ME 315
THEORY OF MACHINES – DESIGN OF ELEMENTS
Fallg 2023
Group Design Project

Assigned: **10/10** **Due:** **12/6, before 11:59 pm On-line, One pdf file each group**

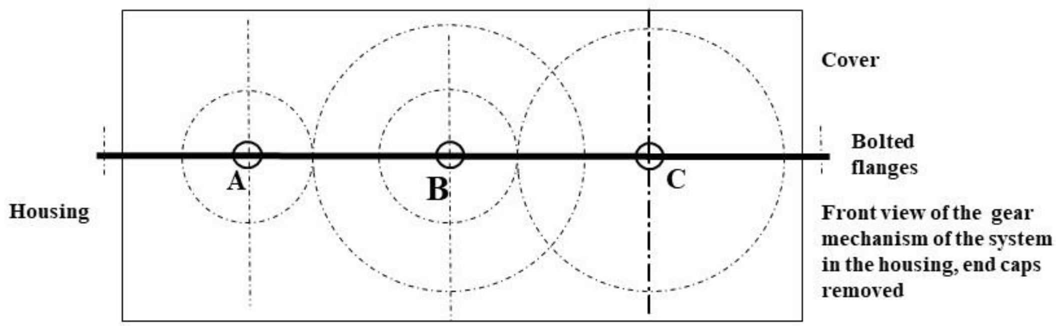
Objectives: 1. Create a structure from a concept
2. Design a simple machine, assessment of future manufacturing options
3. Analyze mechanical elements
4. Practice teamwork.

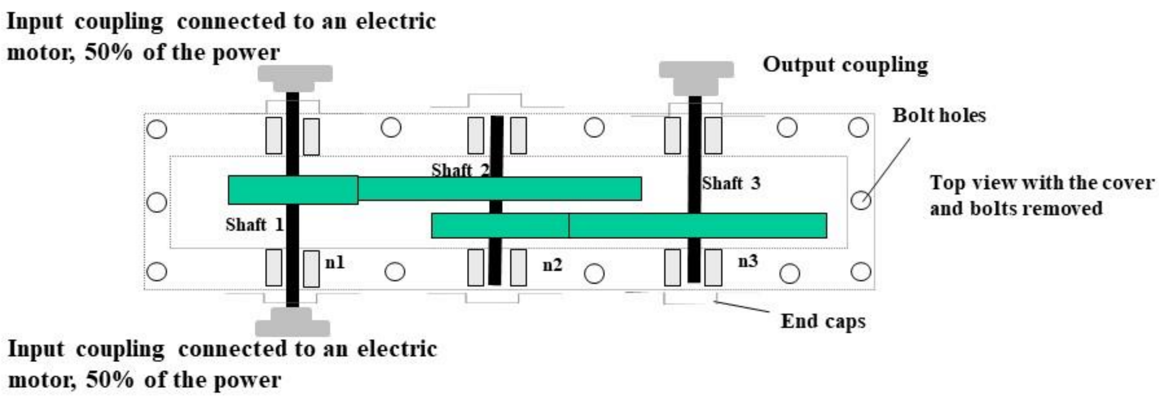
The figure on the next page shows the mechanism plot of a two-stage gear transmission, for transmitting power from shaft A to shaft C with a speed reduction. The inputs to shaft A are from two electric motors connected by couplings. Shaft C is the output shaft, and the output is through a coupling set. The distance between A and C should be determined in the design. The motor speed is 2600 rpm and the power input to shaft A is 70KW. The speed of shaft C should be n3=400 ±3. Assume 100% overall efficiency. Fatigue stress concentration factors should be properly considered based on bending and torsional stresses. The minimum shaft diameter should be at least 20mm to consider the stiffness issue. The transmission is expected to work for at least 5 years (7 days a week, 52 weeks a year, and 8 hours a day), and the reliability is 99%. All other parameters are for the designers to select and determine.

Design this three-shaft gear-train system in a housing separated at the plane of shaft centerlines. **You may choose spur or helical gear sets**.

