



## INVESTIGATION OF CONTACT FATIGUE AND OPERATING PERFORMANCE OF NI-WC COMPOSITE ELECTROCOATED GEARS

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### ABSTRACT

The objective of the work was to evaluate contact fatigue and operating performance of electrodeposited Ni-WC composite coated gears using experimental technique. The electrodeposited Ni-WC coating was characterized for coating thickness, hardness and crystal structure using Electro-Physik gauge, Rockwell Hardness testing machine and X-Ray Diffraction respectively. The operation condition was estimated using designed test rig and vibration pick with CRO. The results show that coated gears are smoother in operation and offer more resistance to wear and fretting due to increased hardness.

### Keywords

Contact fatigue, composite coated gears, Ni-WC coating

### Academic Discipline And Sub-Disciplines

Science and Engineering, Mechanical Engineering

### SUBJECT CLASSIFICATION

Fatigue and Vibration Analysis

### TYPE

Engineering and Experimental study

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## 1 INTRODUCTION

Extensive use of transmission gears in machineries demands improvement of fatigue life of gears. At present, Carburizing, Nitriding, Physical Vapor Deposition and chemical vapor deposition are some of the most adopted techniques to improve surface hardness of gears [1]. Electrodeposition is considered as one of the most important and cost effective industrial techniques for producing protective coatings [2]. Deposition of Ni has been proved to improve wear and corrosion resistance [3]. Presence of WC in Ni-WC composite coating increases the nucleation sites to reduce the crystal size leading to a more uniform coating while imparting hardness to the surface. [4-5] Electro-coating process has key controlling factors such as temperature and pH of the electrolyte, distance between electrodes, whose values were chosen from previous research work [6] to optimize uniform coating thickness.

Contact fatigue results from a Hertzian stress state which is a localized stress state that results when curved surfaces are in contact under a normal load. The contact geometry and the motion of the rolling elements produce an alternating subsurface shear stress [7]. Subsurface plastic strain builds up with increasing cycles until a crack is generated. After the onset of surface pitting the operation of the rolling elements becomes rough and noisy. The crack further propagates deteriorating the operation condition. Study has proved that lubrication may encourage cracks at this stage [8]. Two meshing gears transmitting power experience surface fretting due to contact fatigue. These can be detected by changes in amplitude pattern of the system [9-11]. Though composite coatings have been extensively used for industrial applications it is seldom used for surface property enhancement of gears. Insufficient research has been done towards the design of apparatus to evaluate contact fatigue performance of transmission gears.

The objective of this work is to evaluate the contact fatigue performance of gears that have been coated with Ni-WC composite. The comparison of the smoothness of operation of the coated and non-coated gears is done using vibration analysis.

## 2 EXPERIMENTAL WORK

For electro-coating of Ni-WC composite, distilled water with reagents mentioned in Table 1 was used. Electrolyte was prepared and 200 ml of the same was taken in another flask. It was added with reinforcement particles and ultrasonicated for one hour at 37 KHz for proper wetting and dispersion of particles. It is then added to electrolytic solution and stirred continuously using magnetic stirrer for uniform distribution. pH was adjusted using sodium-Hydroxide (NaOH) to the optimized value of 3.7. Coating was carried for 2 hours for each specimen.

**Table 1:** Composition of chemicals and operating parameters

Chemical Name	Quantity (g/L)	Operating Parameters	
Nickel Sulphate ( $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ )	225-300	Temperature	50°C
Nickel Chloride ( $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ )	30-45	pH	3.7
Boric acid ( $\text{H}_3\text{BO}_3$ )	40-50	Current	0.5 A
Tungsten Carbide (WC)	3	Time	120 min

Initially, the electrodeposition was carried out on MS sample plate to characterize the coating because it is not possible for coating on gears. X-Ray Diffraction method is used for characterization. XRD Maxima- 7000 X-Ray Diffractometer is used for this purpose. Two theta Angle was varied from 10-90 degrees in the steps of 4 degree/ min.

