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COMPUTATIONAL ANALYSIS OF WEAR BEHAVIOR ON PIN ON DISC SETUP FOR THERMAL SPRAY OF COATING

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ABSTRACT

In this paper, we studied and explored the influence of variable load and speed values on the friction and wear behavior of thermal spray coated surface. The wear simulation model including multiple parameters was established based on experimental and theoretical data. The parameters of the model were determined by the test data. The simulation model reflects the basic relationship between input and output of the pin on disc dry sliding wear test. Tests were carried out at rotor speed of 50 rpm, 60 rpm and 70 rpm and nominal load varying from 50 to 100N. Simulation results shows that as the load on pin increase depth wear also increase with angular velocity remains the same and it also reveals the effect of pin diameter on wear depth.

***Keywords**:* Thermal spray of coating, Wear, ABAQUS, Tribology, Finite Element Method

I. INTRODUCTION

The subject of tribology requires a diverse knowledge base from many different scientific specialties. It involves a significant amount of experimental science. In the past, progress has usually been preceded by some experiment or experimental observation. One of the foremost reasons for the lack of concrete finite element modeling is that a tribosystem is made up of many different variables such as contact stress, surface roughness, sliding speed, load, chemical environments, temperature[1,9], humidity, material type, among others. Any modification in the combination of these variables may yield completely different test results. A quicker and approximate approach for engineers to find the wear behavior with a given set of variables and conditions is the use of wear maps [2,3].

Two of the most widely used measures to characterize the performance of a tribosystem are friction and wear. Both friction and wear data can be highly informative to engineers and materials scientists in order to designing and evaluating an engineering system. Due to the complex nature of wear phenomena, such relationships are often nonlinear and have varying nature between tribosystem. It has been clear from the previous research that friction and wear are chaotic processes; however it is possible to model the contact behavior between two materials. An effort to find the wear mechanism was analyzed through numerical and experimental methods where spherical contact pin-on-disc was used [4].Another effort to find wear rate in reciprocating pin on disc was done by Kim et al.[5] using finite element method .

Tribology deals with the synergy of any natural or engineered systems that have two pairs, liquid or solid in contact with each other. The relative motion between these pairs makes it impossible to directly observe and predict the behavior of contact. There are tremendous challenges and areas to be explored. The objective of most tribological testing is to emphasize the frictional power values and to measure the wear values for wear system. In order to protect the machines from wearing out PVD coatings are used. The PVD Crx N coatings are done by RF magnetron sputtering. This results improved mechanical properties like hardness, residual stress and adhesion[6,7,8,10]. Another different coating of polytetrafluoroethylene (PTFE) is studied for wear rate under dry condition and variable loads and speeds is done by Unal et al. [11] and showed little sensitivity to test speed as compared to variable loads.

II. OBJECTIVE OF THE RESEARCH WORK

The objective of this project is as follows:

- To model the pin and disc setup on ABAQUS and analyze the wear behavior of the thermal spray coating.

- To obtain the relationship between angular velocity of the disc and wear depth.

III. DESCRIPTION OF THE PROBLEM

Thermal spraying techniques are coating processes in which melted (or heated) materials sprayed onto a surface. The "feedstock" (coating precursor) is heated by electrical (plasma or arc) or chemical means (combustion flame).Thermal spraying can provide thick coatings (approx. thickness range is 20 micrometers to several mm, depending on the process and feedstock), over a large area at high deposition rate as compared to other coating processes such as electroplating, physical and chemical vapor deposition.

When surfaces are in contact they usually transmit shear as well as normal forces across their interface. With a Pin on Disc **(**PoD) test rig the Coefficient of Friction CoF and wear depth between two materials can be determined.

IV. MATERIAL FOR PIN AND DISC SETUP

In the property module, the material properties of hard chrome (Disc) and cylinder liner (Pin) are specified and body sections are assigned to specified regions of the pin and the disc. The disc and pin consists of one material and one section. In Table 1,the different material properties are presented.

