MCEN6020 Advanced Machine Design

(Semester 2, 2024)

Assignment:

Analysis and design of a gearbox

VALUE: 25%

DUE: FRIDAY, 04 OCTOBER 2024 (5:00 PM)

Before submitting the report:

Check the originality of your report via Turn-it-in. Rewrite and resubmit (before 4 CTOBER 2024) if it contains information copied from other sources.

After submitting the final version of your report:

UPLOAD *the Reasons for the Similarities in the report before 11 OCTOBER 2024 (5:00 PM). This is required if the Turn-it-in similarity index for your report is greater than 20.*

- *This assignment will require considerable effort, so do not leave it until the week it is due.*
- *The specified page limit will be strictly observed. Any information that exceeds the page limit **will not** be considered for marking. For details, refer to the Appendix.*
- *This is an individual, not a group assignment. This is to be done on your own. Do not share your work with other students.*
- *The main body of the report must not contain any sketches or information copied from the lecture notes or tutorials.*
- *The reports having high **Turn-it-in Similarity Index** will be investigated for plagiarism. Therefore, it is recommended that you should upload the report a day or so before it is due, and check its Similarity Index.*
- *Use of ChatGPT or AI is not allowed for this assignment.*
- *Avoid reusing any of the contents of your old report(s) as it may be categorised as self-plagiarism.*

SPECIFICATIONS AND REQUIREMENTS

A company specialises in the manufacture of gearboxes for industrial applications, such as conveyors, belts, pumps, blowers, and generators.

The marketing team has determined a need for one of these gearboxes to satisfy the following customer requirements:

Power to be delivered (output)	2.1 kW
Steady-state input speed	1960 rpm
Steady-state output speed	560 $\pm$ 3 rpm.
Input and output shafts are inline	
Base mounted with 4 bolts	

The gears will be keyed and press fitted to the shaft with a transition fit. The gearbox is targeted for uniformly loaded applications. The expected life of the unit is 10 years, which is based on 7.5 hours per day and 6 days a week. A maximum of 4% failures are allowed over the design life of the unit.

The gearbox should transmit the power from the source to the application with as little energy loss as practical, while meeting the speed and torque requirements.

The design should be a practical proposal, which among other things, considers how the gears are packaged, facilitating assembly and disassembly for maintenance.

As a design engineer, your task is to design the proposed gearbox by analysing force and torque requirements. The core objective is to develop a systematic procedure for gearbox design, showing all the necessary steps and calculations.

It is becoming increasingly important that the engineering products are environmentally friendly. Therefore, it is needed that the design documentation includes strategies, methods, and/or guidelines to reduce the environmental impact in each phase of the life cycle of your proposed gearbox. For this, you are required to provide your recommendations based on a thorough review of the latest literature on environmental protection/management strategies, initiatives, legislations, standards, tools, and LCA case studies.

NOTE:
You must first demonstrate a correct understanding of the basic design of a compound gear train using SPUR gears before suggesting a better alternative.

SUGGESTED STRATEGY

The below information is provided to help you refresh your knowledge of the gearbox design process. It highlights some of the essential elements applicable to the design of a gearbox. Your proposed design should not be limited to the aspects/parameters discussed in this strategy.

There is no exact sequence of steps for any design process. In general, design is an iterative process in which it is essential to make some tentative choices, and to build a skeleton of a design, and to determine which parts of the design are critical. However, understanding the dependencies between the parts of the overall design will help you propose a competitive design in relatively less time.

An outline of the recommended design process that highlights some of the essential aspects of the gearbox design process is appended below:

- Prepare an outline design of what you want to achieve and consider all the possible ways it can be done. The simplest solution is usually the best. How will you achieve the required output, and how will you package the gears? What mountings do you require on the gears/bearings and what shaft arrangements?

- Carefully read the given data, and if required, make the necessary assumptions. Check if you need to comply with any standard values while assuming certain parameters.

- You must first address the power considerations, as this will help you determine the overall sizing needs for the entire system. Any necessary speed or torque ratio from input to output must be determined before addressing gear sizing. Gears have reasonably high efficiency, and there are negligibly small losses due to factors like friction in the gears and bearings.

- Select gears of appropriate sizes to achieve the identified ratios. Care should be taken at this point to select the best combination of teeth numbers to minimise the overall package size (i.e. gearbox size). A difference of one tooth on the smallest gear can make a significant impact on size of the overall package.