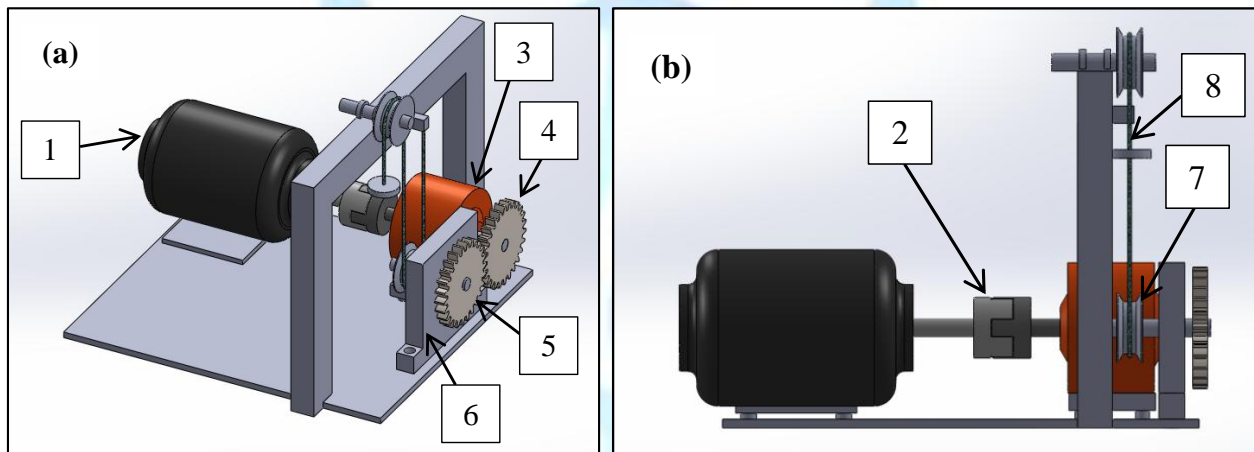
The test gears were applied with masking tape on the area where the coating of the material was not necessary. Only the area of tooth surface is exposed for coating. Same electroplating procedure is followed for gears. Coating thickness measurement was carried out using Electro-Physik gauge. Hardness was measured by Rockwell Hardness Tester using cone indenter at a load of 150 kgf.

For accurate rolling contact conditions between the two teeth surfaces, suitable equipment was designed for testing and assembled. It consisted of an electric motor to drive the gear, gearbox for required speed reduction, the driven gear and pulley for applying torque. Table 2 explains the gear parameters. Figure 1 shows the CAD model of test rig. The main components were, (1) Electric Motor (2) Coupling (3) Gearbox (4) Driver Gear (5) Driven Gear (6) Bearing Support (7) Pulley (8) Rope drive. Torque can be varied by suspending different loads at the rope drive end. During experimentation, the torque was varied in the steps of 0, 0.44, 0.74, 0.88, 1.32 Nm.

Vibration measurement was carried out using vibration pick-up device connected to CRO. Tektronix TDS 2002 B digital storage CRO was used for the purpose. The readings in the form of Excel sheets and waveform images were taken after each hour till the end of fourth hour for each torque.

**Table 2:** Gear specifications

Type	Spur Gear
Material	EN 31
Module	2.5 mm
Number of teeth	52
Facewidth	20 mm
PCD	130 mm
Addendum	2.5 mm
Dedendum	3.125 mm
Speed	24 rpm



**Figure 1:** Schematic of test rig used for experimentation with all the components (a) Isometric view (b) Front View

### 3 RESULT AND DISCUSSION

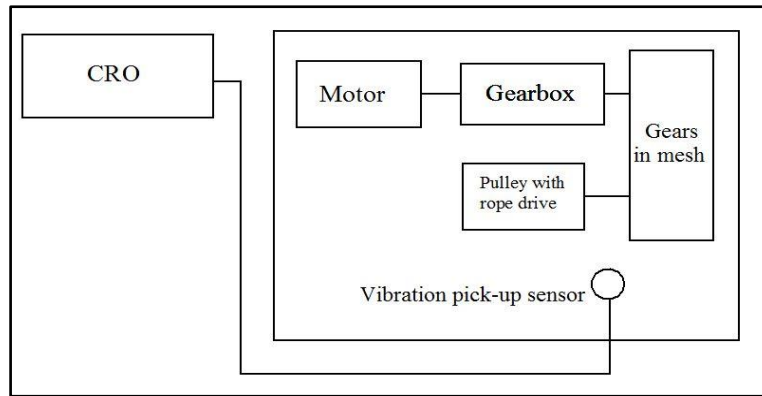
#### 3.1 Characterization

Coating thickness measurement of gear tooth surface with electro-physic gauge indicated average thickness values of 62  $\mu\text{m}$  and 63  $\mu\text{m}$  for driver and driven gears respectively. An 8% increase in surface hardness value was observed in the Ni-WC coated gears. The non-coated gears had a hardness of 105.5 HRC and the coated gears had 113.75 HRC.

