INSTRUMENTED CHARPY IMPACT TEST: OPERATIONAL TIME REDUCTION FOR ACQUISITION AND PLOTING OF THE LOAD - TIME CURVE

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***Abstract**. The objective of this paper is to present a methodology for reduction of the operational time for acquisition and processing of the Instrumented Charpy Impact Test data. The Matlab^{Ò} 6.0 software was applied in research as a operational tool since it allows interaction between computer and oscilloscope as well as mathematical calculations in only one computational routine. As a result, any user without previous and technical knowledge is able to operate the acquisiton and processing plataform in order to obtain the Instrumented Charpy ImpactTest data.*

***Keywords**: Matlab, Instrumented Charpy Impact Test, signal acquisition and processing procedures.*

1. Introduction

The Instrumented Charpy Impact Test has been researched since 1960. It represents a potential tool to be used for mechanical characterization of materials because it is able to provide several and additional data when compared to Conventional Charpy Test. It can participate more and more of development and detailed qualification of new materials disposed continually for instance by metallurgical industries (Kruger, 2003).

At first, the interest in studying the instrumentation of Charpy Impact Test has been decreasing year after year. The industries and research institutions have been using the Instrumented Charpy equipment in user condition. They did not undertaken efforts in order to promote improvements concerning the instrumentation Charpy and determine the properties of test response curve. It presents several inherent complexities to the process, because they are originated from dynamic loading in conjunction with the Charpy machine structure (Tokimatsu, 2004).

Kobayashi (2002) recently classified the transition behavior of steel by considering several temperature regions based on results and analysis of loading-displacement curve obtained from Instrumented Charpy Impact Test, as well as on the characteristics of the specimens fracture surface.

Other important researchers who have been studying the Charpy instrumentation are Kalthoff, Winkler e Böhme (1985). They get the academic respect when presented an accurate methodology to determine the dynamic fracture toughness through the impact response curve and the fracture time of specimen. This procedure has been applied currently by several researchers, even presenting high costs due to necessity of instrumentation by using electric strain-gages set on specimens.

Tronskar *et al*. (2001) presented a study which indicated the development of a method to measure directly the loading-displacement curve during the Instrumented Charpy Impact Test. This technic involves the direct measurement by applying a interferometer laser. The end of ISO tup was instrumented by a piezoelectric sensor and the system was calibrated in Charpy machine as recommend by ISO normalization 14.556 (2000).

Rodrigues (2001) discussed the application of piezoelectric sensor set on machine structure where the specimens are positioned for tests. He verified that transducers presented a response time similar to that one recommended by ISO normalization 14.556. The acquisition platform was composed by a load cell (tup instrumented with electric strain-gages), signal amplifier (frequency response greater than 100 kHz), analogical/digital conversor (digital memory oscilloscope) and finally a computer for results calculations.

There are approximately five more famous manufactures of the Instrumented Charpy Impact Machines in the world. They offer not only signal conditioners and amplifiers, but also exclusive softwares dedicated to process the final results. The instrumentation process of a Conventional Charpy Impact Machine requires intermediate knowledge in the signal acquisition and processing area. Some manufactures of electronic devices offer programs appropriate for communication with computers. Considering the signal processing, mathematical softwares provide commands that allow calculating the curve properties. However, the essential characteristics for the measurement system applied in Instrumented Charpy Machine are not easy of understanding.

The measurement system used for this research has been developed by GC3M (Mechanical and Microstructural Characterization Group). The final result to be reached is to determine a viable, accurate and easy measurement platform for applications in any Charpy Impact Test Machine. Thus, one of the solutions for easy operations bases on automation of impact signal acquisition and processing by using just one computational routine for the complete process.

The signal acquisition can be performed through exclusive software of conversor A/D equipment or interfaces and programming command of conversor. After transferring the data to computer, the signal processing involves the mathematical calculations and response curve plotting of the Instrumented Charpy Impact Test.

Two configurations of signal acquisition and processing were used in this work: the first involves the WaveStar software offered by A/D conversor manufacturer. It was applied to promote the communication between digital oscilloscope Tektronix TDS 220 and computer. Matlab 6.0 was used later to calculate the final results and plot the signals. The second configuration excluded the WaveStar software. The communication between oscilloscope and computer was performed by using just Matlab and adopting characters of *American Standard Code for Information Interchange (ASCII)*.

