IMPROVED METHODOLOGY FOR VALIDATION OF THE FEA MODEL USING TESTING COMPONENTS

[1]Martin RUND, [1]Sylwia RZEPA, [1]Daniel MELZER, [1]Pavel KONOPÍK, [1]Miroslav URBÁNEK

[1]*COMTES FHT a.s. –Dobřany, Czech Republic, EU, mrund@comtesfht.cz*

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Abstract

In most cases, the components (U-profiles, Ω-profiles, box-beams) are used to validate the material model generated from the measurement of individual sheet metal parameters. The validation process consists of comparing the resultant force vs displacement from the experiment to the simulation. The loading conditions during testing are predominantly chosen based on the final application the material, and a component manufactured from it. Taking an example, the U-profiles or Ω-profiles are usually loaded in three-point-bending mode, and the so-called box-beams are loaded axially in compression mode. In mechanical testing for automotive industry, the application of dynamic loading is necessary for observation of the material behaviour under high strain rates. The machine used for this purpose can be a drop weight tower, which is usually instrumented by a crosshead displacement measurement and one load cell. However, such an instrumentation is insufficient for precise description of the component behaviour during dynamic events. The solution is offered by the high-speed 3D DIC measurement of deformation. Nevertheless, there are still many parameters that can be obtained from these tests, which can lead to much more accurate validation of the material model. In addition to the DIC measurement, a local deformation measurement by means of strain gauges and continuous temperature measurement in the notch area were proposed in this study. The result is a complex set of the material properties in a given loading conditions.

Keywords: Material characterization, model validation, steel, dynamic mechanical properties

1. INTRODUCTION

Despite some efforts to break down the verification of the FEA model and to rely only on the results of numerical simulations, it is still general true that the verification of the model is important at least to a limited extent [1]. Nevertheless, this phase should never be overlooked. It is recommended to design the experiment with as many boundary conditions as possible, which was limited by the FEA model itself. Properly defined boundary conditions and components fracture are always crucial for every model creation [2,3]. An example of the model's interactions with boundary conditions is shown in **Figure 1**. Then, the verification itself is based on the correctly defined conditions. If the component is expected to be loaded dynamically, the verification should also include dynamic tests. Last but not least, the material parameters obtained at given strain rate and temperature [4-6] should also be used as input parameters.

The use of components (U-profiles, Ω-profiles, box-beams) for verification of material model is practical and justified. The main advantages are simple and cheap sample production, even in the case of non-metallic materials [7,8]. At the same time, these components allow loading in bending or axial direction. These tests are performed either under quasi-static or dynamic conditions. Instrumented Drop Weight Tower (DWT) is usually used for dynamic purposes. The current development of optical systems then makes it possible to obtain other important material parameters, which may bring another fundamental information in the verification process.

