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Simulation of Sliding Wear Using Finite Element Analysis

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Abstract

This study has been conducted to investigate the effect of sliding speed and loads on the wear behaviour of Aluminium alloy 6063 using pin-on-disc apparatus when the Aluminium pins slide on steel disc. In order to do so, a pin-on-disc apparatus is used for experiments and model developedusing ANSYS15 programfor predicting the wear simulation for dry sliding wear rates.The varying parameters of normal load and sliding velocity were taken as input for the FEA simulation to find out the stress and contact pressure between the disc and pin. The inputs were taken as normal load of 5kg, 7kg and 9 kg (49 N, 68.6 N, 88.2 N respectively)and the sliding velocity as 200rpm, 350rpm and 500 rpm. Results show that the contact pressure increases with normal load but decreases with sliding velocity and stress in pinincreases with normal load and sliding velocity. The obtained results also revealed that the change in both the parameters is very small with increasing sliding velocity as compared to the change w.r.t. increase in normal loads.

Keywords: Pin-on-disc, Aluminium, Contact Pressure, Stress, Wear, Ansys15.

Introduction

Wear occurs when two surfaces in contact have a relative motion resulting in removal of one surface because of the mechanical action of the other sliding surface in contact. The study of wear and friction has been done by several authors over the years.It has been observed that the variation of friction between the two sliding surfaces depend on various conditions such as type of material, surface roughness, temperature, normal load, relative humidity lubrication and sliding velocity. Among all these factors, the two significant factors which play a major role for the variation of friction during sliding are sliding velocity and normal load.

Yanet al. proposed a computational approach to predict the sliding wear caused by a loaded spherical pin contacting a rotating disc. The author proposed a framework according to which a plane strain region exists at the centre of the disc wear track, when the pin contacts and slides on the disc. The author determined the wear rate in this plane strain from a two dimensional idealisation of the contact problem. Periodic unit cell techniques were used in conjunction with a ratchet ting-based failure criterion to predict the wear rate in the central plane strain region. The overall three dimensional wear rate of the disc was determined by scaling the plane strain wear rate with a conversion factor related to the predicted shape of the wear track. The author used this approach to predict pin-on-disc test data from an Al–Si coating using a tungsten carbide pin. The predicted results were found to be consistent with measured data.

Qin, et al. investigated the friction and wear behaviours of pure aluminium, unmodified and modified Mg_2Si/Al composites in a pin-on-disk configuration. The Mg_2Si/Al composite was prepared via a simple cast route, and then the composite was modified by phosphorus, forming modified composite. The author found that the wear rate increases with increasing load, but it varies from linear to rapid increase for all the test materials in the present work, i.e. mild and severe wear regime. The wear mechanism in severe regime was discussed. Similarly, with the increase of sliding velocity, the wear rate was found to be increased.Ameen et al. studied the wear rate of different materials such as aluminium,brass, and steel using pin-on-disc apparatus under the effect of varying parameters like sliding speed, time and loads. Author also made a mathematical model all cases that were studied depending on the method of least squares in foretelling about the wear rate through the knowledge of time limits as a variable with fixing the other variables. It was observed that the cracks which were vertical on the direction of sliding and meet together with the lines of weariness showed that the rate of adhesion wear was direct proportional with the parameters of time, sliding speed and load. The author also found that the least wear rate among different materials under experiment was of the low carbon steel.

