An Analyze on a Wood Processing Automatic Machine

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Abstract: - In this work is presenting an automatic machine used in the wood processing industry. These machines have the advantage of flexibility in achieving of some diverse finished products, by using the same processing tools, the single modification being made on the machine's program. As accurate drive elements are also used stepping motors that can be supplied and controlled in different modes. Hereby is presenting a unipolar control mode of a 4-coil stepping motor controlled by 4 transistors with field effect. For this circuit, there is the possibility of its control by the development mode with microcontroller or PC.

Key-Words: - automatic machine, control, stepping motor, unipolar

1 Introduction

Development of electronics, informatics, mechanical products and technologies represent a logical and concrete step in science and technology evolution.

Electronics allowed the leap and achievement of some mechanical systems with automatic control, based on electric relays, regulators, electric amplifiers with applications in machine-tools, in automotive field, etc. In 1953, at M.I.T. was achieved and were made demonstrations with a numerical controll milling machine. In early '60 are achieved the first industrial robots. The robots' manufacturing and utilization was facilited by previous solving of some technical problems, indispensable for their operation:

- remote manipulation of parts by means of articulated mechanisms, called telemanipulators;
- machine-tools' automation by means of numerical control;
- calculations' and control's automation by means of electronic computers.

Integration of electronics and computing technique lead to the substantial simplification of the mechanical components and cheper systems. Mechanical parts were replaced with cheaper electronic components, more reliable and easier to maintain, because they can facilite self-diagnosis [1,2]. These systems are more precise because precision is not based on the mechanical rigidity and stability, but on electronic measurement and adjustment systems. The mechanical construction's simplification was also facilitated by the descentralized control, by means of microcomputers and electric drives [3].

Introduction of some adjustment systems for position, speed, power, not only that allows the maintaining in reasonable precision limits the programmed measures, but also the obtaining of a quasi-linear behavior, even if the controlled mechanical system is non-linear [4,5].

A system that integrates, in a flexible configuration, mechanical, electronic and control components with numerical computing systems for generating of an intelligent control of movements, to obtain a multitude of functions, is called mecatronic system, and the block diagram of such a system is presented in fig.1 [1,6].

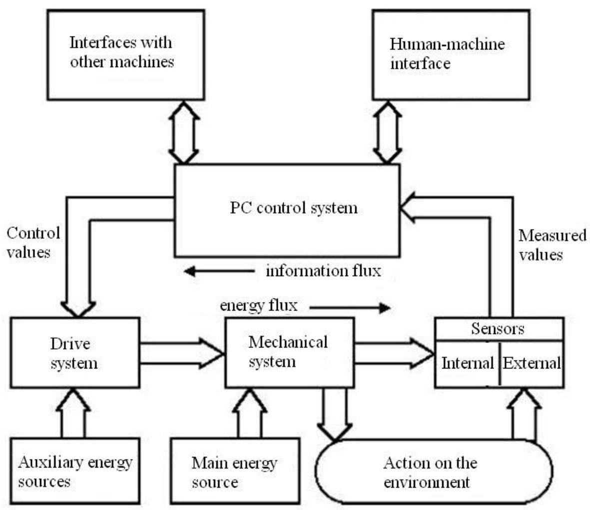


Fig.1. Block diagram of a mecatronic system

For a good operation of such a system, should be achieved:
- integration, that, at its turn, could be: spatial integration (constructive intergrowth of mechanical, electronic and control subsystems), or functional integration, ensured by software;
- inteligent, reported to the system's control functions and featured by an adaptive behavior, based on perception, judgement, self-learning, diagnosing of errors and system's reconfiguration (commutation on intact modules in case of some faults);
- flexibility, featured by the easiness by which the system can be adapted, or can adapt itself to a new environment, during its operation cycle; involves the adequate change of control programs (software) and not its mechanical or electric structure.

The main component of numeric machines is the motor – drive mechanism – cutting tool assembly, as fig.2. Together with sensors and a control unit (hardware and software), makes a complex subsystem. Energy flows (power source - drive train - charge) and information (sensors - control system - the system's drive) are illustrated in fig. 2.

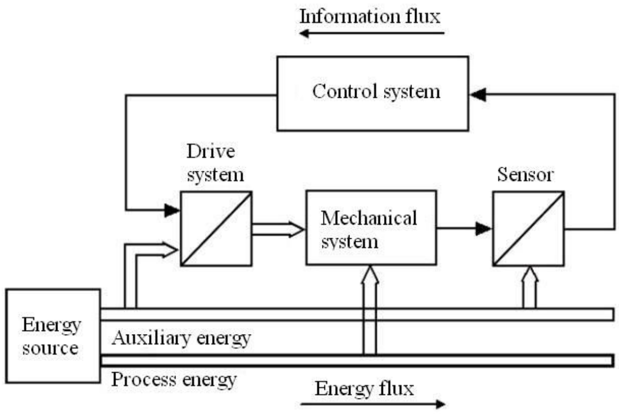


Fig.2. Flow of energy and information

2 Machine's general presentation

2.1 Homag Profi Bof 211-52-PM

The automatic milling machine HOMAG PROFI BOF211-52-PM is a device destined for the complex mechanical processing of wood parts and parts of wood-derived material, i.e.: agglomerated wood plates (laminated or non-laminated), bedded plywood, bedded panles, MDF (medium density fiberboard), HDF (high density fiberboard), etc.

