Applications of magnetorheological brakes in manual control of lifting devices and manipulators

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Abstract. The article is aimed to design and testing of joystick with force feedback used in direct, human control of lifting device. The paper starts with the basic description of designed and tested by us MR rotary brake. Some initial laboratory investigations results of such brakes are presented. The usage of MR brakes in 2 axis joystick is proposed. Such, built by as joystick, is described. It was used as Human-Machine Interface in active control of lifting device. The designed and built 2 axis manipulator with electrohydraulic drive is described. In the paper, the based on PC with input/output card, control system of mentioned above joystick with MR brake and manipulator is described. Finally the control algorithm is proposed.

1. Introduction

Nowadays most devices like working machines, cranes, lifts and manipulators are controlled by human operators which utilize different joysticks and pedals. The natural feedback between the device and the operator is realized by visual observation. Because by this way not all features of the process can be noted, it can happen that the controlled device can meet unforeseen obstacles what can lead to damages or other problems. The illusion of presence can be enhanced by haptic cues which can significantly improve the flow of information from the slave site (device), to the remote operator for many tasks requiring dexterity. The aim of haptic interfaces is to render the mechanical features of controlled objects on the user, thus allowing a feeling of contact with real objects [1, 2]. In this paper we propose the usage of MR brakes in haptic joysticks in order to obtain controlled force (torque) feedback from the device. In such joysticks the produced by this brake movement opposite force can be proportional to the device movement resistance. This force can be controlled electronically by the controller according to the device opposite force [3, 4].

The article presents two-axis joystick with MR brakes used for manual control of two-axis technological lifting device. In the paper the joystick and manipulator construction, their connection to the controller and investigation results are presented. A new design of two-axis hydraulic lifting manipulator is also described. This manipulator is able to handle of different elements.

2. The construction of two-axis joystick with MR brakes and a manipulator

In figure 1, the construction of designed by us, two-axis joystick with MR rotary brakes is presented. The joystick consists of two arms (4, 6) interconnected by a joint (5). The stators of two MR rotary brakes (1, 7) are assembled to the aluminum body (2), which is placed on a heavy foundation. The left
MR brake rotor (12) is connected directly to the bottom arm (6). The second rotor (9) is connected to the cogwheel (10) which is coupled with the upper arm through the tooth belt (3) and the second cogwheel. In the both rotors electromagnetic coils (14) are placed. Gaps between body and rotors are filling with MR fluid. When the coils are supplied, they generate magnetic field which lines closes by working gaps and housing. As a result MR fluid changes its viscosity and as a final effect, a braking torque. The rotors rotation angles (movement of arms) are measured by potentiometers (8, 13).

![Figure 1](image1.jpg)  
**Figure 1.** Two-axis joystick with MR brakes and its photo.

![Figure 2](image2.jpg)  
**Figure 2.** Two-axis manipulator.

![Figure 3](image3.jpg)  
**Figure 3.** Manipulator working area.

In figure 2 the designed and built two-axis hydraulic manipulator is shown. It is based on not commonly known kinematics, which consists of to two arms connected to the body beam and moved by two linear hydraulic cylinders. We used cylinders which had following parameters: stroke 195 and 300 mm, piston diameters 40 mm, supply pressure 25 MPa. At the end of the upper arm (main arm) a gripper can be installed. All mentioned above elements are assembled together by usage of ball-and-socket joints. The length of hydraulic cylinders can be changed according to control signals. The actual position of a manipulator is measured by two rotary encoders placed in the joints which connect
both arms and the second arm to the body. In figure 3 the manipulator working area is shown. It is 900 mm width and 800 mm high. The manipulator was able to produce forces till 10 kN at its end point.

3. The structure of control system

In figure 4 the block scheme diagram of the whole system is presented. It consists of a two-axis joystick with MR brakes and amplifiers, control computer with input/output card and hydraulic lifting device. The hydraulic cylinders in this device are controlled by proportional valves, which are connected to its electronic control cards. This cards control the proportional electromagnets according to signals send from the control computer. The angle positions of joysticks arms are measured by potentiometers. Their output signals are given to A/D converter in input/output card, transformed to digital form and finally send to the computer. The angle positions of lifting device arms are measured by incremental encoders. Their outputs are connected to special up/down counters in the input/output card. The state of these counters represents the measured manipulator joints angle position. It can be easy read by the computer. Additionally the force on the manipulator arm is measured; directly using force transducer (weight measure unit) or indirectly by measurement of pressure differences in cylinder chambers. Pressure sensors are mounted in cylinders chambers and their output signals can be also send by input/output card to the computer.

![Figure 3: Scheme block diagram of the manipulator controlled by haptic joystick.](image)

4. The control algorithm

In the computer the control card type RT-DAC was used which enables the connection of a joystick, sensors and drives to the computer which controls the whole system. The block structure of the control
The information sent to the computer enables the control of hydraulic cylinders velocity by sending voltage signal to proportional valve control cards (ValveX and ValveY). These signals are calculated basing on the difference between the joystick and manipulator arm positions. The signals sent to the joystick MR brakes coils are calculated according to the load force, arm angle and its angle position. The computer sends to the MR brake coils control voltages (BrakeX and BrakeY). These signals are sent through D/A converter. By this way, the impression of being in physical contact to the lifting device and its environment is transformed to the human operator. Because both, the kinematics of the manipulator and a joystick and the applied measurement elements (rotary potentiometers in joystick and rotary encoders in manipulator) are different, and moreover there is no straight relation between the joystick arms positions and hydraulic cylinders displacements the control program is not ease. In our investigations we used Matlab/Simulink software, which give us the flexibility and ability to rapid change of control algorithm and its structure.

5. Conclusion
The paper proposed two-axis joystick with MR brakes which enable force feedback to communicate and interact with a lifting device. This device and a joystick were controlled by usage of a computer with input/output card and by special, worked out by us, algorithm. By the usage of MR brakes in joysticks, the impression of being in physical contact to the lifting device and its environment is transformed to the human operator. Thanks to this, the manipulator can be controlled more accurately.

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