INSTRUMENTED IMPACT TESTING OF SUB-SIZE CHARPY-V SPECIMENS: THE ACTIVITY OF THE ESIS TC5 WORKING PARTY

E. Lucon*

This paper describes the activities of a working party formed in 1992 within ESIS Technical Sub-Committee 5, devoted to instrumented impact testing on sub-size Charpy-V specimens of metallic materials. The group is currently working on the draft version of a test procedure, in line with the document produced for full-size testpieces; in order to validate this procedure, a Round-Robin is presently under way, which should help developing the state of knowledge on the dynamic behaviour of miniaturized impact specimens. Final results of this concerted effort are expected for the end of 1996, but some interesting results are already available to date.

INTRODUCTION

Knowing the mechanical properties of the structural materials of plant components is one of the starting points for reliable integrity assessments and correct residual life predictions. This is of particular, almost vital importance, whenever serious suspects of embrittlement and degradation are present due to service exposure of the components at high temperatures or irradiation.

Reference mechanical data are usually scarce or even unavailable for the oldest plants, which require more careful assessment for continued operation. On the other hand, even if reliable information for the as-received materials were available, their significance and usefulness would be questionable, since they refer to virgin conditions, whilst actual service conditions and related damage mechanisms can deeply affect the materials' behaviour. It is therefore necessary to obtain data from the component itself, so that both metallurgical conditions and residual mechanical properties can be directly assessed.

The evaluation of the mechanical properties, with the exception of hardness

* CISE SpA Tecnologie Innovative, Segrate - Milano (ITALY).

measurements, is by definition a destructive technique, since it requires sampling material directly from the component. This can usually be performed only when the sample size is so small that easy repairing or even no repairing at all is eventually needed to allow further operation of the component. This necessity implies the use of very small specimens, usually not complying with the requirements of widely used test standards.

In the scientific community, particular attention has been devoted to the field of fracture toughness testing, both static and dynamic.

THE ACTIVITY GOING ON WITHIN ESIS

One of the longest-standing and most active amongst the Technical Committees of the European Structural Integrity Society (ESIS) is TC5, which is focused on Fracture Dynamics; inside this Committee, the Sub-Committee on Dynamic Testing at Intermediate Strain Rates, chaired by Hugh McGillivray (Imperial College, London, UK), has been working for several years on different types of dynamic mechanical tests on metallic material, such as impact tests on notched and pre-cracked Charpy-V specimens, dynamic tensile testing and so on. The main objective is the development of validated test procedures for these tests, later to be transferred to international standardising bodies for their transformation into proper test standards. At the end of 1995, the document produced by the group concerning instrumented impact testing of full-size Charpy-V specimens (1) has been approved by the competent ISO committee and is now going to be turned into an internationally valid test standard.

Other documents currently under development include test procedures for instrumented impact testing of pre-cracked Charpy-V specimens, for the calculation of the dynamic toughness (K_{Id} and J_{Id}) of metallic materials, and for dynamic tensile testing with strain rates between 10^{-4} and 10^{3} m/s.

The working group on sub-size Charpy-V specimens

Within the Technical Sub-Committee described above, a working group was formed in 1992 by members who, following different interests and necessities, were concerned with the use of miniaturized Charpy-V testpieces for deriving the impact properties of a metallic material. The author of this paper was elected to be the chairman of this working group, which presently involves about 15 researchers from different European and extra-European laboratories. The group meets twice every year, on the occasion of the plenary meetings of the TC5 Sub-Committee; usually half a day is scheduled for discussion.

The first initiative undertaken within the working group was the preparation of a draft standard procedure; as a preliminary approach, the document was drafted as a more-or-less exact copy of the procedure for full-size specimens (1), inserting modifications where they were obviously needed. Some preliminary discussion led to a few changes, based on the individual experiences of some members with sub-size impact testing; the present version of this document is Draft 4 (2), dating back to May 1994. A new draft version is going to be produced during 1996.

During the plenary meeting held in April 1994, the decision was taken to carry out a Round-Robin with the aim of validating the procedure and shedding some light on several still obscure aspects of the test methodology.

Outline of the Round-Robin. Twelve different organizations are involved in the Round-Robin, 10 from five different European countries (Germany, England, Belgium, Italy, Finland) and 2 from the United States, representing the liaison of this ESIS Working Group with the analogous activity presently going on within ASTM committee E28.07.08. Test specimens were extracted from a plate of ASTM A 533 B Class 1 steel (AEA correlation monitoring material - code designation JRQ); the material was supplied and the specimens were machined courtesy of E. Van Walle (SCK·CEN - Mol, Belgium).

