

Expansion of technological capabilities of the laboratory unit for determining the longitudinal stability of rods

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Abstract. Creation of educational laboratory equipment with high operational efficiency associated with improving the use of the installation by increasing the accuracy and increasing the convenience of measuring as well as fixing when conducting experimental research, expanding its functionality and improving the accuracy of measuring parameters to implement a wider range of studies.

Analysis of the equipment used in the university laboratories has shown that in some cases obsolete samples are used, which do not allow to expand the range of studies and are inferior to modern samples in terms of accuracy and convenience of the measurements being made, although they fundamentally solve the tasks of educational studies [1].

The purpose of this work is to consider the possibility of improving the operational efficiency of such equipment using the example of upgrading the standard installation of the SM-20 model [2] used in the laboratory of material resistance to determine the longitudinal stability of the rod and the critical force causing its loss of stability.

In higher education institutions, students can quite successfully be involved in projects where they can implement their creative abilities within the framework of the progressive paradigm of project-based learning [3-6], which makes it possible to identify their actual creative potential. It also helps them to master the whole chain of “end-to-end” design, performing a complex of stages according to the so-called plan: “from an idea to the real model” at the training stage under the guidance of experienced teachers [7]. This contributes to the development of engineering approaches in solving practical technical problems, providing a significant improvement in the training quality of modern graduates.

Meanwhile, it was decided to solve the task of using simple technical solutions to bring the level of the standard installation functional efficiency to the technical characteristics of the modern similar samples in order to determine the longitudinal stability of the beams/rods of the SM-20 model.

In the standard version (figure 1), the SM-20 model installation does not allow to determine the magnitude of the critical force F_{cr} , causing the rod (beam) deflection, since its design uses the built-in mechanical vernier displacement meter of the pressure nut (7) with a scale of 50 mm the division value of the vernier is 0.1 mm) by which the compression value of the load spring (6) is determined, and the displacement amount corresponding to the critical force F_{cr} is set according to the position of the slider (indicator) of the measuring scale at the time of the beam and its contact with one of the stops (4). The value of F_{cr} itself is then found in the load spring (6) attached to the calibration schedule attached to the installation certificate, that actually remains unknown is the magnitude of the force of the preliminary compression of the load spring (6), which does not allow one to know exactly the origin of the readings.



Other drawback of the installation is that it does not allow testing of beams of various lengths, which limits its technological capabilities, as well as the absence of an automated research mode.

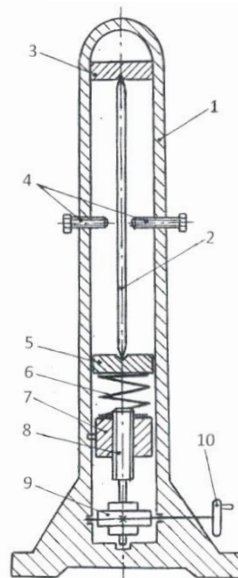


Figure 1. Design and structural diagram of the SM-20 standard installation: 1-body; 2- tested beam (rod); 3- upper support; 4 – stops-limiters; 5- bottom support; 6- load spring; 7- push nut; 8- screw; 9- worm gear; 10- flywheel.

In the modernized version, the installation for determining the beam longitudinal stability (IDBLS) was supplemented with new original units of modular design, namely: measurements of axial force, special structures of the upper support, stops-limiters, as well as an electro-mechanical drive of the loading device. The connecting constructive elements of the new nodes are preserved taking into account the response elements of the standard installation.

In the proposed installation for determining the magnitude of the force, an electronic analog-to-digital converter (ADC) is used, equipped with a force sensor, which is the most commonly used strain gauge sensor, which is a strainer that accepts the tensile load and operates on a bridge electrical circuit to connect to the ADC, which provides him with good sensitivity and sufficient thermal stabilization. The measured value of the force in the form of the error signal from the sensor is sent to the ADC, from where after conversion it is displayed in digital form on the display of the front panel of the control unit.

