Engineering & Instrumentation

CCLRC Rutherford Appleton Laboratory
Chilton Didcot
Oxfordshire OX11 0QX
UK
Tel +44 (0)1235 821900

Density Measurements of Carbon Steel Sample

Prepared by S.J. Robertson

For T.J. Durkin, PPD.

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1. INTRODUCTION.

A sample of a carbon steel was supplied by Tim Durkin with a request to measure the density of the material as accurately as possible. I accomplished this using Archimedes' Principle and repeated the test 10 times to obtain statistical data on the repeatability of the measurement. This report describes the measurement process and reports the results.

2. METHOD.

I used a Stanton CL4D 4-place balance, calibrated 19 August 2004, throughout the test. This balance has a suspension system for density measurements.

I prepared the sample by ultrasonically cleaning it in a detergent solution for 15 minutes to remove any dirt or grease. I washed the sample in running mains water with gentle rubbing, finally rinsed it in demineralised water and dried it by dabbing using a lint-free tissue. I used AR quality water for the test and degassed it by vacuum prior to use. I used copper wire to suspend the sample in water, shaped to fit round the specimen prior to measurement. The method was as follows:

- Suspend wire on hook and weigh (Fig.1(a)).
- Immerse wire in water (to same depth it would have when holding sample) and weigh (Fig.1(b)).
- Remove wire from water, dry and weigh again.
- Suspend dry sample on wire and weigh (Fig.1(c)).
- Immerse sample & wire in water and weigh again (Fig.1(d)).
- Remove sample and dry.
- Record temperature of water.

I calculated the density of the sample as follows:

$$\rho_s = \frac{\left(m^d_{w+s} - \overline{m^d_w}\right)\rho_{H_2O}}{\left(m^d_{w+s} - \overline{m^d_w}\right) - \left(m^{H_2O}_{w+s} - m^{H_2O}_w\right)}$$

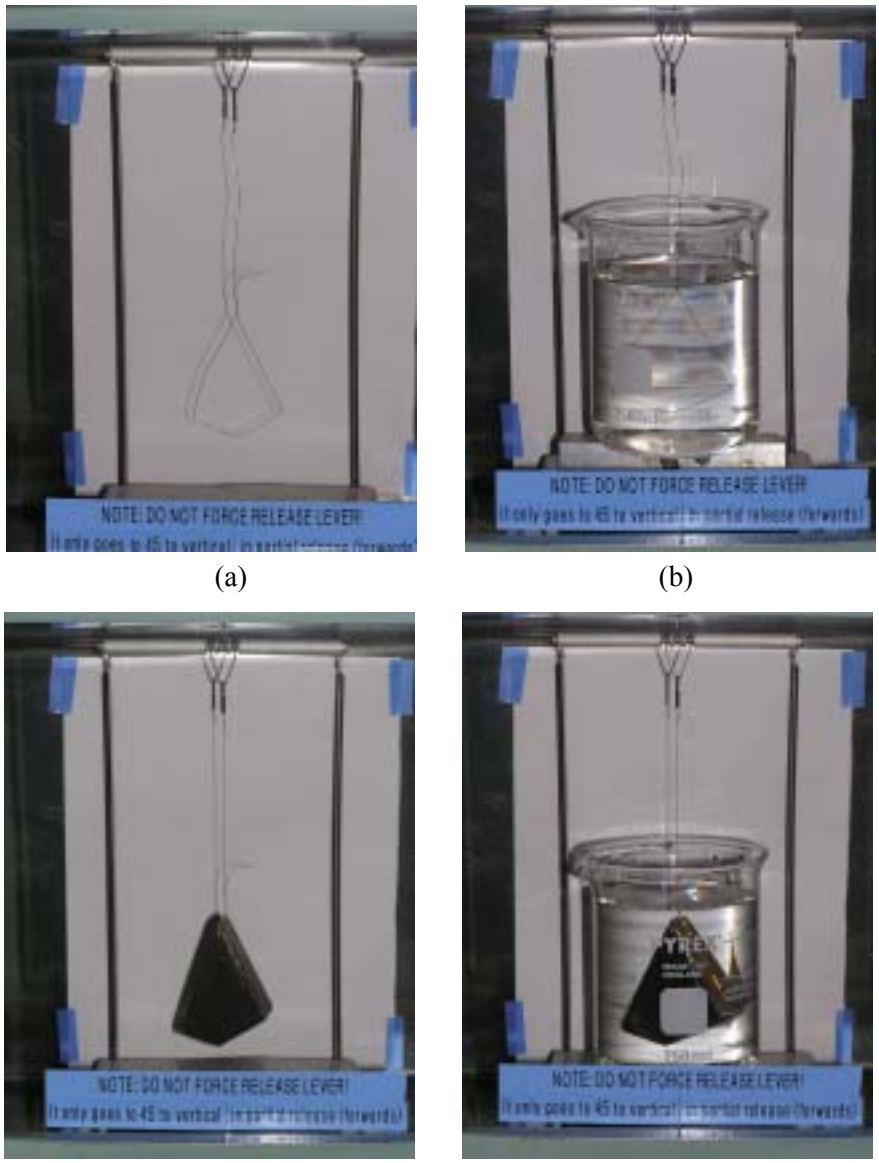
where: ρ_s = Density of sample in gcm^{-3}
m^d_{w+s} = weight mass of wire & sample in g
m^d_w = weight mass of wire in g
ρ_{H2O} = density of water in gcm^{-3}
m^{H2O}_{w+s} = weight of wire & sample in water in g