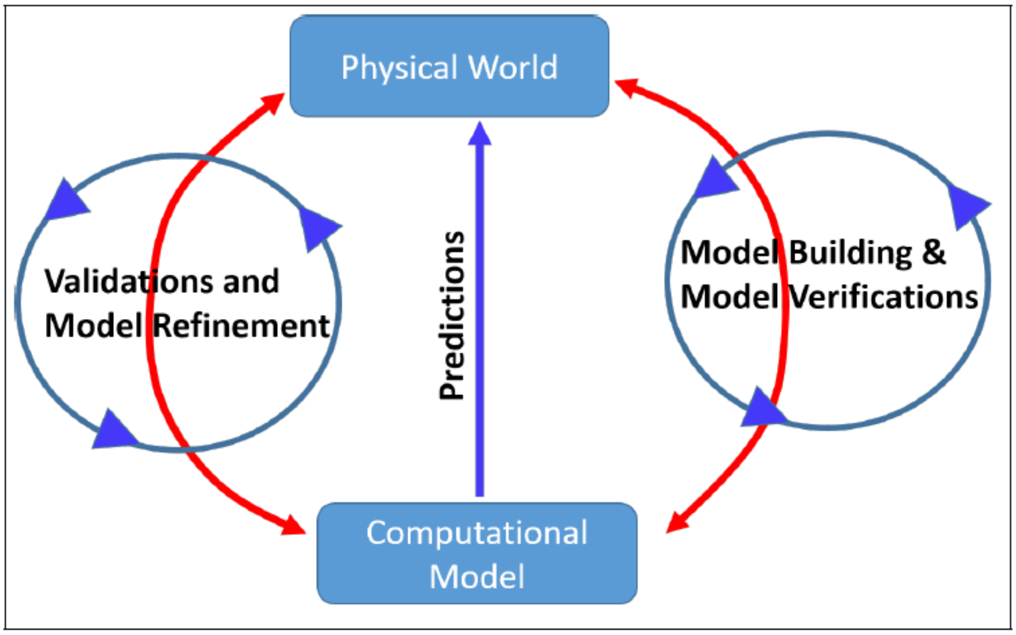


Figure 1 Variation on the Sargent Circle Showing the Verification and Validation Procedures in a Typical Fast Paced Design Group [6].

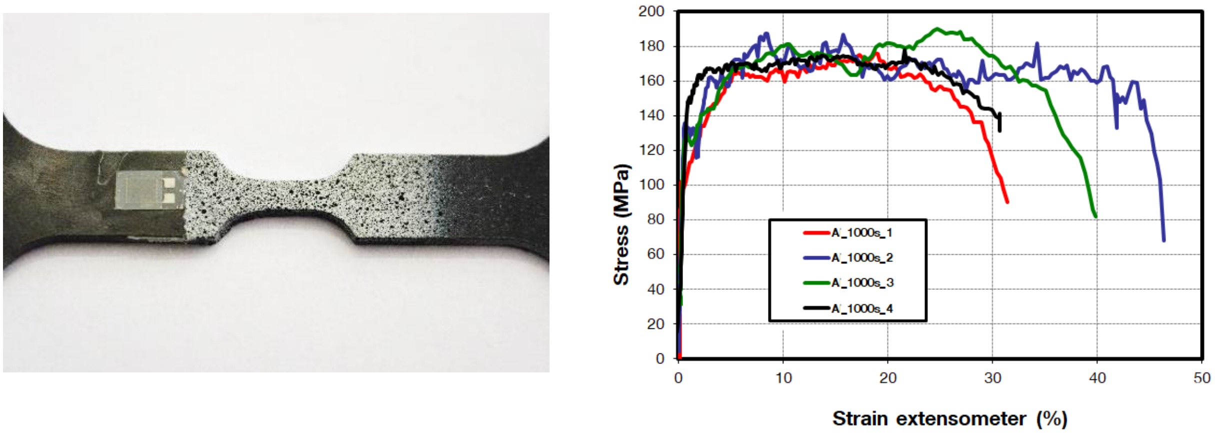
The aim of this article is to present the possibilities of advanced measurement methods on classic Ω-profiles using Digital Image Correlation (DIC), strain gauges and thermal camera. The experimental procedure was performed on Dual Phase (DP) steels, characterized by ferritic-martensitic microstructure, which are commonly used in automotive industry as body panels or bumpers. The advantages of these materials are a high strain rate sensitivity, great uniform elongation and fatigue resistance,

2. STATE OF ART

The demand of verification of the FEA model appeared together with the development of these sciences in the field of aerospace and nuclear engineering. Not surprisingly, the first manual on material verification was published in 1987 by the American Nuclear Society [9]. The first comprehensive book on this topic, which is still valid today, was written by Dr Roach in 1998 [10]. Dr Roach mentioned here the need for not only for verification but also validation of the FEA model. The first standard was released in 1998 by the American Institute of Aeronautics and Astronautics [11]. Subsequently, the US Department of Defence released another one through Defence Modelling and Simulation Office in 2003 [12]. In the following years, a number of standards were created [13-15].

