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EXPERIMENTAL DESIGN, MODELLING AND NUMERICAL CALIBRATION OF A HIGH SPEED SHPB MECHATRONIC SYSTEM USING A PNEUMATIC PROPULSION DEVICE

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Abstract: *This research paper focus on the experimental design and analytical/numerical analysis of a high speed pneumatic compression SHPB bench performed at INSA Rennes (France) – LGCGM Laboratory. The main goals are to present details concerning an improved mechatronic data acquisition system, the performances of the air propulsion system in terms of impact velocities prediction and measurement, together with a novel hybrid analytical-numerical calibration method. This proposed SHPB calibration and numerical analysis method is based on a complete finite element simulation starting from a dynamic elastic equilibrium model and the dynamic mechanical interactions at the interfaces between the striker bar undergoing high pressure air-impact speed propulsion, the incident and the sending bars. As real application of proposed complete FE model has been mentioned the previous and actual research works at INSA Rennes on the use of a two-step inverse analysis technique to identify thermo-mechanical constitutive equations of materials subjected to high strain rates and important gradients of plastic strain, strain-rate and temperature.*

Keywords*: Pneumatic SHPB Device, Mechatronic Design, Impact Velocity Estimation, Analytical-Numerical Calibration, Complete SHPB Finite Element Modelling, Hybrid Analytical-Numerical Model Validation*

1. Introduction

During many manufacturing processes or industrial applications developed in the second half of the 20th century, various metallic or non-metallic structures are subjected to high rates of loadings, severe elastoplastic strains, strain rates and temperatures or localized gradients of strain-stress developed during an impact, choc or crash. The modelling of corresponding material thermos-mechanical behavior becomes a real scientific key which requires design of corresponding dynamic experimental tests together with the use of a rigorous calibration method and reliable data analysis via improved analytical or numerical models. According to the high strain rates which occur during these dynamic tests, elastic waves propagate in the system bench and specimen material at speeds of several kilometers per second. Therefore it is difficult to have an intuitive understanding of the observed physical phenomena. In order to perform quality measurements during the dynamic deformations obtained from rapid loadings, it is nevertheless necessary to take account the description of elastic wave propagation phenomena. The first high-speed mechanical stress tests were conducted around 1870 by John Hopkinson who developed a type of apparatus based on a specific mechanisms to impact a cylindrical bar. In 1914, Bertram Hopkinson [1] introduced a pressure bar to study dynamic events such as the explosive detonation or the impact of different types of projectiles. Essentially, the Hopkinson pressure bar uses the propagation of elastic strain wave's theory to predict strains and stress developed in a material sample. Hopkinson discovered that the small local displacements in the bar are directly related to the length of the elastic wave obtained during the very short times of the impact caused by the material sound celerity. In the case of materials subjected to an impact through a projectile Davies [2] shows in 1948 that it is possible to measure the temporal form of the generated elastic wave using strain gauges instrumented bar. Starting from these previous old studies the first Split Hopkinson Pressure Bars system (SHPB) was introduced in 1949 by Kolsky [3] which has used a gas propulsion device to obtain high speed of a projectile bar and add two other metallic bars (named incident and sending bars) to realize a dynamic compression. Typically the SHPB device offers material testing capabilities for speeds up to 30-40 m/s at strain rates in the range of 10^2 to 10^4 s^{-1}. A lot of other dynamic experimental set-up has been developed further: the Taylor test (gas or explosive propulsion around of 100 m/s), Crossbow device (speed up to 10-30 m/s), Weight Falling, traction or torsion Hopkinson Bars and more recently specific hydraulic press using particular actuators and control devices (speed up to 10 m/s).

The main purpose of this scientific paper is to describe a mechatronic SHPB compression test designed on GCGM Laboratory (INSA Rennes) using a pneumatic propulsion with a robust control of air pressure, laser camera measurement of projectile bar speed, automatic electronic data acquisition of bar's elastic deformations and a calibration method developed from a hybrid analytical and numerical finite element system modelling.

2. Experimental Principle of Pneumatic SHPB System

Kolsky found that the stress and the deformation of an impacted specimen can be directly related to the displacements of the incident and sending bars. Contrary of the Hopkinson pressure bar, in the SHPB device the projectile does not strike directly the specimen. It is first a receiving or incident bar that receives the impact of the projectile (striker bar) and that is subjected to a lot of dynamic elastic deformation pulse. The obtained elastic wave of the receiving bar it is more intense as the speed of projectile is high and is lasts time longer as the projectile is long. This wave is reflected partially by the material sample, the other part passes through it and is subsequently transmitted to a second bar (named sending or transmitter bar) [4-7].

2.1 Framework and design characteristics

The SHPB system designed at GCGM Laboratory of INSA Rennes is presented in the Figure 1.