The data for the density of water was taken from the Handbook of Chemistry & Physics 57th Ed. F11. I fitted a polynomial curve through the data points to obtain intermediate values:

$$\rho_{H_2O} = 4\times10^{-8}T^3 - 8\times10^{-6}T^2 + 6\times10^{-5}T + 0.9999$$

where T = temperature in ^oC.

I carried out the density measurement 10 times in order to obtain statistical data on the repeatability of the test.



(a) (b)

(c) (d)

Figure 1. Photographs of Measuring Sequence.

3. RESULTS.

The results of the 10 measurements are shown in Figure 2. Since the density of any material is dependent on the temperature, the temperature recorded at the time is displayed on a second axis. As can be seen, the temperature effect is negligible. The results are all very consistent, giving a final density of:

$$\text{Density of Steel} = 7.833 \pm 0.003 \text{ gcm}^{-3} \quad (3\sigma \text{ SD}).$$

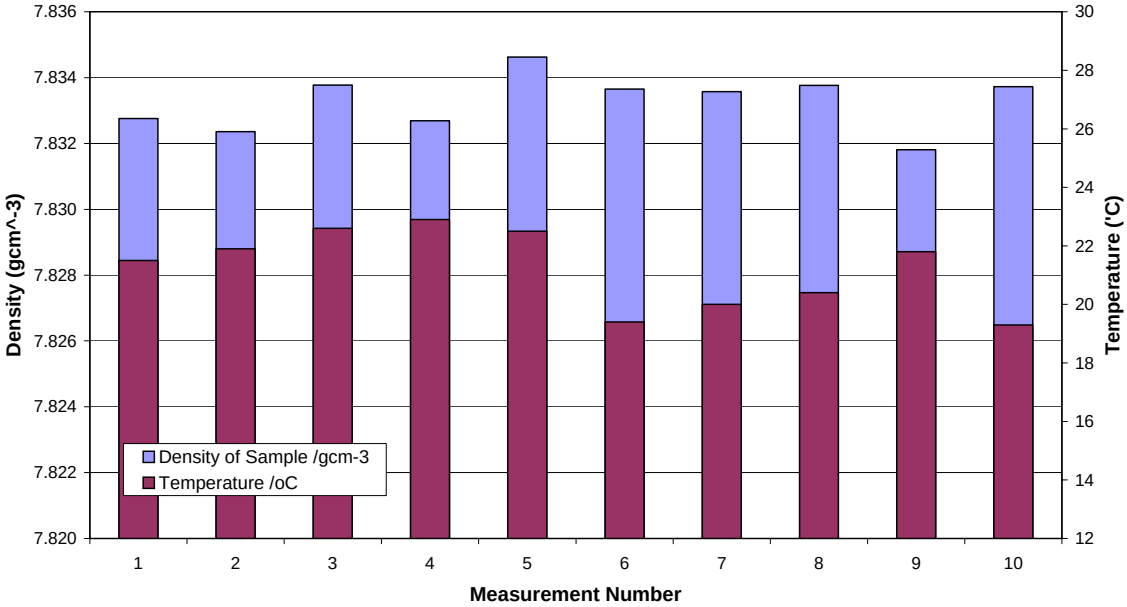


Figure 2. Density Measurements of Steel Sample.