Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 06, June-2018

Rig for Testing Thermal Insulating Materials

A Testing Rig with Flow of Hot Air through a Pipe at Controlled Temperatures.

Aditya Parameshwaran.
Bachelors in Mechanical Engineering
Dept. of Mechanical Engineering,
Maharashtra Institute of Technology,
Pune, India.

Under the guidance of
Prof. Pushkaraj D. Sonawane
(Assistant Professor and Project Guide.)
Dept. of Mechanical Engineering,
Maharashtra Institute of Technology,
Pune-411038, India.

Mr. Manish Taxak
Head- Products & Process Development,
L&L Products India Pvt. Ltd.
Chakan, Pune-410501, India.

***Abstract*— The project involved design of a Test Rig for testing of the properties of thermal insulating materials to be used in automobiles that comply with the upcoming EURO-VI pollution control norms. The project was company funded and sponsored by L&L Products India who provided the project team with the necessary technical inputs and funding. This test rig can be effectively used by the company for testing of the insulating capabilities of a wide variety of advanced materials. The test rig has been designed and manufactured in accordance to the requirements given to the project team by L&L Products India Pvt. Ltd.**

The project team designed the test rig using concepts of mass and heat transfer with advanced thermodynamics for the theory-based calculations. The basic design layout and subsequent thermal analysis was done on SOLIDWORKS and ANSYS respectively. ANSYS was also used to carry out computational fluid dynamics analysis of the flow of hot air through the test rig. Assembly design was then achieved with workable sub-assemblies of the components. These subassemblies, which were designed and constructed by the project were individually tested before the rig was finally assembled and tested as an entire system at L&L Products India Pvt. Ltd.

I. INTRODUCTION

Thermal Insulators are designed to protect a component from absorbing excessive heat either by dissipating, reflecting or simply absorbing the heat. In an automobile powered by an internal combustion engine, the engine and related subsystems are the biggest producer of heat. The surfaces of the parts that carry the exhaust gases can reach temperatures in the range of 500°C to 750°C. Since exhausts often pass near important (and thermally sensitive) components, it is especially important to protect the sensitive parts and modules from heat soak, but also to prevent local overheating of the car body. Thermal insulation protects components within the engine bay. The turbo blanket isolates the heat produced by your turbocharger, and prevents that heat from damaging, or even igniting, components surrounding the turbocharger within the engine compartment, such as plastic and rubber hoses and electrical wiring, as well as painted surfaces, such as the engine bay and the surface of the hood. Also, it prevents areas of localized high temperature from damaging the engine itself. For example, a common cause of head gasket failure in turbocharged vehicles is localized heating of a portion of the engine. The heat differential between the portion of the engine near the turbocharger and the rest of the engine can cause warping of the head, and thus, head gasket failure.

Thermal insulation improves the performance of the turbocharger. In keeping the exhaust gases within the turbocharger hot, turbocharger efficiency is improved. The hotter a gas is, the more expansive it is. Within a contained system of a specified size, the more expansive a gas is, the greater the pressure derived and thus, the greater the flow of gas to escape the containment. With this increased pressure and flow rate for a given engine RPM, the acceleration of the turbocharger's impeller is increased as compared to the same turbocharger with the engine at the same RPM but with cooler exhaust gases. This equates to faster spool up of the turbocharger, as well as greater attainable levels of boost. What a driver will experience with a turbo blanket is greater turbocharger responsiveness. The faster spool up of the turbocharger means less turbo lag and a more linear power curve.

It is also very important to keep engine intake air cool. Therefore, intercoolers are often utilized with turbochargers. Like above, the cooler a gas is (such as intake air), the denser it is. The denser the intake air, the more oxygen it contains per unit volume. The more oxygen reaches the engine, the more power can be obtained. In keeping the heat of the exhaust gases contained within the hot side of the turbocharger and away from the cool side of the turbocharger and the intake path, more oxygen per unit volume reaches the engine, and thus, more power.

II. LITERATURE REVIEW

A. Basics of Mass and Heat Transfer

In heat transfer problems, we often interchangeably use the terms heat and temperature. There is a distinct difference between the two temperature is a measure of the amount of energy possessed by the molecules of a substance.
It manifests itself as a degree of hotness and can be used to predict the direction of heat transfer. The usual symbol for temperature is T. The scales for measuring temperature in SI units are the Celsius and Kelvin temperature scales.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 06, June-2018

Heat, on the other hand, is energy in transit. Spontaneously, heat flows from a hotter body to a colder one. The usual symbol for heat is Q. In the SI system, common units for measuring heat are the Joule and calorie

Thermodynamics tells us:
• The amount of heat transferred (dQ)
• The amount of work done (dW)
• Final system state.

B. Material literature review

Kanthal A-1 resistance wires

The material used for resistance coils is *Kanthal A-1* and the coils are strategically placed in a hollow cuboidal shaped grid structure, in line with the air flow to maximise heat exchange between the coils and air. *Kanthal A-1* is a ferritic iron-chromium-aluminium alloy (FeCrAl alloy) for use at temperatures up to 1400°C (2550°F). The alloy is characterized by high resistivity and very good oxidation resistance.

