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Modelling and thermal analysis of air-cooling system with fin pitch in IC engines

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ABSTRACT
Excessive heat from the system in IC engines is removed by using the air-cooling system in order to avoid damaging and overheating of IC engines. Fins are most preferably used now to enhance convective heat transfer without the use of an excessive amount of the primary surface area. Choosing the configuration of the fin is very important in order to attain maximum effectiveness of the fin. The heat transfer from surfaces in general is enhanced by increasing the heat transfer area of the surface or the heat transfer coefficient between the surface and its surrounding. Extended fins are well known for enhancing the heat transfer in IC engines. Therefore, it is important for an air-cooled engine to utilise the fins more effectively to obtain uniform temperature distribution in the cylinder periphery. The aim of this paper is to investigate the thermal behaviour of the cooling system with fin pitch and surface geometry in ANSYS and modelling is done using solid works software, in order to compare its performance over the conventional fin design.

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KEYWORDS
Air-cooling system; IC engines; fins; heat transfer; temperature distribution

1. Introduction

It is known that in the case of internal combustion engines, the combustion of air and fuel takes place inside the engine cylinder and hot gases are generated (Vinoth Kanna 2018). The temperature of gases will be around 2300–2500°C. This is a very high temperature and may result in the burning of the oil film between the moving parts and may result in seizing or welding of the same (Devaraj et al. 2017). So, this temperature must be reduced to about 150–200°C at which the engine will work most efficiently, drastic reduction of temperature is also not desirable since it reduces the thermal efficiency. So, the aim of the cooling system is to keep the engine running at its most efficient operating temperature (Vinoth Kanna, Vasudevan, and Subramani 2018).

It is to be noted that the engine is quite inefficient when it is in the cold state and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains a maximum efficient operating temperature, then it starts cooling (Vinoth Kanna and Paturu 2018).

It is also to be noted that:

- About 20–25% of the total heat generated is used for producing useful work.
- Cooling system is designed to remove 30–35% of the total heat.
- Balance percentage of heat is lost in friction and carried away by exhaust gases.

There are mainly two types of cooling systems:

- air -cooled system and
- water -cooled system.

2. Air-cooling systems

An air-cooled engine's fins allow heat to be wicked as air flows through them. Internal combustion engines come in many shapes and forms that rely on a liquid-filled jacket or the surrounding air to prevent the engine from overheating. While liquid-cooled engines are smooth in appearance, air-cooled engines are distinguishable by their heavily-finned cylinder heads. These fins provide more than just an aesthetic function; they are necessary to help the engine cool (Murthy and Patankar 1983).

2.1. *Working of the air-cooled engine*

An air-cooled engine operates in the same manner as any internal combustion engine does. A combustible mixture of air and fuel is drawn into the engine cylinder by the motion of its piston, where it is ignited by a spark plug and expelled through the exhaust (Gharebaghi and Sezai 2007). Heat is generated through the combustion, or ignition, of the air–fuel mixture as well as through friction within the engine's internal parts. This heat is transferred to the cylinder head walls and out to the cooling fins. Air passes over the fins to cool the engine as the car, truck or motorcycle moves.

2.2. *The necessity of engine cooling*

All internal combustion engines generate heat during operation, but keeping the engine temperatures below a certain limit is necessary to its safety and efficiency. As the temperatures rise, the efficiency of the engine and its oil decreases (Vinoth Kanna, Devaraj, and Subramani 2018). This often results in a loss of power as the air and fuel mixture is ignited by the heat build-up,

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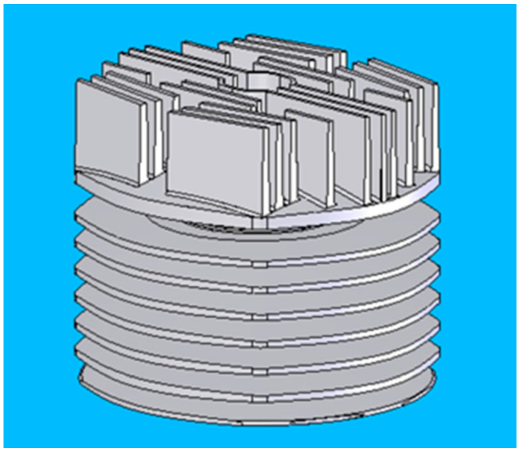

Figure 1. Model of engine (SUZUKI 1802m021509).

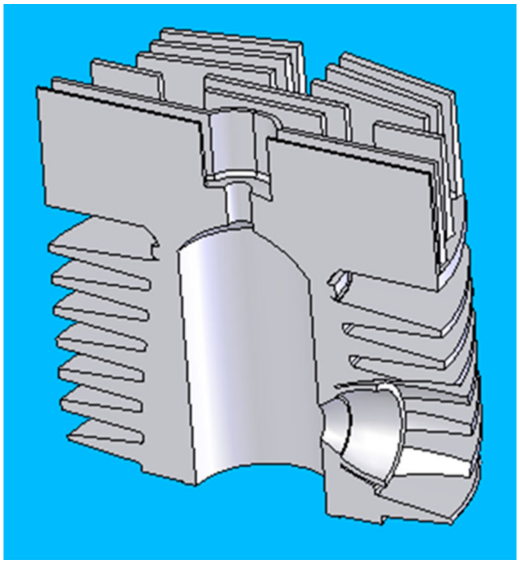

Figure 2. Cross-sectional view of the engine (SUZUKI 1802m021509).

