INSTRUMENTED CHARPY TEST- EVALUATION OF THE FORCE SIGNAL CAPTURED IN THE MEASURE DYNAMIC FRACTURE TOUGHNESS OF METALLIC MATERIALS

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Abstract. The Charpy test is one of the most important mechanical testing of materials. Which has interesting advantages like low costs, simple interpretation of the results and manufacturing sample facilities. However, instrumented Charpy test has shown better results because it was possible to obtain a dynamical reaction from impact load. The main problem is how could be acquire a dynamical signal without any external pertubation. This article results the use of signal acquisition architecture to determine the dynamic fracture toughness of metallic materials. Using extensometry principles, the striker of a Charpy machine was instrumented in conformity with ISO 14.556(2000). The rehearsed material was the AISI 4140 steel in having normalized. The evaluation the signal force measured was done compared the toughness read from dial on machine(W_d) and the toughness calculated from load-line displacement estimated (W_i).

Keywords *Instrumented Charpy-V, ISO 14.556, signal force*

1. Introduction

Recent studies have been bringing valuable contributions, as example the Charpy Centenary Conference 2001 accomplished in France commemorating the a hundred years of Charpy Test. Inside of this context it was published hundred and sixty works of the which approximately ten percent just worried about the instrumentation, interpretation, modeling of the instrumented Charpy impact test. One of the icons in the study of instrumentation is Toshiro Kobayashi, from Technological University of Toyohashi - Japan, publishing work in the development of an evaluation system of the tenacity to the dynamic fracture aided by computer, denominated it CAI - Computer Aided Instrumented Charpy Impact Test, associated to the machine conventional Charpy test. Besides this document, Kobayashi in partnership with Toda, H. and Masuda T. analyzed the obtained signals from instrumented impact test and impact tensile test. They used a machine conventional Charpy test with capacity of 490J with speed of impact of 5m/s and a machine servo-hydraulic of with capacity of 45kN and loading velocity varie from 0,01 to 12m/s.

Manahan M. P. and Stonesifer in CCC 2001 (Charpy Centenary Conference 2001) studied the optimum instrumented striker designs. They revealed that the hammer loading indicated by instrumented Charpy test can be affected adversely by forces inertias in the hammer and for variations in the contact of the distribution of force between the hammer and specimen.

A research about the dynamic fracture toughness of materials welded in vases of pressure of nuclear reactors was published by Schmitt et al. (1994) in International Journal of Pressure Vessels & Piping. In that study, the property was evaluated using specimens craked and it validated the results by means of the numeric simulation. The instrumentation was based in the strain-gages attached in the hammer and on the specimens, close to the support point in the machine test.

Recently, the norm ISO 14.556 consolidates the necessary procedures for instrumentation of a conditional impact test. Thrown in 2000, this document proposes methodologies for assembly and calibration of the force transducer, it specifies, in terms frequency response, the measurement chain of the test, it classifies the material rehearsed starting from the obtained signal. Inside of these procedures and recommendations highlight some as, the dynamic evaluation of the whole system, it is considered satisfactory if a steel specimen presents a initial peak greater than 8kN, for an impact speed between 5 and 5,5 m/s, the calibration of the force to be accomplished applying a well-known force on the instrumented tup, properly set up in an apparatus that represents the same conditions of the dynamic test. For being of a signal transient, the system of recording of the curve forces vs time, it is a recording systems with digital storage, contends electronic interface for treatment of the data through microcomputer and analogue-digital converter at least 8 bit, with a rate of sampling of 250kHz. However, 12 bit is recommended. A storage capacity of 2000 data points is required for each signal over an 8 ms time period, if the recording is to be adequate.

In this study the measurement chain of the instrumented Charpy impact test was evaluated, comparing the values of toughness read from dial on machine and the value of toughness calculated starting from the integration of the curve forces vs displacement. For evaluation of the measurement chain, the steel AISI 4140 was rehearsed in room temperature.

2. Material and Equipments

The material used in this study is AISI 4140 steel in having normalized. Chemical compositions of used sample are shown in Tab. (1). Geometry and nominal dimension of specimen were given in Fig. (1). Specimens for Charpy V-notch are sample in longitudinal orientation.