Cordierite Grid Structure

The cuboidal shaped grid structure is made from a ceramic called *Cordierite*, which has extremely high thermal shock absorption properties as well as can withstand temperatures up to 1300⁰C. *Cordierite* is also relatively light weight and can be easily carved into grid structures due to its highly brittle nature. This also ensures that there is very less thermal expansion of the grid size due to the extreme heat generated within. The ceramic has good insulating properties thus limiting heat losses to a minimum level.

Stainless Steel Pipe

A replica of hot air flow system in automobiles has been recreated using heat-source through which air passes under pressure and expands like in actual working environment in a vehicle. To design the required, we decided on using a stainless-steel pipe. Stainless steel pipe the steel contains both chromium (between 18–20%) and nickel (between 8–10.5%) metals as the main non-iron constituents. It is an austenitic stainless steel. It is less electrically and thermally conductive than carbon steel and is essentially non-magnetic. It has a higher corrosion resistance than regular steel and is widely used because of the ease in which it is formed into various shapes.

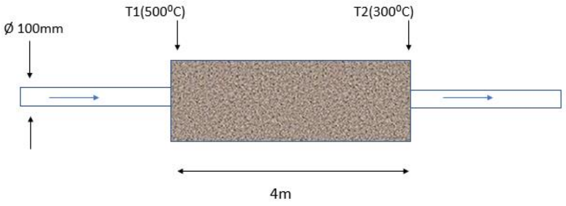
Objectives:

- Design a test rig to observe the temperature variations in a 4m long pipe when subjected to high temperature conditions.
- Maintain consistent temperature of 500 degree Celsius in the section.
- Temperature verification at every 0.5m and wherever necessary.
- Find new materials that could help improve the performance of next generation engines

Design Calculations:

C. Calculations of system pressure and power rating

- <u>Known parameters</u>



Nozzle Diameter (inches)	0.5
Nozzle Diameter (cm)	1.27
Pipe Diameter (inches)	4
Pipe diameter (cm)	10.16
Input Pressure	5.546 bar

Maximum temperature achieved	500˚C
Maximum temperature achieved (degree Fahrenheit)	932˚F

- <u>Calculated values</u>

Area of Nozzle(cm2)	1.27
Area of Heating Unit cross-section (cm2)	81.07

- <u>Input parameters</u>:

System pressure (Before subjected to Heat source)	0.109 bar
Flow in CFM	43
Flow in SCFM	45
Input Temperature	38˚C
Input Temperature (degree Fahrenheit)	101.4˚F

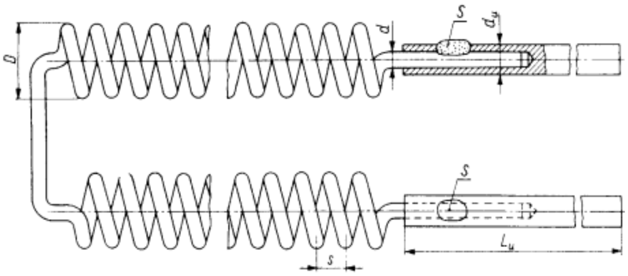
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 06, June-2018

- Power input (kW) = (SCFM*ΔTf)/3193

  Calculated power input = 14.98 kW

  = 15 kW (approx.)

Design of Heating unit



. Resistance R of a (single) heating element:

On the one hand

$$R = \frac{U^2}{P_1}, \quad (1)$$

where

$$P_1 = \frac{P}{3}$$

is the power of one heating element.

On the other hand

$$R = \frac{\rho l}{S} = \frac{\rho l}{\frac{\pi d^2}{4}} = \frac{4 \rho l}{\pi d^2} \quad (2)$$

where,

ρ =resistivity of the Kanthal A-1

A=1 wire at its maximum temperature

l = length of the wire

d = diameter of the wire

S = cross-section of the wire

Comparing (1) and (2) length l and diameter d of the wire can be computed.

4.1.2. Heating element surface load

Surface load po, of a heating element (W/m2) is determined by

$$p_o = \frac{P_1}{A_o} = \frac{P_1}{\pi d l} \quad (3)$$

where

$$A_o = \pi d l \quad (4)$$

. Determination of the wire length

$$l = \frac{\pi d_z^2 U^2}{4 \rho P_1} \quad (6)$$

Determination of the spiral heating element diameter (D)

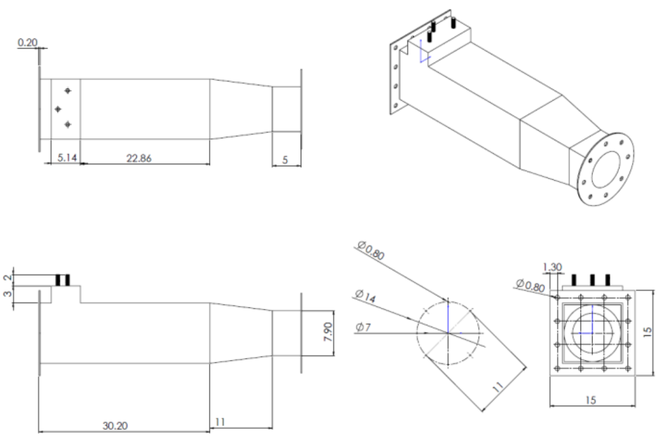
$$D = (5 \div 7)\, d_z \quad \text{- for } d_z > 1 \text{ mm} \quad (7a)$$

$$D = (4 \div 10)\, d_z \quad \text{- for } d_z < 1 \text{ mm.} \quad (7b)$$

Final Calculated Values:

