HIGH PRECISION ROBOT FOR PERMANENT MAGNETS CERTIFICATION

S.G. Taranow, F.B. Grinevich, R.O. Mazmanian, B.A. Marshalenko

Department of Measurement, Institute of Information and Electronics
Kiev Institute of Electrodynamics, 252680, Ukraine
Technical University of Zielona Gora, 65-246, Poland

Abstract: High precision robot-manipulator for high specific magnetic energy certification and separation is described in the paper. A Hall effect sensor is used in robot-manipulator. For provision high accuracy it was used the new method of Hall effect sensor additive error minimization.

Keywords: permanent magnet, principle of reciprocity, robot-manipulator

1   INTRODUCTION

High specific magnetic energy and coercive force permanent magnets are widespread in many branches of science and engineering. The main magnetic parameters of Sa-Co, Re-Co, Nd-Fe-B are in 10÷30 times greater in comparison with ferromagnetic alloys. Mass production of devices with the usage of these magnets result in necessity of their 100% acceptance verification and certification. The main demands to measuring computer complex are high productivity, accuracy and reliability.

A Hall effect sensor that measures residual magnetic induction of a magnet under verification is placed in the air gap between a magnet's surface and electromagnet's pole. The symmetry centers of a magnet's cross-section and a sensor are not coincided. This fact cause an error, which depends on sequence of geometrical sizes of a magnet to be measured, an electromagnet and a magnet's material in general, and, in particular, depends on sizes of a gap, magnet's and electromagnet's pole cross-sections. An additive error belong to the rectangular with sides equal to the error for non-homogeneous distribution of magnetic induction in the gap, as it is shown in Fig. 1.
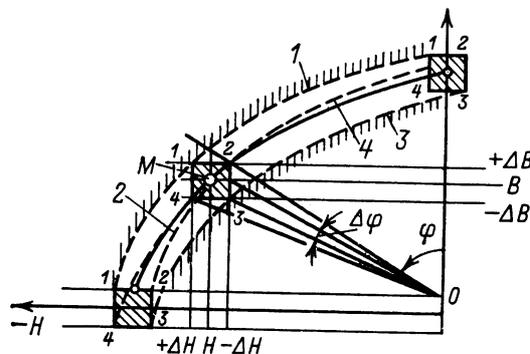

Figure 1.

The operating point that determines a magnetic induction in a gap moves, therefore, alongside the demagnetizing part of a hysteresis loop. An error may be determined in the same way as for comparison results of measurement by a permeameter and a standard magnet [1,2]. This error is negligible for magnetic materials with high factor of rectangularity.

New method of the additive error expelling and linearization of a sensor's conversion function provide high accuracy. The first problem solution is grounded on gyrator's properties of Hall effect e.m.f. Hall effect's e.m.f. is not subjected to the Maxwell principle of reciprocity, but an additive error, caused by a unbalance of equivalent bridge, subjects to this principle. An additive error may be expelled in result of two measurements with direct and inverse usage of Hall and current electrodes. The new method of an additive error correction may be realized in analog or digital form. The second problem is solved by optimization of Hall plate's geometrical sizes and potential electrodes configuration: reducing of by-passed influence of Hall electrodes compensates a negative slope of a conversion function. Combination Hall effect and Gauss effect provides practically ideal linearity in the same sensor.

XVI IMEKO World Congress

Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future

Vienna, AUSTRIA, 2000, September 25-28

2   ROBOT-MANIPULATOR MECHANIZM OF ACTING

The robot-manipulator is the complex of software and hardware that realize a sequential removal of controllable magnets from an initial pack, separation testing magnets for a fit or symbolically unfit magnet packs, forming like an initial magnets pack. Hardware section of the system is intended for an initial magnets pack unpacking on fit and unfit magnets packs, their displacement and positioning, removal and displacement of controllable magnets in the closed magnetic system with a primary Hall effect magnetic sensor for measurement residual magnetic induction. Separation procedures are made by means of mechanisms and electron blocks, which are the part of hardware. Mechanisms of the robot-manipulator provide displacement and positioning in a two-dimensional space: on the front panel of these three magnet packs and the next controllable magnet. Electron blocks, which are the components of hardware, control servomechanisms, providing positioning and displacement of packs and controllable magnets, reading and processing of a measuring information about a residual induction of a magnet by measurement a magnetic induction in the small air gap. The complex hardware includes also IBM-compatible PC which is electrically connected through the interface card and buses with the unit and its components.

