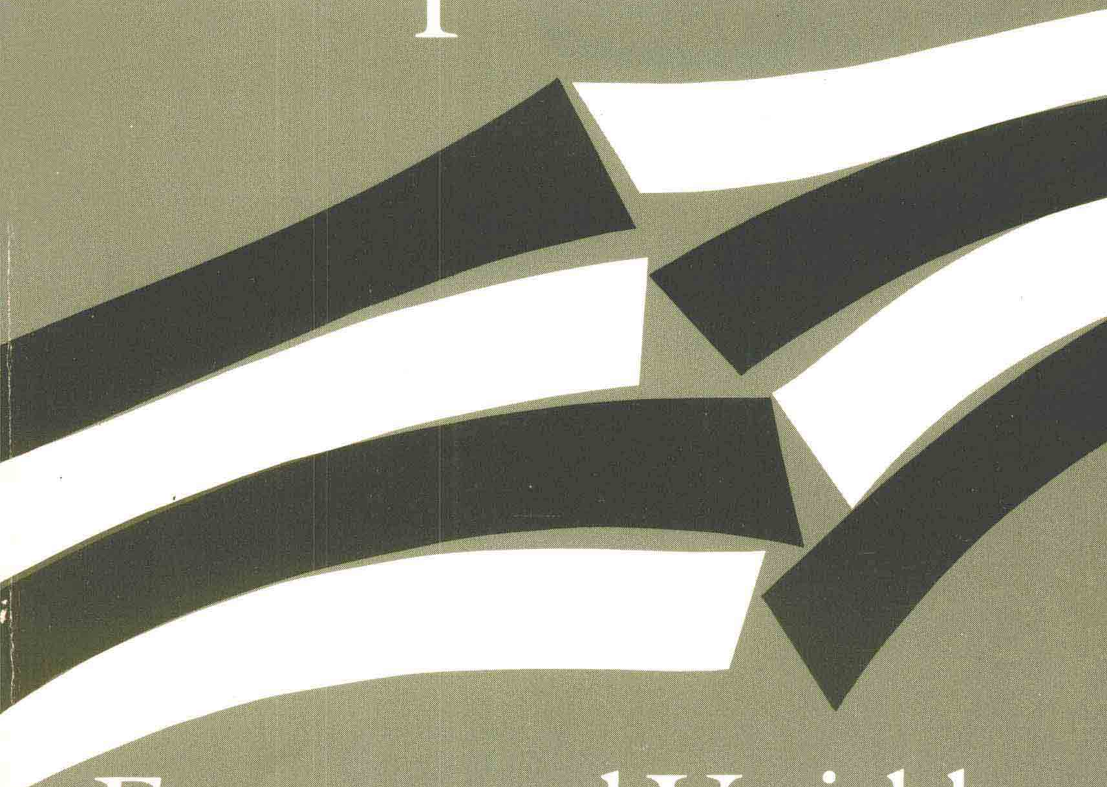
Charpy Impact Test



Factors and Variables

John M. Holt, editor

ASTM

STP 1072

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Charpy Impact Test: Factors and Variables

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ASTM
1916 Race Street
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ASTM Publication Code Number (PCN): 04-010720-23
ISBN: 0-8031-1295-5
Library of Congress No: 90-085687

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Printed in Chelsea, Mich.
December 1990

Foreword

The Symposium on Charpy Impact Test: Factors and Variables, sponsored by ASTM Committee E-28 on Mechanical Testing, was held in Lake Buena Vista, Florida, on 8-9 November 1989. John M. Holt, Alpha Consultants & Engineering, served as chairman and has also edited this publication.

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INTRODUCTORY REMARKS

The Symposium on Charpy Impact Test--Factors and Variables had its genesis at the second meeting of Subcommittee 4--Fracture of ISO Technical Committee 164--Mechanical Testing. Subcommittee 4 had the assignment of reviewing ISO Recommended Practice for Verification of Pendulum Impact Testing Machines for Testing Steel, ISO Designation R442, and of revising where necessary. Although ISO, as does ASTM, requires that documents be reviewed at intervals not exceeding five years, this document had not been reviewed since it was first published in 1965 under the jurisdiction of ISO Technical Committee 17--Steel. There were 15 representatives from seven member countries and a representative from the European Community Bureau of Reference (BCR) at that meeting. The members of ISO technical committees are the national standard writing bodies--not individuals; national-standards writing bodies are organizations such as BSI, AFNOR, SIS, etc. Because there is no national-standards writing body in the United States, Congress has designated the American National Standards Institute (ANSI), as the de-facto body and therefore, the member from the United States.

