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2. Rolling bearing life prediction, theory, and application

Erwin V. Zaretsky
Chief Engineer (Structures and Materials), NASA Glenn Research Center, USA

Abstract

A tutorial is presented outlining the evolution, theory, and application of rolling-element bearing life prediction from that of A. Palmgren, 1924, W. Weibull, 1939, G. Lundberg and A. Palmgren, 1947 and 1952, E. Ioannides and T. Harris, 1985, and E. Zaretsky, 1987. Comparisons are made between these life models. The Ioannides-Harris model without a fatigue limit is identical to the Lundberg-Palmgren model. The Weibull model is similar to that of Zaretsky if the exponents are chosen to be identical. Both the load-life and Hertz stress-life relations of Weibull, Lundberg and Palmgren, and Ioannides and Harris reflect a strong dependence on the Weibull slope. The Zaretsky model decouples the dependence of the critical shear stress-life relation from the Weibull slope. This results in a nominal variation of the Hertz stress-life exponent.

For 9th- and 8th-power Hertz stress-life exponents for ball and roller bearings, respectively, the Lundberg-Palmgren model best predicts life. However, for 12th- and 10th-power relations reflected by modern bearing steels, the Zaretsky model based on the Weibull equation is superior. Under the range of stresses examined, the use of a fatigue limit would suggest that (for most operating conditions under which a rolling element bearing will operate) the bearing will not fail from classical rolling-element fatigue. Realistically, this is not the case. The use of a fatigue limit will significantly overpredict life over a range of normal operating Hertz stresses. (The use of ISO 281:2007 with a fatigue limit in these calculations would result in a bearing life approaching infinity.) Since the predicted lives of rolling-element bearings are high, the problem can become one of undersizing a bearing for a particular application.

Rules had been developed to distinguish and compare predicted lives to those actually obtained. Based upon field and test results of 51 ball and roller bearing sets, 98 percent of these bearing sets had acceptable life results using the Lundberg-Palmgren equations with life adjustment factors to predict bearing life. That is, they had lives equal to or greater than that predicted.

The Lundberg-Palmgren model was used to predict the life of a commercial turboprop gearbox. The life prediction was compared with the field lives of 64 gearboxes. From these results, the roller bearing lives exhibited a load-life exponent of 5.2, which correlated with the Zaretsky model. The use of the ANSI/ABMA and ISO standards load-life exponent of 10/3 to predict roller bearing life is not reflective of modern roller bearings and will underpredict bearing lives.