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Design of a Microcomputer for Controlling a Servo System for Cutting Steel Pipes

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Abstract. This paper deals with the problem of automatic regulation of cutting steel pipes and profiles. The process of making steel pipes and profiles starts from the steel strip by shaping in the forming section, induced longitudinal welding, and finally cutting. It is necessary to cut to a pre-selected length while in motion, which does not disturb the process of continuous operation of the production line. The existing cutting system created problems in the accuracy of product cutting lengths, insufficient synchronization of cutting tools and products, etc. After identifying the problem and analyzing the system, the design of a microcomputer-based control system was initiated to ensure precise regulation of the product cutting process, the final stage of the technical line for seam pipe production.

Key-words: Cutting steel pipes; design; microcomputer; regulation; servo system.

1. Introduction

During the conception of this paper, relevant literature in the field of automatic control theory and regulation was used [1–10]. The aim of presented research in these references is to explore innovative system implementations aimed at enhancing specific stages of steel pipe production. The measurement of non-electrical quantities using electrical display method is given, too. For the sake of practical improvement, the literature in the field of application of operational amplifiers is used.

Reference [1] explores continuous automatic control systems, while [2] focuses on executive electrical authorities through application in regulations. Reference [3], a robotics textbook, examines measurement sensors and their application in robotic control systems. Further, [4] discusses both linear and nonlinear control systems, while reference [5] presents sensors used for electrically measuring mechanical quantities. Reference [6] covers signal processing, precision control, and regulatory techniques. References [7] and [8] serve as fundamental sources on operational amplifiers, covering both theoretical principles and practical applications. Reference [9] is a doctoral dissertation that introduces an innovative approach to automation in rolling mills, where steel strips are produced from steel billets through rolling. Finally, reference [10] is a well-regarded book on control system regulation and analysis.

Cutting in motion has been extensively discussed in many documents and research results [11–18]. These references serve to give an overview of the system for cutting steel products. First, the original systems that performed the cut-off operation via stops are shown. Then increasingly complex systems are processed. As technologies in the world have advanced, investments have been made in innovative systems for cutting. By studying the same and the real system, it was found out which parts need to be improved.

Original solutions for cutting is presented in [11], while [12] deals with the automation of the pump with the application of electrical control. In [13], there is an overview of the system for cutting the product to the desired length. Paper [14] gives an overview of the realization of the flowmeter for powering the electronic unit of the controlled process. Paper [15] presents the measurement of speed and length through the application of a correlation method. Reference [16] gives an insight into the solution of an electronic device for programmed control of pipe cutting. Authors of [17] show the implementation of optical devices that display and measure speed or length pulse-wise and proportionally by changing the frequency. Reference [18] shows servo devices as actuators in industrial processes.

For the part related to digital electronics and computers, literature was used [19–28]. Part of these references refers to the application and design of control systems with the application of microprocessors and microcomputers. In this way, the conditions are created for programming a higher-quality control for cutting steel pipes.

Reference [19] is a basic book on microprocessor technology and electronics, after which the rapid development of microcomputer technology occurs. Reference [20] contributes to the application of computers through software development, while [21–23] from the same author represent the basic literature for the beginning of the study and application of microprocessors. Literature [24] deals with the application of microprocessors and microcomputers. In [25] memories and microprocessors are processed. Reference [26] gives an example of a microcomputer application. In [27] a description of the application of microcomputers in process management is given. Reference [28] also deals with a presentation of microprocessor electronics.

The results from the works of the authors of this paper were used from the literature [29–32]. This literature presents some initial results that were published in the works of the author of this work. One book in the field of actuators is also cited.

Reference [29] provides an algorithm for cutting steel pipes in motion. Paper [30] presents a new adaptive control of pipe cutting in motion, which was implemented using linear integrated circuits, while [31] lists a useful material that processes electric actuators. Reference [32] provides a site that complements and explains this paper in more detail.

More recent works according to [33–43] were used to improve the automation and stability of the system, as well as for further improvements of the cutting system in the future. Part of these references gave some ideas to the authors of the paper for improving some parts in the management design. Citation of this literature will in practice benefit the authors of the paper and all researchers who read and study this paper.