The robot-manipulator software includes resident software, placed in a micro-controller, which fulfills an exchange of a controlling and measuring information with PC, double-directed data communication with actuating mechanisms and the measuring device.

A system's software, which is installed on PC, is an application operating in Windows medium. It provides reception and processing both a measuring information and the whole data about a current state of mechanisms and facilities of block. An application analyses of an information being received is produced

Control signals for device block mechanisms provides an interaction mode with an operator, gives a measuring and an accompanying information in the form convenient for a user.

3   DESIGN

Magnets packs displacement and positioning is one of the main procedures together with a controllable magnet displacement and positioning that perform the robot-manipulator. A current magnet we obtain from an initial magnet's pack. Than, we classify and separate magnets on fit and unfit packs by shift, taking into account both a height of pack magnets and also a non-magnetic insert height. Mechanisms, which implement magnets' displacement and positioning, are shown in Fig. 2.
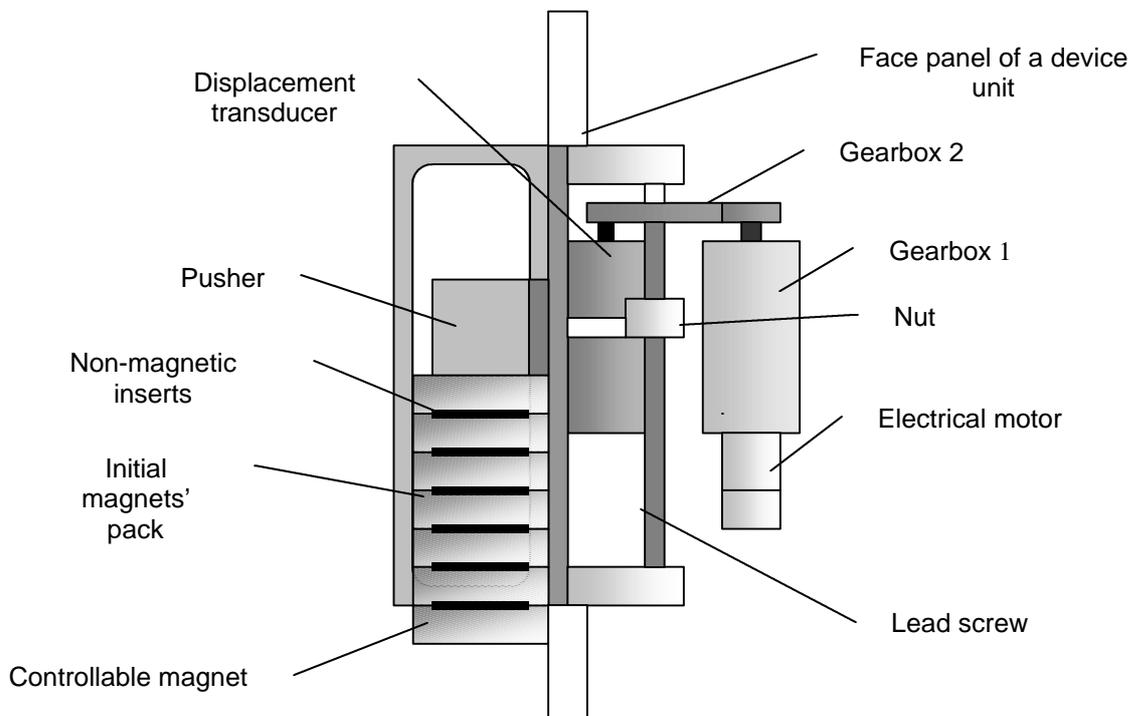

Figure 2.

XVI IMEKO World Congress

Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future

Vienna, AUSTRIA, 2000, September 25-28

Initial magnets' pack due to a magnetic attraction force is engaged with a steel pusher, which transmits a nut translation to a pack from a rotary motion of a lead screw. A lead screw is rotated by an electric motor through gearboxes. A displacement transducer is used for a current position control of a pusher. A transducer is connected with a gearbox through a wheel. An electrical signal, proportional to a co-ordinate of a pusher location, is used for its positioning. Mechanisms for fit and symbolically unfit magnet's packs are made in the same way. The next magnet's removal from a pack, which is intended for a separation, is provided with transport means. On the other words, a frame with a mobile platform provides a controllable magnet catch and fixing. Transport means perform positioning relatively to a feed before magnet removal conduction. A controllable magnet positioning relatively to a device is provided by an initial magnets pack removal.

