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LABORATORY STAND FOR DYNAMIC TESTS OF STEPPING MOTOR DRIVES

ABSTRACT *Problems of dynamic operation of drives with stepping motors are complicated because of the character of operation of these micro-machines. The developed stand is equipped with a number of measurement converters making it possible to monitor and analyze quantities characterizing the motion of stepping motors. Modular structure allows the configuration of the system to be rearranged in a simple way and an easy expansion to be introduced in the future. The assumption of the study is a didactic character of the structure and research program, and possibility of learning advanced techniques related to stepping motor control.*

Keywords*: drive system, stepping motor, laboratory stand, dynamic measurements.*

1. INTRODUCTION

Measurements are the most significant issue, both in R&D works and in operational use of a ready drive. There are just mechatronic drives where we deal with application of additional – as compared to the traditional drives – sets

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of sensors that are indispensable for control and diagnostic procedures. Common usage of simulation methods requires performing identification of the studied systems. Effective methods of testing the drives at the production stage are also indispensable. At the ZKUP (Division of Design of Precision Devices, Institute of Micromechanics and Photonics), within the recent years, there have been consistently carried out works regarding methods and instruments for experimental studies of low-power electromechanical microdrives and actuators.

The subject of the presented work is a design and a realization of a laboratory stand for analysing dynamics of stepping motor drives. Test stands for experimental studies of stepping motors are important for the ZKUP team, because we are still the designers of new devices with drive systems including such kind of actuators.

A good example could be prototype of a 4-axis numerically-controlled mini tool machine. The linear motion within three axes is realized on linear ball ways and screw mechanisms converting the rotary motion to linear, as well as gears. The stepping motors are used as actuators, also in the fourth – rotating axis [3].

The controllers make it possible to control the stepping motors in half-step mode, with the original system of stabilization of the magnetic flow vector. Stabilization is achieved by a change of the supply voltage of the motor (full range for one phase and 0.7 of the full range when two phases are activated).

The designed machine was built as a working device, therefore it t could have been tested. Machine was tested with regard to: force, minimal positioning accuracy, and is now used at a didactic laboratory. The machine can be afforded by small workshops, modelers or didactic centers. As a controller of the machine, a PC computer is used, what makes it even more versatile.

The main parameters are:

- fast positioning up to 840 mm/min within the area of X220, Y160, Z120 mm,
- linear resolution of 5 μm and uncertainty of less than 0.05 mm;
- angular step – 0.025°;
- And the important features for the user are:
- exchangeable tool spindle;
- safety switches;
- light, open (ready for development) structure;
- relatively low power consumption;

The overall dimensions of the machine are: 370×650×430 mm (L×H×W), weight is of ca. 25 kg. Power consumption of the stepping motors is DC12 V / 8 A. Spindle (popular high-speed tool) AC230 V / 130 W. An additional controller makes it possible to use an inverter for changing the speed of the spindle during operation.

The visualization of the tool machine and photos of the main components are presented in Figure 1.

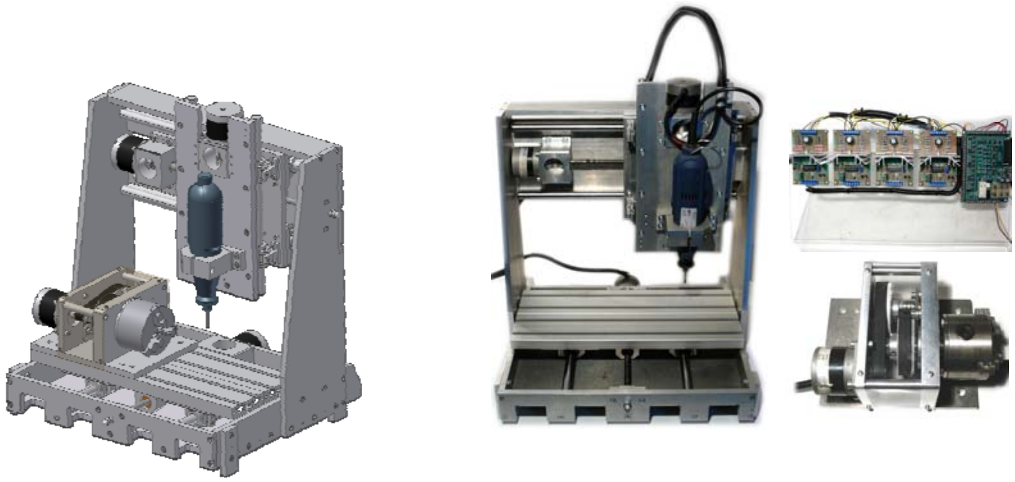


Fig. 1. Mini tool machine designed at ZKUP [3]
left – visualisation, right – real photo of the main components