Table 1. Chemical compositions of sample used.

	C	Mn	Si	Cr	Mo
AISI 4140	0,38-0,43	0,75-1,00	0,20-0,35	0,80-1,10	0,15-0,25

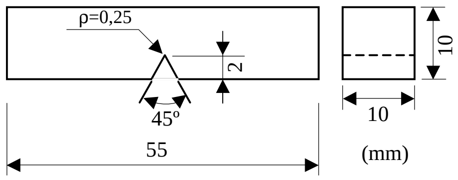

Figure 1. Geometry of specimen used.

The instrumented Charpy impact test was performed on a pendulum Charpy impact machine having a capacity of 300J at room temperature and the impact velocity 5,5m/s. The striker edge is normally designed according to ISO/DIN standards or to ASTM E 23. The instrumentation may be placed on the striker at various locations that have been found to result in significant differences in the impact energies derived from load signal. These differences are a consequence of the particular location of the strain gage on the striker edge, the dynamic response of the tup, and the loading conditions that the tup experiences when the specimens are bent through to large angles (Tronskar, 2001). In the work, the ISO tup design was used and instrumented with strain gages and according with ISO 14.556 - *Charpy V-notch pendulum impact test - instrumented test method.* The centers of the active strain gage were attached on tup 15 mm away from the striker contact point.

The calibration of ISO tup was done with the striker built into the hammer. The force was applied to the striker via a mechanical press with 5.000Kgf capacity. A support block with high stiffness was used in the position of test piece for the calibration. The calibration curve is show in Fig. (2).

For the tests reported the data acquisition was performed using a amplifier developed by Laboratory of Qualities of Energy at State University of São Paulo – UNESP/FEIS/DEE. This equipment has 200KHz frequency response and a Tektronix two-chanel Type TDS 220 12-bit digital oscilloscope with a maximum sampling frequency of 1GS/s, with 2500 memory points/channel. Fig. 3 shows the schematic diagram of the Instrumented Charpy impact test.

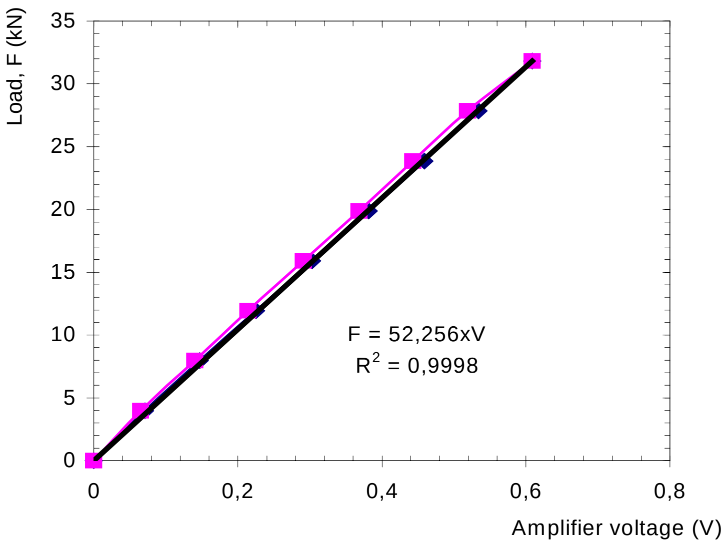

Figure 2. Calibration curve obtained for ISO tup.

In this study no method was used to measure de displacement of specimen. The force-time relationship measured on the striker is proportional to the acceleration characteristic. Given an assumed rigid pendulum of effective mass *m*, the initial impact velocity v_o, and the time t following the beginning of the deformation at t_o, the test piece bending displacement is calculated double numerical integration:

$$v(t) = v_o - \frac{1}{m}\int_{t_o}^{t} F(t)dt \tag{1}$$

$$s(t) = \int_{t_o}^{t} v(t)dt \tag{2}$$

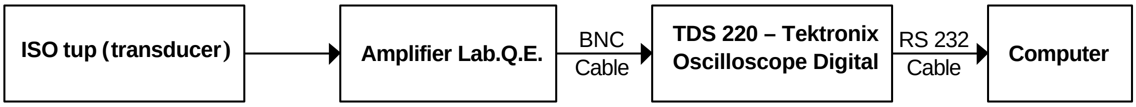

Figure 3. Schematic diagram of the instrumented impact test.