3. EXPERIMENTAL PART

The material models of several Dual Phase materials (DP) were created by means of tensile tests carried at three different strain rates (0.001, 0.1 and 1000 1/s) at room temperature. The specimens were subjected to the highest strain rate loading (1000 1/s) using Drop Weight Tower (DWT) IM10T with the total energy capacity of 3 kJ. The force was measured by means of piezoelectric load cell and simultaneously by the strain gauges mounted directly on the testing specimens to eliminate oscillation waves (**Figure 2**). The specimen deformation was recorded using high-speed camera Phantom V710 and evaluated using optical extensometer based on DIC method. Consequently, material models were verified through dynamic 3-point bending tests using Ω-shaped profiles. The testing setup is described in **Figure 3**.



a) b)

Figure 2a) Geometry of the tensile test specimens for testing at strain rate of 1000 1/s; **b)** Example of the tensile tests results at 1000 1/s

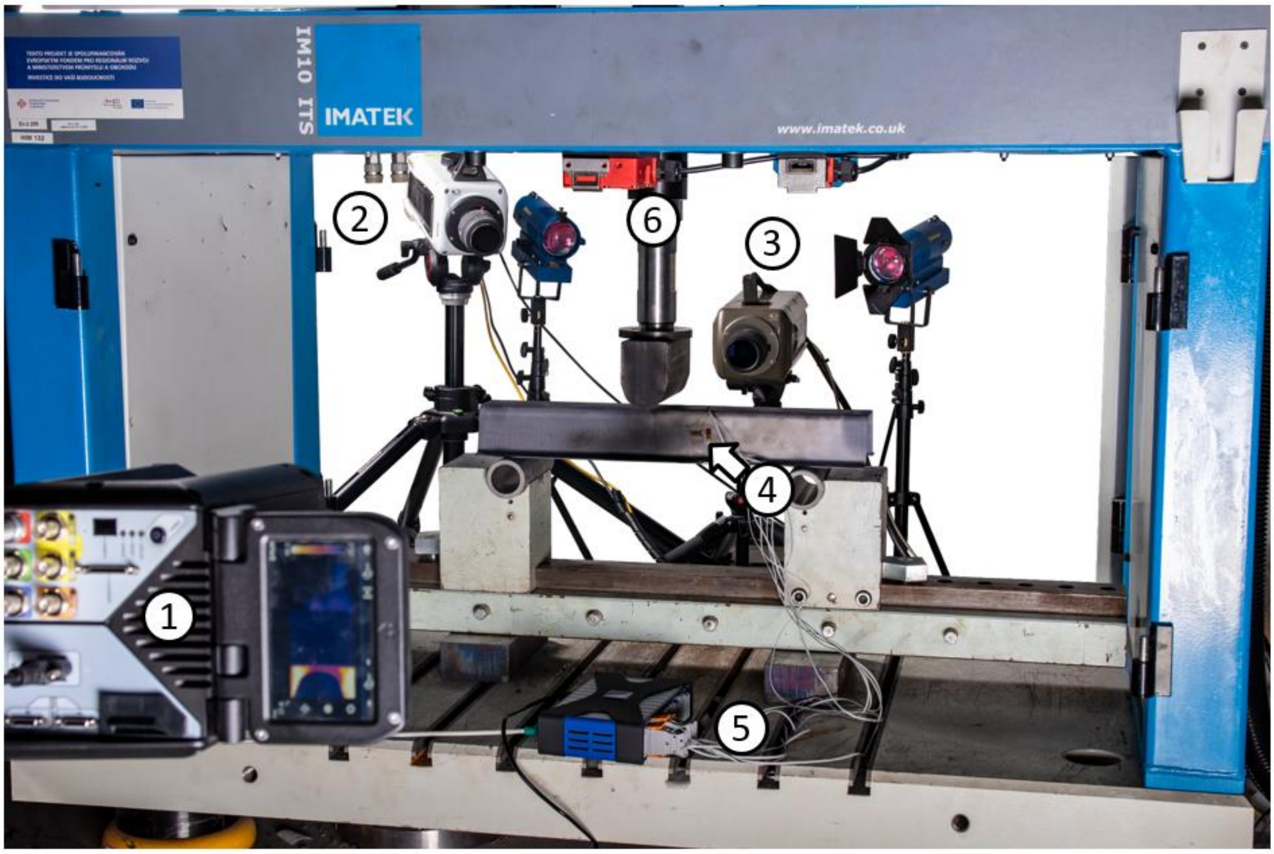
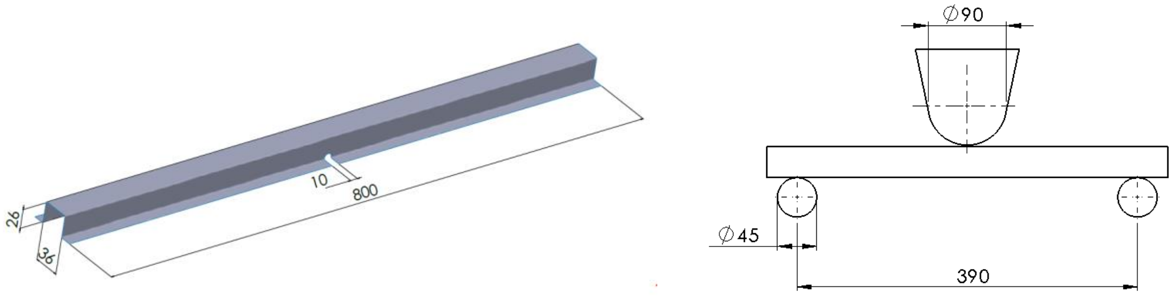


