# WALL CLIMBING ROBOT AND ITS APPLICATIONS FOR BUILDING CONSTRUCTION

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## ABSTRACT

The paper presents the discription of the basic model of the Wall Climbing Robot consisting of three main modules: transport, technological manipulator and control. The experience of the designing and rational attaching methods and devices are analyzed. The main devices of the robots like drives, sensors, control, grippers are discussed. The application of the Wall Climbing Robots for building construction for cleaning, painting, cutting are considered.

## 1. Introduction

Mobile Wall Climbing Robots (MWCR) and Robotics Systems based on Wall Climbing Robots (RSWCR) are intended for motion on vertical and sloping surfaces in complex or extreme conditions including building construction. These robotics systems contains three main modules: transport (proper MWCR), technological and control modules [1]. Technological manipulator is mounted on transport module for performing necessary technologocal operations under continuous motion or in steping stoppage of the transport module.

Research and development of the MWCR accomplished from the 80th in Japan, USA, England, USSR and other contries and a lot of investigations were carried out in this field. For example MWCR supplied with magnetic grippers realised inspection operations on ferromagnetic surfaces and RSWCR equipped by means of vacuum grippers accomplished preventive maintenance [2]. Hitachi Co and Tokyo Gas Ltd. were engaged in developing the inspection robot equipped with ultrasonic sensor system for spherical gas storage tanks [3].

The main advantages of MWCR in applications for building construction may be the follows:

- Possibility to use at high heights under extreme conditions
- Small masses of the robots and a big useful loadings
- Good economical efficiency of the application of robots in high heights without special building means and materials

- The execution durations of the technological operations are rather shorter than conventional process which gives additional economical effect.

## 2. Fundamental principles of arrangement of the RSWCR

The fundamental principles of arrangement and applications of RSWCR were accomplished in the Institute for Problems in Mechnics starting from 1984. Main modules of the RSWCR (Fig. 1) are: transport (1), technological (2), control (3). The technological equipment (4) is mounting on technological module. The transport module has vacuum grippers (5) installed on the legs and cable (6) for connection with control unit (3). Two platforms (1) and (2) of the transport module (Fig. 2) are joined by means of rotating unit (3) and driving system. When platform (1) is connected with the wall by means of vacuum grippers (VG) the driving system has possibility to move the platform (2). When platform (2) is connected with the wall, then platform (1) can move with relative to the platform (2). The technological equipment (for example painting unit 4) is install on manipulator or bracket (5) and it can move in a discrete trajectory (6) by the use of rotating unit (3).

Special pneumatic drives are intended for lifting and putting down of the legs with vacuum grippers (VG).

RSWCR can be realize (Fig. 3) with drive system mounted on one platform (1) with velocity control unit (2) and rotating unit (3). The technological equipment (4) is moving along the trajectory (5) according to this scheme (Fig. 3).

Driving systems with velocity control units (Fig. 4) can be introduced into two platforms (1) and (2) and so it is possible to achieve continuous trajectory (7) both for the technological equipment and for the robot.

Mounting of the controlled driving systems give addiitional advantages when autonomous drives are not necessary. Besides, it can take care of the limitations the size of the bracket of the technological module. In this situation transport module (Fig. 5) including two platforms (1), (2) are moving along the trajectory (4) and two technological devices (3) can realize any arbitrary trajectory (5).

Control system (Fig. 6) includes:sensors (D1) installed on the drives of the transport modules and sensors (D2) mounted on the technological module, microprocessor system (MS) with possibile additional softwares (AS), control panel, electropneumatic converters for distribution of the supply pressure to the pneumatic drives of the transport motion and to the pneumatic drives of the legs and ejector's systems of the vacuum grippers.

