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EXPERIMENTAL AND NUMERICAL INVESTIGATION OF CONNECTOR WITH ELASTOMER JOINT

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Abstract

This paper presents works associated with the design, experimental tests and numerical-analyses of a composite connector, which is a part responsible for increasing the safety of the soldiers.

Nowadays researchers more and more often are searching for modern materials, which, as individual components or structures connected with other materials, meet the requirements of global markets. One of the most important branches of industry, which presently is growing increasingly are high technologies accompanying the safety of soldiers who are the passengers of a military vehicle.

The proposed solution allows protection of the sensitive parts of body (e.g. legs), as well as the entire body of a soldier from the risks resulting from the impact of a pressure wave coming from explosion on the vehicle in which the soldier travels. A combination of classic materials, such as steel, and modern materials with hyperelastic characteristics might be an alternative to the currently used shock absorbers and dampers. Perspective can be using this assembly as a connector between a seat and the military vehicle body or special plates for protecting the crew's feet resting on the floor of the vehicle during explosion of a mine or IED. The analysis is conducted using the LS-DYNA explicit code.

Keywords: *elastomer, connector, LS-Dyna, experimental tests, FEM analysis*

1. Introduction

Energy absorbing constructions, by their nature, are subjected to shock loads. The absorption of the impact energy is about changing a negative increase in the work of energy absorbing structures deformation. The ability of absorption depends on a type of material, structure geometry and a method of destruction. Materials capable of very large deformations, such as rubber, are among the hyperelastic materials requiring appropriate constitutive models and their reliable choice in a particular case. Hyperelasticity means the ability of a material to large elastic deformations under load of low forces without losing the initial properties. Hyperelastic material exhibits non-linear behaviour, which means that its deformation is not directly proportional to the applied load.

2. Experimental tests

The dynamic tests were carried out on the test stand working based on a gravitationally falling hammer.

There are sensors for measuring force and displacement installed on the stand. Force measurement is done using a piezoelectric force sensor M200C50 produced by PCB Piezotronics company coupled to a signal conditioner VibAMP PA-16000D produced by EC Electronics. Displacement measurement is performed with a laser triangulation displacement sensor LKG-502 produced by Keyence [1, 4].

Based on the measured values, i.e., weight of the hammer, drop height, speed of the hammer before hitting the sample, displacement (compression of sample) and strength, there were determined energy discharge, maximum compression and maximum strength. Based on the measurements of force and displacement, the characteristics of force versus displacement were determined.