2. TEST STAND AND ITS COMPONENTS

The purpose was to design a universal laboratory stand for testing dynamic properties of stepping motor drives. In fact, it is a physical model of the drive system with the following components: micromotor with controller, gear unit, load system (model of the driven mechanisms). Additionally, the measurement layer makes it possible to monitor electrical (e.g. currents in the coils) and mechanical signals characterising operation of the drive system.

The visualization of the model of the drive system is presented in Figure 2 [1]. Thanks to a set of exchangeable gears, it is possible to perform experiments at reduction or multiplication gear ratio with: toothed belt drive, belt drive, friction gear and classic gear with toothed wheels (see Fig. 3).
The main measurement procedures applied in the stand include:

- determination of current passage in the motor coil – application of current/ voltage converters *LEM* type makes it possible to record such signal without a galvanic coupling of the measuring circuit with the micromotor winding,
- analysis of signals monitoring movement parameters (angular position of the shafts – by digital encoders – or its angular velocity – with use of miniature DC tacho-generators),
- observations of power cycles of the motor coils,
- observations of the influence of inertial or torque (friction or active) load on the dynamics of the motion of the rotor.

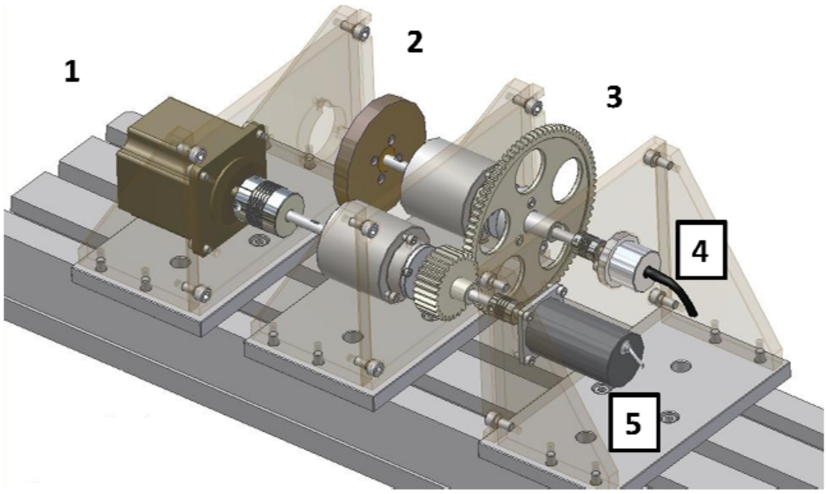


Fig. 2. Main components of the electromechanical component of the test stand
1 – motor under test, 2 – load unit, 3 – power transmission unit (gears module)
4, 5 – transducers for monitoring movement parameters (encoder, tachogenerator)