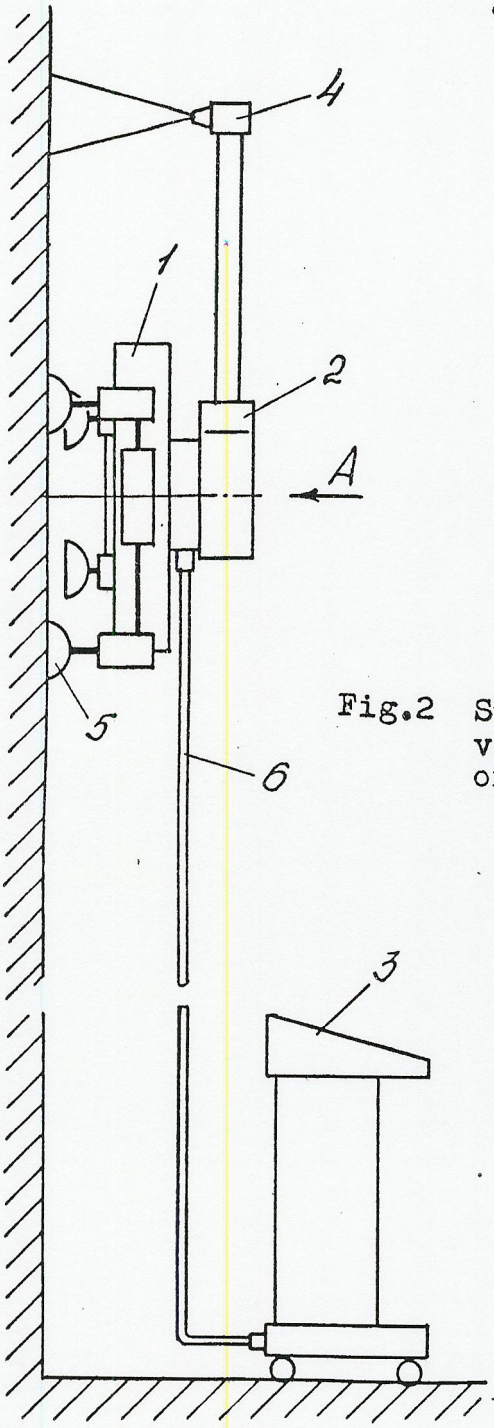


Fig.I Robotic system based on wall climbing robot (RSWCR)

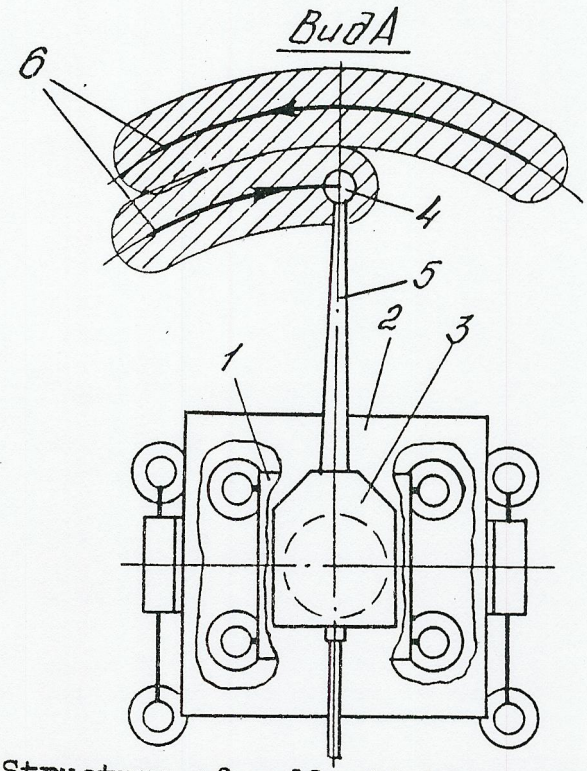


Fig.2 Structure of wall climbing robot without velocity control of the drives located on one platform.