The machine can execute a wide range of operations, specific to the utilization field, e.g.: simple, multiple or combined millings on the 3 translation axis, horizontal or vertical holes, which, at their turn, can be simple, with single-axle chuck, or multiple with multi-axle chuck. Also, the machine executes end-cutting operations at fixed dimension, as well as burring operations using specialized milling cutters [7].

In fig.3 is presented the machine's principle diagram.

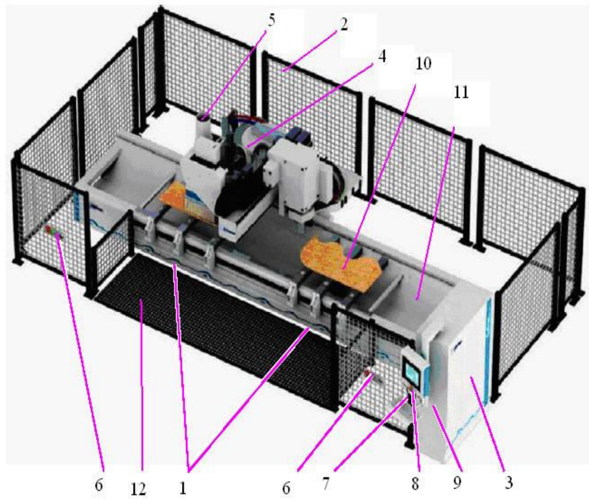


Fig.3. The Homag automatic processing machine's layout

In fig.3: 1 – foot switch; 2 – safety fence (security); 3 – panel with control and computing devices; 4 – numerical control processing device; 5 – inlet for connecting to the central exhausting installation; 6 – operation consoles; 7 – assistance for manual operation; 8 – control pannel; 9 – part (parts) subjected to processing; 10 – wood piece; 11 – fixing table of the parts subjected to processing; 12 – synthetic carpet (safety area).

The Homag processing machine with numerical control is composed mainly from three groups of installations, as follows: mechanical, hydraulic, and pneumatic installation, electric installation and the numerical computing and programming part. The mechanical installation includes the parts' fixing table, provided with fastening devices adjustable on 2 axis, numerical control processing device, safety fence, as well as the compressed air supply installations, greasing automatic installations, cooling and vaccuming circuits. The electric installation is composed by the power and control supply circuits of the diverse equipment's components, as well as the interconnecting circuits between the execution, processing, computing modules and the equipment's external and internal sensors. The equipment's computing system has in componency 2 computing units, peripheral devices for processing information from the labor technical process (internal, external sensors), limit switches, control consoles, keyboard, mouse, etc.

2.2 Main Drive Spindle

The main drive spindle is used as tool spindle. It's used as unit for actuating the processing units. The mechanical and electrical characteristics are presented in table 1.

Table 1

Items	Values
Power, max.	7.5÷21 kW
Rotation speed continuously adjustable	0 – 30000 rpm
Gripping chuck for tools	11000 N
Supply voltage	380÷520 V
Rotation sense	From right to left
Cooling of motors and bearings	Water cooling
Front sealing	Labirinth sealing
Filter's definition	8 microns
Cooling agent's temperature	15 – 45 ^{0}C

Depending on the automatic processing machine's constructive type, can be used motors with powers between 7.5 and 21 kW such as 7.5, 12, 14.5 respectively 21 kW.

2.3 Tools (Units) Changer with 18 Positions

Tools, processing units and equipment are kept in the 18-position processing tools/units changer, for automatic change on the main drive spindle.
Fig.4 shows an 18 position tool exchanger type BXX.