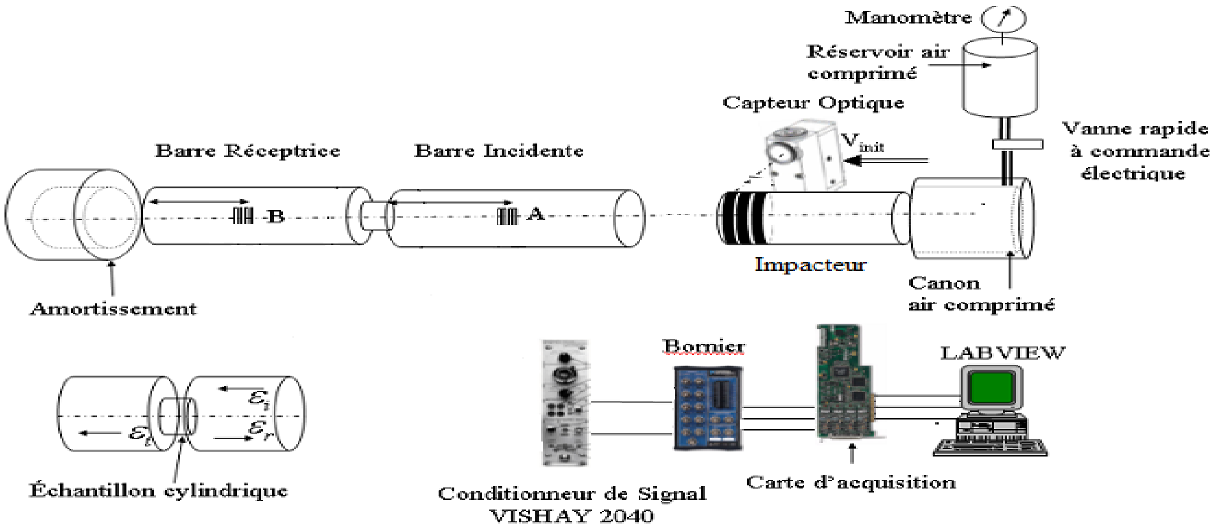


Fig.1. General schema of the compression Split Hopkinson Pressure Bars (SHPB) bench: pneumatic propulsion bars design with automatic acquisition of laser camera and strain gauges A/B signals (incident $\varepsilon_i(t)$, reflected $\varepsilon_r(t)$ and transmitted $\varepsilon_t(t)$ elastic deformations) performed with a Labwiew program, true stress - true strain curves of material specimen obtained from David code [8].

According to the general theory of elastic wave propagation [4-8], to the type of specimen's materials and to the desired obtained strain and strain rate, the choice of the material and bars geometric size requires to take into account some physical conditions. In a first time it is necessary to have similar elastic impedances of the bars as those of tested material specimens. In particular for steels, aluminum or titan alloys, the hardened high strength steel MARVAL18 is used (Table 1).

Table 1: Mechanical end elastic properties of the MARVAL 18 steel bars

Temperature 20°C	E_b [GPa]	υ	$R_{0,2}$ [MPa]	ρ_b [Kg /m^3]	$c_b = \sqrt{E_b / \rho_b}$ [m/s]	$Z_b = \rho_b c_b = \sqrt{\rho_b E_b}$ [Kg/m^{2}s]
MARVAL 18	186	0,33	1840	8000	4821,82	$38{,}57 \cdot 10^6$

To avoid superposition of measured elastic strain gauges by incident and sending bars [7-8] it is necessary to take into account the minimum measurement time using the following relationships:

$$\Delta t_{measure} = t_i = \frac{2 l_{bimp}}{c_b} \leq \frac{l_{bi}}{c_b} \quad \text{and} \quad \frac{l_{bt}}{c_b} \geq \frac{0.5 l_{bi}}{c_b} \tag{1}$$

It is then required to have $l_{bi} \geq 2 l_{bimp}$ and $l_{bt} \geq 0.5 l_{bi}$. Taking into account the maximal average plastic strain of material specimen estimated from the large displacements compression theory by $\bar{\varepsilon} \approx \ln\left[1-(2 v_{imp} l_{b_{mp} i} / l_0 c_b\right]^{-1}$, for a specimen length l_0 = 10 *mm* and an impact velocity v_{imp} = 10 *m/s*, a value around of 25%-50% can be obtained for $l_{bimp} \in [0.5m, 1m] \Rightarrow l_{bi} \geq 1m \div 2m$ and $l_{bt} \geq 0.5m \div 1m$. Furthermore to minimize the effect of the dispersion elastic waves and to have conditions close to the infinite bar wave propagation theory [7], the bars diameters d_b must to be very small as compared to the twist of striker lengths i.e. $d_b \ll c_b t_i = 2 l_{bimp}$. Table 2 synthetizes the chosen geometric characteristics of the Hopkinson bars in order to perform compression impact tests with large plastic deformations of material specimen.

Table 2: SHPB bars geometric characteristics (total length of table support ≈ 5,5 m)

Bars	Air Gun	Striker Bar	Receiving Bar	Sending Bar
Material	MARVAL 18	MARVAL 18	MARVAL 18	MARVAL 18
Diameter [mm]	ϕ_{in} 30.0 and ϕ_{out} 40.0	ϕ 16.0	ϕ 16.0	ϕ 16.0
Length [m]	2.0	0.602 (0.5÷1)	2.0	1.3

