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Development of Microcomputers and Motor Control Software for Steel Pipe Cutting Units

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Abstract. This paper designs the system for automatic regulation of the flying cut-off device for the moving pipe. For the main drive, there are introduced the direct-current motor, reductor, gear and gear-lathe, which is rigidly connected with cut-off device. The speed is regulated by the three-phase thyristor regulator which supplies the DC motor. For the process automation, a microcomputer is designed. On the basis of the projected hardware microcomputer, a software support is offered. The task for the newly projected system is to ensure improved accuracy of the cutting and increase the automation level.

Key-words: hardware, length, microcomputer, motor, pipe, regulation, software, speed.

1. Introduction

The process of development of steel pipes is conducted on technology lines for welding and production. Development starts in line for cutting where steel reels are dissected by length to desired steel stripes whose width is adequate to volume or diameter of pipe. Steel stripes developed in such way are formed using forming rollers. The next step is high-frequency welding using inductive method of energy transfer include in radiofrequency scope.

Furthermore, welded pipes are transported through the zone of weld normalization in order to reach calibrating section where fine processing of steel pipe geometry is conducted. It can be concluded that the production of steel pipes is a continuous process in which the drive is provided using DC motors which are regulated through thyristor regulators of speed. Final conclusion of the process of pipe development is provided in the cutting system while moving on a flying saw.

First installed cutting system included hydraulic components and appropriate mechanical equipment [1–5] and control classic electronics [6–8]. Cutting of steel pipes is conducted in a way to raw connect cutting tool with a long hydraulic cylinder, whose translation is managed by changing of flow of fluid in the cylinder. As a result, there is an analogue speed of the cutting tool unit, named as flying saw. The cutting moment is generated through activation of service-valve and service-pump with changeable flow for powering of final unit of the hydraulic cylinder.

Functioning of moving dissection system included working cycle. Cycle includes accelerating, synchronization with speed of the product, cutting and returning of cutting tool into starting position, after which the new working cycle starts through the new command. Dissection needs synchronization of speed of saw vehicle and steel pipe, when there is a condition for cutting in appropriate angle and to exact lengths. Accuracy of pipes lengths, selected using thumb switches, depending on pre-starting time. This time is needed for generation of the command for start before cancellation of counter, so that at the moment of synchronization, the speed, cutting tool realized by friction saw can be exactly above theoretical point of cutting.

Cutting of moving steel pipes was analyzed and described in numerous works [1–8]. This paper used experiences from [9–16]. The main objective is to increase quality of cutting where dissection angle enters including selected length of a pipe. Development of systems of this kind improved productivity in production of steel pipes. It is worth to mention that the process of production of steel pipes is considered as one of the most massive production lines in the world. The existing cutting system included lacks such as inaccuracy of early start, nonlinearity of frequency voltage convertor and work of a system in opened system.

Management of translation of a cutting tool was solved using service valve and appropriate service pump. There were often stops due to problem of development of impurity in working fluid, which directly decreased the productivity. There is also a problem of different modes regarding temperature which caused inefficient work and stops during production.

Due to mentioned reasons, design of the new system of automatic control is included in order to improve work and increase productivity. Instead of electronics realized using discrete components and integrated components of low level of integration, designing of microcomputer based on microprocessor is involved according to [17–21], and experience from [22–30]. The old solution with service-valve, service-pump and hydraulic cylinder is replaced by DC motor with separated start.

Due to major delays due to the application of hydraulic executive bodies, there was a decrease in production productivity and a reduced percentage of the first class of final steel pipes. This led to a decrease in net income. Following similar systems in the world, similar conclusions were reached. That is why the authors of this paper came up with the idea of removing the servo pump with the appropriate servo valve and the hydraulic cylinder from the cutting system. In place of these, a new executive body, a DC motor, a reducer and a toothed rack with an associated thyristor speed regulator, is designed and introduced. All this resulted from the practice of using such plants throughout the steel pipe manufacturing plant. In addition, the authors, through applied research in this field, had their own developed and patented speed regulators, which made it easier to complete such a new system. Classic electronics were replaced by a newly designed computer, so that the new control system performs adaptive control by cutting pipes on the old friction cutting system.

2. Investigation to Introduction of DC Motor for the Cutting of Steel Pipes

DC motors with separated start can be regulated by speed in two ways, according to [25]. One of regimes is that the speed is changed from zero to nominal value of ω_n by changing of voltage of rotor from zero to its nominal value. During the time, start and motor flux are kept constant. Increasing of motor speed and delivered rotor voltage, the power of engine is also increased while keeping the engine moment constant.

The second way for changing of speed of motor above the nominal value is that the start of motor decreased and the voltage of rotor is kept nearly constant. Two mentioned modes are presented in Figure 1. Regarding the scope of speed from zero to ω_n, moment of engine is constant, while above this speed to its maximum value, moment is constant. During design and development of such types of regulations, the attention must be kept for keeping the start value equal to nominal value because otherwise, the device can receive large speed.

Powering of motor- rotor is conducted through three-phase full-control thyristor bridges, while start included single-phase control. The problem of speed regulation for DC motors was mostly solved in a conventional way by using known solutions of discrete electronic components and linear integrated circuits used for regulation of needed regulators. Involvement of microprocessors developed conditions for design of microcomputers for regulation of motor speed. Such systems were mostly realized to regulate speed by changing of rotor voltage.

