Machine Design Homework 4

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[1]:
```python
# Notebook Preamble
import matplotlib.pyplot as plt
import sympy as sp
from IPython.display import display

plt.style.use('maroon_ipynb.mplstyle')
```

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1 Problem 6-1

1.1 Given

A 10-mm steel drill rod was heat treated and ground. The measured hardness was found to be 300 Brinell.

1.2 Find

Estimate the endurance strength in MPa if the rod is used in rotating bending.

1.3 Solution

Eq. 6-10 on p. 305,

$$S_e' = \begin{cases} 0.5S_{ut} & S_{ut} \leq 200\ ksi\ (1400\ MPa) \\ 100 & S_{ut} > 200\ ksi \\ 700\ MPa & S_{ut} > 1400\ MPa \end{cases}$$

The ultimate strength of steel comes from Eq. 2-36,

$$S_{ut} = 3.4H_B$$

[2]:
```
H_B = 300
S_ut = sp.S('3.4')*H_B

if S_ut <= 1400:
    S_e_prime = 0.5*S_ut
else:
    S_e_prime = sp.S(700)

S_e_prime  # ksi
```

[2]: 510.0

This value is not the final value. The relationship for the refined value is,

$$S_e = k_a k_b k_c k_d k_e S_e'$$

The only necessary k values used for this analysis is k_a and k_b, whose equations are at 6-18 and 6-19 respectfully.

[3]:
```
# See Table 6-2
k_a = sp.S('1.38')*S_ut**-(sp.S('0.067'))
d = 10
```

```python
k_b = sp.S('1.24')*d**-(sp.S('0.107'))
# display(k_a, k_b)
S_e = k_a*k_b*S_e_prime
S_e  # MPa
```

[3]: 428.839455736079

2 Problem 6-3

2.1 Given

A steel rotating beam test specimen has an ultimate strength of 120 ksi.

2.2 Find

Estimate the life of the specimen if it is tested at completely reversed stress amplitude of 70 ksi.

2.3 Solution

Find S_e first.

[4]:
```
S_ut = sp.S(120)  # ksi

if S_ut <= 200:
    S_e_prime = 0.5*S_ut
else:
    S_e_prime = sp.S(100)

S_e_prime  # ksi
```

[4]: 60.0

The S_e' value will be used in place of S_e from Figure 6-23 description. We can use the following relationships to determine N.

$$N = \left(\frac{\sigma_{ar}}{a}\right)^{1/b}$$
$$a = \frac{(fS_{ut})^2}{S_e}$$
$$b = -\frac{1}{3}\log\left(\frac{fS_{ut}}{Se}\right)$$

The value of f is 0.82 from Figure 6-23. The S_{ut} value is $2(S_e) = 120$ ksi.

[5]:
```
def log10(x_):
    return sp.log(x_)/sp.log(10)

f = sp.S('0.82')
a = (f*S_ut)**2/S_e_prime
b = -sp.Rational(1, 3)*log10(f*S_ut/S_e_prime)

display(sp.Eq(sp.Symbol('a'), a.n()),
        sp.Eq(sp.Symbol('b'), b.n()))
```

```
sig_ar = 70
N = ((sig_ar/a)**(1/b)).n()
N  # cycles
```

$a = 161.376$

$b = -0.0716146160158993$

[5]:

116192.956004683

3 Problem 6-17

3.1 Given