The manipulator to extract foreign objects from the hot chamber of the mine

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Abstract. The manipulator to extract foreign objects from the hot chamber of the mine, is developed for the retrieval of foreign objects (including nuclear fuel elements), located in the deep and shallow canisters and boxes of “hot” nuclear safety box camera. The manipulator is a special articulated arm (manipulator’s actuating unit) with two degrees of freedom in the angular coordinate system, electric actuator, gravity balancer to the arm with exchangeable working body. The manipulator is outfitted with three radiation-resistant cameras with built-in illuminators. The article discusses the selection and the justification of the reference system and details of the kinematic scheme.

1. Introduction

Nowadays it is impossible to imagine the production process without manipulator robots. Areas of their application are huge. Each action of the robot is calculated in accordance with the specified software algorithm. The development of the manipulator for extracting foreign objects from the hot chamber of the mine is primarily relevant due to the elimination of the impact of harmful factors on personnel in industries with increased risk when used at nuclear power plants. Robot hand manipulator seems to be the most modern and ubiquitous tool for making manipulations with objects at the moment [1]. The method of capture is analogous to the human hand and is performed by mechanical "fingers". The purpose of this study is to develop the manipulator’s kinematic assumption, designed to extract foreign objects from the hot chamber of the mine. The robot has a number of limitations, such as reach zone, bearing force, the need to avoid a collision with an obstacle, the need for preliminary programming of every movement [2].

2. Manipulator arm for extracting foreign objects from the hot chamber of the miner

The manipulator is actuated by means of actuators that convert primary energy into mechanical energy and perform rotational or translational motion, used to drive a rotational joint. Thus the chips of machines and equipment are cooled by natural convention. This is one of the reasons why the devices are not in monolithic boxes, although this approach ought to ensure reliable protection of internal elements from dust and dirt from outside. The design should be as simple as it is possible (with the help of removing mobile connections from it if it is possible) [3]. With proper application and preliminary analysis of the system’s operation, manipulator is able to provide a number of advantages for production to improve the quality and efficiency of the work process. Besides this increases not only reliability but also maintainability of manipulator. The problem is that these elements are exposed to increased danger from the impact of environmental factors. The microcircuits are made vibration
resistant, capable of withstanding cyclic loads for a long time. All this features ensure a sufficient long-term work of the robot manipulator [4].

3. **Kinematic assumptions for the manipulator**

When developing robot manipulator, a lot of attention is paid to choose a coordinate system in which hand movement will be carried out. The principle of the ordered arrangement of segments and kinematic couples is used, and there is always, at least, one couple of the kinematical bound segments providing transfer of an action in the basic plane. Use of one more degree of mobility of the kinematic scheme provides driving of the basic plane in space and formation of the served volume.

The hand consists from pivotally attached levers. The last one bears a brush with the mechanism of a fingered gripper. The lever is strengthened on an arm of a vertical shaft together with which the hand is raised and turns around a vertical axis. With an equal length of levers and such transmission mechanism, which provides constantly vertical position of a bisector between levers, the brush at disclosure or folding of levers moves rectilinearly in the horizontal direction. Here the chain or lever mechanism can be transmitting [5], [6], [7], [8].

The first engine is designed to rotate the manipulator’s platform around its axis. The second motor serves to move the upper arm vertically. The third motor serves for vertical movement of the manipulator's lower arm. The weight of links is perceived by bearings of kinematic pairs. On the power of drives and braking devices, the weight forces are affected only by the frictional forces in the pairs.

The bar is designed to provide the required level of placement of the articulated manipulator when performing operations to collect and extract parts of nuclear fuel elements of reactor fuel assembly and foreign objects located on the bottom of the shafts or pencil boxes of hot chamber of the mine [9].

The bar consists of an upper section, two middle sections, and a lower section. The hinged manipulator is the executive mechanism of the manipulator for extracting foreign objects (including nuclear fuel elements’ fragments) located in the deep and small pencil cases and boxes of the of hot chamber of the mine [10].