Sr. No.	Variable	Dimension
1	Power Input	15000 Watts
2	Voltage	415 V
3	Resistance	34.445 Ω
4	Resistivity	$1.4645 * 10^{-6}\ \Omega - m$
5	Surface Load Factor	$8 * 10^4 \frac{W}{cm^2}$
6	Wire diameter	1.025 mm
7	Coil Outer Diameter	9.5mm
8	Length of wire	1357mm
9	Length of coil	150mm
10	Pitch of coil	1.94mm

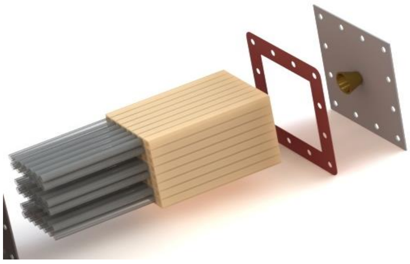
Heating Unit



Line diagram of the Air Heating Unit system.

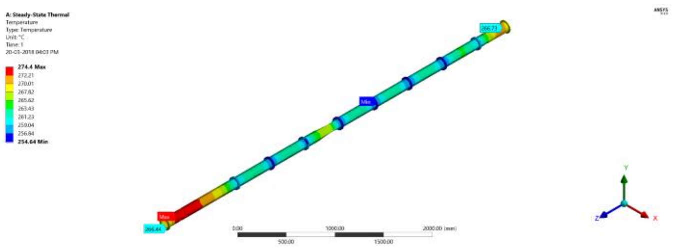
CAD Model of the Internal Layout of the Heating unit

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 06, June-2018



D Thermal Analysis

A thermal analysis was carried out on Ansys to determine the temperatures at the pipe surface when not wrapped in an insulating material. A tetrahedron mesh was used with 9845 nodes and 4553 elements. The internal air temperature and pressure was set as 500 degrees Celsius and 5 bars respectively. The ambient temperature was assumed to be 20 degrees Celsius. The material properties and the temperature are shown in figure.



The analysis result showed the maximum pipe temperature to be 266.73 degrees Celsius and a minimum temperature of 254.64 degrees Celsius.

TESTING

The compressor outlet was connected to the back plate of the heating unit, and air flow and pressure were checked keeping the heater switched off. The pipe and heater were checked for air leakages.

Reference Temperature	550˚C
Blind Temperature	70˚C
Time from Start	15 minutes
T1	514˚C
T2	450˚C
T3	417˚C
T4	379˚C
T5	325˚C
T6	295˚C
T7	264˚C
T8	226˚C
Inlet Air Pressure	6.5 bar

CAD model of testing rig with thermocouples inserted at regular intervals of 500mm through the pipe to measure the temperature of hot air flowing through the pipe.

In the above observations,
T1=Temperature of air at heater outlet
T2 to T8= Temperature of air in pipe at every 500mm distance
Time taken to reach stable temperatures is referred to as 'Time from start'.
These values of temperature drop over the length of the pipe is without the use of any thermal insulation used to cover the pipe's outer surface.

CONCLUSION

The project involved design of a test rig to test the properties of thermal insulating materials to be used in automobiles - the requirement was part of the larger aim of design and subsequent support on meeting of EURO VI pollution control norms. The project was designed using concepts of mass and heat transfer with advanced thermodynamics for the theory-based calculations. The basic design layout and subsequent thermal analysis was done on SOLIDWORKS and ANSYS respectively. ANSYS was also used to carry out computational fluid dynamics analysis of the flow of hot air through the test rig. Assembly design was then achieved with workable sub-assemblies of the components. These subassemblies, which were designed and constructed by the project team were individually tested before the rig was finally assembled and tested as an entire system.

An air temperature of 514˚C was achieved in the pipe within a starting period of 15minutes. The temperatures at every 500mm distance was observed and recorded. Depending upon the reference temperature selected, the time required for attaining a stable temperature was between 10 minutes to 15 minutes. Higher the temperature selected, greater the amount of time required to reach the point of stability. The test rig is installed at L&L Products India Pvt. Ltd. The test rig has since undergone successful commissioning at L&L Products India Pvt. Ltd. for their internal purposes, thus making the project a success.

REFERENCES

[1] *Hering M Podstawy elektrotermii cz.I, WNT, Warszawa 1992. KANTHAL datasheet.
[2] L&L Products India Pvt Ltd. Team Inputs towards:
- Selection of Materials and laying down the concept.
- Support in creating Line Diagram and schematics references.