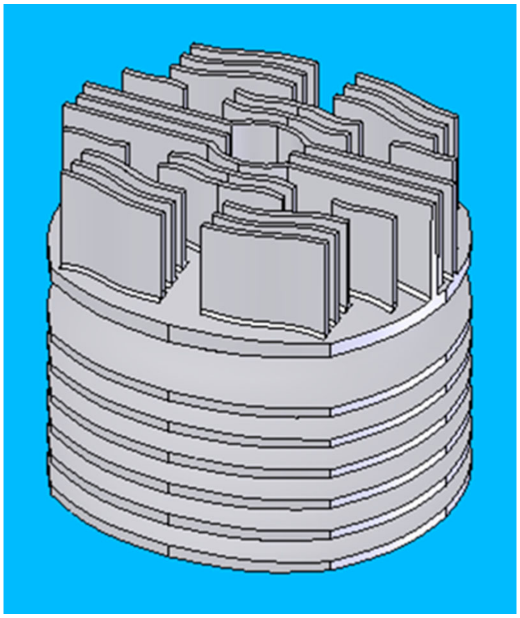

Figure 3. Model of the wavy finned engine.

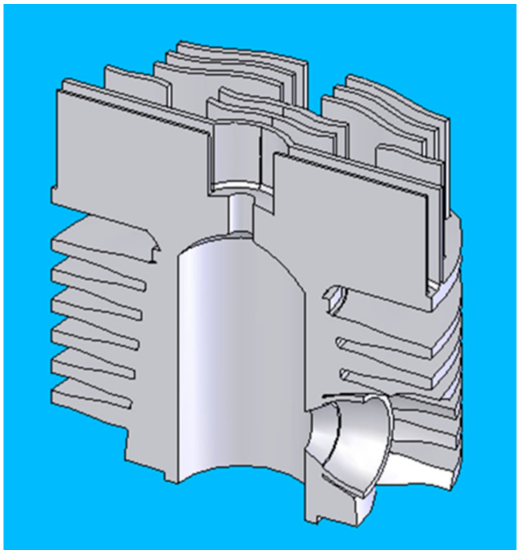

Figure 4. Cross-sectional view of the wavy finned engine.

rather than by the spark plug. This creates a condition called pre ignition, in which the mixture is ignited earlier than needed, reducing power output and potentially damaging the piston. Additionally, excessive heat build-up can cause the engine oil to thin.

2.3. Effect of fin material

To analyse the effect of material properties, copper, aluminium and cast iron were considered for the best heat dissipation considering both the conduction and convection heat transfer parameters. Three numerical models with different fin materials (copper, aluminium and cast iron) and same cylinder material (cast iron) were simulated under same operating conditions, i.e. constant temperature of cylinder inner wall at 150°C and wind velocity of 60 km/h. The temperature contours for cast iron fin. As inferred, the temperature is more distributed on the copper fin, showing greater area of heat transfer (Walker 1991).

The variation of coefficient of heat transfer changes in the fin material at the fin tip. Under steady-state conditions, the copper fin has the maximum surface heat transfer coefficient at (Vasudevan et al. 2017) the fin tip. The aluminium fin is marginally below the copper fin in terms of the surface heat transfer coefficient and the cast iron fin has the lowest value of coefficient.

2.4. Effect of fin pitch

Three different fin pitches of 7, 10 and 14 mm have been analysed for the internal combustion engine cylinder with 80 mm length. The pitches have been measured from fin surfaces (Lee, Lee, and Chou 2013) The number of the fin varies with respect to the change in the fin pitch. The number of fins is 6 for a fin pitch of 7 mm and it is 5 for a fin pitch of 10 mm (Paturu and Vinoth Kanna 2018). It shows the meshed model of six fins having a spacing of 7 mm. Different fin pitches are compared on the basis of net heat dissipated at the fin tip by all the fins in the model (Anon 2017).

The surface heat transfer coefficient is multiplied by the area of one fin and number of fins in every fin geometry. The maximum value of heat transfer is obtained for a pitch of 10 mm. It shows the contour of heat transfer through 10 mm fin pitch geometry at a velocity of 60 km/h.

2.5. *Effect of velocity of air*

To examine whether the performance of different fin pitches varies with wind velocity, simulations are carried out for all the different pin pitches for different air velocities. Meshed models for air domain and fins were created (Emery and Bardot 2004). The numerical analysis is carried out for different velocities from 20 to 80 km/h. The velocity is given in the positive *x* direction. Apart from inlet and pressure outlet, all surfaces of air domain are specified as the wall condition. It shows the contour of heat transfer through 10 mm pitch geometry at a velocity of 20 km/h (Vinoth Kanna and Pinky 2018). The temperature contour of same geometry at 80 km/h. The thermal boundary layer can be easily observed between fins (Devaraj et al. 2017). The region between the fins is hotter for 20 km/h in comparison to 80 km/h, showing less heat transfer at lower wind velocity.

