

Experimental Analysis of Exhaust Manifold with Ceramic Coating for Reduction of Heat Dissipation

Saravanan J¹, Valarmathi T N^{*2}, Rajdeep Nathc³, Prasanth Kumar⁴

¹PG student, Department of Mechanical & Production Engineering, Sathyabama University, Chennai.

²Professor, Department of Mechanical & Production Engineering, Sathyabama University, Chennai.

^{3,4}UG students, Department of Mechanical & Production Engineering, Sathyabama University, Chennai.

*Email id: valarmathi.tn@gmail.com

Abstract. Exhaust manifold plays an important role in the exhaust system, the manifold delivers the waste toxic gases to a safe distance and it is used to reduce the sound pollution and air pollution. Exhaust manifold suffers with lot of thermal stress, due to this blow holes occurs in the surface of the exhaust manifold and also more noise is developed. The waste toxic gases from the multiple cylinders are collected into a single pipe by the exhaust manifold. The waste toxic gases can damage the material of the manifold. In this study, to prevent the damage zirconia powder has been coated in the inner surface and alumina (60%) combined with titania (40%) has been used for coating the outer surface of the exhaust manifold. After coating experiments have been performed using a multiple-cylinder four stroke stationary petrol engine. The test results of hardness, emission, corrosion and temperature of the coated and uncoated manifolds have been compared. The result shows that the performance is improved and also emission is reduced in the coated exhaust manifold.

1. Introduction

The exhaust manifold is used in a multiple cylinder IC engine which collects the exhaust gases from the cylinders into one pipe. During working it dissipates heat and emits harmful undesirable substances like noxious or toxic. Many research works like better change in design, coating, etc. are carried out to reduce these effects to increase the performance of the engine.

Azadiet al [1]performeda review of thermal barrier coating applications in diesel engines to select a proper type and to find coating effects. The coating system has effects on the fuel consumption, the power and the combustion efficiency, pollution contents and the fatigue lifetime of engine components. Durga Prasad et al [2] designed an exhaust manifold with different coatings and analyzed with modelling and finite element methodology techniques. Gopaal and Kumara Varma [3] used finite element analysis technique to reduce the design difficulties of exhaust manifold and concluded that the design made by them is safe and effective. Kandylas and Stamatelos [4] used mathematical modeling



and CFD software to analyze the heat transfer in the exhaust manifold. Mahesh S Vasavan and Jotaniya [5] presented a detailed review on heat transfer analysis in automotive exhaust system. Mouna Challa and Imran Quraishi [6] explained the selection of advanced material using CES software for exhaust manifold based on the benefits and also suggested new manufacturing methods like deformation process, investment casting process, etc. for the exhaust manifold using new materials. Navaneethakrishnan and Vasudevan [7] investigated the performance, emission characteristics of a single cylinder four stroke direct injection diesel engine operating on biodiesel. After comparison they revealed that blends of TME, DEE with diesel up to 20% and 20% by volume provide better engine performance (BSFC and BTE) increased up to 3-4% and the exhaust emission is decreased dramatically. Prabhat Kumar Jha et al [8] carried out experimental studies to reduce the exhaust gas temperature and gas emissions of a Spark Ignition (SI) engine by injecting water in the intake manifold gives better results. Serkan Saridag and Onjen Tak [9] investigated the mechanical properties of zirconia in the scientific literature and revealed that zirconia clearly measures up to any other equivalent manufactured material.

2. Materials and methods

2.1. Specimen preparation for coating

The waste exhaust gases corrode the manifold material due to this some blow holes will occur and noise pollution will increase. In order to avoid these type of failure, in this work some ceramic powders are used on both inner surface and outer surface of the cast iron exhaust manifold. The inner surface of the cast iron exhaust manifold is coated by zirconia powder to arrest the temperature in inside itself this will reduce the heat dissipation. The outer surface of the cast iron exhaust manifold is coated by alumina and titania in the combination range of 60% - 40%. The coated and uncoated manifold which is used for this work is shown in Figure 1 (a) and (b) respectively. The coating is performed using plasma spray technique. The coating for the cast iron exhaust manifold is done by using plasma spray coating technique for a thickness of 250 μm .