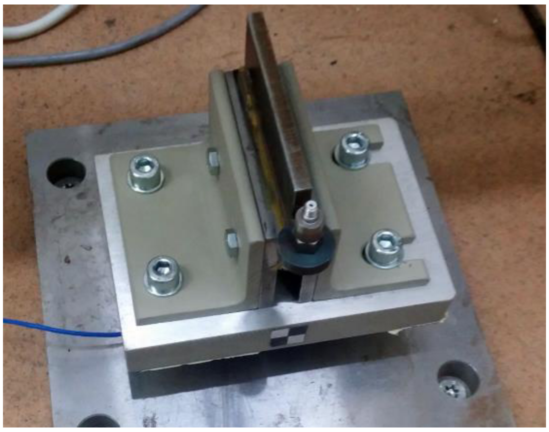

Fig. 1. View of the test stand

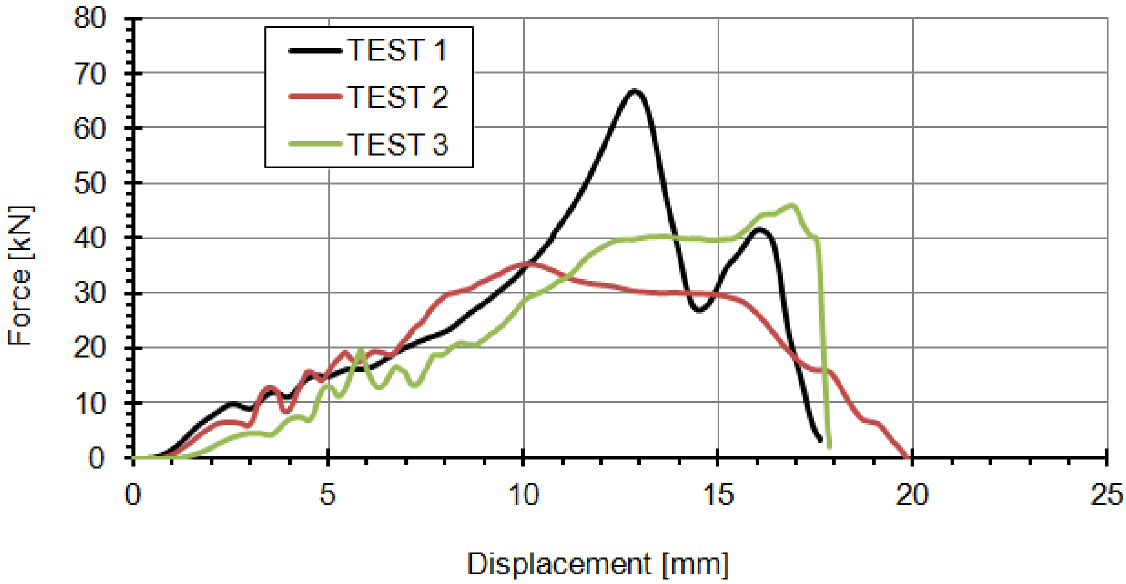

Fig. 2. Characteristic of force versus displacement for experimental tests

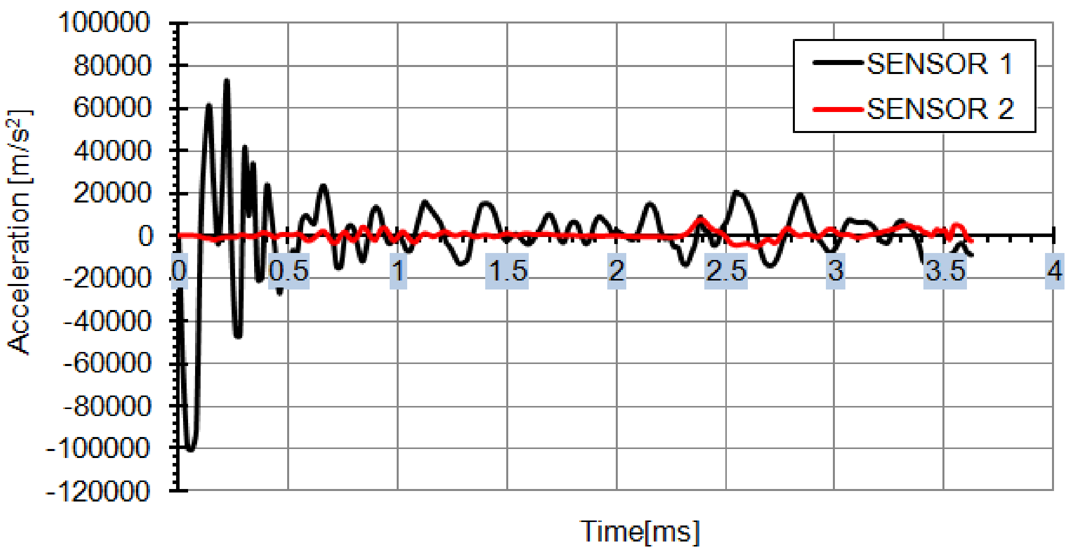

Fig. 3. Acceleration versus time for both sensors in selected experimental test

Additionally, the measurement results are collected from two acceleration sensors installed on the central and profile mounting plates (as shown in Fig. 2).

