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Influences of Bearing Life Considerations on Gear Drive Design

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American Gear Manufacturers Association

TECHNICAL PAPER

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Abstract

Historically, catalog gear drives have been designed with 5000 hours of L10 bearing life at service factor 1.0 power. Advances in bearing analysis methods have brought new considerations to the design and selection process. The impact of new modeling techniques, additional considerations, and various extensions to the traditional bearing fatigue calculations are explored. The modeling of these various additions to a traditional catalog L10 calculation is illustrated by bearing selections for cases of single, double, and triple reduction gear drives. A roadmap is presented listing critical considerations when applying various bearing manufacturer recommendations.

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Introduction

Historically catalog gear drives have been designed with 5000 hours of L10 bearing life at service factor 1.0 power. Advances in bearing analysis methods have brought new considerations into the design and selection process. Reviewing this history using three sample gear drives will illustrate past and current thinking on this subject and the implications of the various assumptions each of the methods make.

Target Design Point

By its nature, a catalog design gear drive is not developed with a known set of load conditions. The designer does not have the luxury of the certain knowledge that it will be operated only at moderate speeds occasionally on Sundays during months that do not have a letter *R* in them. Catalog speed ranges run from 1800 to 100 rpm. Application or service factors per AGMA standards range from 1.0 to 2.0 for various applications. Customers may specify additional requirements such as increased bearing life or limited cooling options that also influence box size. The unit design must be capable of operating at any of these conditions.

For the purposes of this paper, we will make the assumption that the gearing is the limiting member in the drive. Bearings, shafting, and other components, keys, fasteners, etc. will be selected and sized to exceed the rating of the gears. Although optimal, this gearing only limitation is sometimes difficult to achieve in practice when one is balancing the competing options of having a wide variety of ratios and maximum flexibility combined with minimum variation in part dimensions and inventory of parts. For this study, we will assume that we can pick the optimum bearing size regardless of size variation across ratios and multiple reduction drives.

The gear drive will be operated for 60 Hz service at 1750 rpm input speed. Ambient temperature range is –17 °C to + 38 °C. Altitude is assumed to be less than 700 meters. The effect of sump temperature is reviewed by looking at both a 28 °C rise and a 55 °C rise in sump temperature above the ambient of 38 °C. The control in temperature rise can take the form of forced air cooling, water cooling coils, or dedicated pump and oil–to–water heat exchangers.

Gear Drive Designs

In 1997 AGMA was involved in a worldwide study to compare and contrast the various methods used to determine the load distribution factor $K_{H\beta}$. To further efforts in this area, three parallel shaft gear drives were developed to test various assumptions in the calculation models. These gear drives were utilized as the design in the analysis.

The single reduction gear unit has a space envelope of 883 mm wide by 635 mm tall by 1021 mm deep shaft–to–shaft with the following key dimensions listed in table 1.

Based on the above geometry, gear ratings were calculated to AGMA 2001–D04 using the AGMA Gear Rating Suite Version 2.2. Setting required gear life to 10000 hours as recommended in AGMA 6010–F97, and setting service factor equal to unity, we calculate a unit rating of 990 kW at 1750 rpm input speed per AGMA 2001–D04.

The double reduction unit has a space envelope of 1048 mm wide by 543 mm tall by 870 mm deep shaft–to–shaft with the following key dimensions listed in table 2.

Based on the above geometry, gear ratings were calculated to AGMA 2001–D04. Setting required gear life to 10000 hours as recommended in AGMA 6010, and setting service factor equal to unity, we calculate a unit rating of 308 kW at 1750 rpm input speed per AGMA 2001–D04.

The triple reduction unit has a space envelope of 1676 mm wide by 889 mm tall by 1155 mm deep shaft–to–shaft with the following key dimensions listed in table 3.

