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Effect of Cylinder Block Fin Geometry and Material on Heat Transfer Rate of Air Cooled 4-Stroke SI-Engine

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ABSTRACT

The objective of this project is to increase the heat transfer rate of a 4-stroke air cooled Spark ignition engine in order to reduce the losses (friction losses, uneven expansion of piston and cylinder, burning of lubrication oil) associated with heat produced during combustion stroke in engine cylinder. The heat transfer rate of fins is mainly depending on three parameters, one is fin geometry and surface area of fin and material used to manufacture the fins. In order to increase engine efficiency, different fin geometries like circular, rectangular wavy and curved shapes are designed and different types of fin materials like aluminum alloy and copper-alloy are used to increase the heat flux and to increase the efficiency of engine. In this project numerical simulation of the engine cylinder with different fin geometries and fin materials are going to present to improve the heat dissipation rate of an engine. The modelling of fins carried by using SOLID WORKS whereas ANSYS will be used to conduct steady-state thermal analysis. The optimized design of fin geometry and fin material for the engine cylinder willbe stated based on the results obtained from the analysis.

KEYWORDS: Fins, SI engine, Engine losses, Thermal analysis

1. INTRODUCTION

The main power source to run an automobile is engine in which the chemical energy of fuel is converted into thermal energy and again thermal energy is converted into mechanical energy. In automobiles Internal combustion engines are used to produce power. The working of internal combustion engine mainly involves 4-strokes namely suction stroke, compression stroke, expansion stroke and exhaust stroke. During the suction stroke the charge (mixture of fuel and air from carburetor) is entered into the engine cylinder and at the end of compression stroke the combustion of fuel takes place and the high temperature and high-pressure combustible products expands in the expansion stoke or working stroke and the exhaust gases produced in engine cylinder due to combustion are exhausted from the engine cylinder in exhaust stroke. Generally, the temperature produced during combustion stroke of a spark ignition engines are approximately about 500-550 degrees centigrade in order to reduce these high temperatures there are few methods are employed in internal combustion engines. In order to provide cooling system for automobile engines there are few methods are employed like direct cooling system (also known as dry cooling system) and indirect cooling system (also known as wet cooling system) and lubrication system is also acting as cooling system. Providing cooling system to spark ignition engine plays a significant role in reducing losses like friction losses and uneven expansion of piston and engine cylinder, burning of lubrication oil. Here mainly in this project work focusing on dry air-cooling system which involves providing metallic fins on the engine cylinder in order to increase the heat transfer area of engine. The fins are acting as heat exchanges and are mounted on engine cylinder in order to exchange the heat from engine cylinder to atmospheric air through the convection mode of heat transfer. Here heat is transferred through natural convection. The rate of heat transfer of fins is mainly depending on fin geometry and surface area of fins and material used to manufacture the fins. Currently rectangular fins are employed and mostly aluminum alloys are used to manufacture the fins. So, in order to improve the efficiency of fins, different types of fin geometries and materials are used in this project work.

2. REALATED WORK

OBJECTIVE:

To analyze the performance of heat transfer rate in 4-stroke air-cooled engine cylinder block with different fin geometries (fin geometry shapes circular rectangular and curved fins) and different fin materials (aluminum and copper and brass alloys) using steady-state thermal analysis carried in Ansys Workbench. The evaluated results from the analysis are compared between the geometries and materials, so that the highly efficient geometry and material is being identified.

PROBLEM IDENTIFICATION

- Cooling of an air-cooled engine is worse than the liquid cooled engine in which a liquid coolant circuit is installed so that liquid flows through it and absorbs heat from the engine.
- To increase the efficiency of cooling for an air-cooled engine air may be force fed with the use of natural air flow with well-designed and angled fins.
- Generally, in internal combustion engines, 44% of total heat generated is escaped through the exhaust gases,not through either a direct cooling system or through the indirect cooling system. And only 12% of heat is removed by engine fins. About 8% of heat is dissipated through to lubricating oil. In this way heat is transferred from engine cylinder.

LITERATURE REVIEW:

[1]Design and thermal analysis of engine cylinder fin body using various fin profiles.
Author: S.K. Mohammad Shareef, M Sai Vikas, A.L.N Arun Kumar, Abhishek Dasore, Sanjay Chhalotre, UpendraRajak, Trikendra Nath Verma.
Year of publishing: 2021

Observation:This research studied 100cc engine cylinder fins of varied geometry made of cast iron, copper alloy and Al6082 material and suggested using Al6082 material suggested using angular fins overall body weight reduces to 60% and high heat flux.