#### 3.2 Vibration Analysis

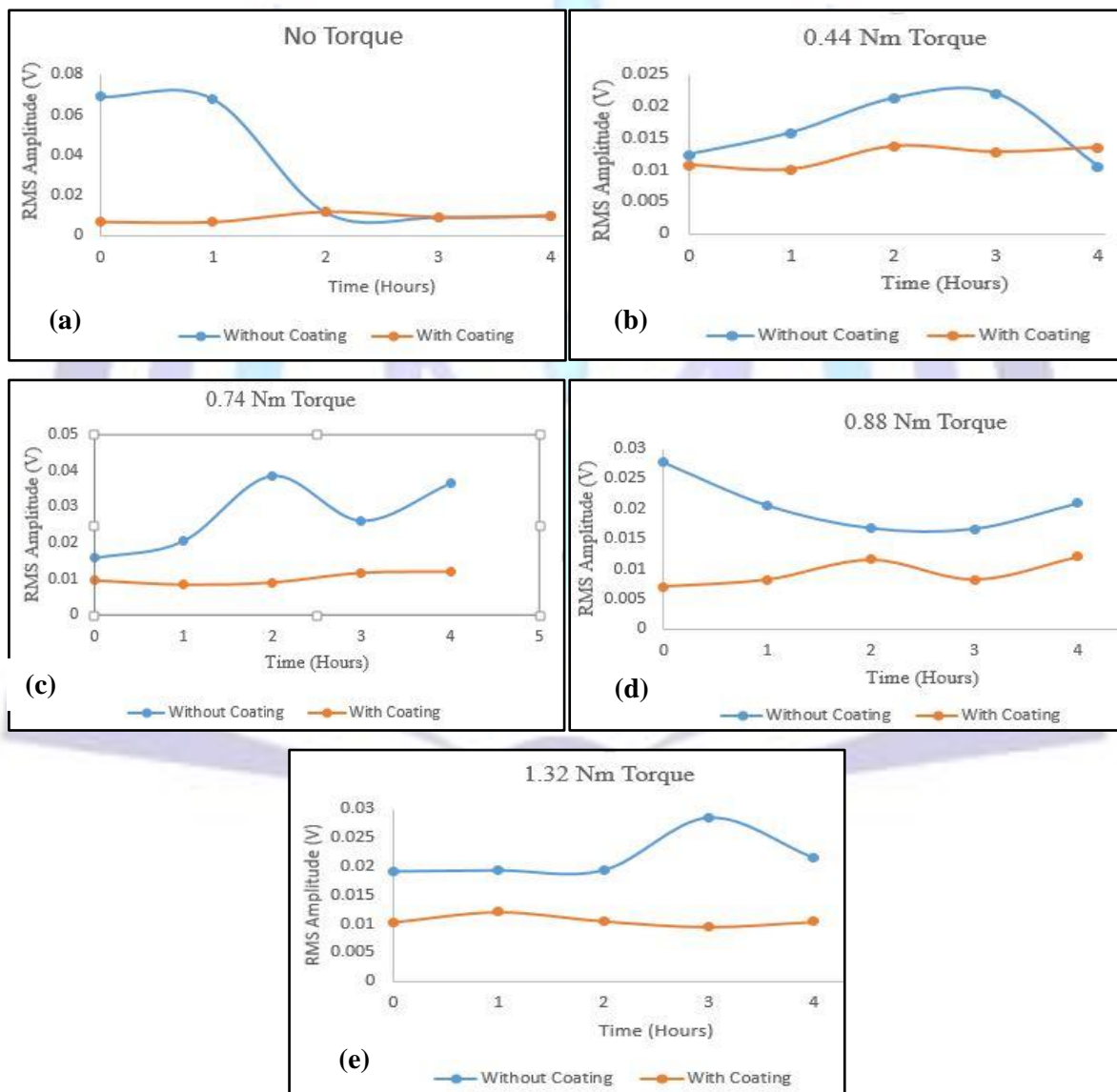
Vibration analysis done using the test rig provides a comparison of vibration amplitudes of coated and non-coated gears during operation.

Block diagram of the test set up with vibration pick up sensor connected to CRO is shown in Figure 2.



**Figure 2: Block diagram of test set-up**

The graph as described in Figure 3 provides a comparison of RMS vibration amplitude for coated and non-coated gears at the different load values. The gears were operated for four hours for each load condition.



**Figure 3: RMS Amplitude vs Time plots for (a) No Torque (b) 0.44 Nm (c) 0.74 Nm (d) 0.88 Nm (e) 1.32 Nm**

From the graphs shown in Figure 3, it can be clearly observed that the amplitude of vibration of coated gears is lesser than that of the non-coated gears. The vibration amplitude variation for coated gears is steady and more uniform with decreased peak values.



The cause for decrease in vibration amplitude for all load conditions is accounted to decrease in sub-surface shear stress. Increase in surface hardness reduces fretting wear thereby reducing the shear stress. Decreased fretting wear makes the operation more smooth reducing the vibration amplitude.

#### 4 CONCLUSION

- Characterization of sample plate through X-Ray diffraction plot confirmed the presence of Ni-WC crystal growth.
- The electro-deposition of 63  $\mu\text{m}$  of Ni-WC composite on the gear tooth surface increased the surface hardness by 8% for coated gears.
- Vibration analysis clearly indicated decrease in RMS amplitude by 36, 19.52, 59.30, 51.96 and 49.61 % for the torque values of 0, 0.44, 0.74, 0.88 and 1.32 Nm for coated gears compared to non-coated ones.

It was concluded that Ni-WC composite coating of 63  $\mu\text{m}$  induced higher surface hardness and made the gears less prone to fretting. Lesser contact fatigue made the operation smoother thereby reducing the amplitude of vibration for coated gears.

#### ACKNOWLEDGMENTS

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