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MMT007 – Precision and Repeatability of the Hardness, Strength and Ductility Tester (HSD)

The Hardness, Strength, and Ductility (HSD) Tester is a nondestructive tool for evaluating the tensile strength properties of metallic materials. This document summarizes the precision and repeatability of the instrument, with respect to the prediction of the yield strength and ultimate tensile strength (UTS). Yield strength is a measure the elastic limit or onset of plasticity for a metallic material, whereas the UTS is a measure of the maximum flow stress prior to the onset of necking in a laboratory tensile test. Precision is defined as the difference between HSD Tester predictions and tensile test measurements for the same metallic material. Repeatability is the ability of the HSD Tester to produce the same measurements on the same sample over time.

1.1 Precision

The precision of tensile strength determination is dependent on the type of metallic material tested (e.g. steel or aluminum), and whether the metallic specimen is homogeneous or heterogeneous (e.g. flat plate or seam-welded pipe). Massachusetts Materials Technologies (MMT) LLC has tested the precision of the HSD Tester by comparing the tensile strength predictions of the HSD Tester with laboratory tensile tests measurements. Any comparison of the HSD Tester measurements should also consider the inherent variability of tensile testing. ASTM E8 states that the standard deviation of inter-laboratory tensile testing of a stainless steel exhibits a coefficient of variation of up to 4.06%, or a standard deviation of 2.83 ksi (19.5 MPa). MMT has tested 24 homogeneous steel materials consisting of flat plates and seamless pipes. A unity plot comparing the HSD Tester 0.5% elongation under load (EUL) yield strength and tensile test measurement is shown in Fig. 1. Comparing the percent error between HSD Tester and tensile test measurements, we find a mean absolute error of 4.3%. MMT has tested 74 pipeline steel materials consisting of heterogeneous seam-welded pipes (ERW, DSAW, flash) and homogeneous seamless pipes. Applying multivariable regression predictions with the HSD Tester, surface replica and surface chemistry, the mean absolute error between HSD Tester measurements and tensile test measurements is 5.1% and 4.0% for the 0.5% elongation under load (EUL) yield strength and ultimate tensile strength (UTS), respectively. The unity plot comparing the 0.5% EUL yield strength and ultimate tensile strength of HSD Tester and tensile testing for all 74 pipes is shown in Fig. 2.

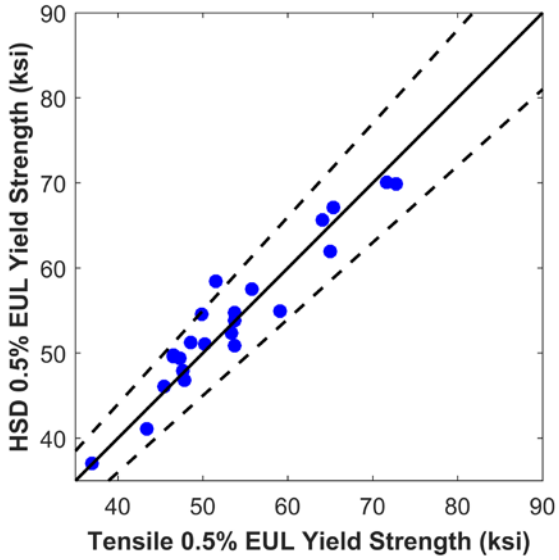

FIG 1: Results for 24 homogeneous steel materials comparing the HSD Tester 0.5% EUL Yield Strength and tensile test measurements. The solid line indicates perfect correlation, and the dashed line indicates +/- 10% of the tensile measurement.