- Gather the necessary information, such as gear outside diameters, hub dimensions, face widths, mounting distance, and clearances etc., related to your selected gears. Similar information is also needed for bearings (Note that you will conduct a thorough analysis to select the exact bearings later). You can perform a quick search of on-line gear and bearing catalogues to find the required data – for somewhere to start, see:

    - Miniature Bearings Australia
    - KHK gears
    - Tea Transmissions Pty Ltd

NOTE: *You can use the bore size and axial dimensions of the closest available size if you can't find a gear with the exact number of teeth.*

- Decide the shaft layout – the axial location of gears and bearings must now be determined. It is extremely important to keep axial distances small. A small increase in axial distance will result in large increase in bending moments. Prepare a rough sketch to visualize your proposed design. At this stage, the diameters of the input and output shafts can be assumed according to your selected gears. ***Detailed analysis and design is required for the counter-shaft.***

- For each shaft component, specify the method of connecting it to the shaft. The gears will be keyed and press fitted to the shaft with a transition fit. The bearings will be press fitted to the shaft with an interference fit. Use appropriate mechanisms / devices to secure the axial location of shaft components.

- Now, get an initial estimate of the total length of the shaft based on the specifications and locations of the gears, bearings and other shaft components that you have selected.

- Once the gear diameters are known and the axial locations of the gears and bearings are available, free-body, shear-force, and bending moment diagrams for the shaft can be constructed. Forces acting on bearings can also be determined now.

- Perform a detailed analysis to select suitable bearings. Consider radial as well as axial loads in the system before making decisions on bearings. Bearing dimensions can be obtained from online catalogues. Alternatively, you can refer to the information in the lecture notes / textbook.

- Now, calculate the exact length of the counter shaft and location of forces. It may change your previous estimates of the forces acting on bearings. Verify that proposed bearings are suitable for the changed loads.

- Select an appropriate material for the shafts. For this, conduct a review of the literature on shaft materials and document your findings. Material types and their suitability for various applications/environment need to be discussed. <u>This information shall come from books, standards and research papers</u>.

- Construct shear-force and bending moment diagrams. This would help you identify the locations under high shearing forces and bending moments.

- Identify the regions of stress concentration (i.e. stress raisers). Decide the stress concentration factors (K_t values). State criteria for each of the selected values of K_t.

- Now, identify the critical locations on the counter shaft. The minimum shaft diameter is required to be calculated for all such locations. This must be done by stress analysis at critical locations. **You must also include strategies to reduce stress concentrations in the counter-shaft.** *The proposed strategies must be specific to your shaft – providing a generic discussion will not be accepted. The recommended modifications must be shown implemented in the final design specifications for the countershaft shaft.* Do not copy figures/images from the lecture notes.

- It is the time to determine if there were any anomalies between your assumed values and the final design output. Carry out a point-to-point comparison between the calculated (or assumed) and physical dimensions of the selected components. For example, your calculated shaft diameters may be different to the bore sizes of your chosen gears and bearings. *How are you going to overcome such discrepancies*? If required, modify your design specifications.

- Analyse the torque transfer mechanisms, such as keys, splines etc.

- How do you plan to hold gears and bearings in place? Provide your choice of the available options. For this assignment, strength analysis of such elements/methods is not required. However, complete specifications and their exact locations must be provided.

- Prepare a detailed sketch illustrating the exact location of each component, and their relationship with each other.

- You may use plain bearings to support the input and output shafts in the gearbox casing. On the other ends, use rolling element bearings.

You may use plain bearings to support the external ends of input and output shafts. The other ends (inside the gearbox) should be supported by rolling element bearings. The countershaft must only be supported by rolling element bearings. Do not do calculations on plain bearing forces/pressures – simply show the shapes, material and positions of those bearings in your design. Also, indicate a suitable lubricant for your proposed bearings.

- For plain bearings, low friction materials are available in many forms, and you should investigate and put forward your choice, discussing its lubrication requirements (if any) and the reasons why you wish to use it. Reviewing the commercially available plain bearings would be helpful.

  The bore size of the relevant gear/pinion can be taken as the shaft diameter of the input and output shafts. Determine the plain bearing size. Also specify the types of fits and relevant tolerances for the shaft and bearings.

- Identify the types of fits for your design (Counter-shaft and its associated components) – the selected fits should comply with the ISO preferred fits. Determine the shaft dimensions required for your selected fits.

- Decide casing arrangements. Consider the followings to determine the overall casing dimensions:
  - Size of gears and bearings
  - Length of shafts
  - Clearances

- Your best judgment of some of the elements / parameters, such as module, retaining rings, check-rings, nuts and bolts, clamping devices, sleeves, spacers, and set screws will be acceptable. For this assignment, strength analysis of these elements is not required. However, you must provide the applicable specifications, for example, size, location, shape and material etc.

- Analysing the gearbox casing and gear tooth for strength, wear and surface fatigue is beyond the scope of this assignment.