Table 1: Material properties of pin and disc

Section Name	Material Behavior	Type	Young's Modulus [N/mm2]	Poisson's Ratio	Section Type
Pin	Mechanical, Elastic	Isotropic	150000	0.3	Solid/Homogenous
Disc	Mechanical, Elastic	Isotropic	103420	0.29	Solid/Homogenous

4.1 <u>DESIGN PARAMETERS OF PIN AND DISC</u>

Table 2: Dimensions of the pin and disc

The Disc		The Pin	
Outer radius	30 mm	Radius	2.5 mm
Inner radius	5 mm	Thickness (depth)	15 mm
Thickness (height)	5 mm		

V. FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) is a computer-based numerical technique for calculating the strength and behavior of engineering structures. It can be used to calculate deflection, stress, strain, buckling behavior and many other phenomena. The power and low cost of modern computers has made Finite Element Analysis available to many disciplines and companies. In the finite element method, a structure is broken down into many small simple blocks or elements. The behavior of an individual element can be described with a relatively simple set of equations. Just as the set of elements would be joined together to build the whole structure, the equations describing the behaviors of the individual elements are joined into an extremely large set of equations that describe the behavior of the whole structure. The computer can solve this large set of simultaneous equations. From the solution, the computer extracts the behavior of the individual elements. From this, it can get the stress and deflection of all the parts of the structure.

5.1. <u>SOLID MODELING</u>

Solid modeling is the first step for doing any 3D analysis and testing and it gives 3D physical picture for new products. In the present work, as the pin and disc are simple configuration, the modeling has been carried out in ABAQUS itself.

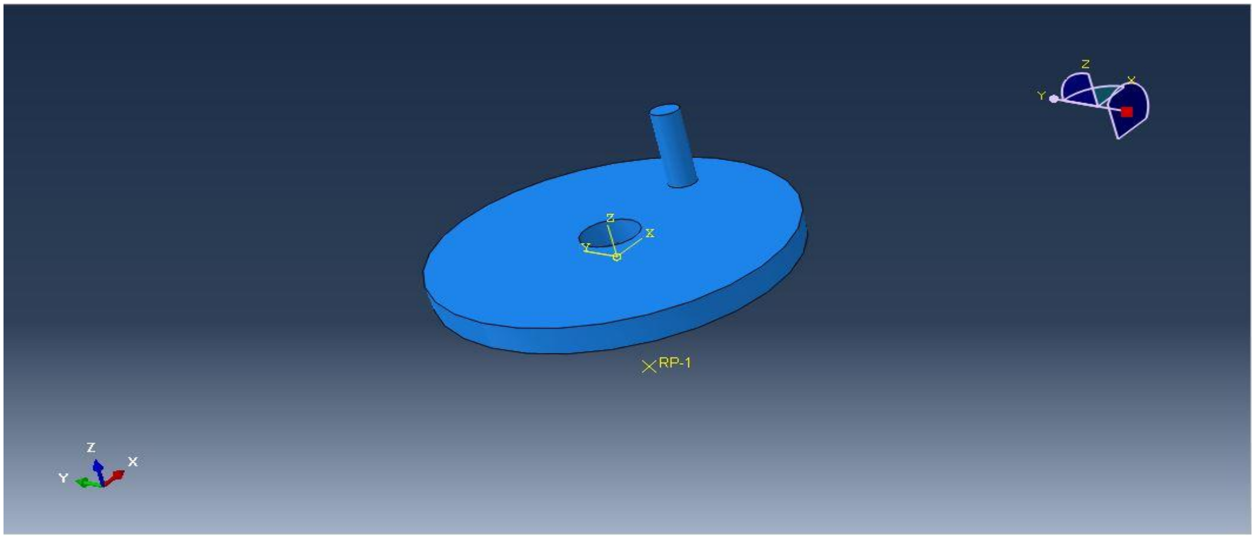

Figure 1: Assembly of pin and disc model

5.2. ASSUMPTIONS FOR ANALYSIS

- The interaction between pin and disc is of frictional type with a penalty of 0.3.
- The material of both pin and disc are isentropic.
- Specific wear rate (K= 6E-5) is constant.

