Wear Analysis of Aluminum Alloy For Automobile Piston Against Cast Iron For Cylinder Liner

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Abstract:

Aluminum alloys are commonly used these days for manufacturing automobile pistons. These pistons are run in cast iron liners. It is a well-known fact that aluminum and its alloys exhibit both abrasive and adhesive wear mechanisms. Normal pressure and sliding velocity, along with the composition of alloy and lubrication, are the governing factors for dominance of a particular wear mechanism. Therefore wear test data for specific values of these governing parameters would be quite useful for predicting wear behavior of the alloy. These tests also indicate as to which wear mechanism is present or dominating in a particular situation. Wear test data for this combination published till date is quite little. Since the composition of the aluminum alloy and cast iron were not available from the manufacturers or from the published data, the samples were prepared by melting the piston and liner of existing automobiles and casting the alloys in the form of pin and disc. These samples were tested using standard pin-on-disc method. The tests were performed under dry conditions. Both the abrasive and adhesive wear mechanisms were observed. An important observation was higher wear rates at lower velocity. This has been explained on the basis of adhesive wear and material transfer mechanisms.

INTRODUCTION

Most of the automotive engines use pistons of Aluminum alloys running in cast iron liners. It is difficult to predict the performance of these alloys due to complex conditions existing inside the IC engine cylinder.[1] Special test techniques have been developed by researchers to establish wear test data under different conditions of load and lubrication. In one method a ring segment was tested against a flat specimen of gray cast iron typical of cylinder liners. A wide range of lubricants was used to evaluate the sensitivity of the tests to lubricant condition.[2] Wear test data for this combination published till date is quite little. Wear in the liners occurs at different rates in different zones of the liner. The maximum wear in the liner has been reported to occur at the point where the topmost piston ring reverses its direction.[3] The initial few minutes of engine operation are critical in terms of wear in the liner. During a two hour test, 75% of the total wear occurred during the first six minutes.[4]. Artificial conditions have also been used for determining wear performance of piston-piston ring-cylinder assemblies.[5] Aluminum and its alloys exhibit both adhesive and abrasive wear mechanisms. Adhesion and material transfer mechanisms play a dominating role in case of aluminum and its alloys.[6,7]

The normal pressure and sliding velocity together are the deciding factors as to which wear mechanism would be prevailing in a given set of conditions. Further, the composition of the alloy also plays an important role. In order to study the wear behavior of aluminum alloy used in automobile pistons, against cast iron used in automobile cylinder liners, samples were prepared by melting these alloys and casting pins and discs from them. This step was taken, as the exact chemical composition of these alloys was not available from the manufacturer. Further, this ensured the exactness of material composition for the test purpose. The samples were tested by standard pin-on-disc machine at different normal pressures and sliding speeds. The results indicate both abrasive and adhesive wear mechanisms prevail in varying levels for different normal pressure and sliding velocity combinations. Higher wear rates were observed under low sliding velocities at certain values of normal pressure. This phenomenon has been explained through the material transfer mechanism.

EXPERIMENTAL PROCEDURE

The experiments were conducted on cylindrical pins. The outer surfaces of the skirt portion of automobile pistons were turned to obtain the representative aluminum alloy. The material obtained from machining was melted and cast into cylindrical bars. The pins were machined to diameter of 8 mm. . The disk was made by melting the cast iron liners of the automobile. The disk was machined to required dimensions and the surface was finished by grinding.

The aluminum alloy pins were tested on standard pin on disk machine to generate the wear data. Wear tests were performed using normal pressures in the range of 0.2 N/ mm^2 to 0.8 N/mm^2. For each pressure four sliding speeds were used in the range of 2 m/s to 8 m/s. The weight of the pins was measured after each run to determine the amount of wear.

RESULTS AND DISCUSSION

The wear rates obtained for different combinations of normal pressure and sliding velocity are given in Table 1. The sliding distance for each sliding velocity is also shown in this table. The wear rates (cu. m. per meter) for different normal pressures are plotted for the four different sliding speeds used in the experiment, as shown in Figure 1.

Table 1: Wear Rate for Different Pressure & Sliding Velocity Conditions

	Wear Rate (cu.m. per meter) x 10^{-12}			
Sliding Distance m	2400	1800	1200	600
Normal Pressure N/ mm^2	**Sliding Velocity m/sec**			
	8 m/s	**6 m/s**	**4 m/s**	**2 m/s**
0.2	1.52	0.753	0.93	1.06
0.3	1.94	1.06	1.22	1.92
0.4	3.65	1.57	2.05	2.72
0.5	5.58	1.97	1.95	3.45
0.6	5.64	4.29	3.18	4.25
0.7	8.88	5.57	3.98	4.84
0.8	17.00	9.01	6.20	5.51

