warm Conductivity: Characterizes the circumstances for the sturdy limits of the intensity exchanger elements.

6. CFD Reenactment Parts

Network/Frameworks: The computational space is partitioned into little control volumes (community cells), which might be applied to cope with the liquid stream and depth move conditions. The cross phase nice (e.G., high-quality as opposed to coarse) is basic for exact effects.

Choppiness Models: These fashions (like okay-ε, okay-ω, or LES) are utilized to reproduce the influences of disturbance within the movement, particularly in the coolant channels.

Stage Change Models: In the occasion that the depth pipe is displayed with two-stage circulation (fume and fluid), particular fashions for level change (vanishing and buildup) are required.

7. Heat Move Instruments

Convection: The trade of depth between the liquid and the walls of the depth line or intensity exchanger.

Conduction: Intensity move through the sturdy substances (e.G., the depth pipe shell, wick, and walls of the depth exchanger).

Stage Change: The crucial device inside heat pipes, where the functioning liquid ingests warmness, disintegrates, gathers, and deliveries warmness, running with effective intensity pass.

Eight. Execution Assessment Parts

Temperature Circulation: The temperature variety throughout the intensity exchanger parts and liquid channels.

Pressure Drop: The anxiety range because of frictional misfortunes inside the move methods, that is primary for siphon and useful productiveness.

Heat Move Coefficient: A proportion of the price at which intensity is moved between the liquid and the robust parts.

Adequacy and Proficiency: These are key signs and symptoms of the way well the intensity exchanger plays, including how much intensity is successfully moved from the reactor to the optionally available coolant.

INTRODUCTION TO CATIA V5R20

Nuclear power plant heat exchanger in Catia:

1. Modelling the Heat Exchanger

Part Plan: CATIA offers a much accomplishing suite to creating 3D models of intensity exchanger elements like cylinders, plates, and shells. Utilizing the Part Plan workbench, architects can make character parts and collect them to border the full depth exchanger shape.

Surface Plan: Since warmness exchangers frequently have complicated, many-sided surfaces for best depth pass, CATIA's Generative Shape Plan (GSD) workbench takes under consideration making and controlling bended surfaces for balances, warmth flow surfaces, or complex calculations.

1. Pressure testing inner CATIA will help in making certain that the depth exchanger with canning take care of purposeful and security conditions without disappointment.

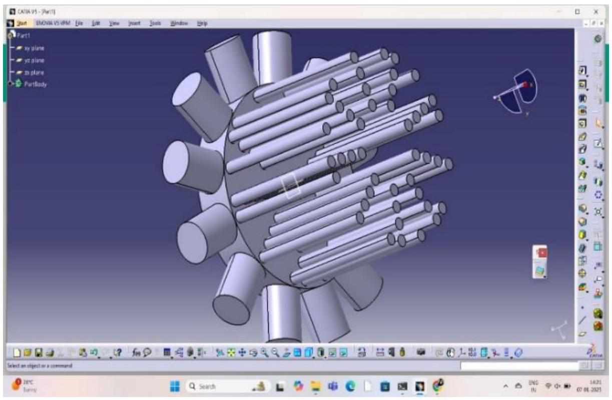


Fig 8.8: Nuclear power plant heat exchanger tubes circular polar and distance (18p & 40 deg)

