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A STUDY OF THE FREE VIBRATION OF SUSPENSION ROD BASED ON FOUR-STAGE ARM MECHANISM BY USING COMPUTER SIMULATION

We analyze the current state of the prospects and problems of using computer technology to determine the operating parameters of movement of the vehicle. Scientific works related to the study of the properties of the vehicle smooth ride are studied. The following example shows that the modern researches of smooth ride do not pay enough attention to issues associated with the processes that occur in the suspension rod of a vehicle. Scientific works related to the choice of the optimal and simple CAD system for conducting computer simulation tests are overviewed. We developed an animating model of experimental car in SOLIDWORKS environment with the staff suspension rod and the suspension rod based on four-stage arm mechanism, which allows a wide range of tests of components of the vehicle. Methodology and hardware-software complex for testing a car are developed. A test of a vehicle of category N1 is conducted. A computer simulation of the motion of the smooth ride of the car with suspension rod based on four-stage arm mechanism is conducted. The comparative analysis of suspension rod performance based on four-stage arm mechanism is conducted.

Keywords: *suspension rod, vehicle, four-stage arm mechanism.*

Problem statement. Modern scientific and technical progress is directly linked with the advent of computers. Calculation of complex tasks in production using computers many times increases production and reduces the cost of design. Striving to meet the highest level of technical requirements that appear in connection with the constant growth of computer technology has led to the emergence of many generally available programs for simulation of technological processes that take place in the car. Without a comprehensive and extensive virtual tests, the development of modern automotive technology is impossible to imagine; the design of vehicles and the legislative requirement to conduct tests have become too complicated. The use of computer technologies for modeling allows to significantly improve the quality of products, as it gives an opportunity to carry out an endless number of tests of one model constantly changing and improving it, without the large costs of material and physical resources.

Computer simulation occupies one of the most important roles in designing of systems of cushioning at the early stages of design. So the use of powerful computers to improve or to create new, more advanced vehicle systems is inevitable step.

Analysis of recent research and publications. Among works devoted to this problem, scientific researches that laid the fundamentals of creating a modern car must be distinguished. Thanks to the work of such scholars as Ya.M. Pevzner [1], R.V. Rotenberg [2] and many others, managed to lay the foundations of scientific schools and work out ways of development of the modern automobile industry, satisfying production and operational requirements constantly.

At the initial stage of the development of the automotive industry, as a science and the creation of the car there were two main groups of car test on the smooth ride [3]:

1. Laboratory;
2. Road.

The main purpose of the laboratory dynamic testing is to determine the dynamic characteristics of the suspension rod, which creates a link between the influence of the vibrational system and its reactions. In addition, dynamic tests determine the parameters of the vibrational system if they can't be found in static conditions: frequency of free vibrations, the coefficients of relative increases, moments of inertia, etc.

Dynamic characteristics allow to much greater extent than the static estimate the properties of the suspension rod during different modes of its work, including conditions close to operating modes. Therefore, the evaluation of the quality of the suspension rod in the laboratory conditions

dynamic test take the central place. However laboratory and road tests complement each other and are combined with the total program.

Conducting laboratory dynamic testing allows you to reduce the amount of expensive and long-term road test. In some cases, laboratory tests are more effective than road ones when identifying the shortcomings of suspension rod performance, as they allow to use different test modes, providing at the same time their full stability. Determination of dynamic characteristics and parameters of the vibrational system can be done for different types of effects on vibrational process [4].

Currently quite a large number of methods to test individual elements of the vehicle are known, in particular, suspension rod elements such as suppressants, spring elements and guide elements. Tests on the smooth ride are conducted, as a rule, at the stage of preparation of serial production or modernization of existing car design. The basic document that regulates laboratory and road tests on the smooth ride is ISS [5].

ISS determines the test object, measuring parameters, measuring equipment, conditions and procedure for conducting the tests.

Road tests are carried out in areas with a special profile, in accordance with the roads with cement concrete coating and paving blocks [6].

Road test, along with such benefits as the absence of need for simulation of road surface, have a number of disadvantages, including:

1. An objective evaluation of smooth ride requires a choice, or the construction of the road respective to road types, and its maintance in good condition.
2. The high cost of the test.
3. Uncomfortable working conditions of test drivers.
4. The complexity of the transducer installation and interception of individual elements of suspension rod.
5. The necessity of the equipment, which work would not have made errors of the vibration that occurs during the test.

Modern methods of designing a car at the stage of design allow to explore and improve the systems of cushioning and vibration protection, evaluate the characteristics of the smooth ride and load of system carriers using mathematical modeling of its movement. Methods of mathematical modeling take into account all the parameters of the suspension rod affected the smooth ride. As a means of learning around the world, the technology of virtual reality used computer graphics and interaction "man-computer" is becoming increasingly popular [10].

