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The Tribological Performance of Mono-layered Multi-striped Nano Coatings

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Abstract

Friction and wear have been shown to be a source of power loss and an increase in manufacturing costs in industry. Many researchers created cutting-edge methods for reducing friction and wear in two sliding components. Lubricants, both liquid and solid, are utilized to improve the working qualities of the materials. The advancement of nanotechnology has provided manufacturers some relief since nano coatings are more dependable at reducing friction and wear. In this study, an attempt is made to deposit Al_2O_3 and TiO_2 in mono-layered and multi-striped coatings, and an interpretation is made to assess the coated disc's tribological achievement using a pin-on-disc apparatus. The grooves necessary for coating are created using an Electric Discharge Machine (EDM), and the grooved disc is coated using a Physical Vapor Deposition (PVD) machine. Tribological characteristics like as wear, friction, and force are investigated. The creative solutions reveal that the force of friction and coefficient are lowered as a consequence of the use of nano coatings, although wear rate is enhanced in some trials due to the unpleasant conditions.

Keywords

Alternate nano coatings, Wear, Frictional coefficient, Frictional force, Mono layered coatings

Introduction

Machining operations, being sophisticated now-a-days, lay emphasizes on minimization of cutting, frictional forces between the tool and job. The tool life is greatly diminished by frictional force and wear. The earlier works are done to improve the tool life by decreasing the friction and wear. It mostly aims on the two mating surfaces coated with nano and micron coatings, which could prove effectual in reducing friction and wear. Fleming et al. [1] has investigated that Ti-6Al-4V surfaces treated by Co-blast with Al_2O_3-SiC or Al_2O_3-B_4C powder mixes displayed enhanced hardness while Al_2O_3-Teflon powder compositions indicated increased toughness. It has displayed a much lower frictional coefficient and wear than the original alloy, respectively. Dobrzański et al. [2] has found that TiN + gradient PVD coatings outperform commercial tool materials with gradient- or multi-layer coatings, as well as single- and two-component coatings applied in PVD or CVD techniques. PalDey et al. [3] observed that an N PVD coating (Ti, Al) alters wear, heat, and oxidation resistance of several tool materials. Addition of Cr and Y alloys markedly upgrade the, Zr and V oxidation resistance and refines wear resistance, Si raises hardness, reluctance to chemical reactivity of nanofilms. Inclusion of boron ameliorates Ti-Al coatings abrasive wear because of origination of TiB_2 and BN phases subjected to deposition conditions. Zhang et al. [4] observed that wear performance of Al_2O_3-13% TiO_2

