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Shock machines for testing Arctic robotics

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Abstract. All industrial products including robots used for various works in arctic zone, can be exposed to various shock loads. In arctic conditions, such loads are: tectonical impacts, impacts from snow mass and other phenomena. To confirm the durability of products exposed to shock loads during exploitation, the impact tests ща products should be preliminary carried out. Such tests are performed in special equipment - shock machines. Shock machines are complex highly automated equipment. The development and production of machines of this type require advanced high technology and serious financial investments. Therefore, a deep understanding of operation principles of shock-testing machines, their design and methods of adjusting is very important. In the current paper the structures and designs of several types of developed shock machines are analyzed in details: single-shock machine, multiple-shock machine, machine with a pneumatic accelerator. Data on the development of a positional multi-motor pneumatic drive by the High School of Automatics and Robotics of Peter the Great St. Petersburg Polytechnic University are presented. The interface of the operation panel of the multiple shock machine is described according to operating modes, recording and processing the results of measuring the parameters of the shock pulse. Directions of research in the field of synthesis of shock machines for testing Arctic robotics are defined.

1. Introduction

While making decisions about starting production, selling or purchasing products, as well as in other cases, final conclusions made are based on the results of tests, which experts attach more importance to than the results of theoretical research and calculations. In engineering practice, tests allow you to determine the initial data for research, verify the calculation and get reliable information about the product [1]. However, the combination of both theory and experiment is the most effective.

The traditional areas of application of testing machines, such as defense and security, nuclear power, rocket and space, aviation, automotive and radio–electronic, have been added recently to the new ones related to the production of consumer goods, as well as equipment operating in extreme, for example, Arctic conditions, in particular extreme robotics [2]. The testing machinery has become widely used in modeling of transport loads in freight and railway transport, during transportation in shop conditions, testing of packaging: boxes, containers, barrels, canisters, boxes, etc. [3], [4], [5].

All large Russian industrial corporations, such as Almaz–Antey, Uralvagonzavod, etc. are equipped with certified testing centers for collective use. Many enterprises that produce responsible products have their own testing laboratories. The high level of interest in testing technologies and equipment is also confirmed by the traditional international conferences "Shock and Vibration Symposium" [6]. Only for 2019 the following events were held: the 90th Shock and Vibration Symposium in Atlanta, the Testing & Control international exhibition of testing and measuring equipment in Moscow, specialized exhibitions and conferences on specific industries, such as the Automotive testing expo, the Aerospace Testing & Simulation Conference, and others.

2. Shock machines

The principle of operation of a shock machine is a relatively long accumulation of energy necessary for reproducing the shock and its subsequent release within a short period of time [7]. The required shape of the shock pulse is provided by using a shaping device (shock pulse-shaping device). There is a wide variety of different types of pulse-shaping devices: hydraulic adjustable shaping devices [8], sawtooth shaping devices [9], semi-sinusoidal shaping devices [10], as well as shock pulses of other required shape.

The market of Russian shock equipment by the beginning of 2020 is quite limited: drop test rig K–200 and Electromechanical stands for multiple shocks VSTS–450/1000 and VSTS–750/1000 series are the only known and available models of such equipment. Drop test rig K-200 [11] is an analog of the machine manufactured in the United States more than 50 years ago, the stands of the VSTS series are the modernized Tira Shock 4110 shock machines [12] developed by Tira Gmbx (Germany, 1980...1990), which are currently in operation in the Russian Federation, but have been discontinued by Tira Shock for a long time. Neither drop test rig K–200 nor VSTS stands do not meet modern requirements for shock testing technology, as they are outdated and have insufficient functionality.

On the other hand, the requests of the industry, problems with the purchasing of expensive imported equipment and its subsequent maintenance, especially in the current conditions of restrictions, made the development and creation of modern Russian shock equipment extremely relevant.

