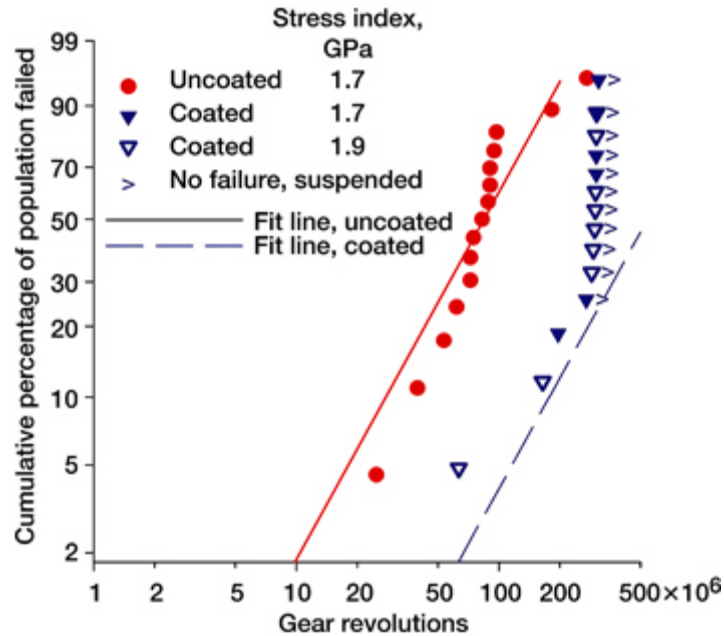


Gear Performance Improved by Coating

Gears, bearings, and other mechanical elements transmit loads through contacting surfaces. Even if properly designed, manufactured, installed, and maintained, gears and bearings will eventually fail because of the fatigue of the working surfaces. Economical means for extending the fatigue lives of gears and bearings are highly desired, and coatings offer the opportunity to engineer surfaces to extend the fatigue lives of mechanical components. A tungsten-containing diamondlike-carbon coating exhibiting high hardness, low friction, and good toughness was evaluated for application to spur gears. Fatigue testing was done at the NASA Glenn Research Center on both uncoated and coated spur gears. The results showed that the coating extended the surface fatigue lives of the gears by a factor of about 5 relative to the uncoated gears.

For the experiments, a lot of spur test gears made from AISI 9310 gear steel were case-carburized and ground to aerospace specifications. The geometries of the 28-tooth, 8-pitch gears were verified as meeting American Gear Manufacturing Association (AGMA) quality class 12. One-half of the gears were randomly selected for coating. The method of coating was selected to achieve desired adherence, toughness, hardness, and low-friction characteristics. First the gears to be coated were prepared by blasting (vapor honing) with Al_2O_3 particles and cleaning. Then, the gears were provided with a thin adhesion layer of elemental chromium followed by magnetron sputtering of the outer coating consisting of carbon (70 at.%), hydrogen (15 at.%), tungsten (12 at.%), and nickel (3 at.%) (atomic percent at the surface). In total, the coating thickness was about 2.5 to 3 μm . As compared with the steel substrate, the coated surface was harder by a factor of about 2 and had a smaller elastic modulus.

All gears were tested using a 5-centistoke synthetic oil, a 10,000-rpm rotation speed, and a hertzian contact stress of at least 1.7 GPa (250 ksi). Tests were run until either surface fatigue occurred or 300 million stress cycles were completed. Tests were run using either a pair of uncoated gears or a pair of coated gears (coated gears mated with uncoated gears were not evaluated). The fatigue test results, shown on Weibull coordinates in the graph, demonstrate that the coating provided substantially longer fatigue lives even though some of the coated gears endured larger stresses. The increase in fatigue life was a factor of about 5 and the statistical confidence for the improvement is high (greater than 99 percent). Examination of the tested gears revealed substantial reductions of total wear for coated gears in comparison to uncoated gears. The coated gear surface topography changed with running, with localized areas of the tooth surface becoming smoother with running. Theories explaining how coatings can extend gear fatigue lives are research topics for coating, tribology, and fatigue specialists. This work was done as a partnership between NASA, the U.S. Army Research Laboratory, United Technologies Research Corporation, and Sikorsky Aircraft.



Weibull plot of fatigue test data for both uncoated and coated spur gears illustrates improved fatigue lives owing to the coating.

Long description. Graph of cumulative percentage of population failed versus gear revolutions for uncoated gears with stress index of gigapascals and coated gears with stress indices of 1.7 and 1.9, along with fit lines.

Find out more about this research at <http://www.grc.nasa.gov/WWW/5900/5950/>

Bibliography

Krantz, Timothy L., et al.: Increased Surface Fatigue Lives of Spur Gears by Application of a Coating. NASA/TM--2003-212463 (ARL-TR-2971), 2003.
<http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?2003/TM-2003-212463.html>

U.S. Army Research Laboratory, Vehicle Technology Directorate at Glenn contact:

Dr. Timothy L. Krantz, 216-433-3580, Timothy.L.Krantz@grc.nasa.gov

Author: Dr. Timothy L. Krantz

Headquarters program office: OAT

Programs/Projects: VSP, UEET, Army Rotary Wing Vehicles