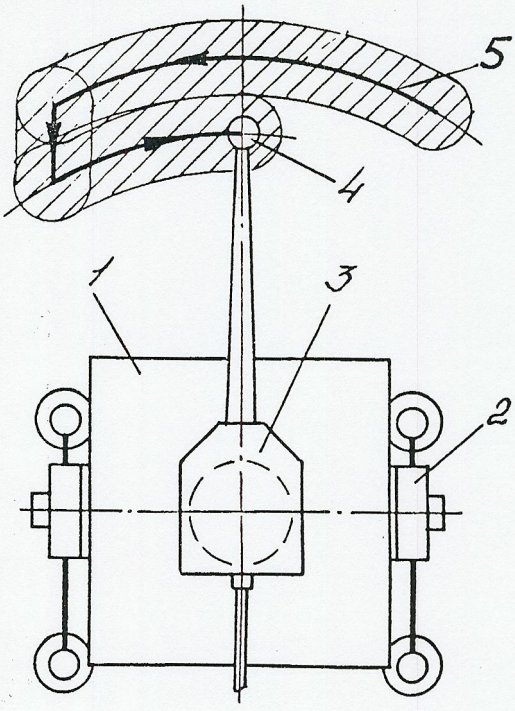


Fig.3 Structure of wall climbing robot with velocity control drives located on one platform..

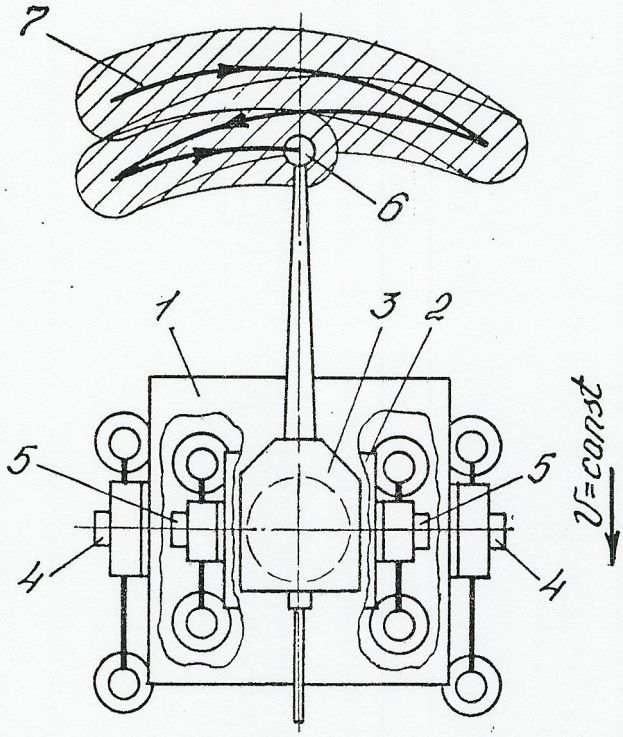


Fig.4 Structure of wall climbing robot with velocity control drives located on two platforms.