ASSUMPTIONS / EXCEPTIONS:

- While designing the shaft, you may have to consider factors that affect the endurance limit of components. Cyclic/fatigue loading, which is discussed in the Materials unit, deals with these factors. For more information, refer to the recommended textbook. *Your best judgment will be acceptable.*
- For this assignment, the mass of the shafts and other components may be ignored.
- Some of this design does not need detailed calculations, and your own estimates of certain sizes/shapes/configurations will be acceptable.
- The shafts for the proposed gear-box are to be made from steel. However, a comprehensive review of the literature on shaft materials is required. For material properties, such as yield strength, ultimate strength etc., refer to your textbook.
- For this assignment, evaluating the environmental performance of the gearbox is not required. Only research-based recommendations are expected.

ADDITIONAL INFORMATION

Report organization:

- The purpose of this report is to explain the design and analysis process. All steps must be explained with sample calculations. *Providing only the final output will not attract any marks*.
- Organise your report in logically-based sections.
- If required, provide ¼ page discussion at the end of each section. This discussion must be limited to critically analysing the contents of that section.
- *Generic comments and long discussion(s) must be avoided*.

Calculations:

Some of this design does not need detailed calculations, and your own estimates of certain sizes/shapes/configurations will be acceptable.

Figures/Tables:

Figures and Tables should be numbered. Each of the figs/tables must have an appropriate caption/heading.

Late assessment policy:

By default, a late assessment attracts a mark of "ZERO." Under special circumstances, such as medical emergency or bereavement, students may apply with supporting evidence for a waiver of this default late penalty. The request for an extension will be reviewed for approval by the unit coordinator or Head of Department. Such applications are to be lodged (online) BEFORE the original assessment due date.

REPORT REQUIREMENTS

You are required to submit a report in a **typed** professional format. *For formatting requirements and page limits, refer to the Appendix.*

Write this report though you are the engineer employed by the company, or a consultant appointed to this task.

Do not write it as a student doing an assignment.

Apart from the cover sheet, the word 'assignment' should not appear in your report. If you wish to refer to these notes, then call them the 'design specification'. Do not use the words 'I', 'we', 'they', 'us' etc., since the report should be 'impersonal'.

Your report shall meet the following requirements:

1. A title page that includes the assignment title, your name & student ID, etc.
2. An executive summary - this must be more than just a few lines. Summarise the **whole** report [*Limit: One A4 page*].
3. Table of contents.
4. List of Figures/Tables (on a separate A4 page).
5. An introduction, ***which is not a repeat of the words of this assignment.*** It needs to be reflective of the contents of the report.
6. Review of literature on environmental protection and assessment: Your findings of the review of the literature shall be demonstrative of the latest research and developments in this field. Simply describing the fundamental concepts, such as environmental impact categories/methods and life cycle assessment is not the purpose of this review. The published papers are good examples to follow. In-text referencing is essential. [Four A4 pages].
7. Literature review (gearbox): A thorough review of the literature on the design, analysis, types and applications of gearboxes. It shall reflect *the latest research and developments* in the areas, such as FEA of gearing systems and maintenance techniques applicable to gearboxes. This section must demonstrate a meaningful review of a wide range of refereed journal papers and books in this area. References to the sources of information must be cited in the text *[Three A4 pages].*

Generic commentary on gears, merely describing the types of gears, information taken from lecture notes or commercial websites will attract no marks.

8. Clear, concise calculations of all gearbox parameters, including speed ratios, gear sizes, torques, forces and shaft diameters.

9. The relevant section shall also include a review of the literature on shafts. The review will include but not limited to shaft and hub connections, shaft materials, shaft failures and root cause analysis. The information in this section shall come from books, standards and journal articles. The literature review must cover a wide range of research articles. In-text referencing is essential. *[Three A4 pages]. This is in addition to the review of the literature on gearboxes.*

10. Complete procedure for the analysis and selection of gearbox components, such as bearings and keys.

11. Sample calculations: Explaining the design procedure with sample calculations in the main body of the report is an essential requirement. All formulas shall be in mathematical format and placed in the main body. Results of any repeated calculations can be provided in a Table placed after the sample calculations. *(Any results or calculations placed in the appendices will not be considered).*

12. Description of symbols/abbreviations: The symbols and abbreviations need to be defined where they are first used.

13. Drawings: The following drawings are required (in AutoCAD / SolidWorks):

    - Fully dimensioned (including tolerances) detail drawing of the intermediate shaft (countershaft). The orthographic views will be drawn in THIRD ANGLE PROJECTION SYSTEM*. Use one of the standard scales listed in the Australian drawing standards.* Provide a title block and all the relevant information on this drawing.

