Effect of load on the wear behaviour of Al$_2$O$_3$ HVOF sprayed coating

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Abstract. Al$_2$O$_3$ HVOF sprayed coating has been deposited with controlled process parameters. SEM characterization was used to characterize the deposited coating. Wear, Residual stresses, COF and hardness, are studied at variable load of 40, 50, 60 and 70N. Surface morphology of Al$_2$O$_3$ HVOF coating shows a molten and un-molten powder with curved laminar structure and confirm homogeneous coating. Experimental results revealed that with increase in load wear, hardness, residual stresses, and COF results were enhanced at higher load (70N). Experimental result shows wear value reduces to 80 microns and COF decreased to 0.25, while hardness and residual stresses increased to 470 HV and -20 MPa respectively. The experimental test results reveal that decrease in COF and wear may be occurs oxide layer formation or due to tribo-film formation under increasing load condition

Keywords— Al$_2$O$_3$ HVOF coating; FESEM-EDS; Residual stress; Hardness; Wear.

1. Introduction

In the modern era, environmental change may be alleviated or uniformly reversed if a 60% decrease in harmful emission through I.C. engines can be achieved by 2050. This is an ample defy as 75% of the automobile industry is still proposed to trust the usage of I.C. engines up to 2040. The sole aim of the current study is to formulate sustainable temperature-dependent coating, which can resist wear, corrosion, and residual stress generation in piston rings.

In this present reality where metals and metal combinations are nearly utilized all over the place, from the automotive industry, to the Aerospace business. It is difficult to locate a solitary material that can be used for all the test conditions and for all purposes [1-4]. Wear has consistently been a significant worry for configuration engineers in the engineering field. Wear is characterize as "harm to a strong surface (for the most part including reformist loss), brought about by the overall movement. Among the different parts of an engine assembly, the erosion present at cylinder ring represents half all out misfortune [5] and furthermore influences engine effectiveness [6-7]. Decrease of COF helps in illuminating energy capability by diminishing consumption of energy because of frictional misfortunes. Reasonable scope of materials, utilization of ointments are a portion of the methodologies of contradicting misfortunes because of grinding. Surface modification builds up new strategy, where a wear evade misfortunes because of erosion [8]. Thusly, the tribological performance of materials regarding hardness, protection from disintegration and scraped area are considered for determination for mechanical applications, with the goal that can have a more drawn-out life expectancy [10]. Notwithstanding, the parts creation made altogether with previously mentioned properties is commonly
not generally viable or monetarily achievable. Surface-metal coatings are an efficient option in contrast to a whole strong collection of metal of the covering material in situations where just surface communication between two different materials is thought of [11-14].

The experimental study of Zhang S [15] observed that the developed coating shows good characteristics with excellent chemical behavior and high thermal stability whereas poor ability to weld. Author further concluded that the tribological properties are also enhanced using Ni coated hBN particles and it also improve sintering process of coating. The experimental study of coating also exhibits high micro hardness with excellent anti-wear capacity [16, 17]. The experimental study of Janka et.al. [18] shows that micro-hardness of coating improves during hardening process. The experimental study of C.R.C. Lima, et al. [19] shows that developed coating exhibits excellent wear, corrosion and erosion wear.

The present work aims the following:

- To study the tribological behavior of developed coating at variable load.
- To study the effect of load of developed coating on micro-hardness, wear, COF and residual stress.
- To study the effect of load on surface morphology of developed coating.