VI. STATIC ANALYSIS

The aim of this analysis is to study pin and disc setup and verification of the results within the desirable limits. ABAQUS software is used to analyze the contact pressure by performing static analysis for the given load and angular velocity to determine the wear depth. Analysis involves discretization called meshing, boundary conditions, loading.

6.1. MESHING

As already mentioned, the used elements are of the type C3D8. It is a continuum solid element. It has 8 nodes, at each corner 1. This is the best option, since the model is made in such a way that the elements are almost square in the contact region.

6.2. BOUNDARY CONDITIONS

To simulate the clamping of the clamp holder, it is important that the BC's (Boundary Condition) are chosen in a proper way. The BC's should not generate extra stresses in the pin and it should be able to apply a force on the top. Using a coupling for the disc is not possible because the material will not able to move after this due to its poison ratio. Therefore, the outer surface of pin is fixed in x and y direction whereas the movement is free in z direction. All these BC's on the surface make sure that the surface is able to move towards the disc in the z direction and that the surfaces of the pin and disc stay aligned.

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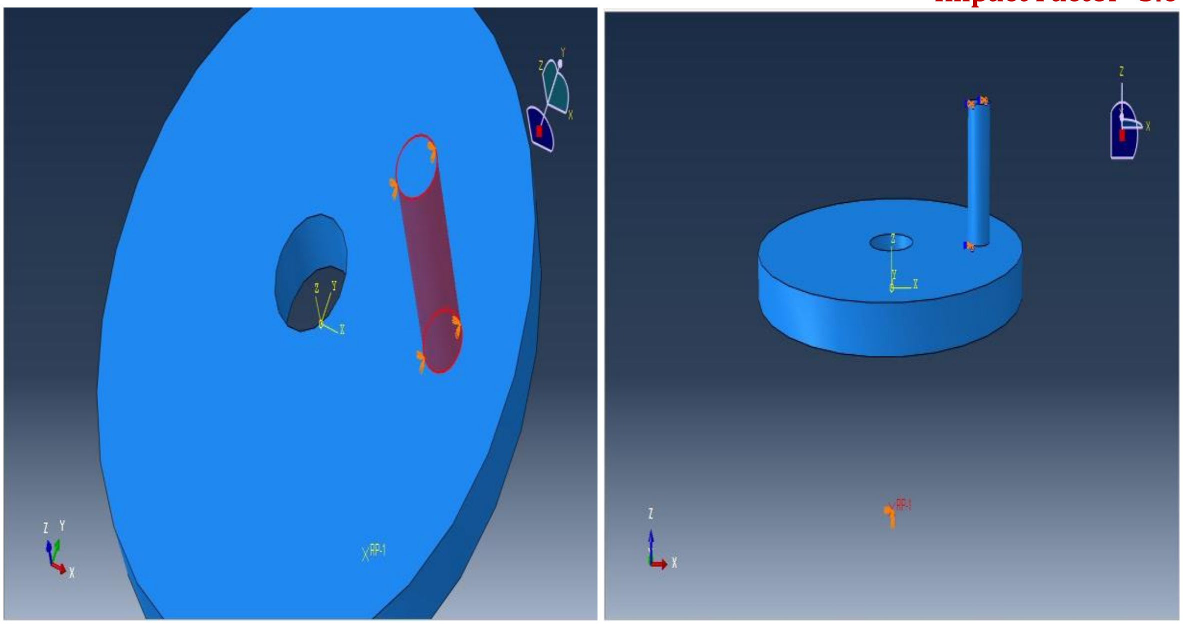

Figure 2: Boundary conditions of pin and disc.

6.3. LOAD

There are two ways in which a force can be prescribed on the top surface. The first one is to make a force vector to act at a node. The second one is to let a pressure act on a surface. The second one is the best. The first option results in a non homogenous force distribution in the upper part of the pin. When a pressure is applied at the top surface the size of the surface is of no importance because the quantity is prescribed in force per unit area and the pressure is distributed equally over the complete top surface.