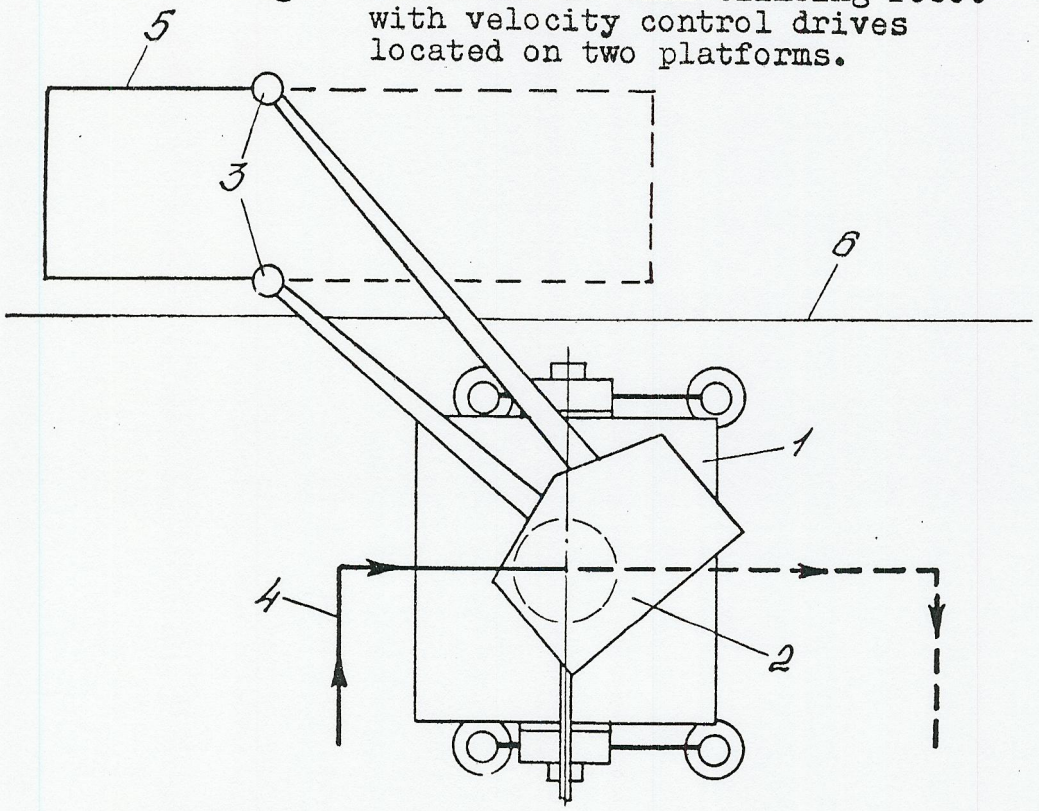


Fig.5 Welding or cutting operations realized by means of technological module located on the transport module in stationary position.

## 3. RSWCR applications for construction engineering

MWCR version with VG can move along vertical and sloping surfaces made up of metal, concrete and plaster with ledges and cavities not usually exceeding approximately 1 - 3 mm.

RSWCR (Fig. 2) can be used for the painting of ceilings and walls inside of the buildings. In this case the painting unit is applied as technological equipment with autonomous drive and robot motion is occured in steping mode without velocity control. Discrete trajectory is suitable for this mode of operations.

Many technologies in biulding construction are required for the realization of the continuous trajectory of the moving of technological equipments (inspection, cleaning, painting and so on). In this case drive system has velocity control unit and it is permited to realize continuous in steping stoppage trajectory (Fig. 3, 4).

Application of RSWCR has great significance in the field of welding and cutting operations. For example it is possible to use RSWCR as shown in Fig. 5. for carring out welding operations of the construction elements having large sizes and located outside of the possible zone of the robot's moving. Technological module is located on the transport module (1) in stationary position and welding apparatus (3) is mounted on technological module. The robot's centre is moving along trajectiry (4) providing welding process along contour (5) above zone (6) of the surface.

The reliability is one of the important problems providing RSWCR successful applications in construction engineering. Insertion of adaptive system with sensors into VG is one of the ways of increasing the reliability. The unsmooth quality of the fixation surface is also an important factor affecting on the reliability of VG fixation. Small unsmooth particles are directly compacted with elastic working parts of the VG which comes into the interaction with the surface. Considerable unsmoothness leading to unsealing of the VG cavity may be compacted by special method depending on their type [5].

One of the methods of increasing the robot's level of fixation reliability on vertical surfaces is the combination of VG and mechanical cluster of VG with the surface of moving. Mechanical cluster may be carried out through pins locating on the VG support, which automatically comes into contact with the surface in the process of vacuumizing the sucker's cavity. This results the increasing level of reliability along shift force, arising due to robot's gravity force during movement along vertical surface. Fig.7 shows experimental characteristics of the dependance of disengagement force F1 and shift force F2 of one VG on the input ejector pressure.