Figure 2 shows the combined general constructive and functional diagrams of the developed IDBLS; figures 3 and 4 represent the drawings of a general view of the upper part of the installation and its assembly, respectively.

In the new version, the upper prismatic support (5) (figure 4) is equipped with a shank (3) placed in the central hole of a special guide sleeve (2) rigidly fixed in the standard threaded hole of the housing (1) of IDBLS instead of the old deaf cover that was a rigid support for the upper support. The shank (3), installed in the guide sleeve (2) on landing with a gap, allows micrometric axial movement of the upper support (5) within the limits of compliance of the sensitive element of the load cell - strain gauge (16) force measuring device. The measuring device is made as a separate modular unit and consists of a vertical bracket, which is a welded unit consisting of a split sleeve (8) and two parallel racks (12) and (13). The sleeve (8) plays the role of a yoke that mates with the outer cylindrical surface of the body (1), and makes it easy to adjust the position of the entire bracket along the axis of the body (1). The force sensor in the form of a strainer (16) is provided with an upper (18) and lower (17) rods of its suspension. The upper rod (18) mates with an adjusting nut (19), resting on a transverse bar rigidly mounted on the uprights (12) and (13) of the vertical bracket. With its lower rod (17), the strainer (16) is pivotally connected to the adjustable length arm of the conversion lever (15) placed on the rolling support (21) in a vertical bracket by means of an axis (20) and having a roller (25) (ball bearing) at the end of the

opposite shoulder that is not adjustable along the arm (24) and which is gaplessly mated with the stop (4) of the shank (3).

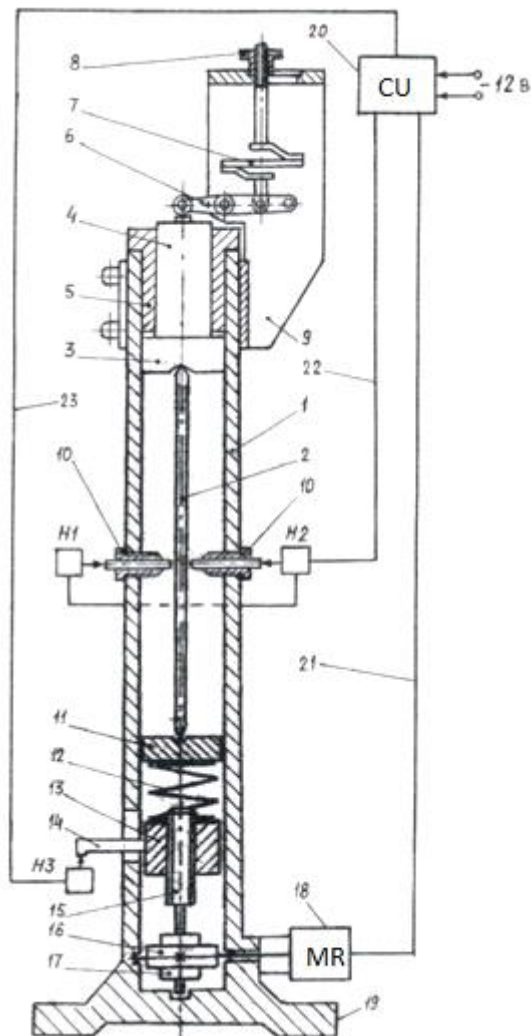


Figure 2. Constructive and electrical circuits of the developed IDBLS:

1 - body; 2- tested beam (rod); 3- upper mobile support; 4 - support shaft 3; 5 - guide bushing; 6 - gear lever; 7- strainer; 8 - adjusting nut; 9 - force sensor bracket (strainer); 10 - limits-stops; 11 - lower pressure support; 12 - load spring; 13- push nut; 14- movable stop; 15 - screw; 16 - worm; 17 is a worm wheel; 18 is a motor-reducer (MR); 19 - installation base; 20 - communication control unit (CU), 21 - functional, inverse: 22 - state of beam 2 and 23 - position of the pressure nut.

