

Comparison in Rating Trends in AGMA versus ISO

by: O.A. LaBath and D. Richter,
Gear Consulting Services of Cincinnati, LLC

American Gear Manufacturers Association



TECHNICAL PAPER

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O.A. LaBath and D. Richter, Gear Consulting Services of Cincinnati, LLC

[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

In the early 1980s, authors from The Cincinnati Gear Company presented several technical papers comparing the gear ratings from ISO and AGMA. These comparisons showed some interesting and diverse differences in the trends when the gear geometry was changed slightly. These changes included addendum modification coefficients, helix angles, etc. There were also some interesting differences when the hardness and hardening methods were changed.

These earlier papers used computer programs developed at The Cincinnati Gear Company to make both the ISO and AGMA ratings. Today, rating programs developed by an AGMA committee are available. The intent for this paper is to use these programs.

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American Gear Manufacturers Association
1500 King Street, Suite 201
Alexandria, Virginia, 22314

October, 2002

ISBN: 1-55589-810-6

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Octave A. LaBath, PE
and Dennis Richter
Gear Consulting Services of Cincinnati, LLC

INTRODUCTION:

Many people have made comparisons of the differences in ratings between AGMA rating methods and ISO rating methods.

In 1977, G. Castellani [1] was the first to point out that there was a difference in the rating trend on spur gears when you change from standard gears to gears with a profile shift.

In an ASME paper [2] presented in 1980 by Imwalle, LaBath, and Hutchenson, the comparisons of AGMA and ISO ratings for 54 different gear sets were studied. In some cases large differences were calculated.

In an AGMA paper [3] presented in 1981, LaBath made a comparison of the change in calculated stresses for three sample gear sets as a function of the profile shift and one sample as a function of the helix angle.

The above study on the difference in trends for corrected gears and different helix angles was included in another AGMA paper [4] also presented in 1981, by Imwalle and LaBath along with a study on 156 gear sets.

In the latter two papers, Imwalle and LaBath showed that with a positive profile shift, the strength rating increases in AGMA and ISO but with different magnitudes. With a negative profile shift, the AGMA strength rating decreases and depending on the gear geometry, the ISO strength rating can go down or sometimes remain almost constant. The durability ratings also had different trends for AGMA and ISO.

The comparisons in the three papers by Imwalle, LaBath, and Hutchenson were based on computer programs written at The Cincinnati Gear Company for the then current AGMA rating standards and the draft ISO standards. The computer programs were based on the interpretation of the various standards by the engineers at Cincinnati Gear.

In a 1989 AGMA paper [5], Dr. Hosel also reported that the rating trends were different for AGMA and DIN (ISO) with respect to the effect of profile shift on the ratings.

In a 2002 paper prepared for NREL [6], Robert Errichello made a comparison of the different rating trends for AGMA and ISO. The durability rating trend for AGMA and ISO with respect to profile shift was almost the same for a spur gear sample. The strength rating trend was significantly different for the spur gear example. Mr. Errichello showed that the trends for both the strength rating and the durability rating were different for a helical gear example. Bob also showed that there was a difference in trends from AGMA and ISO for variations in the pressure angle.

The comparisons made by Mr. Errichello were based on calculations made for AGMA by his GEARTECH AGMA218 program package and for ISO by the ISO 6336 Gear Rating Program copyrighted by AGMA in 1997.

Calculation Method

The comparisons made in this paper will be based on calculations made using the AGMA copyrighted ISO 6336 program and the newly developed AGMA program for calculations per ANSI/AGMA 2001. These two programs are being released as "Gear Rating Suite by AGMA". Using these two programs to do the rating comparisons, the results are independent of any one individual's opinion or interpretation of either standard.

By using these programs, the input data for the gear geometry is the same for both the AGMA and the ISO ratings. This allows for a consistent trend analysis by only changing one gear geometry parameter while holding all of the other gear geometry items constant within the program.

The focus of this paper is to show the trends of the two rating systems by varying specific geometry parameters one at a time. This paper is not trying to establish a "rating constant" between the two rating standards and should not be used as such.

