

# Experimental Analysis of Fin Coated with Yttrium Oxide to Improve Heat Transfer

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**ABSTRACT:** The Engine cylinder is one of the major automobile components, which is subjected to high temperature variations and thermal stresses. In order to cool the cylinder, fins are provided on the surface of the cylinder to increase the rate of heat transfer. By doing thermal analysis on the engine cylinder fins, it is helpful to know the heat dissipation inside the cylinder. We know that, by increasing the surface area we can increase the heat dissipation rate, so designing such a large complex engine is very difficult. The main aim of the present paper is to analyze the thermal properties by coating the cylinder fins with a material which helps in increasing the rate of heat transfer. Transient thermal analysis determines temperatures and other thermal quantities that vary over time. The variation of temperature distribution over time is of interest in many applications such as in cooling. The accurate thermal simulation could permit critical design parameters to be identified for improved life. Presently Material used for manufacturing cylinder fin body is changing yttrium oxide coating.

## I. INTRODUCTION

In the study of heat transfer, a fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to an object, however, increases the surface area and can sometimes be an economical solution to heat transfer problems. The operation of many engineering systems involves heat generation. This may cause serious overheating problems and sometimes leads to failure of the system. The heat generated within a system must be dissipated to its surrounding in order to maintain the system operating

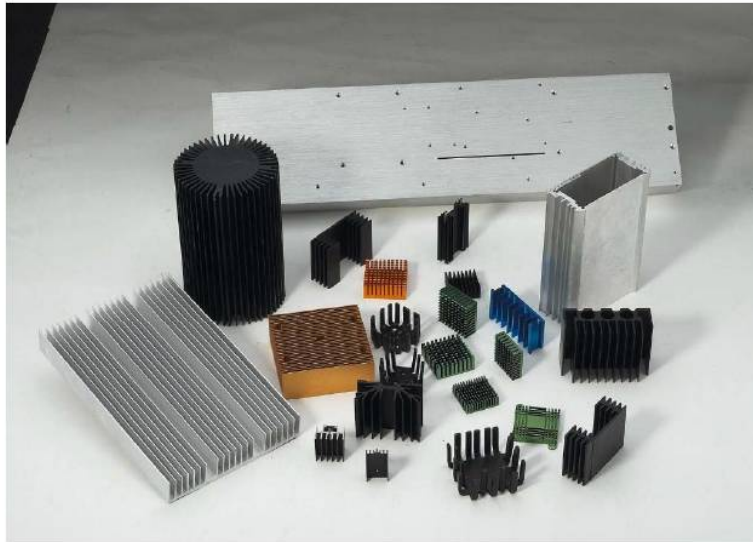
### 1.1 Fin

Fins are commonly used in many engineering applications to enhance heat transfer. A number of studies have been performed in order to increase the heat transfer effectiveness and to reduce the dimensions and weight of heat exchangers. The necessity to reduce the volume and weight of heat exchanger has become more important in many engineering applications like IC Engines, Heat exchangers, etc. Efficient design of fins can improve system performance considerably. Among several available techniques for augmentation of heat transfer in heat exchanger tubes, the use of internal fin appears to be very promising method as evident from the results of the past investigations. This is especially important in modern electronic systems, in which the packaging density of circuits is high. In order to overcome this problem, thermal systems with effective emitters as fins are desirable. In order to achieve the desired steady-state rate of heat dissipation, with the least.

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**Fig 1.1 Fins or Extended surfaces**

Aluminium and copper are ideally suited to the manufacture of many components because of the wide variety of forms and sizes available that minimize costs of machining to final dimensions. It has a unique combination of properties: strength, shock resistance, ductility and conductivity combined with good corrosion resistance and other attributes such as superb machinability. Other beneficial properties are good formability, good spark resistance, low magnetic permeability and toughness retained above and below ambient temperatures. As for handling the heat sink problem, the size of its

outward design, the amount of fin flake, the gap of fin flake, the area of its outward surface all have an intimate relation on enhancing its convection effect and increasing its heat sink ability. The only controllable variable to enhance the convection heat transfer rate is the geometry of the fins. The designer must optimize the size and the spacing of the fin arrays otherwise; using fins can bring more disadvantages than its advantages to the design.