2.1. Single shock machine KSP5

The KSP5 [13] is a testing shock machine of indirect action, when a shock pulse created is a result of interaction of moving shock table with a product mounted on it and an anvil on which a shaping device determining the type and parameters of the pulse is placed.

The shock machine KSP5 (figures 1-3) includes the shock machine itself, the operation panel, the control panels, the sensors, and the compressor.

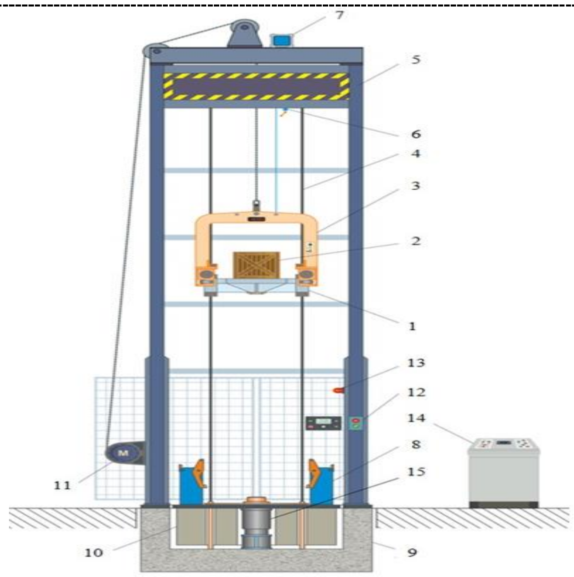

Figure 1. Scheme of shock machine KSP5: 1 – shock table; 2 – test object; 3 – dropper; 4 – guides; 5 – shaft; 6 – emergency limit switch; 7 – lift height sensor; 8 – parking device; 9 – foundation;10 – inertial block; 11 – winch; 12 – auxiliary control panel of the machine; 13 – flashing beacon; 14 – operation panel; 15 – pneumatic cylinder of the sleeve type

Figure 2. Dropper and shock table

Figure 3. Operation panel

The main functional parts of the shock machine are: the shock table 1 for fixing the product with technological equipment (the test object 2), the table dropper 3, the winch 11, the sensor 7 for measuring the height of the table lift, the inertia block 10, the supporting shaft-formed metal frame 5.

The shock table which has a complex shape, synthesized using ANSYS software according to the criterion of specific stiffness, is made of a special light alloy with good damping properties and is equipped with steel threaded bushings, forming a grid of mounting holes on its surface. A shock accelerometer is mounted on the surface of the shock table. The electrical connection of the test object and the accelerometer to the stationary equipment is carried out via a flexible cable.

A design feature of the shock machine is using a controlled air suspension of the inertial block, which allows to effectively translate the kinetic energy of the falling shock table with the product into the potential energy of a compressed air spring, and then release the compressed air into the surrounding shop environment. The air suspension of shock machine is somewhat similar to the currently widely used air suspension for trucks and passenger cars.

2.2. Series of multiple shock machines SMU

In contrast to shock machine KSP5 which is a single-strike machine, the machines of SMU-series are universal: they allow to reproduce both single and multiple strikes with a given frequency. In factory tests, the requirements for multiple impacts are usually reduced to reproducing accelerations in the range of 3 ... 200 g with durations of 3...30 ms at a frequency of 40 to 120 shocks per minute.

The typical law of change in acceleration for multiple impacts is semi-sinusoidal, the total number of shock ranges from several tens and hundreds to tens of thousands, and the duration of the tests varies from half an hour to several working shifts. The structure of the SMU-series stands is shown in figures 4 and 5.