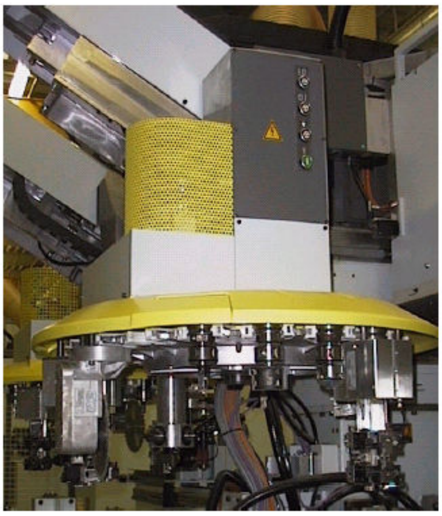


Fig.4. 18-position tool exchanger type BXX

2.4 Multi-Axle Boring Unit

The multi-axle boring unit can be used for simple or multiple vertical bores. Additionl boring units can be mounted on. By means of this device can be performed simmultaneously boring operations, obtaining bores with diameter up to 35mm, and the distance of the bore series is standardized at 30 or 32mm. Maximum boring depth is 70mm. For diversifying the processing possibilities, additional boring units can be mounted. Characteristics of the multi-axle boring units are presented in table 2.

Table 2

Parameters	Values
Number of drive spindles, depending on the unit's type	12 or 17
Number of mounting surfaces for these additional processing units, depending on the unit's type	1 or 2
Spindles' exterior stroke	50 mm
Distance between axis, depending on the unit's type	32 mm or 30 mm
Motor's power	4 kW
Rotation speed of the drive spindles, electronically frequency controlled	1000÷ 9000 rpm
Drill shank's diameter Ø (with gripping surface and adjustment screw)	10 mm
Gripping depth	20 mm
Drill's total length	70 mm
Max. boring depth	40 mm
Drill Ø max.	35 mm
Advance values: max. - At simple boring Ø < 16 mm - At simple boring Ø > 16 mm - Multiple boring WZ Ø max. 10 mm	 8 m/min 5 m/min 5 m/min

The multi-axle boring unit is composed by the following devices:
- burring axle;
- 4-axis horizontal boring head, with tilting saw blade;
- 3 x 2 axis horizontal boring head;
- 4-axis horizontal boring head, rigid;
- 6-axis horizontal boring head;
- 4-axis horizontal boring head, with rigid tiling saw blade.

2.5 Numerical Control Processing Centre

This centre is destined for cutting the furniture parts, or wood components, or wood-based materials. Is composed by the main drive spindle, tools store (changer), execution servo-mechanisms, as well as the related pneumatic and electric installations. The main constructive parameters are presented in table 3.

Table 3
Parameters of the numerical control precessing centre

Parameters	Values
Axis length	
In direction x	3500 mm
In direction y	1700 mm
In direction z	410 mm
Work speed	
In directions x and y	80 m/min
In direction z	30m/min

Movement on the 3 axis is achieved on guiding rails, gear racks or ball-threaded conducting spindles. These are lubricated from case to case, either manual, or automatically by its own greasing system.

2.6 Four-Axis Boring and Milling Uunit

The boring and milling unit is used for making horizontal bores and millings.
The device is shown in fig.5, and its structural parameters are given in table 4.

Fig.5. Four axis milling and drilling BXX unit

The electric part of the Homag automatic milling machine is composed by: electric drive motors, cabinet with the machine's power and control installations and peripheral control equipments (drive consoles, keyboard, general control pannel).
Portal machine control elements are:
-control panel;
-foot switch;
-supply cabinet;
-operating console.
The Homag automatic milling machine is endowed with a static frequency converter Combivert XX F4-C. By this, is achieved the control of the main drive spindle's motor, respectively its maintaining in optimal operation parameters, as well as the protection to overload.

Table 4
Parameters of the 4-axis boring ans milling unit

Parameters	Values
Entrance speed (rpm) max.	9120 rpm
Pinions' ratio	1 : 1.48
Exit speed (rotational) max.	13500 rpm
Rotation sense	Clockwise and programmable (CCW)
Swivelling around axis C	± 360 °
Collet chuck	DIN 6499 ER25
Gripping range	1÷16 mm
Spring chuck Ø standard	10 mm
Tool Ø max.	16 mm
Tool's max. length	80 mm
Tool's length (prolongation)	max. 50 mm

3 Applications Achieved with the Homag Automatic Wood Processing Machine

3.1 Cutting-Out after a Polygonal Contour of a PAL Board Using the WoodWOP Program

Must be available a rough board for processing at dimensions at least equal with the ones of the part that follows to be executed. The steps to achieve the cutting-out are the following [6]:
- Achieving the drawing of a plane part in a graphic program (i.e. AutoCad). The file will be saved with the extension dxf;
- the obtained dxf file is processed in the Converter module of the woodWOP program and then transformed into a file with the extension mpr;
- this file is introduced in the machine by the floppy or CD-ROM unit;
- after making the base settings from the machine's control console, the numerical control processing centre will select the adequate tool and will execute the desired milling following the set of variables generated by the program;
- can be made the checking of the program's corectness by projecting a laser fascicle on the unprocessed board representing the part's final contour.