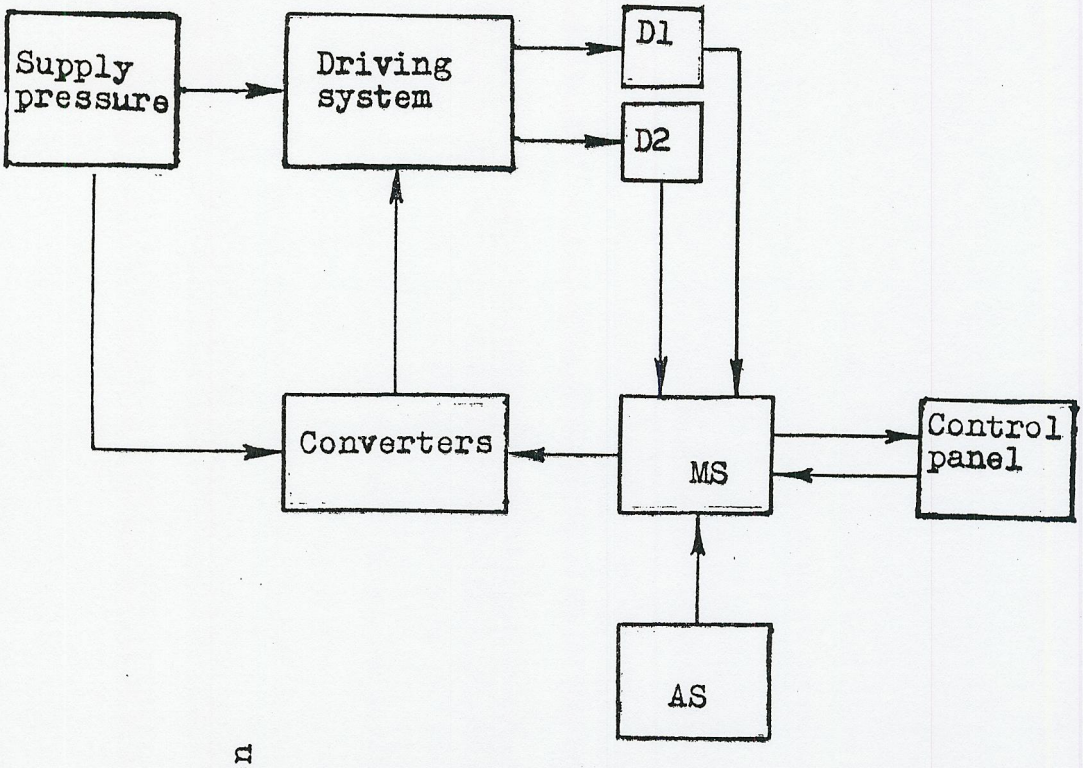


Fig.6 Drive control system of the RSWCR.

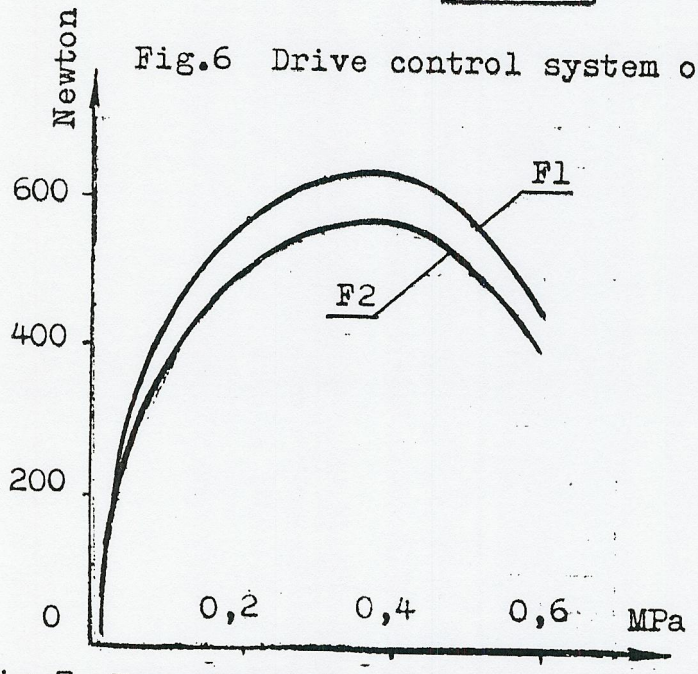


Fig.7 Experimental characteristics of the dependence of disengagement and shift forces of one vacuum gripper on the input ejector pressure.

Further progress of development of the use of RSWCR is connected with expanding types of surfaces of robot's movement which is determined by improving VG constructions and also by increasing the functional abilities of RSWCR due to arranging of mutual operation of several robots simulteneously, carrying out a complex of technological operations on vertical surfaces.

It is necessary to carry out several additional R & D for increase the reliability of the robotic system.

## 4. Summary

The first experimental models of the Robotics Systems based on Wall Climbing Robots with vacuum grippers were made and successfully tested. These systems can be used for construction engineering depending on the technological tasks. In particular the application of the Wall Climbing Robots with different technological equipment for painting, cleaning, cutting etc. may be offered for realization in advanced building construction technology.

## References

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