Sakthivel et al. 2015. *Int. J. Vehicle Structures & Systems*, 7(4), 132-135
ISSN: 0975-3060 (Print), 0975-3540 (Online)
doi: 10.4273/ijvss.7.4.02

International Journal of Vehicle Structures & Systems
Available online at www.maftree.org/eja

Effect of Catalytic Coatings on the Performance, Emission and Combustion Characteristics of Spark Ignition Engines

P. Sakthivel[a,b], N. Nedunchezhian[c] and P. Ponnusamy[a]

[a]*Dept. of Mechanical Engg., Surya Engg. College, Erode, Tamilnadu, India*
[b]*Corresponding Author, Email: sakthitn59k9061@gmail.com*
[c]*Dept. of Automobile Engg., Institute of Road and Transport Technology, Chithod, Tamilnadu, India*

ABSTRACT:

This study discusses the effect of copper, nickel and chromium coating on the spark ignition engine performance, emission and combustion characteristics. The maximum brake thermal efficiency for copper coated engine is about 5% higher than standard engine at full load and about 4% higher than the standard engine at 2800 rpm. Nitrogen oxides emission for catalytic coated engine is 7% to 20% higher than standard engine at full load. It was observed that carbon monoxide and carbon dioxide emissions of standard engine were higher than catalytic coated engines at all loads. Copper coated engine has the lowest hydro carbon emission. Catalytic coated engines have 6% to 12% higher cyclinder pressure when compared to the standard engine. The crank angle of heat release values and combustion parameters indicate that a faster heat release occured for catalyst coated engines. Similarly combustion duration of standard engine is higher than that of catalytic coated engines. Catalytic coatings increase the pre-flame reactions which lead to better and faster combustion.

KEYWORDS:

Spark ignition engine; Catalytic coatings; Emission control; Brake thermal efficiency; Heat release rate

CITATION:

P. Sakthivel, N. Nedunchezhian and P. Ponnusamy. 2015. Effect of Catalytic Coatings on the Performance, Emission and Combustion Characteristics of Spark Ignition Engines, *Int. J. Vehicle Structures & Systems*, 7(4), 132-135. doi:10.4273/ijvss.7.4.02

1. Introduction

The operation of internal combustion engines results in the emission of hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx) and particulate matters. The actual concentration of these pollutants varies from engine to engine, mode of operation and is strongly related to the type of fuel used. Various emission control technologies exist for internal combustion engines, which can offer substantial reductions in pollutants. However, depending on whether the engine is run on rich stoichiometric air fuel ratio, the targeted emissions vary depending up on the levels of control. Lean mixture is one of the promising method for reducing emissions and improving fuel economy in spark ignition engines. The problems associated with lean combustion in engines are increased the cyclic variation of combustion, reduced power output, difficulty in starting, erratic combustion and misfire[1]. Among different available methods, catalytic activation offers a simple and effective solution. Cenk et al [2] have done detailed experimental work to compare the catalytic activation of 8 metals and found out that platinum and copper showed better performance [3]. Number of researchers have undertken detailed analysis of catalytic combustion.

This study aims to select a best non-noble metal catalytic coating material for coating over the piston top and cylinder head in four-stroke spark ignition engine. Their emission and combustion characteristics of catalytically activated spark ignition engine were determined for different catalysts and their performances were compared.

2. Materials and methods

The performance parameters, emission and combustion characteristics of catalytically activated spark ignition engine studies were conducted on an air-cooled, vertical, naturally aspirated, stationary, four stroke, spark ignition single cylinder engine with a displacement volume of 197 cc, compression ratio of 4.5:1 and with a power output of 2.28 kW at 3000 rpm. In this work, experiments were conducted in the speed range of 2200 rpm to 3000 rpm. The engine is coupled with an eddy current dynamometer (20 kW) for loading. The fuel flow rate was measured using gravimetric system. The exhaust emissions were measured using AVL make gas analyzer. The in-cylinder pressure was measured with the help of pressure transducer, which was flush mounted into cylinder head and the corresponding crank angle position was obtained by crank angle encoder.