Due to need and according to the experience from [14–30], design of microcomputers developed for real-time work, in order to regulate speed of motor DC from zero to maximum value in two mentioned regimes. Measurement of speed will be conducted by optical encoder with needed resolution. Included microcomputer, in function of disturbance and according to given algorithm will generate needed management. The aim of introduction of such type of regulation is application of larger level of automatization while improving performances of regulated measures.

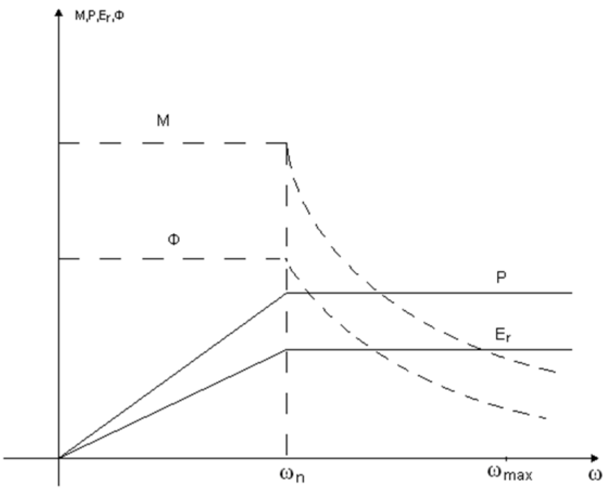

Fig. 1. Graphics of characteristic sizes of motor DC for two types of speed regulations.

Equations of separately excited DC motor are

$$e_r = i_r R_r + L_r \frac{di_r}{dt} + k_e i_p \omega \tag{1}$$

$$k_m i_p i_r = M_t + J \frac{d\omega}{dt} \tag{2}$$

$$e_p = i_p R_p + L_p \frac{di_p}{dt} \tag{3}$$

where:

e_r – rotor voltage, i_r – rotor current, L_r – inductivity of rotor, k_e – engine constant, i_p – excitation current, ω – speed of rotor, M_t – moment of load, k_m – constant, e_p – excitation voltage of start, R_p – resistance of start winding, J – moment of inertia and L_p – inductivity of excitation winding.

Equations (1), (2) and (3) are nonlinear differential equations. Since the analysis is conducted near stationary point with small deviations, linearization can be conducted. Elimination of certain features in (1), (2) and (3), after solving and finding of Laplace transform provides dependency of speed as function of rotor voltage expressed as

$$\omega = E_r \frac{\frac{1}{k_e}}{s^2 T_r T_m + s T_m + 1} - M_t \frac{R_r}{k_e k_m} \frac{1}{s^2 T_r T_m + s T_m + 1} \tag{4}$$

where: $T_r = \frac{L_r}{R_r}$ – electrical time constant and $T_m = \frac{J R_r}{k_e k_m}$ – electromechanical time constant of DC motor. Assuming that the moment of load is constant, (4) provides transfer function

$$W_1(s) = \frac{\Omega}{E_r} = \frac{\frac{1}{k_e}}{s^2 T_r T_m + s T_m + 1} \tag{5}$$

or

$$W_1(s) = \frac{\frac{\omega_n^2}{k_e}}{s^2 + 2\xi \omega_n s + \omega_n^2} \tag{6}$$

where $\omega_n = \frac{1}{\sqrt{T_r T_m}}$ is natural frequency, and $\xi = \frac{1}{2}\sqrt{\frac{T_m}{T_r}}$ is relative coefficient of damping.

For increasing of motor DC speed above nominal value, it is needed to decrease voltage of start of device. Starting with (1), (2) and (3), and considering rotor inductivity as negligible feature, and since the drop of voltage on rotor resistance significantly less than contraelectromotor force of motor, it is considered as transfer function

$$W_2(s) = \frac{\Omega}{E_p} = -\frac{\frac{\Omega_o}{E_{po}}}{(1 + sT_p)(1 + sT_{mo})} \tag{7}$$

where $T_p = L_p/R_p$ is time constant in excitation circuit, a $T_m = \frac{J R_r}{k_e k_m}$ is time constant of rotor circuit. Index “o” marks values in stationary condition.

The transfer function in (7) includes the “–” mark since the decreasing of start voltage increases the rotating speed. It can be concluded by comparing of (6) and (7) that the control of start voltage changes reaction more slowly, but it is provided using less power. These two types of speed regulation must be respected depending on process which is regulated or mode of work of a machine. The most significant effects can be achieved by combining of these two types of regulation, which is provided in this paper.

Regulation of speed of DC motor is provided using three-phase fully controllable thyristor regulator. Due to change in direction, there is a double, antiparallel, thyristor bridge. Device shaft is connected by reductor whose output continues to gear which moves gear lath that is rigidly bounded to the entire unit for flying dissection. Measurement of the motor speed provides the introduction of feedback coupling. All of these elements have to control the motor speed in adaptive way regarding the speed of the product.

3. Designing of the New System for Cutting of Steel Pipes

In order to improve cutting process on technology lines for production of steel pipes, there is a new system of automatic control as it is given in Fig. 2. The power of cutting tool uses gear lath, gear, reductor and DC motor. Gear lath is rigidly bounded to cutting tool so they are moving forward and backward. The DC motor is empowered by antiparallel three-phase thyristor speed controller.