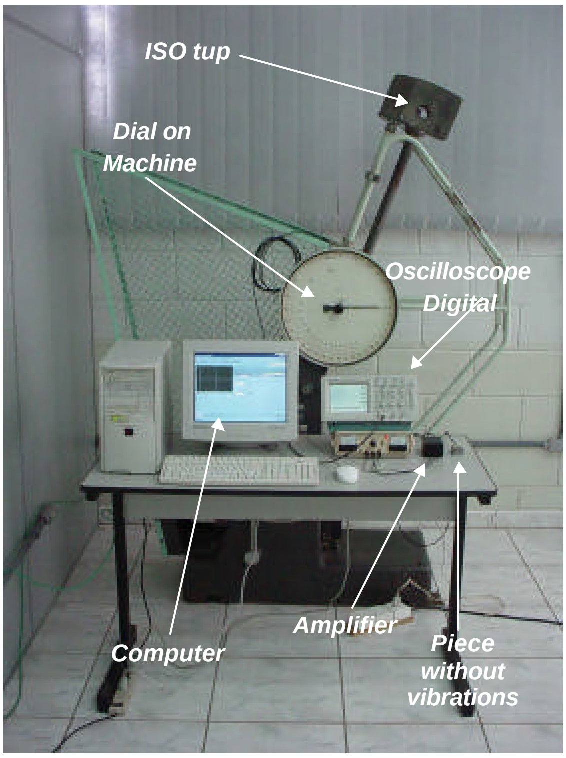

Figure 4. Instrumented Charpy Impact test ready to test.

3. Results and Discussion

Table 2. Toughness read from dial on machine (W_d) and the toughness calculated from load-line displacement estimated (W_i).

Specimen	W_d [Joules]	W_i [Joules]	$(W_d - W_i)$ [Joules]	$(W_d - W_{iV})/ W_i$ [%]
01 *(preliminary)*	33	31,1	1,9	5,8
02	29	28,2	0,8	2,8
03	30	28,8	1,2	1,2
04	29	28,2	0,8	0,8
Médium value	30,2*	29,1*	2,1*	3,6*

The Tab. (2) represents the values of the Toughness read from dial on machine (W_d) and the toughness calculated from load-line displacement estimated (W_i). Four specimens was tested, including the preliminary test. It is notice, that most effective form of evaluating the measurement chain is through the comparison among the certain values of tenacity starting from the integration of the curve force vs displacement and the value read from dial on machine (W_d). It was assumed that the measurement chain is so much the better close they are the values W_i and W_d.

Fig. (5) shows the first test. The fracture process of specimen happened at first 0,5ms from signal recorded. The oscilloscope, in this test, was set to capture the signal in total time 2,5ms and the number of points from the discrete signal was 2500. It is noticed, that the moment of the impact in the signal wasn't discretization in 2500 points, harming the amount of information during the impact. The main reason of this fact, it was the lack of knowledge of the process of fracture of the steel ABNT 4140. The other point observed in this preliminary test, was the noise level very accentuated in the signal. It decided then, that the equipments of the measurement chain were terrified properly and for consequence, the level decreases considerably when analyzing the next tests.

After this preliminary test, it was adopted that the capture of the signal in the oscilloscope would be done in a total time of 0,5ms, this way the signal in the moment of the impact it would be discrete in 2500 points.

Figure (6) shows typical Load-displacement estimated and Toughness estimated-displacement estimated curves obtained from instrumented impact test for specimen with toughness read from dial on machine, W_d=33Joules. The same it happened for Fig. (7), Fig. (8) and Fig. (9), however the toughness from dial was 29, 30 and 29 Joules respectly.

