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## Mobile simulator of the crane to support trainings of crane operators – a concept

### Przenośny symulator suwnicy do wspomagania szkolenia operatorów suwnic – koncepcja

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Presented are crucial indications to build a mobile crane simulator. The simulator will be build on the basis of a laboratory version of crane simulator prototype created in CIOP-PIB. The article also presents principles of its modifications concerning its compatibility with minimal requirements of training programme by UDT. The simulator will allow the supported of practical training of crane operators conducted by training centers.

**KEYWORDS:** mobile simulator, overhead crane, training with use of the simulator

Research into the use of simulators in training [1-3] indicates that it is an increasingly popular teaching resource that not only makes training more attractive, but also reduces its time and reduces costs [4]. The use of simulators contributes to faster mastery of skills related to machine operation and consolidation of knowledge regarding the causes of accident events.

Simulators are useful while learning how to operate stationary machines [5, 6], portable [7-9] and mobile (including cargo movements) [9-11], they are also used in various areas of life: in transport railway and air, in rehabilitation, eg upper limbs [12], and for prototyping of everyday items (refrigerators, cars, etc.), before they are transferred for production, or for designing and modification of work stations [13].

The article presents the most important guidelines for the construction of a crane simulator in a portable version and the assumptions for the modification of a prototype of a crane simulator in a laboratory version, developed at CIOP-PIB. It will also be used as a device supporting the practical trainings of crane operators run by training centers.

#### Crane simulator in a laboratory version

The crane simulator in the laboratory version developed at CIOP-PIB in 2013 [3, 11] will be modified. It was prepared using VR virtual reality techniques, enabling users to be immersed in the virtual environment of a production and warehouse hall.

The participant sits on the simulator seat and after launching the VR equipment, he moves to the virtual environment, where he acts as a virtual operator of the gantry controlled from the level of the cabin. Immersion of the person in the environment takes place through the use of VR equipment in the form of goggles, gloves and tracking system with motion sensors placed on both the user's hands.

The tracking system allows you to observe the position of the sensors in the three-dimensional environment of the environment. The data is then processed and sent to the control unit. In this way, the user of the simulator can observe in real-time his actions during the interactive simulation of the virtual crane operation process. The simulation effect is presented on the VR goggles screens before his eyes.

The virtual crane is controlled by means of real control elements placed on two desks fixed to the operator's seat. Operating them allows the user to interact with the virtual environment and the virtual crane (see figure).

The simulator user can perform typical control tasks related to the transport of loads using a virtual crane equipped with an electromagnet or hook, e.g.:

- transporting long bundles of metal rods in the storage hall to a heavy goods vehicle located in this hall and placing them on the vehicle's body,
- transporting empty bins from the warehouse to the place of the shelter located by the instructor located at one of the work stations indicated by the instructor,
- taking baskets in accordance with the hand signals transmitted by the hook.

During the simulation, an "accident" may occur at any moment and time of the task execution. Such events may result from an error made by the operator, as a result of fast driving, bravado in the environment, moving loads above the work station or over other objects, etc.; they can also be initiated by the installer using the keyboard. The simulation predicted a variety of accidental events, such as a load hit on employees moving around a virtual environment, crushing an employee with a falling load, hitting a load with an obstacle, a hook, a lorry or a truck.

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Fig. Virtual environment generated in the crane simulator

### Assumptions for modifying the simulator from the laboratory version to the portable one

The development of the assumptions for laboratory modification of the crane simulator version was preceded by its verification. The verification was aimed at checking the simulator's ability to support practical training provided by training centers and covered:

- technical equipment of the simulator in the aspect of checking the functionality of real control elements in the field of operating a virtual crane and carrying out tasks including picking up, reloading and transloading of cargoes and VR equipment used, including synchronization of these devices with the environment,
- computer software in the aspect of smooth simulation of virtual gantry operation (ie moving or moving objects in a virtual environment), fluidity of the image displayed in VR goggles or accident events initiated in a virtual environment.

The activities carried out allowed to determine which simulator elements could be used to build a portable simulator, and which should be improved.

