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discussion

A Study of Residual Stress Induced During Rolling[1]

W. A. Glaeser.[2] The work reported here has been of considerable interest since it was first reported because of the seemingly high sensitivity of rolling contact fatigue to hardness differential between balls and races. It has been difficult to come up with a good explanation for the significant differences in fatigue lives measured when differences of only a few Rc points of hardness are involved. Needless to say it must have caused some dismay among bearing company quality control specialists.

The present paper infers that differential hardness between race and rolling element will lead to beneficial compressive residual stresses in the race after operation of the bearing under moderately heavy loads. Further, that an optimum hardness differential can be found which will produce maximum compressive residual stress. Presumably, the X-ray diffraction measurements reflect plastic strain or amount of grain distortion. Since fatigue damage is initiated by structural changes resulting from accumulation of concentrated plastic strain in the rolling contact stress field, the residual stress measurements could reflect the extent of precrack working under the maximum shear stress. The effect of an assumed residual compressive stress on the maximum shear stress or the orthogonal shear stress may not be appropriate. For one thing, the effect may not be simply arithmetic—the effect on the principal stresses should be considered and then the resulting maximum shear stress estimated. Second, the residual compressive stress may have more influence on fatigue crack propagation by decreasing the tensile stress component responsible for crack propagation. In this case it would be interesting to analyze the residual stress condition close to the surface of the bearing race.

Authors' Closure

The authors would like to thank W. A. Glaeser for his discussion. In previously published papers [9, 10, 16],[3] the authors reported the ΔH relationship, where maximum fatigue life for a rolling-element system is obtained where the unit elements receiving the greater number of stress cycles are 1 to 2 points Rockwell C less than the mating elements. Based upon preliminary residual stress measurements of ball specimens run in the five-ball fatigue tester [2] and bearing inner races [1], it was postulated by the authors that there was an interrelation between ΔH, fatigue life, and induced compressive residual stress. With the relation between ΔH and fatigue life for SAE 52100 steel bearings having been established, it was necessary to definitely establish the cause for this phenomenon. As a result, the work reported in the instant paper and in [8] were undertaken. Hence, contrary to Mr. Glaeser's implication, it has not been difficult to come up with a good explanation for the significant differences in fatigue lives measured. Further, the authors have not found bearing company quality control specialists dismayed over the authors' results. What the instant paper does is to definitely establish the ΔH residual-stress, fatigue-life relationship.

In previous work of the authors [2], the effect of residual stress on the maximum shearing stress was derived. The residual stresses are added to the principal stresses. The principal stresses are effectively increased by these residual stresses in the directions parallel to the plane of rolling. In the normal direction, the residual stresses are negligible. One-half the difference between the normal principal stress and the smallest parallel principal stress gives the maximum shearing stress. The presence of the residual stress reduces this difference, giving the relation presented by the authors in the instant paper. What is important is that the residual stress will affect the maximum shearing stress and the maximum octahedral shearing stress, but will not affect the orthogonal shearing stress.

The authors must take exception to several statements made by Mr. Glaeser. It has not been established that a relation exists between rolling-element fatigue and structural changes due to rolling-element operation. On the contrary, where rolling-element fatigue has occurred, no structural changes could be observed using light microscopy techniques [17]. In addition, the critical stresses responsible for crack initiation and propagation have not been definitely established. The various shearing stresses previously mentioned occur on various planes oriented at different angles to the surface. Crack propagation has been observed by the authors to be coincident with all these planes.

The effect of surface residual stress has been considered in the instant paper. Residual stresses are present on the surface of bearing races due to the manufacturing process. These residual stresses remain relatively unchanged during rolling-contact operation. The authors found no correlation between these surface residual stresses, ΔH, and fatigue life.

Additional References

16 Zaretsky, E. V., Parker, R. J., and Anderson, W. J., "Effect of Component Differential Hardness on Rolling-Contact Fatigue and Load Capacity," NASA TN D-2640, 1965.

17 Carter, T. L., "A Study of Some Factors Affecting Rolling-Contact Fatigue Life," NASA TR R-60, 1960.

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[1] By E. V. Zaretsky, R. J. Parker, and W. J. Anderson, published in the JOURNAL OF LUBRICATION TECHNOLOGY, TRANS. ASME, Series F, Vol. 91, No. 2, Apr. 1969, p. 314.

[2] Battelle Memorial Institute, Columbus, Ohio.

[3] References numbered consecutively from those of the paper.