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SIMULATION OF FLEXIBLE PRINTED STRUCTURES DESIGN FOR MOBILE ROBOT PLATFORM

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ABSTRACT

The mobile robot platform was designed for remote performing of special tasks for various fields. For example, these tasks can be the next: reconnaissance and surveillance, research of dangerous objects in the military sphere; surveillance, dangerous objects search and identification in the field of public safety; victims search and assistance during emergencies liquidation; and also tasks for fields of health care and agriculture.

One of the important advantages of proposed robot platform design is replacement of rigid hardware components with flexible ones. Based on the results of mechanical research results for flexible boards and loops the flexible-rigid the interconnections system based on copper-foiled polyimide was designed for the developed robotic platform.

Keywords: flexible printed structures, mobile robot platform, 3D model, polyimide.

1. INTRODUCTION

Mobile robotic systems are distinguished by the presence of a moving chassis with automatically controlled drives. And there is a need to improve the commutation system of mobile robotic platforms using flexible structures – printed circuit boards and cables [1-3]. Flexible printed structures (FPS) provide several advantages over traditional mounting technologies using bulky wires and printed circuit boards on rigid bases [4]. This decision can reduce their weight and size, improve quality, functionality, reliability etc. Such structures ensure the connections stability between the platform modules, even if it is affected by destabilizing external factors, for example, vibrations and shocks during its movement.

Thus, the subject of research is the commutative system of a mobile robotics platform based on flexible polyimide structures.

2. DEVELOPMENT OF A MOBİLE ROBOT PLATFORM

The conducted research made it possible to determine that the main nodes of the robot are the movement control node, the manipulator control node, the main control node, as well as navigation, sensor, technical vision, power control and communication nodes [5-12]. The design of developed mobile robot platform (MRP) is shown in Figure 1.

The control system of proposed mobile platform consists of sensors, actuators, and auxiliary modules such as navigation subsystem, power management subsystem and others.

a) b)

a) total view of MRP; b) MRP control system.

Figure 1. – The developed MRP design

Given the large number of different modules, sensors and actuators, a centralized control system would be impractical. Thus, it was decided to develop a distributed robot control system using ROS. This solution allows for further upgrades to the mobile chassis, increasing functionality and scaling the system as a whole.

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AS4050 magnetic encoders are installed on the wheels of the mobile platform. Readings from the encoders are read via the SPI interface (SPI protocol frequency is 5 kHz). The reading is performed at a frequency of 20 Hz. The data from the encoders is constantly processed in the main program cycle and transmitted to UART1 of the microcontroller in the form of messages transmitted to the Robot System via the RS-485 interface.

The following sensors are used in the design to detect obstacles: infrared sensors E18 D80NK, ultrasonic sensors JSN_SR04T. In addition, DS18B20 temperature sensors and end sensors are used. All sensors are read in the main cycle with a frequency of 10 Hz.

Temperature sensors are used to monitor the temperature inside the robot body. The DS18B20 sensors operate via the 1Wire interface and provide temperature to the nearest tenth of a degree. In the software, this data is rounded to whole degrees.

The control system is based on the main control node, which is built based on a Raspberry PI 4 microcomputer. This node receives all the necessary information using the industrial Modbus protocol. As discussed earlier, all modules can be connected to an internal bus based on the RS-485 interface.

Several individual units are connected to the master unit via special dedicated interfaces. These are the Navigation and Mapping node and CNN computer vision node modules. These nodes solve the problems of local navigation and object recognition for a specific task.

Navigation and Mapping node solves the local navigation task using the Visual Odometry algorithm. The algorithm is based on the use of special points in the image to determine the direction of movement and the distance travelled [13-14].

The Navigation and Mapping node of the mobile platform combines the following devices: brushless DC motors with Hall sensors; tachosensors mounted on the motors; three-axis accelerometer and gyroscope; current consumption monitoring sensor; obstacle detectors; distance to obstacle monitoring sensors; engine temperature monitoring sensors; battery current and voltage monitoring sensors.

The Navigation and Mapping node of the mobile platform is based on a Raspberry PI microcomputer. The microcomputer receives data from the sub-modules for charge control, speed control, and manipulator control via the RS-485 interface and the Modbus protocol. This interface is also used to transmit control commands to the above sub-modules.

The input data for Raspberry PI are:

- from the motor control module: current position based on data from tachos, current consumption of the motors, speed;
- from sensors: rotation angle, accelerometer data, engine temperature;
- from the battery charge level control subsystem: charge level, current consumption, supply voltage, temperature, time since the last charge and discharge.

The diff_drive_controller module from the ROS library is used to perform the task of controlling the driving speed. This module allows you to control the differential drives of the robot's wheels. The control is performed in the form of commands to maintain a given speed, which are divided between the two wheels of the differential pair. The current odometry data is received from the tacho sensors to adjust the current speed depending on the motion control algorithm.