Reference [33] shows a PI controller with phase control and defines control stability. In code [34] the regulated DC voltage converter is processed by changing the frequency. Through analysis and optimization, theory is transformed into useful applied research. In reference [35] the application of the theory of optimization algorithms for the needs of applied research in setting the performance of PI controllers is given. In [36] a two-stage linear and phase controller for integral processes is analyzed. It is characteristic of the [37] that it introduces predictive control when driving vehicles. Reference [38] provides the procedure for adjusting the tower crane system using deterministic gradient algorithms. Reference [39] presents optimization techniques using teaching theory with applied research. In [40] the control of a discrete system is processed by combining data for drive control using the basic ILC model. The authors of work [41] perform analysis and control of the crane system using a hybrid drive system. In doing so, they use developed evaluation methods since they have a lot of references and results in this area. Reference [42] deals with a levitation system that was applied to drive a high-speed train where they apply a cascade control system. In [43] the authors deal with adaptive optimization control using improved algorithms. The work has the character of applied research since it is applied to the control of cranes. The works of these authors are numerous and noted in the field of scientific research and publishing.

The development of such systems is necessary due to the increase in the quality of cut products. One of the well-known companies is Vickers Limited, which has developed several cutting systems. The original systems were intended for cutting profiled sheets whose characteristic is a hydraulic motor and toothed rack. A cutting tool with low inertia is attached to the rack. The material hits and pushes the buffer that drives the synchro generator, whose function is to provide information on how long the product has passed under the cutting tool. The disadvantage is the cost of the limiter and frequent stops when choosing lengths.

Further development of these systems led to the idea of using resolvers. One is connected to the product and the other to the cutting tool. The disadvantage is that the cutting is done when stopping. Perfecting these systems led to the idea of measuring speed with a tachogenerator.

Fig. 1. shows a block diagram of the steel pipe cutting control system in motion.

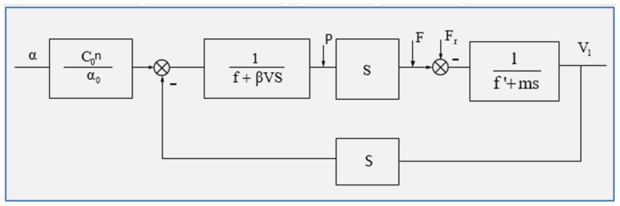

Fig. 1. Block diagram of the system for cutting steel pipes.

The preparation of this paper was helped by a group of papers [38–43] from which ideas were obtained on how such systems can be perfected in the future using new theoretical methods and algorithms.

Further improvement led to the idea of applying systems with pulse generators. The same company is projecting a system with a servo pump that is powered and controlled by a servo valve. In this case, the mass of the cutting tool is small and the responses are fast, which is not this research case. With a weight of about 3000 kg, the system is speed limited and there is a clear delay.

Studying the system for cutting in the world and in our country, it is noticed that in practice there is no greater accuracy because some companies do not apply the premature departure of the cutting tool and some do it in an insufficiently precise and accurate way. The main disadvantages of our old system are the inaccuracy of the premature circuit, the non-linearity of the frequency-voltage converter and the applied TTL technology, which is not immune to interference. For these reasons, a new control system is being designed.

There are few works in this area. Companies that manufacture these pipe cutting systems do not provide complete documentation. Authors who write papers in this area do so by merely describing existing systems. There are not many proposals for introducing new solutions. The motivation of the authors of this work is to show the technical innovation made on this system. The motivation is that in practice it was rarely and difficult to synchronize the speed of the cutting tool with the speed of the steel tube. As a result, there was a bad cut, an error in the length of the pipe. Slippage was occurring in the pipe calibration section, resulting in damage to the calibration rollers. Hence, it created large downtimes and costs due to tool processing. The poor performance of the cutting system had a bad effect on the welding at the welding generator. Because of the mentioned problems, they were eliminated with new solutions. The contribution of the work is enabling the elimination of the listed problems, which results in the reduction of downtime, improvement of product quality and increase in production productivity.