3. Results and discussion

3.1. Performance study

The catalytic coated engines were evaluated for performance characteristics at maximum load and speed from 2000 rpm to 3000 rpm. The results of engine performance, emission and combustion data for both standard and catalyst engine were discussed in the following sections. The brake thermal efficiency vs. load was shown in Fig. 1. It was found that the brake power increases with increase in brake thermal efficiency[4]. The maximum brake thermal efficiency found were 25.12% for copper, 23.85% for chromium, 21.31% for nickel and 20.03% for standard. The brake thermal efficiency of standard engine is slightly higher for initial loads up to 0.9 kW and then catalytic coated engine shows better brake thermal efficiency. The maximum brake thermal efficiency for Copper coated engine is about 5% higher than the standard engine. For other catalytic coatings like chromium and nickel, the maximum brake thermal efficiency were 3.8% and 1.28% higher than that of standard engine Fig. 2 shows the difference in specific fuel consumption with brake power. The fuel consumption of the standard engine varies from 0.791 kg kW^{-1} hr^{-1} at low load to 0.374 kg kW^{-1} hr^{-1} at full load. For copper coated engine, it varies from 0.802 kg kW^{-1} hr^{-1} at low load to 0.298 kg kW^{-1} hr^{-1} at full load. It was observed that specific fuel consumption varies from 0.836 kg kW^{-1} hr^{-1} at low load to 0.314 kg kW^{-1} hr^{-1} at full load for chromium and nickel coating respectively.

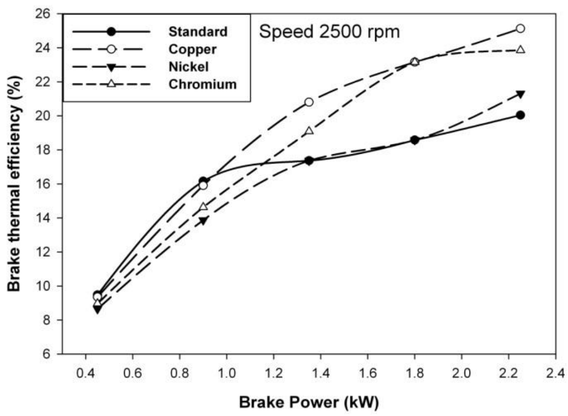

Fig. 1: Variation of brake thermal efficiency with brake power

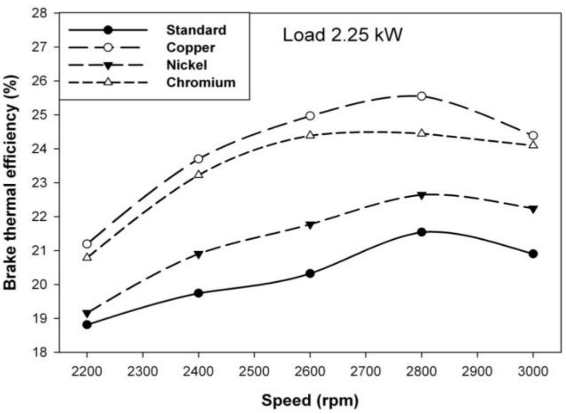

Fig. 2: Variation of specific fuel consumption with brake power

3.2. Engine emission study

The NOx was formed due to oxidation of atmospheric nitrogen at higher temperature inside the combustion chamber. Nitric monoxide and nitrogen dioxide were grouped together as NOx emissions [5]. The variation of NOx emission with brake power is shown in Fig. 3. NOx emission in the case of copper is 165 ppm higher than standard engine at full load. Maximum NOx emission in the case of copper, chromium and nickel was higher than standard engine at 2500 rpm. The reason for the increased NOx is the higher heat release rate inside the combustion chamber because of increased in-cylinder temperature due to catalytic reaction.