[2] Analysis of IC Engine Air Cooling of Varying Geometry and Material
Author: Rajvinder Singh, Suraj Pal, Arashdeep Singh
Year of publishing: 2016
Observation: In this paper we studied about the heat dissipation is depends on the surface area of fin, this paper is evaluated with different dimensions to rectangular fin with different perforations. In this paper the Bajaj CT 100cc engine cylinder fins are designed on solid works and they analyze that the existing material cast iron is less efficient as compared with aluminum alloy 6061 and they also stated that rectangular fins with curves at the corners gives more heat transfer rate in turn increases the efficiency of engine.

[3] Thermal Analysis of Engine Cylinder Head by Perforations
Author: Hrushikesh S Lokhande, Pramod K Jadhao
Year of publication:2018
Observation: In this paper we studied about the perforation developed to the fins by creating a variant in sizes of perforation to develop the heat dissipation and also to reduce the cost and weight of manufacturing without losing its efficiency in performance.

[4] Design and Analysis of a Rectangular Fin with Comparing by Varying Its Geometry and Material, With Perforation and Extension
Kota LeelaSaiBharath, V Pradeep Kumar
Year of publishing: 2021
Observation: In this paper we studied about the heat dissipation is depends on the surface area of fin, this paper is evaluated with different dimensions to rectangular fin with different perforations. In this paper they are mainly focusing on two materials one is Al6061 and Al 1100 and in order to reduce the weight of fins they are making slots on fins also called as perforated fins.

Finally, they concluded that due to perforated fins overall weight of fins is reduced and due to more air contact to the fin surface area more heat transfer is also occurred.

[5] Design Analysis of Cooling Fins for Two-Wheeler using ANSYS

Author: T R Chinnusamy, E Balaji, V Vignesh, T Karthikeyan, M Krishnan

Year of publication: 2019

Observation: This paper gives the information that how to analyze the thermal houses and to increase the air flow performance of wheeler engines by varying geometry of the fins, fin thickness, pitch of the fins and Computational fluid dynamics (CFD) for both conventional and optimized models are to be done under thermal loading conditions. The result of velocity distribution, temperature distribution, total heat flux and directional heat flux values are taken to optimize the problem.

[6] Thermal Analysis and Optimization of Two-Wheeler Engine Cylinder Fins

Author: Mr. Atul Chandanshive, Prof. Dr. S. M. Pise

Year of publication: 2019

Observation: In this paper we studied those fins are the extended surfaces which help to dissipate heat generated in the engine, to prevent the thermal damage some heat should remove from the engine so that analyzing the thermal properties by varying geometry and thickness of cylinder fins to improve the rate of heat transfer thermal analysis of two designs providing slot, reducing the fin thickness and increasing no. of fins is carried out.

[7] Heat transfer analysis and optimization of engine fins of varying geometry.

Author: Pulkit Sagara, Puneet Teotiab, Akash Deep Sahlotc, H.C Thakurd

Year of Publication: 2017

Observation: Engine fins are also made in order to force the air to get more heat transfer through fins because the heat transfer is depending on velocity of the air, ambient temperature and surface of fins. In this research it is clear that heat transfer is more in convex shaped fins as compared to other shaped fins and another advantage of using convex shaped is to reduce the material in manufacturing of fins and weight is also reduced in turn it increases engine efficiency.

8.Numerical simulation to evaluate the thermal performance of engine cylinder Fins: Effect of fin geometry and fin material

Author: Chandrakant R Sonawane, Pratyush Rath, Nishant Vats, Shreyas Patekar, Prakhar Verma, Anand Pandey

Year of Publication: 2021

Observation: In this journal mainly two materials are compared one is aluminum alloy 6061 and aluminum alloy 204 and it is also determined that thickness of fin also vary the rate of heat transfer and in this paper, analysis is done on Honda engine and they concluded that heat transfer rate is more in circular shaped fins as compared with existing rectangular shaped fin and it is obtaining more than 19% of heat transfer and less thickness of fins also increases heat transfer rate. Thickness of fins is also reduced and got more than 2% of heat transfer and they conclude that circular shaped aluminum alloy 6061 has more efficiency of about 27% of heat transfer.