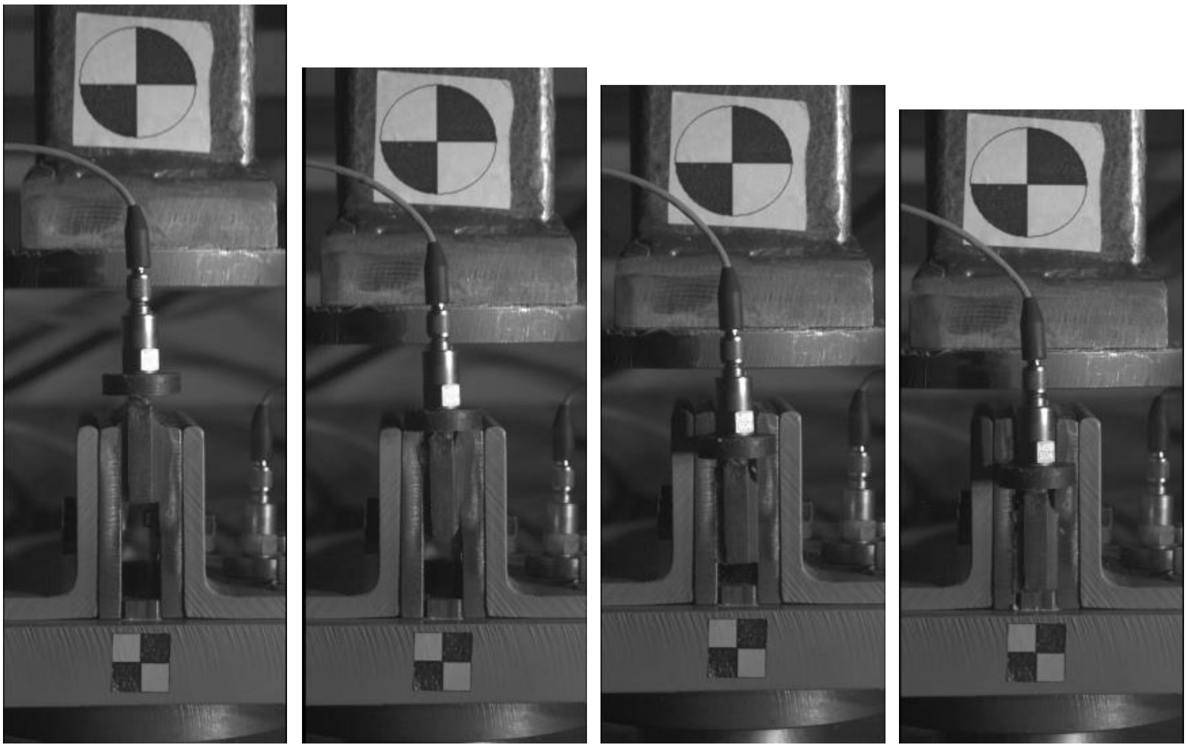

Fig. 4 Experimental test steps registered with the use of camera designed for fast shooting (Phantom V12)

3. Numerical analysis

Numerical models of the investigated connector were developed using modern CAE tools. Geometric models were developed in Catia, a discretization process was carried out using HyperMesh software and all numerical simulations were calculated using the computational code Ls-Dyna [3]. LS-Prepost was adopted for pre- and postprocessing.

To develop discrete models, eight-node brick elements were used. In all simulated variants, the interaction between parts (except metal plates and elastomer connected with an equivalence function) was taken using a contact procedure based on a penalty function method.

To describe the considered model of rubber, SIMPLIFIED_RUBBER/FOAM_WITH_ FAILURE model was used, which is based on the Ogden law:

$$W = \sum_{i=1}^{3} \sum_{j=1}^{n} \frac{\mu_j}{\alpha_j} \left(\lambda_i^{*\alpha_j} - 1 \right) + K(J - 1 - \ln J), \tag{1}$$

$$\rightarrow \sigma_i = \sum_{p=1}^{n} \frac{\mu_p}{J} \left[\lambda_i^{*\alpha_p} \sum_{k=1}^{3} \frac{\lambda_k^{*\alpha_p}}{3} \right] + K\frac{J-1}{J}, \tag{2}$$

where: αj are non-integers, J = λ1λ2λ3 and λ_i^* i = λiJ −1/3, K is a material parameter that controls the size enclosed by the failure surface.