However, one of the major problems of the applied methods is the lack of theoretical experimentally filled mathematical models [6]. However, the results of the current experiment are compared with the results of road, or bench tests for further adjustment of mathematical model.

The works of G.G. Pivnyak [9] and D. Murray [10] show a wide range of use of automatic design in modeling and complex processes of interaction of mechanisms; the choice between different CAD systems is substantiated, basic directions of development and improvement of existing simulation models are defined . A software framework SolidWorks is the most convenient and multi functional product for carrying out modeling of mechanical systems. Of course, the simulation cannot completely replace physical experiments, its purpose is to ensure the correct determination of the results of experiments with nonlinear systems, interpolate and extrapolate their results.

However, the development and the application of numerical methods in the past decades have led to the fact that virtual system design today is a tool, fully integrated into the process of designing a vehicle and items of the road to ensure safety.

The goal of the work. To implement the suspension rod test based on four-stage arm mechanism for free vibrations by using computer models. Manufacture of a full suspension rod is quite continuous, complicated and expensive process. As an alternative it is proposed to use the modern software which allows to build a full-size virtual car and a number of computer simulation tests.

Tasks:

1) creating a computer model of the car with a suspension rod based on four-stage arm mechanism (FSAM) and the issued suspension rod;

2) model verifying using the comparison of computer data and natural experiments;

3) study of suspension rod based on four-stage arm mechanism

В якості базової програми була обрана програма SolidWorks з додатком Motion[7], який призначений SolidWorks with a Motion application [7] has been chosen as a basic program , which is designed for modeling dynamic systems in software environment. The Motion module is designed for simulation of mechanism motion with consideration of kinematic and power factors. The program is fully integrated in SolidWorks, operates on the geometrical model of the basic program, the estimated parameters and results are also made in the model.

The program analyzes the SolidWorks assembly, broadcasting it in the conventional model of mechanism taking into account mass-inertia characteristics. This inertial parameters are adapted to geometry details of SolidWorks, and density (mass) can be designed regardless of the geometric shell. Further, the system of differential equations of motion is constructed for the mathematical model, which is then solved using differencing schemes. The program converts the numerical results in type, suitable for displaying. On this stage, the system again interacts with real geometry. Displaying of the kinematic model (in the form of pictogram), and the results is providing in the graphic window of SolidWorks directly against the background of the assembly model.

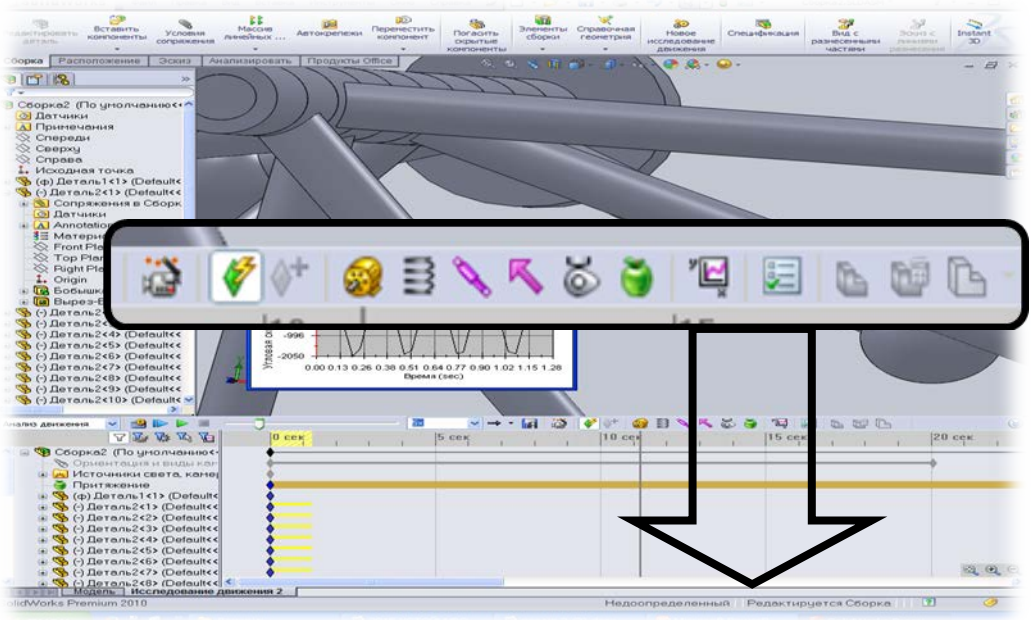

Figure 1. The program interface

Motion module (Figure 1) allows to install different types of sensors (the angular and linear displacement, velocity, acceleration, etc.).

