Design and Performance Rating Procedures for Plastic Gears (Spur and Helical)

INSTRUCTORS:
Damijan Zorko, Borut Černe
Email: damijan.zorko@rdmotion.com, borut.cerne@rdmotion.com

COURSE INFORMATION

Course Description
High performance plastic gears are increasingly replacing metal gears in several applications due to many advantages they exhibit. Main ones are having lower weight, no need for lubrication, cheaper mass production, significantly better noise, vibration and harshness (NVH) behavior and chemical/corrosion resistance.

Design methods for plastic gears are in many ways different and more complex to those for steel gears. In major part the complexity is to be attributed to the material's temperature-dependent properties. Also the production methods are different, which needs to be taken into account during the design phase. The majority of plastic gears are produced by injection molding, which enables great design flexibility, e.g. joining several machine elements into one molded part, as well as a wide range gear geometry modifications.

The course focuses on all aspects of the design process of gearboxes with plastic gears. The covered topics were selected based on state-of-the-art industrial projects, working with stakeholders from automotive, micro-mobility (e-bikes), house appliances, aerospace, chemical, power tools and robotics sectors.

Course Rationale/Students Course Designed to Serve
Suitable for gear engineers, gear/gearbox designers, mechanical engineers working in automotive, robotics, house appliances, power tools, medical.

The program is best suitable for engineers which are already proficient in basic gear design and have knowledge on basic gear theory.

Learning Outcomes

- *Attendees will understand the differences in operation, design and production, between the plastic and metal gears*
- *Attendees will be able to appropriately select materials and lubrication type for a plastic gear application*
- *Attendees will be able to reliably design gear transmissions with plastic gears, taking into aspect all possible failure modes which could occur during operation of their product, as also other important customer requirements, e.g. NVH.*

Required Textbook (Provided by AGMA)
RD Motion's course material

Reference Materials (articles, websites.)

- *Multiple Authors, Polymer gears, (2024). https://shop.elsevier.com/books/polymer-gears/thomas/978-0-443-21457-8.*
- *VDI 2736: Blatt 1, Thermoplastische Zahräder, Werkstoffe, Werkstoffauswahl, Herstellverfahren, Herstellgenauigkeit, Gestalten. VDI Richtlinien, (2014). Only in German language.*
- *VDI 2736: Blatt 2, Thermoplastische Zahnräder, Stirngetriebe, Tragfähigkeitsberechnung. VDI Richtlinien, (2014). Available in English language.*
- *VDI 2736: Blatt 4, Thermoplastische Zahnräder, Ermittlung von Tragfähigkeitskennwerten an Zahnrädern, (2014). Only in German language.*
- *ANSI/AGMA 1106-A97: Tooth Proportions for Plastic Gears, (1997).*
- *AGMA 920-A01: Materials for Plastic Gears, (2001).*
- *JIS B 1759: Estimation of tooth bending strength of cylindrical plastic gears. Japanese National Standard, (2013).*
- *GB/T 44846-2024: Calculation of load capacity for plastic gear, Chinese National Standard, (2024).*
- *ISO 6336: Calculation of load capacity of spur and helical gears, Parts 1-6, International standard, (2019).*
- *ANSI/AGMA 2101-D04: Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth (Metric Edition), (2016).*

COURSE OUTLINE

a. Basic concepts on Plastic gears
   - applications with plastic gears,
   - available materials,
   - design principles with aspect to production technology,
   - production principles.

b. Overview of Plastic gear failure modes and design rating procedures
   - possible plastic gear failure modes and conditions under which they occur
   - comparison to steel gear failure modes
   - highlighting the material properties required to conduct a comprehensive design rating procedure

c. Methods for calculating the operating temperature of plastic gears
   - presentation of available models and highlighting the most appropriate ones
   - showcasing the correlation between the predicted temperatures and measured ones during gear operation

d. Fatigue performance
   - explanation of the fatigue failure mode and different fatigue regimes (LCF, HCF, VHCF)
   - methods to rate plastic gear design against the root fatigue failure mode,
   - methods to rate the plastic gear design against the flank fatigue (pitting) failure mode,
   - methods to improve the load-bearing capacity of plastic gears

e. Wear control
   - wear mechanisms and types of wear that can occur in plastic gear applications
   - wear prediction methods
   - methods to improve the wear performance

f. Gear quality
   - overview of the gear quality parameters with a highlight on the ones having the most effect on the performance of plastic gears
   - quantitative evaluation of quality effects on the gear performance and how to apply them in the design rating process (mechanical – effect on stress and thermal – effect on the operating temperature)

g. Lubrication (practical guidelines)
   - pros and cons of applying a lubricant in a plastic gear application
   - types of lubricants
   - methods to select the best performing lubricant
   - lubrication regimes for plastic gears

h. NVH
   - sources of NVH in a gearbox,
   - effect of wear and transmission error,
   - NVH evaluation methods,
   - appropriate material selection,

- practical guidelines to reduce NVH)

i. Design principles for gearboxes with plastic gears
   - selecting the appropriate tooth thickness and center distance tolerance
   - design principles for complete gearbox, once the detailed gear geometry is defined
   - agile R&D process for the design of gear transmissions with plastic gears

STUDENT FEEDBACK AND GRADING PROCEDURES

Assignments
Group work, case studies, and a quiz are 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@agma.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@agma.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*

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."

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/*