In this material, Ogden functional is internally determined from a uniaxial engineering stress-strain curve by defining a tabulated function of the principal stretch ratio as follows [2]:

$$f(\lambda) = \sum_{p=1}^{n} \mu_p \lambda^{*\alpha_p} \rightarrow \sigma_i = \frac{1}{J}\left[f(\lambda_i) - \frac{1}{3}\sum_{j=1}^{3} f(\lambda_j) \right] + K\frac{J-1}{J}. \tag{3}$$

In the analysed issue, a joint connecting metal plate was made of elastomer Asmaprene Q 55. The strength parameters, which were necessary to describe the numerical model, were tested during experimental tests and then assigned to the constitutive model.

Tab. 1. Material properties of elastomer Asmaprene Q 55 (MAT_SIMPLIFIED_RUBBER_FOAM_WITH_FAILURE)

Parameter	Unit	Value
Density	kg/mm^3	1.25e-6
Linear bulk modulus	GPa	0.2333
PR/BETA	-	0.45
Material failure paramete K	-	100
Material failure paramete GAMA1	-	0
Material failure paramete GAMA2	-	0.02
Damage parameter EH	-	0.001
Specimen gauge length	-	1
Specimen width	-	1
Specimen thickness	-	1

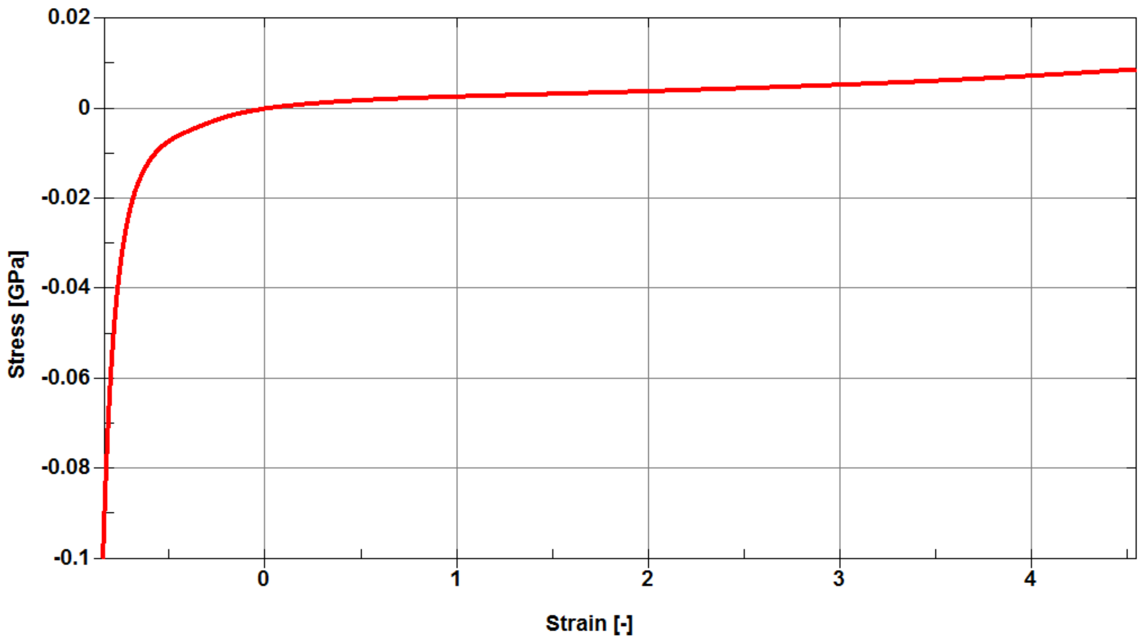

Fig. 5. Characteristic of stress versus strain used for constitutive model

To describe metal plates of connection mounted on the test stand, MAT_PLASTIC_KINEMATIC material model was used.

Tab. 2. Material properties of steel (MAT_PLASTIC_KINEMATIC)

Parameter	Unit	Value
Density	kg/mm^3	7.85e-6
Young's modulus	GPa	207
Poisson's ratio	-	0.3
Yield stress	-	0.35

The examined connection samples were dynamically loaded by hitting the centre plate by a hammer weighting 20.1 kg. The impact speed was 6.64 m/s, which translated into kinetic energy upon impact with a value of about 440 J. A numerical model of the measuring station is shown in the figure below.