The program includes the following possibilities:

- to create a design model based on the assembly of SoIidWorks with reading with its geometry, mass-inertia characteristics of the parts and relationships in the assembly;
- to maintain relevance of calculated models according to the SoIidWorks structure ;
- to create a connection for various types of conditional limitations;
- to simulate the contact connection with the ability to input and output from the contact with regard to damping;
- to create virtual springs, shock absorbers and plastic bushing;
- to assign the direction of movement and virtual engines of various types using functions of the MSC.ADAMS;
- to perform the option customization of the computer and solve the problem of using different types of algorithms;
- to perform the visualization of the kinematics of the mechanism with the simultaneous display of the results in the form of graphs, vectors, icons;
- to record the results in a variety of graphic formats, and import the results of dynamic calculation in CosmosWorks;

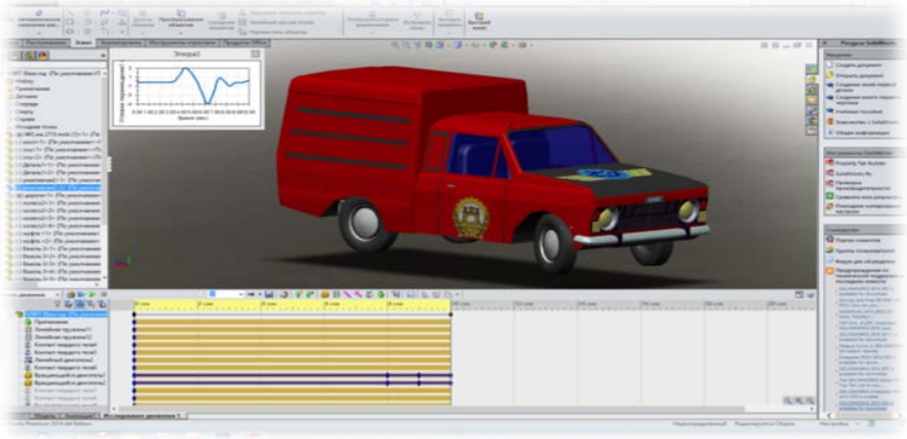

Figure 2. Animated model

But for building a quality model (fig. 2) n the options of suspension rod performance must be extremely accurately assigned, which will determine the accuracy and display the quality results. Therefore a series of laboratory and road tests of the regular suspension rod of tested vehicle were conducted [8] (fig. 4.6)

According to the results of the experiments we obtained the main characteristics of the regular (factory) suspension rod that were used to build a basic animation model of the experimental car inside SolidWorks Motion with basic suspension and suspension based on FSAM. These models take into account all of the mass-geometric parameters of the car and its elements, also the forces of inertia, friction of the lever, the damping elements, friction of tyres bearing surface, gravity and other options (fig. 2).

To conduct a simulation computer tests the following methodology of computer studies is used:

- the model car is set on a flat horizontal plane (the parameters of the elasticity of the surface and the environment are set);
- the front wheels are fixed from turning;
- the virtual measuring sensors of movement are set;
- the car's rear wheels are raised to a height of 55-65 mm from the plane of the measurement (depending on the type of suspension rod);
- car model is tipped and a vibrational process of spring-suspended and unsprung weight is fixed;
- experiments are repeated when the workload model for 25, 50, 75 and 100% of the nominal car load bearing capacity;
- the parameters of the oscilating process are recorded using the built-in Motion sensor module.

According to the methodology, the car tipped from a height of 60 mm, provided the absence of strikes in the qualifier and the detachment of wheels from the platform on which the tests are provided[8] (fig. 3.5)..

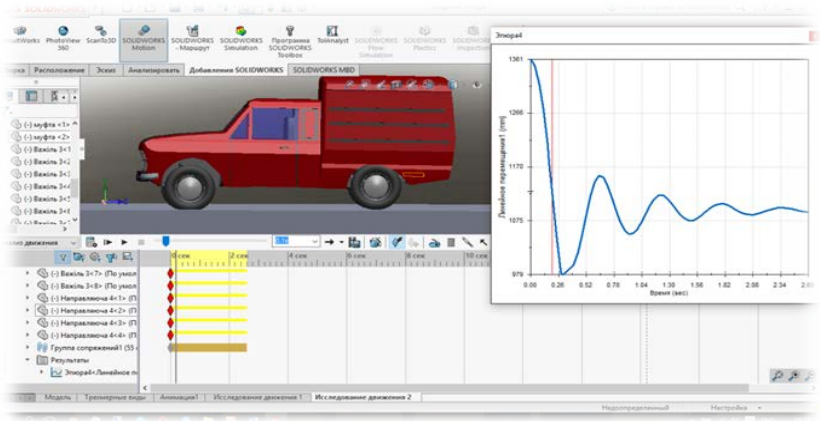

Figure 3. Computer tests execution. Native (factory) suspension rod. Sprung weight 430 kg.