[9] Modelling and Analysis of the thermal behavior of air-cooling system with fin pitch in IC Engines

Year ofPublication: 2018

Author: Vinoth kanna

Observation: Heat Transfer rate is increased by increasing surface area or coefficient of heat transfer, this is done by varying fin geometry and pitch in the case of IC engines (air cooled). This research compared and studied on straight fin geometry and wavy fin geometry and suggested heat transfer rate using wavy fins is less than straight fins.

[10] Thermal Analysis of Engine Fins with Different Geometries

Year of Publication: 2016

Author: L. Natrayan,G. Selvaraj,N. Alagirisamy, M.S. Santhosh

Observation: Convective heat transfer rate for IC engine with air cooled system is depended on amount of air flow and velocity of air flow on surface area of engine cylinder. This research studied effect of angular fin, curved fin, circular fin,rectangular fins geometry made of Aluminum alloy Al 6061, on heat dissipation capacity. This research suggested that curved fin geometry provide more heat transfer rate than all other fins and using wavy fin geometry produce heat transfer rate by providing turbulence.

[11] Design and thermal analysis of engine cylinder fin body using various fin profiles

Year of Publication: 2021

Author: S.K. Mohammad Shareef, M Sai Vikas, A.L.N Arun Kumar, Abhishek Dasore,Sanjay Chhalotre, UpendraRajak, Trikendra Nath Verma
Observation: Optimization of heat transfer leads to increase in efficiency of engine and reduces effect of parts due to thermal failure. This research studied 100cc engine cylinder fins of varied geometry made of cast iron, copper alloy and Al6082 material and suggested using Al6082 material which has less weight. This research suggested by using angular fins overall body weight reduces to 60% and high heat flux.

3. PROPOSED WORK

DIMENSIONS OF ENGINE CYLINDER BLOCK (BAJAJ PULSAR 150cc)

Maximum temperature(T_s)	263
Ambient temperature(T_a)	27
Perimeter of fin surface(P)	737.2mm
Area of fin surface(A)	4186.32mm^2
Fin length	0.116m
No.of fins	6
Bore diameter	56mm
Fin thickness	2mm
Fin pitch	11mm

Table:1

MODELLING IN SOLID WORKS: In this project design of Bajaj 150cc engine cylinder dimensions are considered and variousfingeometriesis made on solidworks. Here four types of fin geometries are designed i.e., rectangular(existing), circular, wavy and curved fins.

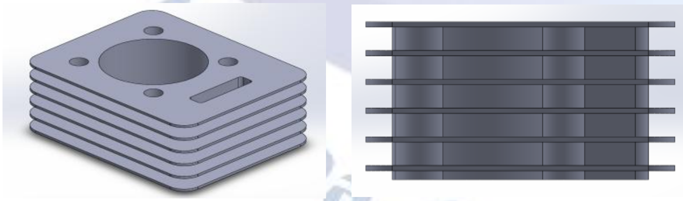


Fig:1 Top view and Front view of rectangular fin in solidworks

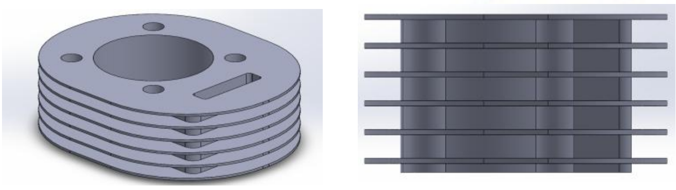


Fig:2 Top view and Front view of circular fin in solidworks

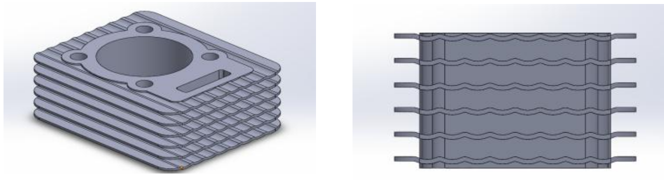


Fig:3 Top view and Front view of wavy fin in solidworks

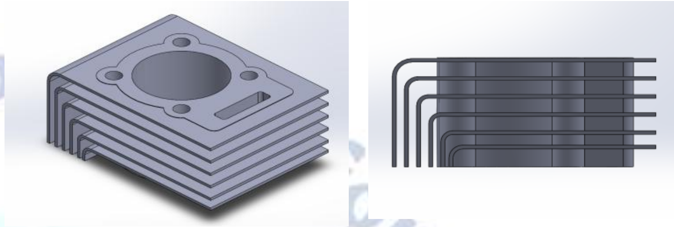


Fig:4 Top view and side view of rectangular fin in solidworks

MATERIAL INFORMATION: In this project we are using exsisting material Al6061 as standard material and other materials like Brass and Copper alloys are also used to determine the efficient material which is suitable for fins. The material compositions are mentioned below.