2. Material and equipments

In this study, the objective was not the material charactering. The specimen geometry and dimensions used in this study was the conventional Charpy specimen (10x10x55 mm). The specimen fracture plane orientation for Charpy V-notch was L-T (longitudinal-transverse).

The Instrumented Charpy Impact Test was performed on a pendulum Charpy impact machine having a capacity 300J at room temperature and the impact velocity 5.5m/s. The striker edge is normally designed according to ISO/DIN standards that is the same as 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. 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 load 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. 1. For the tests reported the data acquisition was performed using a amplifier with 200kHz frequency response, developed by Laboratory of Qualities of Energy at Universidade Estadual Paulista – UNESP/FEIS/DEE. The A/D conversor was a Tektronix two-channel Type TDS 220 12-bit digital oscilloscope with a maximum sampling frequency of 1GS/s, with 2,500 memory points/channel and two signal acquisitions configurations. Fig. 2 shows the schematic diagram of the System Instrumented Charpy Impact Test.

In this study no method was used to measure de displacement of specimen. The load-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:

$$v(t) = v_0 - \frac{1}{m}\int_{t_0}^{t} F(t)dt \tag{1}$$

and

$$s(t) = \int_{t_0}^{t} v(t)dt \tag{2}$$

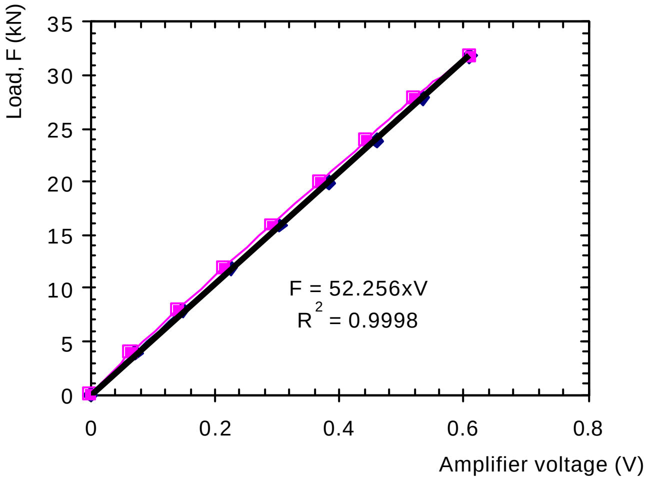


Figure 1. Calibration curve obtained for ISO tup.

