KARMAVEER DADASAHEB KANNAMWAR COLLEGE OF ENGINEERING
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CERTIFICATE

This is to certify that Mr. Brijendra Singh Bhaskar has presented a Pre Submission seminar before the expert committee on 29/03/2017 on the topic titled: **"EXPERIMENTAL OPTIMIZATION OF HEAT TRANSFER THROUGH POROUS MATERIAL HEAT EXCHANGER"** in the DEPARTMENT OF MECHANICAL ENGINEERING, in the faculty of Engineering and Technology, Rashtrasant Tukdoji Maharaj Nagpur University, Nagpur, in compliance with the requirements of direction No. 29 of 2012.

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ABSTRACT

The aim of this study was to optimize heat transfer through porous material heat exchanger. After reviewing literature about porous materials, aluminum foam was identified as the most promising material for use in heat exchanger. There are wide applications of Aluminium metal foam. Traditional practices for liquid to air heat exchangers rely predominantly on different finned surfaces to enhance heat transfer rate. Heat transfer enhancement in these designs is achieved via an increased surface area of simple geometries. Advancement in manufacturing technology led to development of porous materials, for possible utilization in heat transfer equipment's to improve thermal performance and compactness.

The planning for experimentation was carried out and the classical plan of experimentation was used. Then began the search for suppliers of aluminum foam panels; after exploring various manufacturers of metal foam such as M-pore, Germany, Mitsubishi Corporation Japan, K. R. Reynolds Company USA supplier of ERG Aerospace supplied the foam sample. The samples of 20 PPI was imported. The PPI was selected from the mid range of available sizes. The size of sample imported was 101mm X 101mm X 10mm. Then the search began for aluminum tubes which can be used in the heat exchanger. Since the thickness of foam sample was only 10 mm, it was not possible to fabricate the heat exchanger with aluminum tube of 6mm diameter, then it was decided to fabricate the heat exchanger with 9.5 mm diameter tube and same will be sandwiched between two foam panels. Another sample of foam was imported for this. In the experimental study, heat exchanger was fabricated using aluminum tubes sandwiched between the semicircular groves of two aluminum foam panels. The aluminum tubes were connected to common inlet and exit headers. The heat exchanger was fabricated with single pass arrangement and the study was conducted experimentally. For conducting the performance analysis, wind tunnel was required; after referring literature, it was decided to fabricate the wind tunnel, and was fabricated using Plexiglas sheet. The idea of wind tunnel fabrication was taken from reference number [108]. Inlet section was provided with a flow straightner to reduce hydrodynamic entry length; and fully developed laminar flow of fluid as it reaches the heat exchanger. The water was used as the hot fluid and air as the cold fluid. The hot fluid was

CHAPTER-7

CONCLUSION AND FUTURE SCOPE

In this study, heat transfer performance of porous material (aluminum foam) heat exchanger was experimentally obtained using classical plan of experimentation. Porous mater used was aluminum foam imported from ERG Aerospace Corporation. During the experiments, the values of inlet/outlet temperature of cold fluid, inlet/outlet temperature of hot fluid, air velocity and pressure loss between inlet and exit of heat exchanger were measured keeping the hot fluid mass flow rate constant.

a) The thermal performance was measured using the experimental data, Reynolds number, Prandtl number and Brickman number was calculated and finally Nusselt number was calculated.

b) Friction factor was calculated using Pressure drop data.

c) The thermal efficiency of heat exchanger was investigated using effectiveness-NTU calculations.

d) The pumping power was calculated for selecting optimum balance between economy and efficiency of the heat exchanger.

The calculated results are presented graphically in chapter 6 using Figure 6.1 to Figure 6.19.

V. V. Calmidi and R. L.Mahajan [24] studied Forced Convection in High Porosity Metal Foams for foam samples having PPI 5, 10, 20 and 40, the results for 20 PPI sample. The Nusselt number was found to be in the range of 4-10 and at Reynolds number 19-83 for 20 PPI foam sample.

