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EVALUATION OF MECHANICAL PROPRTIES OF CONNECTING ROD COATED WITH Ni-TiO_2

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Abstract

The connecting rod in an automobile engine connects reciprocating piston to rotating crankshaft, transfers the thrust of piston to crankshaft, and converts the reciprocating motion of piston into rotary motion of the crankshaft. As connecting rod is rigid, it may transmit either a push or pull so the rod may rotate crank through both halves. Connecting rods are subjected to inertial forces due to reciprocating mass and gas forces. Gas pressure results in axial and bending stresses. Bending stresses originate due to eccentricities, crankshaft, case wall deformation, and rotational mass force. Therefore a connecting rod must be capable of transmitting axial tension, axial compression and bending stresses caused by the thrust and pull on the piston and by centrifugal force. Therefore, durability of this component is critical importance. The literature survey done during this project gives the idea that no one has carried out Ni-TiO2 composite coating directly onto the connecting rod through electro-co-deposition technique. In this project AISI 4340 alloy steel connecting rod purchased from market of HONDA ACTIVA model 2011 is used for composite coating. 3g, 6g, and 9g Ni-TiO2 is coated through electro-co-deposition technique. The electro-co-deposition equipment is used for composite coating. Here we are focused on Rockwell hardness, tensile strength and corrosion rate of the connecting rod. Further the improvements is brought out here when compared to uncoated and 3g, 6g, 9g coated connecting rod with respect to Rockwell hardness, tensile strength and corrosion rate. The broken uncoated and 3g, 6g, 9g coated connecting rods after the tensile test carried out in UTM is shown in figures. The maximum or peak load in kN and the cross head travel in mm at which breaking of connecting rod occurs during tensile test is noted. Tensile strength graphs showing the deformation caused in connecting rod due to varying load is shown. The uncoated and 3g, 6g, 9g coated connecting rods after the Rockwell hardness test is also shown in figures. The results of Rockwell hardness is shown in the table. The uncoated and 3g, 6g, 9g coated connecting rods after the corrosion test is also shown in figures. The results of corrosion test is also shown in the table.

Keywords: Electro-codeposition, Composite coating, Connecting rod, Nickel-Titanium dioxide.

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1. Introduction

The connecting rod is the main power transmitting rod in an engine. It transmits to and fro movement of piston into circulatory motion of the crankshaft. Therefore, connecting rod must be robust and rigid. Connecting rods are subjected to various stresses due to sudden to and fro movement of the piston. One such stresses are axial and bending stresses. Axial stresses are due to gas pressures. Bending stresses are due to rotational forces and eccentricities. Therefore, connecting rod should have the capacity to transfer axial tension and compression along with bending stresses. That is why connecting rod must be strong enough to bear all the stresses so that it can be long lasting giving better durability. Therefore, in this project we are focused to improve Rockwell hardness, tensile strength and corrosion rate of connecting rod by composite coating through electro-co-deposition technique and conclude what is the improvement that can be advantageous for durability of the rod.

Objective of project

1. The main aim of this project is to apply composite coating directly onto connecting rod.
2. Ni-TiO2 is used as composite coating material here, where Nickel (Ni) is the base metal and Titanium dioxide (TiO2) is in powder form.
3. Out of the four connecting rods taken, three rods are used for 3g, 6g and 9g Ni-TiO2 composite coating and the one remaining is left uncoated.
4. Rockwell hardness test is done on these four connecting rods and the results are obtained.
5. tensile test is done for these four connecting rods and the results with graphs are obtained.
6. corrosion test is done on these four connecting rods and the results are obtained.
7. Whatsoever improvement is found is taken as an advantage, when comparison of results is done for the tensile and hardness tests between uncoated and 3g, 6g, 9g coated connecting rods.

2. Experimental Results

Electrocodeposition is one such technology which is economical as well as feasible technique for obtaining composite metal matrix. The most widely used method is direct current electrocodeposition for obtaining composite coatings. In this project, Nickel composite coatings i.e., Nickel-Titanium dioxide (Ni-TiO2) coating is obtained on connecting rod (made of 4340 alloy steel) of HONDA ACTIVA model 2011. Here the mechanical properties of coated connecting rod is tested, i.e., hardness, tensile and corrosion test. And the improvements when compared to coated and uncoated one is discussed to take the advantage of improved hardness, tensile strength and corrosion rate of connecting rod. The electrocodeposition equipment is shown in figure.

