

# Development of virtual benches for testing the digital twin of a vehicle

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**Abstract.** The article analyzes the approaches to the creation of the concept of a virtual test bench for testing the digital twin of the automotive industry product. Such components of the digital platform as suspension area, power plant, braking and cooling systems are being investigated. The problem of the implementation in the digital twin of such important units as the attachment points of units and assemblies on the vehicle body frame, even surface, driver dummy, the scheme of attachment of body elements, etc is studied. The importance of the implementation of such benches as platforms for assessing the indicators of the vehicle passive safety or as stand for assessing the water tightness of the vehicle body is considered. A number of results that illustrate development areas and success of the authors of the article in these areas are presented. It is shown that the digital platform can be used for certification and rating tests, assessing the comfort and visibility of the driver's cab.

## 1 Introduction

The current level of development of digital technologies has made it possible to create systems for the design of complex technical products based on the so-called digital twins. The main idea in this approach is the use of a mathematical model of the developed product, which provides sufficient accuracy in calculating certain parameters of the product. Thus, virtual platforms and stands began to appear.

Therefore, it allows testing a product with imitation of specified conditions, modes, testing parameters, etc. In fact, virtual stands complement design systems and are used to carry out reliable design checks. It is obvious that such a combination of modeling, evaluation and subsequent optimization of product parameters makes it possible to create systems for automatic product optimization.

The adequacy of the assessments obtained with the help of such stands is determined by the accuracy of the mathematical model and the methods of numerical calculations.

## 2 Elements of the digital platform

Let's start from the top level of the digital platform. Currently, the developed digital platform

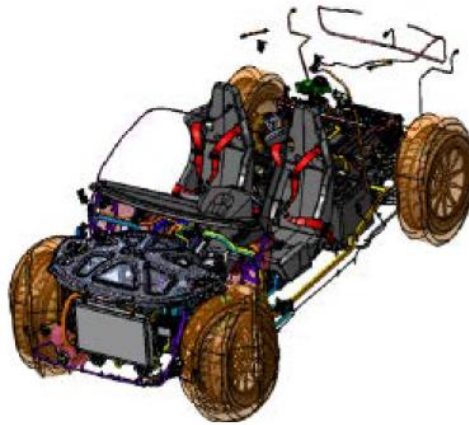
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for virtual testing of the digital twin of a designed vehicle in terms of comfort and safety characteristics of its operation may include:

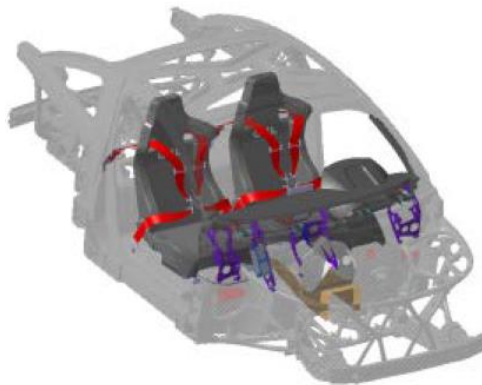
- Stand for assessing passive safety indicators in frontal impact;
- Stand for assessing passive safety indicators in a side impact;
- Stand for assessing passive safety indicators in a rear impact;
- Stand for assessing passive safety indicators during a vehicle rollover;
- Stand for assessing the indicators of aerodynamic resistance and downforce;
- Stand for assessing the kinematic properties of the suspension;
- Stand for the assessment of vibroacoustic comfort;
- Stand for assessing the stiffness and strength properties.

Figure 1 shows a general view of the digital model with its main components developed at the Polytechnic University.



**Fig. 1.** Digital model of the designed vehicle.

According to the model, it is possible to look separately at the suspension, power plant, braking system or the arrangement of interior elements (Fig. 2) of the product, etc.



**Fig. 2.** Elements of the vehicle interior in its digital twin.

Already at the stage of setting the geometrical parameters of the body, it becomes possible to assess the sitting comfort of a driver or passenger dummy (Fig. 3).

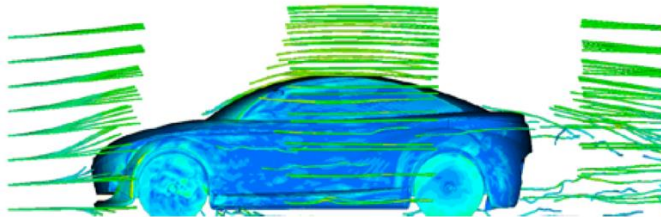


**Fig. 3.** Assessment of comfort and visibility on the digital twin.

Based on the analysis of the model shown in Fig. 3, the dummy sitting comfort is assessed. The visibility limited by the model surfaces is also assessed. The visibility is estimated relative to the ground level, which is also simulated in a digital model, as shown in Fig. 3.