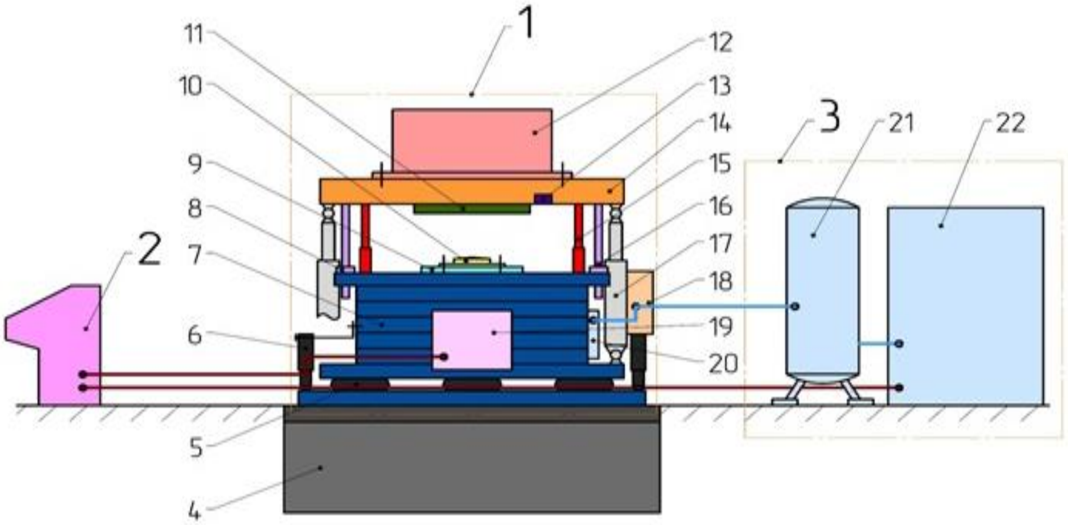

Figure 4. Structure of shock machine SMU1200: 1 – shock machine; 2 – control stand; 3 – compressor; 4 – foundation; 5 – balloon pneumatic cylinder; 6 – shock absorber; 7 – inertial block; 8 – sliding sleeve; 9 – anvil; 10 – shaping device; 11 – open die; 12 – test object; 13 – shock accelerometer; 14 – shock table; 15 – parking racks; 16 – table guide; 17 – pneumatic actuator;18 – pneumatic drive equipment; 19 – switching unit; 20 – pneumatic unit; 21 – receiver; 22 – compressor

Figure 5. Photo of shock machine SMU1200

The main elements of the SMU-series shock machines are the shock machine 1 itself, the operation panel 2, and the compressor 3. Shock machine consists of the shock table 14, inertial block 7, four pneumatic actuators 17 and a number of auxiliary elements.

Developed in High School of Automatics and Robotics shock machines of SMU-series have a pneumatic actuator that provides a wide adjustment features and wide range of playable options. The control range of peak shock accelerations is 1: 100, and the reproducible durations are 1:20, and for a single impact with an accelerator - 1:40. The simplicity of setting impact parameters, ease of adjustment and wide ranges of reproducible parameters distinguishes them from Electromechanical impact machines that use lever or Cam devices as a driving mechanism, the main drawback of which is the insufficient speed of the test object before impact, the complexity of adjustments and settings for test modes.

In practice, the peak shock acceleration and the duration of the shock pulse are correlated with the speed of the object before the impact, and are set by shapers - consumable elements attached to the shock machines. Shapers must have certain properties that are best provided by materials such as felt, rubber, polyurethane, and special polymers. Steel cylindrical springs are also used shock machines.

In shock machines of SMU series, not only the design, but also the software of the control device, based on a new technical solution are original [14]. The program provides a convenient interface for the operator when setting the required operating modes, recording and processing the results of measuring the parameters of the shock pulse. Figure 6 shows the view of the program window in single-strike mode for the SMU1200 model - shock machine.

