

MEN35101 – Machine Element Design, Fall Term 2020

1st Midterm Exam

October 15, 2020

10:30 am to Noon

1. You must clearly show all work in detail and answers on the answer sheets provided.
2. Since this is an open-book exam, you must state every source taken from the textbook in writing your answer. For example,

“From Figure-A-15-7 of the textbook, $K_t = X.XX$ when $r/d = \dots$ ”

“From Table A-20, the ultimate tensile strength of 1015 CD steel is 340 MPa”.

“From Table 6-2, $a = \dots$ and $b = \dots$ when the shaft has a ground surface.”.

“Using Eq. (6-19), $k_a = \dots$ ”

The shaft shown in the figure is subjected to a force of F and a torque of T . Dimensions are given in millimeters.

- (a) **(20pts)** Draw the bending moment and shear force diagrams of the shaft when $L = 180$ mm and $F = 10$ kN.
- (b) **(20pts)** Suppose that the shaft is made of a ductile material having a yield strength of 210 MPa. When $L = 180$ mm, $F = 10$ kN and $T = 4$ N.m, determine the critical location between **C** and **D**. Is failure predicted at the critical location? If you use one of the failure theories for the answer, explain in detail the reason of your selection of that theory.
- (c) **(30pts)** Now suppose that the shaft is made of a brittle material with a ultimate strength of 150 MPa. When $L = 80$ mm, $F = 10$ kN and $T = 0$ N.m, determine the critical location between **C** and **D**. Is failure predicted at the critical location? What is the factor of safety?
- (d) **(30pts)** Supposing that the shaft is made of an aluminum alloy, find the slope at **A** using the Castigliano's theorem when $L = 180$ mm, $F = 10$ kN and $T = 0$ N.m. (Note: Unless you use the designated theorem, you will get zero for this part regardless of your answer.)