coatings revealed that the micro hardness was about 15 - 30% greater than the conventional coating. Wear resistance is significantly upgraded, principally under a high wear load. Lin et al. [5] discovered plasma-sprayed alumina; Titania coatings displayed bimodal microstructure splat lamellae similar to the beginning feedstock's conventional coating. Majority of the γ-Al_2O_3 grains are shorter than 200 nm in diameter. It leads to change of α-Al_2O_3 ranges to 800 from 150 nm. Furthermore, TiO_2 modifications have evaporated, and Ti element melts in Al_2O_3 grains. The bimodal microstructure improves the mechanical characteristics of the nanostructured coating. Rico et al. [6] investigated the dry sliding wear performance of Al_2O_3-13% TiO_2 nanostructured conventional coatings, observing enhanced characteristics of nanostructured material with significantly lower wear rates under all experimental circumstances. Ibrahim et al. [7] initiated that the high hardness, wear resistance and fatigue strength is seen in alumina - 13 wt.% titania coatings than the conventional coated specimens. Mishra et al. [8] studied the repercussions of alternatively coated resistant and lubricant nano coatings to exhibit the hardness, toughness and lubricant properties. The magnetron sputtering technique has helped the tri-layer nano films to sustain the loads up to 2000 gf without any failure. Zhongyu [9] deposited TiC coatings to observe its tribological properties. The nano coatings aided to upgrade the friction and wear qualities of cemented carbide tools with depletion in the wear volume. Kot et al. [10] studied the wear characteristics of multi layered carbon-based coatings conducting a wear test on it. The results have shown that the multi layered coatings exhibited high wear resistance. Zhang et al. [11] and He et al. [12] have surmised that the graded coatings conveyed changes in the tribological attributes. Wang and Miyake. [13] attempted TiAlN based multi-layer coatings and surmised that the wear is less to two times subject to all kinds of coatings when water is applied as a lubricant. Vereschaka et al. [14] guessed the impact of multi-layer coatings on wear phenomena. Thickness of the multi-layered coatings helps in providing long life for tools with minimal wear. Ying et al. [15] decided that the composite coatings tribological properties improvement can be done with particle modification. An outstanding anti-corrosion behavior can be seen by taking modified TiO_2 nanoparticles in the coatings. Gebretsadik et al. [16] deliberated the utilization of composite coatings in tribological studies. Frictional coefficient and robustness of the coatings depends on increment in temperature. Penkov et al. [17] considered concepts of finite element method for exploration of multi-layered carbon coatings. Coating's structure, thickness abetted a key role in reduction of wear up to certain level beyond which its effect is almost reverse. Krella [18] summarized that the layer material influences the multi-layer coatings which possess high wear and fracture resistance. It also depends on layer thickness in terms of number of layers considered. It's better to go for a greater number of layers with minimum layer thickness. Tabakov et al. [19] contemplated the necessity of multi-layer coatings for reducing the thermo-mechanical effect in addition to mechanical and physical properties. An innovative method is used for deposition of coatings and its analysis. Pavani et al. [20] reviewed effect of nano coatings on cutting tool wear. It is recognized that the alternate striped coatings are suggestible on cutting tools rather than single and multi-layer coatings as they may increase the resistance towards wear and the aim of hard and soft materials as nano coatings can be estimated. The deposition of alternate striped resistant and lubricant nano coatings is an advancement of single and multi-layer coatings. It is anticipated to see the individual performance of hard and soft coatings considering that hard material provides enough hardness and soft material for increasing the cutting tool wear resistance during machining. The cutting zone near to the tool tip can have hard coatings whereas the subsequent layers can be alternate soft and hard coatings. The tribological accomplishment of alternate striped nanocoated disc is checked under various load conditions and presented here.

Methodology

The evaluation is constructed in such a way that an individual research, as well as a combination study, may be performed on both non-coated and nano coated discs. Figure 1 depicts a schematic illustration of technique. Furthermore, the approach has been designed in such a way that various parameter impacts may be recorded and cross-checked with other values. The wear and friction coefficient results are compared throughout the course of 18 trials.

First, the disc and pin samples are made using the POD machine's typical dimensions. Figure 2 shows the sketches that were considered for this. For the production of disc specimens the grooves on the disc are formed using the Sinker Electrical spark erosion method while nano coatings are deposited in the grooves. The disc sample is divided into eight sectors, and a copper electrode was employed as a result. Then, using the PVD approach, it is covered with two distinct materials, Al_2O_3 and TiO_2, in alternate grooves, as shown in figure 3. A mask is produced to conceal the undesirable sections while depositing Al_2O_3 and TiO_2 materials independently in alternative grooves. The coating material thickness placed on the

Experimental conditions used

Table 1 shows the technical parameters of the Ducom pin-on-disc wear tester used for experiments. Various tests including characteristics such as speed, track diameter, and load are carried out according on the conditions. The time has been set at 3 min. All trials (Table 2) are carried out with the variation of parameters taken into account separately.

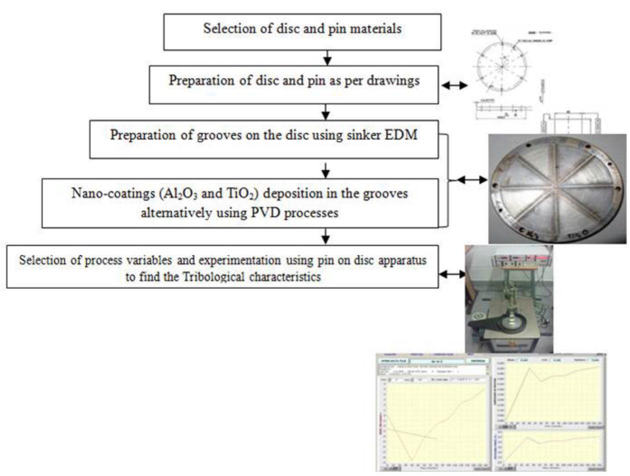


Figure 1: Methodology followed.