A PID controller is used to maintain the set speed. The speed control uses the current speed data provided by the sensors. Considering the error between the measured speed and the desired speed, the voltage at the motor input is calculated.

To debug the control module and perform tests, a test bench was assembled to verify the control algorithm and check the electrical characteristics of the device before the final version is assembled on a printed circuit board.

Based on the above typical wiring diagrams for the main modules that make up the mobile platform motion control module, a wiring diagram for the electrical components was developed, as shown in Figure 2.

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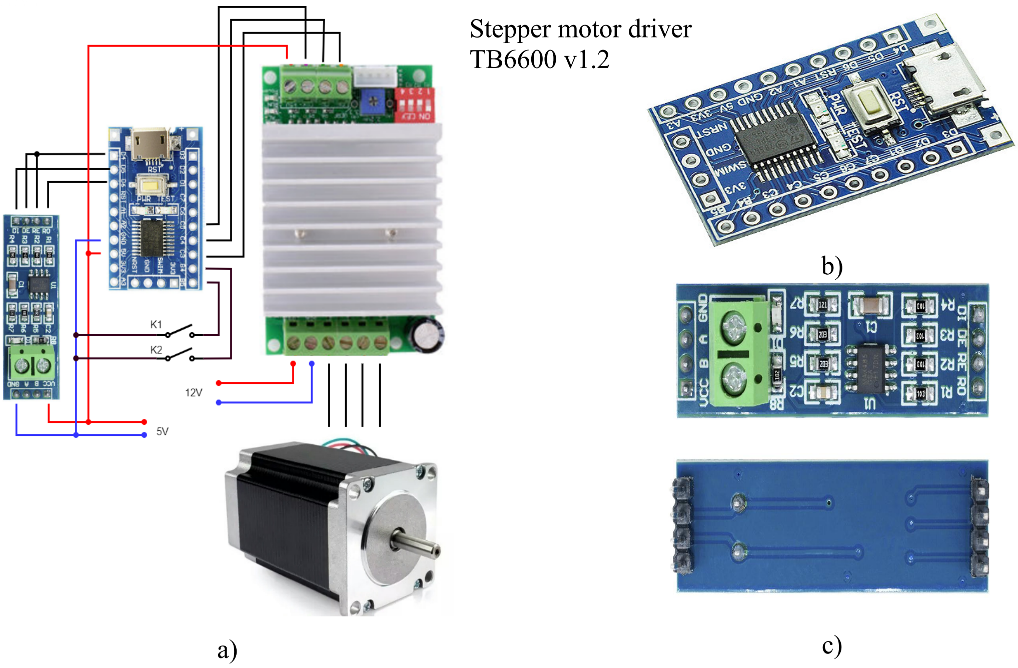


a) combination scheme of the electrical components; b) STM8S103F3P6 module; c) interface module MAX485 UART-RS485.

Figure 2. – MRP electronic components

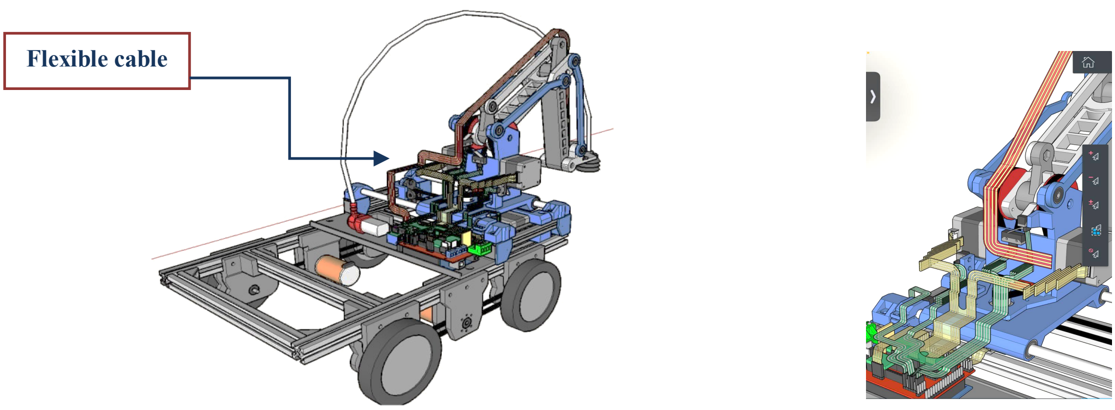
To control the stepper motors, a device of the TB6600 4.5A 45V chip was selected. The STM8S103F3P6 module was chosen as a developer board with a microcontroller for the motion control module of the mobile platform.

An interface module is used to connect to the RS-485 network in our project. The UART-RS485 converter module is based on the MAX485 chip and is designed to connect devices with the common RS-485 interface, which is an industrial standard for connecting peripherals.