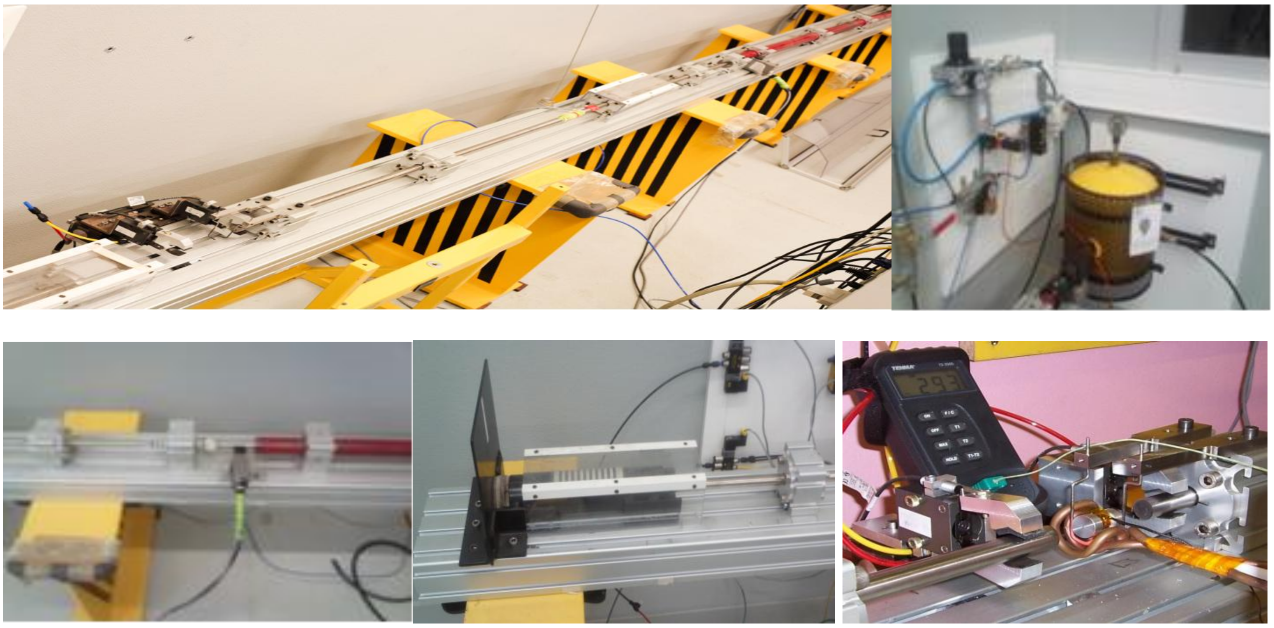


Fig. 2. General view pictures of experimental pneumatic SHPB bench with presentation of principal control and measurement devices

As can be shown in the Figure 2 the striker bar is driven by a pneumatic device using a tank with a volume V_0 of *20* l coupled on a pressurized air via a circuit of rapid control, regulate and secure valves. Using a lot of plastic collars mounted on the striker bar, this one is moved in axial translation by the air pression propulsion on a distance of *1 m* inside the gun undergoing a small friction effect. The axial impact velocity is measured by a laser camera reading a barcode of *50 mm* large with a length of $\lambda_v = 5mm$ for each uniform ditributed white/black slotes, glued on the end of impactor bar surface. So the initial impact speed value is obtained by division of the slote length λ_v with the corresponding measured period times T_v recorded from a specific Labview programm coupled on a high speed NI PCI 6110 acquition card (5 *MHz*). This program is also performed to record in Volt the signals of the twice strain full bridges mounted on the half part of the incident bar and half part of the sending bar using a digital conditionner VISHAY (Figure 1). So the incident $\varepsilon_i(t)$, reflected $\varepsilon_r(t)$ and transmitted $\varepsilon_t(t)$ elastic deformations of the bars can be estimated from a direct conversion or from calibration techniques. Computation of interfaces velocities and loads can be performed from analytical relationships based on the general dynamic elastic deformations propagation inside the bars [7] using David software [8]. An infrared camera and inductive heating coil toghether with a thermal control device, able to keep the initial metallurgical structure of metal specimen and to measure the material self-heating, was provided to make possible tests at different initial temperature [9-11]. It is then possible to identify the thermo-mechanical material specimen behaviour in terms of true stress-elasto-plastic strain for differents strain rates and temperatures using plasticity theory, analytical methods and inverse analysis strategy [9-14].

2.2 Details of pneumatic circuit and Labview data acquisition program

As shown in Figure 3, the propulsion control system of SHPB bench is fully pneumatic and in open loop. When the desired pressure is reached, the air gun is triggered manually by the operator. This operation is sufficient for the tests performed and presented in this article.