The position of cutting tool is indicated by limitless contactless switches D_1, D_2, D_3 and D_4. The speed of cutting tool must be directly proportional with the speed of motor and it is measured by tachogenerator. The speed of the pipe which should be dissected is measured by optical generator of impulses. The length of product is measured by counting of impulses from optical generator of impulses while it is adopted to make proportion: one impulse – 1mm of the length of pipe.

The suggested microcomputer is connected with the process over I/O units, D/A and A/D converters. The selection of desired length of the pipe for dissection is provided by decades/ using BCD selectors which are located on the control board. The current length is presented on display of length located on the control board. The process is automatized so the algorithm can be conducted by program. Microcomputer emits the default length for cutting, measures the length and speed of product and uses program to execute commands to executive elements. Synchronization of speed of cutting tool and product can be provided by measuring of speed of device. Using comparison with the speed of product, it generated needed control to the thyristor speed controller.

Working cycle starts by accelerating to the reference value, after which cutting completes, the system stops and the cutting tool returns to the starting position. Feedback speed can be chosen using potentiometer as the same as minimum speed. In that way, the pressure for holding the entire construction on shields is provided.

After a deep analysis, it has been decided to use a DC motor type SEVER OIM 250 M 1s whose characteristics are:

- nominal rotor voltage $U_r = 400\ V$,
- rated power $P_n = 80\ kW$,
- rated rotor current $I_r = 217\ A$,
- excitation voltage - stator $U_p = 200\ V$,
- excitation current of stator $I_p = 2.8\ A$, (8)
- nominal speed $n_n = 1560\ rpm$,
- rotor resistance $R_r = 0.11\ Ohm$,
- rotor inductance $L_r = 2.7\ mH$ and
- moment of inertia $J_m = 1.15\ kgm^2$.

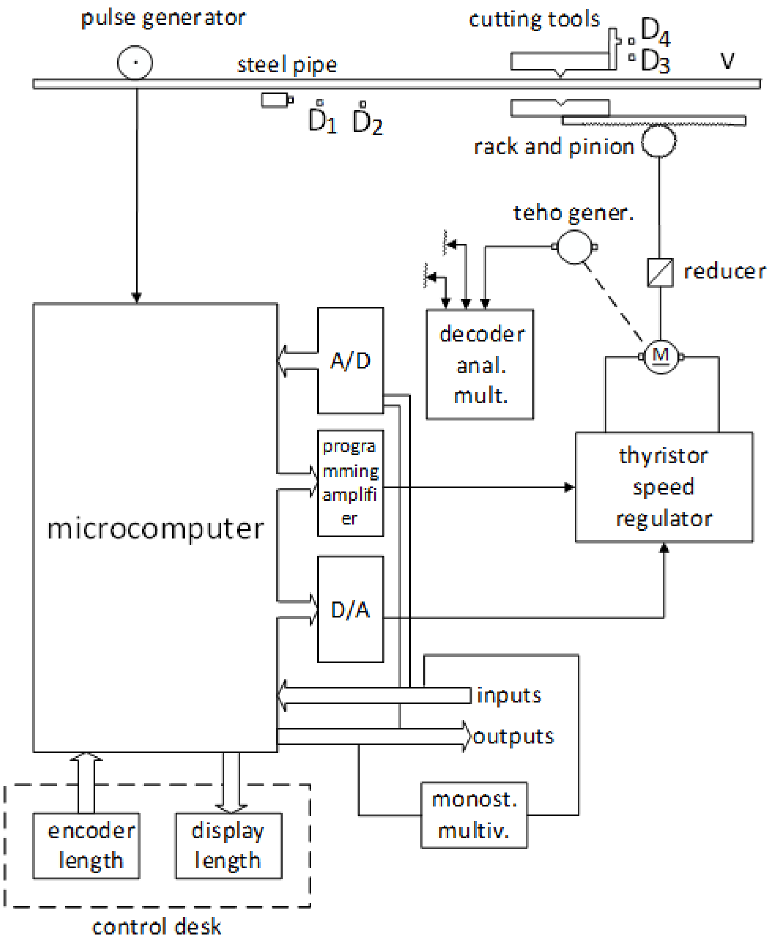

Fig. 2. Block schema of the new system for automatic control on dissection of steel pipes.

The reductor type SEVER Z82 is selected for the reduction of speed. Its features are:

$$\begin{aligned}&\text{gear ratio i = 12.39,}\\&\text{torque M = 4200 N m,}\\&\text{moment of inertia } \mathrm{J_r} = 0.16 \text{ kg m}^2.\end{aligned} \tag{9}$$