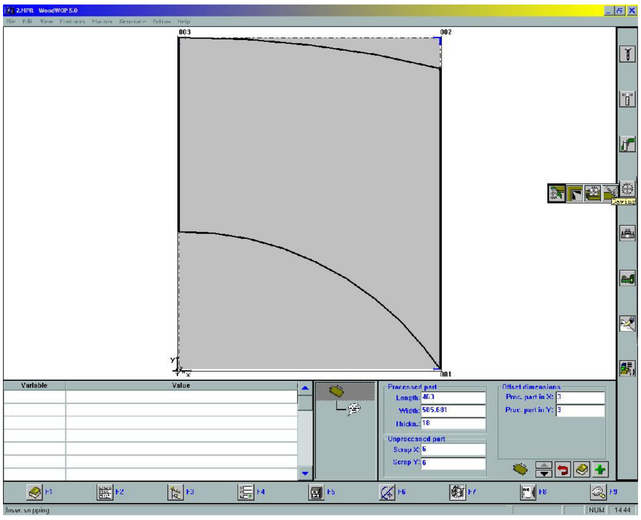


Fig.6. The woodWOP main window. Defining the processing parameters

3.2 Performing of Some Operations Succession to Achieve a Window Using the Klaes Specialised Program

In the program's main window are introduced keyboard, main information concerning the size dimensions, interior dimensions, constructive shape, type of used wood profiles (fig.7).

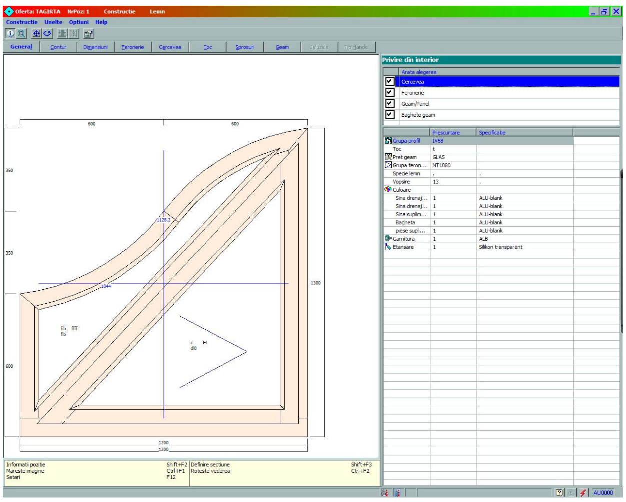


Fig.7. The Klaes main screen. Introduction of main data

In the next sequence. the program generates the dimensions of all rough components necessary to be fixed and processed, as well as the permitted tolerances for these. Also, is specified the types of interior and exterior millings (fig.8).

Depending on the used wood esence, which was previously introduced in the first program sequence, Klaes establishes de forwarding advance of the automatic machine, as well as the speeds of the processign tools.

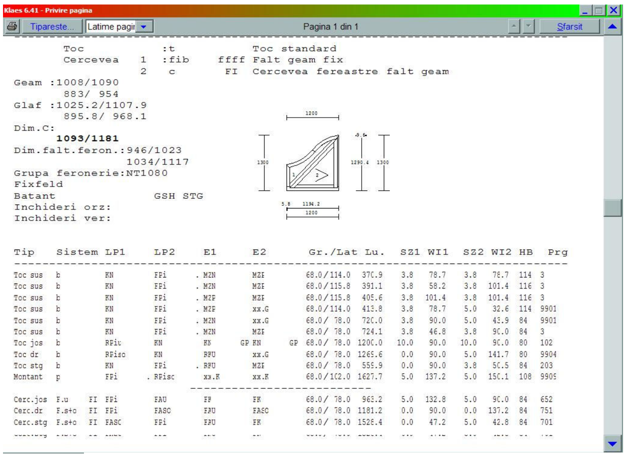


Fig.8. Second sequence of the working parameter calculation

The milling type codes are sent encoded, being decoded by the machine in such way that the tool changer will select the adequate type of mill necessary for the required milling type.

3.3 3D-Modeling of a Support Base Using the Sprut-CAM Program and NC-Tunner Module

Is desired the stepped milling of complex shape, respectively a support base by MDF. For this, is necessary to pass through some standard steps, as follows:

- achieving in a vectorial graphic program (Autocad) the 3D model associated to the desired part. This will be saved with the extension dxf which is accepted by Sprut-CAM;
- the drawing achieved as above is imported in the program Sprut-CAM (fig.9);
- here can be achieved realistic simulations, being able to monitor the mill's trajectory along the part's contour;
- is generated the set of variables depending on which will be executed the processing by the machine;
- the program achieved this way is introduced in the machine, in such way that, after verifying the correct positioning, can be given the start command.

