INSTRUMENTED IMPACT TESTING OF SUB-SIZE CHARPY-V NOTCH SPECIMENS: FINAL RESULTS OF THE ESIS TC5 ROUND-ROBIN

E. Lucon*

The results are described of a Round-Robin exercise, performed in the frame of the activity of a Working Group devoted to Instrumented Impact Testing of Sub-Size Charpy V-Notch specimens within ESIS Technical Committee 5 (*Dynamic Testing at Intermediate Strain Rates*). The Round-Robin involved 13 labs (11 European and 2 from US), and the tests spanned from late 1994 to early 1998; Phase 1 (room temperature tests) has been described in an earlier paper, presented at the 11th European Conference on Fracture (Poitiers-Futuroscope, September 1996). This paper focuses on the outcomes of Phase 2, in which the influence of various parameters (temperature, impact speed, tup and specimen geometry) on test results was investigated.

INTRODUCTION

The use of sub-size Charpy V-notch specimens for instrumented impact testing has been gaining more and more widespread popularity in the scientific community, following the increasing need to estimate in a reliable way the mechanical properties of service-exposed or irradiated plant components. Indeed, this has to be achieved without sampling large quantities of material from the component, if this has to be maintained in operation. Instrumented testing of sub-size impact specimens represents a convenient tool for characterising impact and fracture properties (such as $FATT_{50}$, T_{41J}, USE etc.) using very limited amounts of material or, alternatively, machining small specimens out of previously tested broken specimens. What the experimentalists need is therefore a reliable and unambiguous test procedure, enabling them to carry out tests in the most efficient way; from the point of view of data treatment, all this has to be coupled with soundly based correlations with full-size test data, in order to derive useful predictions in spite of the inapplicability of a "standard" approach to material characterization.

* ENEL Research, Diagnostics & Materials Dep. (before June 1998, CISE SpA) - SEGRATE (MI) - ITALY.

THE ACTIVITY OF THE ESIS WORKING GROUP ON SUB-SIZE SPECIMENS

Within the Technical Committee 5 (TC5) of ESIS, which deals with Fracture Dynamics, the Sub-Committee on *Dynamic Testing at Intermediate Strain Rates*, chaired by Hugh McGillivray (Imperial College, UK) has been extensively working on producing test procedures concerning various types of dynamic mechanical tests, such as impact tests on V-notched or fatigue pre-cracked specimens, dynamic tensile testing and dynamic compression testing. The final objective is to propose such documents, after validation through internal Round-Robin exercises, to international standardising bodies (such as ISO) for their eventual transformation into Test Standards of widespread applicability. The main achievement, from this point of view, was the acceptance by ISO of the Test Procedure on Instrumented Impact Testing of Charpy V-notch Specimens of Metallic Materials, produced by the Sub-Committee in 1994 in its final version, which has now become ISO 14556 standard (1).

The Working Group on Instrumented Impact Testing of Sub-Size Charpy V-notch Specimens

Within the TC5 Sub-Committee described above, a Working Group was formed in 1991, specifically addressed at developing a suitable Test Procedure (also later to become, hopefully, a standard) for instrumented impact testing of sub-size specimens. The Author was elected to be the chairman of this group.

The document produced by this group, initially based to a large extent on the analogous Test Procedure for full-size testpieces, has now reached the stage of Draft 7 (2).

In 1994, a decision was taken to validate the procedure by means of a Round-Robin exercise, with the aim of clarifying some still ambiguous aspects of the methodology.

The Round-Robin programme has involved 13 laboratories (11 from 7 different European countries and 2 from the US); the participation of the American laboratories represented the liaison of the activity of this Working Group with the corresponding ASTM Sub-Committee working on the same topic.

The experimental activity, which was terminated in the spring of 1998, had been sub-divided in two parts:

- Phase 1 consisted of 3 ÷ 5 tests per lab at room temperature on 3 mm x 4 mm x 27 mm Charpy V-notch specimens (already considered by the German DIN 50 115 standard, (3)), using an impact speed of approximately 3 m/s;

- Phase 2 was intended to allow all participants to investigate different aspects of the experimental procedure and to study the influence of various parameters (temperature, specimen and striker geometry, impact speed etc.) on test results.

RESULTS OF THE ROUND-ROBIN

Phase 1

The test results collected during the first part of the Round-Robin, which was officially closed in early 1996 (with some later additions), have already been reported by the Author in a paper which was presented during the 11th European Conference on Fracture (ECF11), held in Poitiers-Futuroscope (France) in September 1996 (4).