Fig. 2.1: Electrocodeposition equipment

A. Electrocodeposition equipment consist of
    1. Magnetic stirrer
    2. Temperature regulator
    3. DC power supply unit
    4. Electrocodeposition process unit

B. Instruments Required
    1. pH meter
    2. Weighing device

C. Chemicals Required
    1. Boric Acid (H_3BO_3)
    2. Nickel Sulphate ($NiSO_4.6H_2O$)
    3. Nickel Chloride ($NiCl_2.6H_2O$)

4. 0.1N Sodium Hydroxide (NaOH)
5. Conc. Hydrochloric Acid (HCl)

D. Additional requirements

1. Titanium dioxide (TiO2)
2. Distilled Water
3. Pure Nickel plate

Table 2.1 Electrolyte solution preparation

Nickel Chloride ($NiCl_2$ $6H_2O$)	**Nickel Sulphate ($NiSO_4$ $6H_2O$)**	**Boric Acid (H_3BO_3)**	**Titanium Dioxide (TiO_2)**	**Sodium Hydroxide (NaOH)**
35 gm/l	250 gm/l	40 gm/l	3,6 & 9 gm/l	5-10 ml/l
pH	**Bath Temperature**	**Current Density**	**Anode**	**Cathode**
4	40	2 A/dm^2	Pure Nickel	AISI 4340 alloy steel connecting rod

E. Preparation of Electrolyte Solution

2.5 liter beaker is used to prepare the electrolyte solution. 375 grams of Nickel Sulphate, 52.5 grams of Nickel Chloride, 60 grams of Boric acid is dissolved in 1.5 liter distilled water taken in the beaker according to the data given in Table 4.1. Sodium Hydroxide 15-20ml is added till the pH of the solution reaches 4.Then Titanium Dioxide powder is added according to the coating requirement i.e., 3, 6 & 9 grams for 1.5 liter electrolyte solution. The complete mixture is well stirred using magnetic stirrer for 20-30 minutes.

Fig. 2.2 Preparation of electrolyte solution

F. Experimental Procedure

First the substrate is cleaned by dipping in 10% solution of Conc. HCl for a duration of 2-3 minutes. Then to obtain 3 grams of Nickel-Titanium Dioxide coating on the substrate i.e., AISI 4340 alloy steel connecting rod, 3 grams of Titanium dioxide is added to the electrolyte solution and well stirred using magnetic stirrer. The beaker is placed inside the electrocodeposition process unit. The beaker temperature is maintained to 400C using temperature regulator. Pure Nickel plate is suspended inside the beaker in such a way that 3/4th portion of the plate gets dipped inside the solution. Similarly cleaned AISI 4340 alloy steel connecting rod is suspended inside the beaker dipping completely in the solution. The cathode wire of the DC power supply unit is connected to the substrate i.e., AISI 4340 alloy steel connecting rod and the anode wire is connected to the pure nickel plate. Both the connecting rod and the nickel plate is placed in such a way that it completely dips in the solution. This completes the circuit. Now the DC power supply unit is turned ON, Current density is adjusted to 2 A/dm2. Current flows through the circuit, hence the coating process begins to take place. This coating process is allowed to take place for duration of 60 minutes, then after DC power supply unit is turned OFF. The substrate is taken out from the beaker and washed with running water and allowed to dry by keeping it exposed to sunlight. In this way 3 grams of Nickel-Titanium Dioxide composite coating is obtained on the substrate. Similar procedure is repeated to obtain 6 and 9 grams coatings.

Fig. 2.2 Electrocodeposition equipment during coating process

3. Results and Discussion

A. Rockwell hardness test results

The following figures i.e., figure 5.1, 5.2, 5.3 and 5.4 show the uncoated and 3g, 6g, 9g Ni-TiO2 coated connecting rods on which the hardness test is carried out. The results are represented in the table 5.1

Fig. 5.1 Uncoated connecting rod

Fig. 5.2 Connecting rod with 3g Ni-TiO2 Composite Coating

Fig. 5.3 Connecting rod with 6g Ni-TiO2 Composite Coating

Fig. 5.4 Connecting rod with 9g Ni-TiO2 Composite Coating

The following table 5.1 shows the Rockwell hardness test results for uncoated, 3g, 6g and 9g coated connecting rods. Three trails were conducted on each of the four connecting rods. The averages of the three trials were taken to get the final hardness value.