In case of selecting the maximum speed of cutting tool of 100 m/min, the calculation provides the value of diameter of the gear:

$$r = 13.27cm. \tag{10}$$

According to technical data, the mass of cutting tool is 2500 kg. In that way, the inertia moment of load has the value of

$$J_t = 43.7kgm^2. \tag{11}$$

Calculation of the inertia moment of the load provides

$$J_0 = \frac{J_t}{i^2} = 0.2846. \tag{12}$$

Calculation for the resistance moment of the load leads to

$$M = 70.88Nm. \tag{13}$$

The change of known values provides the value of the moment of DC motor

$$M_m = k_m I_r = 2.26 \times 217 = 490Nm. \tag{14}$$

Regarding moments, selected device is adequate and the process will include the acceleration moment, while motor works in that regime:

$$M_u = 419Nm. \tag{15}$$

The total moment of inertia is equal to the sum of calculated moment of inertia of the load to the motor shaft, moments of inertia of the engine and reductors:

$$J = J_m + J_0 + J_r = 1.56kgm^2. \tag{16}$$

In order to determine the transfer function of the DC motor, it is important to calculate constants of the motor. Electrical constant of the motor is

$$T_r = L_r / R_r = 24.54ms. \tag{17}$$

According to known facts, following constants can be provided:

$$k_e = 2.3 \frac{Vs}{rad}, \tag{18}$$

$$k_m = \frac{M_m}{I_r} = 2.26Nm/A. \tag{19}$$

Regarding DC motor, and including acceleration with the load, the limiting factor is the current of the rotor. The relation for the current is known, which can be provided by elementary transformations expressed as

$$I_r(s) = U_r(s)\frac{sT_m}{R_r(s^2T_rT_m + sT_m + 1)} + \frac{M_t}{k_m(s^2T_rT_m + sT_m + 1)}, \tag{20}$$

where I_r – current of rotor, U_r – voltage of rotor, and M_t – moment of load.

If the voltage U_r at $t = 0$ changes by bounce function, the idle mode will provide the expression in ”s” domain, which after elementary transformations leads to the expression

$$I_r(s) = \frac{400}{s}\frac{sT_m}{R_r(s^2T_rT_m + sT_m + 1)}. \tag{21}$$

and after elementary transformations it leads to the expression

$$I_r(s) = \frac{400T_m}{R_r}\frac{1}{(s^2T_rT_m + sT_m + 1)}. \tag{22}$$

The time form for the current in ”t” domain is provided by finding the inverse Laplace transformation of the expression (22), which after change of known values for this example provides

$$i_r(t) = 130236.28e^{-20.373t}\sin 0.614836t. \tag{23}$$

For purpose of estimation in forming of control for the DC motor, the graphical presentation of analytical expression for the current in idle mode for the motor will be provided (23). The form of this graphics is presented in the Fig. 3. According to this figure, the abscissa in which one division presents the time t of 10 ms and ordinate is the current $i_r(t)$ in A. According to presented graphics, it can be concluded that the maximum current of the rotor in value of 1450 A can be reached even in the idle mode. Such value of the current would include additional costs for so strong thyristor bridges and other protective equipment which is used in energy electronics. The current is larger 6.7 times than nominal current of the motor DC. Due to this fact, some more optimal and acceptable control should be examined.

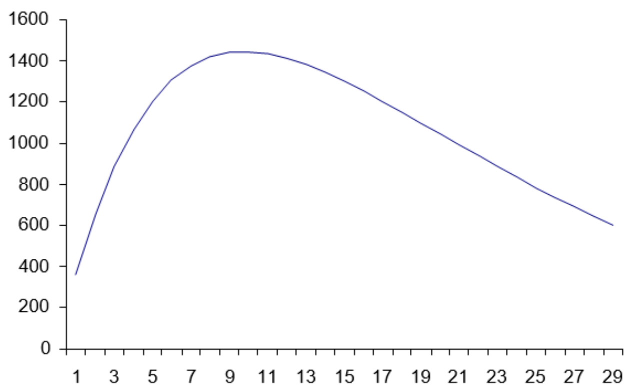

Fig. 3. Graphical presentation of the current of the rotor in the idle mode near bounce entrance (axes abscissa is time $t \times 10^{-1}$ in [ms] and ordinate current i_r in[A]).

Using experience from the literature [16, 25], which used experiments for the control in hydraulic executive elements, there is an introduction of the control of voltage of the rotor in a way to instead of bounce entrance use the tilting character entrance. The expression for the voltage of the tilting character in the time domain is

$$u_r(t) = \frac{400}{\tau} tU(t) - \frac{400}{\tau}(t-\tau)U(t-\tau), \tag{24}$$

The transfer into "s" domain makes the expression (24) as

$$U_r(s) = \frac{400}{\tau s^2}[1 - exp(-\tau s)]. \tag{25}$$

which after change into (21) provides the expression for the current of the device rotor

$$I_r(s) = \frac{400}{\tau s^2}[1 - exp(-\tau s)]\frac{sT_m}{R_r(s^2 T_r T_m + sT_m + 1)}. \tag{26}$$

The solving of expressions and change of known values, including finding of inverse Laplace transform, the current of rotor in the time domain is provided as

$$i_r(t) = i_r^{,}(t) + i_r^{,}(t-\tau), \tag{27}$$

where

$$i_r^{,}(t) = 200[1 - 1.2319\text{exp}(-20.52t)\text{sin}(28.52\text{t+0.95})]. \tag{28}$$

In this case, we examined two types of tilting for control. Fig. 4 gives the graphical representation of the rotor current with the tilting of 0.3 s.

In that way, the nominal voltage can be reached in 0.3 s, while providing the graphic with the maximum value of 210 A, which is significantly less than in case of control with the bounce entrance. It means that this solution is possible for application. Further research applied tilting entrance where needed entrance voltage is reached in 0.6 s, for which the graphics is given in Fig. 5, but with more or less maximum value of total of 177 A.