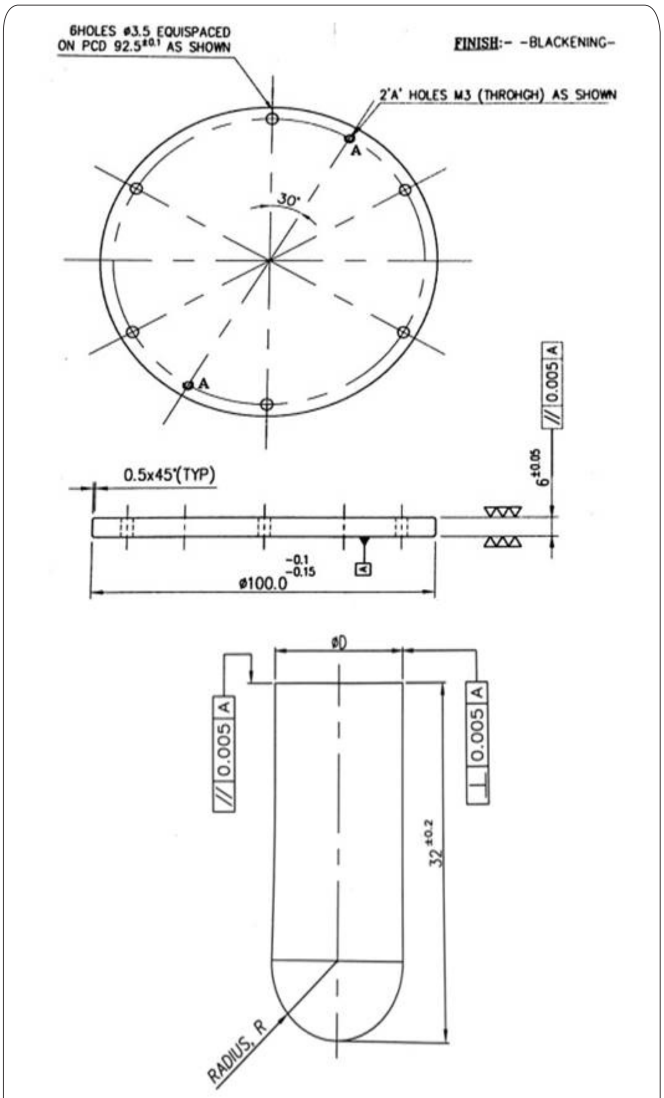


Figure 2: The drawings used for making of the disc and pin samples.

Figure 3: Deposition of nano coatings (Al_2O_3 and TiO_2) alternatively in the grooves using PVD process.

Results and Discussion

Comparison of wear, frictional coefficient, frictional force for coated and uncoated discs

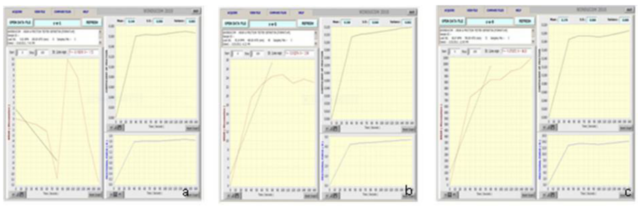
Winducom software graphs obtained for coated and uncoated disc in figure 4 and figure 5. The frictional coefficient fluctuates with load and speed in the same way (Table 3). The frictional coefficient of a uncoated disc reduces with load and speed until 4 kg load and 400 rpm speed, and then increases for the remaining period of variation, as shown in figure 6 and figure 7 at low machining conditions. The coated disc exhibits

Table 1: Test parameters of experiments.

Test Parameter	Values
Specimen pin size	4 to 8 mm dia in steps of 2 mm, 20 to 30 mm long
Wear disc size	100 mm, 6 to 8 mm thick
Wear track diameter	Min: 8 mm, max: 76 mm
Disc rotation	Min: 100 rpm, max: 700 rpm
Normal load	Min: 0 N, max: 100 N

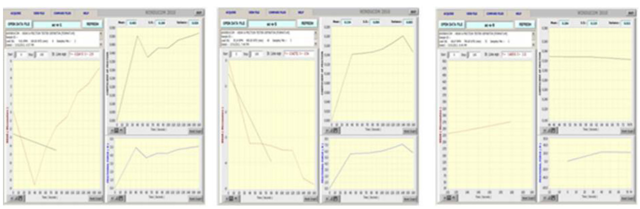
Table 2: Experimental conditions used.