## 1.2 Purpose of Fin

Most internal combustion engines are fluid cooled using either air (a gaseous fluid) or a liquid coolant run through a heat exchanger (radiator) cooled by air. In air cooling system, heat is carried away by the air flowing over and around the cylinder. Here fins are cast on the cylinder head and cylinder barrel which provide additional conductive and radiating surface. In water cooling system of cooling engines, the cylinder walls and heads are provided with jacket. Cooling fins help keep Chevrolet volt battery at ideal temperature. We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same.

So, this temperature must be reduced to about 150-200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attain to maximum efficient operating temperature, then it starts cooling.

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Fig 1.2 Fins in Bike Engine

### II. PROBLEM IN NORMAL FIN

- The engine cylinder is one of the major automobile components which is subjected to high temperature variation
- Engine is made of aluminium alloy which has high expansion coefficient.
- Hence fin is required for heat transfer coefficient, which avoids overheating of engine
- Due to overheating the piston will bind against the cylinder walls & seize the piston.
- The gaskets may get sealed in the oil gallery.
- The engine oil will break down rapidly at very high temperature.
- Overheating doesn't result in full destruction of engine. But prolonged overheating can destroy the engine

#### 2.1 Need for Coating

- By doing thermal analysis on the engine cylinder fins, it helps fully to know the heat dissipation in engine cylinder.
- We know that increasing the surface area of fin we can increase the heat dissipation rate.
- So designing such a large complex engine is very difficult.
- The main aim of the present paper is to increase the efficiency of fin by coating with oxide material.

### III. SELECTION OF MATERIAL

Yttrium oxide is a conversion oxide coating formed on the metal surface as a result of a chemical reaction of the metal atoms with an oxidizing agent (air, aqueous solution, molten salts). Conversion coating is a film of a chemical compound formed in the reaction of the substrate substance with another substance. This reaction distinguishes conversion coating from a conventional coating applied on the substrate surface without changing its chemical state. Examples of conversion coating are Anodizing and Phosphating (oxide film on the surface of anodically connected metal in an acidic electrolyte solution) and Phosphating (coating consisting of an insoluble) Yttrium oxide coating is used mostly for Carbon steels, Alloy steels, Tool and die steels and Cast irons. Stainless steels and Copper alloys may also be yttrium oxide coated. Yttrium oxide coating of steel is composed of magnetite - ferrous-ferric oxide  $Fe_3O_4$

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(FeO\*Fe<sub>2</sub>O<sub>3</sub>), which is formed as a result of oxidation of iron by Oxygen of air or from oxidizing ions (in aqueous solutions or molten salt.

### 3.1 Chemical Properties of Yttrium Oxide

The chemical properties of yttrium oxide are given in the table below.

Table 1.1 Chemical Properties

Chemical Data	
Chemical symbol	Y <sub>2</sub> O <sub>3</sub>
CAS No	1314-36-9
Group	Yttrium3Oxygen 16
Electronic configuration	YttriumKr4d <sup>1</sup> 5s <sup>2</sup> Oxygen 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>4</sup>
Chemical Composition	
Element	Content (%)
Yttrium	78.7
Oxygen	21.1

### 3.2 PHYSICAL PROPERTIES OF YTTRIUM OXIDE

Yttrium oxide appears in the form of a white powder with spherical morphology.

The physical properties of yttrium oxide are provided in the table below.

Table 1.2 Physical Properties

Properties	Metric	Imperial
Density	5.01 g/ml	0.180 lb/in <sup>3</sup>
Molecular Weight	225.81	-

### 3.3 THERMAL PROPERTIES OF YTTRIUM OXIDE

The following are the thermal properties of yttrium oxide.