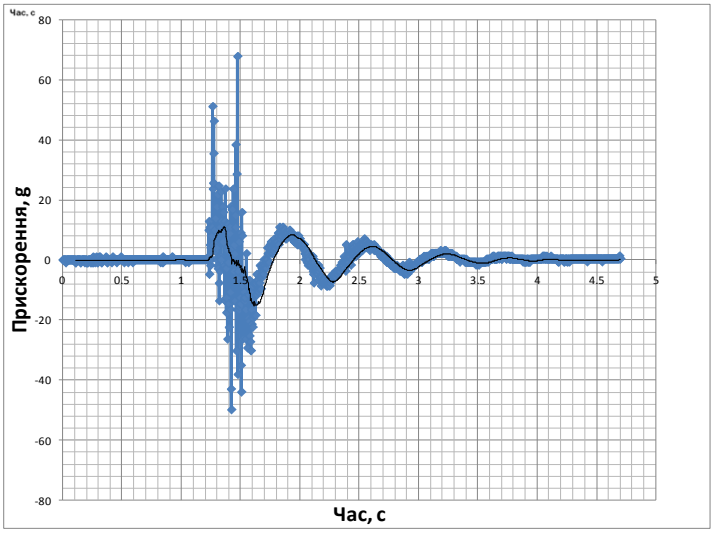

Figure 4. On-site laboratory testing execution. Native (factory) suspension rod. Sprung weight 430 kg.

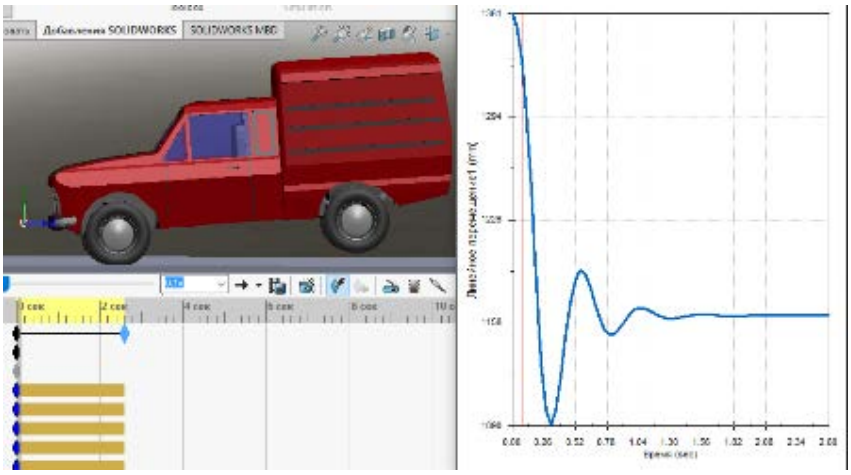

Figure 5. Computer tests execution. Suspension rod based on FSAM. Sprung weight 430 kg.

Fig. 3 presents the computer tests of free vibrations of spring-suspended weight of experimental car with a factory suspension rod, with a given stiffness of elastic element of 2500 kg/m by reset method. Fig. 4 shows the graphics obtained after conducting on-site laboratory testing of a factory suspension rod [8]. When comparing the results an error was discounted, which does not exceed 7%, confirming the efficiency of computer modeling in SolidWorks Motion for the developed methods (simulation model).

Replacing the regular suspension rod in a simulated model on the suspension rod based on the FSAM gives the possibility to check the efficiency of the projected suspension rod without conducting laboratory tests. The simulation model can be used as a base modeling of vehicle with other suspension rod.

Fig. 5 presents the computer test of free vibrations of spring-suspended weight of experimental car with suspension rod based on four-stage arm mechanism by reset method. The frequency of the oscillations of spring-suspended weight corresponds to1.2 Hz.

Experimental vibration frequencies of unsprung weight of the car with a suspension rod on the basis of FSAM, obtained due to a computer simulation fully comply with standards of vibration loading of the driver's seat [5] and cargo of this class of car.

Conclusions:

- simulation 3D-models of experimental car in SolidWorks Motion software environment with a suspension rod on the basis of FSAM and a regular suspension rod according to the requirements of a dynamic analysis of animated models were developed;
- computer simulation and laboratory testing to determine the vehicle's smooth ride with a regular suspension rod were conducted;
- according to the results of the tests a comparative analysis of the free vibration spring-suspension weight of the vehicle in the software environment of the SolidWorks Motion with laboratory tests were conducted;
- the test results coincide within the permissible error of 7%. The next stage of research will require to compare the results of the computer test data of the natural laboratory test car with a back suspension rod based on FSAM.

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