MSE 3380
Mechanical Components Design for Mechatronic Systems

Design Project: Gear Transmission Case Study

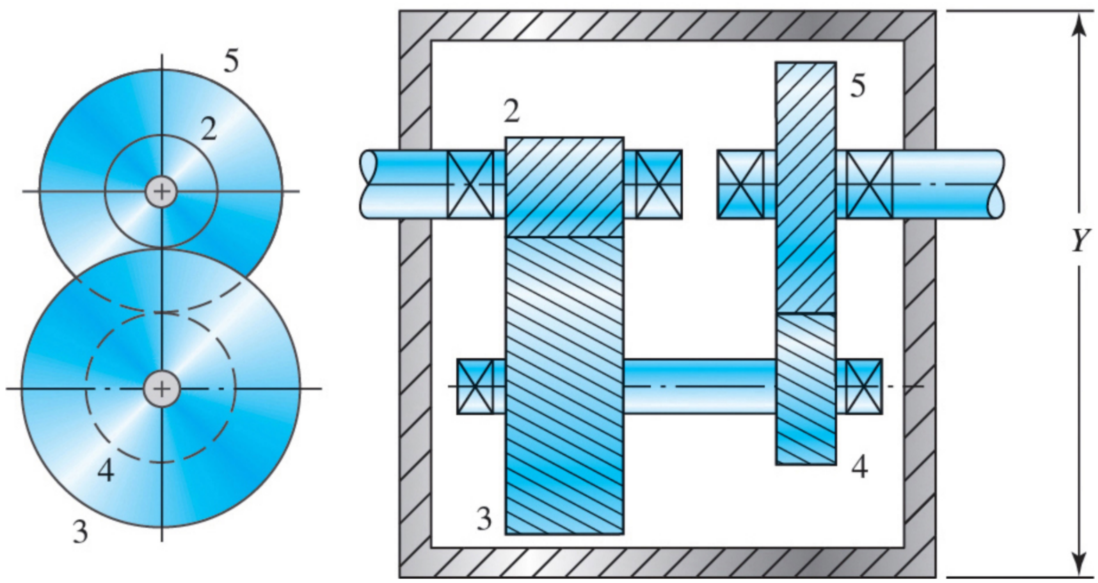
Dept. of Mechanical & Materials Engineering
Faculty of Engineering
Western University

Instructor: Prof. Aaron Price

Document Version: V.1
Due: 5:00 PM on April 8^{th}

Your Objective

A manufacturer has commissioned your group to aid in the design of a two-stage compound reverted speed reducer. The speed reducer should transmit the power from an electric motor to the application with as little energy loss as practical, while reducing the speed and consequently increasing the torque. Your client's marketing team has determined that this new speed reducer must satisfy the requirements detailed in the following sections.



Questions and Clarifications

DIRECT <u>ALL</u> QUESTIONS REGARDING THE PROJECT VIA EMAIL TO MR. COLIN JAFFRAY (cjaffra2@uwo.ca).

1 Project Scope: Following the approach in Shigley Ch. 18 ⚙

A general reducer design sequence is summarized in Shigley §18-1, and while the process is intrinsically iterative in nature, the main steps consist of:

1. Power and torque requirements
2. Gear specification
3. Shaft layout
4. Force analysis
5. Shaft material selection
6. Shaft design for stress (fatigue and static loads)
7. Shaft design for deflection, vibration
8. Bearing selection
9. Key and retaining ring selection
10. Final analysis

For our course we will limit the scope of the project to omit the housing-related considerations, and focus primarily on the design of the gears and the intermediate shaft (the shaft carrying gears 3 and 4). Therefore, for **each of the 4 gears** you are responsible for the specification of:

- Gear dimensions (manufactured in-house using standard sizes)
- Gear materials and condition

For the **intermediate shaft only** you are responsible for the specification of:

- Shaft dimensions and materials (manufactured in-house)
- Shaft deflection analysis at the location of bearings and gears
- Determine the critical speed and verify that resonant vibrations will not be significant
- Bearings and seals (procured from reputable vendors)
- Component interconnections such as keys and retaining rings (procured from reputable vendors)

For the **complete system**:

- Prescribe an appropriate lubrication strategy

The following considerations would normally also be important, but due to time constraints are outside the scope of this project and are therefore **not required**:

- Fastener selection for assembly
- Complete specification of housing dimensions and housing stress analysis
- Couplings at the input and output shafts
- Heat management

⋮

2 Performance Specification, Constraints, and Assumptions ⚖

- Power to be delivered: [Group № mod 5] $\times$ 5 hp + 20 hp
- Steady-state input speed: [Group № mod 6] $\times$ 100 rev/min + 1750 rev/min

- Maximum input speed: Steady-state input speed + 20%
- Reliability: > 99.5%
- Power efficiency: > 95%
- Minimum steady-state speed reduction: 20 : 1
- Usually low shock levels, occasional moderate shock
- 100% duty cycle
- Maintenance schedule: lubrication regularly checked and changed; gears and bearing life >12 kh; infinite shaft life; gears, bearings, and shafts replaceable
- Cost per unit should be minimized to remain competitive
- Production: 1000 units per year
- Operating temperature range: −25 °C to 50 °C
- Sealed against particulates typical of industrial settings