This is a group design work with a group submission. **Each group should have three people**, and **each member is responsible for one shaft system**. The team should consider the best part arrangements for the most effective design in terms of compact structure, stiffness, power density, and cost. The designs or selections of gears, shafts, and bearings should be supported by detailed analyses, while other components (spacers, seals, shims, gaskets, plates, end caps, etc.) can simply come from selections and geometric designs without calculation.

- This project does not require housing design; however, you may consider a rectangular box as the housing for convenience. Bolts can be simply indicated by their centerlines.
- The design work for the input and output elements (couplings) is only limited to the geometry and force calculations that are needed for the shaft design. No need to do CADs for them and no need to show them on the shaft assembly either.
- End caps, spacers, gaskets, shims, and seals should be properly considered in each shaft assembly, but no calculation is required.
- Fits for the gear and bearing mountings should be considered in the assemblies, and the corresponding tolerances should be shown in the part drawings for the shafts and gears.
- Try compact and cost-effective designs. Stiffness issues are not required but should not be ignored.





The output coupling can be on either side of the shaft, choose a reasonable arrangement. The above is a mechanism plot, NOT the CAD drawings to be developed; here the parts are plotted by symbols, not in their true shapes and sizes.

Total design work includes:

1. Gear train design: Train arrangement
   The true train values (velocity ratios) with a proper error analysis.
2. Force analyses, on the gears, and transmitted to the shafts, bearing reactions.
3. The gear design: Geometry of each gear, gear forces, materials
   Stress, strength, and factors of safety, design reliability, and
   Structure design for each gear (inside the bear box) on your shaft.
4. The shaft design: considering all elements on each shaft.
   FBDs, shear force and bending moment diagrams, well aligned.
   Stresses at the critical points.
   Shaft structural design and shaft system design, all elements assembled.
5. Bearing selection and support design: Bearing type, size, C, C0.
   If the bearing life is shorter than 5 years, a bearing change service is needed.
   Schedule of bearing change if necessary.

CAD drawings to be submitted: Assembly section view only (you may draw the keys/keyways along the same line for simplicity).
Major part drawings (the shaft and one gear on the shaft, see next page).

Design report (typed, group report, clearly indicating the work by each member). It should contain four tables (group), and three set of drawings, and three appendices for analyses (individual), which are

A diagram to show rpm and torque on each gear.

Table 1 Geartrain and gear parameters: including power and speed (rpm) of each gear, resultant transmission error, major geometry of all gears, including module and No. of teach of each gear, pressure angle, face width, as well as the centerline distances between shafts, and the total centerline distance AC; torque, gear forces, materials, hardness, factors of safety.

Table 2 Shafts and parameters. Materials, speed, maximum torque, maximum bending moment, location of critical cross section, factors of safety, expected life (infinite of finite).

Table 3 Bearings and parameters: radial/thrust loads, bearing numbers, IDs, ODs, widths, C, Co, life, etc., for each set; whether or not bearing-change services are needed.

Table 4 Overall results. Power, input speed, output speed (rpm), overall design factor of safety, maintenance needs, such as bearing changes, oil changes.

Three shaft assembly drawings (one from each member)

Three shaft part drawings (one from each member)

Three gear part drawings (one from each member). The central shaft (B) designer: submit the drawing for the smaller gear.

- Solid model and major views with necessary sectional views, cutaway views, and sectional views.
- Proper dimensions and tolerances for the gears and bearings, fits on the assembly, tolerances on part drawings.
- For the gear drawings, show major (module, pressure angle, a and b) gear parameters in the drawing title chart.

Each group report should have three attachments for the design analyses, one from each member (handwriting is fine, but it should be clean and clear).

Appendix i Shaft system i and related calculations, including the analyses for 1) factors of safety for the gear; 2) factors of safety for the shaft, and note that shaft A has a belt pulley and B has two output couplings; 3) bearing selection and the related analysis. Make sure you plot the shaft FBD and the bending moment diagrams, well aligned.