To change the gear ratio of the conversion lever (15), in order to expand the measurement range of the axial force, two holes are provided in its adjustable shoulder, which are hingedly connected to the rod (17) and located at different distances from the axis (20) of the lever (15).

The ADC module of the electronic measuring device is housed in the control unit body mounted on the rack (13), and its front side is simultaneously the control panel (39) (figure 3) with functional elements and has a digital display (40) for displaying the measured axial force values.

The standard stops-limiters of the transverse deflection of the beam added the function of simultaneous opening of the power circuit of the gearmotor (19) (figure 2) to stop its rotation automatically when lowering the pressure nut (13) to the lowest position and closing the electrical circuit of the light indicator, the light signal of which facilitates visualization of the moment deflection of the beam at the moment of reaching $F=F_{cr}$. For this purpose, in the case of the stop-limiter (29), a pusher (31) is spring-loaded via a spring (32), which at the time of the beam deflection presses the button of one of the closed-open microswitches (34) (figure 3, H1 or H2 in figure 2 respectively) located on its own brackets (37).

The use of easily removable stops (4) and the upper prismatic support (5) (figure 4) allows using several sets of interchangeable guide sleeves (2) with shanks (3) of different lengths, which additionally allows to investigate the effect of the axial size (length) of the beam (28) on the value F_{cr} .

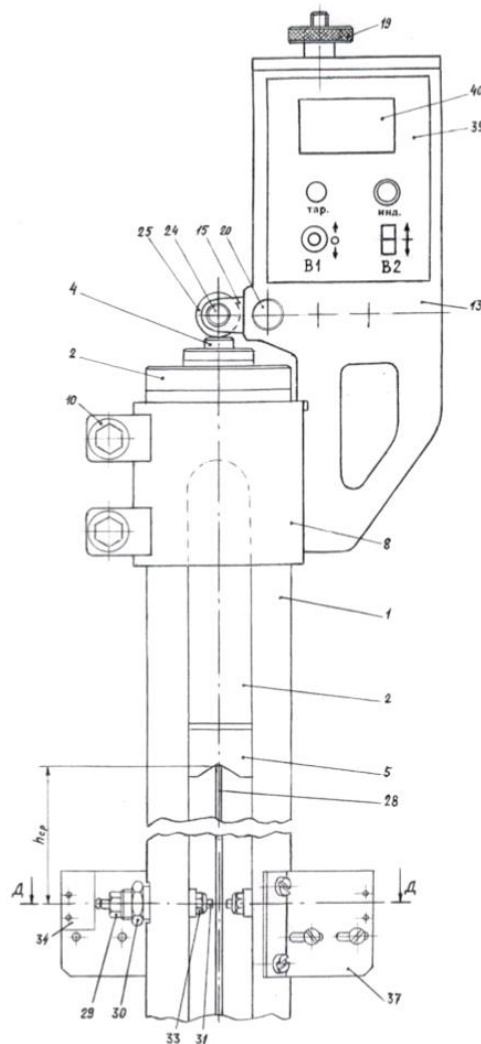


Figure 3. General view of the IDBLS top.