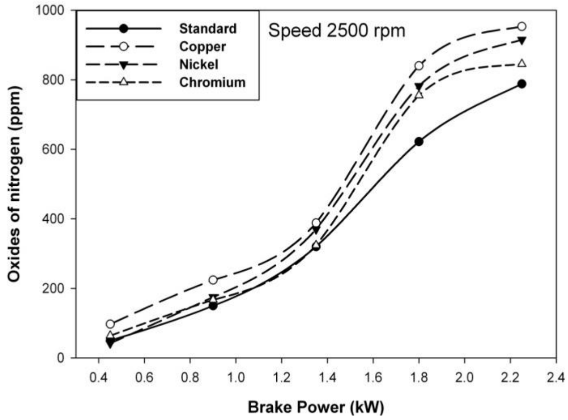

Fig. 3: Variation of NOx emission with brake power

HC emissions were formed as the unburned fuel that cannot penetrate effectively[6]. Unburned HC is a measure of combustion inefficiency[1]. Engine exhaust gases contain a wide variety of HC compounds. Olefins, acetylene and aromatics present in the exhaust gases were partially converted into paraffins. The difference in HC emission with brake power for various coatings is shown in Fig. 4. Copper coated engine has the lowest HC emission when compared to other catalysts. At full load, the HC emission for copper coated engine is appreciably reduced to 130 ppm compared to the standard engine. These improvements are mainly due to catalytic activation of the charge leading to better oxidation of the HC.

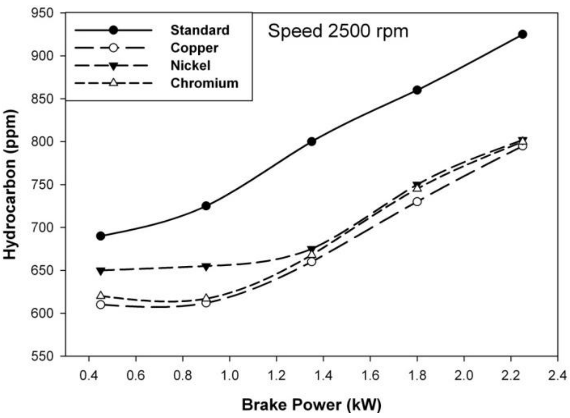

Fig. 4: Variation of HC with brake power

When the fuel does not burn completely, the carbon in the fuel converts into CO which is a measure of combustion in-efficiency. This emission is toxic and must be controlled. Fig. 5 shows the variation of CO with brake power. The CO emission of standard engine is higher than other catalytic coated engines at full load. This may be attributed to reduced in-cylinder temperatures. Carbon dioxide (CO2) serves as a heat absorbing agent during the combustion and reduces the peak temperature in the combustion chamber. Fig. 6 depicts the variation of CO2 emission with load for standard and catalytic coated engines. The CO2 emission varies from 11.1% at low load to 12.3% at full load for standard engine. The amount of CO2 produced by standard engine is higher than catalytic coated engine at all loads.