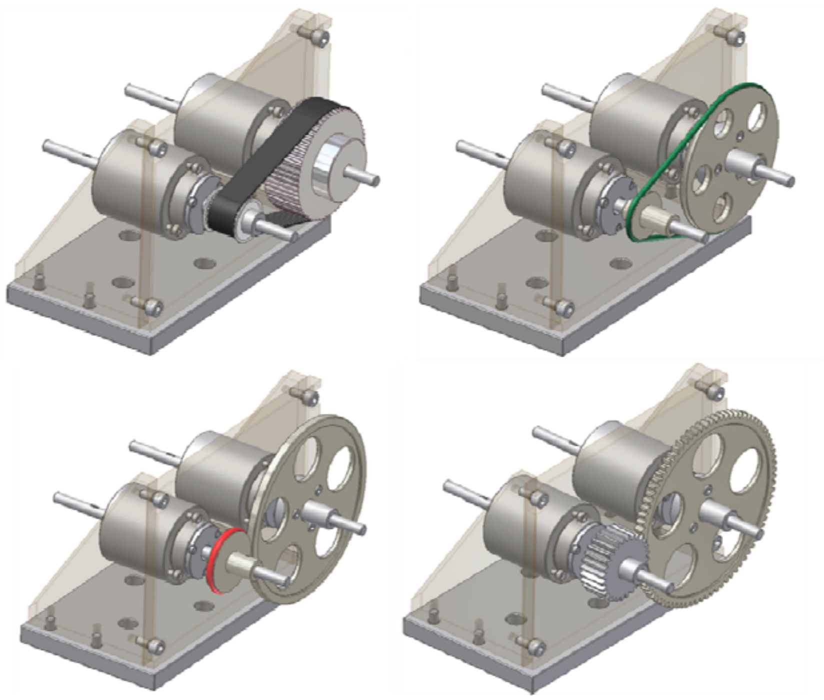


Fig. 3. Variants of the transmission unit (gears) used in the stand

A real photo of the part of the stand visualized in Figure 4 is shown in Figure 4, and a view of the whole system – in Figure 5.

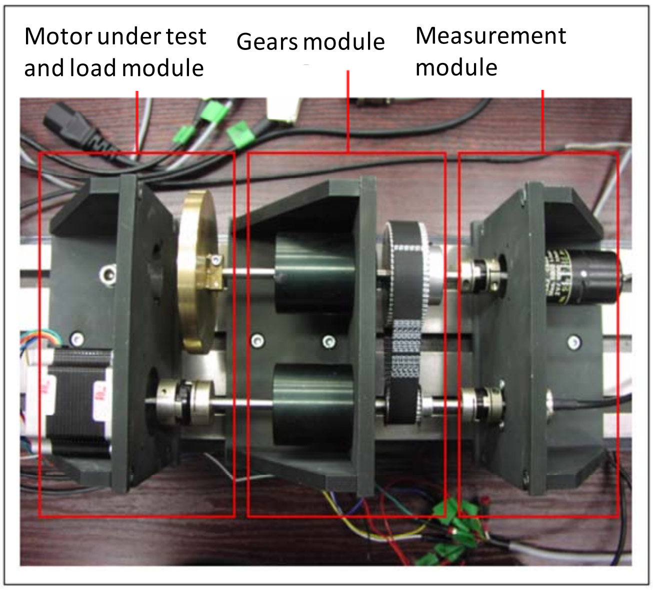


Fig. 4. Test stand – the electromechanical component

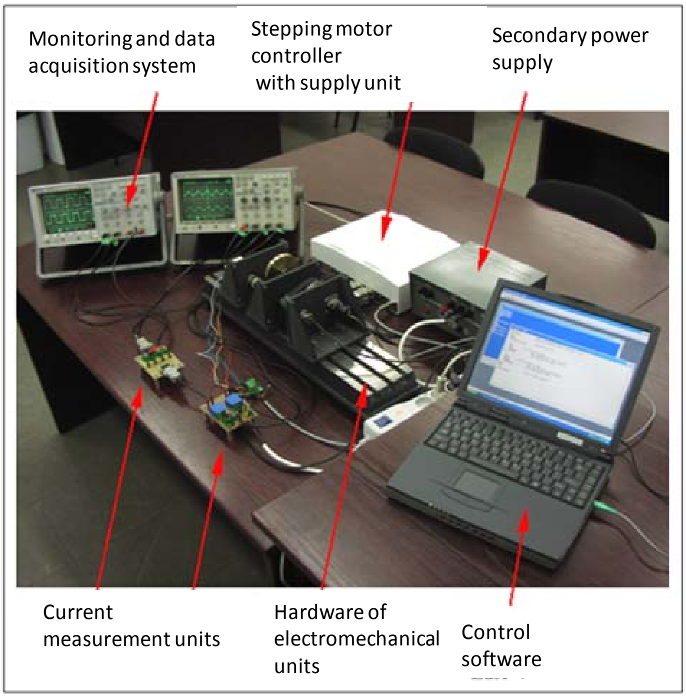


Fig. 5. Test stand – the system

Different controllers can be used for controlling and supplying the stepping motors. We made experiments with a number of commercial controllers, but the basic type used in the experiments is ViX 500IM (full, half and micro-step mode controller by Parker [6]) with the control software Easy-V.