2. Experimental Setup

The 80x80x4mm steel substrate was ground in order to get the smooth surface using 120-1000 grit emery paper. The high quality HVOF sprayed Al₂O₃ coating was developed. Initially high velocity with jet Al₂O₃ powder was sprayed on the substrate for coating deposition. The experimental spray parameters used in present investigations along with process parameters were given in the in table 1 and table 2 respectively. For the deposition of blend composite coating, initially, sand blasting was performed on the test specimens. The SiC grits of size 100μm were blasted onto the test substrate using a pressurized air jet of sand blaster inside the blasting chamber. They were sand blasting offered a surface roughness of 4-5μm. After blasting, samples were heated up to 200°C.

| Parameters used                       | Values   |
|---------------------------------------|----------|
| Mixing powder time (min.)             | 80       |
| Deposition technique                  | HVOF process |
| Argon Flow Rate (mm³/min.)            | 105      |
| Powder driving Temperature (°C)       | 110      |
| Hydrogen Flow Rate (mm³/min.)         | 11       |

| Process Parameter | A₁ | A₂ | A₃ | A₄ |
|-------------------|----|----|----|----|
| Load (N)          | 40 | 50 | 60 | 70 |
| Sliding velocity (m/s) | 0.1 | 0.1 | 0.1 | 0.1 |
| Temperature(°C)   | 40 | 40 | 40 | 40 |
3. Results and discussion

Figure 1(a-b) having magnification X 2000 and X 3000 with scale of 30μm respectively shows the surface characterization of Al2O3 HVOF coating. Surface morphology of Al2O3 HVOF coating shows a molten and un-molten powder with curved laminar structure and confirm homogeneous coating [9-11]. Figure 1 (c) shows results of EDS shows oxides formation in Al2O3 HVOF coating.

Figure 2 shows residual stresses test results for Al2O3 HVOF coating. The stresses value are -135, -90, -45 and -20 MPa at 40, 50, 60, and 70 N respectively. The maximum residual stress developed in the coating at 70 N (-20MPa), while minimum at 40N (-135MPa).

The maximum hardness developed in the coating at 70N i.e. 470 HV, while minimum at 40N i.e. 290 HV as shown in the figure3. The experimental test results reveal that increase in micro-hardness and decrease in residual stresses may be occurs oxide layer formation under increasing load condition [9-14].

Figure 4 and figure 5 shows COF and wear test results for Al2O3 HVOF coating respectively. The experimental test results reveals that COF are 0.65, 0.42, 0.33, and 0.25. The maximum COF developed in the coating at 40 N i.e. 0.65 while minimum at 70 N i.e. 0.25. The maximum wear developed in the coating at 40 N i.e. 290 microns while minimum at 70 N i.e. 80 microns. Experimental test results reveal that decrease in COF and wear may be occurs oxide layer formation or due to tribo-film formation under increasing load condition [9-14].

![Figure 1 (a-c) FESEM - EDS results of Al2O3 HVOF coating](image-url)
Figure 2. Experimental results of Residual stress Vs Al₂O₃ HVOF coating

Figure 3. Experimental results of Hardness Vs Al₂O₃ HVOF coating
Figure 4. Experimental results of COF Vs Al₂O₃ HVOF coating

Figure 5. Experimental results of wear Vs Al₂O₃ HVOF coating

4. Conclusions and future scope
In present study, Al₂O₃ HVOF sprayed coating has been deposited using controlled spray process parameters. For surface analysis SEM characterization was used to characterize the developed coating. Wear, Residual stresses, COF and hardness, are studied at variable load of 40, 50, 60 and 70N.
Surface morphology of Al$_2$O$_3$ HVOF coating shows a molten and un-molten powder with curved lamination structure and confirm homogeneous coating. Experimental results revealed that with increase in load wear, hardness, residual stresses, and COF results were enhanced at higher load (70N). Experimental result shows wear value reduces to 80 microns and COF decreased to 0.25, while hardness and residual stresses increased to 470 HV and -20 MPa respectively. The experimental test results reveal that decrease in COF and wear may be occurs oxide layer formation or due to tribo-film formation under increasing load condition

Following work can be done for future scope:

- To study the tribological behavior of developed coating at high temperature.
- To study the effect of sliding velocity of developed coating on micro-hardness, wear and residual stress.
- To study the effect of temperature on corrosion and abrasion behavior of developed coating.

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