Examples similar to the three examples from the 1981 AGMA papers will be re-examined to determine the rating trends with respect to changes in the profile shift. An example similar to the fourth example from the 1981 papers will also be re-examined to determine the rating trends with respect to changes in the helix angle. Two examples will be added to investigate the differences in rating trends with respect to pressure angle for a spur gear set and a helical gear set.

We will rate the gears as carburized and hardened gearing ground to AGMA Class Q11. This is approximately ISO Class 6. We will assume that the material is per AGMA Grade 2 and ISO MQ. We will use the upper life factor curves and rate the gearing for a life of 10,000 hours. The pinion speed will be set at 1750 rpm. An input power of 250 hp (186.3 kW) is being used and the programs are being used to calculate the factors of safety.

In each example, the first calculated factor of safety becomes the reference factor of safety. The other calculated factors of safety are then divided by the reference factor of safety to get the Factor of Safety Trend value. In the tables, we are calling the Factor of Safety Trend "FST". This is repeated for each rating item, pinion bending, gear bending, pinion durability, and gear durability. The Factor of Safety Trend is calculated independently for AGMA and ISO. The Factor of Safety Trend value is then plotted versus the factor being varied for each example.

How the Rating Programs Were Run

The tooling was specified as not having protuberance. The tooling tip was specified to be a full root radius or as large as the geometry would allow. Since the ISO ratings are made with tooth thicknesses that do not include backlash, the AGMA ratings were also made with zero backlash. No grind stock was specified. The surface finish was specified as 32 RMS for both the flank and the root fillet.

The leads were specified as having an ideal crown/correction with favorable tooth alignment. The gears were specified as commercial. The gear was specified as being a solid blank design. The bearing span was specified as being two times the face width. The gearing was centered in the bearing span. The ISO load distribution factor, KH_{be}, was calculated per method C1.

The AGMA gear quality was specified as 11. The ISO quality was specified as class 8 for the pinion and class 7 for the gear. The ISO dynamic factor was specified per method B. The reliability was specified as 99%. The stresses were for industrial application, the upper curve. A 1.0 application factor was used.

In AGMA, the strength ratings were calculated for the load applied at the HPSTC for the spur gear meshes.

For ISO, a viscosity of 220 was specified.

Again, the absolute ratings are not relevant to this study. The ratings calculated are consistent within the examples used and the trend differences are real.

EXAMPLE #1 – SPUR GEARING WITH VARYING PROFILE SHIFT COEFFICIENTS

This example is a spur gear set operating on the standard center distance. The gear geometry is as follows:

21 teeth on the pinion
84 teeth on the gear
5 module (5.08 normal diametral pitch)
20 degree pressure angle
100 mm (3.939 inch) face width
Standard hob proportions are being used
Center Distance = 262.5 mm (10.3346")

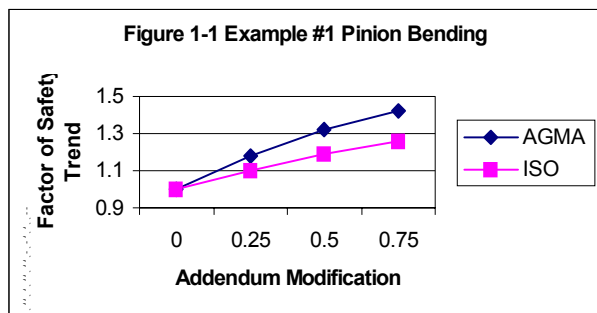
For this example, we will rate the gear set as a standard gear set and then rate it for increasing profile shifts or addendum modification coefficients on the pinion. The profile shift coefficient is as it is defined in the [MAAG Handbook](#) [7].

Since the center distance is being maintained at the standard center distance, the rack shift coefficient for the gear has the same value as the rack shift coefficient for the pinion but is positive on the pinion and negative on the gear.

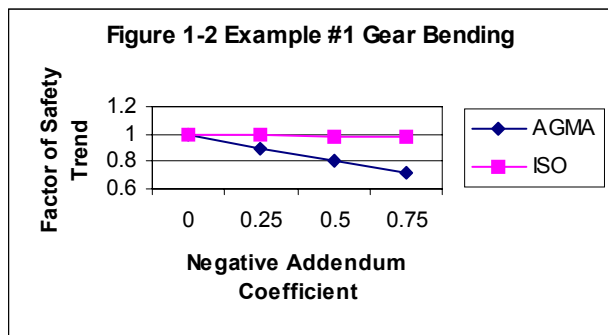
The factors of safety for the various rack shift coefficients are given in Table 1.

