ME 352: Machine Design I **Name of Student:___________________________**

Fall Semester 2019 **Lab Section Number:______________________**

Project 3. Upload to Gradescope before 8:00 am on Monday, November 25th. A formal report is not required, however, credit will be given for a detailed presentation and clearly drawn figures.

The initial design of the shaft at O_2 for the Watt linkage that was analyzed in Projects 1 and 2 is shown in Figure 1. For this design assume that the length of the shaft is $JK = 750$ mm, the thickness of link 2 is $t = 45$ mm, the diameter of the shaft is $D = 50$ mm, and the fillet radii of the shaft at the simply supported bearings at G and H are $r = 5$ mm. The bore diameters of the two bearings are $d = 40$ mm.

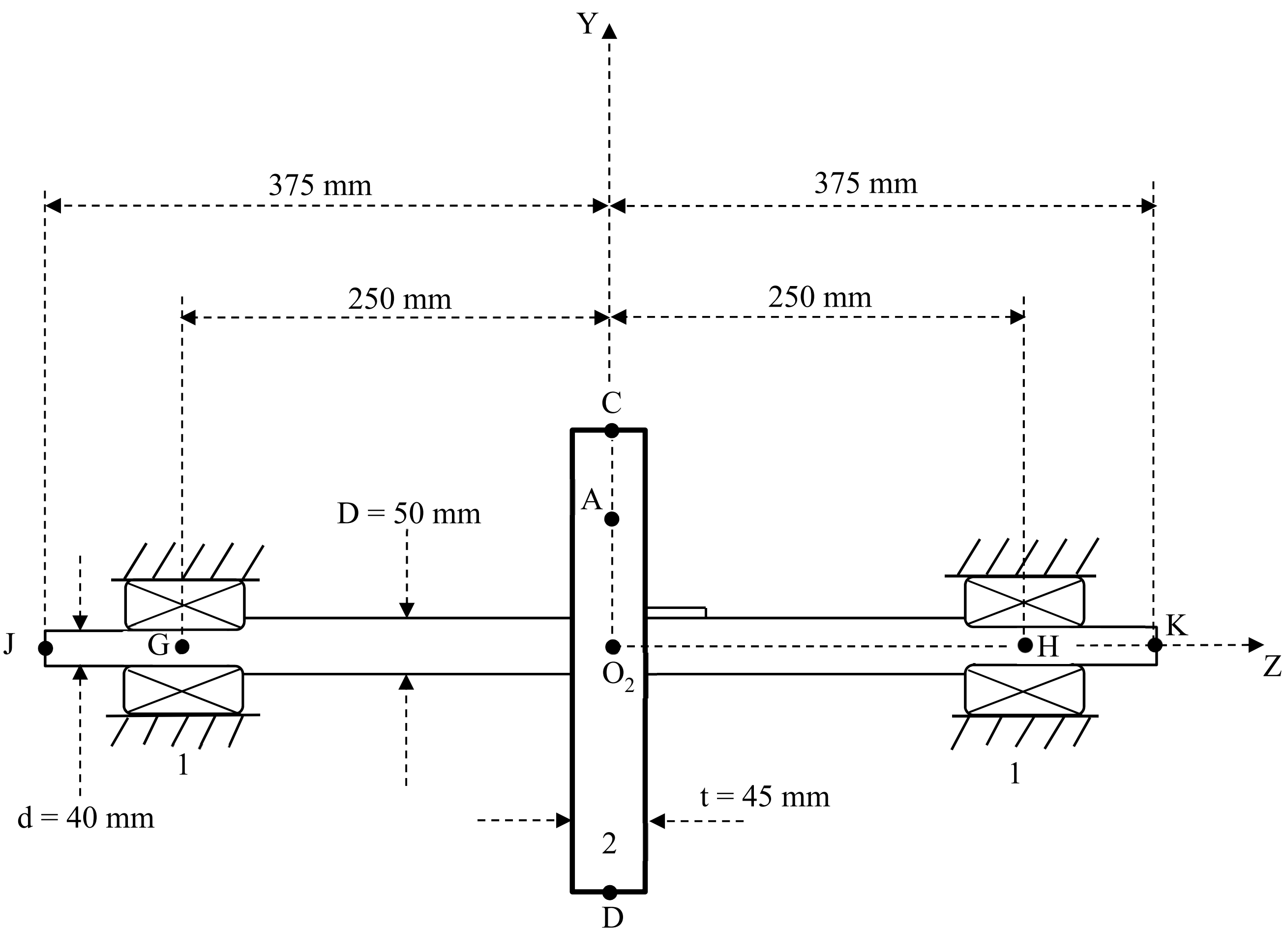

Figure 1. The geometry of the shaft. (Not drawn to scale).

Part I. Analysis of the initial design of the shaft. To validate the initial design shown in Figure 1, you must perform a stress analysis of the shaft. For this analysis, you can assume that the loading on the shaft (which is a function of the posture of link 2, see Project 2) is symmetric and the mass of the shaft can be neglected.

The key to a successful stress analysis is to estimate the fluctuating stresses in the shaft at several candidate failure locations. Combining the stresses with the material properties of the shaft will allow you to predict both static factors of safety and fatigue factors of safety for the shaft. You will also need to select and specify the material properties and the heat treatment of the shaft.

The following steps are the recommended procedure and practical suggestions before commencing a detailed stress analysis for a static failure and a fatigue failure of the shaft:

(i) Generate free body diagrams, shear force diagrams, bending moment diagrams, and a torque diagram for the shaft. For hand calculations, the diagrams can be for a single posture of link 2. Include a detailed discussion of the diagrams.

(ii) Determine the critical sections of the shaft. Clearly document your reasons why they are critical. For purpose of comparison, at least two critical sections of the shaft should be investigated.

(iii) At each critical section of the shaft locate the critical elements of the shaft. Clearly document the number of critical elements that you have identified. Present clear and detailed free body diagrams of the critical elements. Try to limit the number of critical sections and the number of critical elements that you need to consider by careful logic.