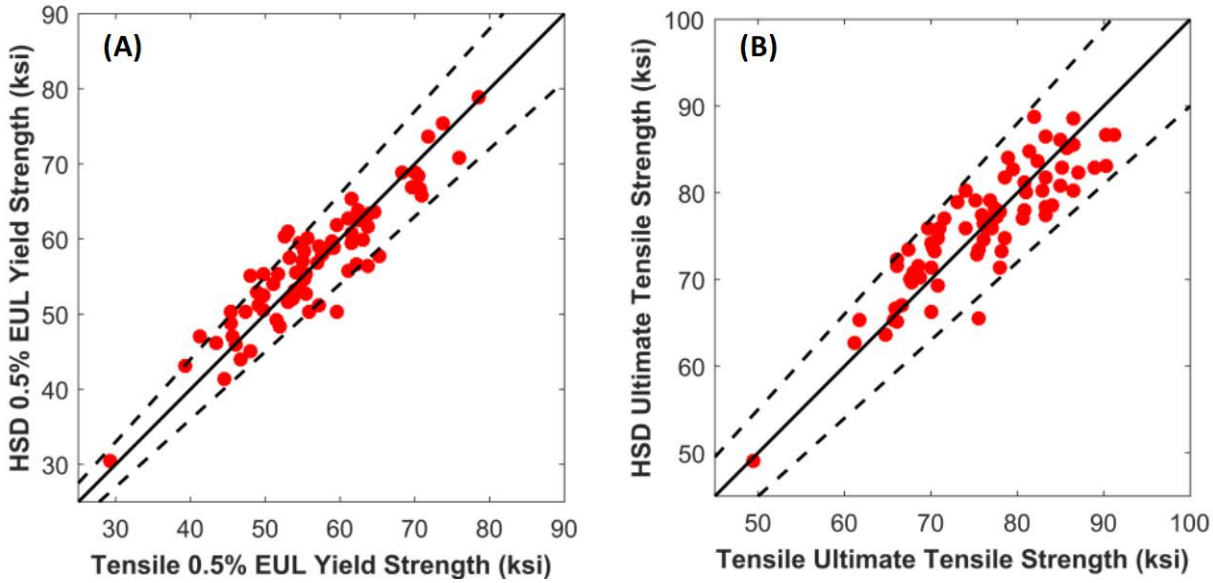

FIG 2: (A) Results for 74 pipeline steel materials comparing the HSD Tester 0.5% EUL Yield strength and tensile test measurements. (B) Results for the same 74 pipes comparing the HSD Tester ultimate tensile strength and tensile test measurements. The solid line indicates perfect correlation, and the dashed line indicates +/- 10% of the tensile test measurement.

1.2 Repeatability

The repeatability of scratch hardness testing results is dependent on the type of metallic material tested (e.g. steel or aluminum), testing conditions (e.g. lubricated or unlubricated), and adequate completion of the surface preparation procedure. Fig. 3 provides examples of the repeatability of tensile strength

predictions for four homogeneous steel materials of varying grade and composition which have been tested 10 or more times.

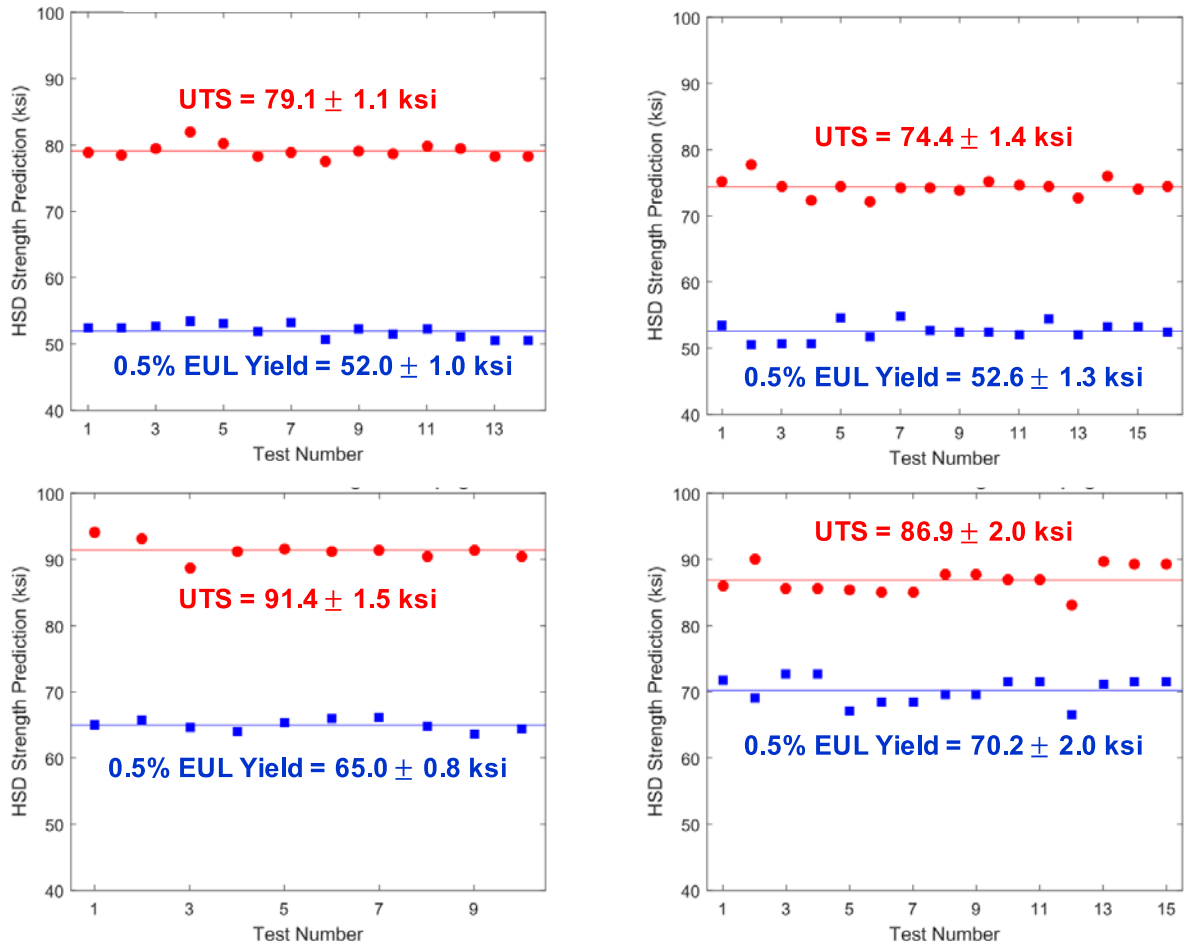

FIG 3: Repeatability of tensile strength property predictions for four different homogeneous steel plate materials. The mean and standard deviation of the material 0.5% EUL yield strength and ultimate tensile strength (UTS) for the tests shown are also shown.

2. Referenced Documents

ASTM E8 / E8M-16a, Standard Test Methods for Tension Testing of Metallic Materials, ASTM International, West Conshohocken, PA, 2016, www.astm.org