A mobile platform of transport means has a bin for a non-magnetic insert receiving with a turn blind for an insert placement on fit and unfit magnet packs being formed. A controllable magnet catch and fixing is fulfilled after a transport means and a controllable magnet positioning. A strong-loaded bumper provides a prescribed force application of a magnet clamp by a mobile platform.

A controllable magnet removal and a non-magnetic insert reception are provided with a transport means shift relatively to a feed. Than, a controllable magnet is put into a closed magnetic system by a transport means for a residual magnetic induction measurement. A controllable magnet installation in one of receiving mechanisms is fulfilled after a classifying.

A controllable magnet grip is provided by a mechanism, which fulfills a linear displacement of a transport means relatively to all other mechanisms and a closed magnetic system. This operation provides magnets' removal and installation in other three mechanisms, an insert acceptance from the initial pack feed, a non-magnetic insert placement on fit and unfit magnet packs. A controllable magnet gets rid of a clamp and is attracted to a pack being formed

It is fulfilled a non-magnetic insert placement between magnets after a controllable magnet installation. A new transport means positioning is performed, and a turn blind of a non-magnetic insert a receiving bin is opened. This blind falls down and places on a magnet being already installed Fig.3 an insert.
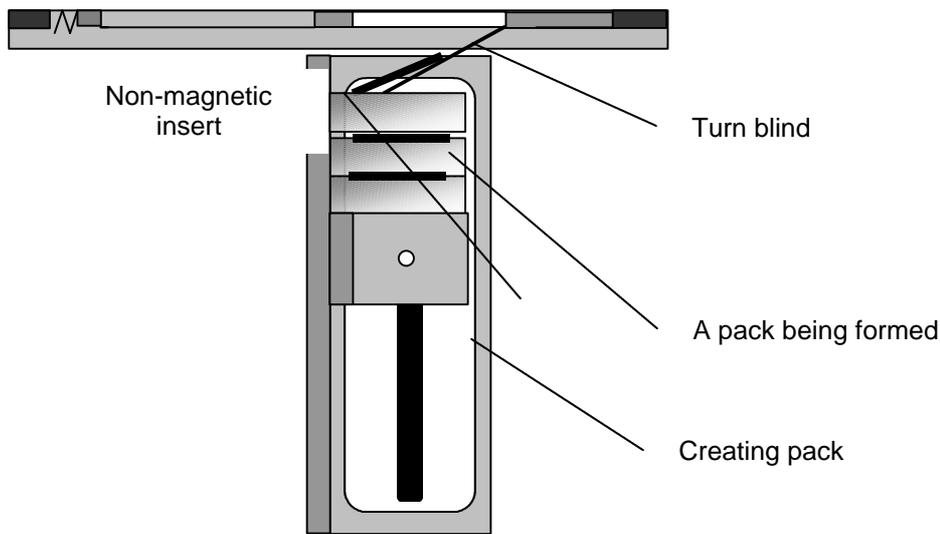

Non-magnetic insert

Turn blind

A pack being formed

Creating pack

Figure 3.

The controllable magnet movement and clamp mechanism in a transport means contains an electric motor with a gearbox, a lead screw with a nut, a displacement transducer. Additional operations at a controllable magnet clamp and unlatch in a transport means and a bin blind turn are provided with driving electromagnets.

4   FUNCTIONAL AND SCHEMATIC DIAGRAMS OF THE ROBOT-MANIPULATOR

A connection between the main mechanisms and blocks of the robot-manipulator is shown in the functional diagram Fig.4. An informational exchange inside a device is fulfilled by a micro-controller, which control mechanisms and blocks in accordance to the installed program. This complex is controlled by bipolar impulses through the interface card. Each of four servo-drives' positioning, three