(iv) Determine the state of stress on each critical element. For the fatigue problem, document the mean stress component, the alternating stress component, the maximum stress component, and the minimum stress component acting on each critical element.

(v) Determine the stress concentration factors. Recall that fatigue is caused by time-varying stresses which initiate at a stress raiser, usually at a local surface imperfection such as a machining mark or a notch in the geometry. Therefore, stress concentration effects are important in fatigue failure. As the stresses are cycled, even at levels below the yield strength of the material, the crack propagates reducing its cross-sectional area. Eventually, the area decreases sufficiently to push the stresses beyond the ultimate strength or the yield strength of the material, in which case the part will break or fracture.

(vi) Apply both static failure theories and fatigue failure theories to size the geometry of the shaft. As a minimum, consider the maximum shear stress theory and the Langer line for static failure and consider the modified Goodman line, the Soderberg line, the ASME ellipse, and the Gerber parabola for fatigue failure.

(vii) Select the most appropriate material for the shaft from the Appendices in the book. Specify the material properties and the recommended heat treatment for the shaft.

Part II. Modify the design of the shaft as necessary. For example, redesign a shaft to achieve a static factor of safety of say at least 10 but no greater than 20. Also, redesign the shaft to achieve a fatigue factor of safety of say at least 4 but no greater than 10. The final design of the shaft will require a complete list of the final dimensions of the most important geometrical parameters of the shaft.

Notes:

(i) Since this is an open-ended project then more information may be made available, upon request, to complete a detailed failure analysis and a possible redesign of the shaft. Also, you should include any other suggestions or ideas that would help to improve the analysis and design of the shaft.

(ii) The report must include all of your work, clearly showing and detailing your important results. Detail your iteration procedures, your findings, and include a discussion of the practical significance of your results. Include a copy of your computer program (spreadsheets). Also, include the important design charts and plots, that support your analysis and design, which should clearly show the important data points.