COMPUTERIZED TEST BENCH FOR TRACTOR CABS

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Abstract: *In the paper is described a new computerized test bench for strength testing of roll over protective structures (ROPS) in tractor cabs. The static test procedure complies with international labor safety standards accepted in the Republic of Belarus.*

Keywords: ROPS, TRACTORS, LABOR SAFETY, AUTOMATION

1. Introduction

A Roll-Over Protective Structures (ROPS) of tractor cabins are highly effective engineering safety controls that can avoid or reduce the severity of injuries in the event of tractor overturns. The testing of protective structures on tractors is aimed to introduce quality assurance methods of the ISO 9000 type that means to simplify existing international trade procedures, to establish specifications and basic performance criteria and to ensure a minimum of quality for the traded tractor models.

In accordance with international standard [1] ROPS to be tested by the application of static loads that simulate the actual loads which can be imposed on the cab or frame when the machine overturns without free-fall. A static test procedure [2], currently adopted worldwide, involves a sequence of loadings, determined on the basis of the tractor reference mass while ensuring preserving intact a survival volume for driver protection in the event of a tractor overturn. At these loadings also there should be registered and estimated values of an energy or a force that have to be absorbed or sustained. The value of the absorbed energy and the magnitude of the allowable deformation under the action of a lateral force are important for assessing the protective ability of a ROPS under conditions corresponding to the impact of a protective structure with frozen soil, concrete, etc.

When testing, there is no need to accurately duplicate loading processes with deformations of the structure close to those which occur during the actual rollover of a particular tractor. The study of the results of various real rollovers and theoretical studies of the characteristics of the ROPS hope that the operator fixed on the tractor driver seat by the security belt will be sufficiently protected at least under the following conditions: when moving the tractor forward at speed of 0 to 16 km per hour on a solid clay surface with a tilt angle up to 30°; when tilting the tractor through 360° along the longitudinal axis without losing contact with the supporting surface.

In accordance with [1], the static test procedure includes the following steps:

- lateral loading imitating tipping machine;
- vertical load imitating roof flip;
- longitudinal loading is performed from the side closest to the operator.

According to safety requirements, all ROPS safety devices must be tested for compliance once every five years by carrying out field tests simulating their loading when the machine rolls over. The Republic of Belarus produces domestic models of tractors and other agricultural machines. "Minsk Tractor Works", OJSC today is one of the largest producers of agricultural equipment, not only in the countries of the former USSR, but throughout the world. Therefore, an urgent task there was a creation in the Republic of Belarus a domestic automated stand for testing and certification of ROPS devices. Such a stand was developed on at the State Institution "Belarusian Machine Testing Station" in cooperation with specialists of the Department of Automated Production Management Systems of Belarussian state agrarian technical university that developed the test automation and program control of the technological equipment of the stand.

2. Computerized test bench description

The stand is made in the form of a power steel frame and mounted on a reinforced concrete base. The test object – a tractor cabin – is installed inside the stand. In order to take into account the rigidity of the mounting the cabin on the tractor base frame, the ROPS device was fixed according to its actual installation on the tractor. Inside the tested ROPS was installed DLV [1] – a dummy simulating the position of the driver.

The loading was carried out by means of vertical and horizontal hydraulic cylinders. The hydraulic system of the stand provides a maximum force of 2200 kN that allows to test the protective cabins of tractors of total weight up to 110 tons. During the testing process monitoring of load force and cabin deformation is carried out.

The loading force is measured by dynamometer АЦД/1С-500/4И-2 [2]. Such dynomometers are of accuracy class 2 and are used to measure smoothly varying tensile and compression forces of various actuators under industrial conditions. Structurally, the АЦД/1С-500/4И-2 dynamometer is a strain gauge sensor that is connected to an electronic measuring indicator (secondary signal converter from a strain gauge sensor) by means of a communication cable. The indicator unit has a backlit liquid crystal display. The unit is self-powered from built-in batteries or from a 220 V network. RS232 digital interface is used to transmit data to a digital control device (programmable logic controller, PLC).

ROPS deformation is measured using a RF 603-245 / 1000-232 laser triangulation displacement sensor [3]. Triangulation laser sensors are designed for contactless measurement and control of position, displacement, dimensions, surface profile, deformations, etc. The operation of the sensor is based on the principle of optical triangulation (see fig. 1). The radiation of the semiconductor laser 1 is focused by the lens 2 on the object 6. The radiation scattered on the object by lens 3 is collected on the CMOS ruler 4. Moving an object 6 – 6' causes a corresponding movement of the image. The signal processor 5 calculates the distance to the object by the position of the image of the light spot on the ruler 4. The sensor is installed so that the monitored object is located within the zone of the sensor working distance range. There should be no other objects in the area of the radiation incident on the object and reflected from it.