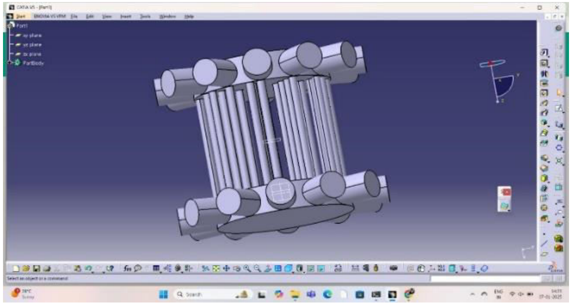


Fig 8.9: Nuclear power plant heat exchanger mirror

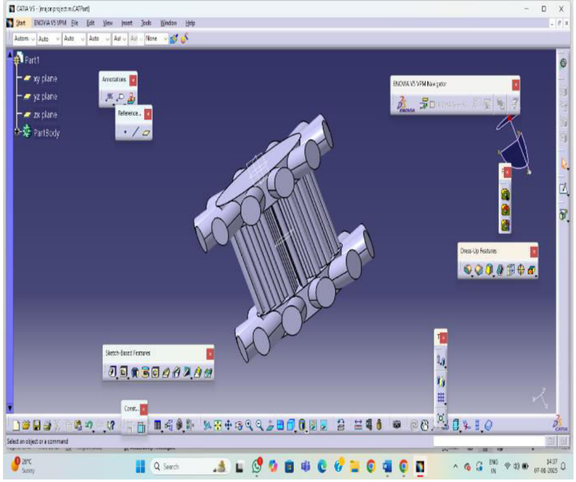


Fig 8.10: Nuclear power plant heat exchanger final design

2. Analysis and Simulation

Thermal Analysis: With CATIA, you can integrate with simulation tools like **SIMULIA** to perform thermal and flow analysis. This helps simulate heat transfer, fluid dynamics, and temperature distribution in the heat exchanger under various conditions.

Finite Element Analysis (FEA): To ensure the structural integrity of the heat exchanger under stress, pressure, and thermal gradients, **FEA** can be carried out within CATIA or linked with external software for a more detailed analysis.

Materials and Stress Simulation

Material properties are essential in nuclear plant applications. CATIA allows engineers to assign different materials to parts based on the real-world materials used in the heat exchanger, ensuring resistance to high temperatures and radiation.

Stress testing within CATIA will help in ensuring that the heat exchanger can handle operational and safety scenarios without failure.

NTRODUCTION TO ANSYS

ANALYSIS TYPES:

The following types of analysis are possible using ANSYS

· Structural Analysis: Static Analysis, Modal Analysis, Harmonic Analysis,

Transient Dynamic Analysis, Spectrum Analysis, Buckling Analysis, Explicit

Dynamic Analysis, Fracture mechanics, and Beam Analysis.

· Thermal Analysis: Steady-state thermal analysis, transient thermal analysis.

· CFD (Computational Fluid Dynamics) Analysis: Laminar or turbulent, Thermal or adiabatic, Free surface, Compressible or incompressible, Newtonian or Non-Newtonian, Multiple species transport.

· Several types of Electromagnetic field analysis and Coupled field analysis.

