Documentation and Validation of EveryCalc's Transmission Strength Tool

Thaddeus Hughes
hughes.thad@gmail.com
thaddeus-maximus.github.io

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Abstract

Making sure a gearbox is designed to handle the stresses that are inflicted upon it can be a tedious and repetative task, but is rather formulaic, making it an excellent candidate for an automated tool with a flexible frontend.

1 Strength of Gears

There are many failure points on a gear, but the most common and the only one that can be fairly analyzed without knowing the exact geometry (such as pocketing, shaft interface geometry) is that of the gear tooth. Engineer's Edge explains the common way of calculating tooth strength by considering the load as being fully transmitted by one tooth which is a beam in bending.

$$W_t = \frac{SwY(N, \alpha)}{D_p}, \tag{1}$$

where W_t is the maximum allowable tangential force on the gear tooth, S is the maximum allowable stress in the gear, w is the width of the tooth, Y is the *Lewis Factor*, and D_p is the diametral pitch (not the module, which is the reciprocal of the diametral pitch).

To determine the torque-carrying capacity of the gear, we substitute in an expression for torque T,

$$T = W_t \ r = W_t \frac{N}{2 \ D_p} \tag{2}$$

$$\frac{2 \ D_p}{N} \ T = \frac{S \ w \ Y(N, \alpha)}{D_p} \tag{3}$$

$$T_{max,gear} = \frac{S_{gear} \ w \ Y(N, \alpha) \ N}{2 \ D_p^2} \tag{4}$$

The Lewis Factor Y is obtained by 1-D interpolation.

LEWIS FACTOR - Y

NO. OF TEETH	14 1/2° INVOLUTE	20° INVOLUTE
10	0.176	0.201
11	0.192	0.226
12	0.210	0.245
13	0.223	0.264
14	0.236	0.276
15	0.245	0.289
16	0.255	0.295
17	0.264	0.302
18	0.270	0.308
19	0.277	0.314
20	0.283	0.320
22	0.292	0.330
24	0.302	0.337
26	0.308	0.344
28	0.314	0.352
30	0.318	0.358
32	0.322	0.364
34	0.325	0.370
36	0.329	0.377
38	0.332	0.383
40	0.336	0.389
45	0.340	0.399
50	0.346	0.408
55	0.352	0.415
60	0.355	0.421
65	0.358	0.425
70	0.360	0.429
75	0.361	0.433
80	0.363	0.436
90	0.366	0.442
100	0.368	0.446
150	0.375	0.458
200	0.378	0.463
300	0.382	0.471
RACK	0.390	0.484

Figure 1: Lewis Factor values, tabulated

S_{gear} will be considered to be the tensile yield strength.

Observations: to make a gear stronger, increasing its width or base material strength will have a linear benefit. Increasing the number of teeth will have a hyperlinear benefit (as it influences the lewis factor). Using a lower pressure angle will help the lewis factor. Using a lower diametral pitch (a coarser gear) will also improve strength.

2 Strength of Shafts

Shafts are considered to be in pure torsion. This means that they experience stress that can be computed as

$$\sigma_{shear,outside} = \frac{Tr}{J} = \frac{Td}{2J} \tag{5}$$

Solving for the torque and substituting in maximum allowable shear stress S_{shaft} for σ yields

$$T_{max,shaft} = S_{shaft}\frac{J}{r} \tag{6}$$

S_{shaft} will be the maximum shear stress, or the tensile yield stress divided by two.

3 Strength of Timing Belt Runs

4 Strength of Chain Runs

5 Strength of COTS Planetaries

5.1 VexPro VersaPlanetary

VexPro's VersaPlanetaries come with a Load Rating Guide

The key failure points identified are:

- 10:1, 9:1, and 7:1 stages have a torque capacity of **100 N-m**.
- Ratchet slices have a torque capacity of **160 N-m**.
- 1/2" hex output shafts fail at **157 N-m**.
- 1/2" round output shafts fail at **130 N-m**.
- 3/8" hex output shafts fail at **57 N-m**.
- CIM-style output shafts fail at **29 N-m**.

These ratings, as this calculator, do not take into consideration bending loads which could further derate the carrying capacity.

5.2 AndyMark 57 Sport

AndyMark's 57 Sport Gearboxes

6 Assembling Components