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Tom Siewert
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Tom Siewert
Ray Santoyo
Materials ReliabilityDivision
Materials Science and Engineering Laboratory

Jolene Splett
Statistical Engineering Division
Information Technology Laboratory

National Institute of Standards and Technology
Boulder, Colorado 80305

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Evaluation Specimens for Izod Impact Machines (SRM 2115): Report of Analysis

Tom Siewert,* Jolene Splett, † and Ray Santoyo*

National Institute of Standards and Technology
325 Broadway
Boulder, CO 80305 USA

In the past few years, we have received a number of requests to verify the performance of Izod impact machines, similar to what we offer for Charpy impact machines. Although there are similarities between Izod and Charpy impact testing, there are some notable differences that needed to be examined, including test temperature (the Izod configuration precludes cooling), specimen orientation, and specimen length. This report describes the development of a final Izod specimen design and test procedure, that produced a suitable mean energy and a coefficient of variation similar to what is found in the Charpy program.

Keywords: impact test; Izod impact; standard reference materials

1. Introduction

ASTM Standard E23 "Standard Test Methods for Notched Bar Impact Testing of Metallic Materials" (Ref. 1) describes procedures for pendulum impact testing in both Charpy and Izod configurations. It is most commonly used with the Charpy specimen configurations, and most users are familiar with verification procedures. However, Standard E23 offers no guidelines for verification of Izod machine performance by test specimens. In fact, there are no known sources for Izod verification specimens from any National Measurement Institute around the world. This report describes the development of such specimens in two steps: (1) investigation of the effects of the differences between the Izod and Charpy configurations, and (2) characterization of the Izod specimens to a degree where they could be used to verify the performance of Izod impact machines.

*Materials Reliability Division
Materials Science and Engineering Laboratory
†Statistical Engineering Division
Information Technology Laboratory

Figure 1 shows a Charpy impact specimen (on the left) and an Izod specimen (on the right). Both specimens have an identical cross section (10 mm by 10 mm) and an identical V notch (located 27.5 mm from one end for Charpy specimens and 28 mm from one end for Izod specimens). Figure 1 also shows a substantial difference in their overall length (55 mm for Charpy and 75 mm for Izod) due to the end clamp design of the Izod configuration.

NIST offers Charpy impact specimens in a variety of energies (from near 15 J to 200 J) that are designed to span the capacity range of most impact machines. For the initial evaluation of Izod machines, we decided to start with a single energy range, and selected the material used in the low-energy range for Charpy machines (SRM 2092). The material is heat treated to the highest strength, so it has a high resistance to fracture but for only a short period of time (Ref. 2), which produces a fairly low absorbed energy value, near 15 J on a Charpy machine. As the force must be counterbalanced by the machine, this sharp blow also translates to a quick shock load to the machine anvil and striker, an effective, yet simple evaluation of the quality of the machine and its mounts. However, the Izod test procedure requires aligning and clamping the specimen in an Izod vise (a relatively slow process), and so this necessitates testing at room temperature, instead of the –40 °C temperature used for the SRM 2092 Charpy procedure. This upward shift in temperature was expected to raise the absorbed energy slightly, and is one example of the procedural changes that needed to be evaluated.

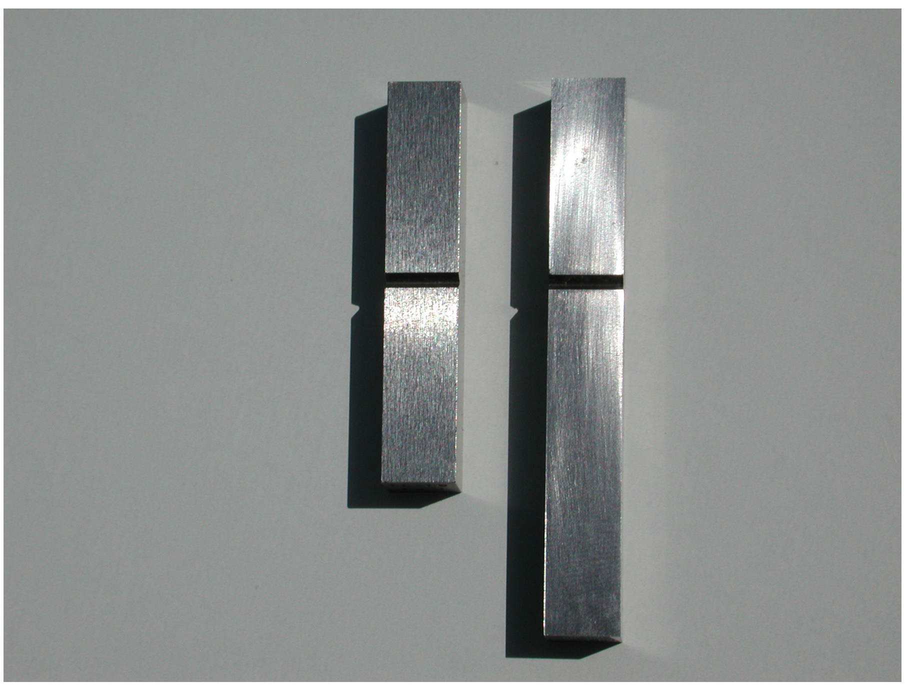

Figure 1. Photograph comparing a Charpy specimen (left) and Izod specimen (right).