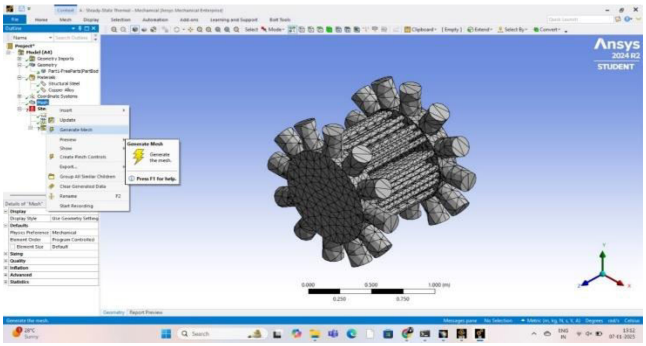


Fig 9.6: Ansys process model generate mesh

Statistics	
Nodes	31296
Elements	15033
Mesh Metric	Non

Table 9.2: Anys Process Model Generate Mesh

STEADY-STATE THERMAL

COPPER ALLOY

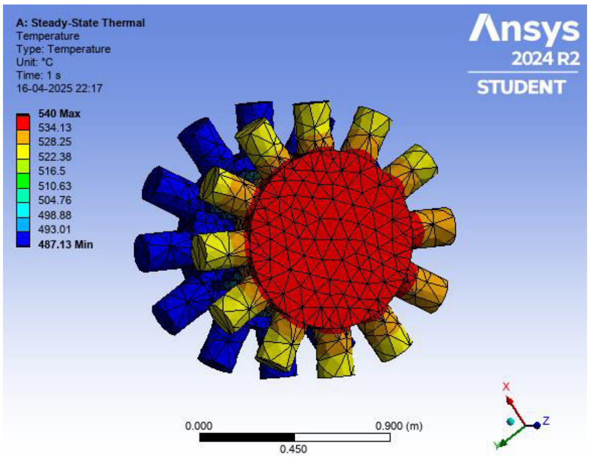


Fig 10.1: Ansys process steady state thermal temperature apply

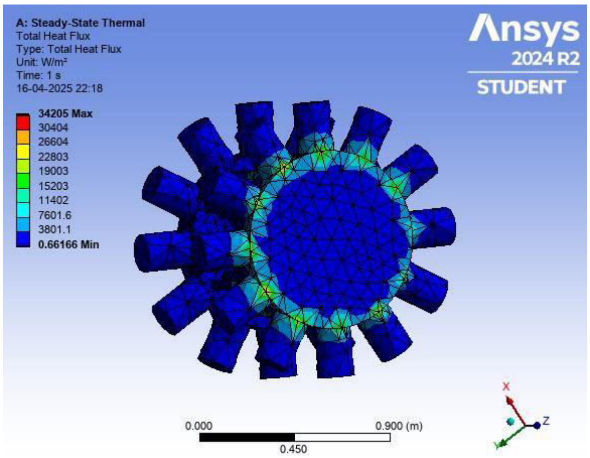


Fig 10.2: Ansys process steady state thermal Total Heat flux apply

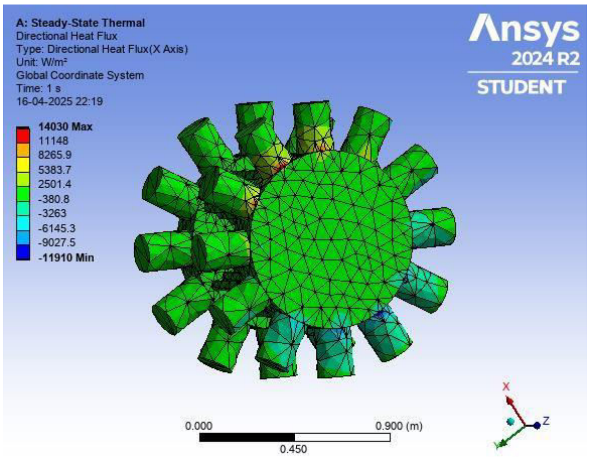


Fig 10.3: Ansys process steady state thermal Directional Heat flux apply

Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
Results			
Minimum	487.13°C	0.66166 W/m²	-11910 W/m²
Maximum	540 °C	34205 W/m²	14030 W/m²
Average	512 °C	3066.1W/m²	128.04 W/m²