This control is satisfying from the aspect of maximum current and the point that this time period can be integrated into entire working cycle of cutting of the steel pipe starting from idle mode to maximum speed. The most limiting factor in such lines is speed of welding or even correction of mechanical deformations of the pipe. Also, quality of the steel material is important, regardless the thickness of the steel stripe, and such welding is mostly planned for welding of low-carbon steel.

Since the control of tilting character is adopted in this paper, it is important to find the analytical form of speed of motor rotation. In that way, the change for the new form of control provides the expression for the speed in the "s" domain

$$\omega_r(s) = \frac{\omega_n^2}{s^2(s^2 + 2\vartheta\omega_n s + \omega_n^2)}, \tag{29}$$

and this form is not included in a table, so it has to be divided as follows:

$$\frac{\omega_n^2}{s^2(s^2 + 2\vartheta\omega_n s + \omega_n^2)} = \frac{A_0}{s^2} + \frac{A_1}{s} + \frac{A_2 s + A_3}{(s^2 + 2\vartheta\omega_n s + \omega_n^2)}. \tag{30}$$

Placing of the system of equations and its solving provides following coefficients:

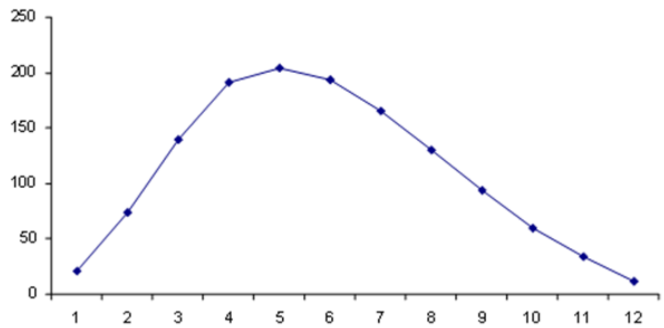

Fig. 4. Graphic of the rotor current in idle mode for control of the tilting character (axes abscissa is time $t \times 10^{-1}$ in [ms] and ordinate current i_r in[A]).

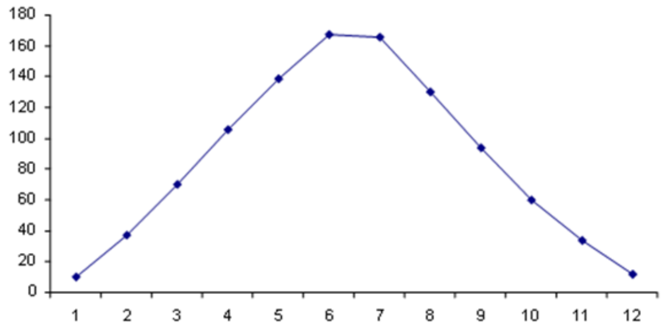

Fig. 5. Graphic of the current of the rotor in idle mode for the control of tilting character (axes abscissa is time $t \times 10^{-1}$ in [ms] and ordinate current i_r in[A]).

$$A_0 = 1, A_1 = -\frac{2\vartheta}{\omega_n}, A_2 = \frac{2\vartheta}{\omega_n}, A_3 = 4\vartheta^2 - 1. \tag{31}$$

Finding the inverse Laplace transform of the expression (30), with change from (31), and after change of known values, leads to the expression for the speed of the device:

$$\omega(t) = t - 0.0332 + e^{-20.5t}[0.0408775 \cos(28.5t + 0.623) + 0.00036 \sin 28.5t]. \tag{32}$$

Analysis of the analytical expression for speed and experiences [16], when the entrance voltage of rotor has tilting character, it is concluded that the speed follows the entrance and that it has the tilting character. It will provide smaller skip in the response which will extend the lifetime of the plant, decrease cases of accidents and increase the accuracy of dissected lengths of steel pipes. In order to get the line speed, the expression (32) is multiplied with the constant which depends on applied agitation and transfer relationships in mechanical form of the system for flying cutting of the pipe.

The pipe cutting system retains the executive body for friction cutting of steel pipes. It is an assembly that has a three-phase motor that rotates the circular saw through a specific transmission. That saw, when it receives the cutting command, descends at a right angle and by developing a high temperature it squeezes the material out of the tube and thus cuts it. The new system given in this paper must behave adaptively in relation to the production speed. The derivation of analytical expressions for the DC motor made it possible to created conditions for fine adjustment by the movement of the saw carriage. In this way, the speed of the saw carriage is optimally adjusted, which results in an improvement in cutting accuracy. The block diagram of the computer system describes which parameters are set at the time of starting the work process. This is called system initialization, where it further communicates via peripherals with other relevant parameters. For urgent needs, an interrupt system is used to activate certain subroutines. Description and better understanding are provided in [16].

Since electronic thyristor regulators work in the regime of current limitation due to protection of the motor and thyristors, it can be approximatively used for estimation that the speed is linear in time in terms of the expression

$$n = \frac{30M_u t}{3.14159J}, \tag{33}$$

which after calculation provides the time of flight till the maximum speed is achieved:

$$t = 665ms. \tag{34}$$

Since the time of flight is less than the time of the response while using the hydraulic service system, it can be concluded that the selected motor is adequate to this purpose. Additional explanations on control will be provided after conception and design of microcomputers and appropriate software.