Table 3: Pressure values for respective load on pin surface

Load (N)	Pressure (MPa)
50	2.564
60	3.055
70	3.565
80	4.074
90	4.583
100	5.093

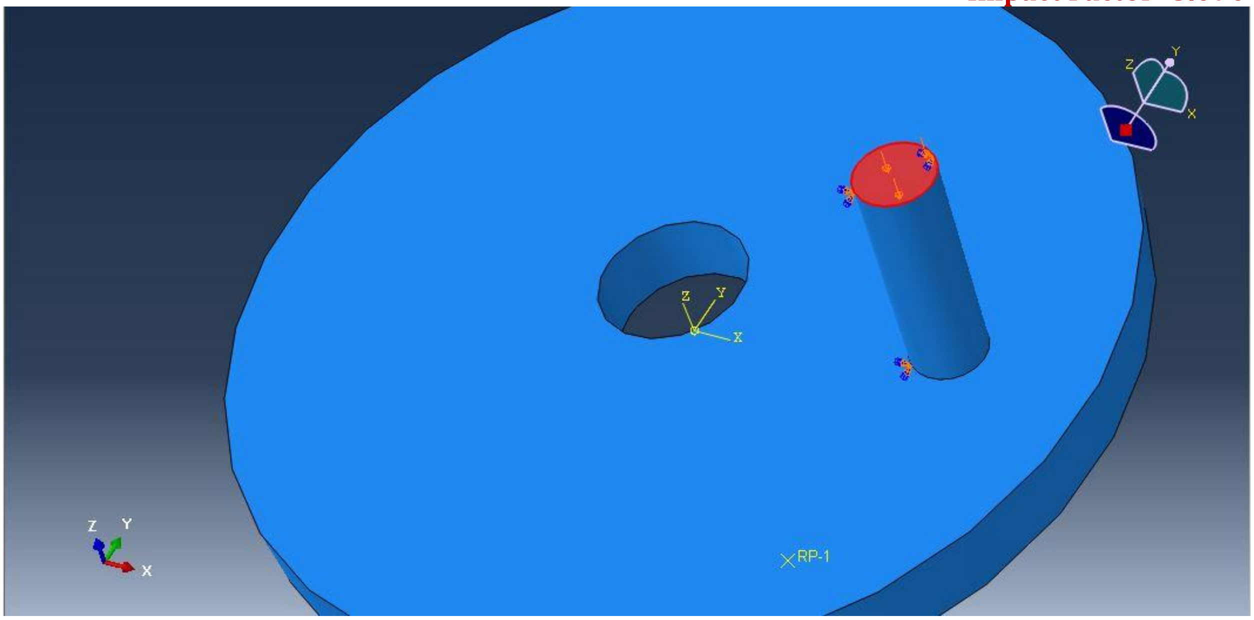

Figure 3: Figure depicting load on pin.

VII. RESULTS AND DISCUSSION

The equation used for the calculation of the wear depth is most popularly accepted Archard equation which states that:

$$W = K \times S \times P$$

Where,
W denotes the worn volume,
K denotes the wear per unit load per sliding distance and
S denotes the sliding distance,
P denotes the contact pressure between the sliding surfaces.

The key outcome expected from an FEA wear analysis is contact pressure (CPRESS). The contact pressure magnitude is recorded for all the sets of inputs and specific wear rate value is taken from the experimental analysis and sliding distance is calculated from the input parameters and finally by putting all the values in archard equation the wear depth is calculated for all sets of inputs.

Table 4: Contact pressure between pin and disc

S. No.	Load(N)	Contact Pressure(MPa) at 50 rpm	Contact Pressure(MPa) at 60 rpm	Contact Pressure(MPa) at 70 rpm
01	50	4.162	3.588	4.247
02	60	4.912	4.279	5.056
03	70	5.732	4.993	5.906
04	80	6.55	5.699	6.747
05	90	7.369	6.415	7.597
06	100	8.189	7.128	8.433

By putting the values of contact pressure and taking wear coefficient K=6e-5 constant for coating material, wear depth calculated are shown in Table 6.