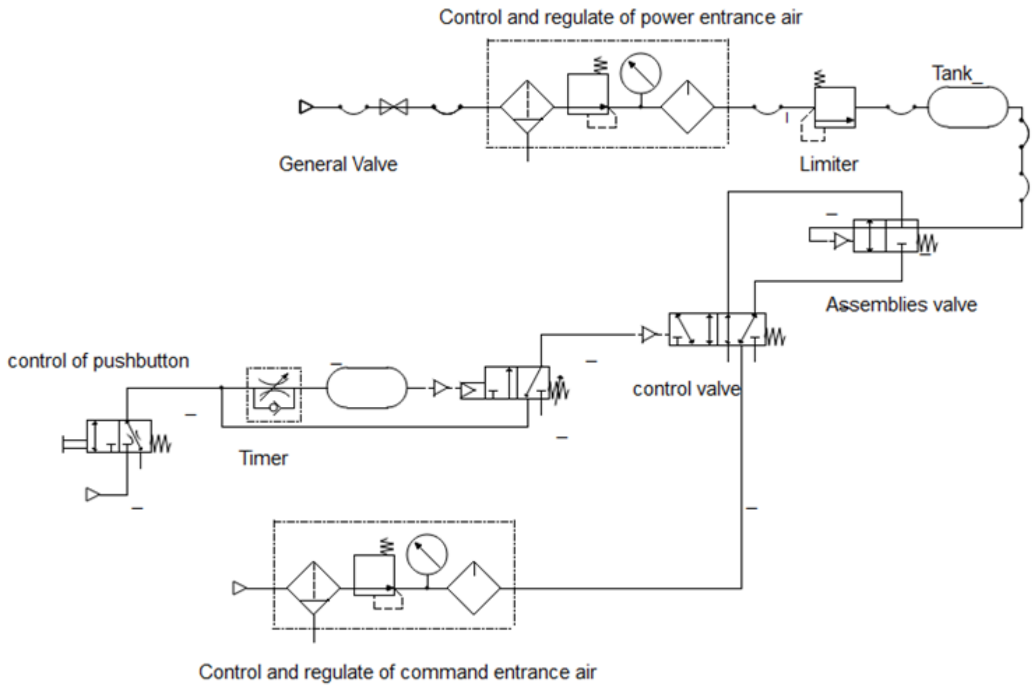
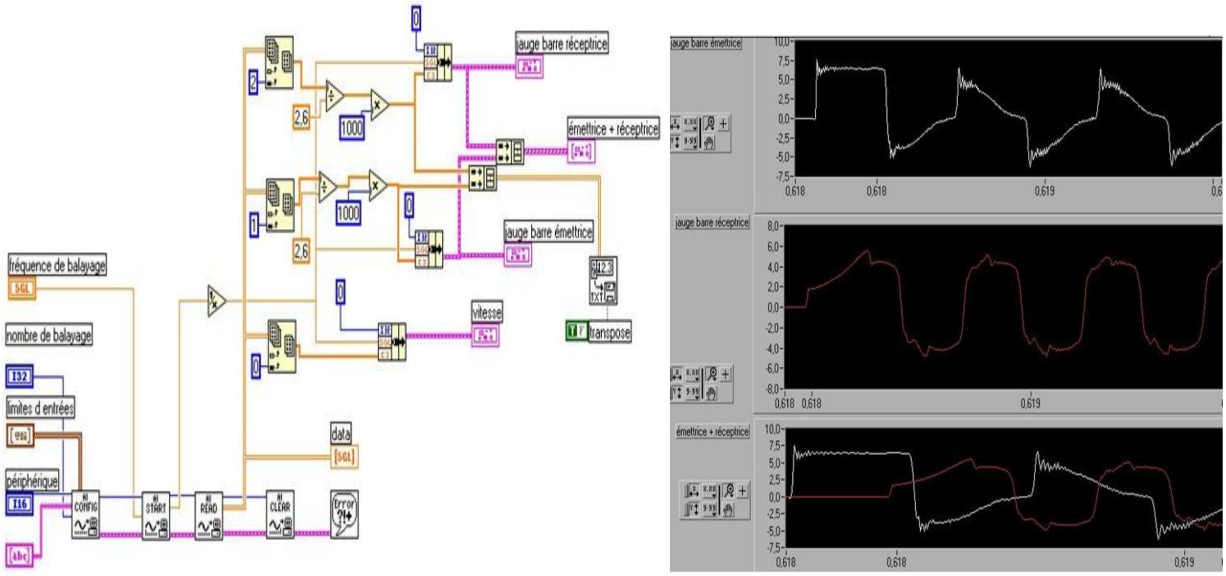


Fig. 3. Pneumatic control circuit used for propulsion of experimental SHPB bench

However, the implementation of a digital control system with feedback of different states of the system will improve its control allow precise and constant pressures when start the move of the striker bar inside the air gun. To resume, with an automatic control system, the pressure keep constant value on the time gap between value pressure regulation and the launch of the test, the repeatability and robustness of the experiments guaranteed and more rigorous studies will be possible. After starting and triggering of the rapid control valve, the air gun projects the striker against the receiving bar. Before the shock, the laser sensor captures on the front of the incident bar the variation of a signal from an uniform succesion of black and white slots with a length of λ_v. Thus is generate a square-shaped signal of period T_v, where the first rising edge acts as a trigger for optical sensor acquisition. The impact speed is deduced there from the ratio λ_v / T_v. The Labview language program developed for a real time acquisition of the optic sensor and gauge full bridges raw signals (Figure 4) allows adjustment of the acquisition frequency f_a and of the scanning number b_s. The product $f_a \cdot b_s$ determines the total acquisition duration.



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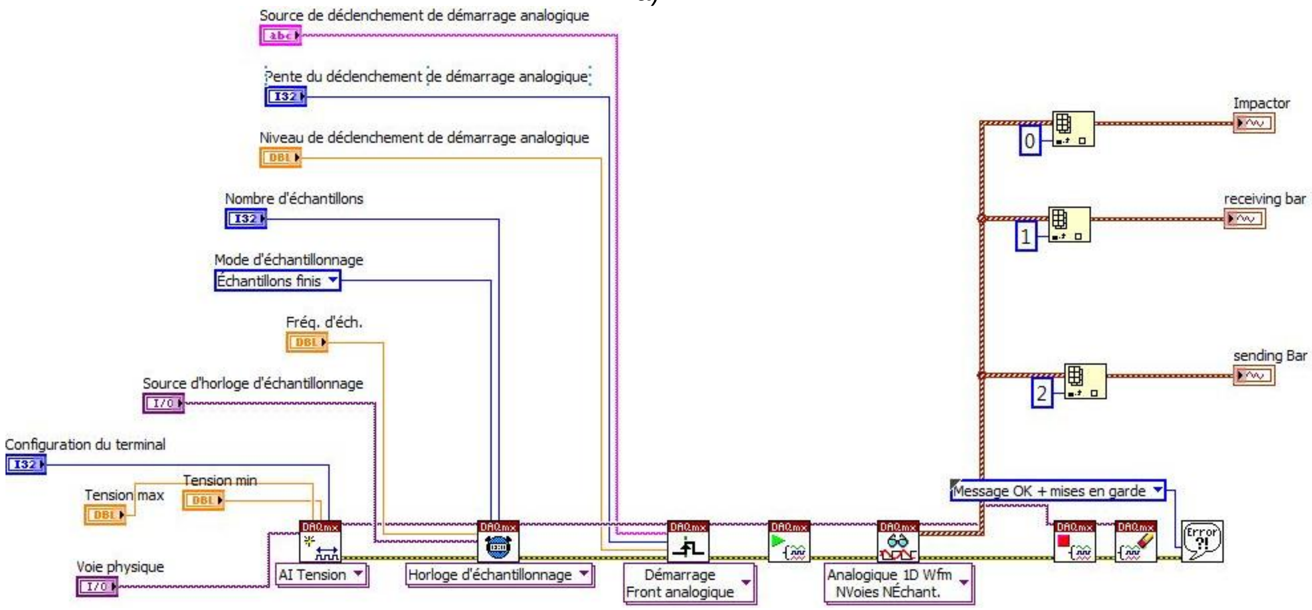


b)