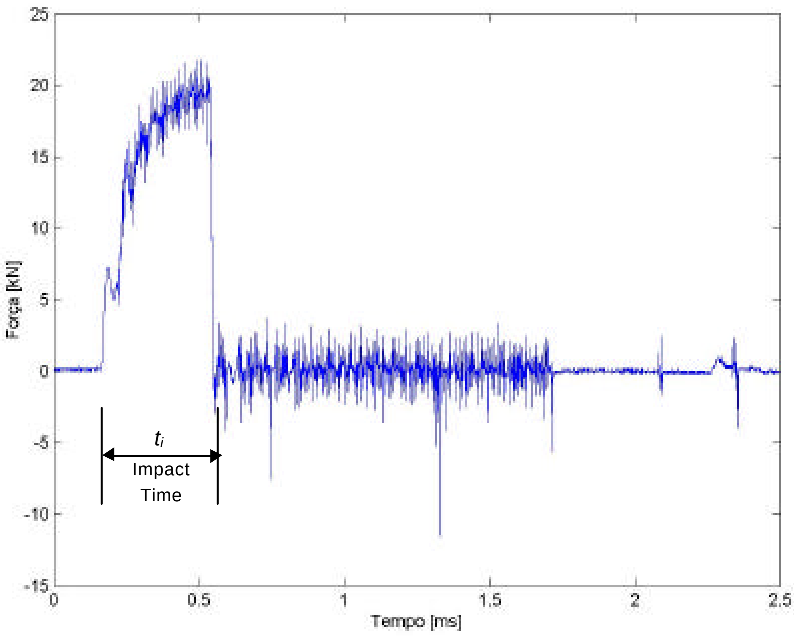

Figure 5. Load-time curve recorded in the instrumented Charpy impact test dicretized in 2,5ms.

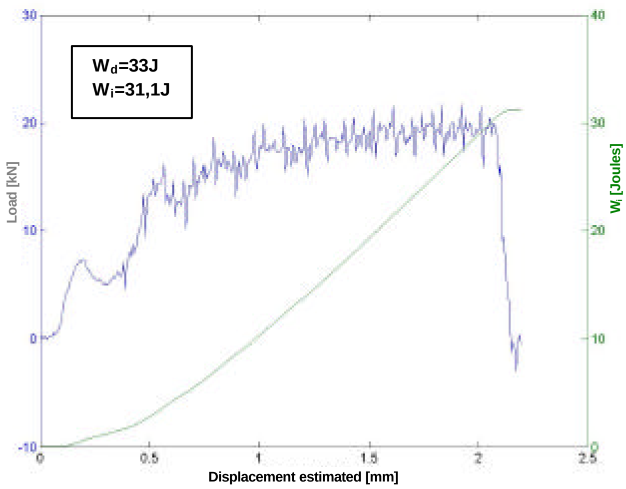

Figure 6. Load-displacement estimated and Toughness estimated-displacement estimated curves obtained from instrumented impact test for specimen with W_d=33J.

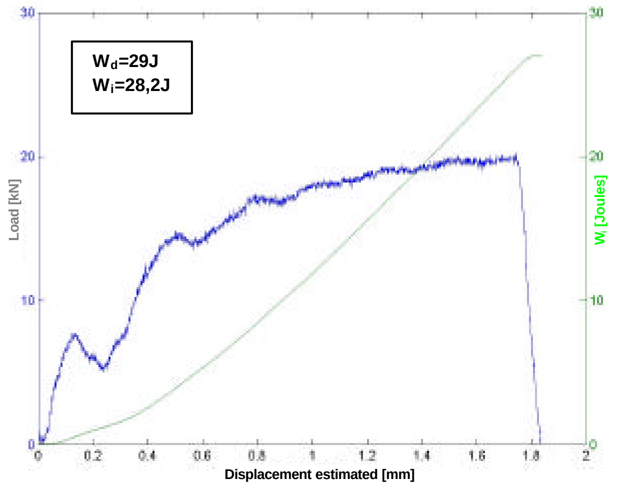

Figure 7. Load-displacement estimated and Toughness estimated-displacement estimated curves obtained from instrumented impact test for specimen with W_d=29J.