Nuruzzamanet al. examined the friction coefficients of aluminum sliding against different pin materials. The authors fabricated pin-on-disc apparatus for the experiments. Results show that friction coefficient varies with duration of rubbing, normal load and sliding velocity. The magnitudes of friction coefficient were found to be different for different material pairs depending on normal load and sliding velocity.Nuruzzaman et al. investigated the friction and wear of copper and aluminium experimentally using a pin-on-disc apparatus.The effects of duration of rubbing on the friction coefficient ofcopper and aluminium were examined.The authors found that the friction coefficient and wear rate of copper were much lower than that of aluminum within the observedrange of normal load and sliding velocity.Prasadet.al, experimentally investigated the effect of fillers like red mud on dry sliding wear behaviour of pure aluminium. Pure aluminium of IE-07 grades was prepared using a stir casting technique. The author fabricated the Aluminium matrix composites with uniform distribution of red mud particles. The author found that the dispersion of red mud particles in aluminium matrix improves the hardness of the matrix material and also the wear behaviour of the composite. The effect was the increase in interfacial area between aluminium matrix and red mud particles leading to the increase in strength. The author also concluded that the coefficient of friction decreases as the load increases.

Shammaa et al. carried out theoretical and experimental examination to study the effect of load and relative sliding speed on the abrasive wear behaviour in drilling bit teeth surfaces of an insert tungsten carbide bit. The experiments were done for varying parameters of sliding velocity and load for dry and wet sliding conditions. The authors have developed a theoretical model based upon the Archard equation which was used for predicting wear simulation by using ANSYS12.1 program.The volume losses in wet tests were found to be higher than the dry tests.

For the present analysis it has been assumed that the wear is dependent upon stress. The variation of friction during sliding at different normal loads varies the contact pressure between the surfaces which represents the different amounts of wear between the surfaces. This change in the contact pressure and the stress with varying loads and sliding speeds has been investigated in this paper by simulating the pin-on-disc un-lubricated contact model in the software Ansys15.

Material and Method: Pin on Disc FE Model

The model presented in this paper is composed of two bodies in contact (Figure 1), a rotating disc of steeland a rigid Aluminium pin of 10 mm diameter on top of it. Table 1 shows the properties of the two materials used.

Table 1: Properties of materials used for FE modelling

Properties	Steel (Disc)	Aluminium (Pin)
Young's modulus	2.1×10^5 MPa	7.2×10^4 MPa
Poisson's ratio	0.23	0.32
Bulk modulus	1.296×10^5 MPa	6.667×10^4 MPa
Shear modulus	$8.53 \times * 10^4$ MPa	2.72×10^4 MPa

The Aluminium pin is used to apply the load on the rotating disc. Both the load on the pin and the rotating velocity of the disc has been taken as variables (Table 2) in this analysis.

Table 2: Design parameters for 3D model

Sr. No.	Factors	Units	Variable / Levels		
1	Rotational speed	rpm	200	350	500
2	Normal load	Kg (N)	5 (49)	7 68.6)	9 (88.2)
3	Wear track diameter	mm	70		
4	Disc thickness	mm	8		
5	Pin diameter	mm	10		
Sr. No.	**Factors**	**Units**	**Variable / Levels**		
6	Pin height	mm	32		
7	Disc diameter	mm	165		