driving electromagnets are switched on commands that also control an analog-to-digital converter. There are two-direction connectors with each of servo-drives. Analog signals of control actions, which are obtained from PC, are transmitted through the connectors from the micro-controller. Double-levels **on** and **off** signals of PC are transmitted on driving electromagnets. Double-level signals of a current error, which exactly determine whether a control action completes at the current moment, are transmitted to the micro-controller from four servo-drives.
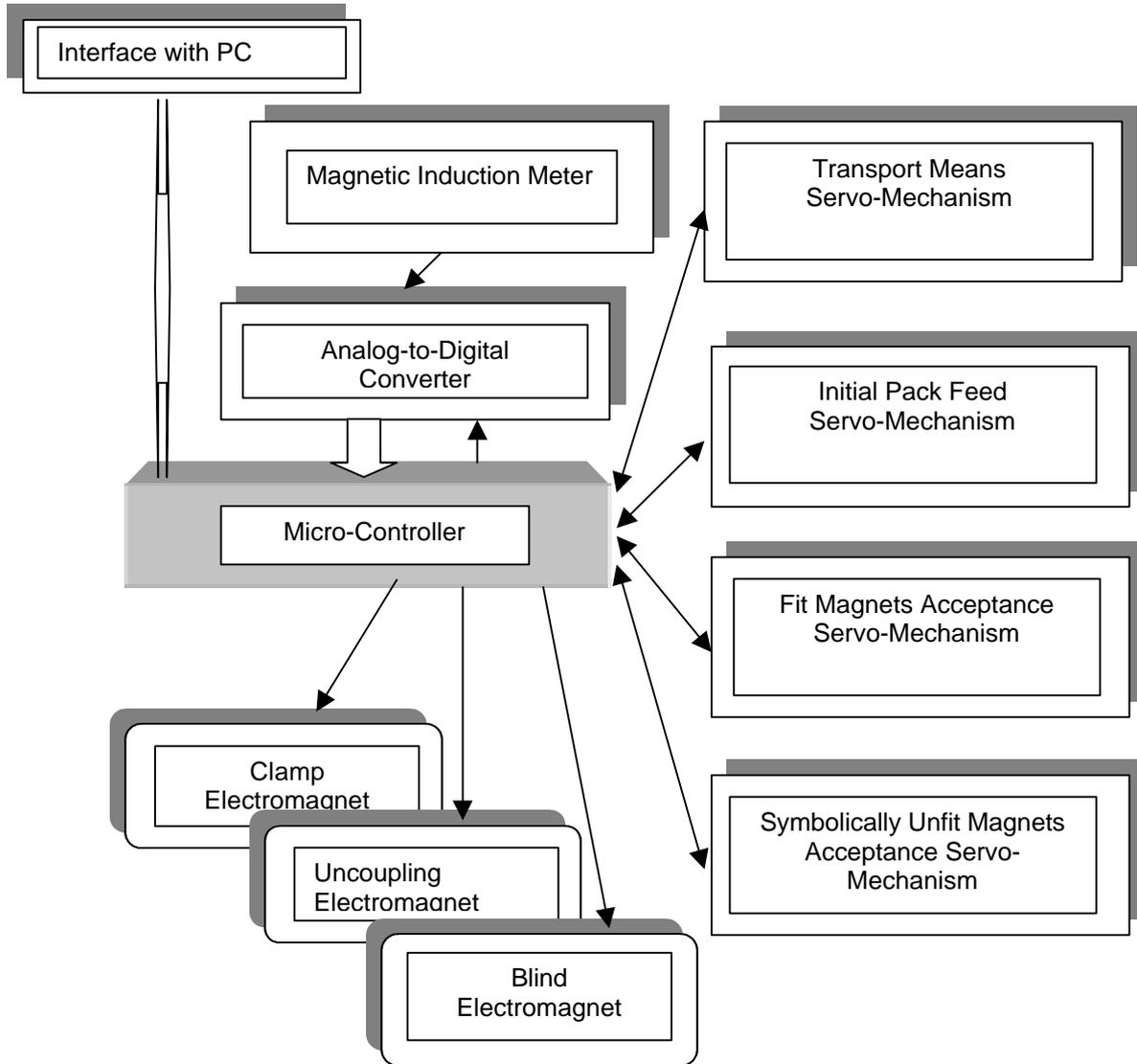

Figure 4.

Thus, a micro-controller provides an acceptance of servo-drives' digital control actions from PC and their conversion into an analog ones. Micro-controller also accepts an information about servo-drives state, as well as an analog-to-digital conversion of a residual magnetic induction measurement and transmittance to PC. Four servo-drives, which provide separation of magnets or their packs movement and positioning, have identical block diagrams Fig. 5. A subtractor compares a control action in an analog form with an output voltage of a position pickup. An error signal is amplified by an amplifier with a definite clipping level and then is transmitted to a power amplifier through an adjustment unit with an electrical motor as a load. An electrical motor's output shaft rotation through a gearbox is transmitted to an executive device and to a potentiometer position transducer shaft. A pusher is an executive device for magnet packs and positioning mechanisms movement.