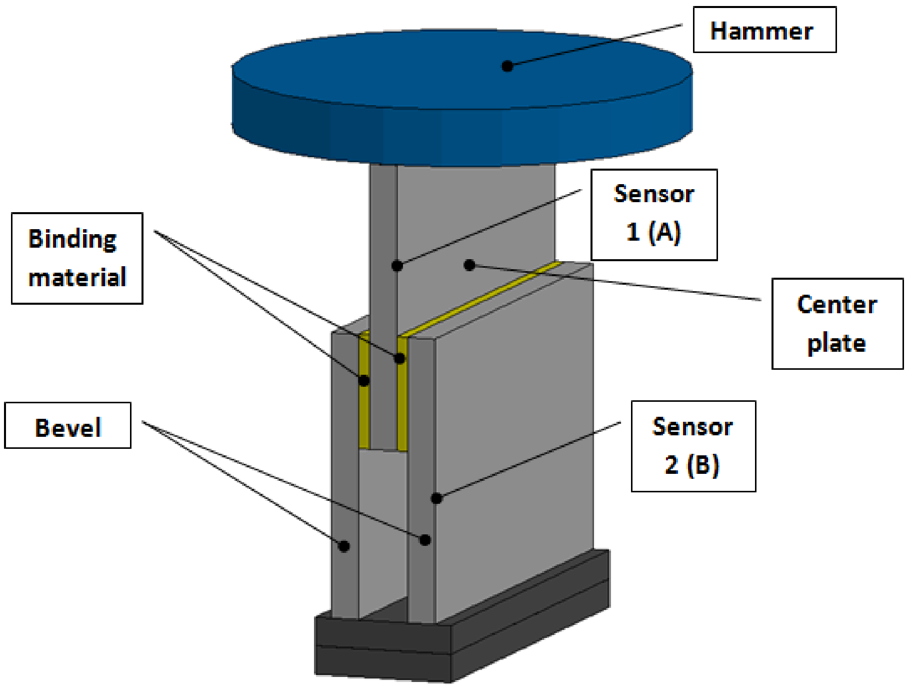

Fig. 6 Numerical model of measuring station

The main phenomenon that the authors wanted to investigate was characteristic of force as a function of the displacement presented in the figure below.