At the subcommittee meeting, agreement was reached that numerous changes needed to be made--some tolerances were too restrictive, some were not restrictive enough, but there were problems in agreeing to the "correct" values. Agreement was reached for some values because various delegates informally presented work that they had personally performed, or reported on work that had been done in their country. However, other values could not be agreed upon because of divergent requirements in various national standards and the supporting data for the various proposals was not currently available. It was suggested that an international symposium be held to discuss the factors and variables that effect the Charpy impact test so that researchers around the world would have a forum at which to present data that would answer some of the questions that had been raised. The USA representative, on behalf of ASTM Committee E28-Mechanical Testing, agreed to sponsor such a symposium as part of the E28 meetings in November 1989. This STP is the result of that symposium.

The original goal of having world-wide research presented on the factors and variables of the Charpy test was achieved. There were three sessions containing 16 papers presented by authors from five different countries. Because attendance exceeded expectations, it appears as if more than just those writing specifications are interested in the topic.

SPECIFIC REMARKS

Twelve of the papers presented are being published in this STP, and one will be published in the ASTM Journal of Testing and Evaluation (Reference 1). The twelve papers fall into three categories, (1) those discussing the pendulum-impact machine, (2) those discussing the specimen, and (3) those discussing the testing techniques; several papers discuss more than one category. In summary, the papers present information on:

* the effect of many of the dimensional parameters of an impact machine, including metrological techniques to evaluate these parameters and a compliance technique for verifying machine acceptability;
* the effect of the geometry of the striker, that is, the 2-mm radius striker specified by ISO and much of the rest of the world, and the 8-mm striker specified by the ASTM;
* the effect of the method of fabricating the notch of a CVN test piece including fatigue precracking;
* the effect of specimen sizes in Charpy impact testing;
* the effect of strain rate including slow-bend tests.

Because the dimensional parameters of the machines are so very important to obtain "proper" impact values, the papers by Porro, et.al., by Schmieder, by Revise, by Lowe, and by Naniwa all discuss how the test machine can influence the results obtained. These papers discuss the effects ranging from the attachment of the machine to its foundation to the metrological methods used to determine angles and linear dimensions. Several of the papers discuss several potential sources for variation in test results due to machine variations. Attention is drawn to the paper by Porro, et.al. presenting the results of a study on the compliance of a machine as a means of assessing its physical condition. Naniwa presents the results of an in-depth study of the differences in the behavior and the deformation of the specimen when struck by an 8-mm striker (the "ASTM striker") and when struck by a 2-mm striker (the "ISO striker").

The specimen was investigated from two points of view: (1) the method of preparing the notch, and (2) the size of the specimen. The papers by Koester and by Fink studied the effects of grinding versus single-point machining; the papers by Fields, et.al., by Mikalac, et.al., and by Interrante, et.al. studied the effect of notch acuity and the method(s) of obtaining a sharp notch. Alexander, et.al. investigated specimen size.

The influence of the temperature conditioning media on test results was reported by Nanstad, et.al. Their paper, and Reference 1, indicate that the temperature of the specimen in the vicinity of the notch at the instant of impact is not necessarily the same as the temperature of the conditioning media.

As a result of the various studies presented, ASTM Committee E28 has initiated ballots changing some of the requirements of ASTM Method E23. ISO Subcommittee 4 has begun to study the results to see how they apply to the revision of their Method R442.

Prior to the Symposium, one attendee was overheard saying, "I see that there is a symposium on the Charpy test; what can be new there?" I believe that the symposium and this STP are definite statements that much is happening in the field of Charpy testing to further the understanding of what is required to obtain acceptable Charpy test results and the proper interpretation of those results.

ACKNOWLEDGEMENTS

I wish to thank the many people that helped to arrange the symposium -- in particular, Dorothy Savini, and the many other members of the ASTM staff, the session co-chairmen, R.D. Koester, and R.J. Goode, and the many people who reviewed manuscripts.

Thanks are also in order to the people who have been instrumental in seeing that this STP was published. These include Monica Armata, Rita Harhut, and the editors of the ASTM Staff and Jim Perrin of the ASTM Publication Committee. In addition, the original reviewers again reviewed the revised papers to insure their quality.

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Reference 1: Tobler, R.L., R.P.Reed, I.S. Hwang, M. Morra, R.G. Ballinger, H. Nakajima, and S. Shimamoto; Journal of Testing and Evaluation, Vol 19, January 1991, pp.34-40.

