A simple approach for modeling impact force parameters for different materials

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Abstract – *On this paper we consider the case of impacts between rigid objects. We are interested on estimating the impact pulse-width and peak force for different materials over a wide range of masses. Some experiments were conducted in order to calculate real values for specific masses, and then a fitting curve model was used to predict new parameters for objects with different masses.*

Keywords – *Parameters Modeling, Impacts*

INTRODUCTION

On this paper we investigate the case of impacts between rigid objects and the estimation of two important parameters: the impact pulse-width, and the peak force. These parameters are required in order to perform a signal processing analysis based on neural networks [1], where the training signals are calculated using a model of the impacting force that is generated during the collision. The purpose is to characterize the response of different materials, like steel, aluminium, bronze, and brass.

A previous work [2] showed that these parameters are largely dependant on the mass of the colliding objects. For this reason, an experimental investigation has been conducted for estimating real values of pulse-widths and peak forces for some specific masses, then a study developed to analyze if it is possible to fit this values into a model, in order to estimate new parameters values for objects with other masses.

PROCEDURE AND EXPERIMENTAL SET-UP

For this study, we propose to use an impact generator device [2], and 12 cylindrical samples of different materials (steel, aluminium, bronze, and brass). Samples dimensions are as follow: all are cylinders with a diameter of $d_c = 30\ mm$, and there are three lengths: $L_1 = 10\ mm$, $L_2 = 30\ mm$, and $L_3 = 50\ mm$, designated as the small, medium and large samples, respectively. Correspondent masses are shown in Table 1. The impacting device is a sensorized impactor on a pendulum, like the one shown in Fig. 1. Samples are located over hard foam and it is possible to adjust the impacting speed by changing the impactor's swing angle. The sensor mounted on the impactor is an accelerometer and its signal is acquired through a 12-bit analog-to-digital converter with a sampling frequency of 2.5 MHz.

Table 1.

Material	**Samples weight in [gr]**		
	Small	**Medium**	**Large**
Aluminium	21.3	61.6	102.3
Steel	56.3	166.9	277.1
Bronze	70.4	209.5	348.1
Brass	60.8	180.1	299.6

Impactor effective seismic mass: 100 gr

In order to have a representative measurement of the impacts, for each sample, ten individual impacts are used to calculate a mean average response in the time domain. From these, the parameters pulse-widths and peak forces are measured, for each material.

With these values, a rational model is used to calculate the best fit curve approximation. Two linear polynomials are used for the numerator and the denominator, as shown in equation (1) [3], with coefficients p_1 and p_2 for the first one, and q_1 for the last one.

$$f(x) = \frac{(p_1 \cdot x + p_2)}{(x + q_1)} \qquad (1)$$

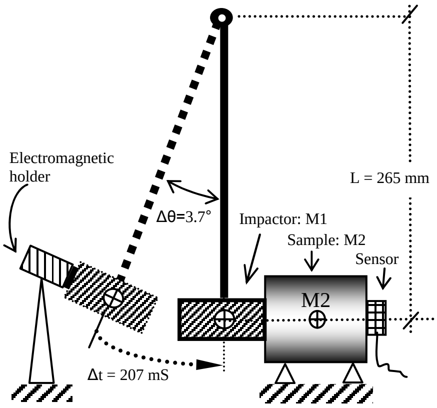

Fig. 1. Impacting device

RESULTS AND CONCLUSIONS

From the experimental measurements using the impacting device, and after applying ten impacts to each sample and averaging the results, the pulse-width and the force peak parameters were calculated. Using these values and the *MATLAB* curve fitting tool, the coefficients p_1, p_2 and q_1 were calculated.

On Fig. 2, a plot of the "pulse-width *Vs* mass" shows the relationship between these two parameters. Hard markers indicate the actual values obtained form the experiments, and dotted lines indicate the model fit approximation. As it can be observed, each material has its own tendency. It is interesting to notice that brass and bronze follow parallel trajectories and never cross, probably because both are mainly made with copper and a different alloy mixture that causes this shift. Aluminium and steel also follow their own trajectory, but cross each other in the beginning of the graph.

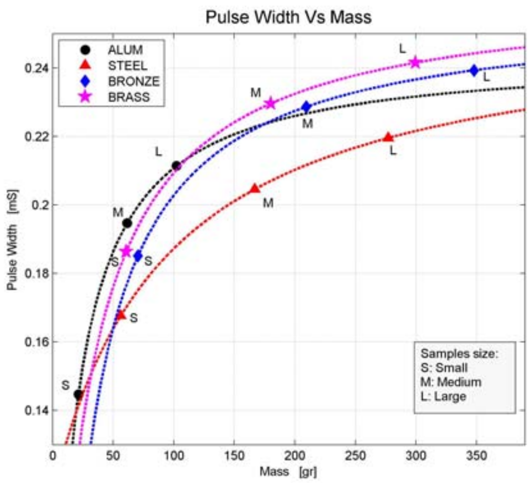

Fig. 2. Pulse-width Vs mass. Hard markers are known experimental results. Dotted lines are curve fitting results.

The relationship between the "pulse-width *Vs* peak force" is shown in Fig. 3. Here as well a model has been calculated and hard markers indicate experimental values for each material. As it can be observed, the peak force increases as the mass and the pulse-width became larger. Brass and bronze show also similar behavior, with a pronounced curve, and for the case of aluminium and steel, the curve is smoother.

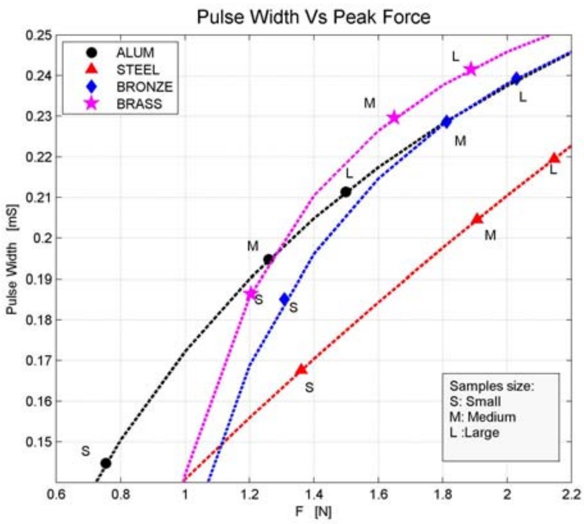

Fig. 3. Pulse-width Vs Peak Force. Hard markers are known experimental results. Dotted lines are curve fitting results

From these results, it is possible to conclude that the data fitting can help to estimate the value of the pulse duration and the value of the maximum force amplitude for objects with different masses and materials, with the advantage that it is not necessary to make specific experiments for every sample. Further work will be conducted to test the procedure for training the neural networks that require these parameters.

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