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Rock Island Arsenal Laboratory

TECHNICAL REPORT

EFFECT OF METAL HARDNESS AND SURFACE FINISH UPON FRETTING CORROSION

By

S. Fred Calhoun

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28 May 1963

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ABSTRACT

The fretting damage to each of two different surface finishes on each of two degrees of hardness of test specimens of the same carbon steel was determined. Five greases of nearly identical composition and physical characteristics were used, thus conceivably nullifying any effect due to these grease properties. If the hardness of the specimens was the same, the smoother finish suffered the most fretting damage in all but one case. When the effects of surface finish was considered it was observed that for the smoother finish the harder material fretted more, but for the coarser finish the softer material was affected most. This seeming contradiction has not been positively explained, but it is hoped that future work will provide information on which an explanation can be based.

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CONTENTS

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FINISH UPON FRETTING CORROSION

OBJECT

To determine what effect the surface finish and the hardness of a metal have upon the damage due to fretting when grease is used as a lubricant.

INTRODUCTION

The literature records concerning the effect of these two factors upon the damage due to fretting is to the most extent qualitative rather than quantitative. It also tends to be somewhat contradictory. Uhlig, Tierney, and McClellan[1] state that the surface finish has very little effect upon the amount of damage by fretting. McDowell[2] also introduces some data which indicates no appreciable differences in fretting due to surface finish. Tomlinson[3] states that fretting damage is greater for highly polished surfaces. The work of Rohm and Wurster[4] supports this observation by showing that vapor blasted surfaces are more resistant to fretting than the unblasted ones. Other investigators who support the claim that a smooth surface is more susceptible to fretting than a rough one include Almen[5], Gray[6] and Campbell[7].

There are on record disagreements to the above observations. Wallace[8] claims that superfinishing the bearing surfaces corrected the damage due to what he calls "brinelling" in automobile wheel bearings. Gross[9] presents some limited data indicating that the smoothest surface will have the highest pitting or fretting resistance. Of interest to this discussion is the almost universal agreement among the referenced investigators that no matter what the finish, two surfaces of like finish will suffer more damage from fretting than will two surfaces of unlike finish.

The question of the effect of metal hardness is almost as confusing as that of the finish and most of the evidence is also qualitative. Almen[5] mentions increasing the hardness of the metal as a means of reducing fretting. Gray and Jenny[6] report that increasing the hardness of steel reduces its tendency to fret. They also state that even the hardest steels will fret if the other conditions are present. Dies[10] believes that the fretting damage is dependent to a large extent upon the hardness of the metal oxide formed as well as upon the hardness of the metal. He found that aluminum fretted hardened steel to a greater extent than did a nitrided steel. Sakman and Rightmire[11] conclude that the greatest damage occurs where both the metal and its oxide were hard.

It was in the hope of resolving some of the confusion that this work was undertaken.

PROCEDURE

Consultation with the metallurgical department led to the adoption of a carbon steel for making all test specimens for this investigation. Proper heat treating of the steel gave two ranges of hardness. One batch checked around a 59-62 Rockwell C and the other at 29-31 Rockwell C. The specimens were then surface finished by grinding to two degrees of smoothness. One group from each hardness range was finished to a 10-15 micro-inch rms and another group to a finish of 100-110 micro-inch rms. The result was four groups of test specimens with the following hardness and surface finish.

TABLE I

Group	Hardness	Surface Finish
1	59-62 RC	10-15 rms
2	59-62 RC	100-110 rms
3	29-31 RC	10-15 rms
4	29-31 RC	100-110 rms

Since all the specimens were made from the same composition of steel, the hardness and surface finish were the only variables associated with the steel.

Five greases were selected for the investigation. They were all qualified under Specification MIL-G-10924A and were calcium hydroxy stearate thickened mineral oil greases. Mechanically they were all stable greases of NLGI #2 consistency as can be observed from their characteristics listed in Table II.

TABLE II

MECHANICAL CHARACTERISTICS OF THE GREASES USED

Grease No.	60 Stroke Pen	10000 Stroke Pen
1	288	297
2	276	282
3	304	313
4	285	270
5	295	268

The apparatus used and the method of conducting the test are fully described in a previous report by the writer.(12) Thus, the only conceivable variables were the surface finish and hardness of the test specimens. Since each set of test specimens was evaluate with each of the five greases, it is felt that a comprehensive survey of the effects of the two furface finishes and hardness ranges was obtained.

RESULTS AND DISCUSSION

The results in milligrams of weight loss are given in Table III. The values given are the averages of at least three separate determinations.