Figure 1.(a) Coated (b) Uncoated exhaust manifold

2.2. Experimental setup

A multiple-cylinder four stroke stationary petrol engine has been used to conduct the experiments. The experimental setup is shown in Figure 2. Infrared thermometer testing machine is used to analyse the temperature of the manifold. And the readings of temperature have been taken. Emission test has been carried out using automotive emission analyzer testing machine. In this experiment the loads used are varying load which varies from 15 to 45N loads. After the load is applied the engine reaches a steady condition at a particular point, during this particular point the readings such as time taken for 20cc fuel consumption, outer surface temperature, inner surface temperature, HC, CO and NO_x are taken.



Figure 2.Experimental setup

3. Results and Discussion

3.1. Microstructure studies

Properties of the coated specimen using plasma spray process were analyzed by using SEM and EDX. The coating thickness achieved is in the order of 125μ . Optimum compositional and structural conditions of the coating component have been analyzed. The micro graph of the fracture surface of the uncoated and coated cast iron specimen samples is shown in Figure 3. The structure exhibited particles of both materials were deformed on impact during the plasma spray and melted on the specimen surface is shown in the Figure 3(c). From the microstructure images it is observed that the grain particles size is less for coated cast iron specimen when compared with a cast iron specimen without coated.

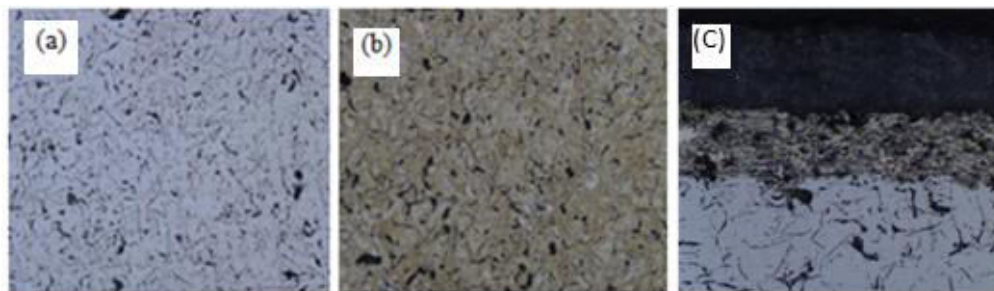


Figure 3.Microstructure of (a) Uncoated (a) polished (b) etchedand (c) Coated cast iron specimens

3.2 Hardness test

In this work specimens have been prepared to test the hardness of both coated and uncoated cast iron material. Vickers hardness test has been carried out for testing the hardness of the specimens shown in Figure 4. The results are presented in Table 1. From the results it is observed that coated cast iron specimen is giving the best results.



Figure 4. Coated specimens used for hardness test

Table 1 Results for the hardness test

Trail No.	Hardness values	
	Coated	Uncoated
1	89	84
2	90	85
3	89	84

3.3 Corrosion test

In this project salt spray test is used for testing the corrosion of a specimen. The salt spray test is a standardized and popular corrosion test method, used to check corrosion resistance of materials and surface coatings. Usually the materials to be tested are metallic and finished with a surface coating which is intended to provide a degree of corrosion protection to the underlying metal. The results are presented in Table 2. Input parameters considered for salt spray process is listed below

- Chamber temperature: 34.5 - 35.5 °C
- pH value : 6.65 - 6.85
- Salt solution collected : 1.0 – 1.5 ml/hr
- Concentration of solution : 5% Nacl
- Air pressure : 14 – 18 Psi
- Component loading in chamber position: 30 ° angle.

Table 2. Results of corrosion test

Time	Rust formation	
	Uncoated	Coated
After 12 Hrs	White rust	No rust

3.4 Emissions test

Automotive emission analyzer is used to measure the gas emission density. It is a five-gas analyzer, which can detect five gases viz. CO, HC, CO₂, O₂ and NO_x emitted during the test. It also gives air - fuel ratio and air surplus rate. It gives accurate and instantaneous results especially when compared to the similar commercially available equipment. The emission testing machine is shown in the Figure 5.