2. Experimental Design and Analysis

A group of Izod specimens was machined and heat treated along with one of our standard batches of low-energy Charpy reference specimens (LL104), using the same shop and steel. The specimens were all tested at the same time, in the NIST Charpy reference laboratory by the same technician. Standard Charpy specimens will fit in an Izod machine, but not vice versa. Thus, we decided to test all feasible combinations of specimens and machines to validate the Izod results. Data were collected *at room temperature* for the two kinds of specimens, Izod and Charpy, as follows.

1. A NIST Charpy reference machine was used to test five Charpy specimens. (Charpy/Charpy)
2. A NIST Izod machine was used to test five Charpy specimens. (Izod1/Charpy)
3. A NIST Izod machine was used to test 25 Izod specimens. (Izod1/Izod)
4. An *external* Izod machine was used to test 10 Izod specimens. (Izod2/Izod)

The raw data are shown in Figure 2 for each of the four machine/specimen combinations, or treatment groups.

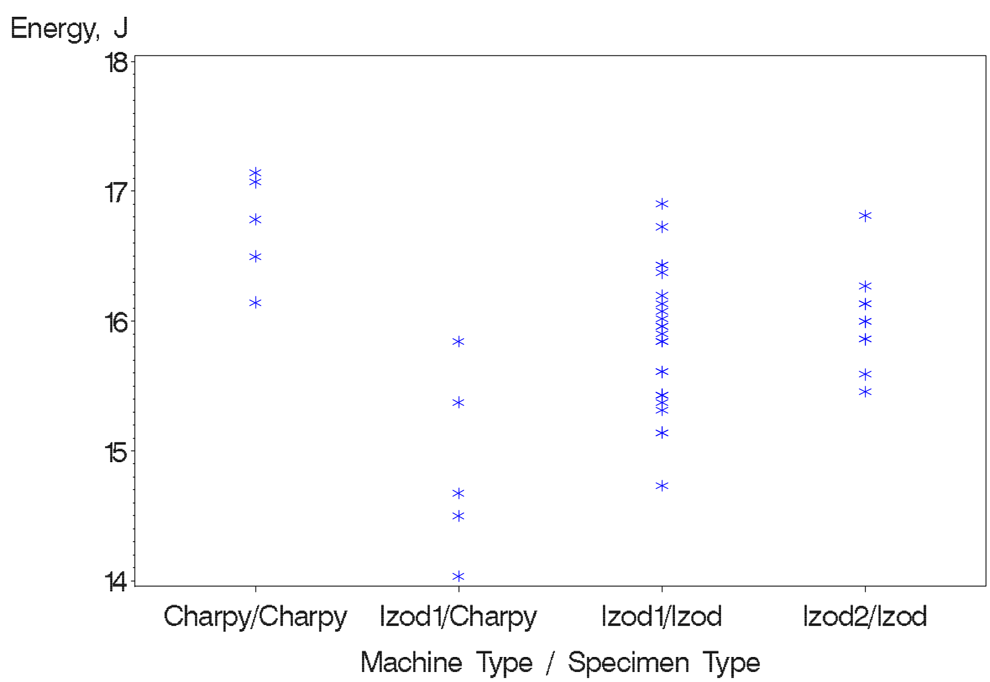

Figure 2. Measurement results for four treatment groups. Some test results are nominally the same, so not all data points are visible on the graph.

Visual inspection of the raw data indicates that there is greater variation in measurements obtained with the NIST Izod machine than measurements obtained with the NIST Charpy machine, regardless of specimen type. In addition, the data points do not overlap at all for Charpy/Charpy and Izod1/Charpy treatment groups. The apparent discrepancy between the two NIST machines (Charpy and Izod1) can be attributed to the difference in toss energy, as only one end of the specimen is free to move as the specimen is struck in the Izod configuration. The possible shift in data means between Charpy specimens tested in the NIST Izod machine to Izod specimens tested in the NIST Izod machine might be at least partially explained by a change in stiffness between the two specimens in the Izod mount. The external Izod machine appears to agree with the NIST Izod machine fairly well. The values for Charpy specimens tested on the Charpy machine at room temperature were several joules higher than the certified value of LL104 (tested at –40 °C), a quite reasonable and expected difference. Figure 3 displays group means along with error bars ($\pm 2 s_i / \sqrt{n_i}$).

