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Development of methods for training operators of manual manipulators

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Abstract. Manipulators with manual control are widely used for moving objects, which is due to the complexity of the process automation and the risk of control errors. The effectiveness of work manipulator operators depends on the number of repetitions of the work cycle by the operator at the training stage and the psychoisiological characteristics of the operator that affect the speed of acquiring control skills. On the example of a hydraulic reloading manipulator, the optimal number of repetitions of working cycles by the operator is experimentally determined, in which the operator is able to provide the minimum time for carrying out the operations of grab, lifting and moving, lowering and placement the cargo.

1. Introduction

Along with the introduction of robotic manipulators, the equipment with manual control continues to be successfully used for carrying out cargo movement operations [1]. This is explained, first of all, by the complexity of the control algorithm, which must take into account the random change in working conditions (the occurrence of obstacles to movement, fluctuations of the transported cargo, etc.), as well as the dangerous consequences of control errors. This is especially true when working with explosive objects, containers with aggressive and combustible substances. In this case, even robotic manipulators must be controlled remotely, manually.

In this regard, it is relevant to study the interaction of the operator of the manipulator with the control system and the quality of the operator depending on the length of service and the level of training.

To date, a fairly large amount of work has been completed in the field of improving the efficiency of training operators of manipulator machines [2-11].

According to studies, the performance of operators depends on the length of service [12, 13]; design features of the machine [14, 15] and work organization methods [16]. An essential factor is the psychophysiological predisposition of a person to work with manipulators.

One of the conditions for ensuring the operator's effective work is the introduction into the educational process of methods of primary recognition of a person's ability to interact with manipulator control systems and, as a result, the determination of the necessary time spent on his training.



The aim of the research is to test the methods of primary testing of operators and determine the volume of training sessions, in which a stable value of operator productivity is achieved when working with a hydraulic overload manipulator.

2. Methods of the experiment

The study was conducted at the training stand «stand hydraulic controlled - hydraulic reloading manipulator (SHC-HRM)», located in the Laboratory of forest machines service «Volga state technological University». The unit is a hydraulic reloading hydraulic manipulator with a carrying capacity of up to 20 kg with remote control from two joysticks and two distributors. The appearance of the SHC-HRM is shown in figure 1.

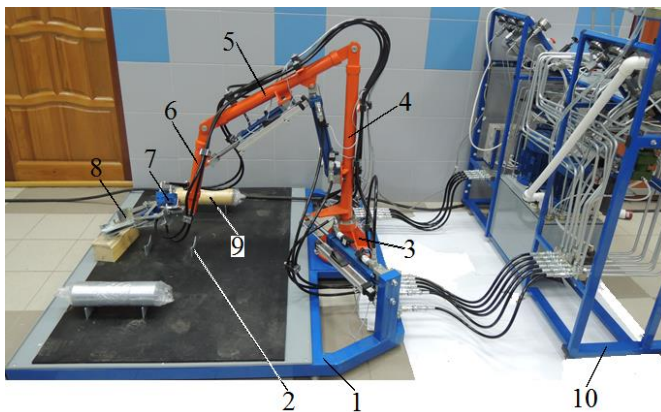


Figure 1. Stand hydraulic controlled - hydraulic reloading manipulator (SHC-HRM):

1 - platform, 2 - stand for fixing, 3 - base, 4 - swivel column, 5 - boom, 6 - a handle, 7 - a rotary grip, 8 - grip lever, 9 - cargo weighing 3 kg, 10 - table.

The manipulator is mounted on a platform 1 with stand for fixing 2 and includes a base 3 with a rotating column 4 attached to it. On the column 4, the boom 5 is hinged, which, in turn, has a handle 6 with a rotary grip 7. The working elements of the rotary grip are the levers 8 that hold the cargo 9. The hydraulic drive pumping unit, hydraulic equipment, controls and measuring devices are placed on the table 10.

Two sets of controls are provided for manipulator control, as shown in figure 2.

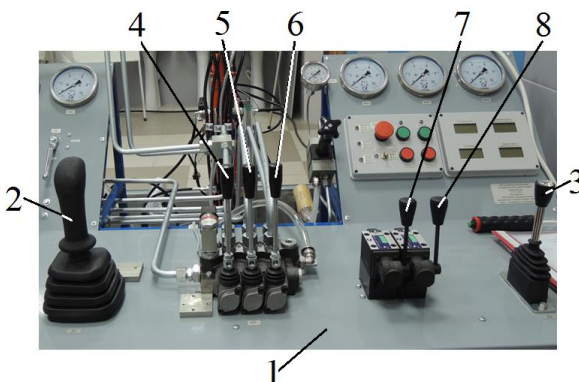


Figure 2. Location of the reloading manipulator controls: 1 - table, 2 - boom control joystick, 3 - handle control joystick, 4 - 6-distributors with proportional manual control, 7 - distributor control opening gripping mechanism of the manipulator, 8 - dispenser control rotation of the gripping mechanism of the manipulator.

