Problem 1.
The steel AISI 4142, heat treated to a hardness of 450 BHN, is subjected to a cyclic loading at a stress amplitude $\sigma_a$ of 800 MPa. Estimate the life $N_f$ in cycles for mean stress $\sigma_m$ of (a) zero, (b) 200 MPa tension, and (c) 200 MPa compression.

Assume the following material properties:

$$S_u = 1757 \text{ MPa}; \quad \sigma_f = 1937 \text{ MPa}$$

Problem 2.
It is desired to model stress-life characteristics of an ASTM A470-7 (Ni-Cr-Mo-V) steel used shafts in turbine generator units. The model is of the form

$$S = AN_f^b$$

(a) Use the given data on log-log coordinates and obtain the constants $A$ and $b$.
(b) Use linear polynomial fit to log N versus log S (i.e. power relationship between stress amplitude and number of cycles to failure) and obtain $A$ and $b$, the constants for the stress-life fatigue modeling.
(c) Basquin’s equation to relate stress amplitude and reversals to failure is given by

$$S = \sigma_f' \left(2N_f\right)^b$$

where $S$ is the stress amplitude, $\sigma_f'$ is the true fracture strength, $N_f$ is the cycles to failure, $b$ is the fatigue strength exponent (same $b$ as in case(b)). Using the results of (b), estimate the true fracture strength.

<table>
<thead>
<tr>
<th>$\sigma_a$, Stress Amplitude, MPa</th>
<th>Cycles to Failure, $N_f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>711</td>
<td>206</td>
</tr>
<tr>
<td>634</td>
<td>475</td>
</tr>
<tr>
<td>594</td>
<td>1250</td>
</tr>
<tr>
<td>551</td>
<td>3700</td>
</tr>
<tr>
<td>539</td>
<td>6700</td>
</tr>
<tr>
<td>531</td>
<td>15000</td>
</tr>
<tr>
<td>527</td>
<td>54000</td>
</tr>
<tr>
<td>481</td>
<td>202500</td>
</tr>
<tr>
<td>452</td>
<td>618000</td>
</tr>
<tr>
<td>427</td>
<td>116500</td>
</tr>
</tbody>
</table>
Problem 3.

A steel alloy has an ultimate strength of 100 ksi, true fracture strength of 150 ksi, and completely reversed endurance strength of 50 ksi.

A specimen is made of this material is subjected to shot peening. This produces a compressive residual stress of –50 ksi, increases the hardness from 200 to 250 BHN, and increases the surface roughness (AA) to 50 μin.

Estimate the endurance limit for the specimen in the peened condition.

Problem 4.

Four strain amplitudes and the corresponding cyclically stablke stress amplitudes from a test data are given for RQC-100 steel under uniaxial stress.

<table>
<thead>
<tr>
<th>εₐ, strain amplitude</th>
<th>σₐ, stress amplitude, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E-3</td>
<td>472</td>
</tr>
<tr>
<td>4.5E-3</td>
<td>505</td>
</tr>
<tr>
<td>1.0E-2</td>
<td>574</td>
</tr>
<tr>
<td>2.02E-2</td>
<td>632</td>
</tr>
</tbody>
</table>

(a) Evaluate the strength coefficient K’ and strain exponent, n, for cyclic stress-strain curve of the Ramberg-Osgood form. E= 200 GPa.
(b) Plots both fitted curve and the data points on the same graph and compare them.
(c) For this material, monotonic stress-strain relationship is approximated as follows:

\[ \sigma_M = 697 + 1629\varepsilon \]

Plot this curve on the results of (b)
(d) Does this steel cyclically harden or soften? How much does the cyclic loading change the yield strength.
Problem 5.

You are given a RQC-100 steel component subjected to cyclic loads with a strain amplitude $\varepsilon_a=0.002$ and with mean stress $\sigma_m = 100$ MPa. How many cycles can be applied before fatigue cracking is expected. Compare the results for Morrow, Manson-Halford, and Smith-Watson-Topper approaches.

$$E = 200 \text{GPa}, \quad \dot{\sigma}_f = 938 \text{MPa}; \quad \dot{\varepsilon}_f = 1.38$$
$$b = -0.0648; \quad c = -0.704$$

Problem 6.

Compare the two approaches for fatigue life predictions for a zero-to-max ($R=0$) strain loading of 0.0 to 0.005. In the first case use monotonic properties ($K,n$) to model the initial loading and cyclic properties ($K', n'$) on all successive loading cycles. For the second case, use cyclic properties on all loading. Use Manson-Halford approach for fatigue life calculations. Assume the following data:

$$E = 185 \text{GPa}$$
$$\dot{\sigma}_f = 1000 \text{MPa}; \quad \dot{\varepsilon}_f = 0.171$$
$$b = -0.114; \quad c = -0.402$$
$$K' = 1660 \text{MPa}; \quad n' = 0.287$$
$$K = 1210 \text{MPa}; \quad n = 0.193$$