Figure 5. Emission indicator set up

3.5 Effect of temperature

The performance and characteristics of the coated and uncoated cast iron exhaust manifold has been performed in the multi- cylinder engine. The outer surface temperature in the manifold is measured by the infrared thermometer testing machine. The inner surface temperature is measured by the thermocouple. The surface temperature obtained for both outer and inner coated and uncoated cast iron exhaust manifold at various load conditions have been compared and presented in Figure 6. It is observed that the use of coated surface reduces the temperature developed when compared to the use of uncoated surface. It is observed that the use of coated surface reduces the temperature developed when compared to the use of uncoated surface. From the temperature study it is asserted that the zirconia coated exhaust manifold arrest the temperature when compared to uncoated exhaust manifold. So this results show that heat dissipation is decreased in the coated exhaust manifold.

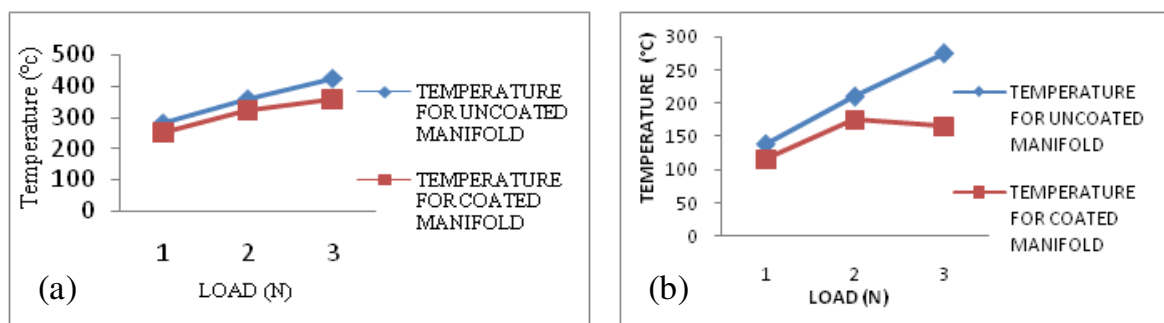


Figure 6. Comparison of (a) outer and (b) inner surface temperature

3.6 Effect of emission of NO_x and CO

The comparison of nitrogen oxide emission from the waste exhaust gases for both coated and uncoated cast iron exhaust manifold is presented in Figure 7(a). From Figure it is observed that the emission of NO_x is less in coated manifold specimen. The comparison of carbon monoxide emission from the waste exhaust gases for both coated and uncoated cast iron exhaust manifold is presented in Figure 7(b). From Figure it is observed that the emission of CO is less in coated manifold specimen.

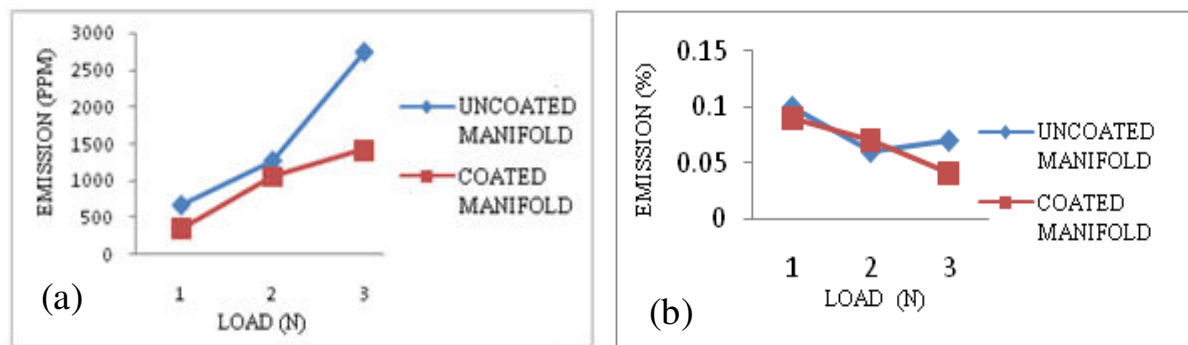


Figure 7. Comparison of (a) NOx and (b) CO emission for both coated and uncoated manifold

4. Conclusion

Based on the experimental results it is concluded that

- The surface temperature, carbon monoxide emission and nitrogen oxide emission is minimized by coating the exhaust manifold at rated load.
- Hardness is increased in the coated manifold.
- No rust formation in the coated manifold.

Finally it is concluded that the coated cast iron gives better performance than the uncoated cast iron exhaust manifold.

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