The method of primary testing of operators is as follows:

1. the Study of safety when working with a Stand hydraulic controlled - hydraulic reloading manipulator;
2. the Study of the mechanisms of management of Stand hydraulic controlled - hydraulic reloading manipulator;
3. getting the task and discussing the order of execution of the sequence of manipulator control operations;
4. completing the task;

5. logging Execution Results;
6. analysis of the results.

Considering the number of students, alternate shift of the tested is allowed, each of which performs a work cycle:

1. supply of the gripping mechanism to the cargo;
2. grip cargo;
3. lifting and moving the cargo towards the stand for fixing;
4. lowering of the gripping mechanism with the cargo for placement in the stand for fixing;
5. disclosure of the gripping mechanism;
6. moving the manipulator to the starting position.

One of the conditions for performing the test was the requirement of accurate stowage of the cargo in the stand for fixing.

The obtained data were processed by statistical methods.

3. Results and discussion

As shown by the analysis of the results of testing operators of hydraulic manipulator with manual control, at the first attempts to implement the working cycle, students spend a significant part of time on memorizing the location of the manipulator controls and the order of manipulator control. At the same time, the cycle time varies in a fairly wide range: from 43 to 199 s, figure 3.

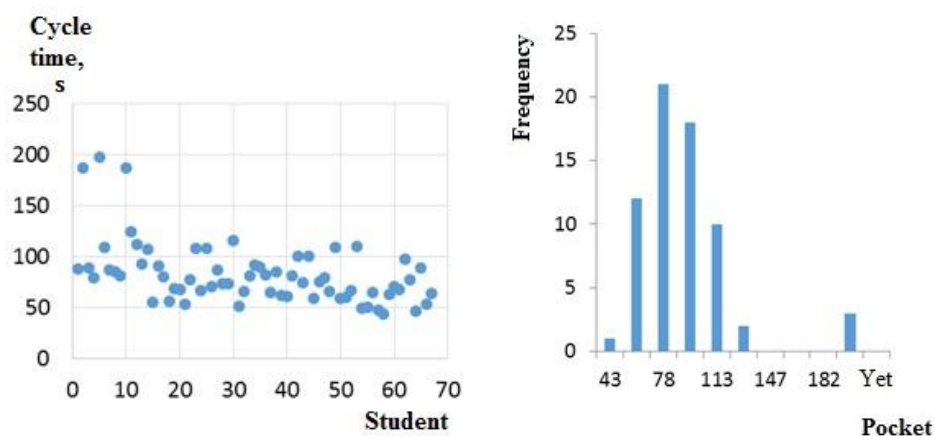


Figure 3. Obtained data and a histogram of the distribution of the working cycle time values.

The analysis of the operator's work cyclogram in each of the attempts makes it possible to identify «weak» points in the operator's interaction with the controls and further improve the performance of the operator's speed.

For convenience, comparing the results of testing manipulator operators, the execution of each operation was recalculated as a percentage of the total cycle time (figure 4).

Bringing the gripping mechanism of the manipulator (figure 4a) takes from 13 to 77 % of the cycle time. Lifting and moving the load to the stand for fixing from 5 to 59 % (figure 4b). Lowering the gripping mechanism of the manipulator with the load for placement in the stand for fixing from 12 to 74 % (figure 4c).

Thus, the operator experiences the greatest complexity in control of the manipulator when performing operations that require increased accuracy of guidance: bringing the grip to the cargo and lowering the gripping mechanism of the manipulator to cargo for placement in the stand for fixing.