2. Description of the Dynamics of the Hydraulic Servo System as an Actuator

In order to manage the system well, it is necessary to analyze and describe the system. The saw carriage has considerable mass and must be taken into account when writing dynamic balance equations. The equation of motion of the saw can be given

$$F - F_r = PS - F_r = m\frac{d^2y}{dt^2} + f'\frac{dy}{dt} \tag{1}$$

or

$$PS - F_r = m\frac{dv_1}{dt} + f'v_1, \tag{2}$$

where: F_r – resistance force, F – force, P – pressure, S – cylinder cross-section, m – saw mass, y – hydraulic cylinder position and f' – friction coefficient. On the other hand, the flow of the pump minus the flow of the lifter of the hydraulic cylinder is equal to the outflow loss increased by the compression loss, i.e.

$$C_0\frac{\alpha}{\alpha_0}n - Sv_1 = fp + \beta V\frac{dp}{dt}, \tag{3}$$

where: C_0 – volume of the servo pump, α_0 – maximum angle of the pump plate ($\pm 18°$), α – current angle, S – cross-sectional area of the cylinder, v_1 – velocity in the cylinder, f – flow coefficient, V – oil volume under compression, $\frac{1}{\beta}$ – compression modulus and n – speed of the motor that drives the pump.

Laplace transformation of (2) and (3) gives

$$PS - F_r = V_1(ms + f') \tag{4}$$

and

$$C_0\frac{\alpha}{\alpha_0}n - SV_1 = P(f + \beta Vs). \tag{5}$$

Based on relations (4) and (5), a block diagram can be given in Fig. 1.

From Fig. 1, with the condition that there is no friction in the system $F_r = f' = 0$, for coupled transmission is provided

$$W_1(s) = \frac{V_1}{\alpha} = \frac{\frac{C_0 n}{\alpha_0 S}}{\frac{Vm}{S^2}s^2 + \frac{fm}{S^2}s + 1}. \tag{6}$$

With shifts

$$\frac{\beta Vm}{S^2} = \frac{1}{\omega_n^2}; \qquad \frac{fm}{S^2} = \frac{2z}{\omega_n}; \qquad k = \frac{C_0 n}{\alpha_0 s}, \tag{7}$$

a coupled transmission in the form is obtained

$$W_1(s) = \frac{k}{\frac{1}{\omega_n^2}s^2 + \frac{2z}{\omega_n}s + 1}, \tag{8}$$

if control is brought to the input of the system from Fig. 1 as in Fig. 2.

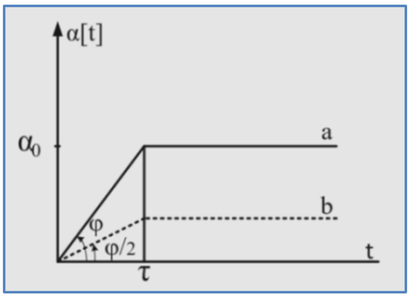

Fig. 2. Input control signal.

Previous systems were realized so that the input control was with constant acceleration. In this research it was conceived that the acceleration would be proportional to the speed of the production line, and therefore to the speed of the flying saw at the time of cutting the pipe.

By finding the Laplace transform of

$$\alpha(t) = \frac{\alpha_0}{\tau} t u(t) - \frac{\alpha_0}{\tau}(t-\tau)u(t-\tau) \tag{9}$$

is obtained by

$$\alpha(s) = \frac{\alpha_0}{S^2 \tau}\left(1 - e^{-\tau s}\right). \tag{10}$$

The output of the system is the speed of the saw $v_1(t)$ and it represents the response of the system to the input $\alpha(t)$ which represents the tilt angle of the servo pump plate, and it is obtained as

