

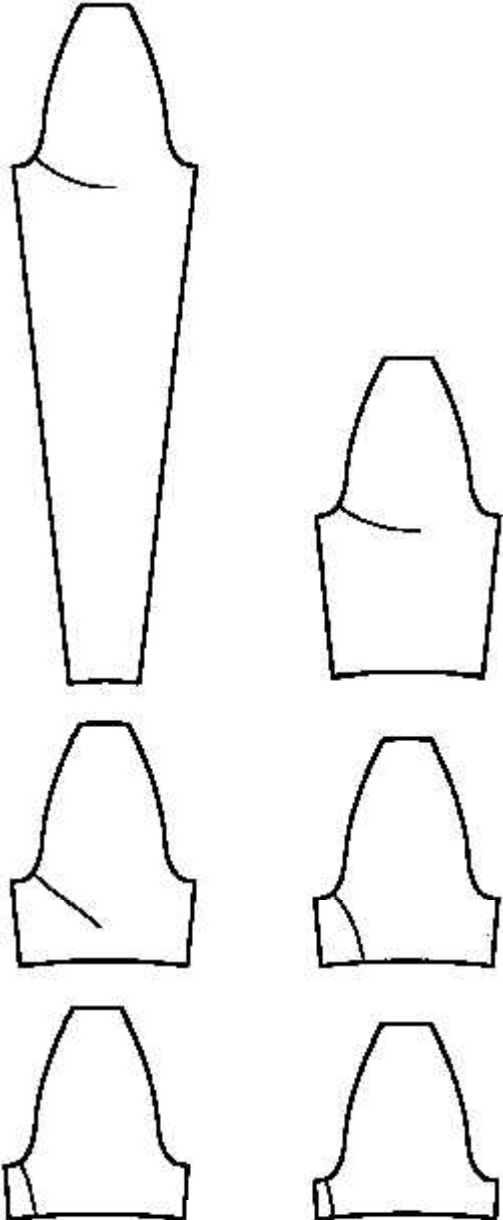
Gear Crack Propagation Investigation

Reduced weight is a major design goal in aircraft power transmissions. Some gear designs incorporate thin rims to help meet this goal. Thin rims, however, may lead to bending fatigue cracks. These cracks may propagate through a gear tooth or into the gear rim. A crack that propagates through a tooth would probably not be catastrophic, and ample warning of a failure could be possible. On the other hand, a crack that propagates through the rim would be catastrophic. Such cracks could lead to disengagement of a rotor or propeller from an engine, loss of an aircraft, and fatalities.

To help create and validate tools for the gear designer, the NASA Lewis Research Center performed in-house analytical and experimental studies to investigate the effect of rim thickness on gear-tooth crack propagation. Our goal was to determine whether cracks grew through gear teeth (benign failure mode) or through gear rims (catastrophic failure mode) for various rim thicknesses. In addition, we investigated the effect of rim thickness on crack propagation life. A finite-element-based computer program simulated gear-tooth crack propagation. The analysis used principles of linear elastic fracture mechanics, and quarter-point, triangular elements were used at the crack tip to represent the stress singularity. The program had an automated crack propagation option in which cracks were grown numerically via an automated remeshing scheme. Crack-tip stress-intensity factors were estimated to determine crack-propagation direction. Also, various fatigue crack-growth models were used to estimate crack-propagation life.

Experiments were performed in Lewis' Spur Gear Fatigue Rig to validate predicted crack-propagation results. Gears with various backup ratios were tested to validate crack-path predictions. Also, test gears were installed with special crack-propagation gages in the tooth fillet region to measure bending-fatigue crack growth.

From both predictions and tests, gears with backup ratios (rim thickness divided by tooth height) of 3.3 and 1.0 produced tooth fractures, whereas a backup ratio of 0.3 produced rim fractures. For a backup ratio of 0.5, the experiments produced rim fractures and the predictions produced both rim and tooth fractures, depending on the initial geometry of the crack. Good correlation between predicted and measured crack growth was achieved when the fatigue crack-closure concept was introduced into the analysis. As the gear rim thickness decreased, the compressive cyclic stress in the gear-tooth fillet region increased. This retarded crack growth and increased the number of crack-propagation cycles to failure.



Effect of rim thickness on gear-tooth crack-propagation path for various backup ratios (rim thickness divided by tooth height). Backup ratios, 3.3 (top left), 1.0 (top right), 0.5 (center left), 0.4 (center right), 0.3 (bottom left), and 0.2 (bottom right).

All studies to date have been two-dimensional analyses; validation has been with narrow-face-width spur gears. In the current analysis, which is being investigated for three-dimensional applications of spiral-bevel gears, data are being compared in a full-scale OH-58 helicopter main rotor transmission application.

Bibliography

Lewicki, D.G.: Crack Propagation Studies to Determine Benign or Catastrophic Failure Modes for Aerospace Thin-Rim Gears, Ph.D. Thesis, Case Western Reserve University, 1995.