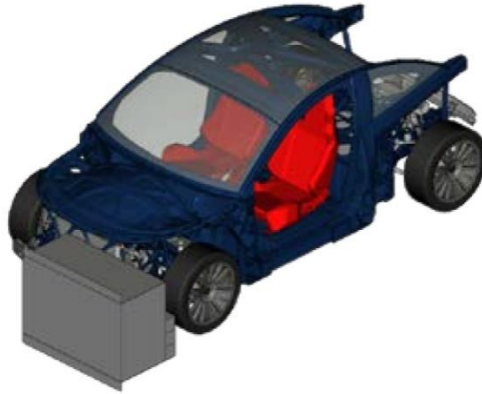
### **3 Assessment based on modeling physical interaction with the environment**

It is true that the main advantage of digital twins is the possibility of implementing virtual stands on their basis for physical modeling with an assessment of the product target characteristics. Thus, for example, Figure 4 shows the result of modeling the flow of the designed vehicle by the incoming air flow during its movement.



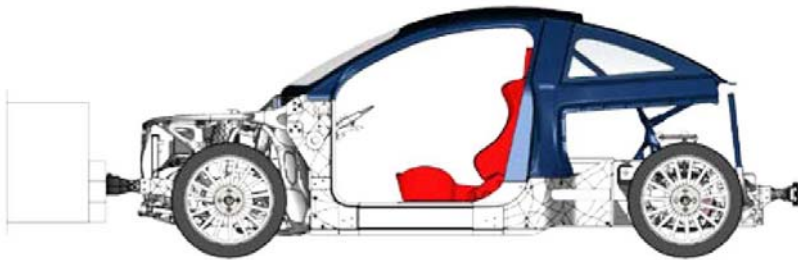
**Fig. 4.** Incoming air flow of the vehicle digital twin body.

Thus, the aerodynamic characteristics of the vehicle's outlines can be assessed. As a result, it is also possible to assess their effect on fuel consumption, throttle response, downforce, etc. Similarly, on the same digital twin, one of the most important assessments for the automotive industry can be carried out, namely, the assessment of the crash test results (Fig. 5).

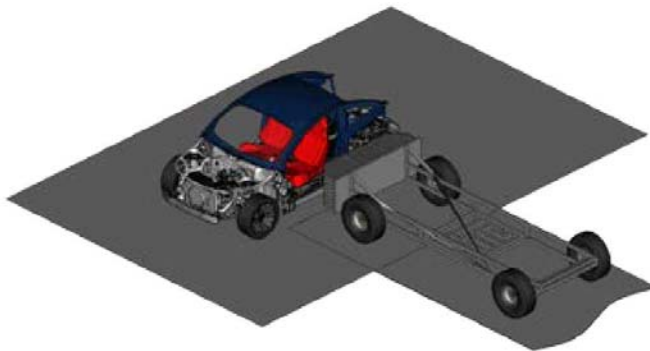


**Fig. 5.** Simulation of a virtual crash test on a digital twin of a designed vehicle.

In particular, this makes it possible to assess the passive safety indicators of a designed vehicle during a frontal, side, rear impact, as well as during its rollover. The developed digital platform thus enables to carry out product certification (Fig. 6) and rating tests (Fig. 7).