A mobile platform is used for transportation. Non-linear threshold unit generates an error signal in digital form.
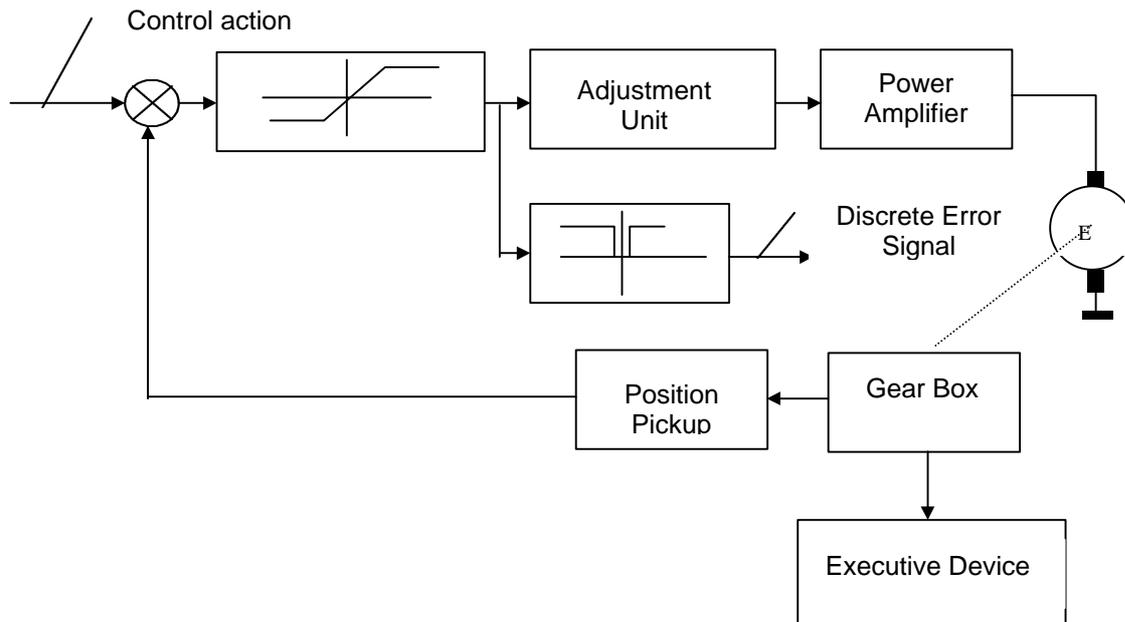
Figure 5.

The generalized functional block diagram of a residual magnetic induction meter consists of a Hall effect generator, which is used as a measuring device and a primary converter, which provides a high accuracy within a wide range of magnetic induction variation.

An output signal of a converter consists of a voltage proportional to an induction being measured and an additive error caused by IR-voltage drop across Hall electrodes. IR-drop is compensated by proportional voltage drop across current electrodes. Output analog signal normalization is fulfilled by change of an amplifier's gain.

The electron block of servo-drives is four channels device. The schematic diagram contains three absolutely identical channels: a give box GB Drive, a value box VB Drive, a non magnets box NB for magnet packs movement and positioning and also a turn magnet TM channel, which controls a transport means of a servo-drive. A last channel differs from other ones only by an additive power amplifier. Operational amplifiers determine and amplify an error signal between a control influence turn task TT and a position pickup voltage turns sensor TS. A frequency correction is fulfilled by a R,C network. An output power amplifier has a motor as a load. Two diodes provide a protection of output transistors. The circuit generates a digital error signal with two-threshold comparators, an univibrator and logic elements. A time delay is fulfilled by an univibrator for a transient completion. After a positioning completion a digital error signal switches an analog multiplexer that controls and determines the equality to zero an output voltage of a turn motor TM. A multiplexer's switch off position gives a possibility to put into zero an executive network device and calibrate a network by an other potentiometer.

The schematic diagram of a micro-controller consists of the integrated circuit U1KP1816BE51 as a single-crystal micro-controller. The 2K-memory device is switched through data bus directly and through an address register. Data exchange with a microprocessor is provided through a parallel input/output port. Four networks of a twelve-resolution digital-to-analog converter for servo-drives control use 8 characters of PA port and 4 characters of PC. Other four characters are used for a choice of one of four analog-to-digital converters. Output analog-to-digital converter signals is formed by buffer amplifiers that generate control signal for a turn task TT, a give task GT, a value task VT, a non task operations. An analog-to-digital conversion by the method of a double integration is used. Switch on/off signals of executive electromagnets such as an immediate stop, an immediate clinch are transmitted through micro-controller and logic elements. A special output element is intended for an urgent switch off of all the drives. An input of servo-drives a turn error TE, a give error GE, a value error VE, a non-error NE and a controller provide digitalization of an error signal for their further transmission into PC. A sequential exchange with PC is fulfilled by hardware of a micro-controller.