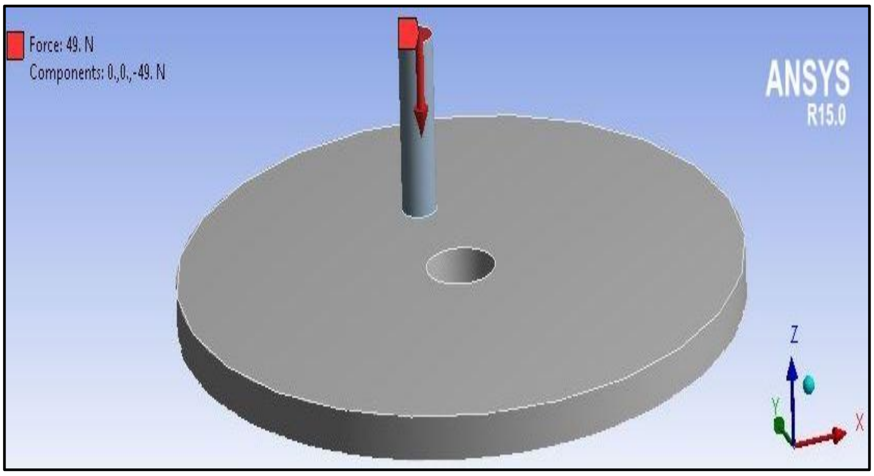


Figure 1: Pin-on-disc model in Ansys 15 program

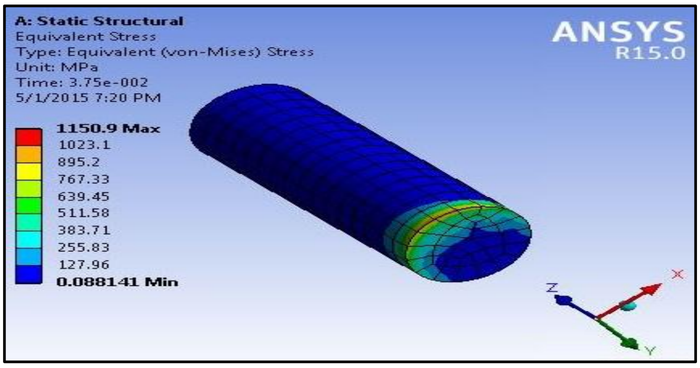
The analysis is performed in threesteps:

- First to create a contact between the surfaces, the pin was displaced towards the disc.
- Secondly, the disc was rotated in steps of degrees for obtaining the particular rotating velocity.
- The static loading step in which a group of load stepseach with an incremental sub-step providing a load repetition to calculate the contact pressure between the surfaces and stresses generated in the pin.

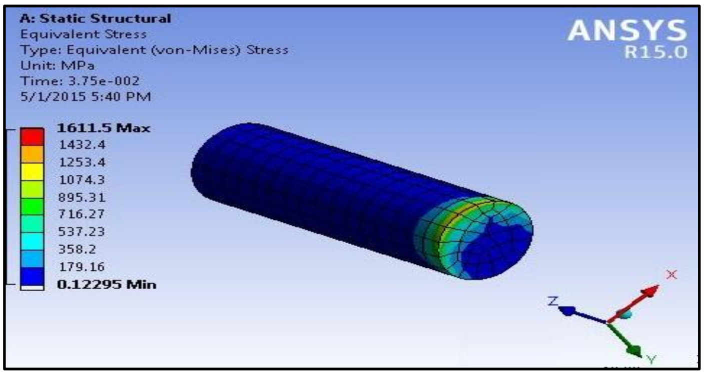
Results and Discussions

In order to see the effect of sliding velocity and normal loads on the contact pressure and stresses between the two surfaces in contact, the FE model was created in Ansys 15 program. The analysis showed how the contact pressure between the two surfaces and stress in the pin changes with respect to the parameters which were sliding velocity of the disc and the normal load on the stationary aluminium pin.

Figures 2 (a-c) show the variation of the stresses developed along the sliding direction with different loads as the wear progresses.



(a)



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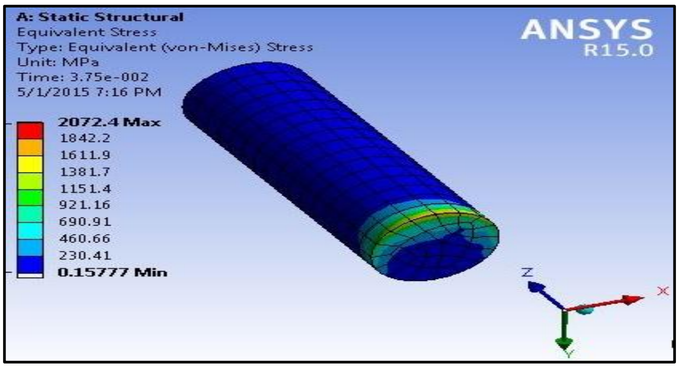
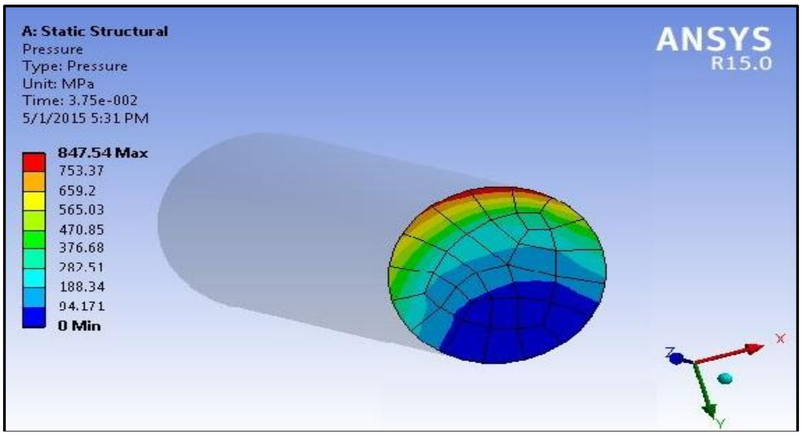


