CEE 300 / TAM 324: Lab 2 Compression and Hardness Worksheet

Lab section: Student name:

General note: use space as needed. The answer length is not suggested by the space.

Q1 (8 pts). Construct an engineering stress–strain curve for each of the materials tested. Note: Convention: Negative stress/strain is compressive. Be careful of how you label your axes and caption the figures.

Show sample calculations where applicable.

Answers:

Cast Iron:

Figure 1: Engineering Stress vs. Strain Diagram for Gray Cast Iron, in Compression with 0.2% Offset Line and Yield Point

Figure 2: Elastic Region of Engineering Stress vs. Strain Diagram for Gray Cast Iron, in Compression with 0.2% Offset Line and Yield Point

1018CR Steel:

Figure 3: Engineering Stress vs. Strain Diagram for 1018 Cold Rolled Steel in Compression with 0.2% Offset Line and Yield Point

1045 NM Steel:

Figure 4: Engineering Stress vs. Strain Diagram for 1045 Normalized Steel in Compression with 0.2% Offset Line and Yield Point

Figure 5: Elastic Region of Engineering Stress vs. Strain Diagram for 1045 Normalized Steel in Compression with 0.2% Offset Line and Yield Point

7075 Aluminum:

Figure 6: Engineering Stress vs. Strain Diagram for 7075 Aluminum in Compression with 0.2% Offset Line and Yield Point

PMMA:

Figure 7: Engineering Stress vs. Strain Diagram for Polymethyl Methacrylate in Compression with 0.2% Offset Line and Yield Point

Figure 8: Elastic Region of Engineering Stress vs. Strain Diagram for Polymethyl Methacrylate in Compression with 0.2% Offset Line and Yield Point

Brief discussion of results and trends:

The 1018 Cold Rolled Steel had the largest modulus of elasticity, being the least elastic, and PMMA had the smallest modulus of elasticity, being the most elastic. The 1045 Cold Rolled Steel and 7075 Aluminum Alloy had the second and third largest modulus of elasticity, respectively. This is consistent with the tension tests which found that the most elastic material was the PMMA followed by the aluminum, with the steel being least elastic.

The ultimate strength could not be compared because for the metals, we had to stop the test before it reached its ultimate strength in order to avoid potentially damaging the equipment.

Q2 (5 pts). From the stress–strain curve of each material, compute: (a) the modulus of elasticity E, (b) the yield strength  y , and (c) the ultimate strength  u in compression. Graphs in Q1 should indicate clearly the methods used to determine these values. Complete Table 1.

Begin filling out Table 4 (in Q5).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measurement or property | | |  | Material | | |  |  |
| Quantity | | Symbol | Units | Cast iron | 1018 CR Steel | 1045 NM Steel | 7075 Alum | PMMA |
|  |  | | Initial data | | | |  |  |
| Diameter | | d0 | mm | 12.98 | 12.66 | 12.61 | 12.66 | 19.16 |
| Cross-sectional area | | A0 | mm2 | 132.3242 | 125.88 | 124.89 | 125.88 | 288.32 |
| Gage length | | l0 | mm | 39.95 | 40.03 | 39.98 | 39.98 | 65.05 |
|  |  | | Strength | | | |  |  |
| Yield load | | Py | kN | 549.92 | 569.80 | 462.64 | 489.50 |  |
| Max. load | | Pmax | kN | 757.99 | 692.2 | 800.72 | 519.94 | 133.84 |
| Reason for stopping test | | — | — | N/A | Instructed to stop the test at a load limit | Instructed to stop the test at a load limit | could not apply sufficient force to continue | Blew up |
| Description of fracture surface and final shape | | — | — | Not Stated | Buckling | Buckling | Significant Buckling | Shattered |
|  |  | | Hardness-Rockwell B (1/16’’ ball, 100 kgf) | | | |  |  |
| Average observed hardness readings (uncorrected for  curvature) | | HRB | — | 98.4 | 92.6 | 92.4 | 85.8 |  |
| Correction for curvature\* | | HRB | — | 1.58 | 1.87 | 1.88 | 2.21 |  |
| Rockwell hardness | | HRB | — | 100.0 | 94.5 | 94.5 | 88.0 |  |
| Brinell hardness (converted) | | HB | kgf/ mm2 | 240 | 205.5 | 205.5 | 175 |  |

Table 1—Compression and hardness data

\* For the Rockwell B scale, if the specimen diameter is 0.5 in. (13 mm), the correction (which is to be added to the observed Rockwell B reading) is given by the linear relationship (adapted from Wilson conversion chart):

Correction = 6.5 - 0.05 \* HRBuncorrected

For example, if the observed Rockwell B hardness reading is 80 HRB on the cylindrical surface of a 0.5 in. dia. specimen, the curvature correction is equal to +2.5 HRB, and thus the corrected Rockwell B number is 82.5 HRB. The value of the curvature correction is rounded to the nearest multiple of 0.5.