TABLE III

	10-15 RMS		100-110 RMS	
Grease No.	59-62 RC	29-31 RC	59-62 RC	29-31 RC
1	1.4	1.0	0.7	0.9
2	0.7	0.4	0.0	0.2
3	0.6	0.5	0.6	0.9
4	0.8	0.5	0.0	0.4
5	1.1	0.8	0.5	0.7

A study of Table III reveals that the smoother finish (10-15 rms) suffered more fretting loss than the coarser finish (100-110 rms). This was true for both hardness ranges. Grease No. 3, however, seemed to have another factor affecting the fretting loss, as it did not follow the trend of the other four greases. For the 59-62 RC specimens it gave the same loss and for the 29-31 RC specimens less loss for the smoother finish.

A possible explanation for this observed effect of surface finish is found in the work of Feng and Rightmire[13]. They postulate that the contact between any two surfaces is between a comparatively few high spots or asperities. The smoother the surface the greater the number of asperities that could contact. A rough surface would have fewer contacts. The smoother surface would thus have more metal to metal contact and hence more metal transfer or plucking and consequent oxidation and damage. Barnett[14] also supports this theory. This theory is based on the premise that the pressure between the surfaces is not great enough to cause appreciable plastic deformation.

When comparing the effects of hardness of the metal upon fretting an apparent contradiction is encountered. For the smoother finish (10-15 rms), the harder specimens (59-62 RC) incurred the most fretting damage in all cases. For the coarser finish (100-110 rms), the softer metal (29-31 RC) had the most fretting loss for all greases tested.

To explain this reeming contradiction observed in the effect of hardness on the coarser finish a probable cause is also found in the work of Feng and Rightmire[13]. They state that plastic deformation due to the distribution of the load over a relatively few high spots results in more metal to metal contact and hence more metal transfer and "plucking". The conditions of pressure used in this investigation were evidently sufficient to cause enough plastic deformation in the softer material to increase the area of metal to metal contact and thus result in more fretting. The harder material would suffer less plastic deformation and hence have less surface in contact.

The explanation of the greater loss for the harder material in the 10-15 rms finish is not so apparent. The concensus of opinion expressed by the literature is that the harder surface will reduce fretting. Most also admit that like materials and like surface finishes will increase fretting damage. Since in this investigation like materials of equal hardness and surface finish were always used together, it is felt that these factors were equalized. Evidently the harder material produces more fretting when rubbed against an identical material of equal hardness and when both are of fairly smooth finish. It is entirely possible that there is a surface finish of such a smoothness that the hardness of the material would have no effect upon fretting. It is expected that more information concerning this phenomena will be available from future work.

LITERATURE REFERENCES

1. Uhlig, H. H., Tierney, W. D. and McClellan, A., "Test Equipment for Evaluating Fretting Corrosion," ASTM Symposium on Fretting Corrosion," ASTM Symposium on Fretting Corrosion, Technical Publication #144, 25 June 1952.

2. McDowell, J. R., "Fretting Corrosion Studies of Several Combinations of Materials." Ibid.

3. Tomlinson, G. A., Thorpe, P. L., and Gough, H. L., "An Investigation of Fretting Corrosion of Closely Fitting Surfaces," Proceedings, Institute of Mechanical Engineers, Vol. 141, No. 3, 1939.

4. Rohm, A. E., and Wurster, H. J., "Fretting Corrosion in Aircraft and Aircraft Accessories," Lubrication Engineering, Vol. 7, 12 February 1951.

5. Almen, J. O., "Lubricants and False Brinelling of Ball and Roller Bearings." Mechanical Engineering, Vol. 59, June 1937.

6. Gray, H. C. and Jenny, R. W., "Investigation of Chafing on Aircraft Engine Parts," SAE Journal, Vol. 25, No. 11, November 1944.

7. Campbell, W. E., "The Current Status of Fretting Corrosion," ASTM Special Technical Publication No. 144, 25 June 1952.

8. Wallace, D. A., "Superfinish," SAE Journal, Vol. 46, February 1940.

9. Gross, M.R., "Laboratory Evaluation of Materials for Marine Propulsion Gears," Proceesings of the ASTM, Vol. 51, 1951, pp. 701-716.

10. Kurt Dies, "Fretting Corrosion, A Chemical-Mechanical Phenomenon," The Engineers Digest, Vol. 2, No. 1, January 1945.

11. Sakman, B. W., and Rightmire, B. G., "An Investigation of Fretting Corrosion Under Several Conditions of Oxidation," TN-1492, NACA, June 1948.

12. Calhoun, S. Fred, "Reduction of Fretting Corrosion of Greases by Use of Extreme Pressure and Antiwear Additives," Rock Island Arsenal Report No. 62-651, 20 February 1962.

13. Feng, 1-Ming, and Rightmire, B. G., "A Fundamental Study of the Mechanism of Fretting," Final Report OOR Contract No. DA-19-020-ORD-3312, 1955.

14. Barnett, R. S., "Fretting Corrosion," Lubricating Engineering, Vol. 8, No. 4, 1952.

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