Table 5.1: Trial and average readings in HRC

Material	TR1	TR2	TR3	Average
Uncoated CR	50	55	48	51
3g coated CR	56	50	55	53.67
6g coated CR	56	60	52	56
9g coated CR	61	63	58	60.67

Where, TR - Trial Readings
CR – Connecting Rod
HRC - Hardness Rockwell C Scale

B. Tensile test results

Connecting rods after the tensile test are shown in figure 5.5, 5.6, 5.7 and 5.8 for uncoated, 3g, 6g, 9g Ni-TiO2 coated connecting rods respectively.

Fig. 5.5 Uncoated connecting rod after tensile test

Fig. 5.6 3g coated connecting rod after tensile test

Fig. 5.7 6g coated connecting rod after tensile test

Fig. 5.8 9g coated connecting rod after tensile test

The tensile test conducted in UTM gave the tensile graph shown in figure 5.9, 5.10, 5.11 and 5.12. The graph is a plot of applied load and displacement in lateral direction.

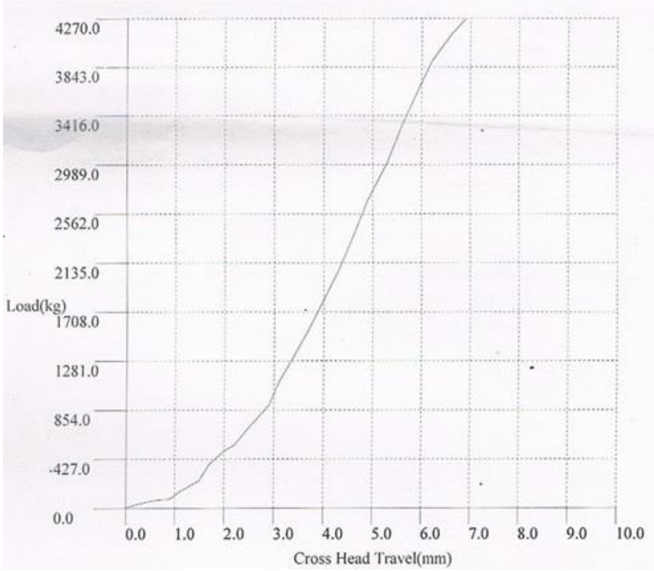

Fig. 5.9 Applied load versus deflection plot for uncoated connecting rod

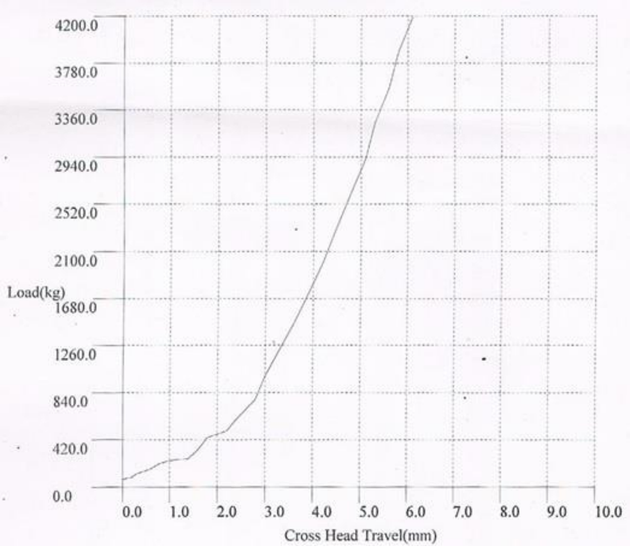

Fig. 5.10 Applied load versus deflection plot for 3g coated connecting rod

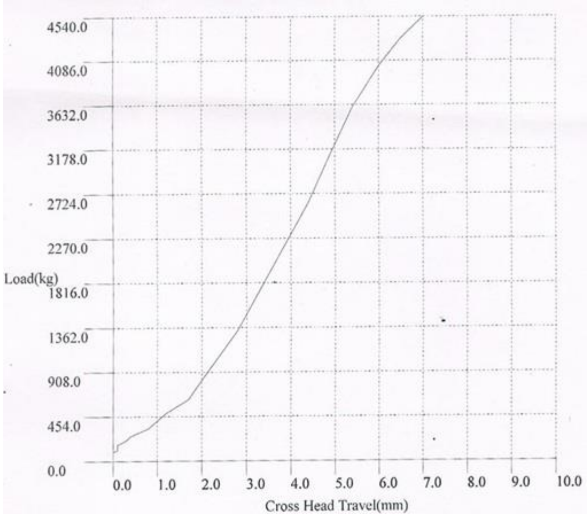

Fig. 5.11 Applied load versus deflection plot for 6g coated connecting rod

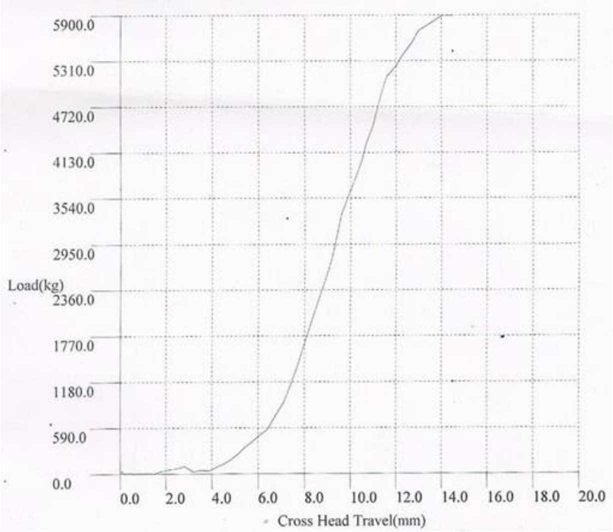

Fig. 5.12 Applied load versus deflection plot for 9g coated connecting rod

The table 5.2 shows the failure load in Kg and lateral displacement in mm during tensile test carried out in UTM for uncoated, 3g, 6g and 9g coated connecting rods.

Table 5.2 Results of tensile test for uncoated, 3g, 6g and 9g coated connecting rods