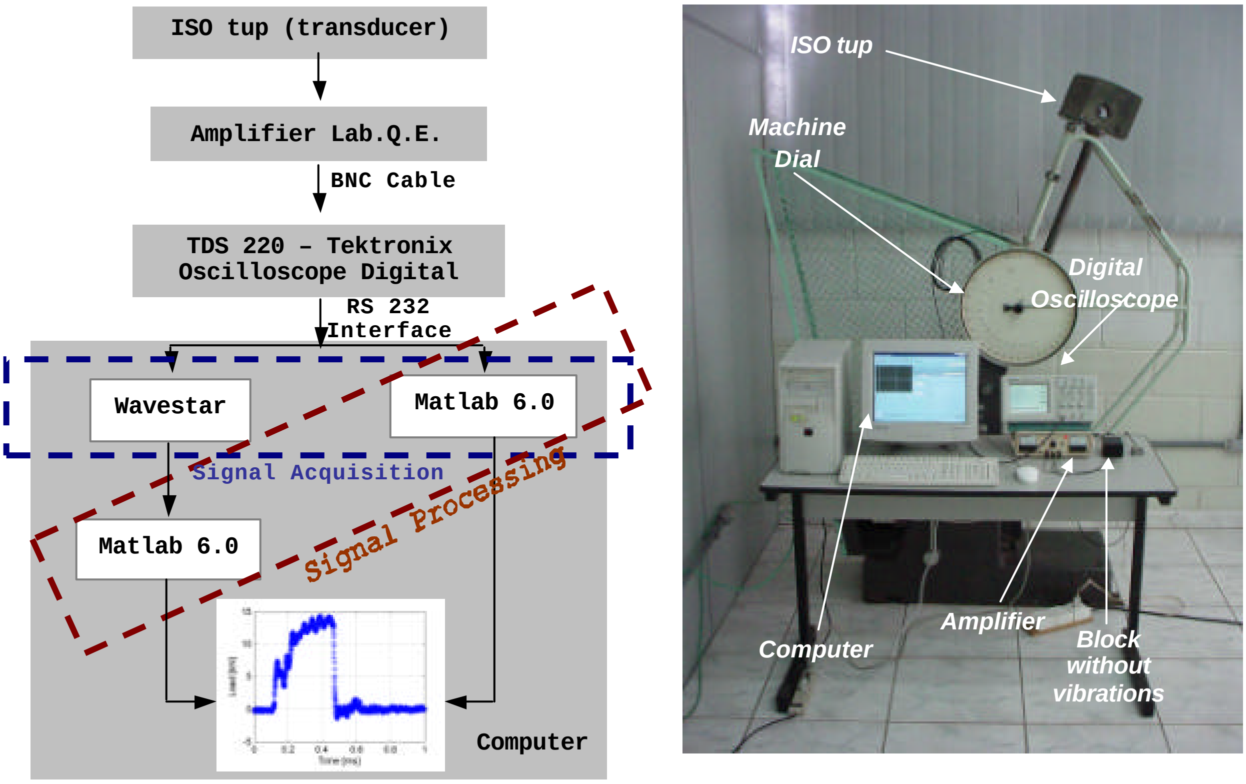


Figure 2. Schematic diagram and experimental setup of the System Instrumented Charpy Impact Test.

3. Signal acquisition and processing

3.1. Signal acquisition and processing through WaveStar and Matlab

Two softwares were used considering this acquisition and processing configuration: WaveStar and Matlab. The first software performed the communication between oscilloscope and computer through RS-232 interface. The data measured in each oscilloscope channel were provided in 2,500 x 1 matrix, which corresponds to 2,500 points per channel. The disadvantage of this signal acquisition system was the absence of commands for mathematical operations of the measured data vector.

The WaveStar software did not allow determining the estimated displacement from Instrumented Charpy Impact Test by applying Eq. (2). Meantime, the Matlab 6.0 software was used to calculate the double integration and determine the estimated displacement. Furthermore, the Matlab was useful because presented mathematical commands specially prepared for numerical integrations.

The communication between two softwares was done by saving the data originating from WaveStar with “txt” extention and later loaded them to Matlab. These procedures required a lot of attention and appropriate denomination for files “txt” in order to control all a piece of information provided by tests. Each signal acquisition and processing elapsed around 2 minutes. The methodology applied in signal processing is schematically presented in Fig. 3.

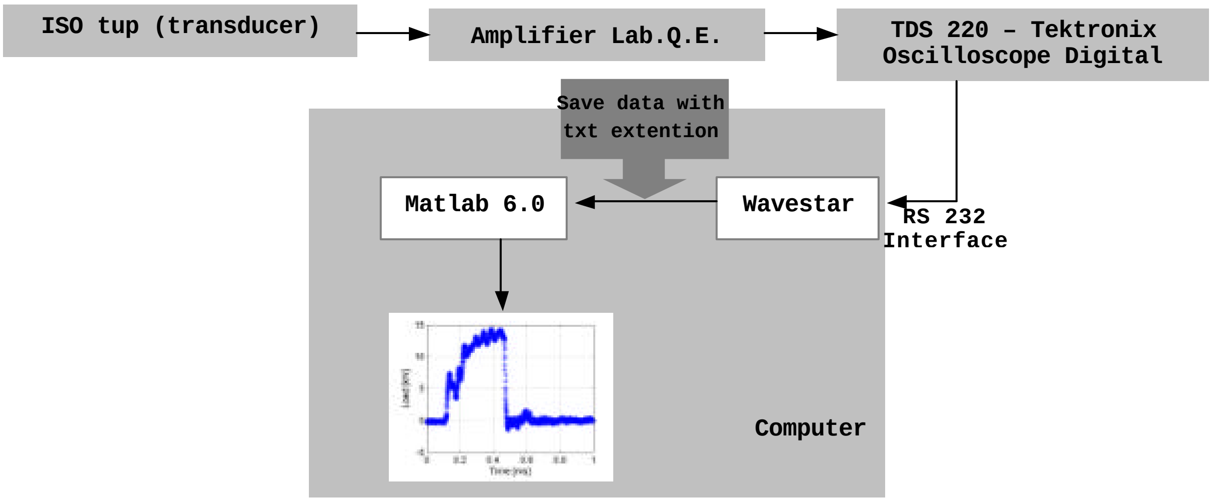


Figure 3. Schematic diagram of the Signal Acquisition and Processing by WaveStar and Matlab softwares.