2.6. *Advantages of an air-cooled engine*

One of the most significant advantages of an air-cooled engine lies in its relative simplicity in relation to its liquid-cooled counterparts. The cooling fins are cast directly onto the cylinder head at the time of manufacture, while liquid-cooled (Walker 1991) engines use thin coolant pockets or channels machined into the cylinder head. Accessing any part of an air-cooled engine can be done directly without having to drain coolant or remove radiators (Thulasi and Rajagopal 2013).

Table 1. Specification of engine (Liu, Ling, and Peng 2015).

Engine type	Single cylinder, two stroke
Stroke	50 mm
Cylinder bore	50 mm
Length of cylinder	87 mm
Length of fins	45 mm
Number of fins (in cylinder)	7
Pitch of fins	10 mm

3. Methodology

Modelling of the air-cooling system is done in solid works.

- Determination of the heat transfer coefficient.
- Thermal transient analysis of the conventional fin for pitches of 8 and 10 mm is carried out in ANSYS.
- Thermal transient analysis of the wavy fin for pitches of 8 and 10 mm is carried out in ANSYS.
- Comparison of conventional and perforated fin heat transfer rate.

4. Modelling in solid works

In this work, reverse engineering has been carried out in a two-stroke engine of SUZUKI 100 cc engine of model 1802m021509 (Figures 1–4).

By conducting reverse engineering, the calculated specifications of engine are as follows (Table 1):

5. Analysis in ANSYS

Figures 5 and 6.

5.1. *Transient analysis results*

Figures 7–10.

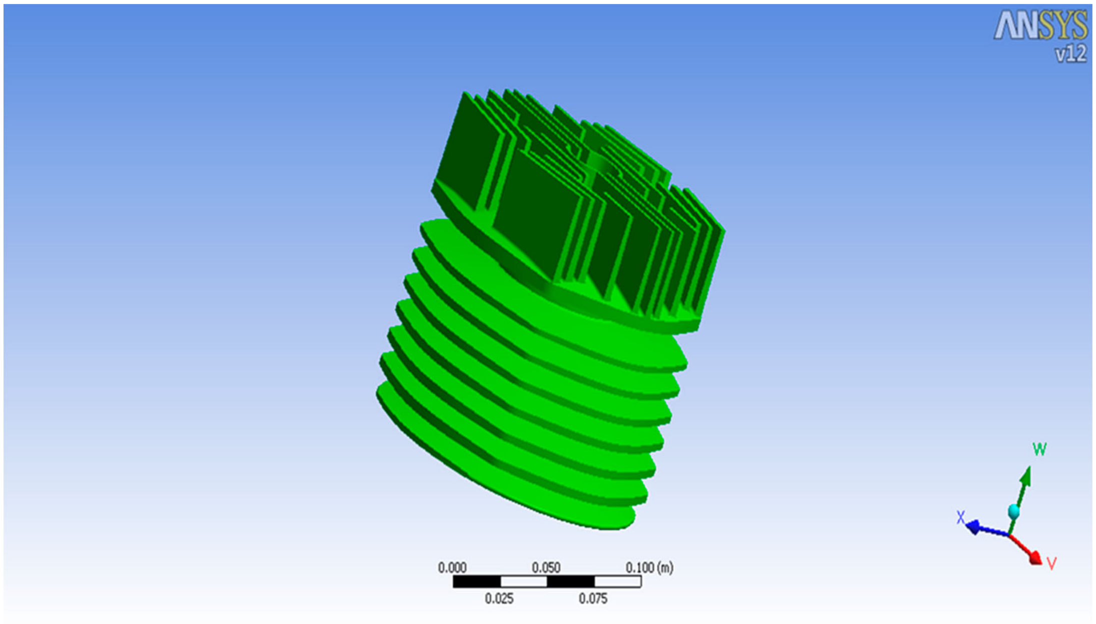

Figure 5. ANSYS imported model of the cylinder with fins.