Due dates (Steps 1-2, will be collected counted, but not graded)

Step 1:	Train design and Initial shaft and gear design (geometry, force, strength, etc.)	10/31
Step 2:	Bearing selections and design modifications Basic CAD assembly, all draft completed.	11/14
Final report submission (group submission only, one pdf file/group)		12/6, 11:59pm

Cover page to use (make sure you use this page-2 points, this is for grading)

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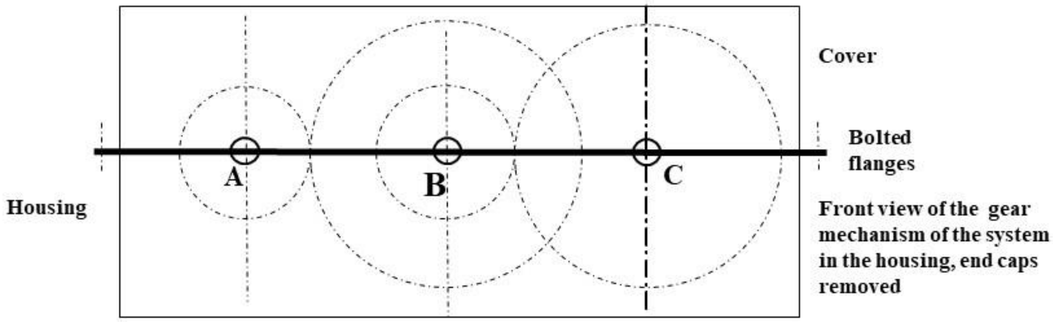
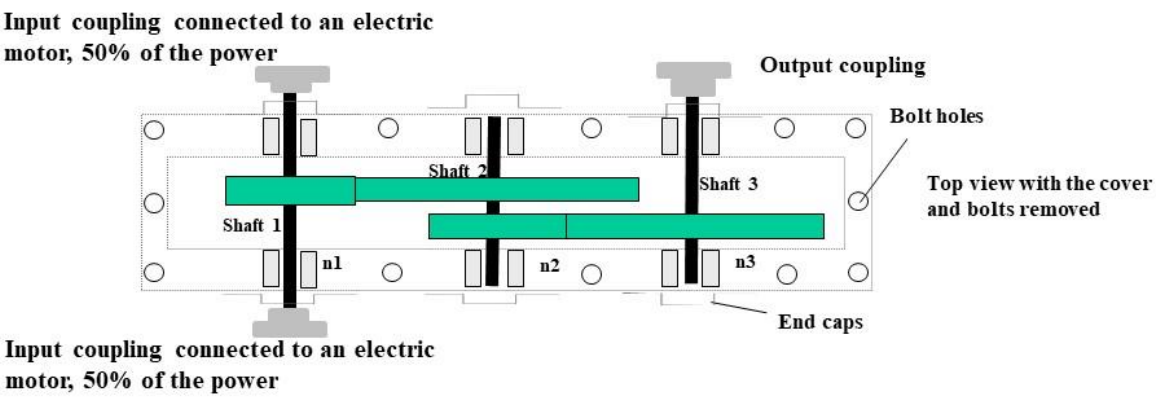
Spring 2023

