6.52 Estimate the Brinell and Rockwell hardnesses for the following:

(a) The naval brass for which the stress–strain behavior is shown in Figure 6.12.
(b) The steel alloy for which the stress–strain behavior is shown in Figure 6.21.

**Solution**

This problem calls for estimations of Brinell and Rockwell hardnesses.

(a) For the brass specimen, the stress-strain behavior for which is shown in Figure 6.12, the tensile strength is 450 MPa (65,000 psi). From Figure 6.19, the hardness for brass corresponding to this tensile strength is about 125 HB or 70 HRB.

(b) The steel alloy (Figure 6.21) has a tensile strength of about 515 MPa (74,700 psi) [Problem 6.25(d)]. This corresponds to a hardness of about 160 HB or ~90 HRB from the line for steels in Figure 6.19. Alternately, using Equation 6.20a

\[
HB = \frac{TS\text{(MPa)}}{3.45} = \frac{515 \text{ MPa}}{3.45} = 149
\]
Using the data represented in Figure 6.19, specify equations relating tensile strength and Brinell hardness for brass and nodular cast iron, similar to Equations 6.20a and 6.20b for steels.

**Solution**

These equations, for a straight line, are of the form

\[ TS = C + (E)(HB) \]

where \( TS \) is the tensile strength, \( HB \) is the Brinell hardness, and \( C \) and \( E \) are constants, which need to be determined.

One way to solve for \( C \) and \( E \) is analytically—establishing two equations using \( TS \) and \( HB \) data points on the plot, as

\[
\begin{align*}
(TS)_1 &= C + (E)(BH)_1 \\
(TS)_2 &= C + (E)(BH)_2
\end{align*}
\]

Solving for \( E \) from these two expressions yields

\[ E = \frac{(TS)_1 - (TS)_2}{(HB)_2 - (HB)_1} \]

For nodular cast iron, if we make the arbitrary choice of \((HB)_1\) and \((HB)_2\) as 200 and 300, respectively, then, from Figure 6.19, \((TS)_1\) and \((TS)_2\) take on values of 600 MPa (87,000 psi) and 1100 MPa (160,000 psi), respectively.

Substituting these values into the above expression and solving for \( E \) gives

\[ E = \frac{600 \text{ MPa} - 1100 \text{ MPa}}{200 \text{ HB} - 300 \text{ HB}} = 5.0 \text{ MPa/ HB (730 psi/HB)} \]

Now, solving for \( C \) yields

\[ C = (TS)_1 - (E)(BH)_1 \]

\[ = 600 \text{ MPa} - (5.0 \text{ MPa/ HB})(200 \text{ HB}) = -400 \text{ MPa (59,000 psi)} \]

Thus, for nodular cast iron, these two equations take the form

\[ TS(\text{MPa}) = -400 + 5.0 \times \text{HB} \]
\[ TS(\text{psi}) = -59,000 + 730 \times \text{HB} \]

Now for brass, we take \((\text{HB})_1\) and \((\text{HB})_2\) as 100 and 200, respectively, then, from Figure 7.31, \((TS)_1\) and \((TS)_2\) take on values of 370 MPa (54,000 psi) and 660 MPa (95,000 psi), respectively. Substituting these values into the above expression and solving for \(E\) gives

\[
E = \frac{370 \text{ MPa} - 660 \text{ MPa}}{100 \text{ HB} - 200 \text{ HB}} = 2.9 \text{ MPa/HB} \quad (410 \text{ psi/HB})
\]

Now, solving for \(C\) yields

\[
C = (TS)_1 - (E)(\text{BH})_1
\]

\[
= 370 \text{ MPa} - (2.9 \text{ MPa/HB})(100 \text{ HB}) = 80 \text{ MPa} \quad (13,000 \text{ psi})
\]

Thus, for brass these two equations take the form

\[ TS(\text{MPa}) = 80 + 2.9 \times \text{HB} \]

\[ TS(\text{psi}) = 13,000 + 410 \times \text{HB} \]
Variability of Material Properties

6.54 Cite five factors that lead to scatter in measured material properties.

Solution

The five factors that lead to scatter in measured material properties are the following: (1) test method; (2) variation in specimen fabrication procedure; (3) operator bias; (4) apparatus calibration; and (5) material inhomogeneities and/or compositional differences.
6.55 Below are tabulated a number of Rockwell B hardness values that were measured on a single steel specimen. Compute average and standard deviation hardness values.

<table>
<thead>
<tr>
<th>HRB1</th>
<th>HRB2</th>
<th>HRB3</th>
</tr>
</thead>
<tbody>
<tr>
<td>83.3</td>
<td>80.7</td>
<td>86.4</td>
</tr>
<tr>
<td>88.3</td>
<td>84.7</td>
<td>85.2</td>
</tr>
<tr>
<td>82.8</td>
<td>87.8</td>
<td>86.9</td>
</tr>
<tr>
<td>86.2</td>
<td>83.5</td>
<td>84.4</td>
</tr>
<tr>
<td>87.2</td>
<td>85.5</td>
<td>86.3</td>
</tr>
</tbody>
</table>

Solution

The average of the given hardness values is calculated using Equation 6.21 as

\[
HRB = \frac{\sum_{i=1}^{15} HRB_i}{15}
\]

\[
= \frac{83.3 + 88.3 + 82.8 + \ldots + 86.3}{15} = 85.3
\]

And we compute the standard deviation using Equation 6.22 as follows:

\[
s = \sqrt{\frac{\sum_{i=1}^{15} (HRB_i - HRB)^2}{15 - 1}}
\]

\[
= \sqrt{\frac{(83.3 - 85.3)^2 + (88.3 - 85.3)^2 + \ldots + (86.3 - 85.3)^2}{14}}
\]

\[
= \sqrt{\frac{60.31}{14}} = 2.08
\]