How to Achieve Optimum Performance in a Miniature Gear Train

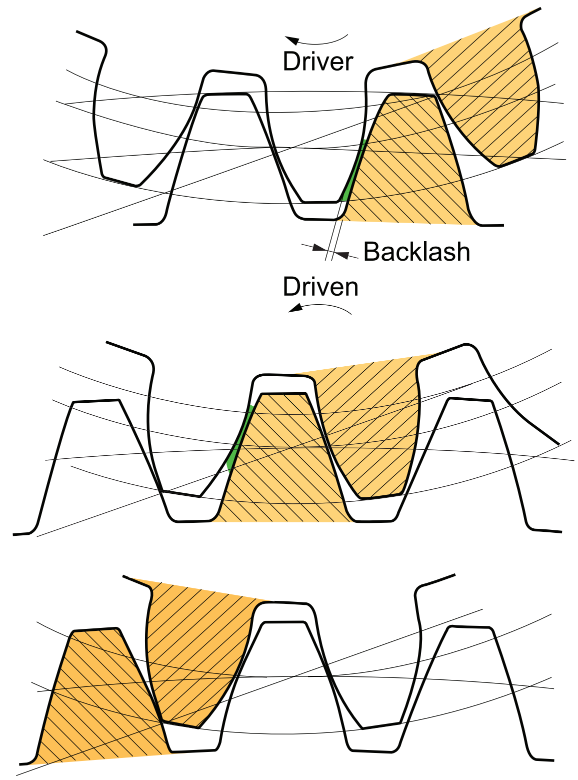
By David Ladyzhensky, Engineering Manager

Smooth, accurate gears and optimum performance is the goal of any new design. Achieving those goals in the early design stage not only meets performance requirements but makes your design cost-efficient. A key component of this is being able to accurately predict dimensional changes due to any type of surface finishing. Other benefits include lower manufacturing costs and no time lost due to design error.

In a gear mechanism, the center distance between shafts and the tooth thickness of the gear define correct mesh and reliable performance of a gear train. To achieve an accurate gear mesh in a mechanism, it is necessary to account for any dimensional changes that may occur after surface finishing, case hardening or heat treatment.

Many precision miniature gears require a certain surface finish or hardened case on both flanks of the gear teeth for a variety of reasons. Many of these finishes may result in a build-up of tooth thickness.

Gear data geometrical parameters are calculated values. Predicting the gear data for miniature precision gears before finish, which may change in tooth size after finish, therefore becomes extremely important (See Figure 1).



(Figure 1.)
Meshing sequence of a pair of gears viewed from the transverse plane.

Design Guidelines

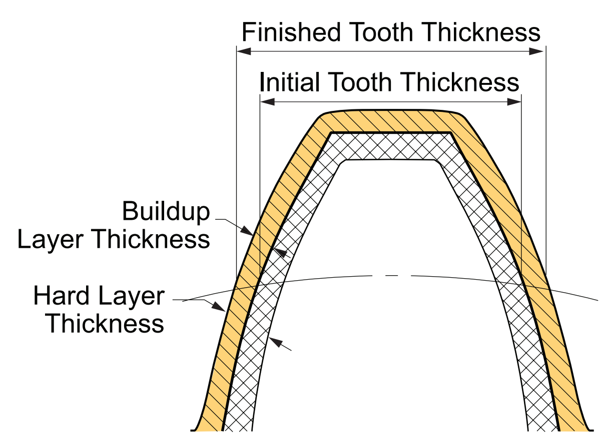
Examples:

Aluminum gear teeth often are hard anodized, and the hard layer thickness may be within .001" to .002". As a result, 50% of the layer thickness diffuses into the stratum and the other 50% is build up.

For steel gears, the nitro-carburizing procedure adds an additional 10% build up of a hard layer thickness (See Figure 2).

Many steels contract after heat treatment; as a result the size of the gear may change.

In most cases the thickness of the finish layer may be accurately controlled by the producer up to .0002" tolerance, or may depend on the material properties which can be predicted by the designer with a high level of accuracy.



(Figure 2.)

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The following equations help to answer the question of how to calculate the initial gear data in order to provide the correct mesh after procedures that bring dimensional changes to gear teeth.

The Designer must define the particular finish layer thickness or amount of contraction depending on the type of treatment which corresponds to given working conditions.

If the gear data is checked with the Master Gear, the designer would need to calculate the limits of the gear Testing Radius before finish in order to get the correct measurements after finish.

Testing Radius for any Spur Gear:

T.R. = T.R. std. + M / D.P.

Standard Testing Radius,
T.R. std. = N / (2 x D.P.)

Where N = number of teeth,

D.P. = diametrical pitch,

M = Modification factor,

M = Gear Cutting Tool Displacement x D.P.

Calculated Modified Gear Tooth Thickness is:

$Tm = \pi / (2\ D.P.) + (2 \times M \times \tan \Phi) / D.P.$
Φ = pressure angle (degrees or radians)

Assume that the required after finish tooth thickness should be Tm = +000/-.001",

The controlled growth of tooth thickness is
$\Delta T = +/-.0002"$

Then the upper limit of tooth thickness before finish should be:
T bef. max. = (Tm + .000) – (ΔT + .0002")

The lower limit of tooth thickness before finish should be:
T bef. min. = (Tm - .001”) – (ΔT - .0002")

Change in Testing Radius (or change in Center Distance with Master Gear) is:

$\Delta C1 = (\Delta T + .0002) / (2 \times \tan \Phi)$

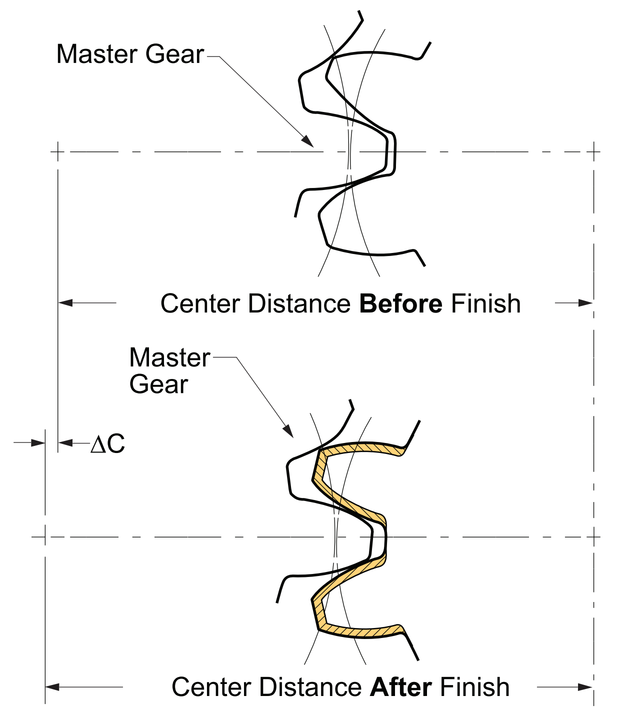
$\Delta C2 = (\Delta T - .0002) / (2 \times \tan \Phi)$

Hence, the Gear Testing Radius before finish should be:

T.R.1 = T.R. max. – ΔC1

T.R.2 = T.R. min. – ΔC2

(See Figure 3.)



(Figure 3.)

By following these steps the Designer will accommodate the dimensional changes that occur due to finishes or heat treatment, resulting in a smooth and quiet running miniature gear train.

This article offers general design guidelines; it is recommended that you contact our Engineering Staff who specialize in gear design to discuss your specific application.