3. FLEXIBLE SWITCHING INTERCONNECTIONS AS PART OF THE MRP

Based on the results of the research, flexible-rigid interconnections for the developed robotic platform were designed, as shown in Figure 3. The FPS base material is polyimide PM-A foiled by copper with a thickness of 100 μm.

It is used for the manufacture of flexible foil dielectrics, printed circuits, and other products that operate at temperatures ranging from -260 °C to +220 °C. The material has good physical characteristics and retains elasticity over a wide temperature range. The base is oil-resistant, insoluble in organic solvents, moderately resistant to acids and alkalis, and has high radiation resistance.



a) general MRP view with flexible-rigid interconnections;
b) an enlarged view of the area where the flexible cable is routed from the hardware to the moving part of the platform.

Figure 3. – MRP improved with flexible-rigid interconnections

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An experimental study of the effect of the breaking force on the fracture of the FPS test specimen shown in Figure 4 was carried out using the UIT STM 010 tensile machine.

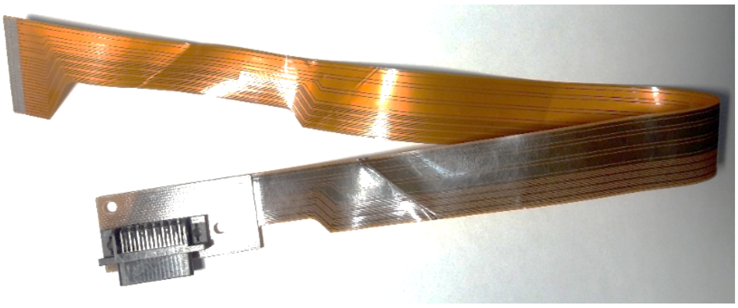
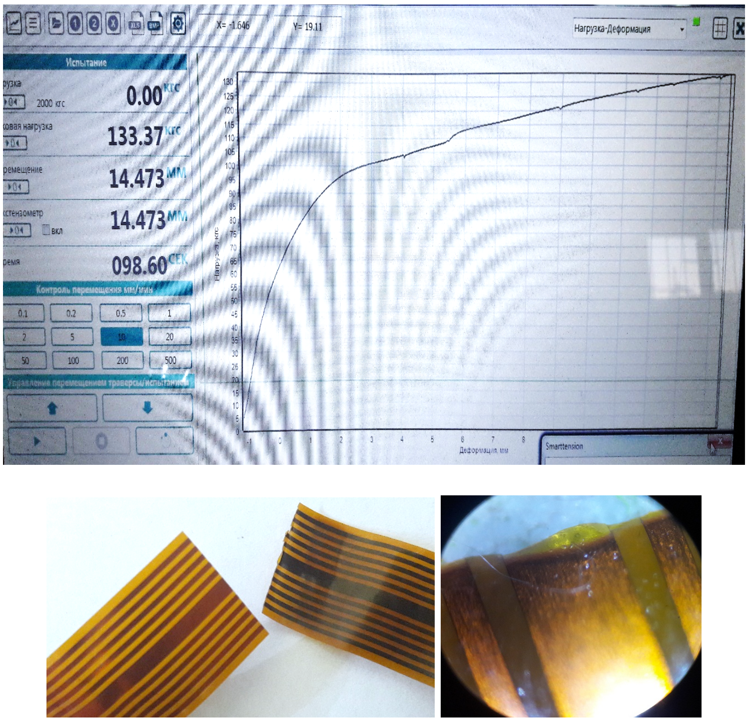


Figure 4. – Test sample of polyimide FPS

The experiment speed of 5 mm/min was chosen. The break of the sample occurred when loading was 130 kgs and after elongation by 14 mm. In Figure 5 there is a graph of the FPS break and its state at the break point is shown.

Therefore, based on the experiments results, the following conclusions can be formulated: in the case of a polyimide-based cable with copper conductors, the base was stretched more than the conductor layer.

Considering the obtained results, namely the proportional sections of the breaks graphs, we can conclude that the test sample can withstand non-critical loads up to 40 kgf.



a) breakdown graph of the polyimide sample with copper traces;
b) FPS at the break point.

Figure 4. – Результати дослідження зразка FPS на розрив

4. CONCLUSION

As a result of the research, it was proposed to improve the design of the developed mobile robotic platform. So, one of the important advantages of proposed robot platform design is replacement of rigid hardware components with flexible ones.

Based on the results of stress-strain state studies for flexible boards and flexible-rigid loops the interconnections system based on copper-foiled polyimide was proposed for the designed robotic platform.

According to the results of the conducted research, it is possible to note the suitability of the proposed structural and technological solutions of flexible-rigid interconnections for use in MRP.

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