The work of Gyles e.t. al. [40] for tube bundles in staggered and aligned configuration shows that in the velocity range of 0.2-1.2 m/s, the heat transfer coefficient is in the range of 350-1350. It clearly shows that the value if heat transfer coefficient for aluminum foam heat exchanger is higher i.e. h=1999.08 w/m^2-K than tube bundles in different arrangements. The lower value of heat transfer coefficient h= 8.021 W/m^2-K is found to be very low, mainly due to higher pressure drop in foams.

Jiang et al [48] performed experiments on micro porous heat exchanger and found that the effectiveness of micro porous heat exchanger lies between 0.57-0.65 for NTU range of

CERTIFICATE

This is to certify that the research work presented in Ph.D. thesis entitled "***Failure Analysis of Primary Suspension Spring of Rail Road Vehicle***", is the own work of **Mr. Manoj A. Kumbhalkar** conducted in the Department of Mechanical Engineering, Karmavir Dadasaheb Kannamwar College of Engineering, Nagpur under our supervision. We further certify that this work has not been submitted earlier in any University or Institution for any research degree to the best of our knowledge.

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ABSTRACT

Springs are subjected to cyclic load and failures are not uncommon. However, the high rate of failure of the specific spring in the composite assembly calls for the investigation. WAG-9 type electric rail vehicle, of Indian Railways' fleet used for goods train hauling and maintained at Ajani, Nagpur Electric Loco Shed of central railway has a history of frequent failure of middle axle primary inner suspension spring. The study of failures revealed that, this specific component fails at a very high rate.

The failure investigation starts the experimental spectroscopy analysis to find chemical composition for different failed specimens of springs and it is observed that all parameters are within the recommended range. Also the stiffness of primary middle axle and end axle suspension springs has been checked on spring testing machine to measure deflection of spring and it is as per recommended values. Further static stress analysis is carried out using analytical and finite element analysis for various phases of operation of rail vehicle like straight track, curved track and also for tractive effort. The static stress analysis has not revealed the cause of failure and hence the dynamic analysis is performed.

For dynamic analysis, dynamic model of suspension system is considered and analyzed using analytical method, finite element method and using MATLAB Simulink model. The vibration response of actual suspension system is also measured using FFT analyzer. It has been seen that, the frequency of excitation and the natural frequency of the system are very close to each other which has resulted into suspension vibration amplitude of 6 mm to 8 mm.

Fatigue analysis is carried out using finite element method to investigate the effect of dynamic loading on the failures of suspension spring. This analysis revealed that the middle axle inner suspension spring has finite life and due to which spring failure occurs earlier.

To avoid these failures some modifications are suggested in the suspension system and one of them is incorporated by Electric Loco Shed, Ajni, Nagpur and it is observed that failures of middle axle primary inner suspension spring are reduced by 88%. This modification is also incorporated by other loco sheds and the results are encouraging.

CHAPTER 6

CONCLUSIONS AND FUTURE SCOPE

6.1. CONCLUSIONS

From the detail static, dynamic and fatigue analysis of primary suspension spring, the conclusions of research work are as follows.

- The experimental spectroscopy analysis ensured the chemical composition of spring material as per recommended ranges and experimental spring stiffness measurement using spring testing machine for all primary suspension springs yielded the recommended stiffnesses and hence the cause of failure is not attributed to material composition and design specifications of suspension spring.
- The static stress analysis carried out for the three cases i.e. straight track, curved track and tractive effort has resulted the induced stress values well below the yield stress values and hence, it could not reveal the cause of failure.
- The dynamic analysis performed on dynamic model of suspension system revealed the natural frequency, excitation frequency and amplitudes. Due to closeness of natural frequency with excitation frequency, the amplitude of vibration is observed to be more than excitation amplitude which resulted in variable displacement and spring force. This has been also verified from the polished damper marks observed on the damper.
- The fatigue analysis reveals that, the middle axle inner suspension spring has a finite life of 1.89×10^4 cycles which clearly indicates that the spring fails because of fatigue failure with crack initiation at inside diameter. This has been confirmed from the observation of cross section of the actual failed spring.
- To reduce the failure rate of inner suspension spring and hence to increase its fatigue life, four types of design modifications are suggested as follows.