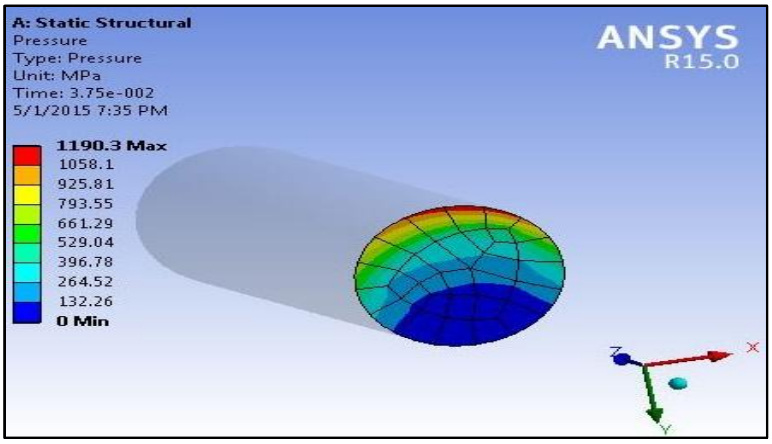
(c)

Figure 2: (a) Stresses in the pin for load 5kg (49 N), 200 rpm; (b) Stresses in the pin for load 7kg(68.6 N), 200 rpm; (c) Stresses in the pin for load 9kg (88.2 N), 200 rpm.

The analysis shows that the stress values are changing over time due to the wear and the changing contact, so the wear at any particular point is changing over time since we have assumed that the wear depends on stress. This change of wear with time can be seen from the contact pressure at different loads representing different amounts of wear as in Figures 3(a-c).



(a)