When referring to stability, it is clarified that the newly introduced thyristor motor speed regulator has two regulation loops. The inner loop is a current loop and the outer is a speed control loop. Both loops have integrated PID regulators that stabilize the operation of this system. It is not excluded that the same system installed in different environments does not give the same results. This means that in one case the system is stable and in the other oscillatory unstable. In addition to theoretical contributions, the authors of this paper have developed many engine speed regulators, where some solutions have been patented, most of which have been used many years in practice. However, a complete explanation and presentation of those solutions are out of the scope of this paper.

4. Contribution to Microcomputers Design

In order to automatize system for cutting in moving, the microcomputer will be projected. Newly projected system with the computer is presented in Fig. 6. Using entrance data, the microcomputer via program generated command signals while automatically controlling the process of cutting. The algorithm of the work of the system is presented in Fig. 7. The working scheme of the system will be described with the initialization of the system. After that, the default length of the pipe for dissection will be read. For the one-time interval, defined by duration of the quasistable multivibrator period of multivibrators, impulses of the optical generator are calculated. Their result represents the speed of the product. The length is calculated by counting impulses with the use of the breakdowns system.

According to data on speed, the current limitation and the time of premature are calculated. After that, there is an examination that there was a coincidence. Regarding case of premature the loop will be left by extraction of the output for the current limit. After this step, the output control for the 1 quant will be increased. The algorithm is continued by sending output for the analogue multiplexor and for the initiating of the conversion of A/D converters. Investigating of the condition of A/D converters, if the option "data valid" is on a high level, the loop will not be left. Otherwise, the output will be readed. The A/D output of the converter presented the speed of the motor.

After that, there is an investigation if the speed of the product (pipe) is reached. If that is not the case, the loop will not be left, otherwise the algorithm continues. The next program step is sending output for cutting of the pipe. After completion of the cutting, the tool for tightening and dissection will increase to upper position. The increasing to the upper position will stop when the detector D_4 is activated.

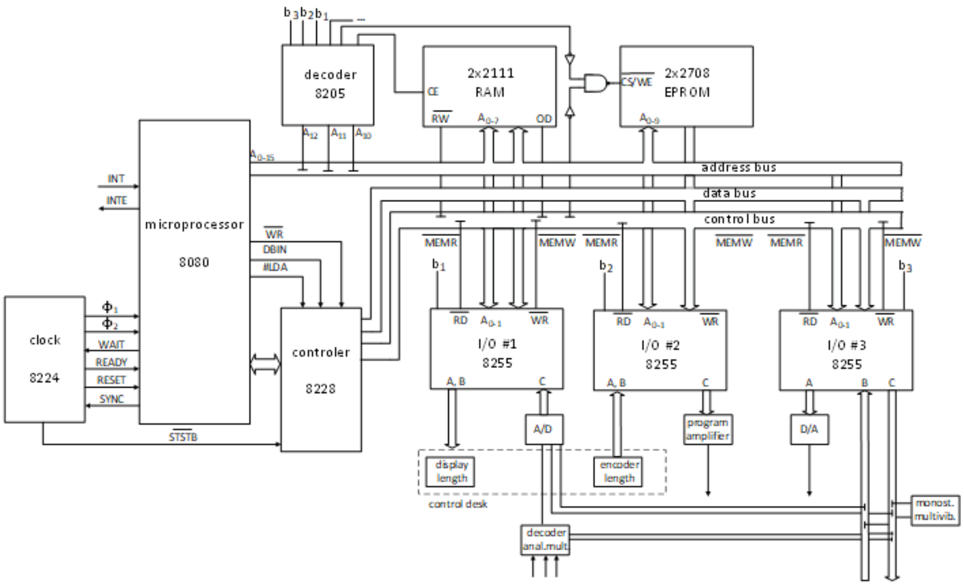

Fig. 6. Block scheme of the hardware presentation of the newly projected microcomputer.

After completed dissection, the register of current length is annulated and the output for reading of feedback speed is sent. The feedback speed will be provided by initiation of the conversion of A/D converters and according to fulfillment of conditions for reading, the condition of converters is read. After this reading, the output for maximum limit of the current will be sent.

Output management is decreased for the one quant until the reference value for the feedback speed is reached. After that, there is an investigation if the detector D_2 is activated for slowing down while saw carts are moving backward. When it is activated, the loop will be left by sending the output word for analogue multiplexer. When the conversion is initiated, according to the fulfilment of conditions, the data on small speed will be read. Since data on the small speed is read, the output control for one quant will be read until reaching the reference value. After that, the minimum limit of the current will be sent for keeping shields and the algorithm will return to the beginning by new reading of the needed length of the pipe for the cutting.

Microcomputer for program steps, block scheme in Fig. 5 are presented in Fig. 6. This computer is based on 8-bit processor and its timeline control used clock generator 8224. Also, there is use of controller from this kind of generators 8228, while memories EPROM (2 x 2708) and RAM memory (2 x 2111) are also included. The decoder 8205 is used for the selection of the unit and it use address paths A_{12}, A_{11} and A_{10} for entrances.The system includes three programming input-output units of type 8255 through which the microcomputer is connected with the process.

Outputs I/O#1 of the unit (A,B) are presented on display for the presentation of the current length of the pipe, (C) is the entrance of A/D converter. The one A/D converter is used for conversion of data on speed of the motor, feedback and minimum speed which provided by application of decoders and analogue multiplexor. Decoder is used for two inputs and it is needed to have at least three outputs for activation of multiplexor through which analogue data are moved for converting in A/D converter.