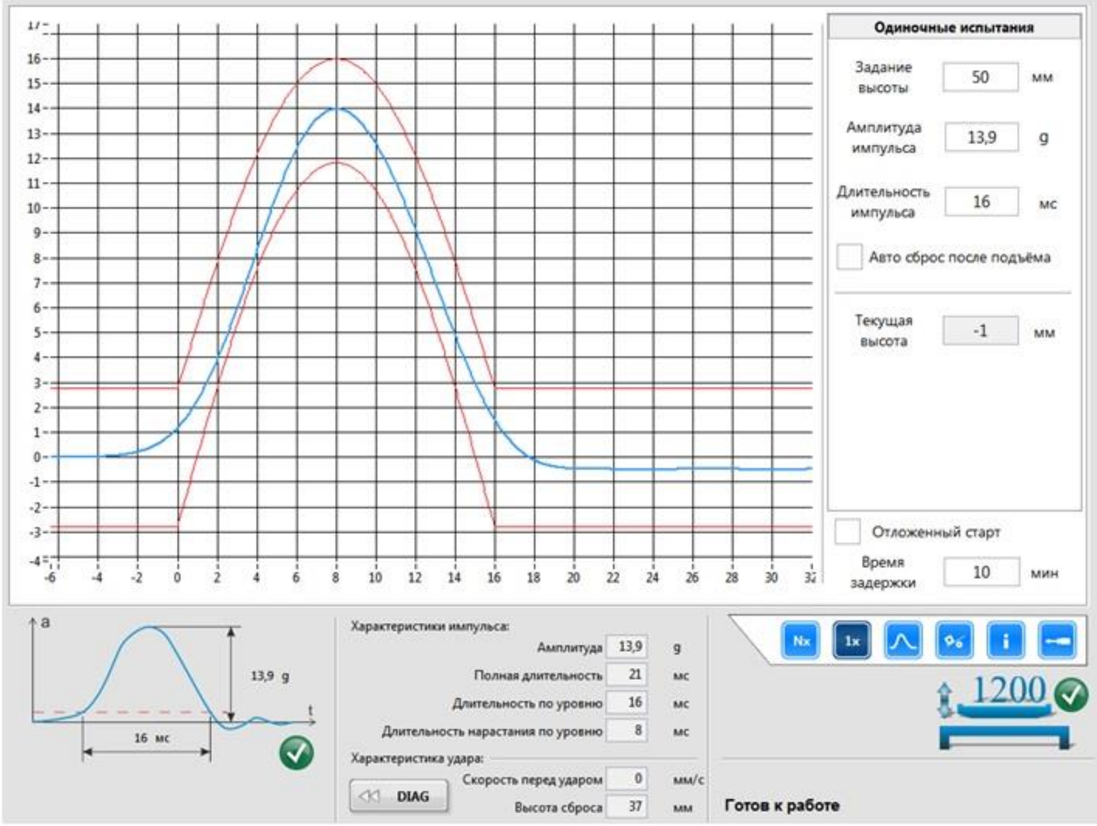

Figure 6. SMU1200 shock machine program window in test mode

The upper and lower curves in the central part of the program window set the tolerance field for the amplitude and duration of the shock pulse according to the technical conditions for testing a particular product. At each stroke, the curve of the pulse received during playback is superimposed on the line of the tolerance field. With the help of a pneumatic drive, the shock table rises to the desired height, providing the required speed before shock. The algorithm for reaching the specified amplitude of the shock table and its maintaining is adaptive [15].

In the right part of the window, the test task is displayed, in the lower part - the actual characteristics of the shock pulse and icons of other possible modes (windows of the shock machine control program): multiple strikes, analysis of graphs, settings, and locks.

The algorithm for controlling the rise of the shock table is implemented using a positional multi-motor pneumatic drive. The system provides synchronous control of several pneumatic motors, which is necessary for strictly vertical lifting of the impact table and its accelerated or free fall on the anvil with a set of shaping devices.

3. Conclusion

Eight test machines of various types have been developed, manufactured in High School of Automatics and Robotics and delivered to industrial enterprises in Saint Petersburg and the Russian Federation for the past few years. Customers admit their competitiveness in comparison with foreign counterparts. A large amount of research has been done, the monograph has been published, 12 articles, 6 patents on inventions have been obtained obtained, more than 20 graduate works of students and several PhD theses have been made made.

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