Fig. 4. Labview program of experimental data acquisition a) version using gauge bridges calibration factor to recorded elastic strains signals $\varepsilon_i(t)$, $\varepsilon_r(t)$, $\varepsilon_t(t)$ in μdef, b) version using automatic triggering and record of gauge bridges tensions expressed in Volt

2.3 Theoretical estimation of initial impact velocity

Using theorem of mechanical energy balance the kinetic energy variation of the striker ΔE_c is equal to the work *W* of the bar surface force generated by air pressure i.e.:

$$\Delta E_c = \frac{1}{2}mv^2 = W = \int_0^l \left(\iint p(x)dS \right) dx \text{ with } m = \rho g l_{imp} \pi d_b^2 / 4 \tag{2}$$

where *m* is the mass of the striker bar, *v* the impact velocity obtained after the move on a distance equal to *l* and *p(x)* represents the air pressure value of each axial bar position *x*.

Or if p_c is the initial absolute pressure inside the tank of volume V_0, taking into account the atmospheric pressure p_0 and the isothermal perfect gas law the axial pressure variation is obtained from:

$$p(x)(V_0 + Sx) = p_r V_0 \text{ with } p_r = p_c - p_0 \tag{3}$$

Consequently, assuming a uniform pressure distribution on the plastic collar glued on the bars along its section *S,* the corresponding mechanical work can be computed by:

$$W = \int_0^l p(x) S dx = \int_0^l \left(\frac{p_r V_0 S}{V_0 + Sx} \right) dx = p_r V_0 \ln\left(1 + \frac{lS}{V_0}\right) \tag{4}$$

Starting from Eq. 2 the obtained impact velocity can be obtained from the following relationship:

$$v = \sqrt{\frac{2V_0}{m} \ln\left(1 + \frac{lS}{V_0}\right)} \cdot \sqrt{(p_c - p_0)} \text{ or } v = \left(\alpha / \sqrt{l_{imp}}\right)\sqrt{(p_c - p_0)} \tag{5}$$

Here α is a variable depending of tank capacity, inner section $S = \pi\Phi^2/4$ of the gun, material and geometry of the bars. Starting from the SHPB material properties and geometric characteristics given on Table 1 and 2 the tank volume is $V_0 = 20\,l = 2 \cdot 10^{-2} m^3$, the displacement is *l=1m* and the collar surface glued on the front of the striker bar has a surface $S = \pi \cdot 30^2 / 4 \times 10^{-6} m^2 = 706{,}86 \times 10^{-6} m^2$ which approximate $\ln\left[1 + (lS/V_0)\right] = 0{,}035$ and $\alpha \approx 0{,}029$.

Variations of estimated impact velocities for different striker bar lengths l_{imp} from 0.5 *m* to 1 *m* are presented in Figure 5 together with a comparison between the experimental values and the theoretical ones for the case of l_{imp} = 0,602 *m*.

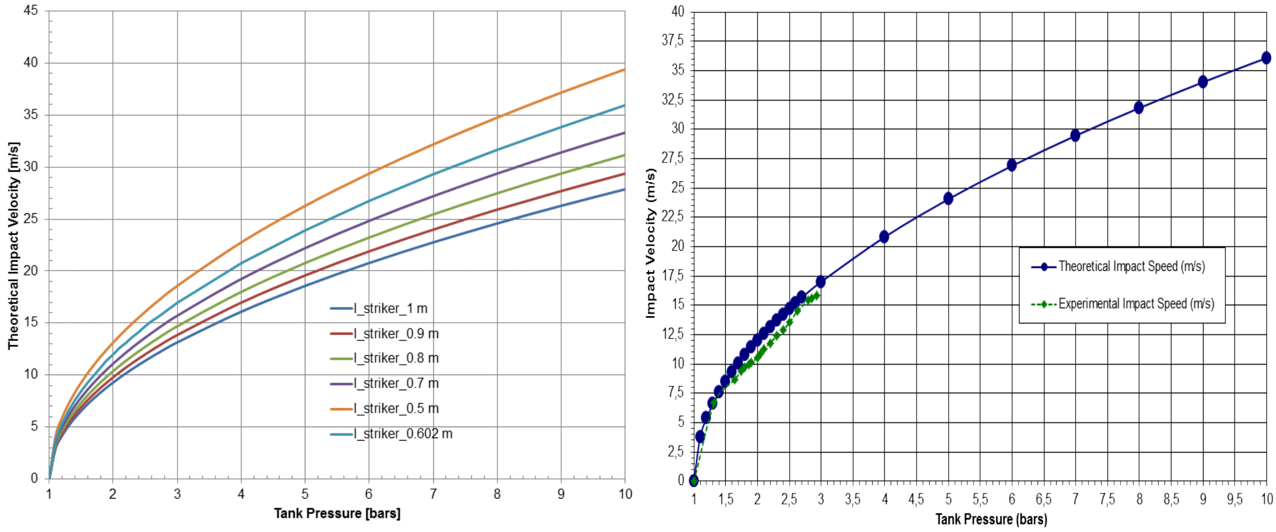


Fig. 5. a) Variation of theoretical impact speed with the absolute tank pressure for different length of striker bars (0,5 m to 1 m) b) Comparison between the theoretical impact speed and experimental values obtained for the striker with a length of 0,602 m.