The main parameters of the control are, velocity up to 3000 rpm, MOSFET chopper amplifier (16 kHz), positioning range +/- 2 147 483 647 steps. Possible velocity control procedures are presented in Figure 6.

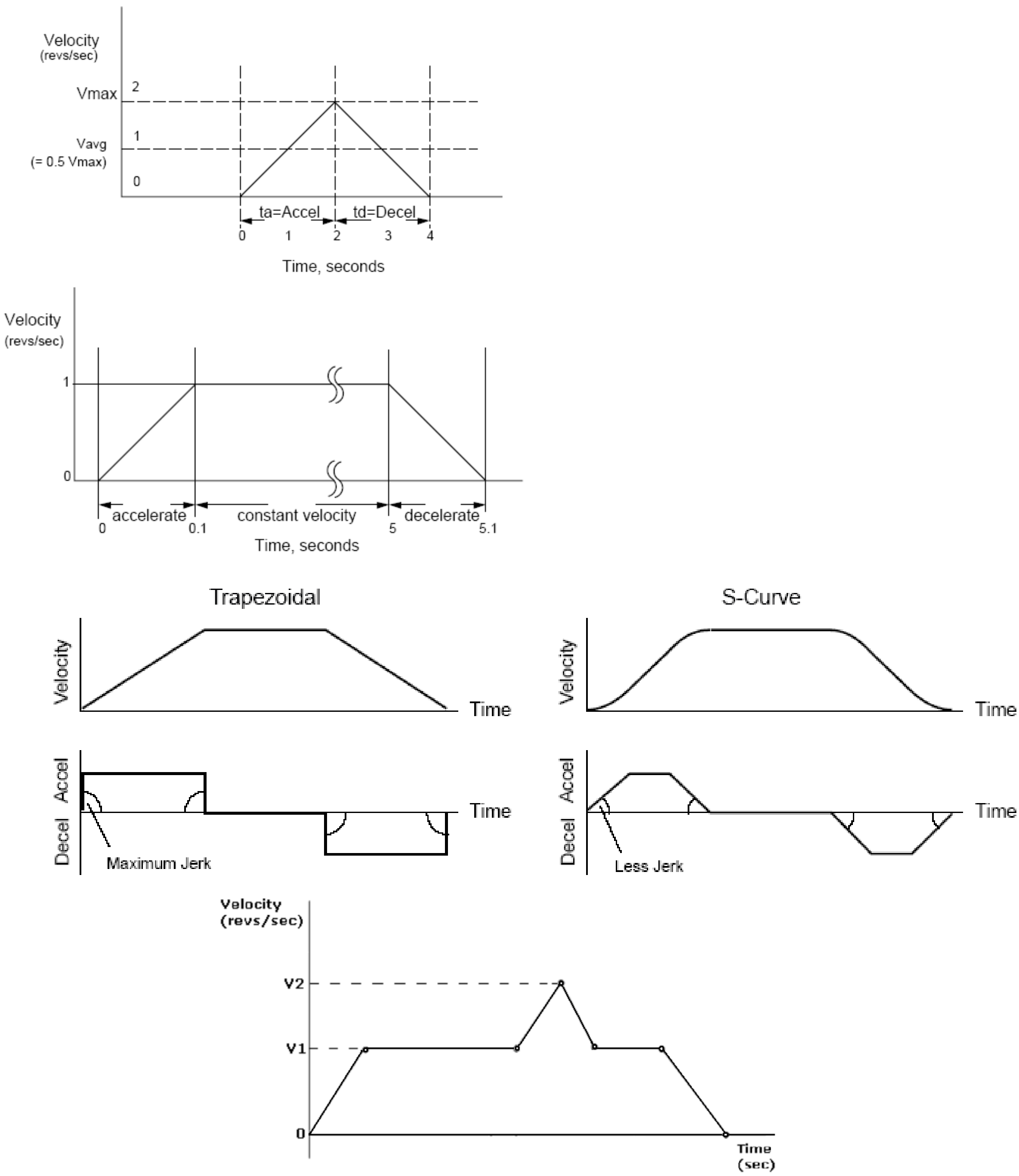


Fig. 6. The Easy-V – control procedures of stepping motor [6]

Current course in one phase (against the signal from the monitoring encoder) is presented in Figure 7.