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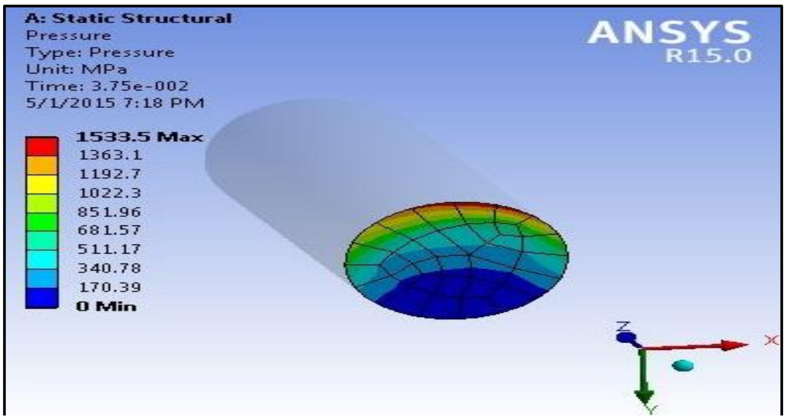
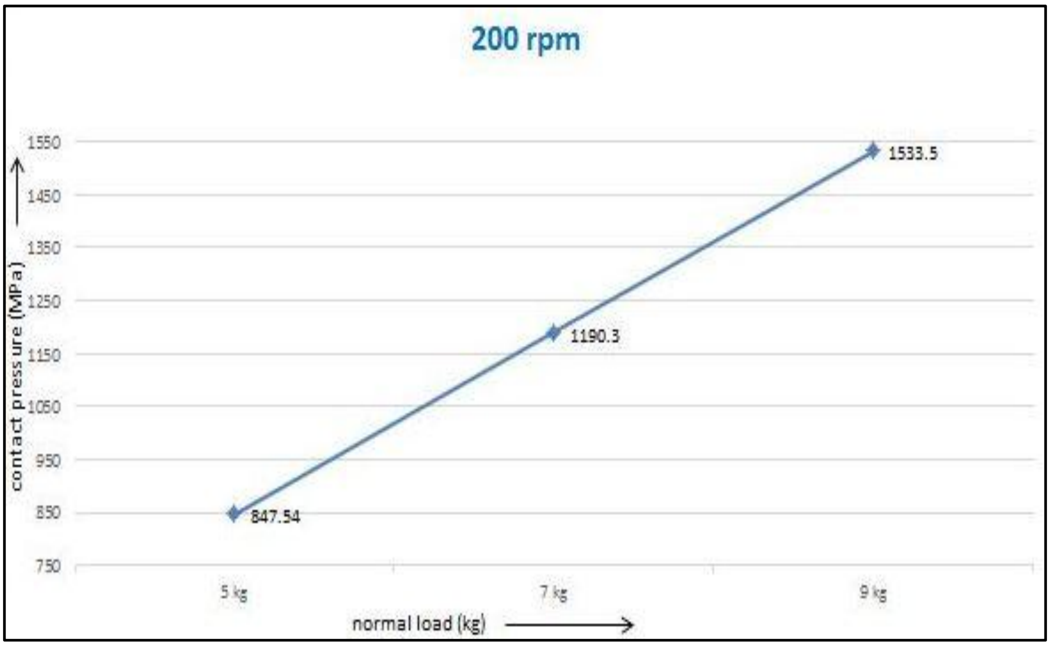


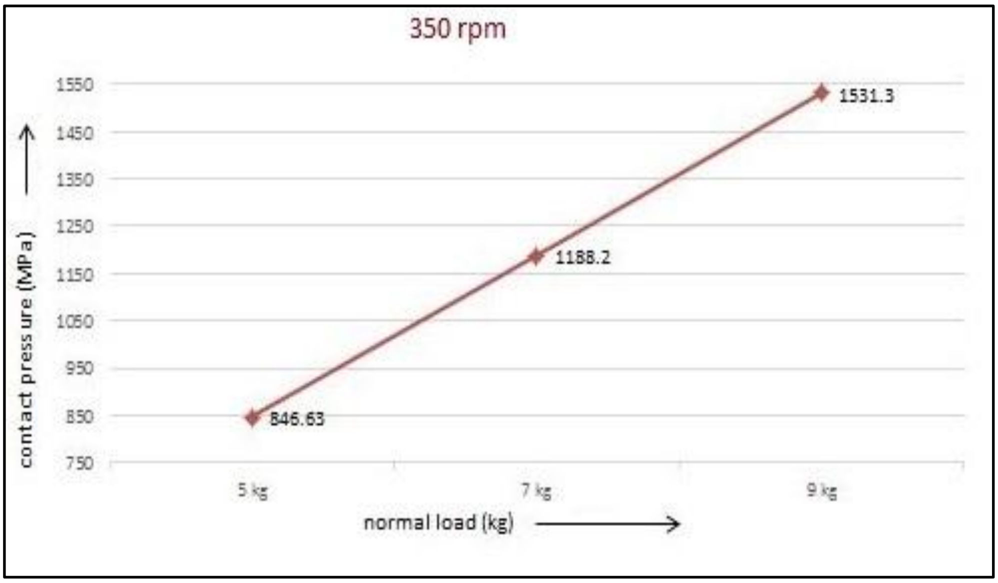
(c)

Figure 3: (a) Contact Pressure in the pin for load 5kg (49 N), 200 rpm; (b) Contact Pressure in the pin for load 7kg(68.6 N), 200 rpm; (c) Contact Pressure in the pin for load 9kg (88.2 N), 200 rpm.