3.2. Signal acquisition and processing through Matlab

The WaveStar software was unconsidered in this methodology. A unique computational routine was implemented for processing and capturing the signal. The computational routine was composed by commands and functions. The routine was developed by applying Matlab and allowed the serial port interface communication.

Matlab’s serial port interface provides direct access to peripheral devices such as modems, printers, and scientific instruments that you connect to your computer’s serial port (MATLAB External Interfaces, 2001).

Over the years, several serial port interface standards have been developed. These standards include RS-232, RS-422, and RS-485 – all of which are supported by Matlab’s serial port object. In this study, the used interface standard for connecting computers to oscilloscope is RS-232. The serial port object supports functions and properties that allow you to configure serial port communications, use serial port control pins, write and read data and record information to disk (MATLAB External Interfaces, 2001).

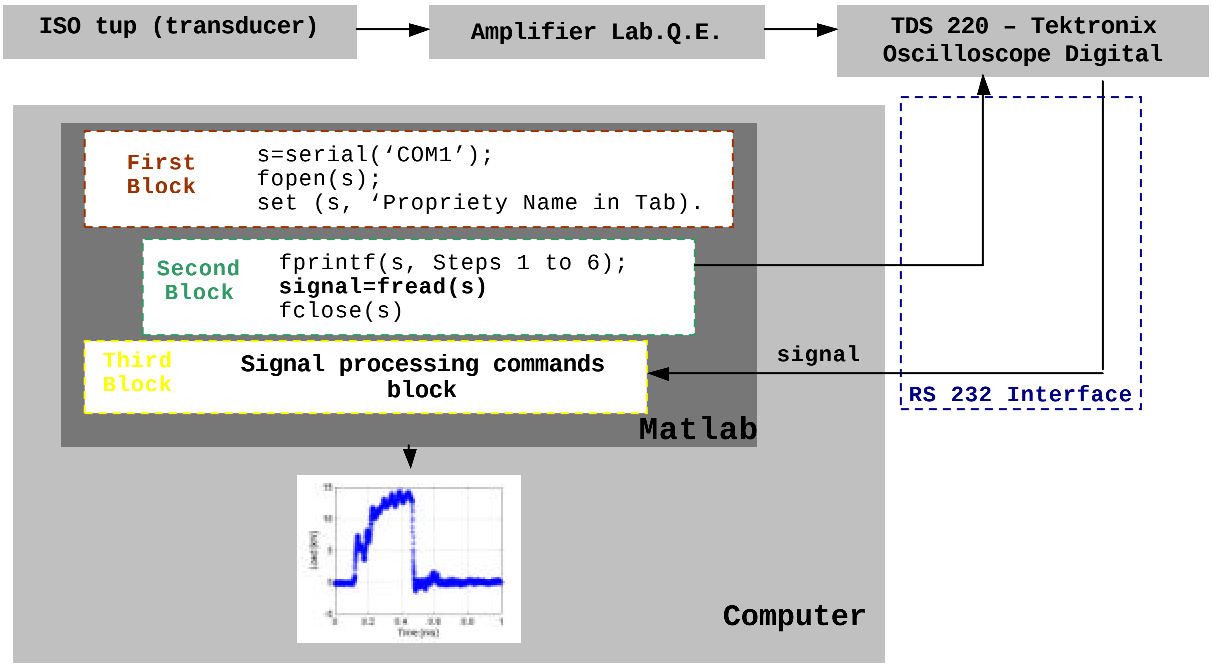
The commands were transmitted to the oscilloscope using the enhanced American Standard Code for Information Interchange (ASCII) character encoding. Commands change instrument settings or perform a specific action (Programmer Manual, Tektronix). The commands used were classified as three blocks: the Matlab commands block to set communication to oscilloscope, the signal acquisition commands block and the signal processing commands block. The last block was used in methodological from item *2.1. Signal Acquisition and Processing through WaveStar and Matlab*.

The first command *serial function* established the communication between oscilloscope and Matlab. Then, it created and required the name of the port connected to oscilloscope as an input argument. It was used port COM 1, so the serial port object in Matlab was given by s=serial (‘COM1’). The methodology applied in signal acquisition and processing by Matlab is schematically presented in Fig. 4.

