



Operator Precision Gear Grinding Online Courses

Part A: Gear Grinding Theory/Controlling Part Datums

**Part B: Gear Geometry Optimization, Grinding Simulator,
Setup Errors, Troubleshooting**

INSTRUCTOR:

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COURSE INFORMATION

Course Description

Explore precision gear grinding processes, machine input variables, kinematics and Gear Geometry in Part A, Grinding Simulator, machine alignment, setup errors, pitfalls, common gear fatigue failures and expectations related to finish ground gearing in Part B. Learn definitions of gearing component features, application loads and process steps from blanking, through heat treatment to finished part ready to ship. Study aspects of Quality Assurance, Inspection Documentation and corrective actions for measured non-conformances. Understand pre-heat treat, heat treatment distortion and post heat treatment operations including the how's and why's to produce finished gears that conform and perform to end user expectations. Calculate gear form grinding cycle times for real life examples for various accuracy levels on commercially available software.

It is recommended that you spend a minimum of 1 hour reading and reviewing the material before the online class.

Who Should Attend

This course would be of interest to both entry and high level generating and form gear grind operators, inspectors, process Engineers and quality assurance people who need to better understand why and how gear designs are optimized and how to work with non-standard gear geometry. The course would also benefit pre-finishing operators by understanding part datum control and subsequent gear finishing processes. Participants can also gain insight on how improper finishing techniques can contribute to premature gear failures. Entry level gear designers, process and manufacturing engineers can develop a basic understanding of gear finishing cycles, cycle times and cost. Gear manufacturing project managers and production managers can develop a better understanding of time required to set up and finish high performance gear sets that will meet or exceed application expectations.

Part A Learning Objectives

- Be able to ask questions of gear designers and manufacturing engineers to acquire all information required to produce conforming finished gears
- Understand basic and advanced gear tooth geometry, loads and target accuracy
- Review and challenge control of part datums through 5 gear processing steps, use datum's consistently through all operations given part process prints
- Anticipate and correct for part distortion during heat treatment knowing the actual heat treatment process used.

- Understand gear geometry and typical field failures, achieve compliance with finished parts to meet print requirements and customer performance expectations
- Select tooth grinding parameters Q_w , metal removal rate and V_w , volumetric limit for dressing given part print, heat treatment and grinding wheel specification used
- Understand gear grinding kinematics for both form and generating machines

Part B Learning Objectives

- Learn about gear performance optimization techniques used to optimize power density
- Accurately measure pre and post finish gear tooth Helix, Profile and tooth thickness given finished tooth geometry specifications and modifications calculated from Loaded Tooth Contact Analysis
- Review calculations on form grinding cycle times based on various target accuracies, Q_w material removal rate, V_w volumetric limit for dressing and grinding techniques
- Avoid and detect the presence of Twist Error
- Avoid and detect presence of grind burn temper
- Avoid typical gear fatigue failure modes, bending fracture, macro-pitting and micro-pitting resulting from improper tooth finishing
- Identify common non-conformances, causes and re-create them on gear grinder models, apply problem solving techniques and corrective actions suggested in trouble shooting guide provided with course material

Required Textbooks (Provided by AGMA)

Operator Precision Gear Grinding manual by Terry Klaves.

COURSE OUTLINE

Part A

❖ Why Finish Case Hardened Gears

- Correct for growth and distortion that occurs during heat treatment
- Improve finished accuracy to take full advantage of high strength, case hardened material
- Introduction to gear tooth bending and contact fatigue loading
- Introduction to applied load, torque, speed, horsepower
- Definition of basic and advanced gear geometry
- Review current gear accuracy standards and requirements
- Allowable bending and contact fatigue stresses for various materials
- Review gear processing steps: Turn, Hob, HT, Grind bores or journals, Grind Teeth

❖ Finishing Options – Case Hardened Gears

- Form Grind – kinematics and advantages
- Generating Grind – kinematics and advantages
- Skive
- Hone
- Gash
- Five Axis Machining

❖ Print Data and Finished Requirements

- Part datums
- Part geometry
- Example of gear manufacturing summary
- Micro-geometry
- ❖ Target Production Accuracy
 - Target accuracies for various processes in A and Q values
 - Active and obsolete gear accuracy standards
- ❖ Gear Finishing Process Steps
 - Consistent control of part datums
 - Gear tooth roughing and stock allowance
 - Discuss hob roll software that matches roughing hob parameters with finishing stock
 - Gear tooth size measurement
 - Predict dimensional changes during heat treatment
 - Special processes to be considered – shot peen, isotropic finishing, black oxide coating
- ❖ Finish Grinding Machine Setup
 - Required machine data input
 - Machine axis alignment
 - Work holding tooling
 - Grinding wheel selection, Q_w , V_w
 - Wheel dressing parameters
 - Limitations of on-board inspection
- ❖ Grinding Wheel 101
 - Grinding wheel definitions and descriptions
 - Dressable and Non-dressable grinding wheels
 - Tool wear
- ❖ Internal/External Gearing Basics
 - Target performance parameters, spur vs. helical
 - Twist error
 - Tooth helix
 - Tooth profile
 - Tooth spacing
 - Inspection per ISO and AGMA accuracy standards
- ❖ Growth During Heat Treatment
 - Backlash
 - Tooth size measurement tools and techniques
- ❖ Tooth Surface Finish
 - Micro-pitting
 - Macro-pitting
- ❖ Additional Gear Specifications
 - Surface Hardness

- Case Depth
- Core Hardness

Part B

- ❖ Gear Geometry Optimization for Maximum Power Density
 - Profile shift
 - Nonstandard addendums
 - High contact ratio
 - Asymmetric gear teeth
 - Tuning a gearset for performance
 - Loaded Tooth Contact Analysis - development of microgeometry to improve face contact and reduce transmission error
 - Twist error
- ❖ Gear Grinding Simulator
 - Review actual gear grinding simulator software calculations of grinding cycle times of a given part for various target accuracies, surface finishes and grinding processes
- ❖ Grind Burn and Temper
 - Grind burn/temper
 - White burn
 - Inspection for grind burn – nital etch – ISO 14104
 - Barkhausen
- ❖ Gear Rating and Failures Related to Improper Finishing
 - Tooth bending fatigue from grind steps
 - Macro-pitting from grind burn/temper
 - Micro-pitting from reduced contact area
- ❖ Troubleshooting Finish Grinding
 - Machine Alignment
 - Machine setup/alignment and troubleshooting related gear accuracy issues on gear grinder models
 - Terry Klaves gear grinding troubleshooting guide
- ❖ Summary, Review and Discussion

STUDENT FEEDBACK AND GRADING PROCEDURES

Assignments

Assignments and learning activities are given and directed at the discretion of 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

Plagiarism¹, 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.testtakingtips.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.”