Test Parameter	Values
Parameters	Low
Track diameter (mm)	8
Load (Kg)	1
Speed (rpm)	100



(a) 1st experiment (b) 5th experiment (c) 9th experiment

Figure 4: Winducom software graphs obtained for coated disc.



(a) 1st experiment (b) 5th experiment (c) 9th experiment

Figure 5: Winducom software graphs obtained for uncoated disc.

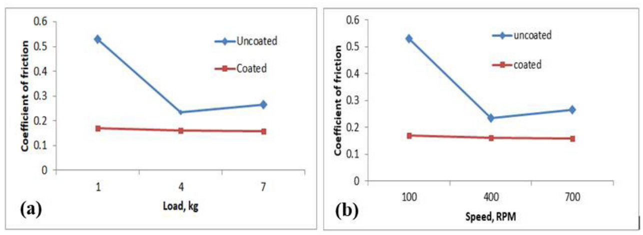


Figure 6: Variation of frictional coefficient with respect to **(a)** Load and **(b)** Speed for uncoated and coated discs under low machining conditions.

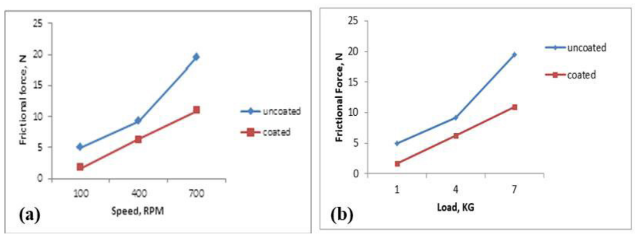


Figure 7: Variation of frictional force with respect to **(a)** Speed and **(b)** Load for uncoated and coated discs under low machining conditions.

Table 3: Experimental results.

Parameters	Low			Medium			High		
Exp. No.	1	2	3	4	5	6	7	8	9
Uncoated disc									
Frictional coefficient	0.53	0.234	0.265	0.15	0.18	0.33	0.158	0.358	0.33
Force	5.0	9.2	19.45	1.5	7.2	23.0	1.54	14.0	25.0
Wear	5.2	0	92.5	3.9	0	550	0	250	275
Coated disc									
Frictional coefficient	0.169	0.16	0.158	0.16	0.12	0.137	0.105	0.177	0.2
Force	1.68	6.3	11	1.6	4.7	9.5	1.0	7.0	14
Wear	11	54.5	36	30	25	23	9.1	26	104

little variation with load and speed, settling at a constant value of around 0.18. The frictional force fluctuates with load and speed in the same way. The frictional force for a uncoated disc rises with load and speed. The coated disc exhibits the similar trend, with less frictional force under low machining settings, as seen in figure 8 and figure 9. Wear varies more for coated discs than for uncoated discs. Wear on uncoated discs is constant until 4 kg load and 400 rpm and thereafter increases. Under low machining circumstances, the coated disc showed a dip and subsequently an increase in wear, as seen in figure 10 and figure 11. Similarly, plots for medium and large track diameters are constructed, as shown in figure 12 and figure 13.

Conclusion

According to recent research on the performance assessment of alternative coated nano coatings and their wear characteristics, the lubricating action of the nano coatings is the primary source of the decrease in frictional forces and frictional coefficient. The combination of Al_2O_3 and TiO_2 has proven its usefulness in decreasing friction since solid lubricants are more effective in lubricating machine components. The frictional coefficient values for nanocoated discs remained significantly below the uncoated disc values for low, medium, and

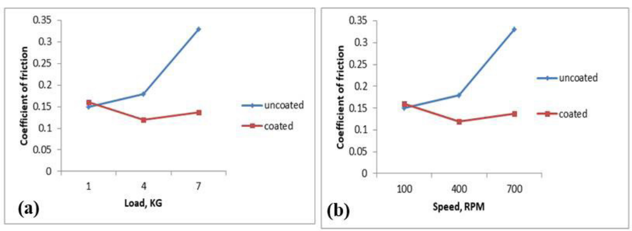


Figure 8: Variation of frictional coefficient with respect to **(a)** Load and **(b)** Speed for uncoated and coated discs under medium machining conditions.

