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Designing Shafts for Long Life

Fatigue lives are affected by many factors.

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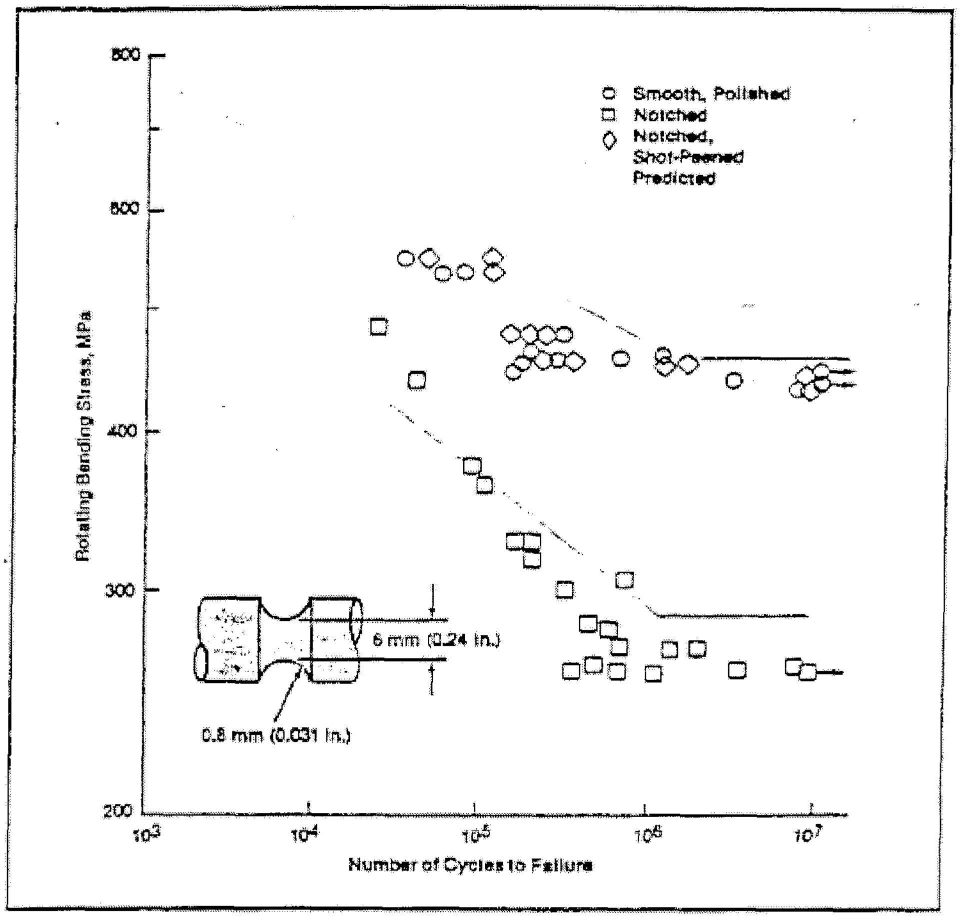
An improved method has been developed for choosing the sizes of power-transmitting shafts for limited or unlimited service lives under a variety of operating conditions. In essence, the method replaces some traditional simplifying approximations and guesswork by more-refined design equations based on considerations of metal fatigue. The method will be especially beneficial where critical compromises have to be made between shaft weights and reliabilities or where the penalties of shaft failure are severe.

The basic problem is to estimate the diameter required for a shaft to survive a specified number of cycles under an expected sequence of steady or variable-amplitude loads. Preferably, the analysis for a given shaft would begin with the experimental determination of its curve of stress amplitude versus number of stress cycles to failure under the appropriate mean loading condition (see figure). However, in the absence of full fatigue-life data, the analysis is based on a nominal-stress-approximation, in which a straight line on a log-log plot connects the true fracture strength at 1 cycle to the fatigue limit of the shaft at 106 or 10' cycles.

A number of factors are introduced to modify the stress levels and slopes on the log-log fatigue-life plot for the effects of environmental, geometrical, and loading conditions likely to be encountered in service. These factors are based on previous experimental and theoretical determinations of the effects of surface finishes, temperatures, the inclusion of more inherent defects with increases in size, stress concentrations at splines and keyways, pressfitted collars, residual manufacturing stresses, and corrosion.



The Stress Versus Fatigue Life of a proposed shaft design is plotted, then modified to account for expected operating conditions and used to calculate a shaft diameterrequired for a given fatigue life. If the diameter of the shaft represented by the plot equals or exceeds the required diameter, the shaft is considered adequate.

The effects of variable-amplitude lowing are treated by expressing a complicated, irregular loading history as a series of constant-amplitude events and by invoking the Palmgren-Miner linear-damage rule. This rule assumes the accumulation of damage at a linear rate without regard to the sequence of loading and in some cases may have to be replaced by more-complicated cumulative-damage theories that express the effects of different load sequences.

In some applications of the new design method, it was shown that occasional cyclic overloads reduce the fatigue strength considerably or else require the use of a much larger shaft diameter. The sensitivity of shaft fatigue life to bending stress was fond to depend primarily on the tensile strength and the overall fatigue-life- factor: the lice might vary with stress to the - lath power for a small, smooth, high-strength-steel shaft or to the-5th power for a large, rough, heavily notched, low-strength-steel shaft.

This work was done by Stuart H. Loewenthal of ***Lewis Research Center.*** *Further information may be found in NASA Tm-87354 [N86-2766yINSPJ, "New Methodology for Shaft Design Based on Life Expectancy."*

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