Parameters	**Uncoated C.R**	**3g coated C.R**
Failure load in Kg	4264.5	4191.03
Displacement in mm	6.9	6.1
Parameters	6g coated C.R	9g coated C.R
Failure load in Kg	4533.66	5891.92
Displacement in mm	7.0	14.5

C. Corrosion test results

The following table 5.3 shows the corrosion test results for uncoated, 3g, 6g, and 9g coated connecting rods for 24 48 and 72 hrs. The results of corrosion test are represented in the Mils Penetration per Year (MPY).

C.R	24 hours	48 Hours	72 Hours
Uncoated C.R	13.25	17.09	21.28
3g coated C.R	17.76	15.63	14.13
6g coated C.R	11.66	10.865	9.72
9g coated C.R	6.625	6.757	5.74

Table 5.3: Results of corrosion rate in MPY of uncoated, 3g, 6g and 9g connecting rods for 24, 48 and 72 hrs

The figures 5.13,5.14, 5.15 and 5.16 show the uncoated, 3g, 6g and 9g coated connecting rods after corrosion test.

Fig. 5.13 uncoated connecting rod after corrosion test

Fig. 5.14 3g coated connecting rod after corrosion test

Fig. 5.15 6g coated connecting rod after corrosion test

Fig. 5.16 9g coated connecting rod after corrosion test

4. Conclusion

The motive of this project was to bring some improvement in the Rockwell hardness, tensile strength and corrosion rate of the connecting rod. From the results we conclude that Rockwell hardness is gradually improving from uncoated to 9g coated rod. The percentage of increase of hardness from uncoated rod to 3g coated rod is 5.235 %, from uncoated rod to 6g coated rod is 9.8 %, and from uncoated rod to 9g coated rod is 18.96%.