Table 1 and all of the other tables are presented at the end of this paper.

This information has been normalized around the factors of safety for standard gearing and is plotted in Figures 1-1, 1-2, 1-3, and 1-4.



As you can see, for this spur gear, both AGMA and ISO give an increased factor of safety for bending stress on the pinion when the addendum modification coefficient is increased. This is what would be expected since the tooth thickness increases as the addendum coefficient is increased. As the value of the positive addendum modification is increased, AGMA gives more of an increase in the factor of safety than does ISO.

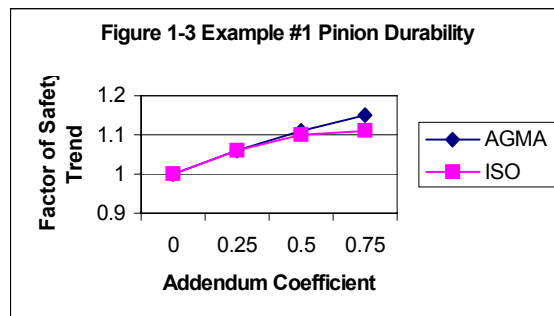


For this plot, the addendum modification coefficient is negative. On this spur gear, AGMA gives a reduction in the factor of safety for bending when there is a negative addendum modification coefficient. As the value of the negative addendum modification coefficient is increased, AGMA gives a corresponding higher reduction in the factors of safety. This is what would be expected since the tooth thickness is reduced as the amount of the negative addendum modification is increased.

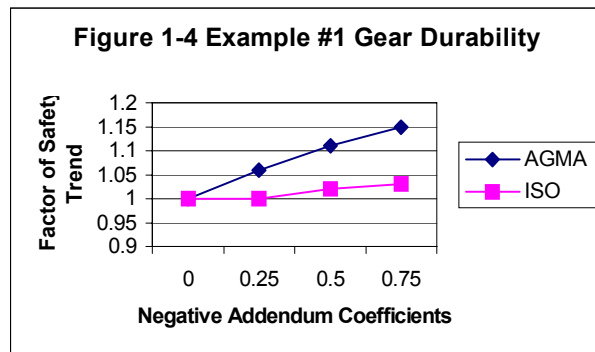
In ISO, for this spur gear, the factors of safety for bending is almost independent of the increasing negative addendum modification coefficient and the decreasing tooth thickness.

It is the goal of this paper to present the differences in the trends not to explain the differences. For this

reason, there will be no discussion as to why the AGMA and ISO results are so different.



When there is a positive addendum modification coefficient, both AGMA and ISO calculate a higher factor of safety for durability on this spur pinion. As the value of the positive addendum coefficient is increased, the factor of safety calculated increases for both AGMA and ISO. With an almost extreme value of positive addendum modification coefficient, $x=0.75$, AGMA gives a slightly higher increase than ISO does.



Even though there is a negative addendum modification on the gear, both AGMA and ISO give an increase in the factors of safety for durability on this spur gear. The increase in the factor of safety is increasing with the increasing value of negative addendum modification coefficient. The increases in the factors of safety are higher in AGMA than they are in ISO.

EXAMPLE #2 – HELICAL GEARING WITH VARYING RACK SHIFT COEFFICIENTS

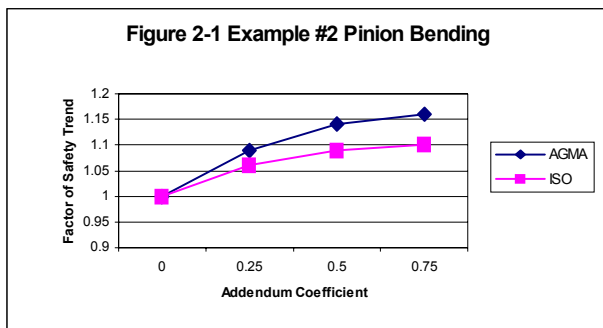
This example is a helical gear set operating on the standard center distance. The gear geometry is the same as that used in Example #1. The only difference is the helix angle. Due to the helix angle, the standard center distance is a little larger than

that used with the spur gearing in Example 1. Center Distance = 271.76 mm (10.6992").