1.ALUMINIUM ALLOY (Al6061)

Material Composition:

Table:2

structural Isotropic Elasticity	
Derived from	Young's modulus and Poisson's ratio
Young's modulus	69000MPa
Poisson's Ratio	0.33
Bulk Modulus	67647MPa
Shear Modulus	25940MPa
Isotropic coefficient of thermal expansion	2.4×10^{-5} /°C
Isotropic thermal conductivity	0.17W/mm°C
Specific heat constant pressure	1.3×10^{6}mJ/kg°C
Density	2.7×10^{-6}kg/mm^3

2.Brass Alloy(UNS C36000)

Material Composition:

Table: 3

Structural Isotropic Elasticity	
Derived from	Young's modulus and Poisson's ratio
Young's modulus	117000MPa
Poisson's Ratio	0.34
Bulk Modulus	121875 MPa
Shear Modulus	37000 MPa
Isotropic coefficient of thermal expansion	1.7×10^{-5} 1/°C
Isotropic thermal conductivity	115 W/mK
Specific heat constant pressure	3.8×10^{5}mJ/kg°C
Density	8.49 g/cm^3

3. Copper Nickel alloy(CuNi10Fe1Mn3)

Material composition:

Table: 4

Structural Isotropic Elasticity	
Derived from	Young's modulus and Poisson's ratio
Young's modulus	1.35×10^{5} MPa
Poisson's Ratio	0.33
Bulk Modulus	1.3235×10^{5}MPa
Shear Modulus	50752 MPa
Isotropic coefficient of thermal expansion	1.7×10^{-5} 1/°C
Isotropic thermal conductivity	0.05 W/mm°C
Specific heat constant pressure	3.8×10^{5}mJ/kg°C
Density	8.9×10^{-6}kg/mm^3

ANALYSIS: The designed fin geometry models from solidworks is imported into ANSYS workbench. And to perform the steady state thermal analysis drop it into ANSYS workbench.Then edit the engineering data for various materials like aluminium alloy(Al6061), Brass Alloy (UNS C36000), Copper nickel alloy (CuNi10Fe1Mn3).Open the module and create a fully defined fine tetrahedron mesh by inserting automatic method to increase the quality of meshing.Apply the boundary conditions (Temperature load and convection) to the cylinder block by appropriate selection of geometry.Solve the solutions and observe the readings for the temperature and the total heat flux.Repeat the same for all the models and compare the results to determine an effective engine cylinder block.

BOUNDARY CONDITIONS FOR ENGINE CYLINDER BLOCK:

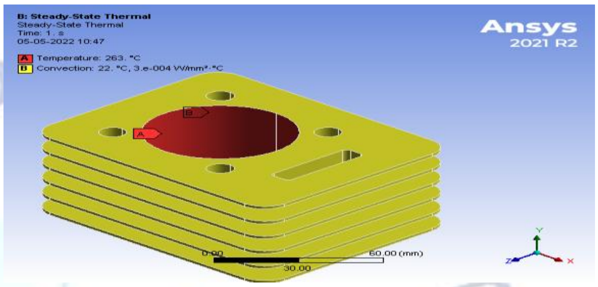
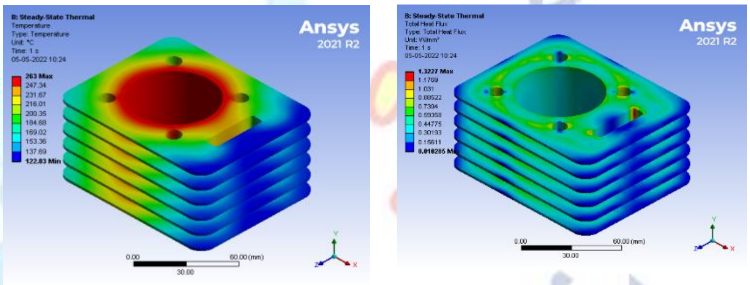


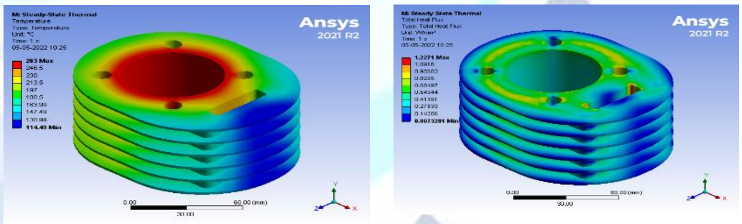
Fig:5

STEADY STATE THERMAL ANALYSIS: Material: Aluminium alloy (Al6061)