3.3. Matlab commands block

3.3.1. Matlab commands block to set communication to oscilloscope

Before writing or reading data from oscilloscope, both the serial port object created in Matlab and the device must have identical communication settings (MATLAB External Interfaces, 2001). Configuring serial port communications involves specifying values for properties that control the baud rate and the serial data format. These properties are given in Table 2.



```
s=serial('COM1');
fopen(s);
set (s, 'Propriety Name in Tab).
```

```
fprintf(s, Steps 1 to 6);
signal=fread(s)
fclose(s)
```

Figure 4. Schematic diagram of the Signal Acquisition and Processing through Matlab

Table 2. Communications settings of the Matlab's serial port object.

Property Name	Description
BaudRate	Specify the rate at which bits are transmitted
DataBits	Specify the number of data bits to transmit
Parity	Specify the type of parity checking
Terminator	Specify the teminator character
InputBufferSize	Specify the size of the input buffer in bytes
Timeout	Specify the waiting time to complete a read or write operation

The commands used to set the proprieties communications in Matlab was "set" function. For example, to set de property BaudRate of serial port object created in Matlab just using the: set(s, 'BaudRate', 9600). The oscilloscope communications settings was done own device. The settings properties in this study was: BaudRate: 9600, DataBits: 1, Parity: none, Terminator: CR, InputBufferSize: 10000 and Timeout: 15 seconds.

3.3.2. Signal acquisition commands block

The first step in acquisition process was connected the serial port object created in Matlab to oscilloscope. The connection was done with *fopen function*, fopen(s), s is serial port object created in Matlab.

The oscilloscope control via Matlab was done with *fprintf function*. It was necessary to know what the oscilloscope commands to transfer data. These commands were found in the Programmer Manual, Tektronix, 2001. To transfer signal or waveforms from the oscilloscope to computer, do the following steps with *fprintf function* (Programmer Manual, Tektronix):

1. Use the Data:Source command to select the signal source.
2. Use the Data:Encdg command to specify the signal data format.
3. Use the Data:Width command to specify the number of bytes per data point.
4. Use the Data:Start and Data:Stop commands to specify the portion of the signal that you want to transfer.
5. Use the Wfmpre command to transfer waveform preamble information.
6. Use the Curve command to transfer signal data.

For example, to transfer the signal to Matlab, it's necessary to send to oscilloscope the Curve command by the *fprintf function*: fprintf(s, 'curve?'). After the signal data transferred to Matlab, another Matlab function was used to read the data. This function is *fread*. The schematic diagram of the Signal Acquisition and Processing through Matlab is showed in Fig. 4.

3.3.3. Signal processing commands block

All signal acquisition and processing configurations used the same signal command block. The sign processing performed by Matlab applied 5 operations to present the response curve of Instrumented Charpy Impact Test. For each operation, several Matlab functions were used. These operations are mentioned below:

1. Data input: ISO tup (transducer) calibration factor;
2. Correction from Voltage vector [V] to load [kN];
3. Beginning and ending setup of specimen fracture process;
4. Calculation of the estimated displacement and fracture toughness;
5. Response curve plotting of the Instrumented Charpy Impact Test.

4. Results and discussion

The results are provided graphically and plotted through two signal acquisition and processing settings. All signal characteristics were maintained in their configurations. Figure 5 represents a signal obtained from impact test with energy 23 Joules measured by Charpy machine dial. The curves are presented as load-time, load-displacement estimated, load-time-toughness, load-displacement estimated-toughness. The curve load-time represents the impact signal from strain gages attached onto ISO tup (transducer), and the others curve were calculated by signal processing command block. The curve load-displacement estimated was determined by double numerical integration, Eq. (1) and Eq. (2). The curve load-time-toughness was determined using a Matlab function, calling *trapz function*, that by a single integrate from curve load-time. It same happened to curve load-displacement estimated-toughness, but from curve load-displacement estimated.

It is relevant to mention that the essential difference between the configurations of signal acquisition and processing based on operational time spent for each procedure. The configuration with WaveStar and Matlab elapsed around 2 minutes. However, the configuration with Matlab only provided a reduced time nearly 30 seconds. Thus, the operation time reached a reduction of 75%.