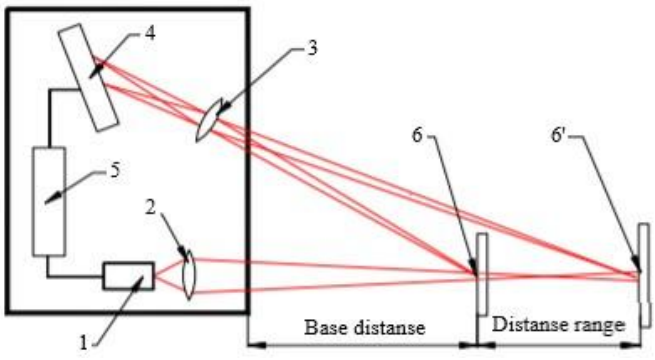

Fig. 1 *Laser triangulation distance meter.*

Ethernet interface is used to transfer data to PLC. The accumulation and transfer of data to PLC occurs in stream mode. At the same time, the internal sensor transfer buffer is first filled with measured data (buffer size – 168 measurements). After filling the buffer, the sensor automatically transmits a packet with data accumulated in this transmission buffer to the UDP network.

The value D of the result transmitted by the sensor is normalized so that the full range of the sensor (S mm) corresponds to the number of 4000h (16384), so the result X [mm] is obtained by the formulae:

$$X = \frac{D \cdot S}{4000h}. \quad (1)$$

A PLC B&R X20CP1301 [4] manufactured by B&R (Austria) is used as a digital control device. PLCs of the X20 series can be used both in standard applications and in tasks requiring the highest performance. They provide a run cycle time of 200 µs. The X20CP1301 is equipped with an Intel x86 200 MHz compatible processor, 128 MB RAM and 1 GB built-in flash drive. The FRAM for saving remanent variables has 16 kB available. B&R PLCs of the X20 series are equipped with RS232, Ethernet and USB interfaces. Кроме того, каждое ЦПУ имеет соединение POWERLINK для связи в режиме реального времени. The X20 series CPU is designed to be mounted on a mounting rail inside the control panel.

VNC technology uses standard communication methods to allow a system to be controlled remotely from a desktop or laptop (see fig. 2). TCP/IP is used for the network, which means nearly any Internet-capable network connection can be used. The Remote Frame Buffer (RFB) protocol is documented and has been implemented in Visual Components on the server side. The VNC visualization can be operated with either a mouse / touch screen (recommended) or using the PC keyboard. Compared to a local visualization, operating a visualization of the described control task via VNC has the only limitation that the performance (page generation) is limited to 100 ms. In general, if the performance of the VNC server controller is not sufficient, a higher refresh rate should be used. Therefore, key or button actions that must be stopped promptly during processing cannot be configured via VNC.

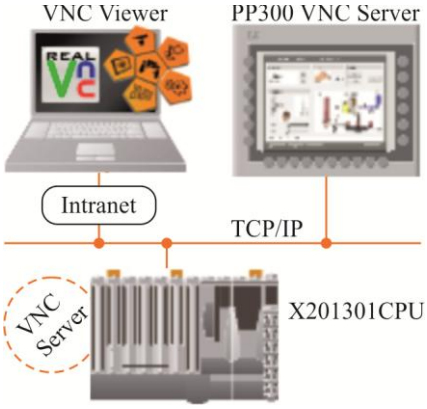

Fig. 2 *Virtual Network Computing architecture of the ROPS test bench.*

The appearance of the main program window is shown in fig. 3. The main program window contains the following controls:

1 choice of the test type;
2 tractor weight input/output field;
3 input/output field for the maximum limit value of the load force;
4 input/output field for the maximum limit value of the deformation energy;
5 output of the data of laser triangulation displacement sensor;
6 output of the dynamometer data;
7 output of the current value of absorbed deformation energy;
8 hydraulic pump control button;
9 hydraulic valve control button;
10 moving forward ″On/Off″ control button for the horizontal loading test;
11 moving backward ″On/Off″ control button for the horizontal loading test;
12 moving forward ″On/Off″ control button for the vertical loading test;
13 moving backward ″On/Off″ control button for the vertical loading test;
14 graph showing the change in time of the current absorbed deformation energy.

Fig. 3 *Main window appearance of the control PLC program.*

The test bench is certified for compliance with international standards in the Republic of Belarus. Currently, the bench is used to test ROPS of the tractors manufactured in Belarus by "Minsk Tractor Works", OJSC. ROPS tests of European and American tractor manufacturers are also commercially performed on the orders of Russian companies importing agricultural machinery.

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