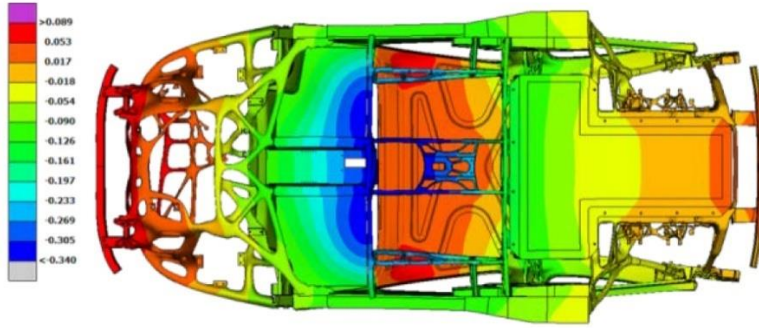


**Fig. 6.** Carrying out certification tests on the digital twin of the designed vehicle.



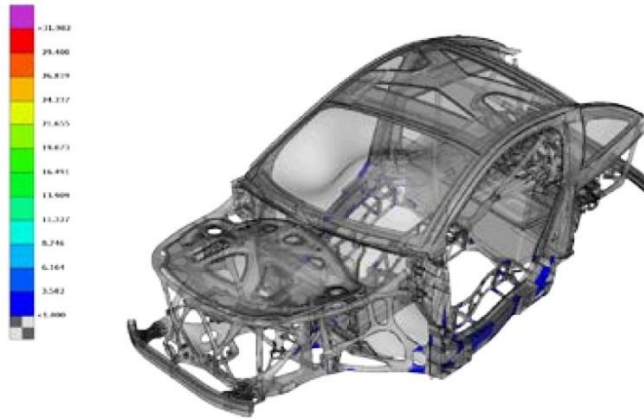
**Fig. 7.** Total acoustic pressure.

The finite element method used in 3D design makes it possible to assess the stiffness and strength of the vehicle digital twin with predictable accuracy on the corresponding virtual test bench (Fig. 8).

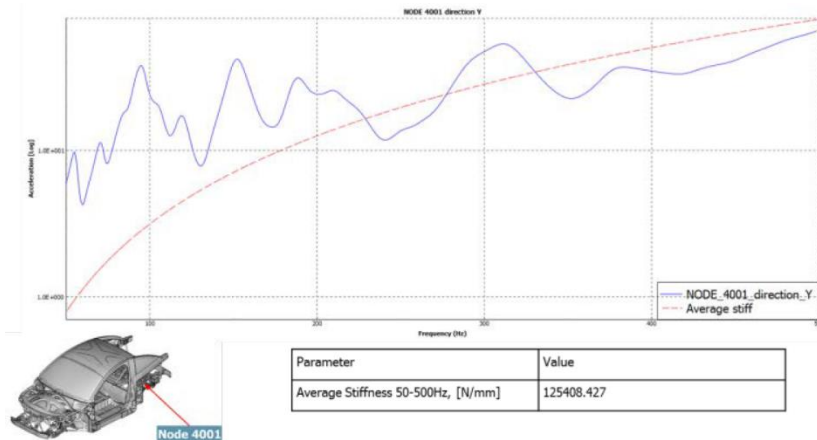


**Fig. 8.** Assessment of the stiffness and strength of the digital model of the designed vehicle.

Moreover, the proposed digital platform offers virtual stands for assessing, respectively, the natural frequencies of the digital model (Fig. 9), as well as the vibroacoustic comfort of the digital twin (Fig. 10).



**Fig. 9.** Assessment of natural frequencies of the digital model.



**Fig. 9.** Results of the assessment of vibroacoustic comfort.

Furthermore, automated programs for processing and analyzing the results of virtual tests have been developed. Thus, it is possible to fully control all set targets. This means that the

introduction of feedback from the output of such a monitoring program to the input of the program for adjusting the parameters of the digital twin of the designed model allows the automation of the optimization process for the specified parameters of the designed product. It can be an iterative process. The complexity of the implementation of such a program lies in the need to solve the problem of multi-criteria optimization of the digital twin parameters.

Necessary documentation has been developed for the demonstrated platform. Technical requirements for digital twins and virtual stands have been developed. These requirements must be entered in order to carry out reliable design checks. A guide to the use of virtual test benches has also been developed.

## 4 Conclusion

The article demonstrates the results of the development of a digital platform for testing and assessing the digital twin parameters of an automotive product. Assessment and testing are carried out on the so-called virtual stands, the basic part of which are digital twins.

Thus, such a system is a linkage of a computer-aided design system with a computer model of the designed product. The latter is built on the basis of mathematical models reflecting certain physical properties and processes in the designed product and its components. To ensure the convergence and adequacy of the results of the computer model operation, suitable numerical methods for calculating the developed mathematical models, constructing finite element models are required.

The developed platform makes it possible to certify and verify the correspondence of the designed product parameters to the requirements imposed by the relevant standards at the corresponding virtual stands. The main ones include the requirements for passive safety, which is determined by the stiffness and strength of the structure. The virtual stand, due to the presence of such components as a mathematical model and a module for assessing the correspondence of product parameters to specified requirements, allows optimization of the digital twin parameters. Thus, for example, automatic topological optimization of product design is particularly relevant.

In the general case, the optimization of such a complex technical product as a vehicle is a challenging task. In most cases it results in the problem of multi-criteria optimization. Moreover, taking into account the nonlinearity of the digital twin, the solution of this problem requires appropriate mathematical approaches. The use of artificial intelligence and machine learning methods and technologies is promising.

A separate issue that is not considered in this article, but is extremely relevant, is the issue of validating a digital twin, based on its verification on a physical twin.

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