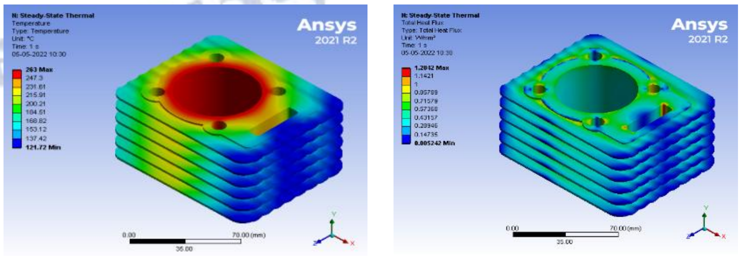
(a) **(b)**

Fig:6 rectangular (a)temperature distribution, (b) total heat flux



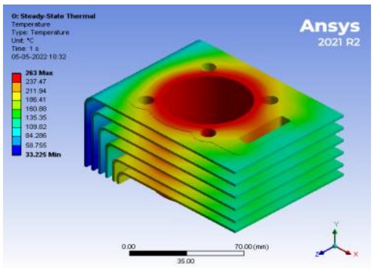
(c) **(d)**

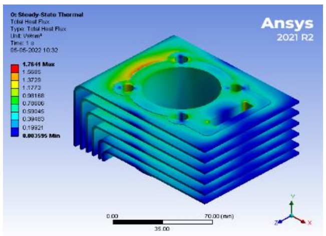
Fig:7circular (c)temperature distribution, (d) total heat flux



(e) **(f)**

Fig:8wavy (e)temperature distribution, (f) total heat flux

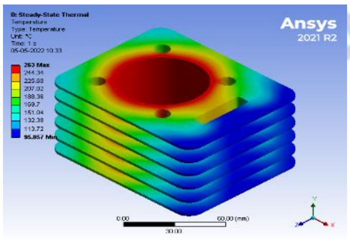


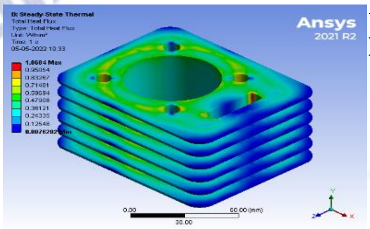


(g) (h)

Fig:9curved (g)temperature distribution, (h) total heat flux

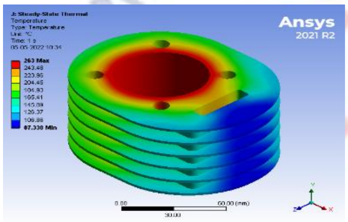
Material: Brass alloy (UNS C36000)

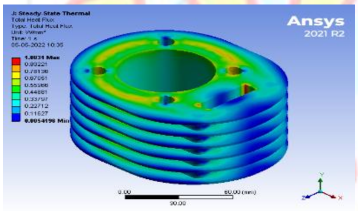




(i) (j)

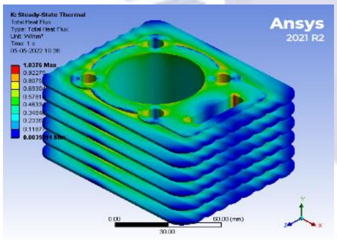
Fig:10rectangular (i)temperature distribution, (j) total heat flux

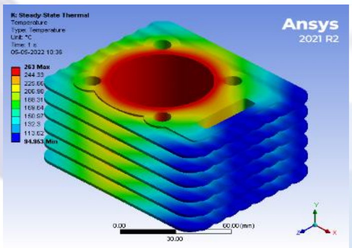




(k) (l)

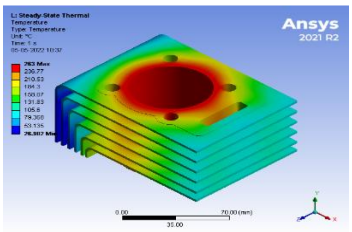
Fig:11 circular (k)temperature distribution, (l) total heat flux

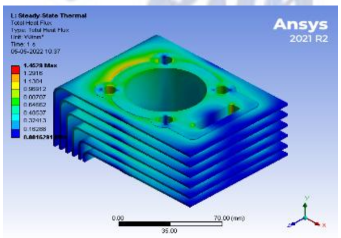




(m) (n)