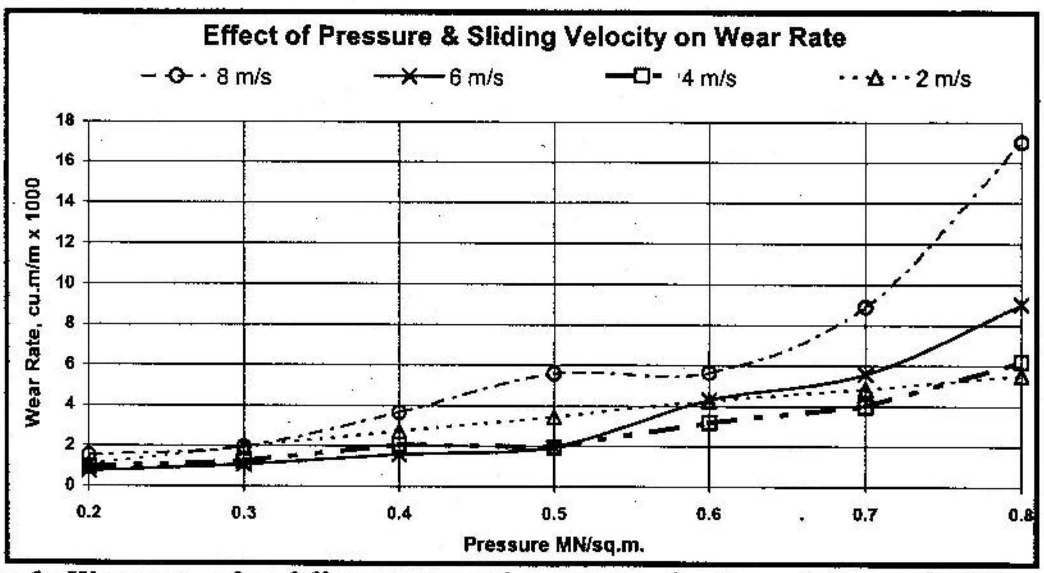

Figure 1: Wear rates for different normal pressures for four sliding velocities.

For sliding speed of 2 m/sec the wear rate (cu. m. per meter) shows a very steady and linear increase with normal pressure throughout the range of normal pressure used. This indicates that only abrasive wear phenomenon is active for this speed and other mechanisms are either absent or significant. An interesting observation is that the wear rate for sliding speeds of 4 m/sec is below that for speed of 2 m/sec up to normal pressure of about 0.75 N/mm^2. Similarly, the wear rate for sliding speed of 6 m/sec is below that for sliding speed of 2 m/ sec up to the normal pressure of about 0.6 N/mm^2. The lower wear rate at sliding speeds of 4 m/sec and 6 m/sec may be due to strain hardening phenomena, which might be absent at sliding speed of 2 m/sec. In case of sliding speeds of 4 m/ sec and 6 m/ sec the wear rate is seen to increase significantly after normal pressure of 0.5 N/ mm^2. Beyond the normal pressure of 0.5 N/mm^2 the strain hardened layer is unable to sustain and consequently the wear rate increases. Since this increase in the wear rate is not very rapid, it may be suggested that the dominant wear mechanism is still abrasion. In case of sliding speed of 8 m/sec, the wear rate is smaller than that for speed of 2 m/sec up to normal pressure of 0.3 N/mm^2. This may again be attributed to strain hardening phenomenon. In the pressure range of 0.5 N/ mm^2 to 0.6 N/ mm^2 the wear rate remains more or less constant. This may be due to beginning of adhesion phenomenon and the consequent formation of a layer of aluminum alloy, on the facing CI disk. Such a layer would tend to reduce the abrasive component. The wear rate is seen to increase steadily up to normal pressure of 0.5 N/mm^2. This can be attributed, as before, to the inability of the strain hardened layer to sustain and the dominance of abrasive wear. The rapid increase in the wear rate beyond the normal pressure of 0.6 N/mm^2 can be safely attributed to ingress of adhesive wear phenomenon.

CONCLUSION

Wear tests were performed on Aluminum alloy for automobile pistons, against cast iron, under dry conditions on a pin on disk wear testing machine. Wear rate for different conditions of normal pressure and sliding velocity were determined. Effect of phenomena affecting the wear rate like abrasion, adhesion and abrasive and strain hardening were studied. The wear rate was observed to be high for low normal pressure due to absence of strain hardening effect. It was found to increase, at moderate rate, when the normal pressure was increased. This change may be attributed to onset of strain hardening. Further increase in the normal pressure resulted in faster increase of wear rate, due to adhesive wear. Wear test data generated through these tests and the observations on mechanisms like adhesion, abrasion and strain hardening should be useful in further research in this area.

REFERENCES

1. Truhan JJ, Kodali P., "A comparison of rig and engine testing to measure in-cylinder wear in heavy duty diesel engines," pp 76, Proceedings of the fourth international filtration conference, San Antonio, TX, 2001.
2. John J. Truhan, Jun Qu, Peter J. Blau, "A rig test to measure friction and wear of heavy duty diesel engine piston rings and cylinder liners using realistic lubricants," Tribology International, pp 211-218, Vol. 38, 2005.
3. Kodali P, Truhan JJ, Richardson D., "A study of cylinder liner wear," Proceedings of the third international filtration conference. San Antonio, TX, Sept 1999 p. 68.
4. G.C. Barber and K.C. Ludema, "The break-in stage of cylinder-ring wear: a correlation between fired engines and a laboratory simulator," Wear, Vol. 118, pp 57-75, 1987.
5. P. Pawlus, "Effects of honed cylinder surface topography on the wear of piston-piston ring-cylinder assemblies under artificially increased dustiness conditions," Tribology International, pp 49-56, Vol. 26(1), 1994.
6. Stachowiak G.W. and Batchelor A.W., Engineering Tribology, Elsevier, 1993.
7. Rigney D.A., Chen L.H., Naylor M.G.S. and Rosenfeld A.R., "Wear process in sliding systems", Wear, Vol. 100, pp 195-219, 1984.

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