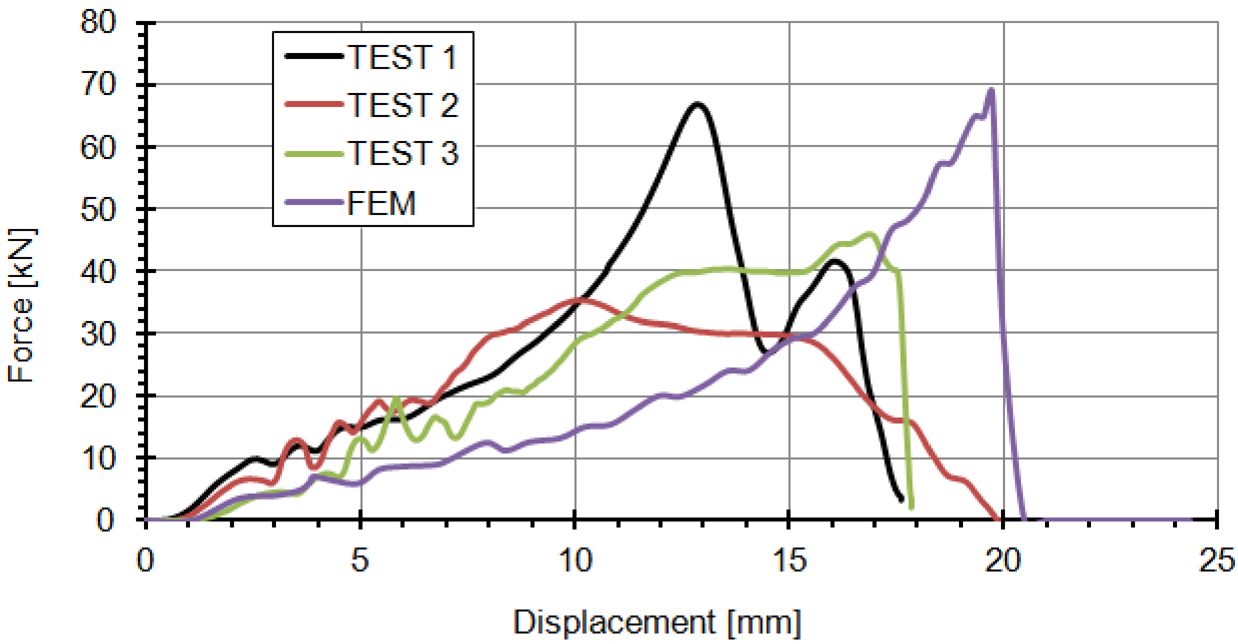

Fig. 7 Characteristic of force versus displacement for experimental and numerical tests comparison

The accelerations recorded from the selected nodes installed in the centre and profile mounted plates were also analysed and showed in Figure 8.

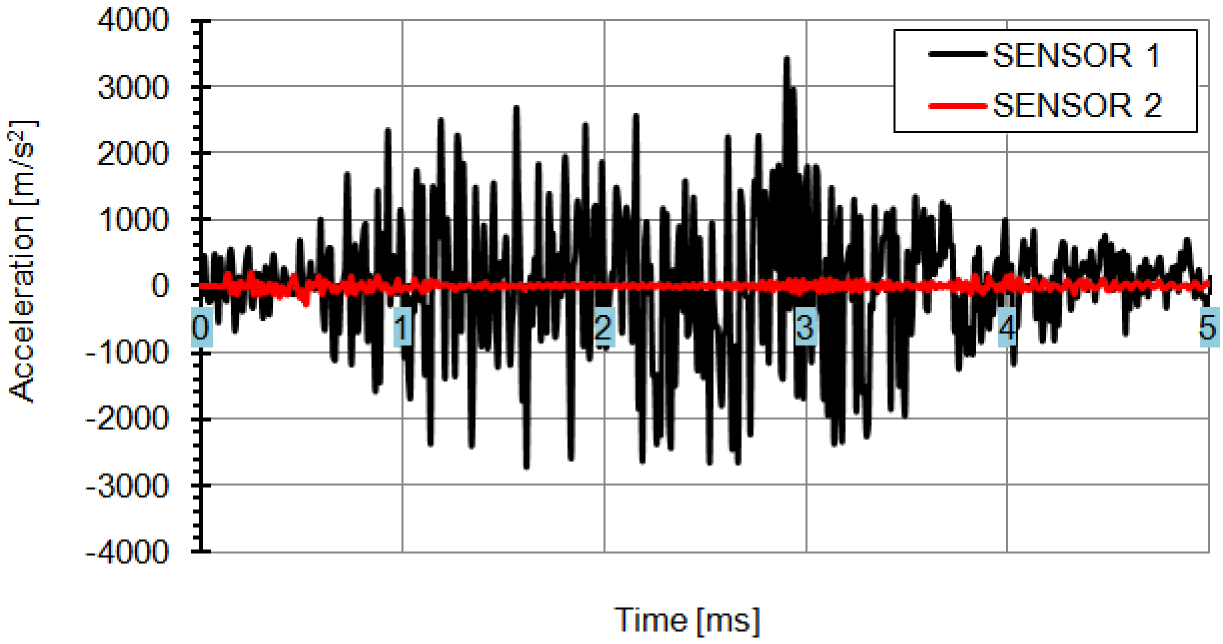

Fig. 8 Acceleration versus time for both sensors in numerical test

The selected shots from the numerical analysis compared in time with the experimental results are presented in Figure 9.

