Calculating Dynamic Loads, Sizing Worm Gears and Figuring Geometry Factors

Robert Errichello

Answers submitted by Robert Errichello, Gear Consultant, GEARTECH, Townsend, MT, and Technical Editor, Gear Technology

Questions submitted by Mark H. Swalley, U.S. Navy, Puget Sound Naval Shipyard, Bremerton, WA

Q: What is the best method to measure or calculate dynamic loads in a low-speed spur gear subject to load reversals?

A: Strain gages are commonly used to measure dynamic loads. They are a good choice because they are readily available, relatively inexpensive, and accurate for capturing transient loads such as you describe. Computer modeling, on the other hand, is accurate only if mass, stiffness and damping are precisely known. Damping is especially difficult to estimate and usually requires strain measurement on the actual system to determine accurate values. Therefore, strain measurement is the best choice for determining dynamic loads in your application. Additionally, the measurements can help determine system damping, which you could use in a computer model to explore alternative design changes to reduce dynamic loads.

Q: How should the strain gages be placed, and how should the signal be transmitted?

A: Your transducer and method of transmitting signals are state-of-the-art. To capture tooth bending stresses, the gages should be placed on the root fillet at the point of maximum bending stress. That point can be found by painting the root fillets with brittle lacquer and applying loads to the gears. The first place to crack the brittle lacquer is the point of maximum stress. However, it is seldom practical to mount gages at the critical point because of interference with the mating gear’s tips. You need to decide what it is you want. Is it maximum tooth bending stress, or is it the maximum dynamic torque applied to the gears? It may be sufficient to measure the torque and calculate tooth stresses.

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Question submitted by Christian Williams, Texas A&M University, College Station, TX

Q: How does the desired gear ratio for a worm and worm gear relate to the actual size of the gears? For example, if I want a gear ratio of 30:1, what diameter constraints are placed on the gears for that ratio?

A: Worm wheel diameter is set by required load capacity. ANSI/AGMA 6034-B92, “Practice for Enclosed Cylindrical Wormgear Speed Reducers and Gearmotors,” relates worm wheel diameter to tangential load as follows:

\[ D_m = \sqrt[3]{W_t \times (C \times C_m \times C_v \times F_e)} \]

Where:

- \( D_m \) = mean diameter of the worm wheel
- \( C \) = materials factor (accounts for the worm wheel material’s strength)
- \( C_m \) = ratio correction factor (accounts for the gear ratio)
- \( C_v \) = velocity factor (accounts for sliding velocity and varies with diameter, lead and speed of the worm)
- \( F_e \) = effective face width of the worm wheel (\( F_e = F_G \) or \( F_e = (2/3)d \), whichever is less.)
- \( W_t \) = tangential load

The diameter of the worm can vary somewhat without significantly influencing load capacity. ANSI/AGMA 6022-C93, “Design Manual for Cylindrical Wormgearing,” recommends a worm diameter in the following range:

\[ C^{0.875} \leq d \leq C^{1.6} \]

Where:

- \( C \) = center distance
- \( d \) = worm pitch diameter

ANSI/AGMA 6022-C93 provides guidelines that give a practical overview of worm gear design.

You should audit the gearset to ensure it meets the design guidelines of ANSI/AGMA 6022-C93 and rate the load capacity in accordance with ANSI/AGMA 6034-B92 to ensure it has an adequate service factor for the application.

Question submitted by Richard Friedmann, Nichols Aircraft Division, Parker Hannifin Corp., Ayer, MA

Q: Is there a closed-form solution for the Lewis form factor?

A: No, there is no known closed-form solution. However, an efficient algorithm for numerically solving the problem is given in AGMA 908-B89 (Ref. 1). The algorithm is readily programmed using the flow chart given in AGMA 918-A93 (Ref. 2). Benchmark examples useful for validating software are given in Reference 2 and tables of \( J \) factors are given in Reference 1. The algorithm derives from References 3 and 4.

References

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