The contact pressure between the surfaces increases with increase in normal load at a constant sliding velocity of the disc and decreases slightly at same load but different sliding velocities. Figure 4 (a-c) shows the variation of the contact pressure w.r.t changing loads at three different sliding velocities.



(a)



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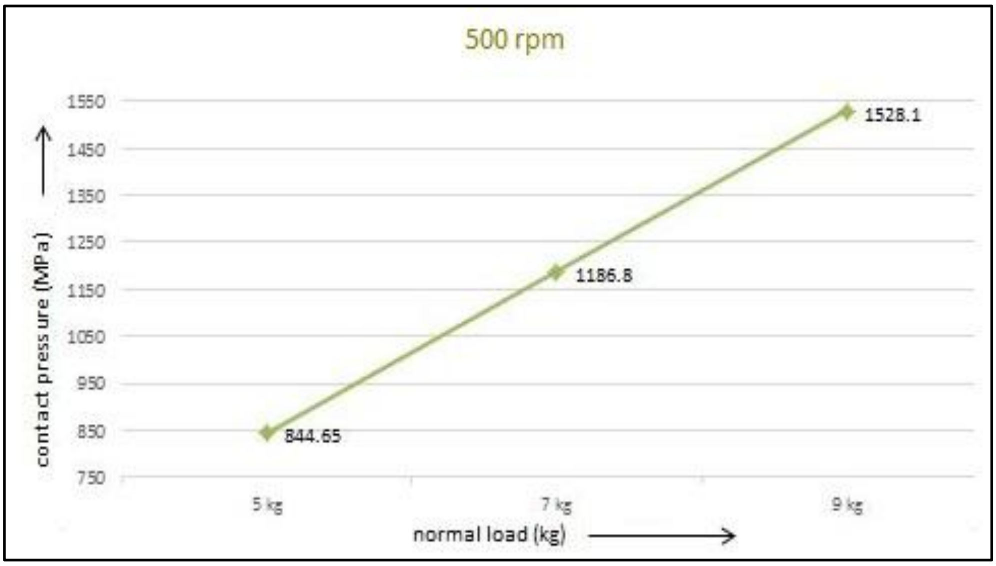
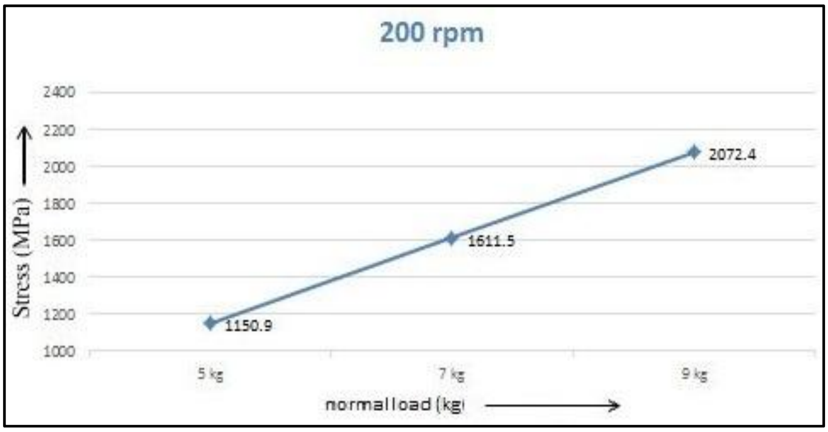