$$v_1(t) = \mathcal{L}^{-1}\left[\alpha(s) W_1(s)\right]. \tag{11}$$

When solving (11), a response is in the form

$$v_1'(t) = \frac{C_0 n}{\tau S}\left[t - \frac{2z}{\omega_n} + \frac{1}{\omega_n\sqrt{1-z^2}} e^{-z\omega_n t} \sin\left(\omega_n \sqrt{1-z^2}\, t - \vartheta\right)\right], \qquad t \le \tau \tag{12}$$

and

$$v_1(t) = v_1'(t) - v_1'(t-\tau)u(t-\tau), \qquad t > \tau. \tag{13}$$

The system feedback is given in the form

$$W_2(s) = \frac{\omega_n^2}{s(s+2z\omega_n)}. \tag{14}$$

It can be concluded from (14) that the system whose coupled transmission is of the second order has a feedback transmission with the property of astatism of the first degree. The rate constant is

$$k_v = \lim_{s\to 0} sW_p(s) = \frac{\omega_n}{2z}. \tag{15}$$

If the input data is replaced, the result is obtained

$$z = 0.7; \qquad \omega_n = 12.55\ \text{rads}^{-1}; \qquad v_{\text{max}} = 1.66\ \text{ms}^{-1}. \tag{16}$$

Relation (12), after changing the known, becomes

$$v_1'(t) = 5.53\left[t - 0.111 + 0.11e^{-8.79t}\sin(9.04t + 1.57)\right]. \tag{17}$$

Applying the Mihailov criterion, it is shown that the system is stable. We conclude that the investigated regulation system is stable with a phase reserve of $65°$. The dynamic error ε has a value of $0.615\ \frac{\text{m}}{\text{s}}$. The velocity $v(t)$ has a periodically damped flow.

3. Designing an Adaptive Control System with a Microcomputer

The analysis of the old system leads to the conclusion that it cannot satisfy because it does not ensure the accuracy of the lengths of the cut products.

For these reasons, the design of a new automatic control system is approached with the aim of improving the accuracy of cut lengths.The system has a basic appearance as shown in Fig. 3.

One microcomputer is introduced to manage the entire system. In order to define themicro-computer architecture, it is necessary to describe the process with its requirements. Fig. P1 of the attachment [32] shows the block diagram of the process with the sequence of operations to be completed during one work cycle.

First, the set length for cutting is read and then the speed of the product is measured or calculated. Premature is calculated using speed data. Then the condition is examined whether there is a coincidence with prematureness, and if so, a signal is generated for the start of the saw. When the control $u(t)$ reaches the reference value, it is necessary to activate the cut-off. When the cut is complete, the cutting tool returns to the upper position and the saw returns to the zero position.

Inputs to the system are: from the length selector, where this is changed according to production requirements, information from the pulse generator whose frequency is proportional to the speed of the product, and inputs from detectors that provide information about the position of the cutting tool. The outputs are: for commands to lower the cutting tool, raise it to the upper position, clamp and release the jaws for fastening with the product in the moment when cutting is performed. Given that the system should work in real time, monostable circuits that are programmed to be activated will be used. Two eight-bit outputs are connected to D/A converters and serve to control the servo system.

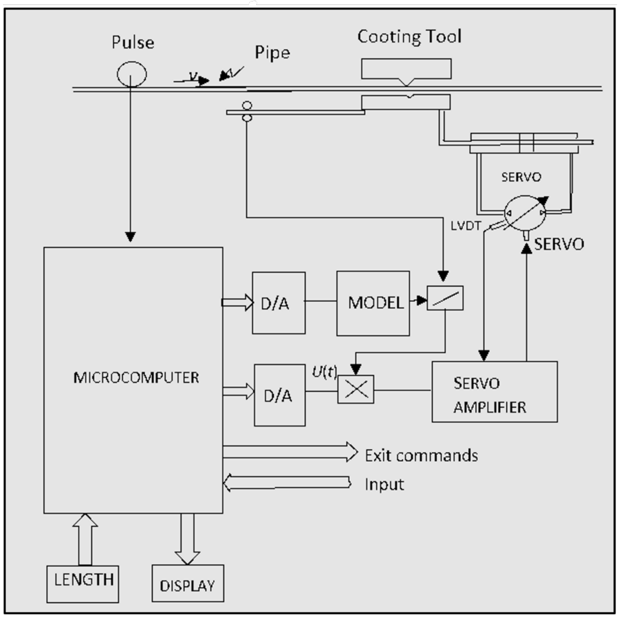

Fig. 3. Block diagram of the system of regulation with a servo system using a computer.