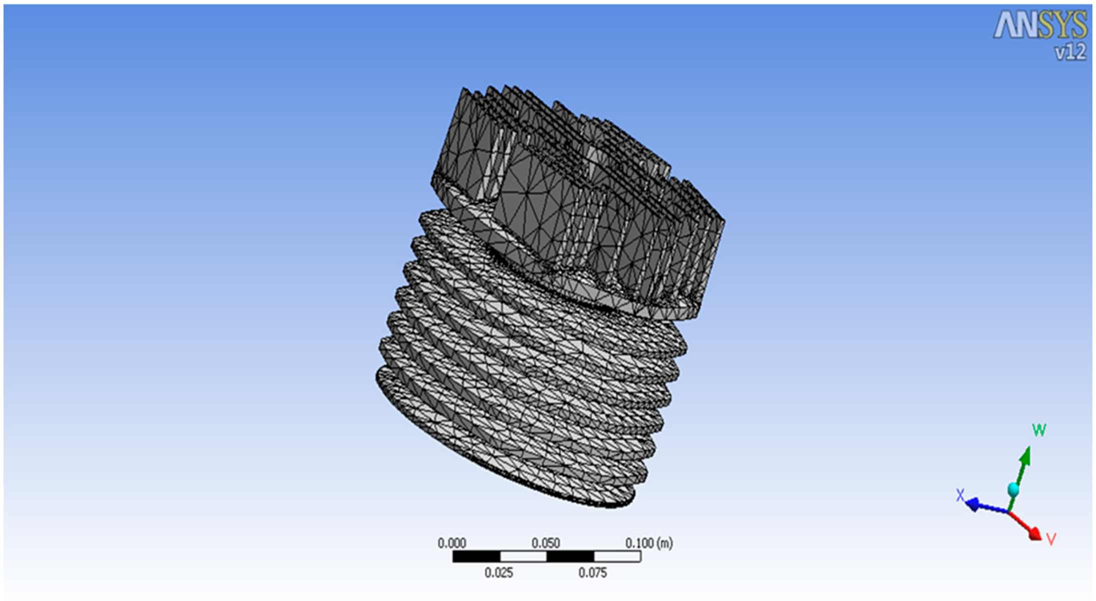

Figure 6. Meshed model.

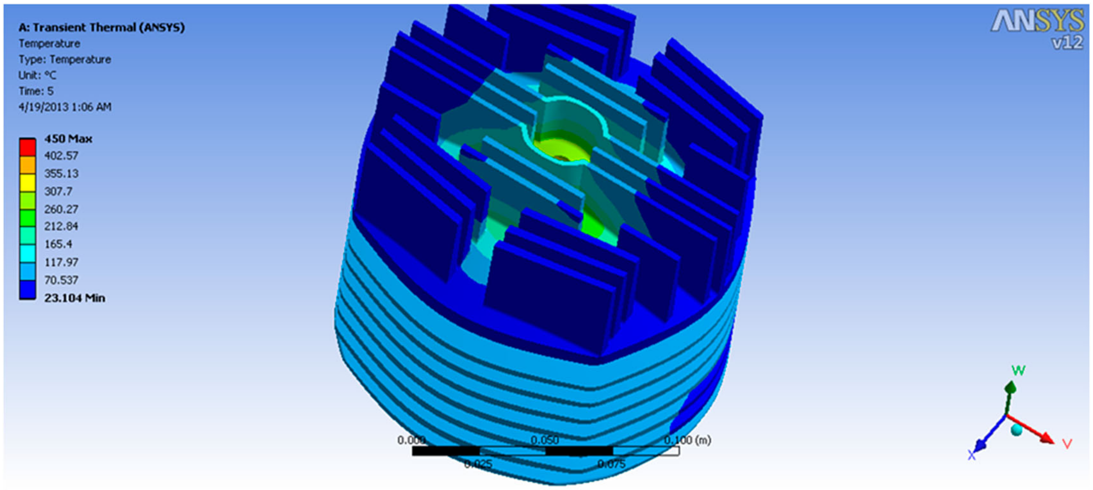

Figure 7. Temperature distribution in straight fins of pitch 8 mm.

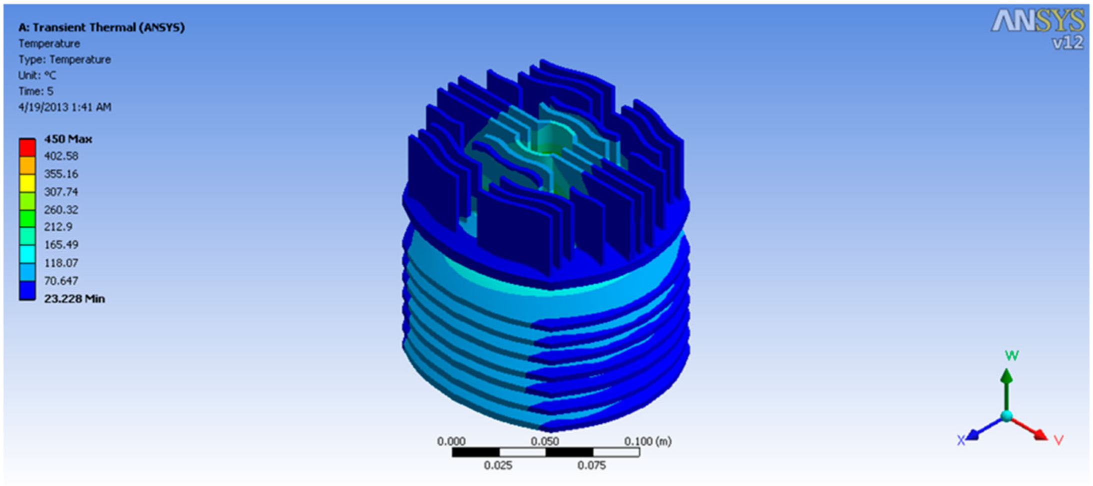

Figure 8. Temperature distribution in wavy fins of pitch 8 mm.