It can be observed that using a maximal tank pressure of 8 bars for impactors with short length (0,5 m à' 0,6 m) the impact velocity varied from 5 *m/s* to 30-35 *m/s* as compared to an impactor with a length of 1 *m* where the maximum impact speed is limited to 25 *m/s*. The use of a striker with the length of 0,602 *m* (mass $m \approx 0,96\,Kg$), if the tank pressure is expressed in bars an estimation of impact velocity can be obtained by $v \approx 11,82\sqrt{(p_c - p_0)}$.

Table 3: Theoretical and experimental impact speed obtaned from different values of tank pressure for the striker with a length of 0,602 m

Tank Pressure (bars)	Theoretical Impact Speed (m/s)	Tank Pressure (bars)	Exp Impact Speed (m/s)
1	0	1	0
1,1	3,73	-	-
1,2	5,29	-	-
1,3	6,47	1,32	6,68
1,4	7,48	1,55	6,86
1,5	8,35	1,64	8,67
1,6	9,15	1,74	9,41
1,7	9,89	1,8	9,7
1,8	10,57	1,87	10
1,9	11,21	1,9	10,1
2	11,82	2	10,56
2,1	12,39	2,05	10,84
2,2	12,94	2,1	11,3
2,3	13,47	2,2	11,8
2,4	13,98	2,3	12,4
2,5	14,47	2,4	12,9
2,6	14,95	2,5	13,52
2,7	15,41	2,63	14,54
3	16,71	2,8	15,4
4	20,47	2,85	15,6
5	23,63	2,93	15,82
6	26,42	-	-
7	28,95	-	-
8	31,27	-	-
9	34,43	-	-
10	35,46	-	-

The experimental values of initial impact velocities measured by laser camera for a lot of tank pressures show very good correlation with the curve of theoretical variation plotted in Figure 5b and values detailed in Table 3. An average estimation error of 10 % is obtained due essentially to the friction phenomena caused by the local contact of a striker bar with the inside surface of the gun through the mounted plastic collars.

3. Finite Element Modelling and Numerical Calibration of SHPB System

In a classical way the full bridge gauge tension *U* (μV) is expressed in function of the corresponding elastic deformation value ε (μdef) starting from the formula:

$$U = U_0\left[\frac{F_g\varepsilon(1+\upsilon)}{2+F_g\varepsilon(1-\upsilon)10^{-6}}\right] \tag{6}$$

Here U_0 is the bridge supply voltage expressed in Volt and F_g the gauge factor. Starting from an acquisition frequency of 1 *MHz* caused by the very short time of the impact around of 1 *ms* it is required to record 1μ*V*/μ*def*. Consequently to obtain a reliable sensitive recorded tension, the dynamic conditioner amplifier uses a gain factor *G* ($\widehat{U} = GU$) and the equation (6) gives:

$$\varepsilon = \frac{2\widehat{U}\cdot 10^6}{U_0 G F_g (1+\upsilon) - \hat{U} F_g (1-\upsilon)} \approx \frac{2\widehat{U}\cdot 10^6}{U_0 G F_g (1+\upsilon)} \tag{7}$$

where $\widehat{U}$ (expressed in Volt) represents the tension values recorded by the output of Labview program (Figure 4) and $U_0 G \gg \widehat{U}$ i.e. $U_0 \gg U$.

As can be seen, the variation of gauge deformation with the recorded tension is quasi-linear, consequently it is possible to define the calibration factor K_{exp} by the ratio between the corresponding gauge deformation value and the recorded tension i.e.:

$$K_{exp} = \varepsilon / \widehat{U} \quad (\mu def / Volt) \tag{8}$$

For a gauge factor F_g equal to 2.09, a gain *G* around of 250 and a supply voltage of the bridge of 7.5 *V* it is obtained K_{exp} = 1000/2,6 = 384,62 μ*def /Volt*. If an empty experimental SHPB test is performed at an initial impact velocity v_{imp}, an analytical estimation of calibration factor K_{an} can be obtained from the ratio of values corresponding to incident elastic deformation $\hat{\varepsilon}_i$ and tension $\widehat{U}_i$:

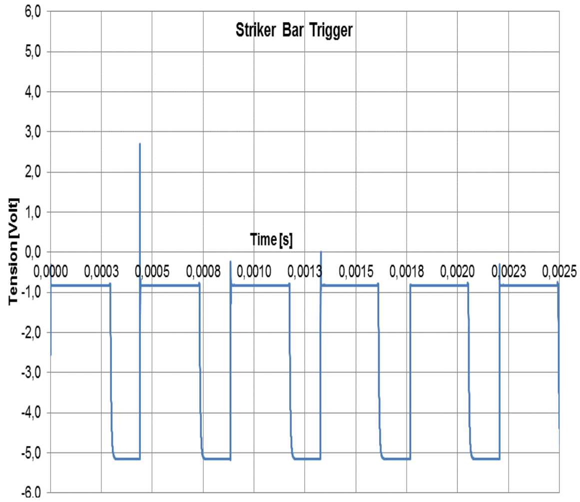
$$K_{an} = \hat{\varepsilon}_i / \widehat{U}_i \quad (\mu def / Volt) \tag{9}$$

Or the general theory of bar's elastic wave propagation shown that for an impact velocity *v* $\hat{\sigma}_i = \frac{1}{2}\rho c_b v \cong E_b \hat{\varepsilon}_i$ and $\hat{\varepsilon}_i = \frac{\rho c_b}{2E_b} v = \frac{v}{2c_b}$. So:

$$K_{an} = \frac{v}{2c_{\exp}\widehat{U}_i}\cdot 10^6 \quad (\mu def / Volt) \tag{10}$$

where the bar's celerity c_{exp} can be estimated using the expression (1) from the time period $t_{i_{\exp}}$ of the first slot of the recorded incident signal $\widehat{U}_i(t)$ by $c_{\exp} = 2 l_{imp} / t_{i_{\exp}}$.