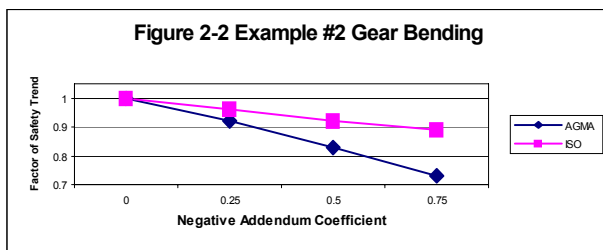
Again, we will rate the gear set as a standard gear set and then rate it for increasing profile shift coefficients on the pinion and decreasing negative profile shifts on the gear.

The factors of safety for the various profile shift coefficients are given in Table 2.

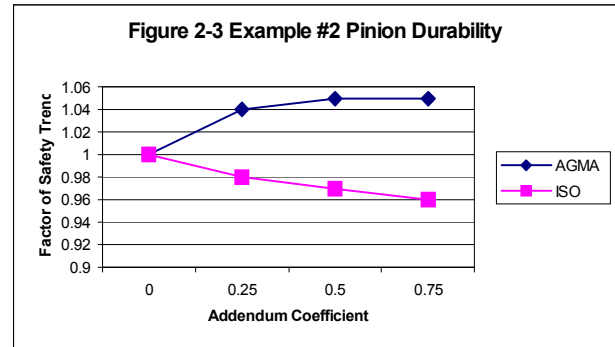
This information has been normalized around the factors of safety for standard gearing and is plotted in Figures 2-1, 2-2, 2-3, and 2-4.



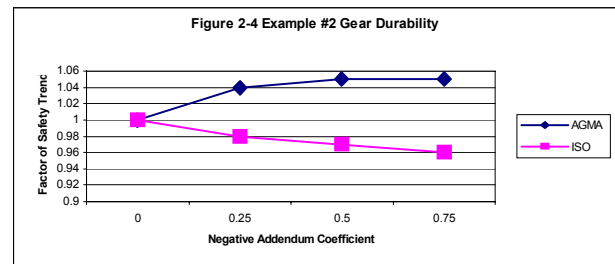
For this helical pinion, both AGMA and ISO give an increased factor of safety for bending stress on the pinion when the addendum modification coefficient is increased. Similar to the spur pinion example, as the value of the positive addendum modification is increased, AGMA gives more of an increase in the factor of safety than does ISO.



On the gear, the addendum modification coefficient is negative. On this helical gear, both AGMA and ISO give a reduction in the factor of safety for bending when there is a negative addendum modification coefficient. As the value of the negative addendum modification coefficient is increased, both AGMA and ISO give a corresponding higher reduction in the factors of safety. The reduction in the factors of safety for bending by ISO is less than that from AGMA.



When there is a positive addendum modification coefficient on the pinion, AGMA calculates a higher factor of safety for durability on this helical pinion. As the value of the positive addendum coefficient is increased, the factor of safety calculated increases for AGMA. Here, ISO is calculating a reduction in the factor of safety for durability on this helical pinion. As the addendum modification coefficient is increased, the ISO calculated factor of safety actually reduces. Even for $x=0.75$, the differences in the factors of safety are less than 5% for both rating systems compared to a standard pinion.



Similar to the spur gear example, even though there is a negative addendum modification on the gear, AGMA gives an increase in the factors of safety for durability on this helical gear. The increase in the factor of safety is increasing with an increasing value of the negative addendum modification coefficient. In ISO, there is a decrease in the factor of safety for this helical gear when there is a negative addendum modification coefficient. As the value of the negative addendum coefficient is increased, there is a corresponding decrease in the factor of safety. Again, the differences are less than 5% compared to a standard gear.

EXAMPLE #3 – SPUR GEARING WITH VARYING PRESSURE ANGLE

This example is a spur gear set. The gear set is a standard gear set. With the exception of the pressure angle, everything else is the same as that