Table 10.1Copper Alloy

STRUCTURAL STEEL

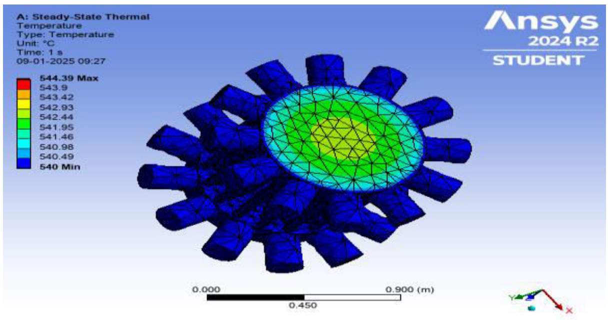


Fig 10.04: Ansys process steady state thermal temperature apply

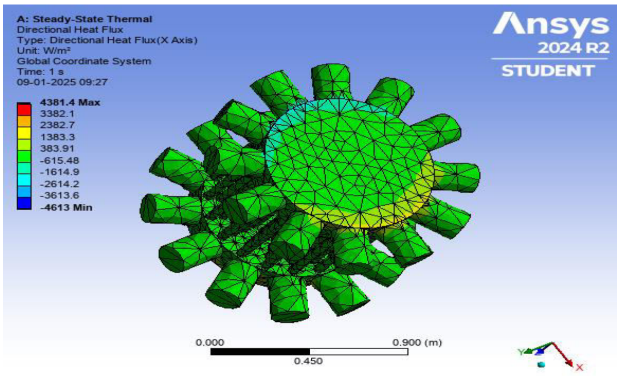


Fig 10.05: Ansys process steady state thermal Directional Heat flux apply

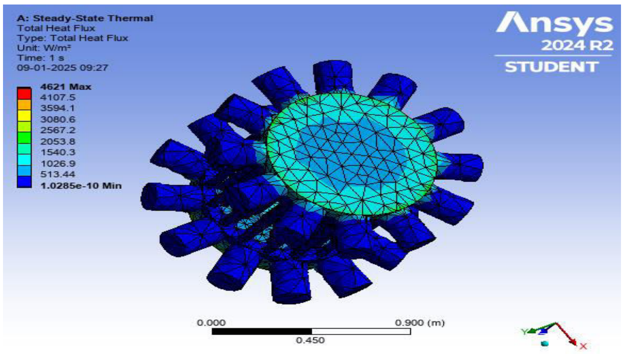


Fig 10.6: Ansys process steady state thermal Total Heat flux apply

2581-4575
International Journal For Recent Developments in Science & Technology
Crossref
A Peer Reviewed Research Journal

Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
Results			
Minimum	540. °C	1.0285e-010 W/m²	-4613. W/m²
Maximum	544.39 °C	4621. W/m²	4381.4 W/m²
Average	540.19 °C	403. W/m²	-1.7023 W/m²

Table 10.2 Structural Steel

ALUMINIUM ALLOY

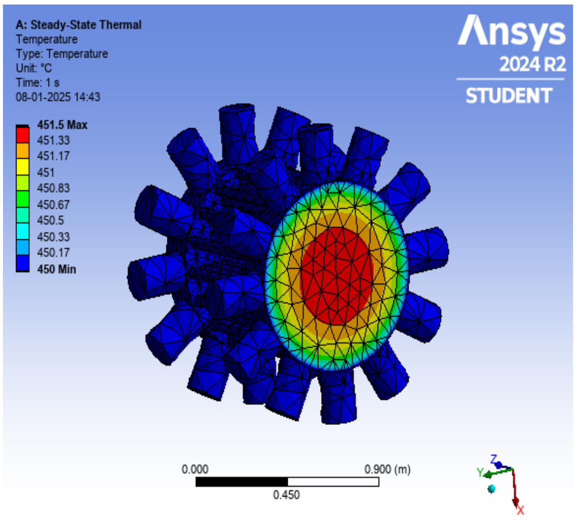


Fig 10.07: Ansys process steady state thermal temperature apply

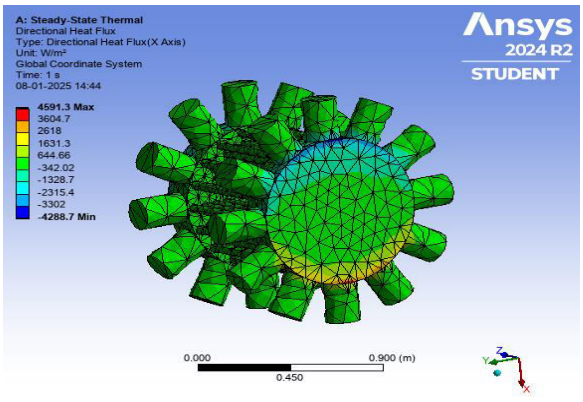


Fig 10.08: Ansys process steady state thermal Directional Heat flux apply

Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
Results			
Minimum	450. °C	6.3487e-010 W/m²	-4288.7 W/m²
Maximum	451.5 °C	4591.7 W/m²	4591.3 W/m²
Average	450.08 °C	478.06 W/m²	-1.8378 W/m²