    - Annotated assembly drawing (orthographic views) of your proposed design, which clearly shows the **general arrangement of components**. The drawing shall include a sectional view. Use part numbers, balloons and leaders to label the parts in the assembly. The parts' list and a title block shall be part of your assembly drawing.

      NOTE:

      a) The drawings shall conform to Australian drawing standards that govern the production and interpretation of detail and assembly drawings. A complete reference to the source must be cited if you prefer using any other drawing standard.

b) *In addition to the above, provide sectional views or component part drawings, if necessary, to fully describe the design.* ***You are NOT required to produce detail or manufacturing drawings of the components except the countershaft.***

14. A conclusion (One A4 page).

15. Appendices: Appendices shall only be used for the information taken from other sources. This includes gear/bearing catalogues and design tables/charts, etc. Such information **must not** be placed in the main body of the report. Reference to this information must be cited in the relevant sections of your report, otherwise this information has no purpose.

16. References: For citing and listing the references, follow the **Chicago or Numbered style**. It is recommended that you should use ENDNote to manage the references.

17. You are required to submit the soft copies of your report and drawings. Upload the softcopies (PDFs) of the report and drawings to Blackboard. The filenames must contain your student ID. The following files (in PDF) are required by the due date:

    - completed report ***(Use Turn-it-in results to verify the originality of your work),***
    - detail drawing of the shaft,
    - assembly drawing of the gearbox.

18. **Upload** your Reasons for the Similarities in the report to Blackboard if the Turn-it-in similarity index for your report is greater than 20 [Limit: One A4 page]. For the due date, check the front page of this brief.

19. The report shall not contain any hand-written information.

Marking criteria:

Assessment element	Requirements	Weighting
Introduction/ Executive summary	The introduction provides a good coverage of the project. It includes an extended description of the project objectives and outlines the report in a clear, concise and appropriate writing style. It serves as a guide to various sections of the report. The executive summary is inclusive of the project objectives, methodology, and outcome. It also highlights if there were any major obstacles in completing the project, and what was done to overcome the hurdles.	5%
Technical contents	The report demonstrates a systematic and logical analysis of the given task. The literature review and gearbox design/analysis demonstrate a correct understanding of the underlying theory. The findings of the literature review and gearbox analysis follow a logical and coherent flow. The information/data is presented in a clear and appropriate format. The interpretation of the data is logical and correct. Explanations of interpretations are evident. Results are stated clearly. Logical assumptions are based on highly quality and authentic sources. Data analysis and presentation meets or exceeds the stated requirements. The analysis is demonstrative of research-based decisions about various design parameters. The drawings conform to the given specifications and drawing standards. Appropriate conclusions are drawn. Conclusions are sufficiently detailed and linked back to the theory.	85%
Presentation	The presentation is of high quality. The report is complete including an executive summary, title page, table of contents, list of figures/tables, and conclusion. It is demonstrative of a professional style/format, neatness, clarity, completeness, correct referencing, figure captions and numbering, and table headings and numbering.	10%

To gain more than 3/10 for this assignment, besides being correct, it must be unique, i.e. **not** similar in wording or layout to other student's reports, or have similar diagrams, calculations, spread-sheet layout, or any content which has been copied. Your discussions should be clear, concise, and well thought out.

APPENDIX:
Report formatting and page limit requirements.

<table>
<tr><td rowspan="4">PAGE SETTINGS</td><td rowspan="4">Select the normal settings for margins.</td><td>Top:</td><td>2.54</td></tr>
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<tr><td rowspan="6">FONT SIZE / STYLE</td><td>Style</td><td colspan="2">Times New Roman / Calibri</td></tr>
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<tr><td>Sub-headings</td><td colspan="2">12</td></tr>
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<tr><td colspan="2">EQUATION FORMAT
(Examples)</td><td colspan="2">$(\frac{\sigma}{S_n})^2+(\frac{\tau}{S_{sy}})^2 = 1$
$F_e = F_r\left[1 + 1.115(\frac{F_t}{F_r} - 0.35)\right]$</td></tr>
<tr><td colspan="3">LINE SPACING</td><td>1.5</td></tr>
<tr><td colspan="3">SPACING BETWEEN PARAGRAPHS</td><td>6 pt</td></tr>
<tr><td colspan="3">PAGE LIMIT</td><td>30</td></tr>
<tr><td colspan="4">a. The page limit is exclusive of cover sheet, title page, table of contents, list of Figs/Tables, executive summary, reference list, appendices and the <u>two</u> AutoCAD drawings. Any other sketches / drawings are included in the page limit.
b. Any information that exceeds the specified page limit will not be considered for marking.</td></tr>
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