1.103 CIVIL ENGINEERING MATERIALS LABORATORY (1-2-3)

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LABORATORY ASSIGNMENT NUMBER 10

PROPERTIES OF HEAT TREATED STEEL

Purpose: You will learn about:

(1) Measurement of the surface hardness
(2) Measurement of Charpy toughness
(3) How to heat treat steel
(4) Effects of heat treatment of high carbon steel

Organization:

- Meeting A 15 minute *Group* meeting to watch austenitizing
- Meeting B 15 minute Sub-*Group* (unscheduled) to prepare specimens
- Meeting C 45 minute *Group* meeting to measure hardness and toughness
- Meeting C 45 minute Sub-Group meeting to measure tensile properties
- Data Will be posted immediately after each lab.

Reading:

- Read this handout and know what you will be doing in the lab
- Read ASTM E18 *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*
- Read ASTM E23 *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

Overview:

For this laboratory we are going to investigate how the properties of steel change as a result of heat treatment. We will measure the tensile stress strain strength curve as in the second and third labs, the hardness of the steel, and the toughness.

We will be testing type 4130 steel which is a high carbon alloy steel commonly called tool steel. The original specimens are cold formed. We will harden the specimens by heating them to 1585°F (the austenitizing temperature) and then very rapidly cool (quenching) in an oil bath. This 'as quenched' state contains very high internal stresses resulting in a hard and brittle behavior. We will then take several of the quenched specimens and perform further heat treatment (temper) to reduce the internal stresses and the brittleness. One set of specimens will be tempered to 450°F, one set to 850°F, and one to 1200°F. You can see in the attached figure how this tempering changes the mechanical behavior.

In an effort to increase your involvement in the laboratory, you will be partly responsible for heat treating the specimens. Heat treating takes several days to perform so you will be preparing the specimens during the week of the consolidation lab. Austenitizing is the first step and we will watch the oil quenching from 1585^{o}F during the *Group* meeting. The specimens will then be stored at 350 ^{o}F until they are tempered. The oven will be set to the three tempering temperatures according to the following schedule.

Temperature	*Day*	*Date*
850^{o}F	Thursday	29th
1200^{o}F	Friday	30th
450^{o}F	Monday	3rd
850^{o}F	Tuesday	4th

Each Sub Group will be testing specimens at three conditions according to the following schedule.

Sub Group	*A1*	*A2*	*B1*	*B2*
Quenched	yes	yes	yes	
450^{o}F		yes		yes
850^{o}F	yes		yes	
1200^{o}F		yes		yes
Untreated	yes		yes	yes

It is your responsibility to temper your specimens in time for the *Group* meeting to measure hardness and toughness. Tempering requires you to put the specimens in the oven, heat them for at least 2 hours, and remove them from the oven. All this will be done in the machine shop between the hours of 9 and 4. During the first part of the testing lab sessions you will need to clean the surface of the specimens. The hardness and toughness testing will be done in the mechanical engineering undergraduate lab during the end of the *Group* meeting at 4:30. The tensile testing will be done in the usual Sub Group time slots.

Procedure for Tension Tests:

<u>*Preparation:*</u>

- Set up the data acquisition system and record on the data sheet the channel numbers, the transducers and the calibration factors. Check to be sure that everything is working correctly.
- Number the specimens and be careful not to mix up the specimens because they all look about the same.
- Measure the diameter and specimen gauge length of each specimen. The gage length is measured to the base of the taper.
- Determine the gauge length of the extensometer with the caliper. The gauge length should be measured with the locking pin in position. Record the output voltage corresponding to the gauge length.

<u>*For Each Specimen*</u>

- Zero load cell.
- Screw the specimen into the grip.