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Forwarded herewith the thesis entitled **"EXPERIMENTAL OPTIMIZATION OF HEAT TRANSFER PERFORMANCE IN HEAT EXCHANGER BY USING NANOFLUID"**, submitted by **Prashant B. Maheshwary** under the guidance of **Dr. C. C. Handa**, Professor & Head, Mechanical Engg. Department, K D K College of Engineering, Nagpur in the fulfillment of the requirement for the award of the degree of Doctor of Philosophy in the faculty of Engineering and Technology (Mechanical Engineering), Rashtrasant Tukadoji Maharaj, Nagpur University, Nagpur.

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ABSTRACT

It is revealed after rigorous literature survey that, first time comparative experimental study is carried out to see the effect of concentration, shape and size of five different metal oxide nanoparticles (Al_2O_3, TiO_2, MgO, CuO, and ZrO_2) in the context of thermo-physical properties like thermal conductivity, viscosity, density, pumping power etc in general and heat transfer performance of a heat exchanger in particular. Here, a standard experimental setup Two Wire (hot) Method is used.

I) Detailed experimental study was performed to investigate the effect of concentration, particle size and shape on thermal conductivity of Al_2O_3-water, TiO2-water, MgO-water, CuO-water and ZrO_2-water based nanofluids. In this work, nanofluids were prepared by two step method in water using probe sonicator. All these nanofluids are prepared at 0.5-2.5 Wt. % of concentration with an interval of 0.5 Wt. % and its thermal conductivity was measured in the temperature of range 303-353 K. The increase in thermal conductivity is noticed with concentration of all nanofluids. Further, the thermal conductivity is increased by reducing particle size of Al_2O_3, TiO2, MgO, CuO and ZrO_2 in nanofluids using probe sonication process. Moreover, increase in thermal conductivity is also achieved by changing the shape of Al_2O_3, TiO2, MgO, CuO and ZrO_2 nanoparticles.

The cubic shape, 2.5 Wt. % concentration and 60 minutes probe sonicated Al_2O_3-water based nanofluid indicated highest thermal conductivity. This study concludes that out of all three parameters (concentration, particle size and shape), concentration has significant effect on the thermal conductivity of Al_2O_3-water, TiO2-water, MgO-water, CuO-water and ZrO_2-water based nanofluid.

II) In-house heat exchanger (radiator) is developed as another experimental set up to gather experimental data base by conducting the experimentation. Experimentation here, also studies the influence of three independent parameters that is concentration, shape and size of nanoparticles.

The influence of the parameters on thermal conductivity of the nanofluid is studied experimentally by performing more than 600 tests.

CHAPTER - 8

CONCLUSIONS AND FUTURE SCOPE

8.1 Introduction

The data generated and collected during experimentation has been converted to interpretable form and this interpretable data has been analyzed to draw some logical results for useful conclusions. Results are discussed in previous chapter.

It is revealed after rigorous literature survey that, first time comparative experimental study is carried out to see the effect of concentration, shape and size of five different metal oxide nanoparticles (Al_2O_3, TiO_2, MgO, CuO, and ZrO_2) in the context of thermo-physical properties like thermal conductivity, viscosity, density, pumping power etc in general and heat transfer performance of a heat exchanger in particular. Here, a standard experimental setup Two Wire (hot) Method is used.

Experimental setup with heat exchanger (radiator) was developed to study the influence of three independent parameters i.e. concentration, shape and size of nanoparticles. A generalized approximate optimized empirical equation developed establishes the effect of independent parameters i.e. concentration, shape, size, etc. on response variables ΔT, Q and h

Though generally the chapter of conclusion do not cover the tables of the analysis work, but looking to the exhaustive and bulky contents of Chapter no 6 (Results and Analysis) and 7 (Formulation of Mathematical Model) comparative tables are added with the conclusion for easy understanding, this may kindly be understood.

Based on the results, graphs, mathematical models and the analysis of results, the following conclusions can be drawn:

1. After following above three approaches, it is observed that the results converge to the same conclusion as established by Two Wire (hot) Method. That is, Al_2O_3/W naofluid has highest thermal conductivity followed by TiO_2, ZrO_2, MgO and CuO. Also concentration of nanoparticles has the highest impact on increasing the