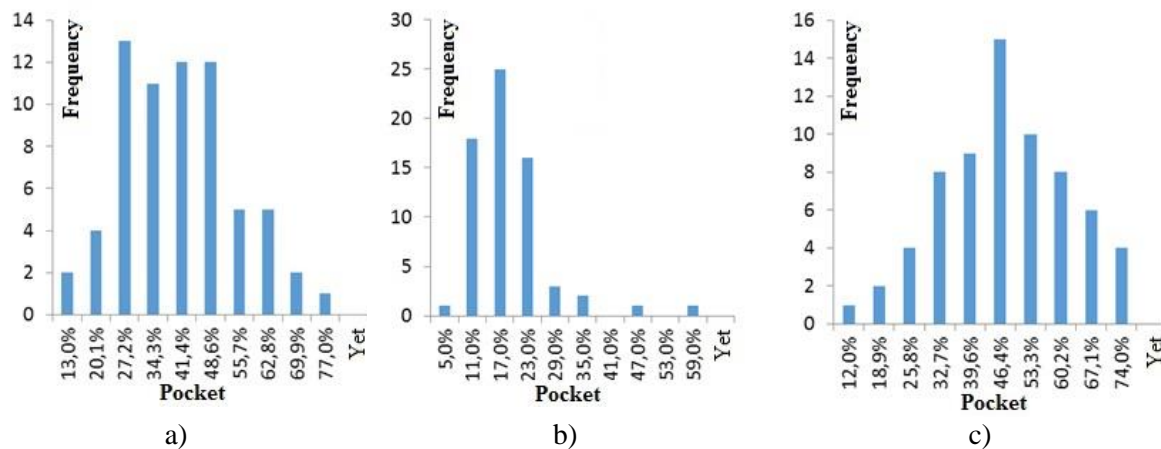


Figure 4. Histograms of the distribution of the operation time values: a) Bringing the gripping mechanism of the manipulator to the cargo; b) Lifting and moving the load towards the stand for fixing; c) Lowering the grip with the load for placement in the stand for fixing.

To evaluate the effectiveness of the training of manipulator operators, two operators were selected: the one that showed the worst time (198 and 187 s) and the closest to the "average" time (92 and 87 s) of the of the duty cycle. Each of the operators was given the task of continuing the execution of the cycle with an intermediate analysis of the shortcomings of the work. The results of the study are presented in figure 5.

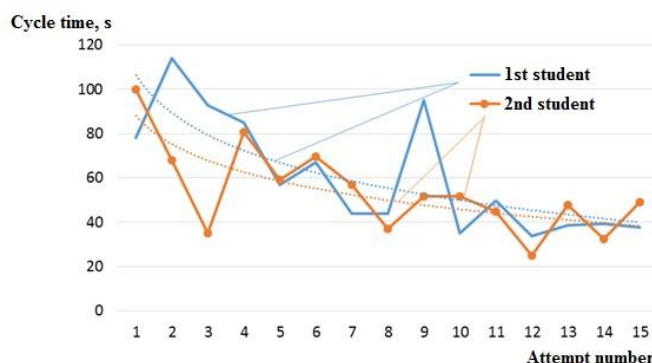


Figure 5. Change in cycle time in the learning process for the first and second operator.

As can be seen from figure 5, the learning process is unstable and differs in a significant scatter of results:

- for the first operator: from 33.8 to 114 s;
- for the second operator: from 25 to 100 s.

In general terms, the dependence of cycle time on the number of repetitions can be represented as a logarithmic curve:

$$y = A * \ln(x) + B \quad (1)$$

where y – cycle time, s; A and B – coefficients that take into account the psychophysiological characteristics of a particular operator.

For the data presented in figure 5, the values of the coefficients of equation (1) are determined, the results are presented in table 1.

Table 1. Values of coefficients taking into account the psychophysiological characteristics of a particular operator.

Testable	Coefficient A	Coefficient B
Trainee 1	-24.49	106.27
Trainee 2	-18.27	87.887

As the results of the study showed, initially the worst or best results of the operator test have a significant impact only on the first ten attempts to implement the work cycle.

In the future, the indicators are stabilized (both operators reached the average cycle time of about 40 s) and have a smaller range of values:

- for the trainee 1 up to 9.8 s;
- for the trainee 2 up to 14.8 s.

Further training it does not significantly improve the indicator of operators

As improvements should be noted the ability to combine operations performed; improved smoothness of the course; reduced swinging of the cargo at the maximum reach of the manipulator boom; more accurate positioning of the components of the manipulator and reducing the number of corrective actions when capturing and placing the cargo in the stand for fixing.

It also solves the problem of remembering the location and purpose of controls and bringing them to automatism.

4. Conclusion

Based on the results of the study, the following can be conclusions:

1. A significant impact on the performance of operators of manually operated manipulators is exerted by the duration of operating time on a particular type of manipulators with existing controls. Moreover, the most comprehensive indicator is the runtime of the work cycle.
2. In the process of training, operators acquire the basic skills of working with the manipulator and memorize the functionality of the controls, as a result, the time of the work cycle is reduced (up to 5.8 times) and the stability of the results by reducing the range of cycle time (no more than 37.1 %).
3. At the beginning of training, the most time in the work cycle is spent by the operator on pointing the gripping mechanism of the manipulator at the load (up to 77 %) and laying the cargo in the stand for fixing (up to 74 %).
4. Stabilization results of operators' work begins with the 10th repeated and should be kept to a minimum (no more than 23.2 %) with the number of repeated up to 15.
5. After stabilizing the results, the operator gains a steady skill in working with the manipulator controls and understands the kinematics and dynamics of the manipulators, which allows us to proceed to the further stages of training.

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