The Pendulum-Impact Machine

Francesco Porro, Rodolfo Trippodo, Roberto Bertozzi and Gianluca Garagnani

IMPACT TESTER COMPLIANCE: SIGNIFICANCE, SENSITIVITY AND EVALUATION

REFERENCE: Porro,F.,Trippodo,R.,Bertozzi,R.,Garagnani,G.,"Impact Tester Compliance: Significance, Sensitivity and Evaluation", Charpy Impact Test: Factors and Variables. ASTM STP 1072 , John M. Holt, editer, American Society for Testing and Materials, Philadelphia 1990.

ABSTRACT: The compliance is very sensitive to internal mechanical factors concerning the load system, as the hammer, the tup, the anvils and the base to foundation attachement.
In order to verify the sensitivity of compliance measurements, a series of experimental tests has been performed, with artificial and real defect located at the most critical parts.
In order to overcame the need of an instrumented impact tester an instrumented specimen has been prepared, together with its electronic system for impact tester compliance measurement.
The compliance measurement, after verification of the impact tester with direct and indirect methods, as per ASTM E 23 or ISO R 442, can be helpful for verification of the good working condition of the pendulum and for the detection of onset of anomalies.

KEYWORDS: compliance, impact testers, pendulum, Charpy specimens,

INTRODUCTION

As pointed out by Bluhm [1] the flexibilties and the softness of the impact machine play a primary role in the determination of the correct value of the energy spent to break the specimen.

Dr.Porro is Quality engineering supervisor at Ansaldo ABB Componenti, via Lorenzi 8, 16152 Genova, Italy;
Ing. Trippodo is the director of CERMET (Regional Research Center for Materials), via Moro 26, 40068 San Lazzaro di Savena, Bologna, Italy;
Mr.Bertozzi is research scientist at CERMET; Dott. Garagnani is research scientist at Department of Metallurgy, University of Bologna, Italy.

The record of the strain of an instrumented tup actually made on an instrumented impact machine, Fig.1, definitely supports the hypothesis of the presence of vibrations during specimen rupture, resulting in loss of energy by elastic deformations, in the case of brittle fracture.

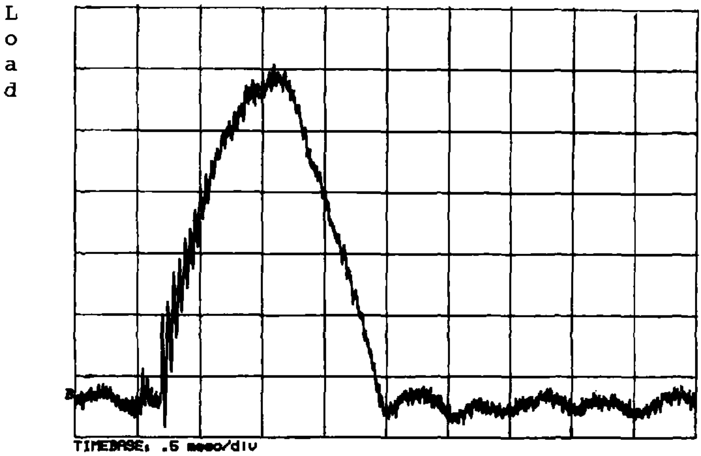


Fig.N.1: load signal from an instrumented impact tester tup showing typical vibrations during specimen rupture

In order to minimize the influence of this vibrational energy on the adsorbed energy reading, it is necessary to have an impact tester with low compliance.

This important conclusion motivated the authors to take into consideration verification of the impact tester compliance to assure homogeneity of behaviour from one tester to another.

It is well known that the reliability of the impact tester measurements is a matter of discussion when two impact testers (typically customer or inspection agency and manufacturer impact testers) measure different energy values from specimens of the same material.

This work is oriented to analyze the possibility to use the compliance, together with other characteristic impact tester parameters, for the detection of existing or impending anomalies.

BACKGROUND

The rule that governs the energy transformation during an impact test is as follows:

$$Ep = Ea + Ek + Ee + Ef \tag{1}$$

where Ep = potential energy of the hammer (weight * height) to be converted into kinetic energy after the hammer release;

Ea = energy absorbed by the specimen during its rupture;

Ek = kinetic energy remaining after impact;
Ee = energy stored by the system hammer/specimen/anvils by elastic deformation;
Ef = energy lost by friction and windage during the blow;

The quantity Ee represents the energy stored and lost by the loading system of the specimen and therefore unavailable for breaking the specimen.