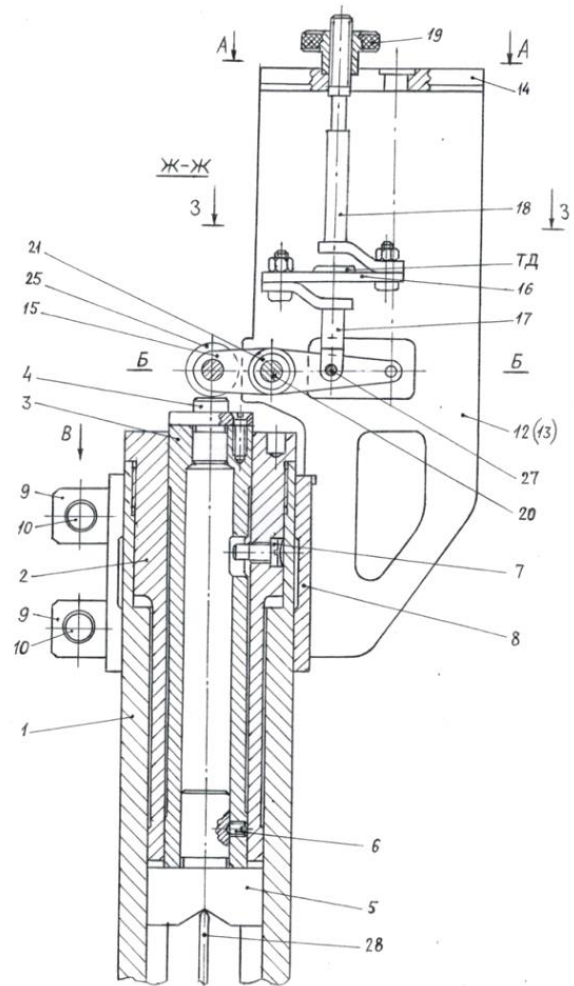


Figure 4. General assembly of the IDBLS.

In order to automate and facilitate the measurement of F_{cr} , an electromechanical drive of a loading device (figure 2) is additionally provided in the installation design, consisting of a 12 V reversible DC electric motor combined with a gearbox (MR) (19) which causes the worm (16) to rotate (figure 2), acting by means of a pressure nut (13) on the load spring (12).

In the developed version of the IDBLS, the procedure for determining the critical force F_{cr} is performed in semi-automatic mode as follows.

The test sample (beams) of the rod (2) is placed in the lower and upper prismatic supports according to the articulated scheme of its installation, that is, without rigid fixation of the beam in the supports. Then, by briefly pressing the 2-position button B2 (figure 2) on the front panel (39) of the control unit (figure 3), voltage pulses are applied to the MR (19) electric motor (figure 2) of the worm drive (16), gradually compressing the load spring (12) to select gaps in the chain: the lower support (11) - the beam (2) - the upper support (3) - the gear lever (6) - the load carrier (7).

The moment of the end of the total gap sampling in the specified kinematic chain is judged at the beginning of the increase in the axial force, at the same time they stop pressing the button B2, thereby stopping the compression of the load spring (12), and on the control panel 39 (figure 3) they press the “tar” button indications of the measured force. Resetting the readings of the magnitude of the load before starting the measurements eliminates the influence of the total weight of the beam (28) itself (figure 4), the upper support (5) with the shank (3) and the support (4), as well as the unbalanced part of the conversion lever (15) to the measured axial force acting on the beam (28). Then 3-position toggle switch B1 (figure 2) is transferred from a neutral position to an upper one; this closes the corresponding power supply circuit of the electric motor (19), by means of which through the gearbox (18) a slow continuous rotation of the screw (15) takes place; its lifting the locking nut (13), which compresses the loading spring (12), thus gradually increasing the axial force F .

At the moment when F reaches the critical value F_{cr} , the beam, due to the loss of longitudinal stability, is usually sharply bent. At the same time, it presses on the pusher (31) (figure 3) of one of the stops (29), which acts on the H1 or H2 button (figure 4) of the closed-open microswitch (34), which causes the MP (19) motor supply circuit to open simultaneously and the compression stops load spring (12) accordingly (figure 2), as well as the closure of the electrical circuit of the light indicator “ind” on the control panel (39) (figure 3), which by its light signal notifies about the bending of the beam and thus allows you to track the visual more clearly but determine the time to reach $F = F_{cr}$. At the same time, thanks to the memory function of the measuring device, its digital display (40) records the maximum value of the axial force F_{cr} .

To return the kinematic elements of the installation to its original position for the new measurement, the B1 toggle switch is moved to the lower position. Thus, the presented development allowed improving the accuracy and improving the convenience of conducting laboratory studies by automating the measurement process, as well as expanding the functional potential of IDBLS due to the possibility of additional studies of the effect on the value F_{cr} of the beam length.

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