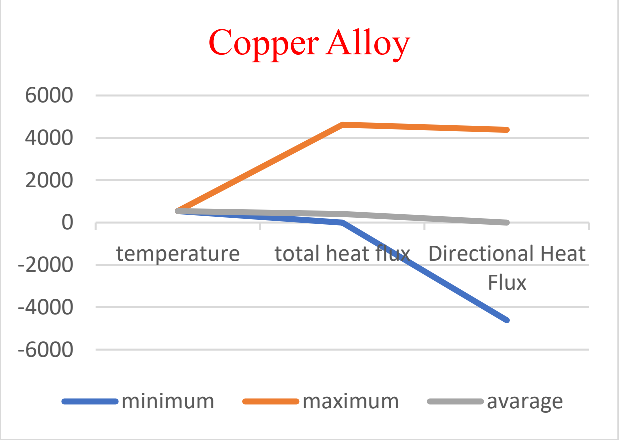
Table 10.3 Aluminium Alloy

RESULTS& DISCUSSION

COPPER ALLOY

Type	Temperature	Total Heat Flux	Directional Heat Flux
Results			
Minimum	500. °C	2.3457e-010 W/m²	-4556.7 W/m²
Maximum	504.61 °C	4878.7 W/m²	4878.3 W/m²
Average	500.24 °C	507.94 W/m²	-1.9526 W/m²

Table 11.1: Copper Alloy

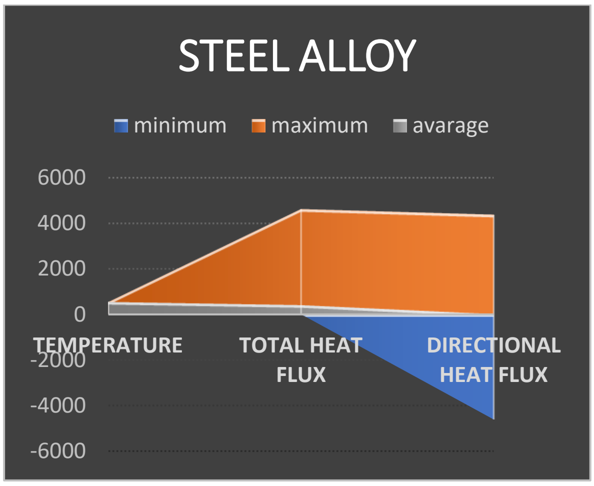


Graph 11.1: copper alloy Results

STRUCTURAL STEEL

Type	Temperature	Total Heat Flux	Directional Heat Flux
Results			
Minimum	540. °C	1.0285e-010 W/m²	-4613. W/m²
Maximum	544.39 °C	4621. W/m²	4381.4 W/m²
Average	540.19 °C	403. W/m²	-1.7023 W/m²

Table 11.2: Structural Steel

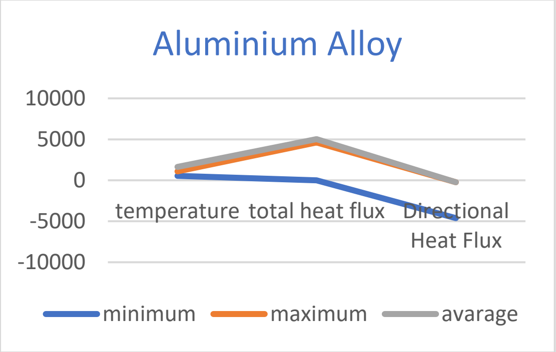


Graph 11.2: structural steel Results

ALUMINIUM ALLOY

Type	Temperature	Total Heat Flux	Directional Heat Flux
Results			
Minimum	450. °C	6.3487e-010 W/m^2	-4288.7 W/m^2
Maximum	451.5 °C	4591.7 W/m^2	4591.3 W/m^2
Average	450.08 °C	478.06 W/m^2	-1.8378 W/m^2