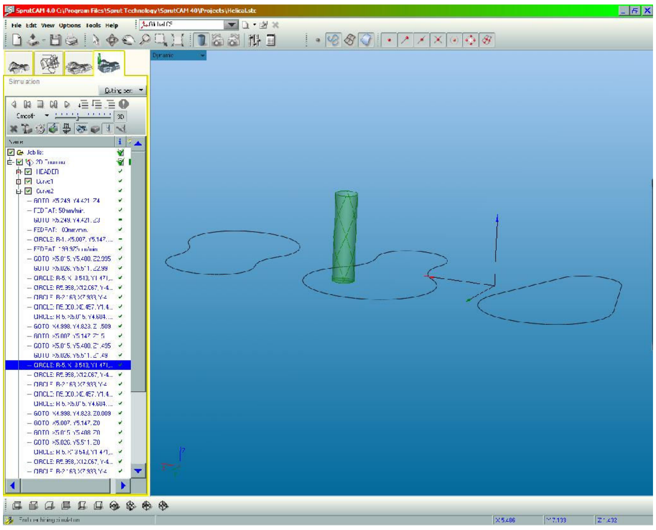


Fig.9. Presenting the milling trajectory and the list of variabled in Sprut-CAM

4 Control of a Stepping Motor

4.1. Construction and Operations

For precise tool positioning, at the automatic machines are used stepping motors. At these motors, the rotor couple's achievement is made by the impulses applied upon the stator's coils. Constructively, the stepping motor is achieved with permanent magnets or with variable reluctance. The difference between a variable reluctance stepping motor and one with permanent magnets is that the rotor and stator are made of ferromagnetic material and has a lower number of stator poles (and on which coils are mounted).

Thus, is obtained an extremely precise movement of the rotor by applying of some rectangular-shape voltage impulses. At small rotational speeds, these motors develop a great couple. They have the disadvantage that once with the speed increase, at the same supply voltage as for small speeds, the couple decreases very much due to impedances.

Stepping motors development has been made by its robust and simple mechanical structure. This machine is capable of high torque density and it does not have a sinusoidal winding structure. The windings are in the stator. The structure and concentrated windings lead to torque pulsations and noise problems. This type of machine are base on the principle that a magnet attracts a piece of iron. The structure of the stepping motors is like a solenoid that has been arranged to produce rotary motion.

The conservation of energy equation for a machine is:

$$E_{ei} = E_{lo} + E_{st} + E_{mec} \tag{1}$$

Where E_{ei} – electrical energy input; E_{lo} – electrical losses; E_{st} – stored energy in fields; E_{mec} – mechanical energy.

The average torque T_{ave} realizing by the movement of the rotor has been through an angle $\Delta\theta$:

$$T_{ave} = \frac{E_{mec}}{\Delta\theta} \tag{2}$$

(2) has been derived under the assumption that the movement of the rotor was slow [8,9,10].

Step motors are different for DC motors, such as structure, and in terms of power supply / control. To make a complete revolution, step motors must perform a sequence of steps of a few degrees each. To supply them properly with DC and / or control them (the rotation) with "one step" or more, the internal structure of the motor must be known. The writing on the step motor's case indicates (in most cases) the number of steps necessary to make a complete revolution. For example a motor with 200 steps per revolution has step increments of 1.8 °, a motor with 400 steps per revolution has a resolution of 0.9 ° / step and a motor of 48 steps, 7.5 ° / step.

To obtain the number of steps for one revolution it is sufficient to divide the 360 degrees of a circle by the angle for one step as indicated on the motor's plate. If we denote the number of steps with Np, then the angular displacement is:

$$\alpha = \frac{360°}{N_p} \tag{3}$$

Example: If the number of steps is 400, then the angular displacement is:

$$\alpha = \frac{360°}{400} = 0.9°$$

The stepped motors are classified in unipolar and bipolar motors (with more complex control). At unipolar motors, with two, four or more coils, one end of the coils is connected to the positive or negative terminal, and the other end is connected through a transistor to the other terminal. There are three control modes of the unipolar motors: mono-phase, bi-phase, and semi-pulse. These controls are found also at the control of bipolar motors. If the motor has four coils, for the motor's control are used four transistors.

In principle, there are three possibilities of supply for the stepped motors:

- supply from a source of increased voltage in series with a resistor of ballast that limits the current through stator;
- supplying of the coils from a source in commutation of high voltage in such way to obtain a