The activity was divided in two phases. For Phase 1 tests, participants were required to perform a minimum of 3 tests at R.T. (23 ± 2 °C) on DIN 50 115 (3) *Kleinstprobe* Charpy-V specimens (thickness = 3 mm, width = 4 mm, length = 27 mm, span = 22 mm). Tests were to be performed with an instrumented tup conforming to the requirements of EN 10 045 standard (ISO tup), using any type of impact test machine available (full-scale or small-scale pendulum, drop-weight, servohydraulic machine). Impact velocity was nominally restricted to the range 2.7 ÷ 3.0 m/s. Analogue filtering of the force signal during the tests was not allowed, but any procedure for evaluating the force/displacement curve (especially concerning the determination of yield force) could be employed. The test procedure had to follow, whenever applicable, the requirements given in Draft 4 of the Proposed Standard Method. This first phase has been completed by late summer 1995, and the results are available in the form of a TC5 Test Report (4).

For Phase 2 of the Round-Robin, currently under way, participants are free to investigate the influence of any parameter or condition on test results (specimen geometry, test temperature, impact velocity, ASTM or ISO tup geometry, etc.); test results are also expected to be useful for investigating various literature approaches available for correlating sub-size to full-size specimen test data.

The completion of this activity is scheduled by the end of 1996.

Characteristics of testing equipment and test conditions. Preliminary to the start of the Round-Robin activity, a questionnaire had been distributed among the participants, in which they were asked to report about the characteristics of their testing equipment and the procedure normally used for evaluating instrumented impact tests. A remarkable variety of different test machines, acquisition systems and elaboration routines was reported, thus allowing the influence of such features on test results to be considered.

Four different types of impact machines were used: full-scale pendulum (3 labs), small-scale pendulum (5 labs), drop-weight machine (1 lab) and servo-hydraulic high speed machine (1 lab). Available energy ranged from a minimum of 9 J to a maximum of 300 J. The upper frequencies of the measuring systems ranged from 100 kHz to more than 1 MHz; the sampling rate varied from 0.4 to 5 μs and the number of points per curve from 1018 to 16000.

An extensive range of methods for evaluating the load-displacement curve has been reported ("human eye", smoothing and/or fitting procedures, self-produced or commercially available computer routines); displacement was in most cases calculated from initial velocity and time measurements, as recommended in the draft procedure.

Phase 1 results. The test procedure required participants to report characteristic values of force, displacement and energy related to various moments in the course of the force-displacement diagram (yield point, maximum force, end of test). Data reported for R.T. tests performed at 3 m/s are shown in Figures 1 ÷ 3; with only a few exceptions, acceptable scatter has been achieved, in spite of the different types of instrumentation and analysis procedures employed, also accounting for the material's intrinsic inhomogeneity and lab-to-lab variability.

As an important side product of this preliminary testing phase, the values of total impact energy (W_t), calculated by participants under the force-displacement curve, have been compared to measured dial energy values (whenever an indicator was available on the test machine). The results are shown in Figure 4: the dashed line represents perfect identity between measured and calculated energies, while the dotted lines on either side define a ± 0.5 J tolerance range, enclosing all reported data points with just one exception.

REFERENCES

(1) ESIS TC5 Sub-Committee on Dynamic Testing at Intermediate Strain Rates, "Proposed Standard Method for the Instrumented Charpy-V Impact Test on Metallic Materials", Draft 10: 14 January 1994.

(2) ESIS TC5 Working Party on Instrumented Charpy Testing on Sub-Size Specimens, "Proposed Standard Method for Instrumented Impact Testing on Sub-Size Charpy-V Specimens of Metallic Materials", Draft 4: 8 May 1994.

(3) DIN 50 115, "Testing of Metallic Materials; Notched Bar Impact Test; Special Forms of Test Pieces and Methods of Evaluation", Deutsche Norm, April 1991.

(4) E. Lucon, "Round-Robin on Instrumented Impact Testing of Sub-Size Charpy-V Specimens: Results of Phase 1", Final Report, 19 September 1995.

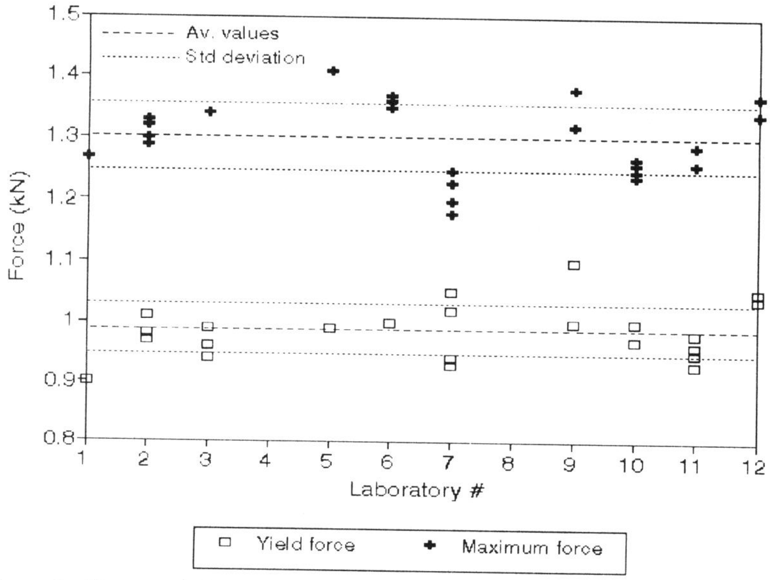

Figure 1 Characteristic values of force reported in Phase 1 of the Round-Robin.