Also from the results we conclude that tensile strength is gradually improving from uncoated to 9g coated rod except for 3g coated rod which is slightly decreased compared to uncoated rod. The percentage of increase of tensile strength for 6g and 9g coated rods when compared to uncoated rod is 6.31% and 38.16% respectively. 3g coated rod not made much difference in improving the tensile strength of the rod giving the tensile strength slightly less than the uncoated rod which is the only negative results of the project.

Also from the results we conclude that corrosion rate is gradually improving from uncoated to 9g coated rod. The percentage increase in corrosion rate for 3g, 6g and 9g coated rods when compared to uncoated rod is 33.6%, 54.32% and 73.02% respectively.

References

[1] D E Rusu, P Cojocaru, L Magagnin, C Gheorghies, G Carac. "Study of Ni-TiO2 nanocomposite coating prepared by electrochemical deposition".

[2] M S Ali Eltoum, A M Baraka, M Saber M and E Lfaith A Hassan. "Electrodeposition and characterization of Nickel-titania nanocomposite coatings from gluconate baths".

[3] S M Madani and A J Novinrooz. "Synthesis and characterization of Ni-TiO2 composite coatings by electro-co-deposition".

[4] I Pavlov, L Benea, J P Celis and L Vazquez. "Influence of nano-TiO2 codeposition on the morphology, micro topography hand crystallinity of Ni/nano-TiO2 electro synthesized nanocomposite coatings".

[5] M J Kim, J S Kim, D J Kim, H P Kim and S S Hwang. "Effects of current density and agitation on codeposition behavior of electrodeposited Ni-TiO2 composite coating".

[6] Sunil Kumar, Kapil, Avnish Kumar. "Effect on hardness and composition by the coating of Ni-TiO2-Al2O3 & Ni-Al2O3 on tungsten carbide cutting tool".

[7] Peter Odetola, Patricia Popoola, Olawale Popoola and David Delport. "Parametric variables in electro-deposition of composite coatings".

[8] Yuxin Wang, Weiwei Chen, Abdul Shakoor, Ramazan Kahraman, Wei Lu, Biao Yan, Wei Gao. "Ni-TiO2 composite coatings on copper produced by sol-enhanced electroplating".

[9] S. Jeyaraj, K. P. Arulshri, P. S. Sivasakthivel, S. Dhasarathy, R. Saravanan and G. Muralidharan. "Experimental investigations and effect studies on electrodeposited nickel-slag powder composite coatings".

[10] B S Praveen Kumar, K M Narayanappa and Ramesh. "Artificial neural networks approach to predict wear behavior of Ni-WC composite coatings deposited by electro-co-deposition".

[11] Kimberly L. Nelson "Enhanced performance and functionality of titanium dioxide papermaking pigments with controlled morphology and surface coating".

[12] Behzad Rezaei, and Hamid Mosaddegh Department of Chemistry, Isfahan University of Technology, Isfahan, Iran. "Applications of Titanium Dioxide Nanocoating".

[13] Xiaobo Chen and Samuel S Mao, Lawrence Berkeley National Laboratory, and University of California, Berkeley, California. "Titanium Dioxide Nano materials: Synthesis, Properties, Modifications, and Applications".

[14] Rui Zhang, Dr. Saveria Santangelo, Dr. Enza Fazio, Dr. Fortunato Neri, Dr. Massimiliano D'Arienzo, Dr. Franca Morazzoni, Dr. Yihe Zhang, Dr. Nicola Pinna, Patrícia A. Russo. "Stabilization of Titanium Dioxide Nanoparticles at the Surface of Carbon Nanomaterials Promoted by Microwave Heating".

[15] Sara Mohammadi Bilankohi, Majid Ebrahimzadeh, Hossein Ghaforyan. "Simulation of optical characteristics of Nickel and Nickel/Titanium Dioxide core/shell nanoparticles".

[16] Helen H. Lou, Department of Chemical Engineering, Lamar University, Beaumont, Texas, U.S.A. Yinlun Huang, Department of Chemical Engineering and Materials Science, Wayne State University, Detroit, Michigan, U.S.A. "Electroplating".

[17] Yahia H. Ahmad and Adel M. A. Mohamed, Center for Advanced Materials, Qatar University, Doha. "Electrodeposition of Nanostructured Nickel-Ceramic Composite Coatings".