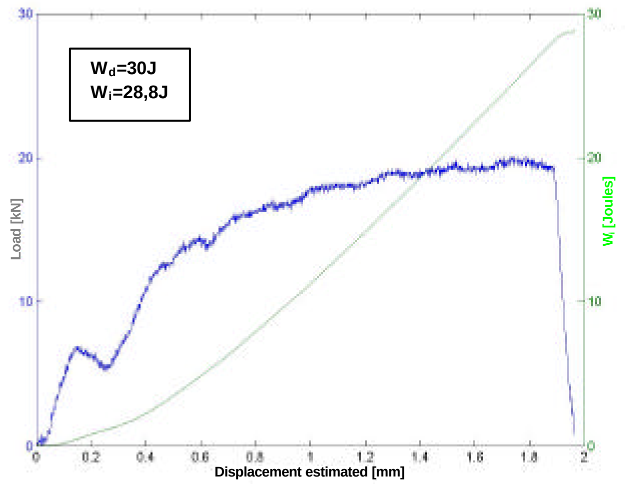

Figure 8. Load-displacement estimated and Toughness estimated-displacement estimated curves obtained from instrumented impact test for specimen with W_d=30J.

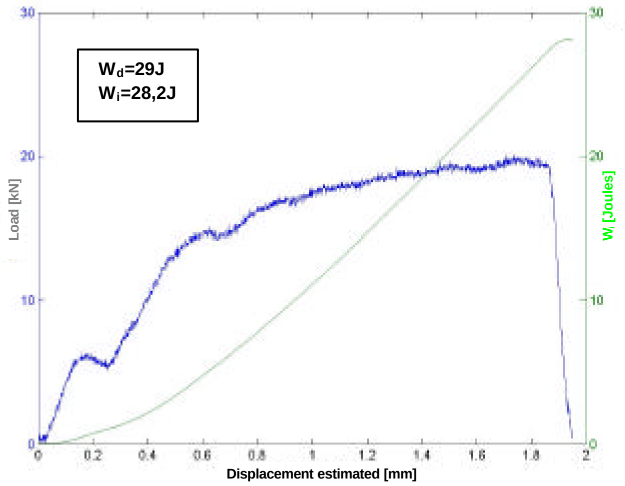

Figure 9. Load-displacement estimated and Toughness estimated-displacement estimated curves obtained from instrumented impact test for specimen with W_d=29J.

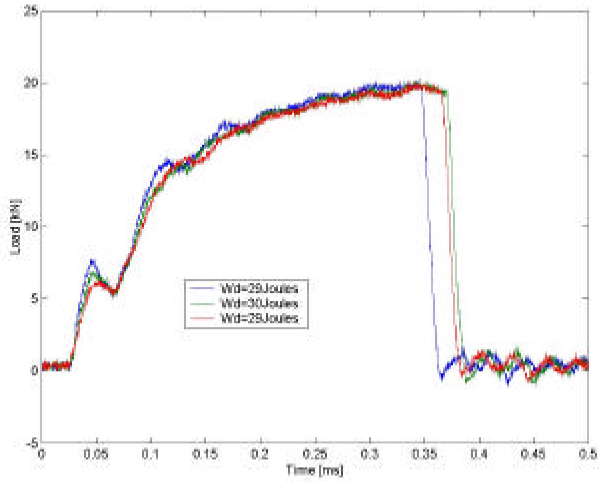

Figure 10. Comparative between the load-time curves obtained from instrumented Charpy impact test for three specimens.

It can seen from Fig. (10), that the curves from test are superposed, warranting the reproductibility from measurement chain. It means that, for materials with low toughness the instrumented Charpy impact test developed are responding satisfactorily.

4. Conclusion

The present research work has developed a measurement chain for instrumented Charpy impact test. This chain involves the use of an ISO striker instrumented according by ISO 14.556 and an amplifier developed by University of São Paulo – Ilha Solteira with response frequency 200kHz. The chain showed satisfactorily and accuracy, it can be evidenced by analysis in Tab. (2) and Fig. (10). In Tab. (2), the medium error was 3,6% including the first test, and in Fig. (10) the curves are superposed.

The noise level is other factor that can commit the quality of the signal. The next step will be a study of use of digital or analogical filters. According to preliminary studies, the analogical filters could attenuate the signal, on the other hand the digital filters understand two models: filters used after the sign to be digitalized or filters used for fittings of curves by polynomials. It must think and to discover which is the best alternative to minimize the effect of the noise in the signal.

Nevertheless, the principal objective of this work is to develop a measurement chain at least cost possible and great accuracy, and can be applied at any equipment impact test.

5. Acknowledgement

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