Outputs from the length encoders are connected to inputs (A,B) of the input-output unit I/O#2. The output (C) of the mentioned unit is continued to programming amplifier whose output presented the current limitation for the thyristor speed regulator. During higher speeds of the pipe, outputs of the programming amplifier are even higher so the device and the cutting tool accelerate with higher acceleration.

While decreasing speeds, the acceleration decreases also, so the synchronization can be achieved at the same time which makes the entire control system adaptive. The way of the entire system of the saw during translation and early start are considered as linear dependencies in the function of production speeds of pipes. Until now, these dependencies were nonlinear which has made their accurate calculation and practical realization more difficult.

D/A convertor is empowered from (A) from the unit I/O#3, whose output presents the control for the thyristor speed regulator. Other inputs in microcomputer, such as data from limit switches, A/D converters and monostable multivibrator are presented by the input (B) of the same unit. The output (C) of this unit presents the final word where outputs are presented by the output for initiation of the conversion of the A/D converter, monostable multivibrator and for generating of commands needed during dissection of pipes.

The breakdown system is organized starting from the address 000H and it includes reserved memory to the address 003FH. Subprogram MNOZ, for multiplying of two one-byte numbers with the result of two bytes is located starting from the address 0040H. In order to convert numbers from BCD code into binary code, the subprogram PRETV is developed. It is located starting from the address 0080H. The main program is located with the starting address 00C0H.EPROM memory includes addresses from 0000H to 08FFH, so the stake is located starting from the largest address. Input-output units have following addresses:

PORT1 - 0C00H,PORT2 - 0C01H,PORT3 - 0C02H,

PORT4 - 1000H,PORT5 - 1001H,PORT6 - 1002H,

PORT7 - 1800H,PORT8 - 1801H iPORT9 - 1802H.

According to instruction diagrams of flows, subprograms and main program are developed in a symbolic language for this type of microcomputers and they are presented in https://github.com/valentinanejkovic/romjist2022/blob/main/SorceCode-Asembler.asm. According to dynamic analysis, it is concluded that the selected configuration of the system including microcomputer is adequate to its purpose.

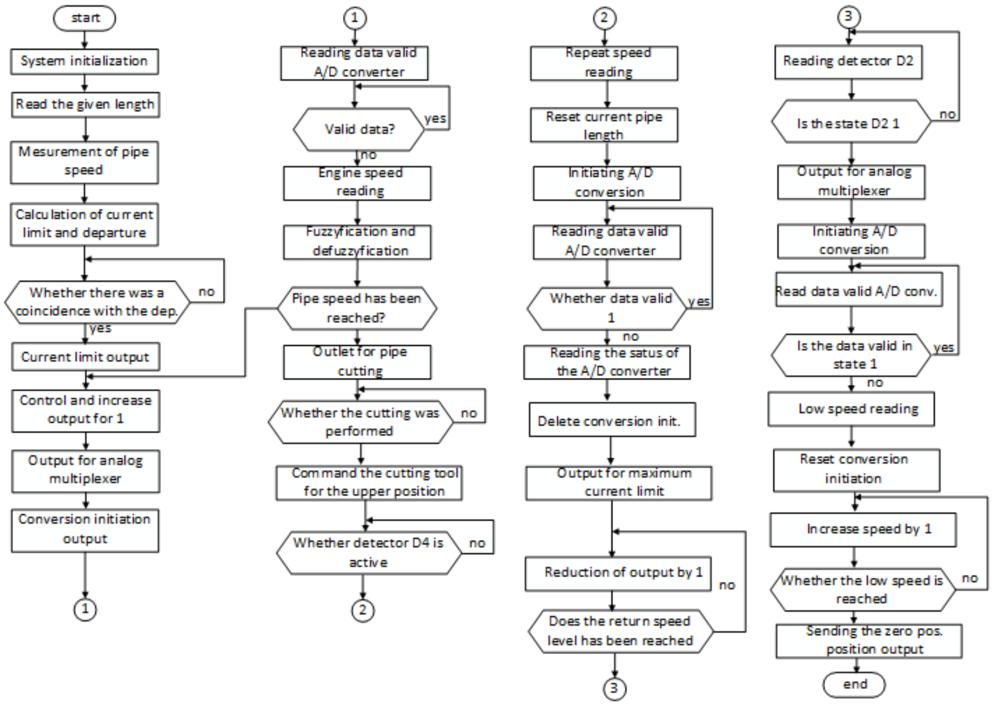

Fig. 7. Algorithm of the work of the microcomputer for control of motor and cutting of pipes.

5. Discussion and Results

Several years of researches of the system for cutting of steel pipes provided facts on lacks which developed numerous stops in production. Reasons for it lie in a nature of executive hydraulic elements which change their characteristics due to wear. It led to large stops due to replacement of vital parts and continuous change of filters and working fluids. Regardless that, the way of design of such systems did not move deeper in considering of the theory in order to design an optimal control scheme.

The problem of accuracy of lengths of product lies in raw understanding of the system response which was designed and researched by researches. The main problem lies in ignoring of speed of response to given commands. When one pipe is dissected, the counter resets by setting the selected length, and coming of each millimeter from optical meter decreases condition of counter for one unit.