The main remarks emerging from Phase 1 can be summarized as follows:

1. Although different impact machines and test procedures have been employed by the participants, no problems have emerged in applying the draft test procedure.
2. The scatter in the characteristic values reported is reasonably low (in the range 4% ÷ 8%) in the case of force and energy values, remarkably higher for displacement values (10% ÷ 22%).
3. The influence of impact speed and upper frequency of the measuring system on test data appears quite moderate, except for characteristic values relevant to test termination (displacement s_t, absorbed energy W_t).
4. Mean values of total calculated energy (W_t) are consistently lower than dial energy values, although the difference is always kept below ±0.5 J.

A detailed analysis of Phase 1 test results is presented in (5), including the determination of repeatability and reproducibility of the test method in accordance with the ISO 5725-2:1994 standard.

Phase 2

Nearly all participants chose to investigate the influence of temperature on test results; additionally, a few labs concentrated on other parameters as well, such as impact speed, specimen and striker geometry, span value, specimen side-grooving.

Influence of temperature. Figures 1, 2 and 3 show the characteristic values of force at yield point (F_{gy}), maximum force (F_m) and total calculated energy (W_t) reported by participants as a function of temperature. Apart from a few anomalous data, reasonable scatter was achieved, on account of the different impact speeds used (ranging from 2.6 to 3.9 m/s) and the problems connected with temperature control, which is indeed a very critical aspect in the case of very small specimens.

Influence of specimen geometry. Although all labs used DIN-type specimens, several tests were performed using a different geometry (*Half-Size* specimens, B = 5 mm, W = 5 mm, L = 27.5 mm); this enabled some attempts at normalizing energy values to be performed. The most successful was based on fracture volume normalization ($W \cdot b^2$), as shown in Fig.4, where full-size specimen data, available from the literature, are also reported. As expected, a shift in transition temperature is evident, in that smaller-size testpieces tend to behave in a more ductile manner; this was also confirmed by shear fracture measurements.

Effect of side-grooving. The effect of side-grooving was investigated by CISE on DIN-type specimens, tested a 3 m/s at different temperatures. Comparison with plain-sided data clearly shows that side-grooving significantly increases constraint conditions at the notch root, shifting transition curves towards higher temperatures.

Calculated energy values VS dial readings. The very satisfactory comparison between measured (KV) and calculated (W_t) energy data, obtained in Phase 1, was thoroughly confirmed by Phase 2 results: nearly all reported W_t results lie within a ±0.5 J tolerance band with respect to machine dial readings.

A more detailed analysis of the results of Phase 2 is presently under way; preliminary elaborations are available in the form of a Draft Report (6).

Acknowledgments

The Author wishes to gratefully acknowledge the friendly collaboration of all Working Party members, especially those who took part in the Round-Robin.

REFERENCES

(1) ISO 14556, "Steel - Charpy V Pendulum impact test - Instrumented test method".

(2) "Proposed Standard Method for Instrumented Impact Testing of Sub-Size Charpy V-Notch Specimens of Steels", prepared by the Working Party *European Standards on Instrumented Charpy V-Notch Testing of Sub-Size Specimens*, ESIS TC5, Draft 7: 12 June 1997.

(3) DIN 50 115, "Prüfung metallischer Werkstoffe - Kerbschlagbiegeversuch - Besondere Probenform und Auswerteverfahren", April 1991.

(4) Lucon, E., "Instrumented Impact Testing of Sub-Size Charpy-V Specimens: the Activity of the ESIS TC5 Working Party", ECF11, Mechanisms and Mechanics of Damage and Failure, Editor J. Petit, pp.621-626.

(5) Lucon, E., "Round-Robin on Instrumented Impact Testing of Sub-Size Charpy-V Specimens: Results of Phase 1", Final Report, 2 April 1998.

(6) Lucon, E., "Round-Robin on Instrumented Impact Testing of Sub-Size Charpy-V Specimens: Results of Phase 2", Draft Report, 2 April 1998.

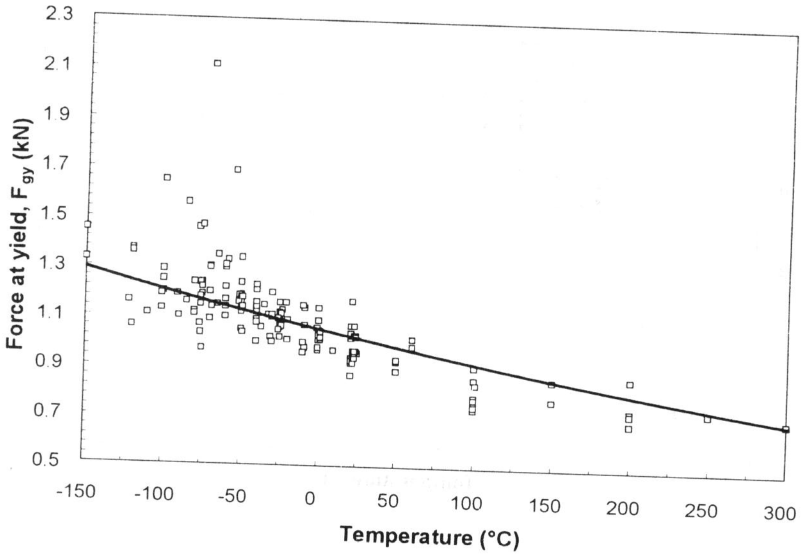

Figure 1 Values of force at general yield reported by Phase 2 participants.