The elements to be used in the case of technical equipment are:

- seat with an aluminum structure supporting the two control panels,
  - VR gloves with the possibility of bending fingers.
- However, in the case of computer software:

- virtual environment - the dimensions of the production and warehouse hall will be preserved as well as the placement of the equipment in the production and storage part,
- scenarios related to the movement of transport means (trucks, goods vehicles) and employees after a virtual environment,

- scenarios of control tasks in the scope of performing typical activities related to the simulation process of virtual crane operation,
- procedure for making baskets in accordance with the manual signals issued by the hook.

The following elements of the program will be modified:

- control panels in the scope of replacement of control elements in order to enable the control of a virtual crane, as it is in reality, e.g. by means of joysticks with a potentiometer and with a suitable handle,
- aluminum construction of the simulator in the area of appropriate tracking system cameras location,
- user's tracking system, which will be replaced by a portable system that allows simulation process to be carried out in a training center,
- computer software including: virtual environment in the aspect of increasing the realism of the displayed image and eliminating irregularities in it and scenarios of control tasks, which will additionally be supplemented with new activities related to picking up loads by means of a crane, i.e.: transport and parking long loads, not only on heavy goods vehicles (this functionality is already there), but also on the indicated storage areas in the production hall; collecting a full basket with semi-finished products located at one of the work stations in the production hall and transporting it to the truck,
- simulator documentation regarding the crane simulator utilization program in accordance with the minimum UDT programming requirements and the operating instructions.

### Guidelines for constructing a simulator in a portable version for practical training

The simulator in the portable version for the purpose of conducting practical training should meet the following requirements:

- dimensions of the simulator enabling its use in operating conditions,
- easy assembly in operating conditions and demounting for transport,
- repetitive method of setting up the simulator and its calibration, e.g. VR instrumentation with a portable tracking system,
- virtual crane control by means of control elements placed on two control panels, possibly resembling real desks used in overhead cranes,
- image from the virtual environment should be displayed directly on the VR goggles screens, right in front of the user's eyes,
- simulation image should be displayed on the monitor an instructor or trainer,
- possibility of implementing a training program based on guidelines included in the programs used by training centers, described in the simulator manual in the portable version.

In addition, the simulator should enable:

- conducting an interactive simulation of the service process cranes in the scope of performing typical activities when making, transporting and setting aside cargo,
- conducting the simulation process in accordance with the guidelines of training programs used by training centers,
- intuitive control of a virtual crane using its virtual and real control elements,
- presenting a virtual environment including: a production and warehouse hall surrounded by walls (with pillars, windows, gates, entrance doors), with a ceiling and a floor with communication routes and deforestation fields for cargoes; equipment, accessories and other devices used in the production and warehouse process (eg: machines, devices, tables, cabinets, boxes, tools, vehicles, transport trucks); animated events (eg moving of trucks with loads, movement of employees - at work stations or walking along designated roads - and hook animation presenting manual signaling signs); interactive virtual gantry with operator's cab (consistent with the actual interior design of the cabin in terms of shape, color, height, seat layout and controls),
- initiating, under certain conditions, dangerous situations, leading to accidents, in line with old and new recommendations,
- supervising the course of the simulation process by an instructor or a trainer at the keyboard level in order to: indicate to the simulator user the appropriate load (basket or bundle of bars) for transport to the destination; indication of the cargo delivery destination (eg for: truck driving, storage field at the work station or in the warehouse); initiating dangerous situations leading to an accident event, e.g. starting an animation of a truck carriage, an employee or a worker avatar appearing on a road transported by a cargo crane; a preview of the simulation process of virtual gantry operation.

## Conclusions

The most important assumptions of modernization of the simulator in the laboratory version and guidelines for the construction of the simulator in a portable version are briefly presented. On their basis, a portable crane simulator will be built to support training conducted by companies or training centers (for use in operational conditions).

The training participant will be able to participate in the inter-active simulation process of the virtual crane service and perform typical activities related to this process. It will also allow you to master the skills of making loads, operating them in the work environment, and the precision of putting them away at the destination.

The use of the simulator in the training will enable the presentation of dangerous, dynamic phenomena, such as loss of load, charging the load with work environment

objects or other users of communication routes, etc., which can not be carried out under real conditions for safety reasons.

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