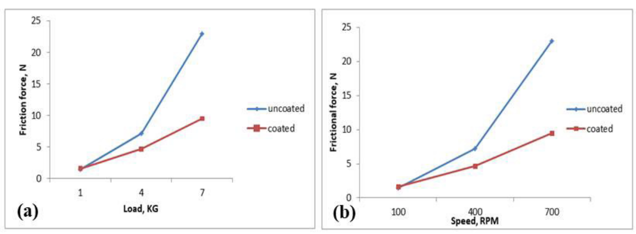


Figure 9: Variation of frictional force with respect to **(a)** Load and **(b)** Speed for uncoated and coated discs under medium machining conditions.

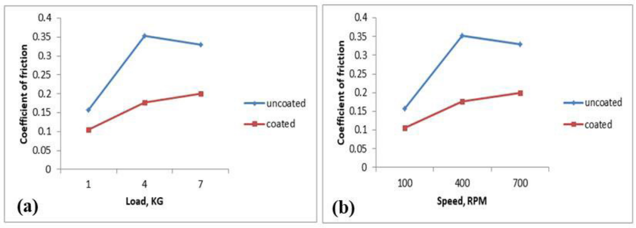


Figure 10: Variation of wear with respect to **(a)** Load and **(b)** Speed for uncoated and coated discs under medium machining conditions.

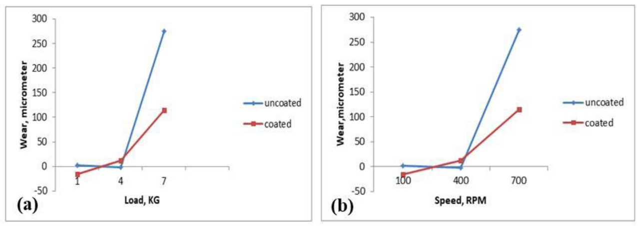


Figure 11: Variation of frictional coefficient with respect to **(a)** Load and **(b)** Speed for uncoated and coated discs under high machining conditions.

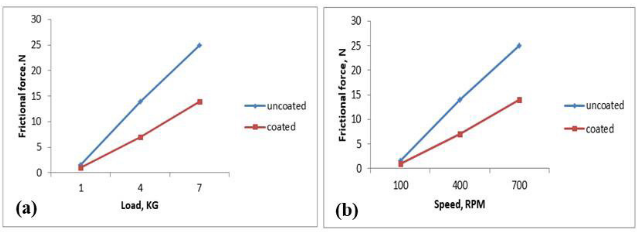


Figure 12: Variation of frictional force with respect to **(a)** Load and **(b)** Speed for uncoated and coated discs under high machining conditions.

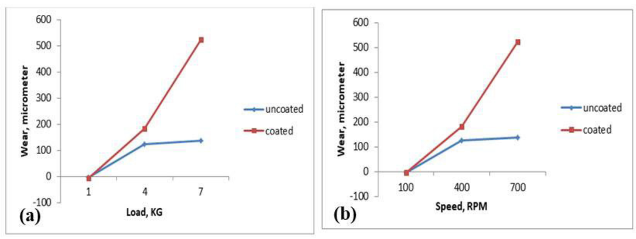


Figure 13: Variation of wear with respect to **(a)** Load and **(b)** Speed for uncoated and coated discs under high machining conditions.

high track diameters, and the graph revealed that the frictional coefficient gradually rose with load and speed. The FF for low, medium, and high track diameters all followed the same pattern. It gradually rose with load and speed, and the values for the nanocoated disc remained lower than the uncoated disc. The wear rate of a coated disc is enhanced. The cause might be that a hard substance is rubbing against another hard material, causing even more wear. Surface fatigue wear is also an issue for both coated and uncoated surfaces.

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Conflict of Interest

There are no conflicts of interest, as per author.

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