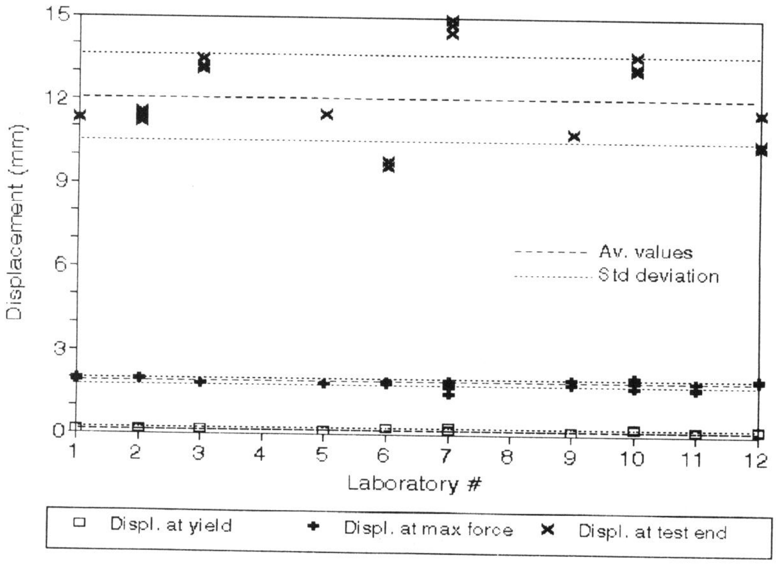

Figure 2 Characteristic values of displacement reported in Phase 1.

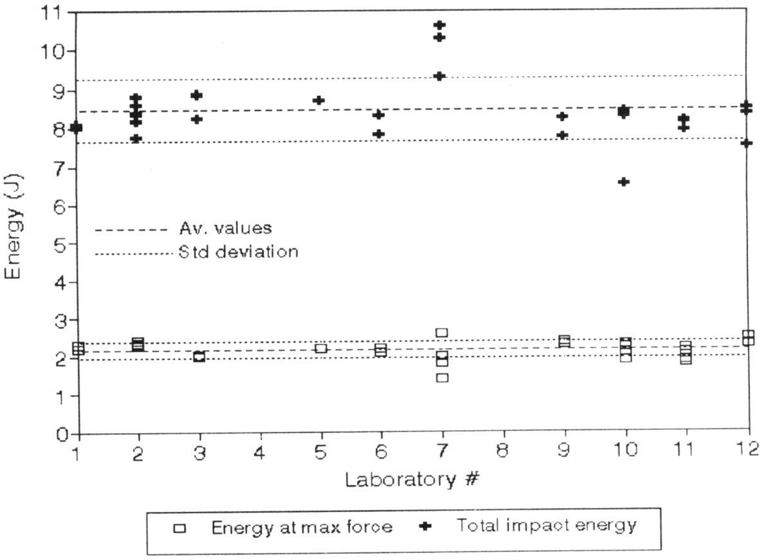

Figure 3 Characteristic values of energy reported in Phase 1.

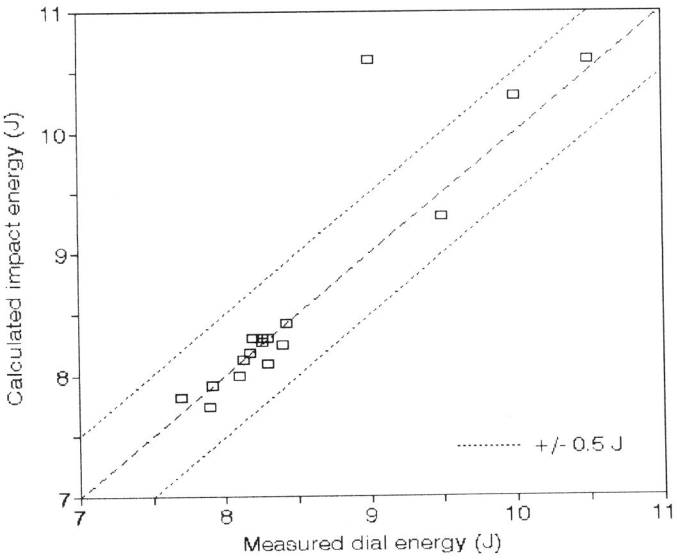

Figure 4 Comparison between calculated and measured values of impact energy.