Shaft optimization tool test case

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Given Loads

$M_{min} = 1000$ lb-in	$T_{min} = 0$
$M_{max} = 5000$ lb-in	$T_{max} = 1800$ lb-in

Material Prop

$S_u = 75$ ksi
$S_y = 50$ ksi
• Surf finish - machined

other sel.

reliability = 99.99%
$D/d = 1.2$
$r/d = .1$ (well rounded)
SF = 1.5

$$M_a = \frac{5000-1000}{2}$$

$$M_a = 2000 \text{ lb-in}$$

$$M_m = \frac{5000+1000}{2}$$

$$M_m = 3000 \text{ lb-in}$$

$$T_a = \frac{1800-0}{2}$$

$$T_a = 900 \text{ lb-in}$$

$$T_m = \frac{1800+0}{2}$$

$$T_m = 900 \text{ lb-in}$$

$S'e = .5 S_u$ (bc $S_u < 200$ ksi)
$S'e = 37.5$ ksi

K_a (Surface factor)
→ machined

so $K_a = 2.7(75\text{ksi})^{-.265}$
$K_a = .85999$

K_b (Size factor)
→ guess
$K_b = .9$ initially

$K_c = K_d = 1$

K_e (reliability factor)
for 99.99%
$K_e = .702$

So: $S_e = K_a K_b K_c K_d K_e S'e$
$= (.85999)(.9)(1)(1)(.702)(37.5\text{ ksi})$
$S_e = 20.374$ ksi

K_f and K_{fs} initial guesses from table bc no d

for $\frac{r}{d} = .1$ $K_f = 1.7$, $K_{fs} = 1.5$

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goodman line

$$d = \left[\frac{16n}{\pi}\left\{\frac{1}{S_e}\sqrt{4(K_f M_a)^2 + 3(K_{fs} T_a)^2} + \frac{1}{S_{ut}}\sqrt{4(K_f M_m)^2 + 3(K_{fs} T_m)^2}\right\}\right]^{1/3}$$

$$d = \left[\frac{16(1.5)}{\pi}\left\{\frac{1}{20374\text{psi}}\sqrt{4(1.7\cdot 2000)^2 + 3(1.5\cdot 900)^2} + \frac{1}{75000\text{psi}}\sqrt{4(1.7\cdot 3000)^2 + 3(1.5\cdot 900)^2}\right\}\right]^{1/3}$$

$$d = \left[7.639\left\{.35293 + .13953\right\}\right]^{1/3}$$

$$d = 1.55529 \text{ in}$$

now go to iteration

find K_b (size factor)

$$K_b = \left(\frac{1.55529\text{ in}}{.3}\right)^{-.107}$$

$K_b = .8385$

finding q, q_s, K_t, K_{ts}

$\frac{r}{d} = .1 \Rightarrow r = .1(1.5553)$

$r = .15553$

$\frac{D}{d} = 1.2$

and using $S_u = 75$

$K_t = 1.6$

$K_{ts} = 1.35$

$q = .82$ (fig 6-26)

$q_s = .86$ (fig 6-27)

$K_f = 1 + q(K_t - 1)$
$= 1 + (.82)(1.6-1)$

$K_{fs} = 1 + q_s(K_{ts} - 1)$
$= 1 + (.86)(1.35-1)$

$K_f = 1.492$

$K_{fs} = 1.301$

new $S_e = K_a K_b \cancel{K_c K_d} K_e S'_e$
$= (.8599)(.8385)(.702)(37.5)$
$S_e = 18.981$ ksi

$$d = \left[\frac{16n}{\pi}\left\{\frac{1}{S_e}\sqrt{4(K_f M_a)^2 + 3(K_{fs} T_a)^2} + \frac{1}{S_{ut}}\sqrt{4(K_f M_m)^2 + 3(K_{fs} T_m)^2}\right\}\right]^{1/3}$$

$$d = \left[\frac{16(1.5)}{\pi}\left\{\frac{1}{18981\text{ psi}}\sqrt{4(1.49 \cdot 2000)^2 + 3(1.301 \cdot 900)^2} + \frac{1}{75000\text{ psi}}\sqrt{4(1.49 \cdot 3000)^2 + 3(1.301 \cdot 900)^2}\right\}\right]^{1/3}$$

$$d = \left[7.639\left\{.33165 + .1222\right\}\right]^{1/3}$$

$\boxed{d = 1.5135\text{ in}}$