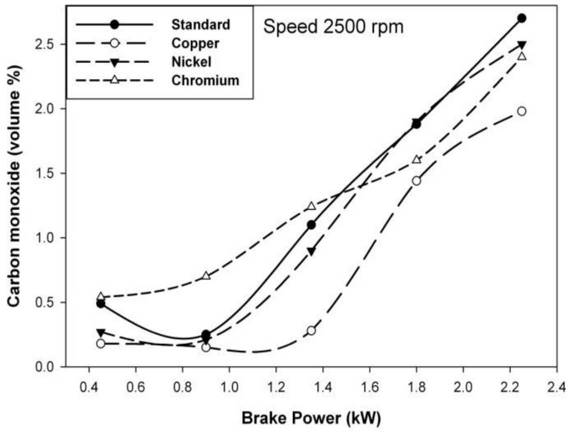

Fig. 5. Variation of CO with brake power

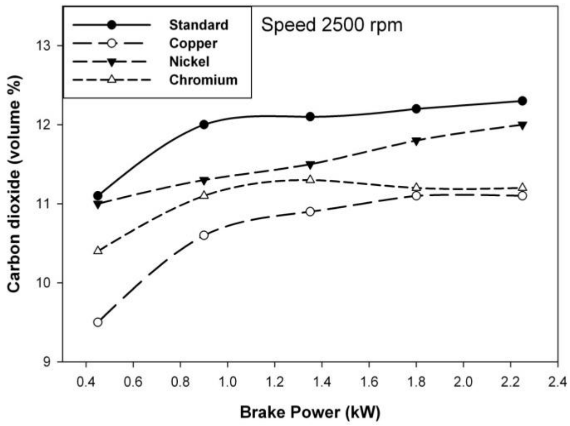

Fig. 6: Variation of CO2 with brake power

Fig. 7 shows the variation of exhaust gas temperature with brake power for standard and catalytic coated engine at 2500 rpm. It is observed that the exhaust gas temperature increases with load because more fuel is burnt to meet the power requirement. For standard engine, the exhaust gas temperature showed marginally low, at all the loads compared to catalytic coated engine. At maximum load the exhaust gas temperatures were 273 °C (standard), 300 °C (copper), 282 °C (chromium) and 280 °C (nickel).

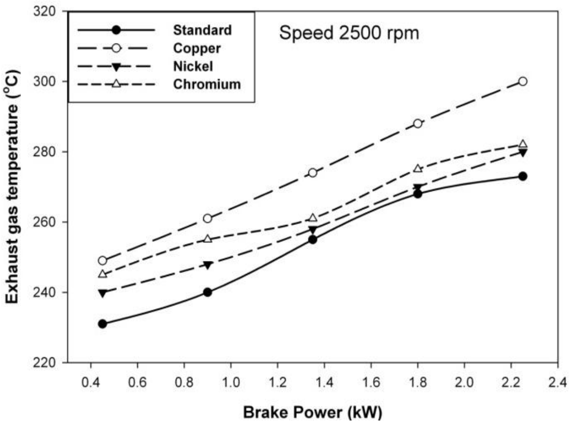

Fig. 7: Variation of exhaust gas temperature with brake power

3.3. Combustion study

Fig. 8 shows the variation of cylinder pressure with crank angle at full load for standard and various catalytic coated engines. The cylinder pressure obtained at full load indicates higher value for 14.874 bar (copper), 14.416 bar (chromium), 14.089 bar (nickel) and 13.274 bar (standard). Higher values of cylinder pressure indicate faster combustion rate. Improved combustion is obtained as a result of charge activation process in the presence of the catalyst. Catalytic coated engines have higher cylinder pressures compared to the standard engine. Fig. 9 shows the rate of heat release with respect to crank angle. Faster heat release occurs for copper coated surface. Maximum heat release occurs for copper (17.372 $kJ^{-1}m^{-3}$ deg^{-1}) at 21° crank angle, chromium (16.18 $kJ^{-1}m^{-3}$ deg^{-1}) at 29° crank angle, nickel (16.106 $kJ^{-1}m^{-3}$ deg^{-1}) at 29° crank angle and standard surface (15.725 $kJ^{-1}m^{-3}$ deg^{-1}) at 32° crank angle.