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Table 1. Single Reduction Drive

Item	Pinion	Gear	Both/Units	Pinion	Gear	Units
Overall Ratio			4.214			
Tooth Combination			14/59			
Normal Module			8.00 mm			
Normal Diametral Pitch			3.175 in^{-1}			
Normal Pressure Angle			20 deg			
Helix Angle			11 deg			
Centre Distance			304.8 mm			
Center Distance			12.00 in			
AGMA Quality Number			A6 – Q11			
Heat treatment			Carburized			
Manufacturing Method			Ground			
Outside Diameter	137.97	503.63	mm	5.432	19.828	in
Operating Pitch Diameter	114.10	480.82	mm	4.492	18.930	in
Root Diameter	100.20	465.81	mm	3.945	18.339	in
Active Face width	127	127	mm	5.00	5.00	in

Table 2. Double Reduction Drive

Item	Pinion	Gear	Both / Units	Pinion	Gear	Units
Overall Ratio			18.264			
High Speed Set						
Tooth Combination			15 / 63			
Normal Module			4.5 mm			
Normal Diametral Pitch			5.644 in^{-1}			
Normal Pressure Angle			20 deg			
Helix Angle			11 deg			
Centre Distance			182.88 mm			
Center Distance			7.2 in			
AGMA Quality Number			A6 – Q11			
Heat treatment			Carburized			
Manufacturing Method			Ground			
Outside Diameter	82.19	301.55	mm	3.235	11.872	in
Operating Pitch Diameter	70.33	295.42	mm	2.769	11.630	in
Root Diameter	61.30	280.43	mm	2.413	11.041	in
Active Face width	76.2	76.2	mm	3.00	3.00	in
Low Speed Set						
Tooth Combination			17 / 69			
Normal Module			6.00 mm			
Normal Diametral Pitch			4.233 in^{-1}			
Normal Pressure Angle			20 deg			
Helix Angle			9 deg			
Centre Distance			266.7 mm			
Center Distance			10.50 in			
AGMA Quality Number			A6 – Q11			
Heat treatment			Carburized			
Manufacturing Method			Ground			
Outside Diameter	121.03	436.35	mm	4.765	17.179	in
Operating Pitch Diameter	105.44	427.96	mm	4.151	16.849	in
Root Diameter	93.49	408.69	mm	3.681	16.090	in
Active Face width	120.65	120.65	mm	4.75	4.75	in

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Table 3 Triple Reduction Unit

Item	Pinion	Gear	Both / Units	Pinion	Gear	Units
Overall Ratio			30.8			
High Speed Set						
Tooth Combination			20 / 44			
Normal Module			7.00 mm			
Normal Diametral Pitch			3.6286 in^{-1}			
Normal Pressure Angle			20 deg			
Helix Angle			11 deg			
Centre Distance			236.22 mm			
Center Distance			9.3 in			
AGMA Quality Number			A6 – Q11			
Heat treatment			Carburized			
Manufacturing Method			Ground			
Outside Diameter	163.77	336.702	mm	6.448	13.256	in
Operating Pitch Diameter	147.64	324.80	mm	5.812	12.788	in
Root Diameter	131.70	304.62	mm	5.185	11.993	in
Active Face width	101.6	101.6	mm	4.00	4.00	in
Intermediate Speed Set						
Tooth Combination			15 / 50			
Normal Module			9.00 mm			
Normal Diametral Pitch			2.822 in^{-1}			
Normal Pressure Angle			20 deg			
Helix Angle			12 deg			
Centre Distance			304.8 mm			
Center Distance			12.00 in			
AGMA Quality Number			A6 – Q11			
Heat treatment			Carburized			
Manufacturing Method			Ground			
Outside Diameter	162.99	482.57	mm	6.417	18.999	in
Operating Pitch Diameter	140.68	468.92	mm	5.538	18.462	in
Root Diameter	120.03	439.65	mm	4.726	17.309	in
Active Face width	127	127	mm	5.00	5.00	in
Low Speed Set						
Tooth Combination			15 / 63			
Normal Module			11.00 mm			
Normal Diametral Pitch			2.309 in^{-1}			
Normal Pressure Angle			20 deg			
Helix Angle			12 deg			
Centre Distance			457.2 mm			
Center Distance			18.00 in			
AGMA Quality Number			A6 – Q11			
Heat treatment			Carburized			
Manufacturing Method			Ground			
Outside Diameter	203.43	754.96	mm	8.009	29.723	in
Operating Pitch Diameter	175.84	738.55	mm	6.923	29.076	in
Root Diameter	152.46	703.97	mm	6.002	27.715	in
Active Face width	177.8	177.8	mm	7.00	7.00	in

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