Taming Tooth Deflections: The Case for Profile Modifications

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COURSE INFORMATION

Course Description
Tooth deflections under load can cause involute interference which leads to very high tooth surface loads in regions of high sliding and low tooth curvature radius. These conditions loads can produce scoring, spalling and wear failures. Proper profile modifications applied to both members of the mesh eliminate the deleterious effects of the deflection induced involute interference and allow the gear set to yield its maximum inherent load carrying capacity. Proper profile modifications also allow a gear set to operate with lower noise and vibration levels.

Course Rationale/Students Course Designed to Serve
When designing external or internal spur or helical gears that are subject to moderate to high loads an often neglected or inadequately addressed factor is the deflection of the teeth under load. Deflections are even more important where gear mesh noise is important. In this course we will discuss both tooth deflections and the optimum methodology for applying appropriate profile modifications to ensure that maximum load capacity combined with minimized gear mesh noise are simultaneously achieved.

Learning Objectives:
- Learn how teeth deflect, what involute interference really is, the potential consequences of inadequate profile modifications, and the differences between tip relief, flank relief and fully modified profiles
- Calculate tooth deflections under load and, most especially, how to modify a gear set properly to completely eliminate involute interference
- Examine the optimum drawing definitions for profile modifications and how to interpret involute inspection charts to determine if the drawing required profile modifications have actually been produced on the gear set

Required Textbooks (Provided by AGMA)
AGMA's Taming Tooth Deflections by Raymond J. Drago, PE

COURSE OUTLINE

The starting point is a discussion of what profile modifications are and the circumstances where they must be considered as part of the overall design process. While modifications are applied to all different types of gears our treatment here concentrates on those applied to the involute profile shape of external and internal spur and helical gears. The basic requirements for controlling the profile modifications applied to the "tip" and "flank" of a gear tooth are discussed in detail both regarding magnitude and shape relative to the involute. The "ideal" barrel shape of the optimum modification is discussed in detail using definitive illustrations. The difference between a simple "tip relief" and a well defined complete profile modification that addresses actual tooth deflection is discussed in detail. The relation between "involute interference" and tooth deflections is presented via easily understood graphics. The effect of tooth deflections on the load distribution along the profile and resultant tooth load distribution is explained graphically. The relation between an increase in the possibility of a spalling failure rather than a pitting failure is addressed in order to better understand the benefit of optimally defined and applied profile modifications through the use of distinct graphics. In order to foster better understanding of the modes of failure that can result from a lack of modifications or less than ideal modifications graphical representations of the failure crack propagation path and character is presented in detail. While the main driving force in the application of ideal profile modifications is minimizing the possibility of spalling, pitting and tooth bending fracture failures, as high pitch line velocities optimum profile modifications are required to prevent surface scoring damage. The mechanism that causes scoring is discussed with regard to both deflection and surface sliding velocity.

Noise from the gear set can also be adversely affected by inappropriate modifications, especially those that are too great for the actual tooth deflections. This area is addressed via easy to understand graphic representations. The concept of just enough as opposed to too much or too little modification is addressed via noise related test results.

While the discussions presented center on modifications, we will also address cases where profile modifications and not required and some where they can be detrimental, especially where noise characteristics are of the highest importance.

Having addressed the conditions that require the application of profile modifications, we will next address how the modifications must actually be applied during the manufacturing process to actually obtain optimum beneficial effect. While in most cases the profile contact ratio of a gear set is between 1 and 2 it can be very advantageous to design parallel axis gear sets with a profile contact ratio greater than 2. The methodology required to successfully apply profile modifications to the teeth of such “special” gears is also addressed.

The magnitude of the maximum profile modification is important however the manner in which this optimum modification is applied to the gear teeth is very important and will be addressed in graphic detail. We will also address the details of how the calculated profile modification is applied (controlled) during the manufacturing operation by discussing in detail how the optimum modified tooth shape is best defined on the engineering drawing to ensure that the desired result is actually obtained. Essentially the optimum drawing detail required is discussed in detail using actual examples for different applications.

Finally, the methods that can be used to confirm that the proper modifications have been applied are discussed in detail for both modest size gears and extremely large gears (i.e. pitch diameters in the range of 10 to 20 feet, and greater in some cases!) gears are discussed with detailed pictures of significant examples as the medium.

STUDENT FEEDBACK AND GRADING PROCEDURES

Assignments
A self-graded assessment is administered during this course. Immediate feedback is given, and the material is reviewed by the instructor.

COURSE MANAGEMENT

Weather Delays and Cancelations
We will communicate any cancellations, delays or other concerns for safety prior to class via email, voicemail, and/or text message. Please be sure that we have all pertinent contact information as you travel to your class location.

Attendance for Domestic and International Students
Please be mindful that these are short, accelerated courses. Attendance is extremely important. If you are going to be absent from any class day, please contact the course coordinator.

Plagiarism, Cheating and other types of Misconduct
Plagiarism[1], cheating and other types of misconduct are unacceptable.

Students with Disabilities
Students requiring assistance and accommodation should complete the Special Accommodation Request form and submit it to Stephanie Smialek, Education Manager at smialek@motionpower.org. She can be reached at 773-302-8026.

Grievance Procedures
Students who have concerns about the class are encouraged to contact Stephanie Smialek, Education Manager, at smialek@motionpower.org or 773-302-8026.

Outline Changes
The instructor reserves the right to modify the outline during the course of the class.

LEARNING AND OTHER RESOURCES

Links for writing resources:

- grammar.ccc.commnet.edu/grammar
- www.merriam-webster.com

Links for Math resources:

- www.sosmath.com
- Khan Academy on www.youtube.com

Links for time management, study skills and note taking resources:

- www.mindtools.com
- www.testakingtips.com

Links for career resources:

- https://www.agma.org/newsroom/jobs/

Industry News:

- https://www.agma.org/newsroom/industry-news/

1 Plagiarism is defined as "the use or close imitation of the language and thoughts of another author and the representation of them as one's own original work."