The Figure 6 plot the recorded experimental tensions obtained from laser camera reading the striker barcode and from the full gauge bridges for a tank pressure around of 1,9-2 bars and an acquisition frequency f_a = 1 *MHz*.



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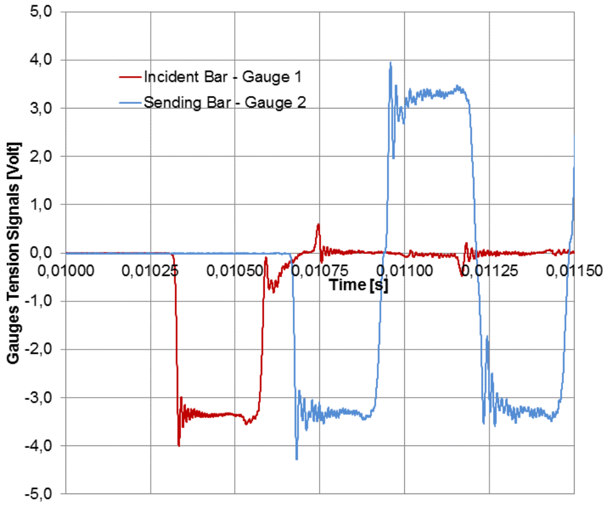


b)

Fig. 6. a) Square-shaped signal of laser camera recorded by triggering option of Labview program, b) Gauges tension signal variation corresponding to the elastic deformation of the bars for a tank pressure of 1,9-2 bars

Starting from the square-shape signal corresponding to the succesion of black and white slots with a constant length of λ_v= 5 mm the time period T_v is estimated to be equal to 0,5138 *ms* and consequently the obtained impact velocity is $v = \lambda_v / T_v \approx 10\,m/s$. The signal of incident deformation measured in Volts has a value close to $\hat{U}_i = 3{,}33V$ with a time broadness $t_i = 0{,}254\,ms$ and the experimental celerity can be evaluated as $c_{\exp} = 2 l_{imp} / t_{i_{\exp}} = 2 \cdot 10^3 \cdot 0{,}602/0{,}254 \approx 4740\ m/s$. As compared to a previous estimation about of 4821 *m/s* [11] the error of the sound celerity is smallest that 2.5%. Using the equation (10), the analytical calibration factor becomes K_{an} = 317 *μdef /Volt* i.e. 17% differences as compared to the classical strain gauge's calibration method.

To improve the calibration procedure in order to avoid approximations of gauge factor, gain choice and measurements errors, a robust and more general numerical calibration method is proposed. This numerical method is based on a lot of empty SHPB experimental tests without specimen performed for different initial impact velocities and on a finite element modelling of the entire bar's system. The following steps must be followed:

1. Empty experimental compression SHPB test (without any sample or specimen) with contact of incident and sending bar and at a desired initial impact velocity *v* chosen with respect to the diagram impact velocity-pressure. In this case it can be proved that $\varepsilon_i < 0, \varepsilon_r = 0, \varepsilon_t = \varepsilon_i < 0$ [14];

2. Time variations recorded of tensions $\widehat{U}_i(t)$, $\widehat{U}_r(t)$ and $\widehat{U}_t(t)$ (corresponding to the experimental gauge elastic deformations $\varepsilon_i(t)$, $\varepsilon_r(t)$ and $\varepsilon_t(t)$) found using Labview program);

3. Estimation of the real initial impact speed $\hat{v}$ from the time period T_v of the first square-shaped signal of the recorded laser camera signal using the formula $\hat{v} = \lambda_v / T_v$;

4. Estimation of the celerity c_{exp} from the time period $t_{i_{\exp}}$ of the first slot of the recorded incident signal $\widehat{U}_i(t)$ by $c_{\exp} = 2 l_{imp} / t_{i_{\exp}}$;

5. Finite Element simulation of the entire SHPB system based on same conditions as the experimental one (using same celerity speed value and same impact velocity) and extraction of elastic strains $\varepsilon_{i_{num}}(t)$, $\varepsilon_{r_{num}}(t)$ and $\varepsilon_{t_{num}}(t)$ corresponding to geometric positions of the two gauge bridges (one on the half part of the incident bar and other on the half part of the sending bar).

6. Computation of the calibration factor K_{num} = $\mathrm{Max}\left|\varepsilon_{i_{num}}(t)\right| / \mathrm{Max}\left|\widehat{U}_i(t)\right|$ = $\hat{\varepsilon}_{i_{num}} / \widehat{U}_i$

7. Comparisons of the whole time variation of incident, reflected and transmitted elastic strains for both experimental and numerical values.

An axisymmetric dynamic Finite Element Modelling of SHPB test choosing an initial impact velocity of 10 *m/s* and an incremental time of 10^{-6}s is performed using Cast3M code [15] based on tridimensional elastic properties of the bars, inertial effect and QUAD4 mesh (Figure 7).