Fig:12wavy (m)temperature distribution, (n) total heat flux

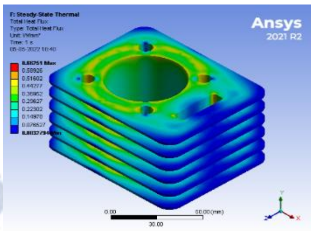


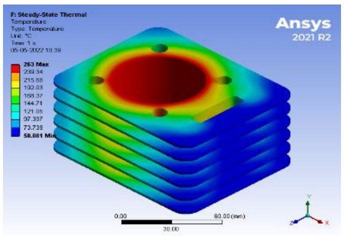


(o) (p)

Fig:13curved (o)temperature distribution, (p) total heat flux

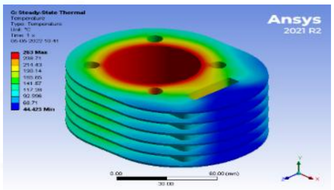
Material: CuNi10Fe1Mn3

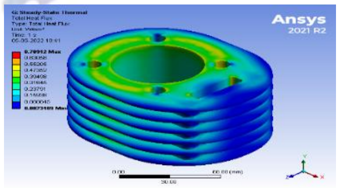




(q) (r)

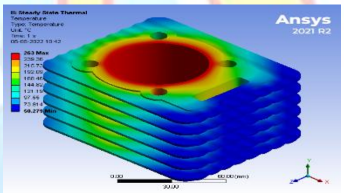
Fig:14rectangular (q)temperature distribution, (r) total heat flux

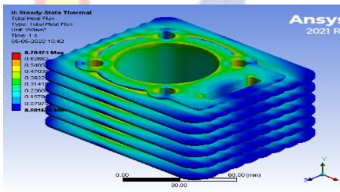




(s) (t)

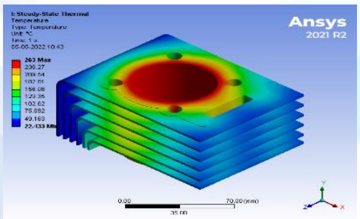
Fig:15 circular (s)temperature distribution, (t) total heat flux

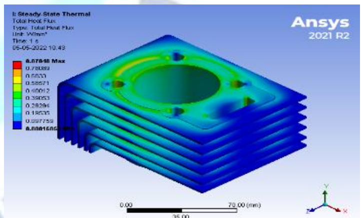




(u) (v)

Fig:16wavy(u)temperature distribution, (v) total heat flux





(w) (x)

Fig:17curved (w)temperature distribution, (x) total heat flux

4. RESULTS

From the above analysis we have values of temperature distribution and total heat flux of fins for various geometries and resulted values are tabulated below.

Table: 5

Material -Brass Alloy (UNS C36000)				
Geometry Of fins	Temperature (°C)		Total heat flux (W/mm²)	
	max	Min	max	min
Rectangular	263	95.057	1.0684	0.0076202
Circular	263	87.338	1.0031	0.0054196
Wavy	263	94.953	1.0376	0.0039211
Curved	263	26.902	1.429	0.0016291

Table:6

Material -Copper Nickel alloy (CuNi10Fe1Mn)				
Geometry Of fins	Temperature (°C)		Total heat flux (W/mm²)	
	max	min	max	min
Rectangular	263	50.081	0.66251	0.0032794
Circular	263	44.423	0.70912	0.0023109
Wavy	263	50.279	0.70474	0.001676
curved	263	22.433	0.87848	0.0001685

Table: 7

Material -Aluminium Alloy (Al6061)				
Geometry Of fins	Temperature (°C)		Total heat flux (W/mm²)	
	max	min	max	Min
Rectangular	263	122.03	1.3227	0.010285
Circular	263	114.49	1.2271	0.0073281
Wavy	263	121.72	1.2842	0.005424
curved	263	33.225	1.7841	0.003595

5. CONCLUSION

Hence, based on the above analysis the temperature is minimum for copper nickel alloy(CuNi10Fe1Mn) curved fins and total heat flux is maximum for Aluminum alloy(Al6061)curved fins, so based on the results both the temperature as well as heat flux is optimal for curved fins as compared with rectangular, circular and wavy fins and compared with copper alloy and brass alloy, aluminum alloy(Al6061) is more efficient.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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