Table 1.3 Thermal Properties

Properties	Metric	Imperial
Melting Point	2410°C	4370°F

## IV. METHODOLOGY

### 4.1 Coating

A coating is a covering that is applied to the surface of an object, usually referred to as the substrate. The purpose of applying the coating may be decorative, functional, or both. The coating itself may be an all-over coating, completely covering the substrate, or it may only cover parts of the substrate. An example of all of these types of coating is a product label on many drinks bottles- one side has an all-over functional coating (the adhesive) and the other side has one or more decorative coatings in an appropriate pattern (the printing) to form the words and images.

Paints and lacquers are coatings that mostly have dual uses of protecting the substrate and being decorative, although some artist paints are only for decoration, and the paint on large industrial pipes is presumably only for the function of preventing corrosion.

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## 4.2 SURFACE PREPARATION

Surface preparation is the most important factor in determining the success of any protective coating system. It affects the performance of the coating more than any other variable. In other words, if the surface preparation is poor, coating performance is invariably going to be poor. If the surface preparation is good, then the coating applied over it is likely to perform well.

## V. RESULT AND DISCUSSION

### 5.1 Fin Temperature Test

Table1.4 Test Report

S.NO	VOLTS	AMPS	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>
1	40	0.3	38	35	33	29
2	45	0.36	40	39	36	31
3	50	0.42	41	38	37	33

The above test is taken using the pin fin apparatus. the fin is supplied with currents to create a heat in fin at various places along the fin temperature is measured. In order to calculate the heat transfer coefficient throughout the fin. Through which the efficiency of the fin can be calculated.

### 5.2 Test Result

For ALUMINIUM FIN

1) Reynolds Number (Re):-  
 $Re = (v \cdot m \cdot L_c) / \nu_a$   
 $Re = 2315.3413$

2) Nusselt Number (Nu):-  
 $Nu = 0.615 \cdot Re^{0.466}$   
 $Nu = 22.73$

3) Coefficient of Heat Transfer (h):-  
 $h = Nu \cdot k_{air} / L_c$   
 $h = 119.3836 \text{ w/m}^2\text{k}$

4) Fin Parameter (m):-  $m = \{(h \cdot 1) / (k \cdot A)\}^{1/2}$   
 $m = 5.733$

5) Fin Efficiency:-  
 $\eta = \{\tanh(m \cdot l)\} / m \cdot l$   
 $\eta = 92\%$

For YTTRIUM OXIDE COATED FIN

1) Reynolds Number (Re):-  
 $Re = (v \cdot m \cdot d_{fin}) / \nu_a$   
 $Re = 2412.53$