Design Project

Group submission





Group members

John Jones	Shaft system 1
Joe Jones	Shaft system 2
Jerry Jones	Shaft system 3

Grade

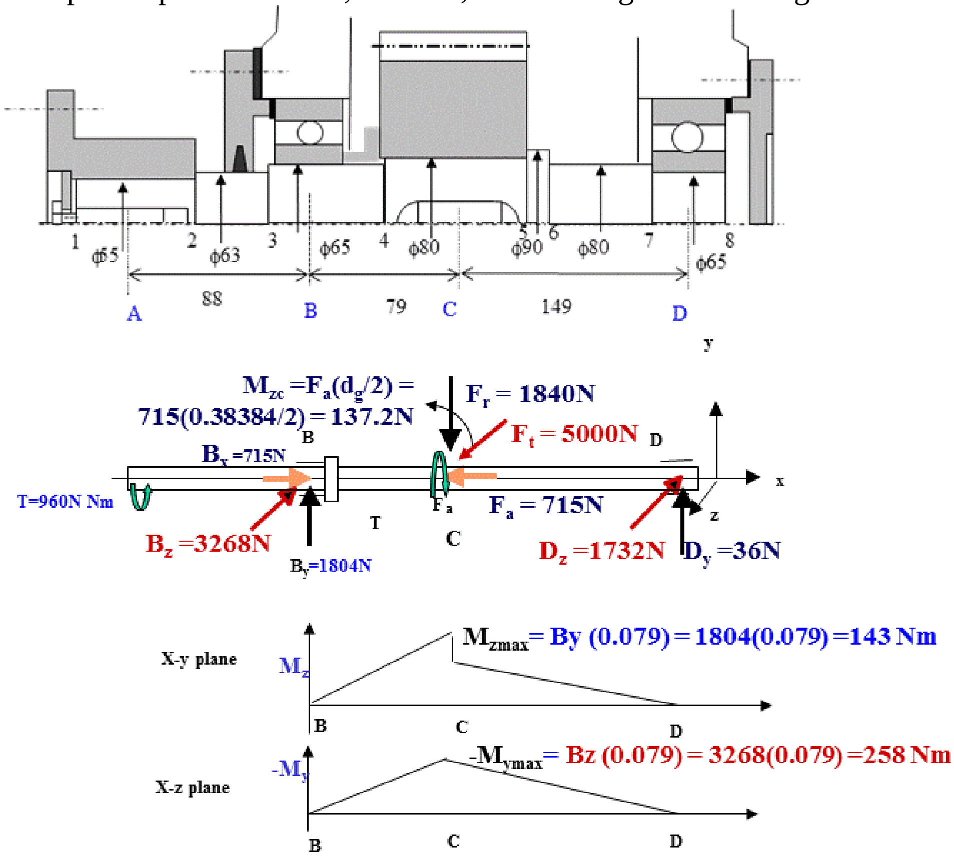
On-time step dues	/5
Structural design, drawings	/40
Design analysis	/35
Report writing	/20

Total____________

Details of the appendices for design analyses

1. **Shaft analysis**, **give equations used.**
(Note that the figures below are for demonstration only.)
Show a simplified plot of your shaft with key dimensions, followed by a mechanical model (FBD) with force application information.

Shaft no. X
1) Simplified plot of shaft X, its FBD, and bending moment diagrams



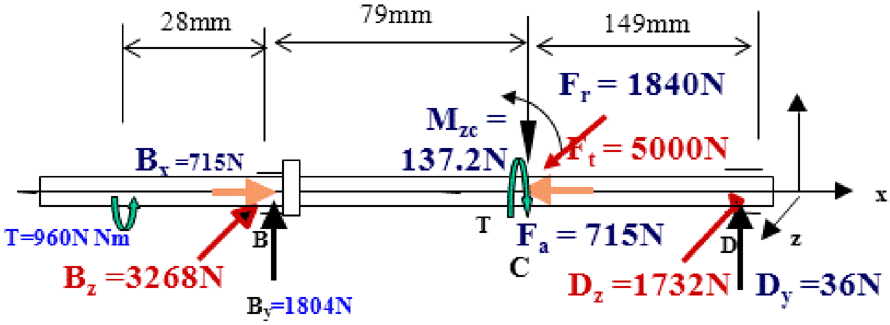
2) Critical cross sections
3) Most critical point
4) Stresses
5) von Mises stresses
6) Goodman and Yield factors of safety

2. Gear Analysis (give equations used)

Gear No. Y on shaft No. X
1) Gear forces, dimensions, speed, life expected
2) Materials, hardness, strength factors, strengths analysis
3) Stress factors and stresses
4) Factors of safety

3. Bearing selection (give equations used)

Bearings at B and D for shaft No. X



1) Reaction forces, resultant radial and thrust forces
2) Bearing type
3) Equivalent loads, life expected
4) Calculated C (or C1)
5) Bearing selected, ID, OD, and width.
6) If bearing changes required or not (In case the load is too heavy, you may choose to reduce the bearing life and arrange bearing change once or twice)