The energy dissipated as elastic deformation of the loading system, for a given load P, introducing the definition of stiffness that is the ratio load/deflection, is:

$$Ee = \frac{P^2}{2 * Sm} \qquad (2)$$

where Ee = energy stored by the system hammer/specimen/anvils by elastic deformation (J);
P = load (N)
Sm = system stiffness (N/m)

The compliance, or displacement under a given load, can be expressed in terms of stiffness of the system as follow:

$$Co = \frac{1}{2 * Sm} \qquad (3)$$

where

Sm = stiffness of the loading system (N/m)
Co = impact tester compliance (m/N)

After substitution, the formula (2) can be written:

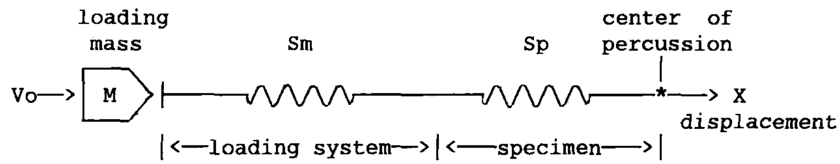
$$Ee = Co * P^2 \qquad (4)$$

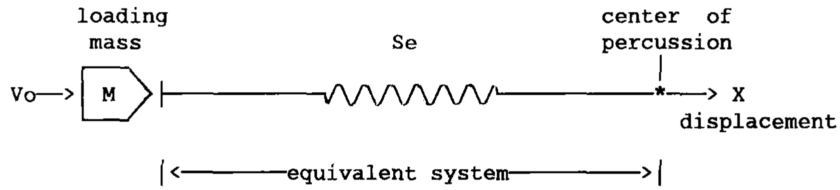
After the original idealized model suggested by Bluhm [1] for the determination of the stiffness, two methods are currently available.

The first, described by Venzi [2], has only experimental difficulties; this approach has been followed by the authors and the results obtained will be discussed in the following.

The second, used by Ireland [3], requires an instrumented impact tester, presents sufficient mathematical difficulties to require a computer for integration and shows lack of precision due to the interpretation limits of the computer during the determination of the characteristic points on load-time curve (yielding load and yielding time).

Following the Venzi approach [2], the pendulum-specimen system can be sketched as follows, during a blow in the elastic field :





where:

M = pendulum mass (specimen mass is neglected, as Bluhm [1])
Vo= impact velocity (just before impact)
X = displacement of the centre of mass M,coincident with the centre of percussion (one degree of freedom assumed as Bluhm [1])
Sm= loading system stiffness, inverse of loading system compliance Cm
Sp= specimen stiffness, inverse to specimen compliance Cp
Se= equivalent stiffness (ratio load/deflection), inverse of equivalent compliance Ce

The displacement "x" is the sum of the displacements of the specimen and the loading system:

$$X = X_{\text{loading system}} + X_{\text{specimen}} \qquad (5)$$

and the following law relates the three stiffnesses:

$$\frac{P}{Se} = \frac{P}{Sm} + \frac{P}{Sp} \qquad (6)$$

where P is the load on the system (action and reaction at the interface tup-specimen)

Then the relation between the stiffness and the compliance is:

$$\frac{1}{Se} = \frac{1}{Sm} + \frac{1}{Sp} \qquad (7)$$

$$Ce = Cm + Cp \tag{8}$$

In order to solve the equation, i.e to obtain the value of Sm, it is necessary to have the values of Sp and Se.

The value of Sp can be calculated theoretically. The formula for a unnotched specimen with square cross section is :

$$Sp = \frac{(4 * E * L)^4}{W^3} \tag{9}$$

where Sp = specimen stiffness (N/m)
E = elastic modulus of the material
L = specimen width (typ. 10 * 10 mm)
W = span between anvils (typ. 40 mm)

The value of Sp for a standard unnotched specimen made in AISI 4340 hardened steel (55 HRC) is:

$$Sp = 133.4 * 10^6 \ \mathrm{N/m} \tag{10}$$

The value of Se can be obtained experimentally with the following considerations.

The law that describes the equilibrium of the hammer translation for a blow in an elastic field is (drop angle $\alpha < 10°$):

$$M * \frac{d^2 X}{d t^2} + Se * X = 0 \tag{11}$$

the solution of this equation is:

$$X = Xo * \sin(\Omega * t) \tag{12}$$

$$\text{where} \quad \Omega = \left(\frac{Se}{M}\right)^{\frac{1}{2}} = \frac{2 * \pi}{T} \tag{13}$$

T = oscillation period of the system pendulum-specimen for elastic blow

The value of Se is determined by the equation:

$$Se = \left(\frac{2 \pi}{T}\right)^2 * M \tag{14}$$

By the knowledge of Sp and Se it is now possible to solve the equation (7) to obtain the value of Sm.