Table 5: Wear depth ate different rpm of disc

S. No.	Load(N)	Wear (µm) at 50 rpm	Wear (µm) at 60 rpm	Wear (µm) at 70 rpm
01	50	0.1307	0.13526	0.18686
02	60	0.1543	0.1613	0.22237
03	70	0.18	0.18822	0.25975
04	80	0.20577	0.21484	0.29674
05	90	0.2315	0.24183	0.3341
06	100	0.25726	0.2687	0.3709

Experimental validation: For any simulation work, validation is most important to verify the accuracy of the simulation work. For the experiment purpose, hard chrome disc and cylinder liner pin is tested in pin on disc apparatus with same parameters as used in simulation work i.e. sliding speed, load and running time. Then the values of wear depth have been noted down and mentioned in Table 6.

Table 6: Experimental values of wear at different rpm of disc
Comparative graphs are plotted using experimental data and analytical data

S. No.	Load(N)	Wear (µm) at 50 rpm	Wear (µm) at 60 rpm	Wear (µm) at 70 rpm
01	**50**	**0.1286**	**0.1432**	**0.18422**
02	**60**	**0.1524**	**0.18711**	**0.23245**
03	**70**	**0.18232**	**0.20351**	**0.26241**
04	**80**	**0.21478**	**0.22841**	**0.3113**
05	**90**	**0.2426**	**0.2517**	**0.3569**
06	**100**	**0.26289**	**0.28459**	**0.39287**

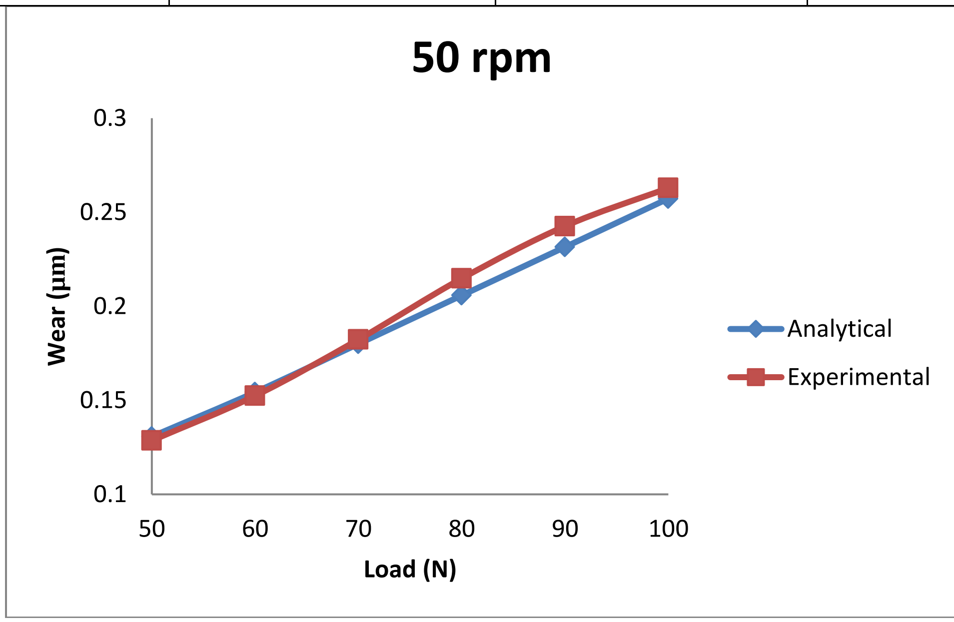

Figure 4: Figure showing comparative wear versus load graph at 60 rpm.