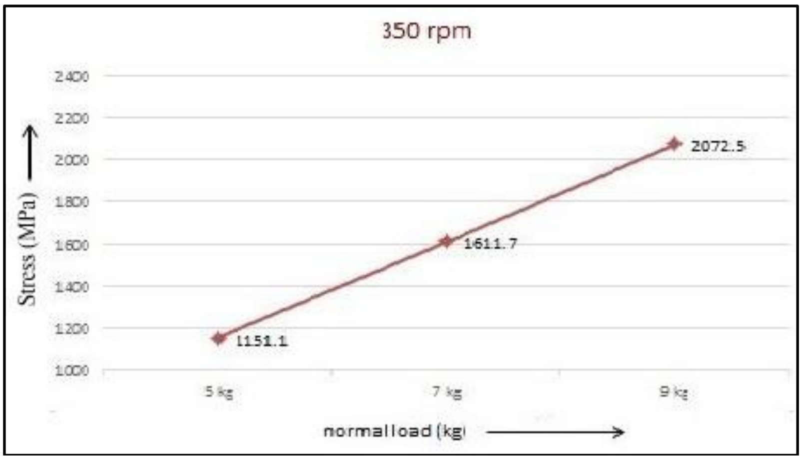
(c)

Figure 4: (a) Contact Pressure in the pin for 200 rpm at different normal loads; (b) Contact Pressure in the pin for 350 rpm at different normal loads; (c) Contact Pressure in the pin for 500 rpm at different normal loads.

The stresses in the pin increase with increase in normal load at a constant sliding velocity of the disc and increases slightly at same load but different sliding velocities. Figure 5 (a-c) shows the variation of the stresses w.r.t changing loads at three different sliding velocities.



(a)



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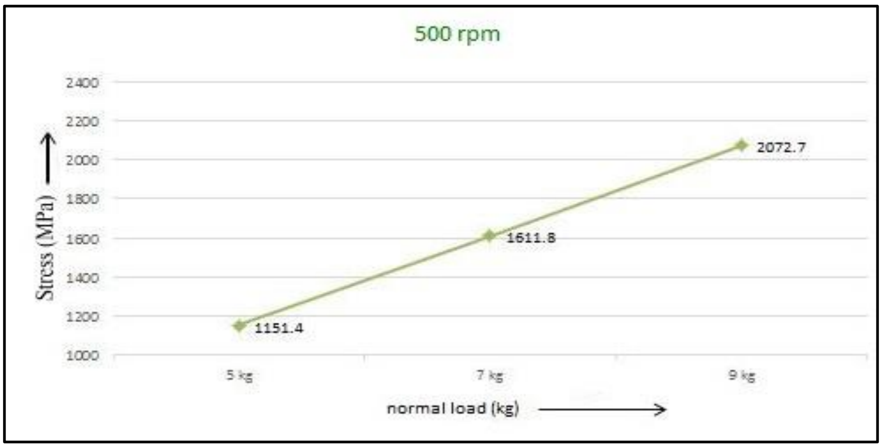

(c)

Figure 5: (a) Stresses in the pin for 200 rpm at different normal loads; (b) Stresses in the pin for 350 rpm at different normal loads; (c) Stresses in the pin for 500 rpm at different normal loads.

Conclusion

From this study, the obtained results are summarized as:

1. Within the observed range of normal load and sliding velocity, the stresses in the pin increase with increase in loads and sliding velocity. The maximum stress of 2072.7 MPa in the pin is observed at the load of 9 kg (88.2 N) and 500 rpm and the minimum stress of 1150.9 MPa is observed at 200 rpm and 5 kg (49 N) of load.
2. The contact pressurebetween the surfaces increases with increase in loads but decreases slightly with increase in sliding velocity. The maximum contact pressure of 1533.5 MPa is observed at the load of 9 kg (88.2 N) and 200 rpm and the minimum amount of pressure is observed at a load of 5 kg (49 N) and 500 rpm.

3. From the observed values of stresses and contact pressure it can be concluded that the wear between the two contact surfaces increases with increase in loads and sliding velocity.

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