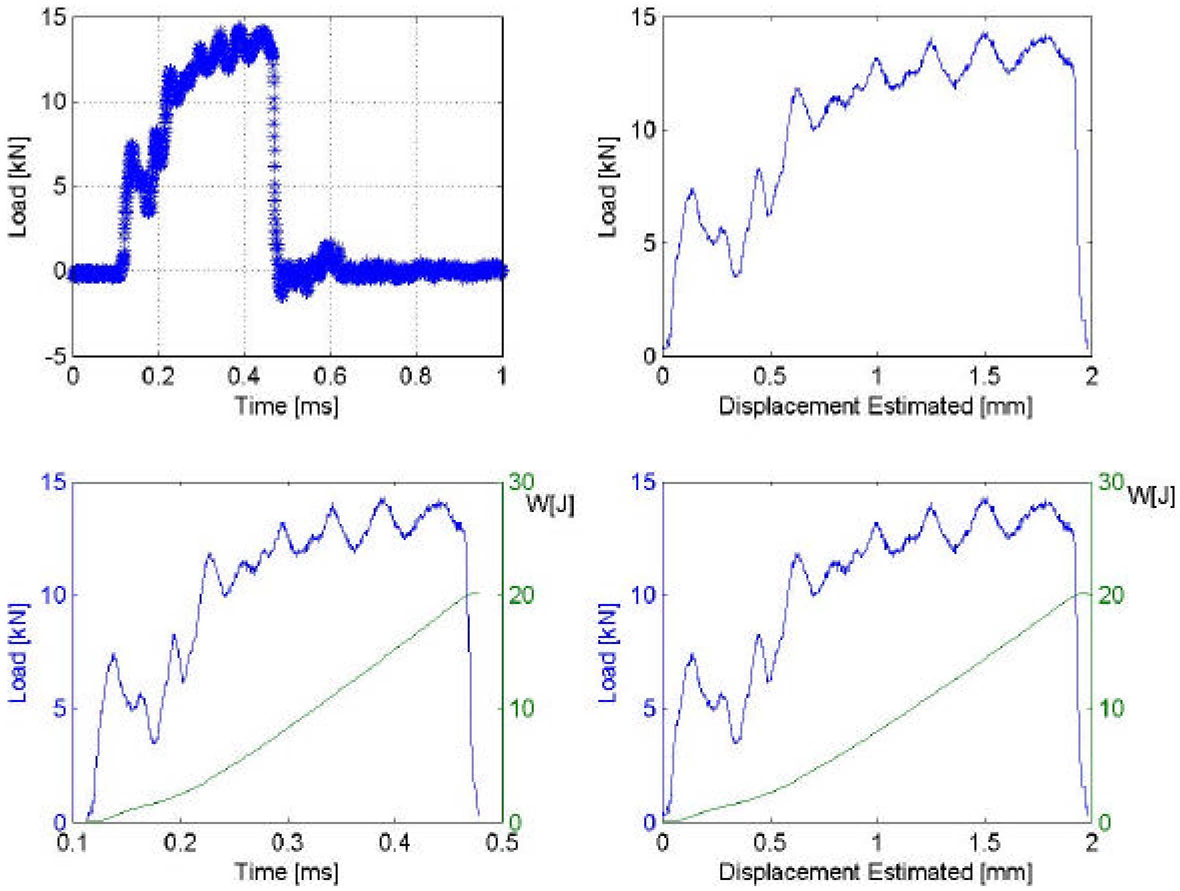


Figure 5. Curves load-time, load-displacement estimated, load-time-toughness, load-displacement estimated-toughness of the specimen with toughness read on machine's dial equal 23 Joules.

5. Conclusions

Details of the programming Matlab to acquire and process the instrumented Charpy Impact Test signal were introduced in this article. The signal can be acquired and processed rapidly and simply by one computing routine. This configuration of signal acquisition and processing will be use on the next works to evaluate the dynamic fracture toughness for both ductile and brittle materials.

The signal acquisition block was a perfect tool to acquire any signal from any device with ASCII and serial interface. In this study, one channel from device was used but the oscilloscope has two channel to read. In a future, it will be develop a new signal acquisition block to read the both channel.

The measurement system used in this study is by according with ISO 14.556 standard. This system can be installed on any conventional Charpy impact machine for any impact energy. The measurement chain construction was developed with strain gages and signal proprieties concepts. It knows that this measurement system developed with strain gages concept is more inexpensive than a comercial instrumented machine. An others measurement system with piezoelectric concepts had been developed with a good accuracy, but the equipments used are more expensive than strain gage equipments.

6. Acknowledgements

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