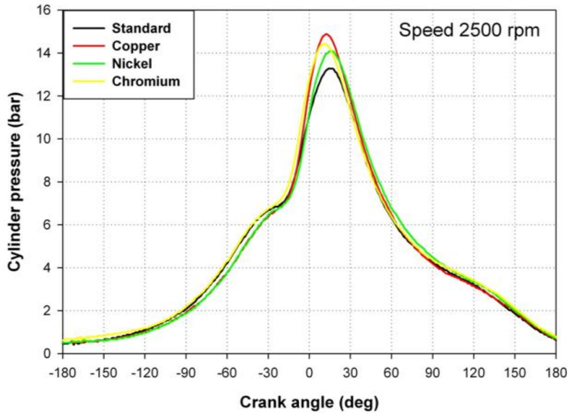

Fig. 8: Variation of cylinder pressure with crank angle

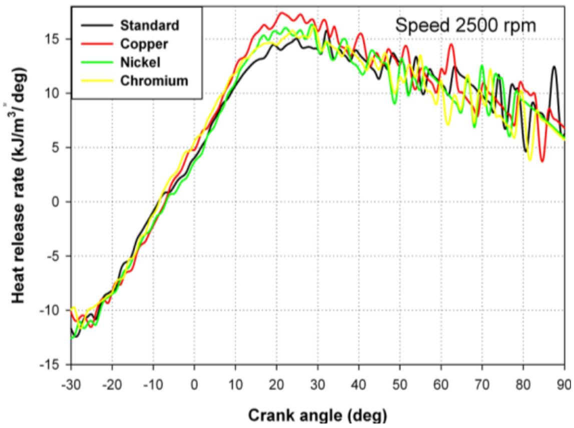

Fig. 9: Variation of heat release rate with crank angle

The variation in cylinder pressures from cycle to cycle is a fundamental combustion problem for spark ignition engine. This originates during the initial flame development period and propagates into the turbulent combustion period. Fig. 10 shows the variation of cylinder pressure for different catalytic coatings. The average cylinder pressures of catalytic coated engine were 14.947 bar, 14.525 bar, 14.209 bar and 13.404 bar for copper, chromium, nickel and standard surface, respectively. This is due to faster combustion process of catalytic coatings. The variation of cylinder peak pressure with respect to speed for different catalytic coated surface is shown in Fig. 11. Catalytic coated engines have higher cycliner peak pressure compared to the standard engine. Fig. 12 shows the maximum heat release rate with respect to speed decreases with increase in speed. The maximum heat release rate for copper coated surface was 18.497 kJ m^{-3} deg^{-1} at 2200 rpm and 16.342 kJ m^{-3} deg^{-1} at 3000 rpm. For the tested engine speeds the maximum heat release occurs for catalytic coated surface when compared with standard engine at all speeds. This is due to higher cylinder pressure for catalytic coated engine and also efficient combustion with catalytic activity.