Older systems worked in a way that when the condition of length counter reaches zero, there is command for moving of saw in translation. The saw accelerates until it reaches the speed of technological line and then the command for activation of cutting is given. During that time, the mistake in lengths appear, which is the function of speed.

Less perfect systems introduced the system of activation of translation with early start before moving counter of length back to zero. However, there was the problem since the response was not accurately calculated. Beside current, this work analytically calculated the speed of translation given by the expression (32). In order to calculate the moved way, it has to be calculated using the expression

$$s(t) = \int v(t) + C, \qquad (35)$$

where speed $v(t)$ is calculated by the expression (32) which is calculated by certain constant. In nowadays practice, the moved way was calculated graphically, which led to deviations in lengths. In order to present this problem in exact way, the graphic of the accurately defined premature using integration will be illustrated using (35) according to [16], which is presented in Fig. 8. Fig. 8 shows that this dependency is nonlinear which identified mistakes in lengths even in hydraulic systems which included rough attempt to realize the premature of the start. Authors of this paper achieved it, which is presented in their papers [16, 22–30]. In order to help researchers and engineers, programs were realized and made available by the authors of this paper in [16].

Monitoring of new theoretical and scientific results [34–40] helped to foresee the possibility of applying fuzzy controller in the algorithm shown in Fig. 7. It would be a new variant of management by calling the subroutine for phasing first, and then for dephasing in the computer program.

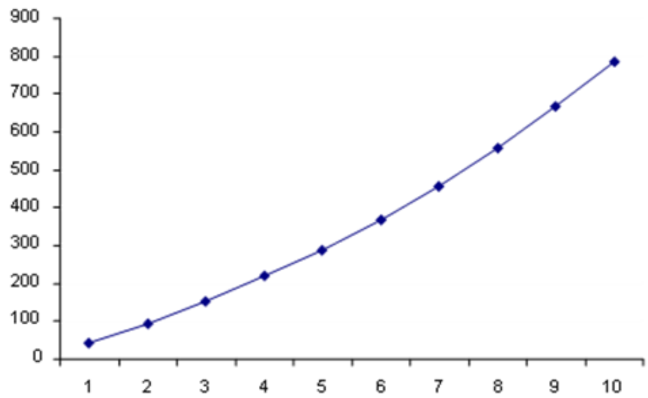

Fig. 8. Graphic of premature start by calculating of way using integration of the speed (axes abscissa is speed $v \times 10^{-1}$ in [m/min] and ordinate length L_{pr} in [mm]).

Through several years of research, authors of this work, in theoretical and practical way concluded that many companies which are producers of this equipment did not want to present their equipment completely. Regarding showing capacity on only one product, where only maximum possible speed is investigated, the system was setup only in one point. Authors of works who are dedicated to these problematics expose the matter in certain segments, while trying to improve it by quoting of modelling using various simulation packages.

For these reasons, authors of this paper identified problems and according them designed one new system in which as executive element the electrical motor was used. For the automatization of the entire system, the microcomputer was designed. Studying of this work will be simplified since everything presented is methodical and transparent, starting from identification of existing problems to realization and use in practice.

That is the reason why authors of this work, using identification of problem with electrohydraulic executive elements, projected new system in which DC motor for power is introduced and it is much more precise for the control. Besides that, its working life cycle is much longer and maintenance is less and cheaper. When introduction of adaptive control is added, the dependency from figure 8 becomes linear.

The application of computers is possible for making this dependency into control, as presentation via table. After that, the interpolation can be conducted in order to obtain exact premature. Regarding application of hydraulic elements, each contamination and impurities of working fluid cause change of speed and moved way, which lead to large errors in lengths of pipes. It makes the product out of any class for use. All of this has decreased productivity and performance.

6. Conclusions

The contribution of this work is design of system for automatic control of cutting of steel pipes. Nowadays mass application of hydraulic and pneumatic elements in such systems was replaces by introduction of DC motor and microcomputers which automates the entire process of design of steel longitudinally welded pipes.

Lack of firstly installed system was analyzed through providing of description of working cycle. Through existing large practical experience in work and studying of such systems, it is concluded that the new system should be designed. This system should remove most of lacks and increase reliability of the work of unit for cutting of the final product.

The power of flying saw adopted application of DC motor, reductor, gear and lath. According to the process, the current working mode was analyzed while starting to the speed of the pipe in design process. The new system of acceleration during start should be adaptive according to the speed of the pipe. Work with tilting control and current limitation caused linearity of the function of speed in time t. That is the reason of appearance of good situation that the time of premature is a linear function, which was not the case in earlier systems.

Higher level of automatization is a consequence of introduction of new microcomputer which is designed and integrated into entire system of this process. Connecting with the process is conducted via converters and input-output units. Beside this, the thyristor speed controllers designed. It empowers the executive element for translation. Regarding the hardware, the programming was conducted in order to improve needed performances of the entire dissection system.

The system is described by needed equations, needed calculations were conducted as confirmation of action in practical application. The algorithm of the entire process was given, including software and graphical presentations for purpose of illustration and confirmation of ideas in theory through practical application in the production. Authors of this work constantly follow and contribute to welding and thermia, which is confirmed by [32,33] in order to improve practice using theoretical science contributions.

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