- Put the bottom grip into the crossbar adapter and lock in place load pin.
- Slowly raise the actuator to insert the top grip into the upper adapter and lock in place with the pin. Be sure the load cell still reads the correct zero value.
- Attach the extensometer to the specimen such that the gauge is in the mid-point of the specimen.
- Adjust the extensometer such that the output is close to the value corresponding to the gauge length.
- Apply a small seating load by lowering the actuator (20 kN).
- Record starting value of displacement transducer that measures the actuator displacement.
- Start the data acquisition system with 1 sec. reading rate. Be sure to specify a large enough data file. Remember you can BYPASS data storage and change reading rate anytime during the test to maintain a manageable data size.
- Deform the specimen at about 0.05 cm/min.
- Once the specimen yields (based on the shape of the load versus displacement curve) increase the displacement rate.
- After the specimen fails, measure the diameter at the point of failure and the final gauge length.

Calculations:

Tensile Stress, σ , is the force measured by the load cell divided by the initial cross sectional area. Note that this is the nominal stress and that the actual stress is much larger because the area reduces during the test. For each specimen compute the final stress using the measured area after failure.

Specimen Strain, ε , is the extensometer deformation divided by the extensometer gauge length. This is best estimate of the engineering strain.

Apparent Strain, ε_a , is the actuator displacement divided by the specimen gauge length. This value ignores the apparatus deformations and can be seriously in error.

Young's Modulus, **E** , is the slope of the linear regression line through the data up to the proportional limit.

Proportional Limit, σ_p , is the stress at which the stress strain relationship deviates from linearity (this requires a somewhat subjective determination).

Yield Stress, σ_y , is the stress at which the material begins to undergo significant deformation without much change in stress (depending on the particulars of the stress strain behavior this can also be rather subjective).

Strain Rate, ε , is the change in strain per hour. For class you should compute this incrementally from the extensometer strain and the time. If you do the calculation between each data point you will introduce a lot of noise due to the closeness of the reading in time. Therefore, try doing the computation between three data points and assigning the rate to the middle strain value.

Report:

The report should contain the following items.

- A graph of the stress strain curve showing the extensometer measurements for each specimen.
- A graph of the tensile strength as a function of treating temperature.
- A graph of the Rockwell hardness and Charpy absorbed energy as a function of treating temperature.
- A summary table of the elastic modulus, proportional limit, yield stress, tensile strength, elongation, and area reduction for each material.
- Add to this table the Rockwell hardness, the absorbed energy from the Charpy test, the lateral expansion from the Charpy test.
- A sketch of the failure geometry and note any significant observations.
- One set of example calculations (one measurement point).
- The data sheets.
- One page of computer calculations and raw data.

1.103 CIVIL ENGINEERING MATERIALS LABORATORY (2-1-3)

TENSILE TESTING AND STRESS STRAIN PROPERTIES OF MATERIALS

DATA SHEET

DATE _____ All dimensions in _____ Group No. ___________ Date _______

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Device	Force	Actuator Disp.	Extensometer
Calibration. Factor	____________	____________	____________
DAQ Channel	____________	____________	____________
Input Voltage	____________	____________	____________

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Material Type ________ Gage Length ________ File Name ____________

Diameter _________ , _________ , _________ , _________ = ________________

Zero Load ________ Zero Actuator Disp. _________ Zero Extensometer ___________

Diameter of Neck ____________ Final Length ________________

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Material Type ________ Gage Length ________ File Name ____________

Diameter _________ , _________ , _________ , _________ = ________________

Zero Load ________ Zero Actuator Disp. _________ Zero Extensometer ___________

Diameter of Neck ____________ Final Length ________________

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Material Type ________ Gage Length ________ File Name ____________

Diameter _________ , _________ , _________ , _________ = ________________

Zero Load ________ Zero Actuator Disp. _________ Zero Extensometer ___________

Diameter of Neck ____________ Final Length ________________

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Material Type ________ Gage Length ________ File Name ____________

Diameter _________ , _________ , _________ , _________ = ________________

Zero Load ________ Zero Actuator Disp. _________ Zero Extensometer ___________

Diameter of Neck ____________ Final Length ________________

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Material Type ________ Gage Length ________ File Name ____________

Diameter _________ , _________ , _________ , _________ = ________________

Zero Load ________ Zero Actuator Disp. _________ Zero Extensometer ___________

Diameter of Neck ____________ Final Length ________________

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