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Miner's Rule – A More Definitive Approach

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American Gear Manufacturers Association



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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

ANSI/AGMA 2001-B88, Appendix B presents the fundamental method for evaluating Miner's Rule. To analyze the load spectrum, stress values are calculated for a given load and then modified using "K" or "C" factors. When computing the stresses for other points, the stress values are usually simply ratioed rather than recomputing the stresses using new "K" and "C" for each point. In this paper, the effect of using a dynamic and load distribution factor for each load point is evaluated and compared with the simple ratioing approach. Comparisons are made for a number of aircraft histograms as shown in AGMA 911-A94 along with a commercial ground application.

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1500 King Street, Suite 201
Alexandria, Virginia, 22314

October, 1995

ISBN: 1-55589-657-X

MINER'S RULE, A MORE DEFINITIVE APPROACH

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Reduction gearbox designs for aerospace applications are based on a design life that is usually established by the application. This requirement has increased from 6,000 hours for a military application thirty years ago to 50,000 hours for commercial applications of today. In the sixties, S/N curves had definitive endurance limits and it was not uncommon to design below the knee of the curve at the take-off or military power rating. In this manner, any mission profile (load schedule) would be satisfied for all but the emergency power or transient conditions of operation. Since these conditions were expected to occur infrequently, the effect on design life would have been minimal. One might think that this procedure would lead to a relatively conservative design. But, in the case of gas turbine engine reduction gears, quite the opposite was true. In a typical turboshaft engine helicopter application the planetary reduction gear system, see Figure 1, is driven by a sun gear at 20,000 rpm. With three planets being driven, 10^{10} cycles are reached in less than 3,000 hours. The tank engine is also a turboshaft type and the reduction gear system is shown in Figure 2 and again the sun gear drives three planet gears which see alternating bending in this star type system. The input design speed is 22,000 rpm so that 10^{10} cycles are reached in an even shorter time than in the first example. With the advent of finite life S/N curves and new design life requirements having escalated to 50,000 hours, the load schedule or duty cycle life, as it is known for commercial applications, has become of prime importance in the continuing effort to achieve the lightest weight overall system design.

* Usually 100% power, 100% speed

Miner's Rule was developed to evaluate the effect of varying loads on the life of the material. If a material is operated at a given stress level with an allowable fatigue life of 10^6 for a period of 5×10^5 cycles, then one half of the life at that stress level has been used up. If it is then operated at a different stress level with an allowable fatigue life of 10^4 cycles for 5×10^3 cycles, then one half of the life at that stress level has been used up. When the sum of these fractional lives equals one, then the

total life is used up. If the duty cycle or mission profile life is less than the design life requirement, then the gears require redesign. For gearing there are two failure modes, bending and compression, that relate to fatigue; Each one has to be evaluated in a full Miner's Rule analysis.

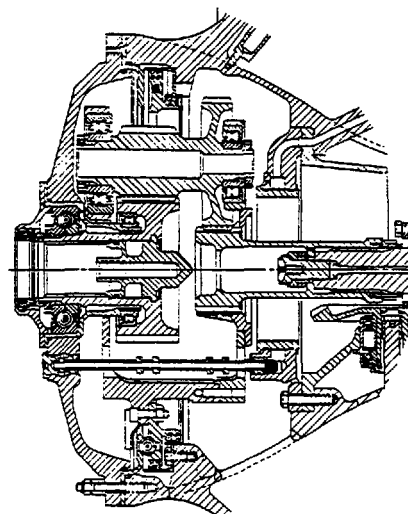


Figure 1. Turboshaft Engine Reduction Gearbox

AGMA 2001-B88, September 1988 Appendix B contains the procedure for using Miner's Rule. Part of the discussion states that "The stress used in reducing the data for gear teeth is not measured stress, but a calculated stress number, using the calculation methods of AGMA 2001." This implies that the stress levels at each duty cycle point should be determined from the stress equations given