Q3 (5 pt). Construct a true stress–strain diagram for 1045 NM steel in compression and overlay it on the engineering stress–strain curve.

Diagram overlay:

Figure 9: Overlay of Engineering Stress and Engineering Strain plot with True Stress and True Strain Plot for 1045 Normalized Steel

Q4 (4 pts). For hardness tests, calculate the average hardness value for steel and aluminum based on the entire section’s data provided on MTIL website. Convert measured Rockwell hardness numbers to Brinell hardness numbers, using the conversion chart in Table 5 of your lab manual, and compare with measured Brinell hardness numbers for the two materials tested by both hardness methods. Complete Table 3.

Table 2—Comparative hardness data (lab section average)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Measurement or property | | | Material | |
| Quantity | Symbol | Units | 4340 Steel | 7075 Al |
| Hardness—Brinell (ball diameter D = 10 mm; indenter load = 3000 kg) | | | | |
| Brinell hardness number | HB | kgf /mm2 | 694.7 | 186.7 |
| Hardness—Rockwell B and C | | | | |
| Rockwell B hardness number | HRB | — | 122.26 | 95.5 |
| Rockwell C hardness number | HRC | — | 61.98 | 14.56 |
| Brinell hardness (converted from Rockwell B or C hardness) | | | | |
| Converted Brinell hardness number | HB | kgf /mm2 | From C: 658  B is out of range | From C: 195.5  From B: 214.1 |

Discussion:

Q5 (2 pts). Complete Table 3 below. Transfer tensile test data from Table 1 of your Lab 1 worksheet.

Table 3—Summary of results

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mechanical property | | |  | Material | | |  |  |
| Quantity | | Symbol | Units | Cast iron | 1018 steel | 1045 N Steel | 7075 Al | PMMA |
|  |  | | Tensile properties (from Tensile Test Lab) | | | |  |  |
| Young’s modulus | | E | GPa | 120.28 | 184.16 | 207.02 | 65.93 | 3.26 |
| Yield strength | |  y | MPa |  | 574.4 | 462.65 | 509.87 |  |
| Ultimate strength | |  u | MPa | 378.98 | 601.92 | 800.72 | 564.78 | 79.38 |
| Percent elongation | | %EL | — | 0.93 | 0.92 | 4.64 | 17.22 | 8.04 |
| Shape changes during deformation | | — | — | Not Stated | Necking | Necking | Necking | None |
| Nature of fracture surface | | — | — | Not Stated | Cup & Cone | Cup & Cone | Cup & Cone | Flat |
| Rockwell (corrected for curvature) | | HRB |  | 103.5 | 95.5 | 98.5 | 89.0 |  |
| Brinell (converted) | | HB |  | 264 | 214.1 | 230.8 | 177.8 |  |
|  |  | | Compression properties | | | |  |  |
| Young’s modulus | | E | GPa | 140.98 | 213.4 | 207.93 | 74.58 | 2.73 |
| Yield strength | |  y | MPa | 549.92 | 569.8 | 462.6 | 489.5 |  |
| Ultimate strength | |  u | MPa | 758 | 692.2 | 800.72 | 519.94 | 133.84 |
| Shape changes during deformation | | — | — | Not Stated | Buckling | Buckling | Buckling | Considerable Buckling |
| Nature of fracture surface | | — | — | Unknown | Did not fracture | Did not fracture | Did not fracture | Small pieces everywhere |
| Rockwell (corrected for curvature) | | HRB |  | 100.0 | 94.5 | 94.5 | 88.0 |  |
| Brinell (converted) | | HB |  | 240 | 205.5 | 205.5 | 175 |  |
| Brinell—SI force units | | p = 9.81m/s2 × HB | MPa |  |  |  |  |  |

Q6 (6 pts). Using the data in Table 3, construct a plot of yield strength  y as a function of

Brinell hardness HB. Convert Rockwell hardness values to Brinell hardness values to include on the plot and plot the yield values from both the tensile and compressive tests with the associated Brinell hardness values. Explain any results that do not follow expected trends.

Answer:

Figure 10: Yield Strength, σy, and Brinell Hardness HB Compared for 7075 Aluminum in Tension and Compression, 1018 Cold-Rolled Steel in Tension and Compression, 1045 Normalized Steel in Tension and Compression, and Gray Cast Iron in Compression Only

Upon applying a linear curve fit to the data, the data do not show a linear statistic relationship between hardness using the Brinell scale and yield strength. (R2 = 0.0335)