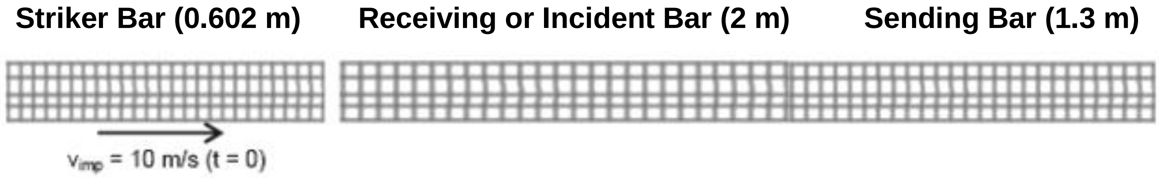
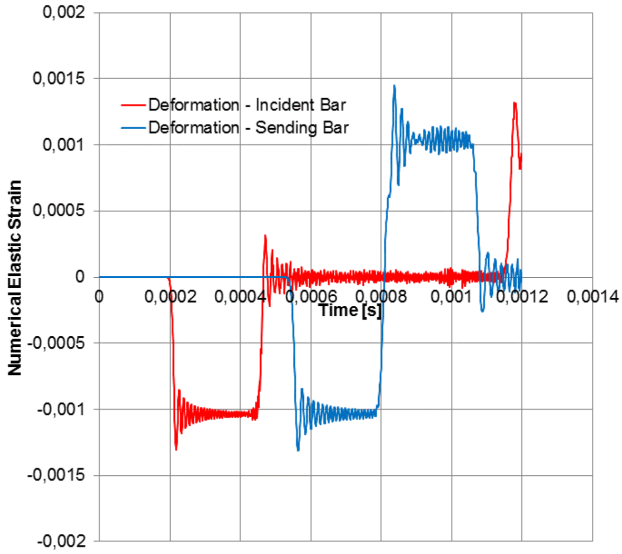


Fig. 7. Mesh of the striker, receiving (incident) and sending bars used for a Dynamic Finite Element Simulation of the SHPB device using Cast3m code

Results concerning the elastic deformations and axial stress obtained from gauge bridges positions are illustrated in Figure 8. Same numerical results are obtained using Abaqus or LsDyna FEM as has been proven in a previous scientific research [14].



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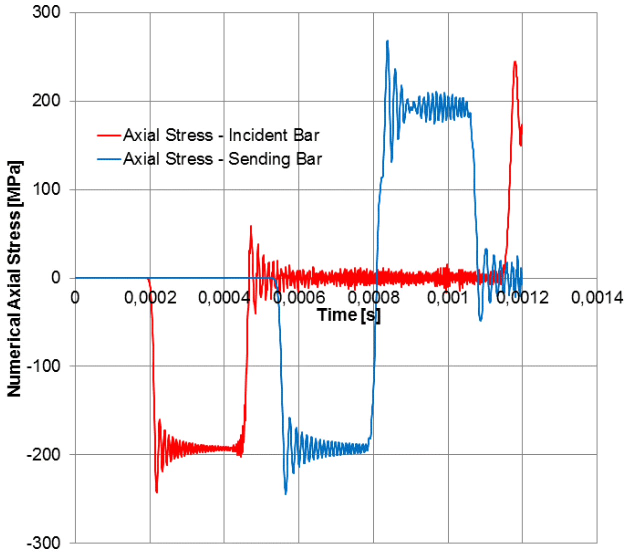

b)

Fig. 8. Numerical results corresponding to the gauge bridges position obtained from the Dynamic Finite Element Simulation using Cast3M code a) Elastic Strains, b) Axial Stress

It can be observed that $\mathrm{Max}\left|\varepsilon_{i_{num}}(t)\right|$ = 1034,7 *µdef* and $\mathrm{Max}\left|\sigma_{i_{num}}(t)\right|$ = 191 *MPa* values close to the analytical estimations gived by $\hat{\varepsilon}_{i_{an}} = v/2c_b \cong$ 1054,9 *µdef* and $\hat{\sigma}_{i_{an}} = 0{,}5\rho c_b v \cong$ 189,6 *MPa*. Taking into account the experimental tension value obtained from the incident deformation signal the numerical calibration factor can be estimated by K_{num} = 310,7 *µdef /Volt.* As compared to the analytical calibration factor the error is around of 2%. Despite the validation of the proposed calibration method it is possible to conclude that this numerical strategy can be performed for more complex conditions as for example in the case of viscoelastic or non-metallic materials bars, to see for optic fibbers measurements of elastic deformations where analytical computation models are too approximate or no more valid. Furthermore the entire finite element model can be used to simulate SHPB tests using different shape of specimens undergoing complex strain path especially used to identify by inverse analysis non-linear thermo-mechanical material behavior and valid them by comparisons of numerical-experimental elastic deformations of the bars as can be shown in previous works of Gavrus et al. [9-14].

4. Conclusions

The experimental design and quantitative description of the pneumatic compression SHPB bench confirms the robustness of impact speed control together with experimental validations of theoretical dependency on tank pressure set point. A new hybrid analytical-numerical calibration method has been proposed to estimate the elastic strains of the incident and sending bars. A complete dynamic finite element simulation of the SHPB system without specimen has been performed to establish a more rigorous conversion of the gauge full bridge tensions based on information obtained from the incident elastic wave signal. Comparisons with analytical formulas based on elastic wave propagation theory of infinite bars have shown the high precision of the finite element modelling results and permits to valid the calibration methodology. It is also possible to confirm again the rightness of the two-step inverse analysis technique developed in previous research works at INSA Rennes to identify thermo-mechanical constitutive equations of metallic materials under severe loadings. Based on the generality of the proposed numerical calibration method this one will be applied in a future work to improve the SHPB acquisition system using local optic fibers sensors to measure with a more accuracy the elastic deformations of the bars.

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