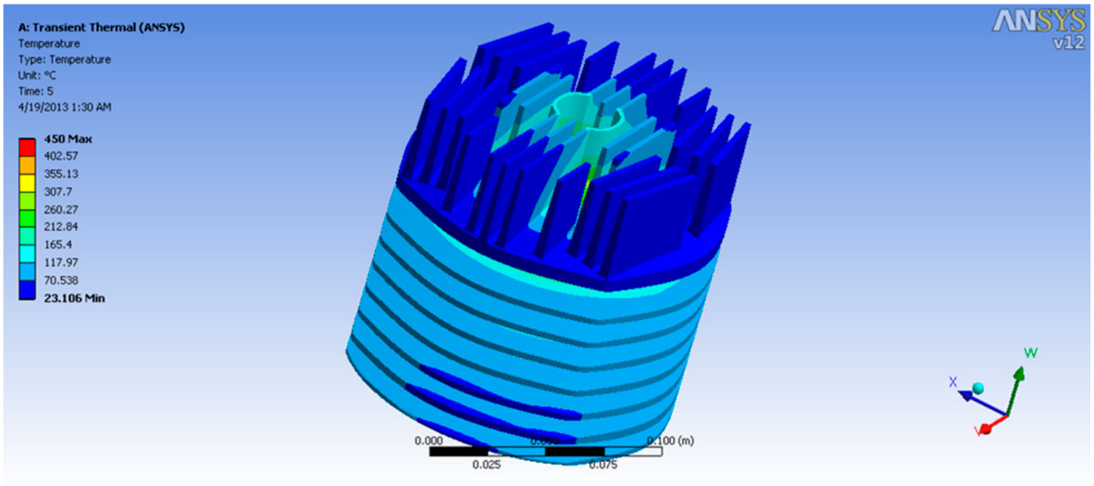

Figure 9. Temperature distribution in straight fins of pitch 10 mm.

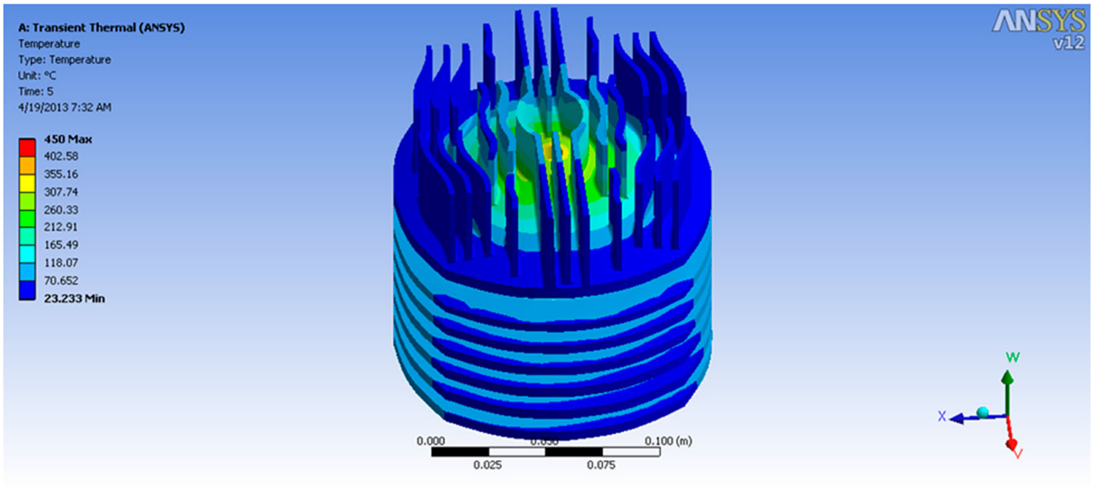

Figure 10. Temperature distribution in wavy fins of pitch 10 mm.

5.2. Graph for temperature distribution in fins with pitch 8 mm

Figure 11.

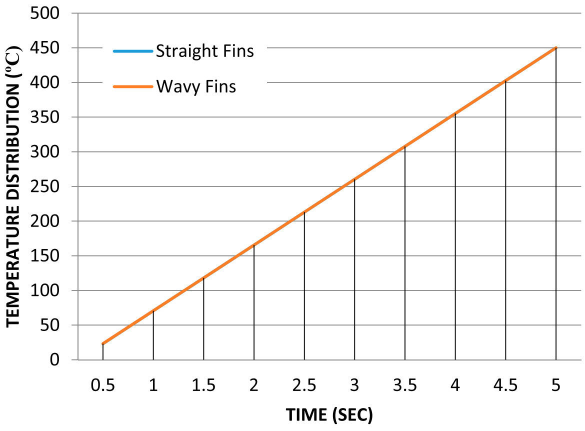

Figure 11. Straight fins of pitch 8 mm vs wavy fins of pitch 8 mm.

5.3. Graph for temperature distribution in fins with pitch 10 mm

Figure 12.