The schematic diagram of a magnetic induction meter consists of a stable current source, which is assembled on 3 operational amplifiers. A voltage drop across the standard resistor is applied to integrator's input and thus provides independence of a Hall effect sensor's e.m.f. from a current stability.

XVI IMEKO World Congress

Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future

Vienna, AUSTRIA, 2000, September 25-28

5   THE ROBOT-MANIPULATOR SOFTWARE

The robot-manipulator software consists of resident and system software. Resident software of a micro-controller provides an information exchange with PC, servo-drives and executive electromagnets' control, current information collection about servo-drives' state. Resident software is inaccessible for a user.

A user is supplied with system software in two 3"5 disks. System software is an application for operation in Windows environment in a multi-windows interface mode with a user. PC monitor screen has three windows: Parameters, Operation Table, and Information.

Parameters window is intended for of magnets' parameters setting. Controllable magnet's material is determined by a corresponding option. A text margins, provided with scrollers, permit to install non-magnetic inserts height, magnet's quantity in the initial and output packs, magnet's dimensions in a pack. An information window contains text margins with scrollers for magnet's separation in fit and symbolically unfit magnets' packs with respect to accepted resolution of a residual magnetic induction of magnets to be measured. An additive text field without a scroller gives a current information about magnet's number in packs.

The robot-manipulator window with text fields Instruction, Operation, Induction shows also the face panel of the device with the main element of the robot-manipulator disposed on it: pushers of feed receiving mechanisms, the transport means, the magnetic circuit. The robot-manipulator operation control buttons are also disposed on the panel.

The text field Instruction contains a recommended order of operations in each moment. In Induction text field a residual magnetic induction of a controllable magnet after a measurement is presented. It is also informed about the next operation in a corresponding text field. The menu provides a rapid access for a program functions File, Start, Service. A menu File being opened, includes icons Print and Exit. Return into Windows is fulfilled through a menu icon Exit.

The menu Start includes icons Modes and Start. Through the icon Modes it is possible to choose a Step-by-Step or a Continuous modes of the robot-manipulator operation. The menu icon Start provides an access to the robot- manipulator operation start in one of two modes.

In a Step –by -Step mode scrollers are placed near mechanisms' images, which permit to control manually a removal and positioning of operating elements of the robot-manipulator.

At the robot-manipulator operation, magnets in each of mechanisms are displayed, an indication of mobile elements in an animation mode is provided that gives a possibility to represent identically its state. Additional text messages, duplicated by a sound signal, are appeared in time moments, when an operator intervention is necessary.

The Service Menu being opened contains icons Run and Adjustment for the robot-manipulator mechanisms' adjustment.

6   DATA OF ROBOT-MANIPULATOR

- material of magnets   Nd-Fe-B, Sa-Co, Re-Co, alloys of Al-Ni-Co, ferrite;
- length of magnets   5÷35mm;
- width of magnets   5÷35mm;
- height of magnets   3÷10mm;
- quantity of magnets in a package   8÷24;
- range of measurement   0.2÷1.5T;
- error   0.5%;
- time of measurement   5s.

REFERENCE

[1] Ñ Òàðàííâ (ðåä). Ãàëüâàííîãàíèòíûå ïðåîáðàçîâàòåëè â èçìåðèòåëüíîé òåõíèêå Ýíåðãîàíèçäàò, Îîñêâà, 1984

[2] S. Taranov, E. Andrievsky, B Marshalenko The Computer Measuring Complex for High Magnetic Energy Permanent Magnets Verification, 9th IMEKO Symposium, Italy, 1998

AUTHORS: Prof. Dr. Sc. F. GRINEVICH, Ph.D. R. MAZMANIAN, Ph.D. B. MARSHALENKO, The Institute of Electrodynamics, Ave. Pobedy 56, Kiev-57, Ukraine 252680, Tel +38044 446 5068, Fax +38044 446 9494, e-mail: Grif@IED.Kiev.Ua , Prof. Dr. Sc. S. TARANOW, Institute of Information and Electronics, Technical University of Zielona Gora, ul. Podgorna 50, 65-246,Zielona Gora Poland, Tel. +4868 328-2329, Fax +4868 324 4733, e-mail: S.Taranow@IIE.PZ.Zgora.Pl