3 Deliverables

Final Report

Due: 5:00 PM on April 8th

Each group must submit a project package to OWL consisting of:

- Report document in PDF format (20 pages max)
- MATLAB files in a single ZIP archive

Your design is to be communicated via a report prepared in accordance with the formatting guidelines stipulated in §4. Note that the project specification is intentionally open-ended as per CEAB design attribute requirements. All calculations are to be submitted as MATLAB files. The report must convey the following aspects of your design methodology:

1. Determination of the kinematic requirements and appropriate factors of safety with justification
2. Specification of gear ratios and reduction stages
3. Free body, shear force, bending moment, axial load, and torsion diagrams for intermediate shaft
4. The loads on each gear and their associated dimensions and configuration
5. AGMA stress analysis for each of the gears
6. Complete specification of **intermediate shaft** profile based on fatigue and deflection analyses at critical sections and manufacturing considerations, including a fully-dimensioned SolidWorks drawing (c.f. F18-3, to be included in the PDF document, not a separate file).
7. Bearing specification (manufacturer/model number/configuration) for the **intermediate shaft** only. Prescribe a recommended lubrication strategy.
8. Specification of keys and retaining rings (manufacturer/model number)

3.1 Peer Evaluation

As per the course outline, you have the opportunity to evaluate the contributions of your group members if you feel that the load was not borne in a fair and/or equitable manner. To this end, a personalized link to your Peer Assessment will be distributed via email shortly after the project due date. Completion of the peer evaluation is optional; unless otherwise indicated the grade will be distributed equally amongst the team members. Peer evaluations are private and not shared with the other members of the group.

4 Reporting Requirements

The report should follow a clear, complete, and logical presentation and discussion of the problem and solution, with consistent and professional formatting. Use captions where required. Ensure to justify the reasons for the design choices made in your analysis. The document should be double-spaced using a 12-pt Times New Roman typeface.

4.1 Required Report Structure

Title Page: Indicate title of report, date of submission, group number, student names and numbers. The title page does **not** count towards the 20 page limit.

Table of Contents: Number all pages of the report and refer to section headings. The table of contents also does **not** count towards the 20 page limit.

Scope/Introduction: Briefly introduce the design problem and relevant background information. The focus should be to identify the purpose of the report.

Specifications and Performance Criteria: Identify any additional specifications and constraints imposed on the design not provided in the original description. Reports must correctly identify all group-dependent output requirements and specifications for the system, and state and justify any general assumptions.

Design Process: Document your engineering design process in detail in accordance with the requirements stipulated in §3. This section constitutes the bulk of the report.

Conclusions: A short summary of your findings and relevant conclusions arising from them.

References: Clearly identify sources you used to perform the analysis. Consult the IEEE Reference Guide for citation style information.

Appendices (as required): An area to present supplementary documentation. Any included appendices must be referenced in the body of the report. Appendices do not count towards the 20 page limit.

4.2 Reporting MATLAB Calculations

Where you are requested to submit MATLAB calculations, ensure that these are well presented. The purpose of engineering design calculations is not only to verify that a design is acceptable but also to provide clear documentation so that an engineer, not familiar with this project, could reproduce and verify your design calculations. Take note of the following in preparing your calculations:

- Provide clear comments to indicate the purpose of each calculation

- As your design progresses, multiple iterations are required, therefore, create your MATLAB script such that key variables are input by the user. It is recommended that you validate your scripts using an example from the textbook to ensure you have entered the formulae correctly
- Clearly state and discuss the validity of all key assumptions
- Cross-reference key relations unless they are commonplace
- Define all notations and employ a meaningful, consistent, and self-explanatory variable-naming policy
- Provide free-body diagrams
- Highlight key results
- Typically, a calculation in the report is presented in the following fashion:
  - Reference the equation employed and associated assumptions
  - Show a table or list of values for the variables in the equation
  - Display results (or a table of results if the same calculation is repeated)
  - Do not show substitution and simplification steps for the calculation
  - Final answers should be presented with appropriate significant figures

⚠ POORLY PRESENTED CALCULATIONS WILL NOT BE GRADED.

4.3 Design Drawings

For each report, a complete part drawing must be prepared that communicates the design of the intermediate shaft. The drawing must be included in the report PDF, not as a separate file. All dimensions and annotations must be specified in accordance with the **ASME Y14.5** standard.

5 Evaluation Rubric

For transparency, an analytical rubric will be published within our OWL site's Project submissions tool well in advance of the deadline (typically in Week 6).

6 Some Potentially Useful Resources

1. Lateef Adewale Kareem (2022). Shear Force Bending Moment, MATLAB Central File Exchange.
2. Robert Greenlee (2012). MATLAB Functions for Mechanical Engineering Design III, University of New Mexico.

7 Revision History

V.1 2022-02-02: Original document