Figure 3. Treatment group means with error bars. The error bars are twice the standard error of the mean.

A one-way analysis of variance to compare group means indicates that at least one mean is different from the others (p value <0.0001). Next, we compared each group to Izod1/Izod separately to determine whether other treatment groups can validate the Izod1/Izod results. Table 1 displays the results of the comparisons of the individual treatment groups.

Table 1. Pairwise comparisons of treatment group means.

Parameter	Estimate, J	Stan. Error, J	t Value	Pr > |t|
Charpy/Charpy – Izod1/Izod	0.893	0.249	3.59	0.0009
Izod1/Charpy – Izod1/Izod	–0.950	0.249	–3.82	0.0004
Izod2/Izod – Izod1/Izod	0.176	0.190	0.93	0.4

The analysis indicates that the means of the Izod1/Izod and Izod2/Izod treatment groups do not differ significantly. However, the means for both Charpy/Charpy and Izod1/Charpy treatment groups differ significantly from Izod1/Izod. Thus, only the Izod2/Izod data can be used to confirm the Izod1/Izod data. The Charpy specimens measured on the NIST Izod machine do not (and were not expected to) validate the Izod1/Izod measurements, but do show the differences between (a) Izod specimens tested in an Izod machine, and (b) Charpy specimens in an Izod machine or Charpy specimens in a Charpy machine.

3. Material Homogeneity

The manufacturing process for Izod specimens was identical to that for Charpy specimens, the only difference being that the Izod specimens were machined to slightly different dimensional specifications than those of Charpy specimens. Thus, the batch of Izod specimens is considered to be fairly homogeneous, based on past experience with specimens manufactured for the Charpy verification program.

4. Reference Value and Uncertainty

Table 2 displays the information necessary to compute the reference value and its associated uncertainty for batch LL104 of Izod SRM specimens.

Table 2. Summary statistics for Izod data.

	Izod Machine #1 - NIST	Izod Machine #2 - External
n_i	25	10
$\bar{x}_i$	15.836 J	16.012 J
s_i	0.522 J	0.375 J
$u(\bar{x}_i) = \bar{s}_i / \sqrt{n_i}$	0.104 J	0.119 J
υ_i	24	9

The measurement equation used to determine the reference value is

$$Y = X + B,$$

where $X = \bar{x}_1 = 15.836$ J is the mean of the 25 measurements of Izod specimens taken on the NIST Izod machine, and B is an unknown bias that has a Type B rectangular distribution centered about zero. The reference value is

$$Y = X + B = 15.836 + 0 = 15.836 \text{ J}.$$

We used a method called BOB (Type B on Bias) to compute the uncertainty of the reference value using the NIST Izod within-machine variation and the variation between the two Izod machines. (See Ref. 3 for details regarding the BOB method.)

The within-machine uncertainty, $u(X) = u(\bar{x}_1) = 0.104$ J, was computed using the 25 measurements on the NIST Izod machine and has $\upsilon_X = \upsilon_1 = 24$ degrees of freedom.

The between-machine uncertainty $u(B)$ and associated degrees of freedom υ_B,

$$u(B) = \frac{|\bar{x}_1 - \bar{x}_2|}{2\sqrt{3}} = \frac{|15.836 - 16.012|}{2\sqrt{3}} = 0.051 \text{ J, and}$$

$$\upsilon_\mathrm{B} = \frac{\frac{1}{2}(\bar{x}_2 - \bar{x}_1)^2}{u^2(\bar{x}_1) + u^2(\bar{x}_2)} = 0.62 \Rightarrow 1,$$

were computed based on the rectangular Type B distribution.

The combined standard uncertainty of the reference value is

$$u_c(Y) = \sqrt{u^2(X) + u^2(B)} = \sqrt{(0.104)^2 + (0.051)^2} = 0.116 \text{ J}.$$

The Satterthwaite approximation (Ref. 4) was used to compute the effective degrees of freedom as follows:

$$\upsilon_c = \frac{u_c^4(Y)}{\frac{u^4(X)}{\upsilon_X} + \frac{u^4(B)}{\upsilon_B}} = \frac{(0.116)^4}{\frac{(0.104)^4}{24} + \frac{(0.051)^4}{1}} = 15.5 \Rightarrow 15.$$

Thus, the expanded uncertainty associated with a 95 % confidence interval is

$$U = t_{0.975,15}(u_c) = 2.131(0.116) = 0.247 \text{ J}.$$

5. Discussion

The results presented in this document indicate that an Izod machine verification program similar to that for Charpy machines is feasible. We developed appropriate test methods and validated the NIST Izod measurement results with a secondary Izod machine. We computed a reference value and its associated uncertainty. The data for the two Izod machines agree well, but Izod data do not agree with Charpy data, even when specimens are produced from the same batch of material. This disagreement may be due to inherent differences between the two types of machines, such as, for example, differences in toss energy for the two machines.

6. References

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