Table 11.3: Aluminium Alloy



Graph 11.3: aluminium alloy Results

Comparison Table

	Copper Alloy	Structural Steel	Aluminum Alloy
Metric	Case 1	Case 2	Case 3
	Temperature (°C)	Temperature (°C)	Temperature (°C)
Minimum	487.13	670.00	650.00
Maximum	540.00	544.39	451.50
Average	512.37	540.19	450.08
	Total Heat Flux (W/m^2)	Total Heat Flux (W/m^2)	Total Heat Flux (W/m^2)
Minimum	0.66166	1.0285e-10	6.3487e-10
Maximum	34,205	4,621	4,591.7
Average	3,066.1	403.00	478.06
	Directional Heat Flux (W/m^2)	Directional Heat Flux (W/m^2)	Directional Heat Flux (W/m^2)
Minimum	-11,910	-4,613	-4,288.7
Maximum	14,030	4,381.4	4,591.3
Average	128.04	-1.7023	-1.8378

CONCLUSION

Inrecent years, there has beena growing interest indesigning and developing power plants using heat pipe cooled micro-reactors. These plants offer advantages such as compact design, increased safety, improved reliability, and easy transportation. Heat pipes in these systems efficiently transfer heat produced by the reactor to the working fluid in the main heat exchanger, even when there is a small temperature difference. This study focuses on analyzing the performance of a heat exchanger that receives heat from 192 potassium heat pipes connected to a 5 MW micro-reactor.

The study examines three materials for the heat exchanger: Copper Alloy, Structural Steel, and Aluminum Alloy. These materials were chosen for their high-temperature resistance and ability to conduct heat effectively. The analysis, performed using ANSYS Workbench, shows that Structural Steelprovidesthebest performance inbothheat transferandeffectiveness. **StructuralSteel**transfers themostheatwitha**TotalHeatFluxof4621W/m^2**andachievesthe**highesteffectiveness**amongthe tested materials.

Insimpleterms,theresultsshowthatusingStructuralSteelintheheatpipesandheatexchanger optimizesthesystem'sperformance.Structural Steelmaximizestheheattransferandmakestheheat exchangermoreeffective.Thismakesitthebestchoiceforensuringefficientoperationofheatpipe cooled micro-reactors, contributing to improved performance and reliability of the power plant

REFERENCES

1. **Lechiteal.(2024).** Investigationoftime constantsinDPHE and shellandtube heat

exchangers undertransient inlet velocityconditions.InternationalJournalofHeatandMassTransfer.

2. **Aicher(2024).** The effect ofcounter flow withinthe nozzle portionofa DPHE installed onthe shell side wall. Experimental Thermal and Fluid Science.

3. **Meatal,(2023).**ExperimentalanalysisofheattransferinaDPHEwithsupercriticalCO_2:Effects of pressure, mass flow, and buoyancy force. Energy Conversion and Management.

4. **Raghavan,(2023**).Performanceanalysisofatwo-pipehelicalheatexchangerunderparalleland counter flow configurations. Heat Transfer Engineering.

5. **Dizaji,(2022)** mentalinvestigationoftransferandpressuredropinadoublepipeheatexchanger with corrugated tubes. Applied Thermal Engineering.

6. **Bhaduria (2022).** Experimental and statistical analysis of heat transfer and pressure drop in a double pipe heat exchanger with twisted inner tube geometry. InternationalJournalofThermal Sciences.

7. **Tang(2022).** Numericaland experimentalstudyonthermalperformanceofDPHE withvarious twisted inner tube cross-sections. Applied Thermal Engineering.

8. **Dunagan (2021).** Effect of artificial roughness via helical ribs on the thermal performance of heat exchangers. Journal of Heat Transfer Engineering.

9. **Reddy, N. S. (2021).** Heat transfer analysis of horizontal twin pipes with helical fins on the annulus side. International Journal of Heat and Fluid Flow.