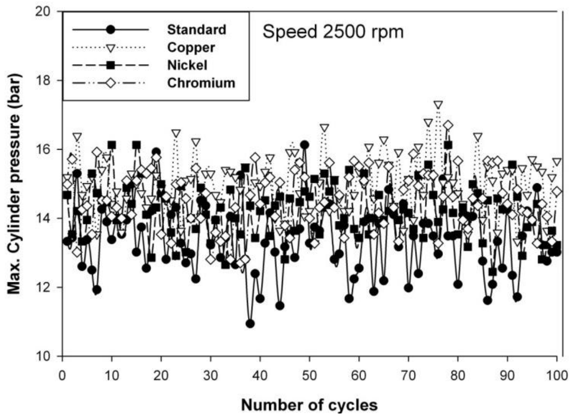

Fig. 10: Cyclic variations of cylinder pressures

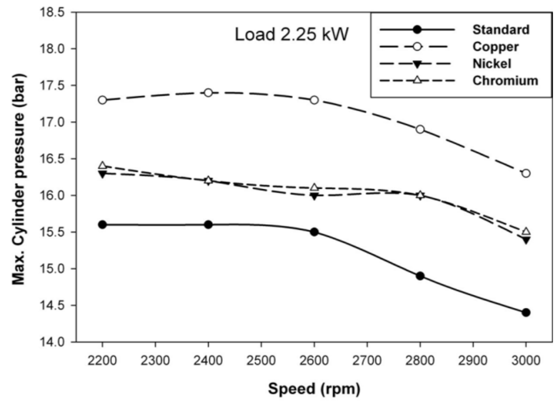

Fig. 11: Variation of max. cylinder pressure with engine speed

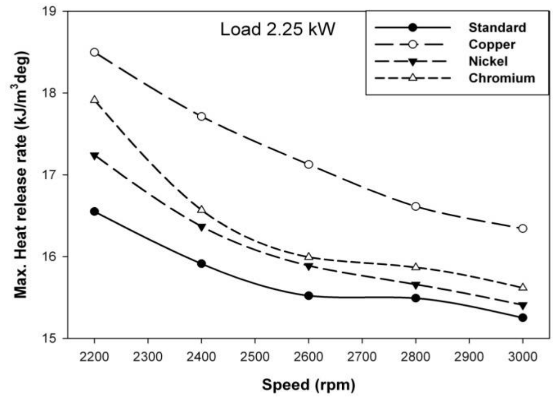

Fig. 12: Variation of maximum heat release rate with engine speed

4. Conclusions

The catalytic coated engines showed lower fuel consumption compared to the standard engine at full loads. Among the catalysts, the lowest specific fuel consumption is achieved for copper coating. Catalytic coatings increases pre-flame reactions which lead to better and faster combustion. NOx emission for catalytic coated engine is 7% to 20% higher than standard engine at full load. This higher NOx emission may be due to higher temperature of combustion chamber. CO emission of standard engine is higher than catalytic coated engine at full load which may be attributed to reduced in-cylinder temperatures. The amount of CO2 produced while using standard surface is higher than catalytic coated engine at all loads. Copper coated engine has the lowest hydro carbon emission when compared to other catalysts. The higher temperatures enhance combustion, and stimulate oxidation reactions throughout the expansion. As a result, unburned HC are completely oxidized. This is due to increase of flame speed with catalytic activity.

Catalytic coated engines have 6 % to 12 % higher cyclinder pressure compared to the standard engine. Higher values of pressure indicate a faster combustion for catalytic coated engines. The crank angle of heat release values and combustion parameters indicate that a faster heat release occur for catalytic coated engine. The combustion duration of standard engine is higher than that of catalytic coated engines. Catalytic coatings increases pre-flame reactions which lead to better and faster combustion.

REFERENCES:

[1] P. Ponnusamy. 2015. Investigation of emission characteristics over catalytic coated surface with EGR in SI engine, *Int. J. Emerging Trends in Engg. and Development*, 4(5), 67-74.

[2] C. Sayin, K. Uslu and M. Canakci. 2008. Influence of injection timing on the exhaust emissions of a dual-fuel CI engine, *J. Renewable Energy*, 33(2), 1314-1323. http://dx.doi.org/10.1016/j.renene.2007.07.007.

[3] G.A. Karim and M.G. Kibrya. 1986. Variations of the lean blowout limit of a homogeneous methane-air stream in the presence of a metallic wire mesh, *ASME Transactions*, 108(3), 446-449. http://dx.doi.org/10.1115/1.3239927.

[4] M.V.S.M. Krishna and K. Kishor. 2008. Performance of copper coated spark ignition engine with methanol-blended gasoline with catalytic converter, *J. Scientific and Industrial Research*, 67(7), 543-548.

[5] K.Narasimha, M.V.S.M. Krishna, P.V.K. Murthy, D.N. Reddy and K. Kishor. 2011. Performance of copper coated two stroke spark ignition engine with gasohol with catalytic converter with different catalyst, *Int. J. Applied Engg. Research*, 2(1), 205-218.

[6] P. Ponnusamy, R. Subramanian and N. Nedunchezhian. 2011. Experimental investigation on performance, emission and combustion analysis of a four stroke SI engine with various catalytic coating, *European J. Scientific Research*, 63(2), 182-191.

EDITORIAL NOTES:

Edited paper from National Conference on Technological Advances in Mechanical Engineering TAME 2015, 20 August 2015, Chennai, India.

GUEST EDITOR: Dr. K. Umanath, Dept. of Mech. Engg., VelTech HighTech Dr. Rangarajan Dr. Sakunthala Engg. College, Chennai, India.