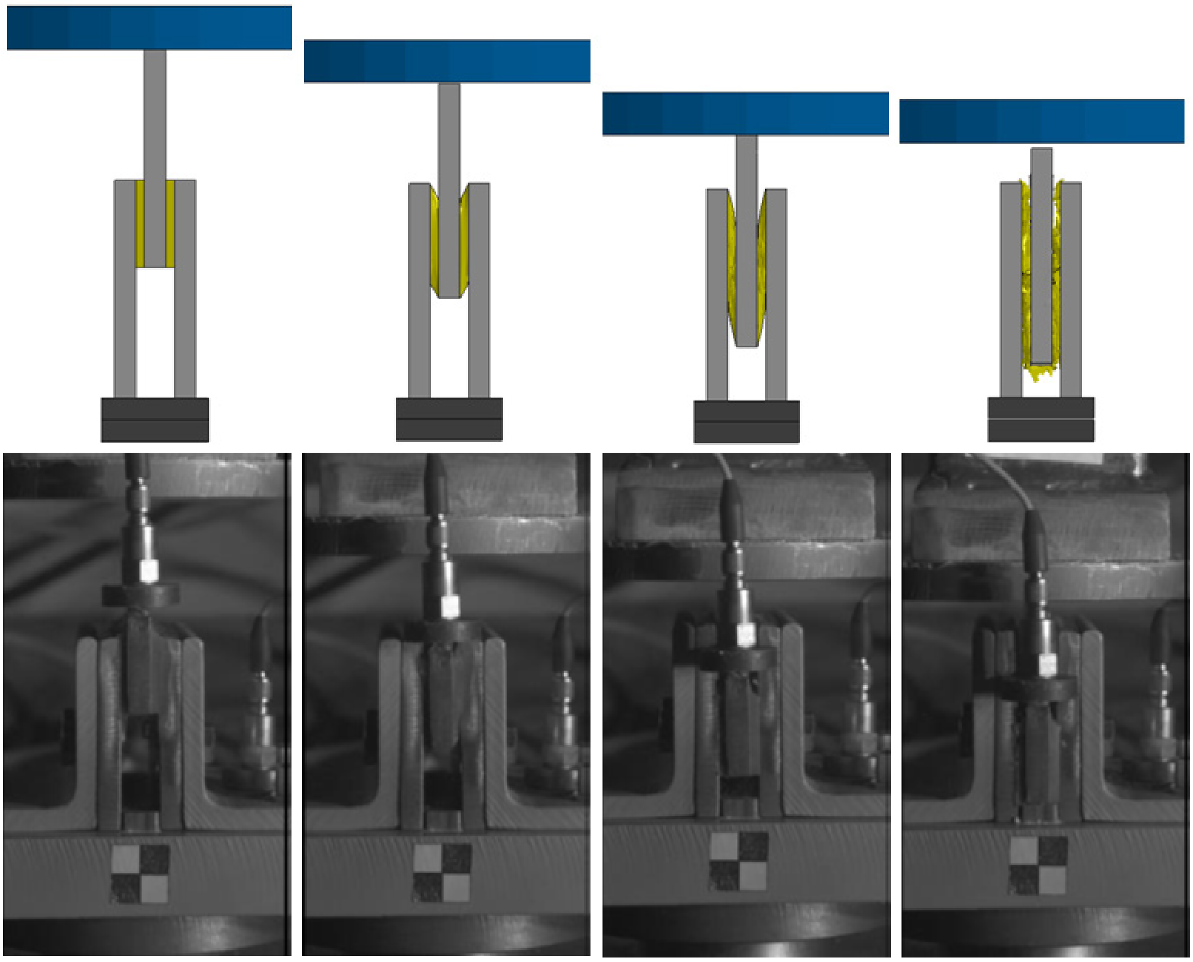

Fig. 9 Numerical and experimental test steps comparison

4. Conclusions

Based on the results, some conclusions can be formulated:

- acceleration measured in sensor 2 (B) has been significantly reduced in relation to the acceleration registered in sensor 1 (A),
- progressivity of characteristics of the force versus displacement obtained with the numerical analysis is slightly lower than progressivity of the experimental results,
- an advantage of simulation is lack of problems resulting from inaccuracy of the samples,
- a graph of force versus displacement allows observing the effects of work performed by the joint
- the results obtained based on the experimental studies are characterized by a fairly large discrepancy. The reason for such results may not be very accurate repeatability of test samples.

Acknowledgments

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