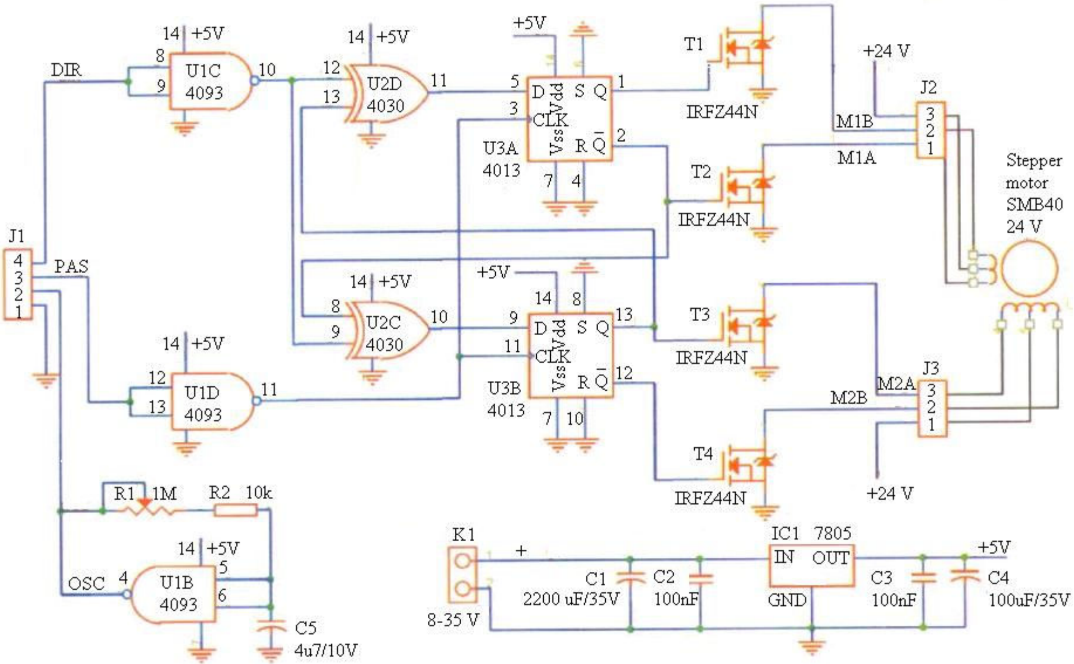


Fig.10. Electronic control circuit for stepped motor

great couple at high rotor speeds;

- supplying of the coils through a constant current source, that will maintain the current through coils at the same value regardless the rotor's speed. Once with the rotor speed's increase, the applied voltage is higher and higher. This is the most suitable solution in supplying of stepped motors.

4.2. Control of an Unipolar Stepper Motor

In fig.10 is presented the electronic control diagram for a motor type SMB40-9602-A Japan (fig.11), supply voltage 24 V, resistance of one coil 130Ω [11,12]. The motor's control is unipolar.

The circuit from fig.10 contains an oscillator achieved with U1B, the frequency modification can be made from R_1. At connector J_1 the pin from the oscillator is connected to PAS, and the modification of the rotation sense can be made from DIR (connected to mass or to +5V). The circuit can be connected (at PAS and DIR) to a development board with microcontroller or PC, for this to be interconnected into more complex equipment.

The logical gates OR-EXCLUSIVE (U2D and U2C) are used to achieve the reversal of the outputs Q and /Q of the flip-flop circuits (U3A and U3B). The power elements are transistors with field effect that can be controlled directly by the flip-flops' outputs.

The integrated circuits and signals from exterior are of 5V, for stabilizing the voltage there is IC1 (7805). Supplying of the coils, connected by module through J_2 and J_3 can be done between 8 and 24 V; the higher the voltage, the higher is the couple obtained.

The circuit was achieved experimentally and were made measurements with the 2-channel digital oscilloscope RIGOL DS 5022M.

Experiments were made with the coils supplied to a voltage of 15 V. At 15V, the current absorbed by the circuit as idle is of 0.22 A, and on-load of 0.24 A.