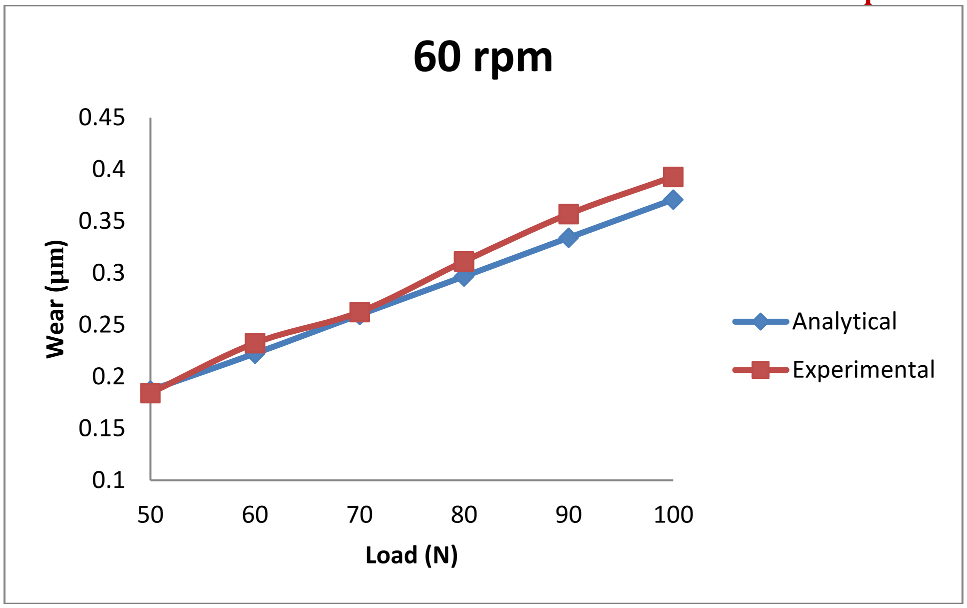

Figure 5: Figure showing comparative wear versus load graph at 60 rpm.

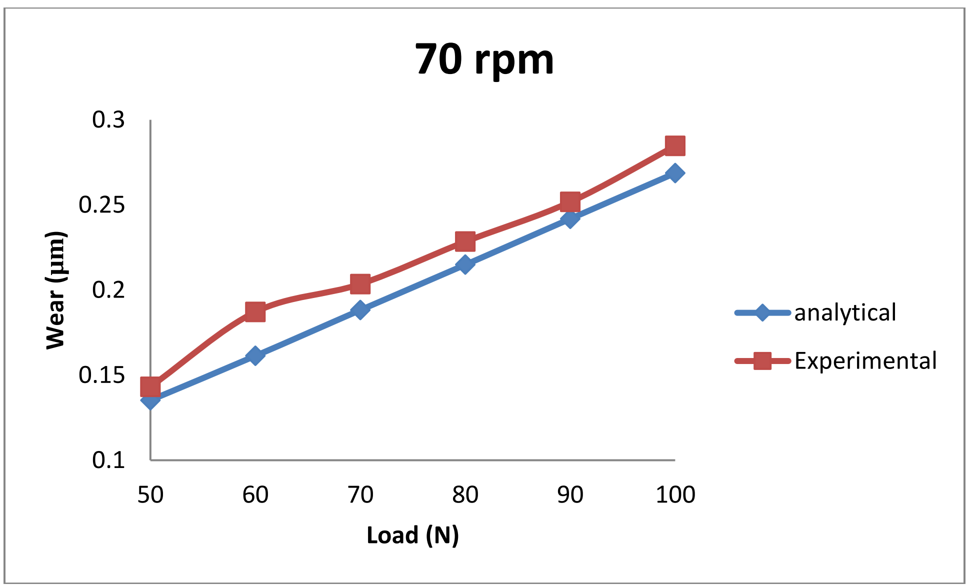

Figure 6: Figure showing comparative wear versus load graph at 70 rpm

Based on above graphs and results it can be concluded that the results obtained from experimental and analytical methods are almost same as; with the increase in load and angular velocity, wear depth also increases. The two important outcomes expected from a wear model from engineering standpoint are: change in dimensions and localized effects of wear. The presented FEA model addresses both aspects. Dimensional changes resulting from wear are seldom uniformly distributed; therefore any wear prediction model averages the changes in dimension across the contact in consideration. The FEA model can gives wear results at nodal level, which can be averaged across the contact.

VIII. CONCLUSION

In the present research work, a Pin-on-Disc system has been analyzed using ABAQUS CAE 6.13. The finite element model used for analyses has been updated based on experimental results from the Pin-on-Disc test.

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- A good and reliable Pin on Disc FE model has been built. The simulations of the Pin on Disc tests give good and reliable results.
- The results out of the Finite Element model are verified with experimental results and the results are almost the same.
- The pressure distribution that has been calculated by FE program is probably accurate representation of the pressure distribution in real life.

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