1. (20%) A shaft made of a 1095 HR steel with machined surfaces rotates at a speed of 1500 rev/min and supports a bending force of $P = 8$ kips, as shown in Fig. P1, where the notch radius is $r = d/5$, and $R_1$ and $R_2$ are the bearing forces. Letting $d = 2$ in. in the first trial, specify a diameter $d$ using a design factor $n_d = 1.6$ for a life of 3 min.

2. (20%) A nonrotating round bar made of a 1095 HR steel undergoes cyclic loading such that $\sigma_{\max} = 70$ kpsi, $\sigma_{\min} = -20$ kpsi at the critical point $C$, as shown in Fig. P1, where the notch radius is $r = d/5$. If $d = 2.5$ in., estimate the number of cycles to a fatigue failure for this round bar using: (a) modified Goodman criterion, (b) Gerber criterion.

3. (20%) A shaft has the properties $S_e = 300$ MPa, $S_y = 490$ MPa, and $S_{ut} = 600$ MPa. The shaft is subjected to an alternating bending stress of 110 MPa, an alternating torsional stress of 80 MPa, and a steady torsional stress of 90 MPa. Find the factor of safety $n_y$ guarding against a static failure.

4. (20%) For the shaft in Problem 3, find the factor of safety $n_f$ guarding against a fatigue failure using (a) modified Goodman criterion, (b) ASME-elliptic criterion, (c) Gerber criterion, (d) Soderberg criterion.

5. (20%) In computing the size factor $k_b$ for a nonrotating round bar in bending with diameter $d$, show that the effective dimension $d_e$ is given by $d_e = 0.370d$. 

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Fig. P1