COMPARISON OF AGMA AND AASHTO GEAR RATINGS

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ABSTRACT

This paper covers the specifications and ratings of spur and helical gears used in movable highway bridges. It compares the ratings used to design these gears per paragraphs 2. 6. 11 and 2. 6. 12 of "Standard Specifications for Movable Highway Bridges 1978," copyrighted, 1979 by the American Association of State Highway and Transportation Officials (AASHTO) and the latest gear rating standard of the American Gear Manufacturers Association (AGMA) which is AGMA standard 218.01, dated December 1982.

This paper suggests certain changes and modifications that could be made to the current AASHTO standard to align it more closely to current gear technology, manufacturing methods and material selection.

INTRODUCTION

For practical and economic reasons, gears will continue to be used now and in the future for movable highway bridges. Eventhough they were designed and developed centuries ago, they remain a very viable means of power transmission not only for bridges but for almost every industrial and commercial application where speeds and torque need to be changed. Since a gear set delivers constant horsepower, the output shaft torque changes inversely to the speed change. A properly designed and lubricated gear set typically will lose as little as one percent of the horsepower transmitted through the mesh.

Even today there is ongoing development and testing of gears. The gear industry continues to upgrade designs, use better materials and heat treating processes, and improve manufacturing quality.

RATINGS

AGMA ratings consider both the pitting resistance of a gear tooth as well as its strength. Each rating is determined by a separate formula and the lower rating determines the capacity of the gear set.

Pitting occurs due to surface fatigue. Under load, the gear teeth are subjected to high compressive stresses. If the endurance limit of the gear material is exceeded then the cavities or pits form on the surface of the teeth.

In regards to strengh, a gear tooth is essentially a cantilever beam which is stressed and deflected every time it meshes with its mating element. Maximum tooth stresses occur at the root or bottom of the teeth since that area has the highest bending movement due to it being farthest from the load. Also the tooth root is an area of discontinuity which creates a stress concentration and magnifies the bending stresses.

AASHTO gear ratings address only the strength of the gear teeth. Movable bridge gearing is an intermittent operation which would extend the time when pitting would occur. Also, while gear teeth can continue to operate and transmit power with pitting, fractured gear teeth will render the gears unsuitable for continued operation.

The current AASHTO standard permits the load to be applied to only one tooth. While this would be the case for gears made of low quality, most gears today are manufactured at a quality level where load sharing by more than one tooth occurs, Load sharing reduces the stresses on a single tooth thereby allowing a gear to transmit more load.

GENERAL COMMENTS REGARDING THE AASHTO STANDARD

The AASHTO standard mentions helical gears. It also mentions that "They shall be assembled so that one gear of each pair may have a slight axial movement to permit operations at the correct locations relating to the other gear." Later in the specifications it says, "Helical gear teeth shall be cut to the same normal profile as spur gear teeth. The helical angle shall be not less than 23 deg. and not more than 30 deg."

In the gear industry this description would lead one to believe that the standard is referring to a herringbone gear. Herringbone gears require careful axial alignment so that the apexes of each pair will line up. This is important so that each helix will take an equal share of the load. Helical gears have only one helix and do not require the "slight axial movement" that the specification call for.

Herringbone gears are cut to the same transverse profile as a spur gear and not to the normal profile as specified in the standard.

Herringbone gears are usually cut with helices in the 23 to 30 degree range as stated in the standard. Most are cut with a 30 degree helix. A single helical gear usually is cut with a helix angle less than 23 degrees because lower helix angles produce less thrust forces.

The trend in gears today is toward higher hardness and stonger materials. Alloy steels are being through hardened and cut as high as 400 BHN (43Rc). Many gears are being surface hardened by induction hardening and carburizing processes up to 60Rc. The higher hardnesses permit smaller gears for a particular application. Economic and competitive considerations is the main influencing factor causing gear manufacturers to design and manufacture gears with higher hardness and stronger materials.

The current AASHTO standard permits only the 20 degree involute profile for gearing. When additional tooth strength is required, many designers today select a 25 degree involute. This involute can increase gear tooth strength typically by 20 percent at little or no increase in cost. **Table A** shows what improvement in rating that the AGMA standard allows.

There is a trend toward more gears made to metric sizes and standards. While almost all gear cutting machines are adaptable to metrics, gear cutting tools of metric proportions are required. Some manufacturers already have an extensive inventory of metric tools. Metrics may cause economic hardship to others.

COMPARISON OF RATING OF SPUR GEARS

Table B compares the ratings of spur gears with the AASHTO standard versus AGMA standard 218.01. The allowable ratings are higher using the AGMA ratings in all cases. This is mainly due to the fact that AGMA allows load sharing between the teeth while AASHTO does not. Also allowable stresses were kept uniform for the sake of comparison.

Load sharing between the teeth should be allowed since gears today are usually made with the necessary tolerances and quality so that the load is not solely applied to a single tooth.

TABLE A

COMPARISON OF GEAR RATINGS FOR SINGLE HELICAL GEARS
20° vs. 25° PRESSURE ANGLE PER AGMA STANDARD 218.01
DECEMBER 1982

PINIONS 20 TEETH   GEARS 70 TEETH   ALL 275 BHN
FULL DEPTH TEETH   ALLOWABLE RATING IN LBS./IN. FACE

	Transverse Dia Pitch	20° P. A.	25° P. A.
Pinion	3/4	11,100	13,600
Gear	3/4	12,300	14,900
Pinion	1	8,400	10,200
Gear	1	9,300	11,200
Pinion	1 1/2	5,700	6,800
Gear	1 1/2	6,300	7,500
Pinion	2	4,300	5,200
Gear	2	4,800	5,700
Pinion	3	3,000	3,500
Gear	3	3,300	3,800
Pinion	4	2,100	2,400
Gear	4	2,500	3,000
Pinion	5	1,900	2,200
Pinion	5	2,100	2,400
Pinion	6	2,000	2,300
Gear	6	2,200	2,500

TABLE B

COMPARISION OF GEAR RATINGS FOR SPUR GEARS,
AASHTO RATING VS. AGMA STANDARD 218.01

PINIONS 20 TEETH GEARS 70 TEETH
ALL 275 BHN FULL DEPTH TEETH

ALLOWABLE RATING IN LBS/IN FACE

	Transverse Dia. Pitch	AASHTO Rating	AGMA 218.01 Rating
Pinion	3/4	12,800	13,800
Gear	3/4	16,700	16,700
Pinion	1	9,100	10,200
Gear	1	11,900	12,300
Pinion	1 1/2	5,500	6,600
Gear	1 1/2	7,100	8,000
Pinion	2	3,700	4,900
Gear	2	4,900	5,900
Pinion	3	2,100	3,200
Gear	3	2,800	3,800
Pinion	4	1,400	2,300
Gear	4	1,800	2,800
Pinion	5	970	1,800
Gear	5	1,300	2,200
Pinion	6	730	1,500
Gear	6	950	1,800

CONCLUSION

Almost all industries today are accepting the AGMA standards as the guide for gear design. They correlate closely to foreign standards and are being upgraded by the latest technology and field data.

The current AGMA standards allow wider choices in those parameters that permit gears to operate with better performance, and at the same time, with reduced costs.

The AASHTO gear standard should be reevaluated with respect to present designs and terminology, material choices and manufacturing capabilities.

Gear failure by pitting should be considered. The AGMA standard permits analysis of pitting on less than infinite cycles which could occur on movable bridge gearing that is operated intermittently.

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