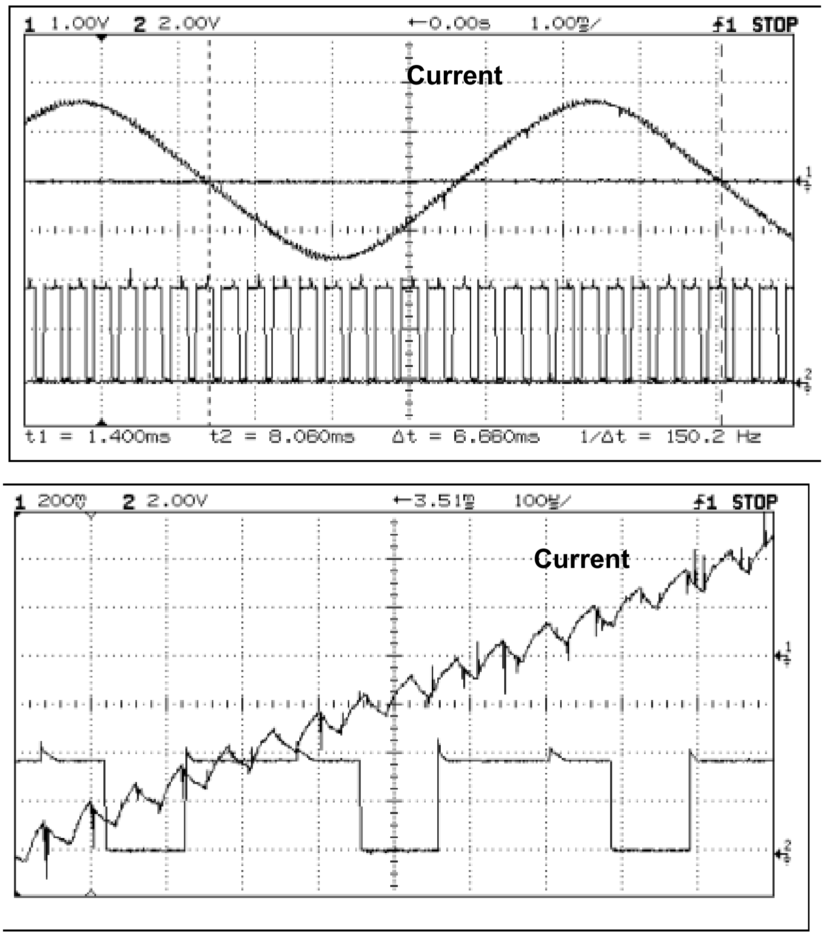
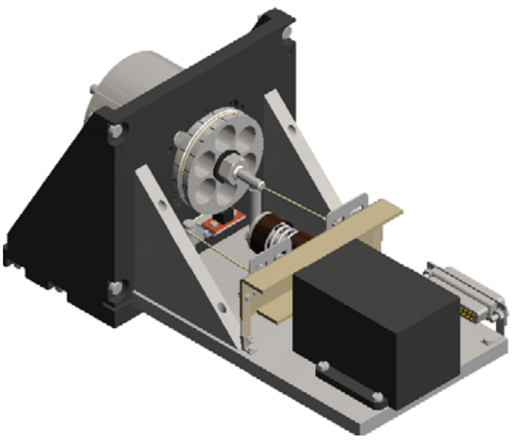


Fig. 7. Current courses in one coil of two phase hybrid stepping motor against signals from an encoder with 1000 marks per rev (time window on the lower figure shows the chopper effect)



While apply load (friction torque), a practical solution could be electromagnetic powder brakes with specialised control units. We have started elaborating a design of a controlled electric brake-dynamometer device. It is assumed that

Fig. 8. Visualisation of the automated friction brake-dynamometric system according to Prony's concept [7]

the device is designed to apply a passive load in a form of a braking torque according to Prony's method within a range of 0 to 0.5 Nm. The measurement of the braking torque is based on application of strain gauges. The device (see the visualization in Fig. 8) is equipped with a system measuring speed of the drum, which allows the user to record characteristics of an engine without an additional module in the measuring station [7].