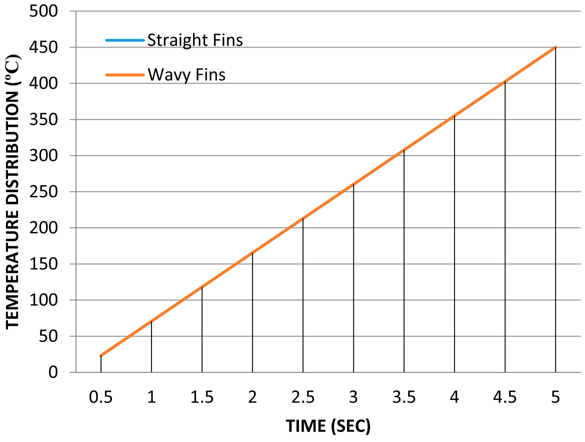

Figure 12. Straight fins of pitch 10 mm vs wavy fins of pitch 10 mm.

5.4. Graph for temperature distribution in straight fins

Figure 13.

5.5. Graph for temperature distribution in wavy fins

Figure 14.

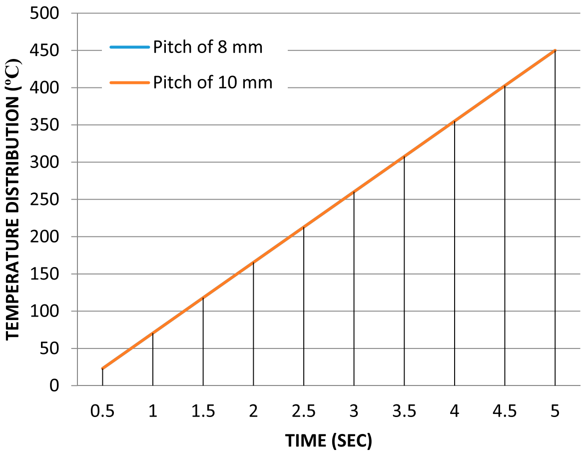

Figure 13. Straight fin of pitch 8 mm vs straight fin of pitch 10 mm.

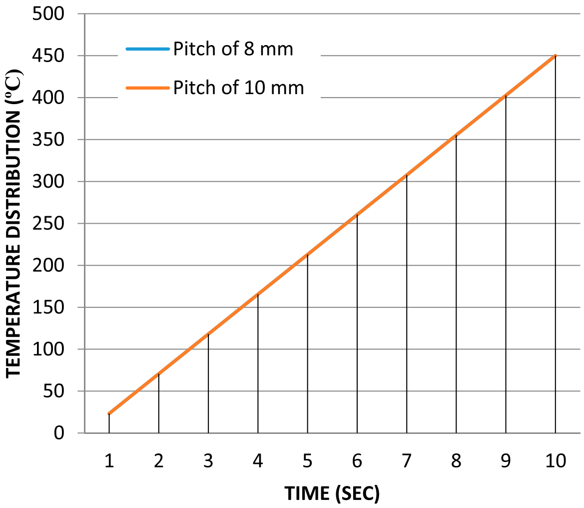

Figure 14. Wavy fin of pitch 8 mm vs wavy fin of pitch 10 mm.

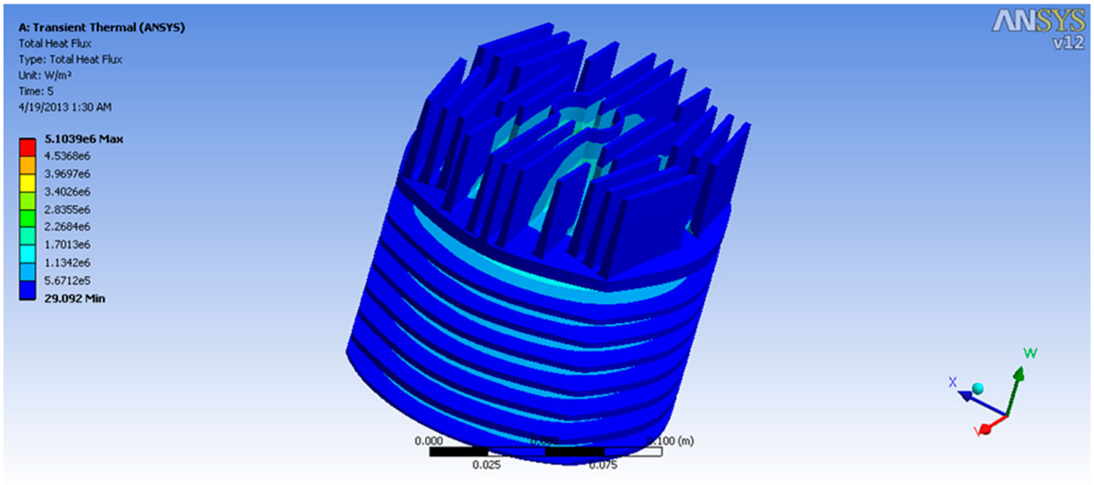

Figure 15. Heat flux in straight fins with pitch 8 mm.