2) Nusselt Number (Nu):-  
 $Nu = 0.615 \cdot Re^{0.466}$

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$$Nu=24.95$$

3) Coefficient of Heat Transfer (h):-

$$h=Nu*k_{air}/d_{fin}$$

$$h=141.834w/m^2k$$

4) Fin Parameter (m):-

$$m= \{ (h \cdot l) / (k \cdot A) \}^{1/2}$$

$$m=4.65$$

5) Fin Efficiency:-

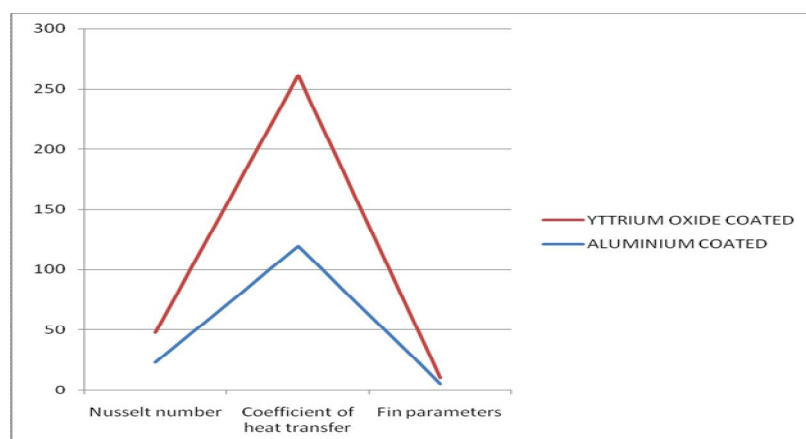
$$\eta= \{ \tanh (ml) \} / ml$$

$$\eta =94\%$$

**Table 1.5 Comparison Between Normal Fin & Coated Fin**

PARAMETERS	ALUMINIUM COATED	YTTRIUM OXIDE COATED
Reynolds number	2315.3413	2412.53
Nusselt number	22.73	24.95
Coefficient of heat transfer	119.3836	141.834
Fin parameters	5.733	4.65
Efficiency	92%	94%

The above comparison table between the normal aluminium fin and yttrium oxide coated shows a good performance result. That the yttrium oxide coating in the fin helps in increasing the heat transfer coefficient and hence the efficiency of the fin also gets increased by coating the fin with yttrium oxide.



**Fig 1.3 Comparison of Normal Fin And Coated Fin**

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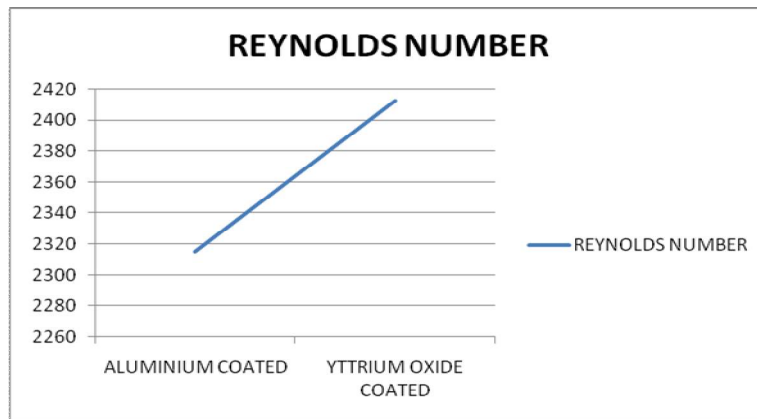


Fig 1.4 Comparison of Reynolds Number

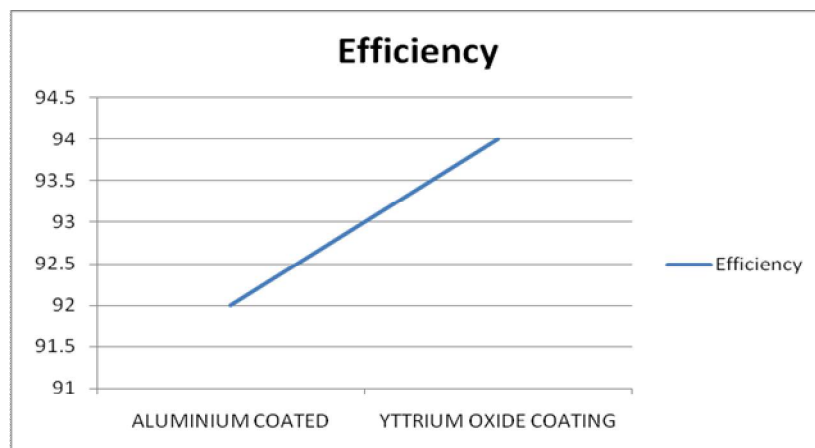


Fig 1.5 Comparison of Efficiency

## VI. CONCLUSION

This work is made with pre planning, that it provides high efficiency than the normal fin. The above result clearly explains that the fin coated with yttrium oxide is more efficient in heat transfer rate compared with the normal aluminium fin. This increase in heat transfer coefficient, that increase the rate of heat dissipation from the fin..So, the efficiency of the fin is increased which directly increases the fin & engine performance. Its also economical to make such kind of yttrium oxide coated fin its does not have any such big disadvantages. Hence implementation of coated fin in bike engine in order to increase heat transfer co-efficient is an good suggestion.

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