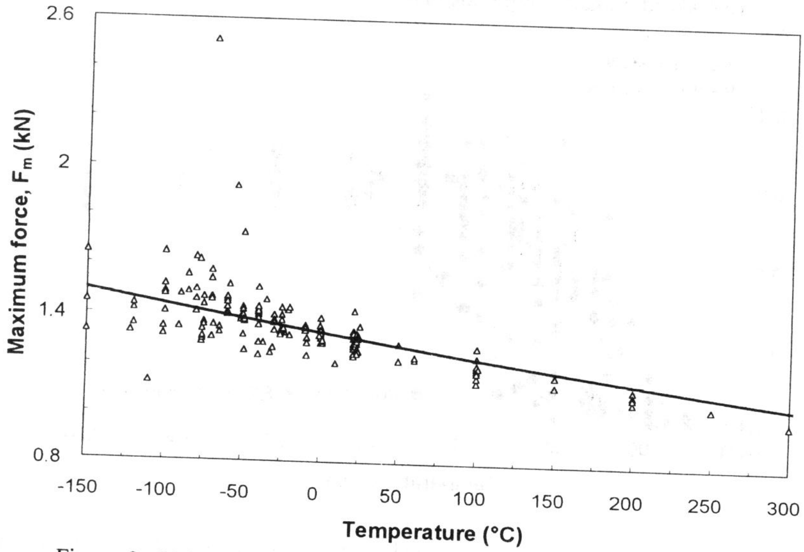

Figure 2 Values of maximum force reported by Phase 2 participants.

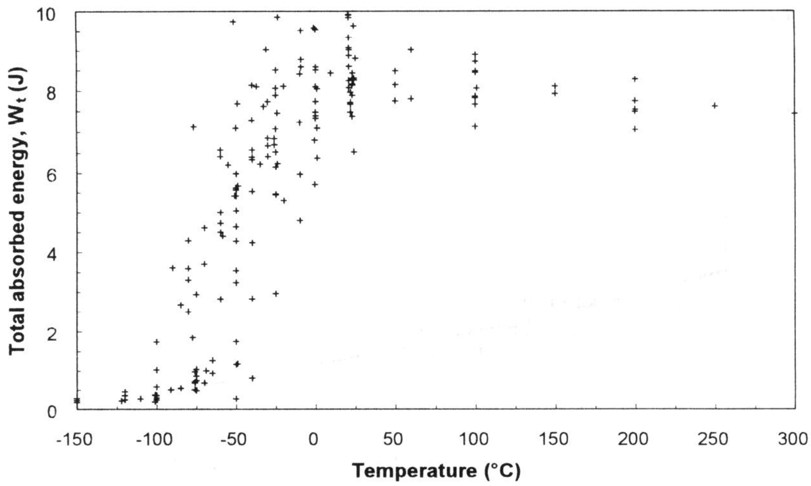

Figure 3 Values of absorbed energy reported by Phase 2 participants.

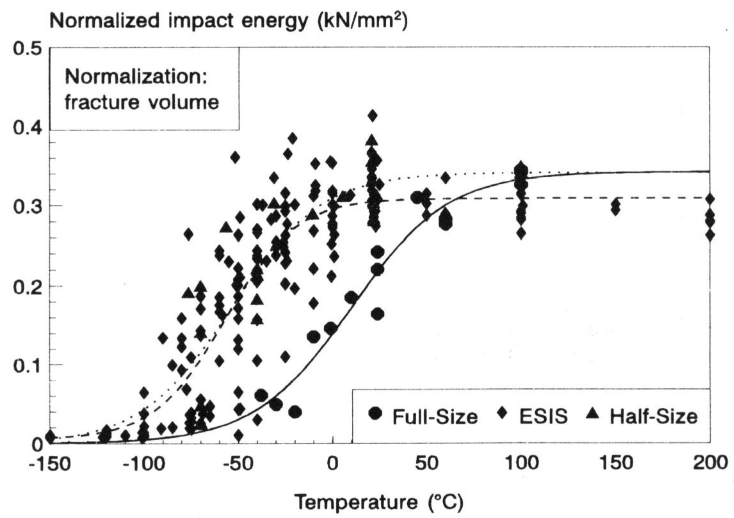

Figure 4 Comparison between absorbed energy values on different specimen types, normalized by fracture volume ($W.b^2$).