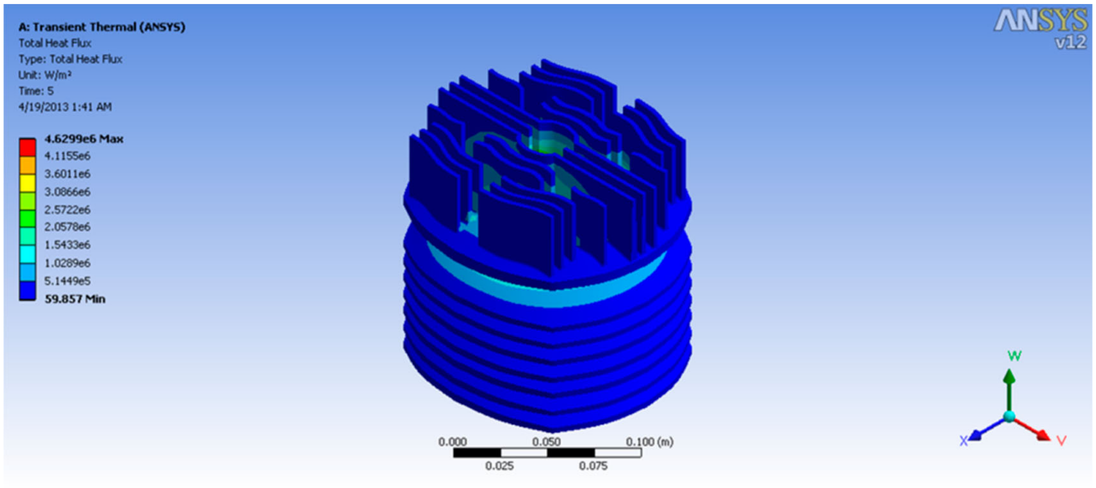

Figure 16. Heat flux in wavy fins with pitch 8 mm.

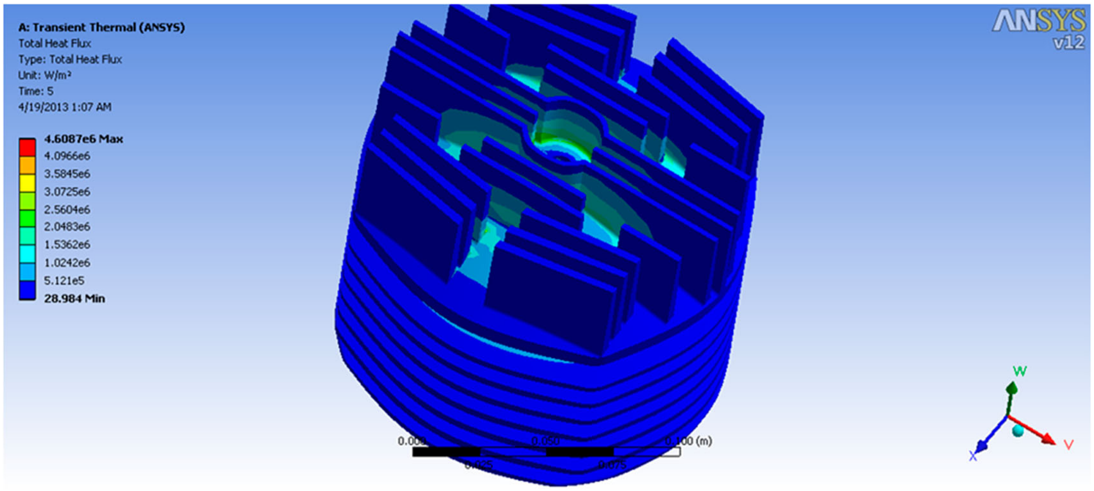

Figure 17. Heat flux in straight fins with pitch 10 mm.

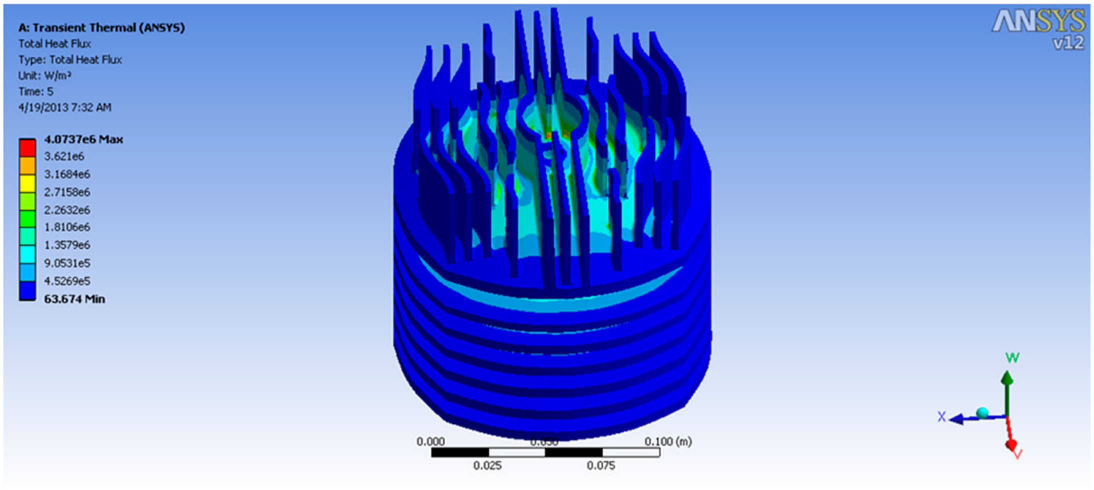

Figure 18. Heat flux in wavy fins with pitch 10 mm.