3. EXEMPLARY EXPERIMENTS

Development of test stations for determining frequency characteristics of stepping motors and studies of procedures of their accelerating under conditions of extreme loads was a subject of scientific interest of ZKUP IMiF and co-operative teams [2, 4, 5].

Problems of dynamic operation of drives with stepper motors are complicated because of a character of operation of these micro-machines that introduces pulsating input functions into a flexible electromechanical structure (created by attaching the gears and the couplings). A good example are experiments conducted with use of the presented test system.

In Figure 9, there is presented angular velocity curve recorded for the belt drive with 2-phase hybrid stepping motor. The velocity signal was taken from a miniature DC tacho-generator. Movement was realized first at constant value of acceleration, and then with an analogous value of deceleration. Maximal value of the average velocity of the rotor was of 630 rpm (210 rpm on output shaft). It is possible to observe the resonance regions at both rising and falling arms of the velocity triangle – occurring at the same level of the signal.

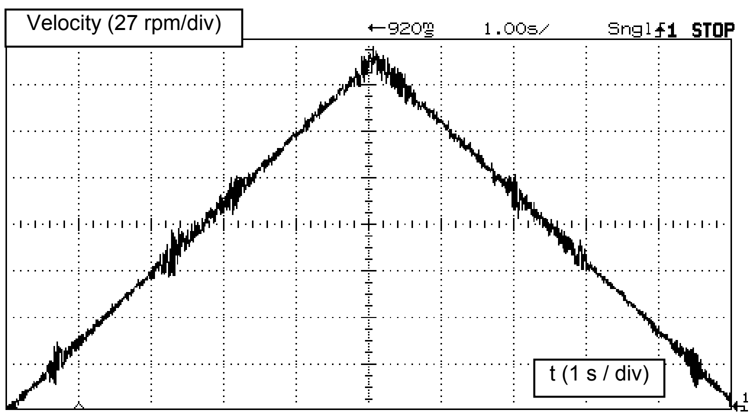


Fig. 9. Angular velocity curve during the test of belt gear drive operating at constant acceleration and deceleration (description in the text)

4. REMARKS AND CONCLUSION

Experimental studies of electromechanical drives are not only a direct tool for learning features of objects, and useful at the stage of designing and optimizing a system. They are also an indispensable basic element of the identification process of mathematical models, which enable to carry out a formal analysis of various phenomena – e.g. with application of simulation methods. In the case of the presented test station, it is possible to model non-linear phenomena occurring in the process of conversion of the electric energy into the electromagnetic one, and finally into the mechanical one, provided mutual dependencies between the mechanical and electrical quantities of the drive are determined in an experimental way. Because of a strongly dynamical character of operation of the drive, performing of the measurements was possible thanks to application of measuring transducers characterized by both wide bandwidth and high resolution.

It should be pointed out that the designed control module is also useful for pulsed supplying of electromagnets used in test stations, where it is required to apply a pulse of force having certain time parameters and a small value. Such systems can be widely applied in studies of dynamic properties of micro-specimens.

In order to prepare a ZKUP research team for R&D works in the field of modern drives it is required to improve methods of formal description of the related phenomena (including development of models for computer simulation) as well as methodologies and equipment used for performing various experimental studies.

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LABORATORYJNE STANOWISKO DO BADAŃ DYNAMIKI UKŁADÓW NAPĘDOWYCH Z SILNIKIEM SKOKOWYM

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STRESZCZENIE *Zagadnienia dynamiki układów napędowych z silnikami skokowymi są skomplikowane, przede wszystkim ze względu na charakter pracy tej klasy mikromaszyn. Opracowane stanowisko, wyposażone w zestaw przetworników pomiarowych umożliwia monitorowanie i analizę wielkości charakteryzujących prace silnika skokowego. Modułowa struktura stanowiska umożliwia zmianę struktury układu napędowego (różne rodzaje przekładni do transmisji mocy, różne silniki i algorytmy sterowania) oraz dalszą rozbudowę układu. Należy podkreślić zarówno zastosowanie dydaktyczne stanowiska, jak i możliwość prowadzenia prac badawczych dotyczących sterowania silnikami skokowymi i dynamiki układów napędowych.*