The articulated manipulator consists of a base, a hand, a brush, a replaceable gripper [10], [11]. To reduce the power of the drive, the manipulator arm has a counterweight fixed to the milled groove of the upper end of the hand. On the shaft of the bearing unit of the arm is attached a brush on which the manipulator's body is located - a four-finger grip and a television radioactive resist camera intended for obtaining an overview from the side of the manipulator grasp. A good solution to reduce the net cost of an element base under radiation exposure’s maximum is to remove a part of camera’s elements (in particular responsible for an initial processing of a signal received by a camera) to an external unit, also located at a distance from a radiation source. This solution not only provides an opportunity to reduce an amount of components, receiving the highest dose of radiation, but also helps to reduce the size and weight of a camera and allows to simplify the design and circuit of the device operating under constant negative radiation exposure [12], [13].

The simpler the device, the less weaknesses and reasons for failure it has. Thus, only lens, vidicon and minimum of electronic circuits have to be located in camera unit in order to achieve maximum of radiation tolerance. The main part of electronic circuits is removed to television system remote unit located outside radiation exposure. As for an optical part of a system, thanks to special circuit design and use of rad-tolerant vidicon as light-to-signal transducer it provides excellent image quality and sharpness in high radiation fields. Cameras can be equipped with standard or fisheye fixed lenses. All lenses are made of rad-tolerant glass, not darkening under radiation exposure [14].

The main features of rad-tolerant CCTV systems are their radiation tolerance, high resolution, operating time, ability to reach remote parts of reactors, protection level and resolution. Rad-tolerant TV camera, minimization of electronic circuits, exposed to radiation, specialized software for receiving, processing and recording images contribute to implementation of the above mentioned features and operation of rad-tolerant CCTV systems twenty four by seven [15], [16], [17].
The movement of the spring claws is achieved by moving the motor-reducer bushing (fig. 1). The number of resilient tines of a four-finger grip can be changed. The angular position of the claws is controlled by a geared motor, the torque from which is transmitted to the feet via a worm gear. In order to exclude the protruding parts of the manipulator from being caught by the elements of the hot box of the chamber, when it is removed, two belts of balloon-type centralizers are mounted on the hinged manipulator.

The main task of such a system is to move the grip of the manipulator to a given point in the space of the working area of the robot \((X_w, Y_w, Z_w)\). This task can be realized by influencing on the angles of rotation and displacement in the manipulator joints \((\alpha, \beta, \gamma)\), using servodrives [17].

Fig. 2 shows the experimental model of the described manipulator.
4. Conclusions

As a result of this work, a kinematic scheme of the manipulator for extracting foreign objects the hot chamber of the mine has been developed. It is a special articulated manipulator with two degrees of mobility in an angular coordinate system, an electric drive, a counterweight on the arm, and a replaceable working member. The manipulator is equipped with three radioactive resist cameras with built-in illuminators. When assembling the manipulator, the upper section is hung on the crane-beam of the technological room of the separated safety chamber. Then, depending on the performed work, the required number of medium sections is connected to the upper section. The lower section with the hinged manipulator is installed. Depending on the type of collected objects, one or another working organ is installed on the wrist: a four-finger grip or a clamping grip. By lifting the crane-beam manipulator to the required height in the shaft, the manipulator is fixed from rotation using the copying manipulator of the hot chamber [15], [16]. Producing successively necessary movements by hand, brush and grip of the manipulator, the fragments of nuclear fuel elements or the objects are captured. Consecutive movement of the arm and the hand, the manipulator is moved to the position for extraction from the mine - the hand is moved to the zero position, the control is performed on the indicator on the control panel. The brush, in the event that a fuel rod with a length of more than 180 mm is extracted, is moved to a position 90 ° relative to the axis of the manipulator, if the length of the nuclear fuel elements' fragment is less than 180 mm, to position 0 ° relative to the axis of the manipulator. The positions of the components of the manipulator and the object to be lifted are monitored visually by means of integrated television system.

Figure 2. Experimental model of the manipulator, which extracts foreign objects from the hot chamber of the mine
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