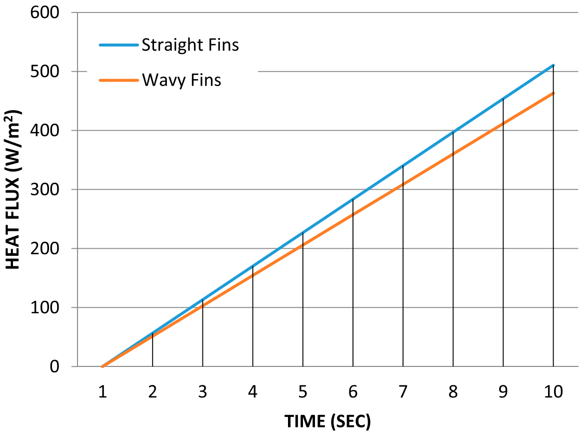

Figure 19. Straight fins of pitch 8 mm vs wavy fins of pitch 8 mm.

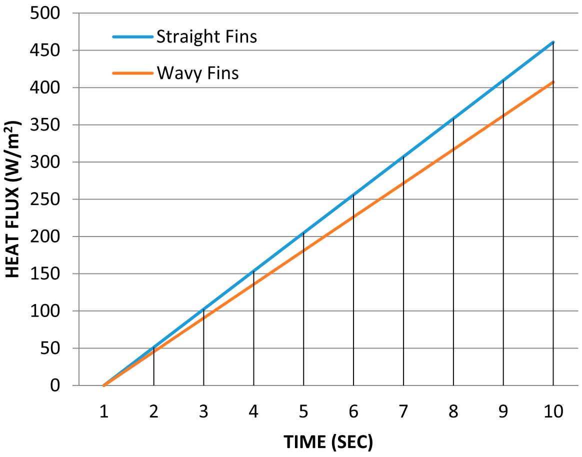

Figure 20. Straight fins of pitch 10 mm vs wavy fins of pitch 10 mm.

5.6. Heat flux

Figures 15–18.

5.7. Graph for heat flux in fins with pitch 8 mm

Figure 19.

5.8. Graph for heat flux in fins with pitch 10 mm

Figure 20.

5.9. Graph for heat flux in fins

Figure 21.

5.10. Graph for heat flux in fins

Figure 22.

6. Conclusion

A comparative study was made on the pitch of 8 mm and pitch of 10 mm in the straight fins and wavy fins and it was found that

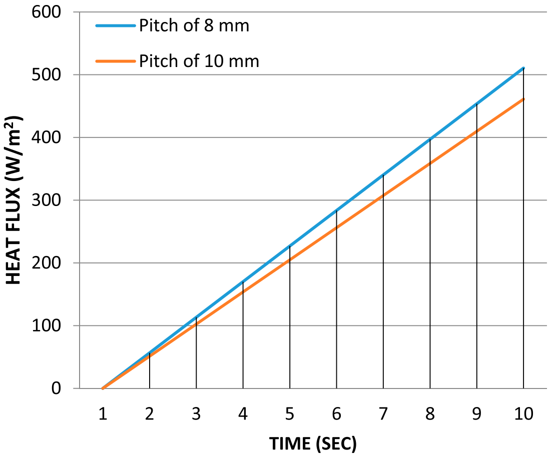

Figure 21. Straight fin of pitch 8 mm vs straight fin of pitch 10 mm.

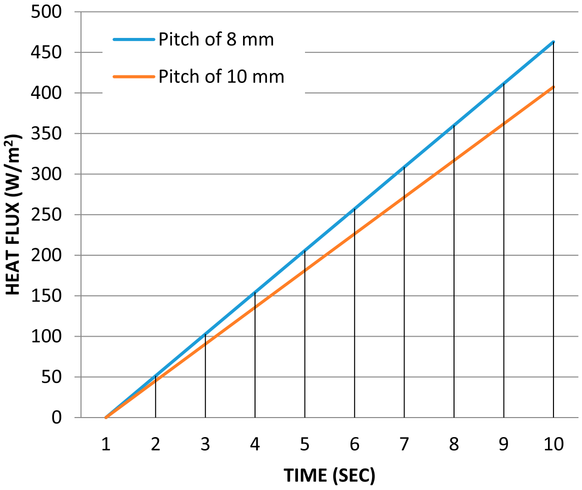

Figure 22. Wavy fin of pitch 8 mm vs wavy fin of pitch 10 mm.

- The pitch of 8 mm gives more heat transfer rate when compared to the existing fin pitch of 10 mm by 9.71% for straight fins.
- In the case of wavy fins, the pitch of 8 mm gives more heat transfer rate when compared to the existing fin pitch of 10 mm by 12.01%.
- In design considerations, the wavy fins give almost equal temperature distribution with respect to straight fins.
- The heat transfer rate is less in wavy fins when compared to straight fins by 9.21% in 8 mm of pitch and 11.62% in 10 mm pitch.

Disclosure statement

No potential conflict of interest was reported by the author.

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