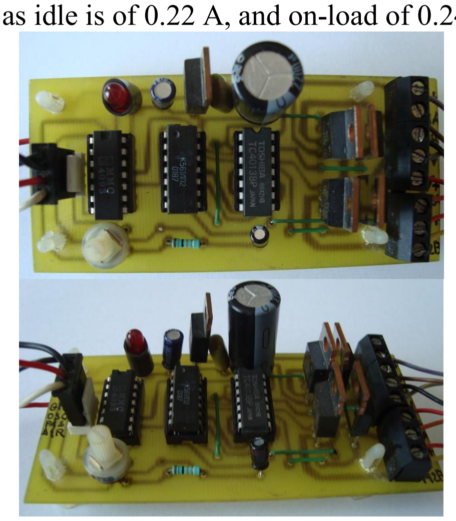
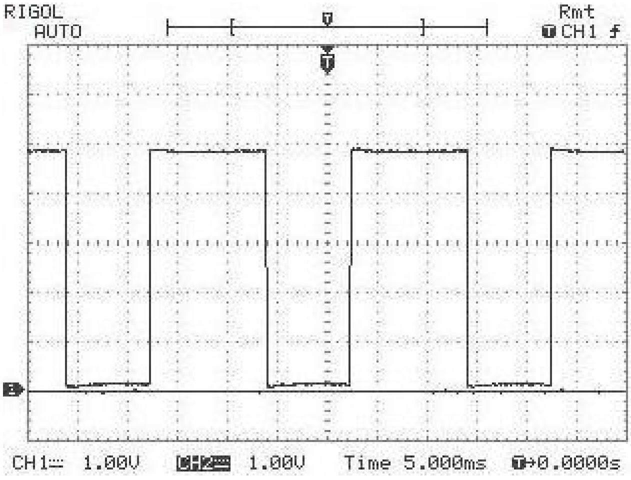
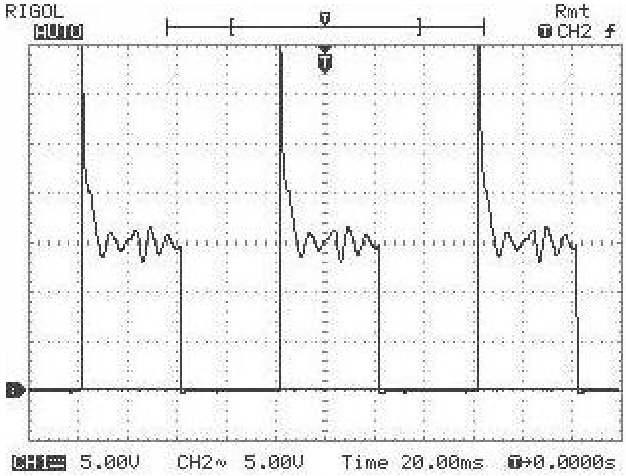


Fig.11. Unipolar stepping motor SMB40-9602-A

Fig.12. Experimental setup of electronic control for stepping motor



a.



b.

Fig.13. a. Signal from oscillator (U1B 4093);
b. signal between M1A and mass (on transistor T_2)

The signal generated by the oscillator, fig.13.a, can be modified by the potentiometer R_1 from fig.10. The signal between the drain and source to a transistor, fig.13.b, shows the resistive-inductive character of the load with a dumped oscillating regime.

In fig.14, 15.a and 16.a the signals are decreased 10 times in amplitude. It was used the internal divider from the oscilloscope's testers.

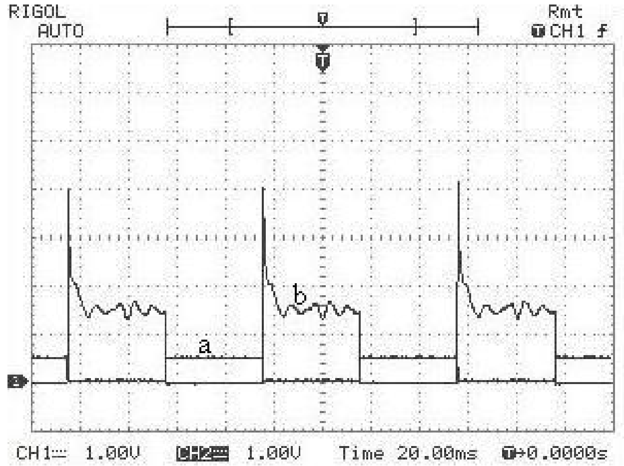
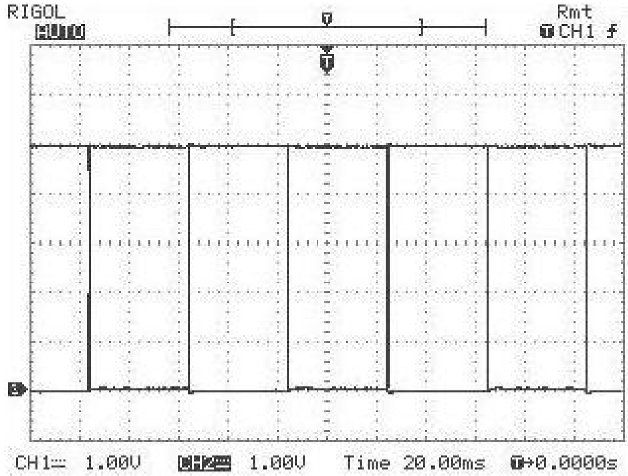
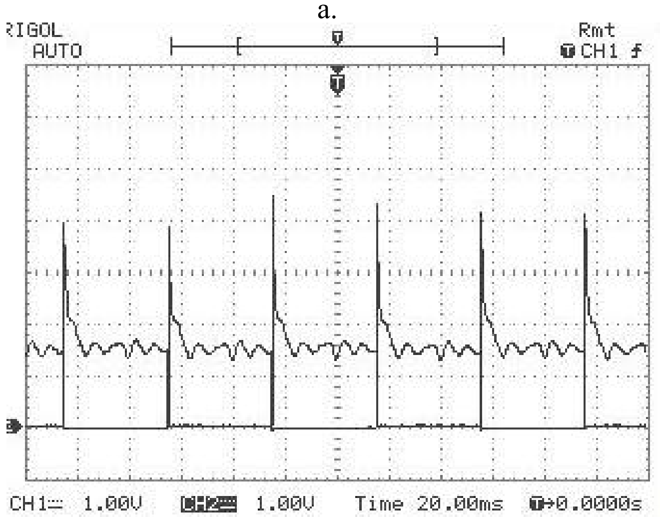