Figure 3 Testing setup for dynamic 3 point bending test. 1) High-speed thermo-camera, 2-3) High-speed camera Phantom V710, 4) position of the strain gauge, 5) HBM high-speed data logger, 6) DWT striker

Dynamic 3-point bending tests were performed in standard “gravitation” mode, which means that the mass carriage and the striker were not accelerated. **Figure 4Figure** presents the geometry of the specimens and schema of the testing setup.



a) b)

Figure 4a) Geometry of the omega profile; **b)** Schema of the test setup

The advanced techniques were used to monitor deformation of the specimens in the course of the test. One side of the specimen was covered by stochastic pattern and recorded by two high-speed cameras. First camera was located axially symmetric to the 3-point bending test setup. Second high-speed camera was placed above the specimen and recorded the top of the specimen. Test records were used for further DIC analysis. Opposite side of the specimen was recorded by a high-speed thermo-camera. The position and direction of individual systems are presented in **Figure 5**. Temperature of the 3PB specimen increased from 25 °C to 30 °C in critical areas.

The local measurement of the deformation in location not suitable for DIC were performed by means of the strain gauges mounted in two specimen locations (on the hem and top in two orientations). **Figure 6** shows the sequence of specimen deformation recorded by the high-speed camera and converted to DIC. The example results of the test are presented in **Figure 7**.