Fig.14. Signals on transistor T_1: a. Signal between grid-source; b. Signal between drain-source

The two signals from fig.14 are anti-phased. When signal between the grid and the source is 1 logic, between the drain and source is 0 logic, and reverse.

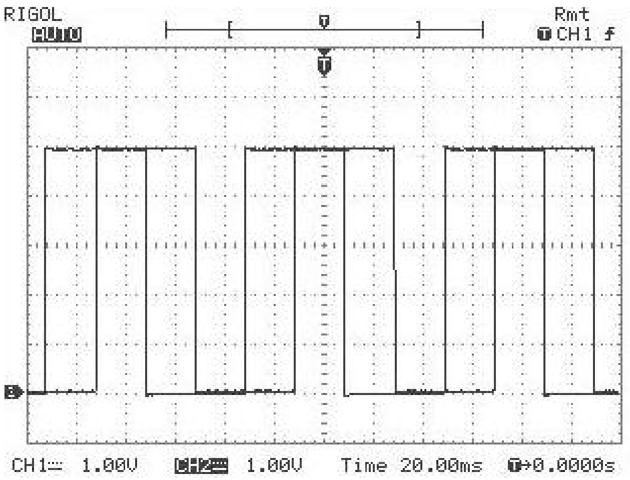


a.

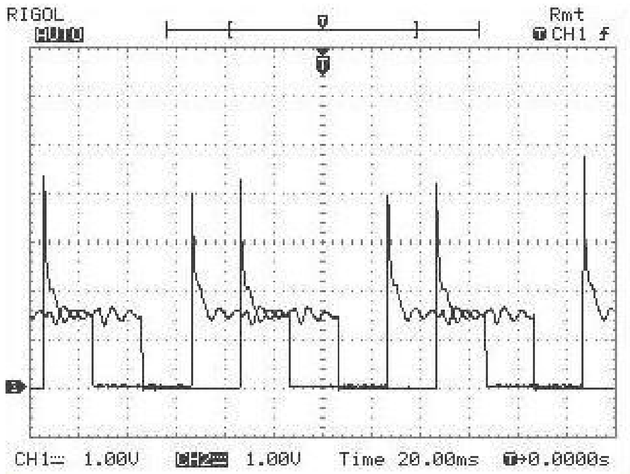


b.

Fig.15. Signals on transistors T_1 and T_2: Signal between grid-source; b. Signal between drain-source



a.



b.

Fig.16. Signals on transistors T_2 and T_3: a. Signal between grid-source; b. Signal between drain-source

At passing in blocking state of transistors, the voltages between drain-source are of approximately 2.25-3 times higher than the supply voltage.

Signals from fig. 15 prove the operation mode for two serial coils (same group): when a coil is supplied with a voltage, through the other is not going current and reverse. Signals from the two coils (M1A and M1B) are in anti-phase. There are no dead times at controlling of two coils from the same group.

In fig.16 were made measurements for two different coils (different groups) M1A and M2A. The control signals, fig.10.a are applied in quadrature (dephased at 90^0). Signals from the two control transistors (fig.10.b) are dephased by 90^0 electric. The power loss at these motors is important, the operation temperature being high. Should be mounted radiators for dissipating the heat.

Regarding loss of power, particularly due to thermal effects, which are important for step motors, the following observations were made: at very low rotation speeds (low-frequency control) the motor develops high torque at the drive shaft. If step motors are supplied from a fixed voltage source (stabilized) at low frequency there are no specific problems. However if the control frequency increases (rotation speed increases) the torque decreases significantly due to the high impedance of the coils.

5 Conclusions

The continuous increasing needs made necessary the equipments' perfectioning.

Using of static converters in motors' supply makes the last to benefit of the optimal operation regimes without being overstressed under load.

When implementing a new processing device on the machine, from mechanical viewpoint it should be compatible in the gripping system and able to work at maximum drive spindle's speed. From electric viewpoint, the tool should be configurated from software, in such way to be selected from changer when the technical process requires it. Being completely automated, only one person is necessary for operating the machine.

The stepping motors are frequently used in applications where is needed precise positioning and adjustment. The motors' intelligent control can diminish the thermal loss, especially at small rotor speeds. Bipolar supply is recommended due to achievement of high couples at spindle.

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