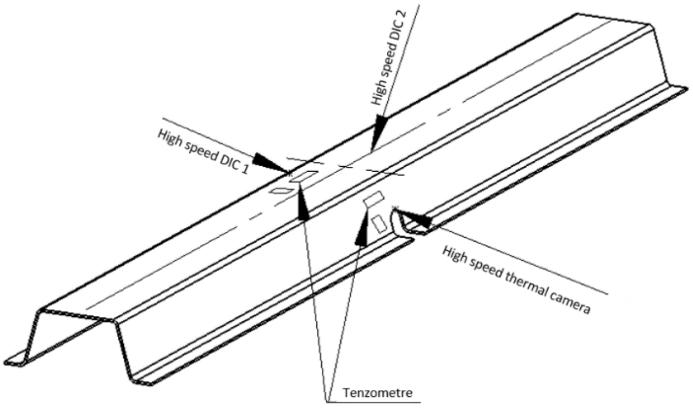
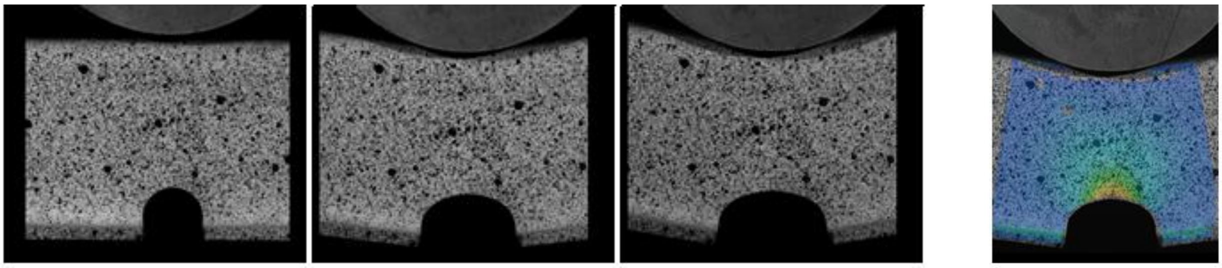
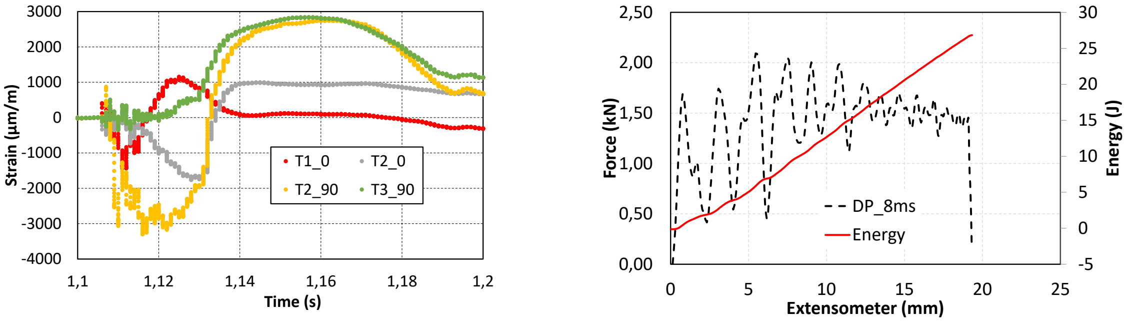


Figure 5 Direction and position of individual devices intended for test monitoring



a) **b)**

Figure 6a) Specimen deformation recorded by high-speed camera located axially symmetric to the testing setup; b) Example of the evaluation by DIC



A B

Figure 7 3PB test example of the records from a) Strain gauges, b) Load cell and DIC

4. DISCUSION

There were a total of three different systems used to refine the test results, namely the DIC systems, thermo-camera and local measurement of the deformation by means of strain gauges. The DIC system revealed that a crack is formed in the notch region when a logarithmic deformation of 0.78 was reached. At the same time, the temperature increased by 5 °C. The records from the strain gauges show that in the first phase, the area was exposed to compressive stress, which was further converted to tensile deformation during the deformation process.

The use of strain gauges is precise and useful in locations, where conventional optical systems cannot record. Compared to DIC cameras, it is a very cheap tool that can give useful information, however it is important to place them correctly. Simultaneously, it is necessary to realize that strain gauges can detect limited amount of deformation.

5. CONCLUSION

The aim of this paper is to present extended measurement options for material model verification. The obtained parameters such as temperature field, deformation development in the notch area and on the upper side of the Ω -profile can then significantly contribute to the refinement of the material model.

The use of all these systems makes it possible to use much more complex geometries for material verification, where different notches or asymmetrical loads can lead to the achievement of the required state of stress.

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