The servo system enables the translation and synchronization of the speed of the saw with the speed of the product. A new feedback loop is introduced, which provides adaptive control by measuring the speed of the saw and the process model. There is also a display output that shows the current length of the product being cut in one working cycle. The output for adjusting $u(t)$ with the state diagram of the detector is shown in Fig. P2 of the attachment [32]. The control $u(t)$ represents the output of the D/A converter and it is discrete in nature.

Thanks to the speed limitation, even though $u(t)$ is of a discrete character, the slope of the servo pump plate will be linear. In order to fulfill this condition, it is necessary to send the output at certain moments, and this is achieved with the oscillator O_1. At the same time, the speed of the program loop for sending the output must be of such a duration that it is possible to send the output at the next moment.

The architecture of the microcomputer has the appearance as shown in the Fig. 4 and it is based on the Intel microprocessor 8080. This microcomputer has sufficient speed and the microprocessor is 8-bit. In addition to the microprocessor, a clock generator 8224 and a controller 8228 are used. For this research it is adopted a configuration with a RAM memory of 256 bytes and an EPROM of $1\,\text{kbyte}$.

The RAM memory is organized by two type 8111 memories as shown in the Figure P4 of the attachment [32]. The EPROM memory is composed of 4 chips of type 8702. Decoder 8205 is used to select the memory. The input to the decoder is taken from the address bus A_8, A_9, A_{10}. The output of the decoder is connected to the MEMR signal through the logic "and" circuit, so that the chip is selected by a certain address.

The microcomputer system has three programmable I/O units of type 8255 and they are used for coupling with the process. Through them, the necessary inputs are brought in, and after processing, they send commands to the process. A more detailed description of the input and output coupling of the entire control system is given in Fig. P5 of the attachment [32].

Selection of the length of cutting off the product is done with decimal/BCD encoders. The output of one D/A converter is fed to the servo amplifier and the other to the process model. The system has the possibility of using the interrupt system with the desired choice of priority. The necessary hardware for generating the RST instruction is shown in Fig. P6 of the attachment [32]. The highest priority is the output from the detector, which signals that the saw is close to the end position in which a severe breakdown of the cutting system can occur. Upon receiving this request, processing is performed according to the subroutine for this interruption, and generates the stop output, which blocks the flow of oil for translation. In addition to this programming option, special hardware is also used for blocking, which increases the security of the entire system. The second interrupt level is the input from the pulse generator, and a special subroutine for its processing ensures the measurement of the length of the product.

The labels have the following meanings: RA – control for servo amplifier, RB – input to the system model, RC – premature value, RBSZ – product speed value, RD – product length value, Ugi – pulse generator output, MM_2 – output of monostable $614\,\text{ms}$, $ULMM_2$ – input to MM_2, MM_1 – monostable output $50\,\text{ms}$, $ULMM_1$ – input to monostable MM_1, RL – selected cutting length, O_1 – oscillator $2.5\,\text{ms}$, RP – return speed value, RO – holding pressure on bumpers, and RE – reference value for RA and RB.

Microcomputer software consists of three subroutines called by the main program is required. Premature departure is calculated by reading values from the table and performing interpolation. The subroutine for dividing two-byte data by 8 occupies 37 bytes in memory, and for its execution, at a clock frequency of $1\,\text{MHz}$, it requires $372\,\mu\text{s}$. One piece of information about the length of the premature takes up 12 bits.

In order to save memory space, the data is densely packed, and a special subroutine is used to read it. This subroutine occupies 120 bytes, and its execution requires $526\,\mu\text{s}$. The interpolation is performed by a subroutine occupying 59 bytes, with an execution time of $3.144\,\text{ms}$. The main program occupies 406 bytes in the EPROM memory. The subroutine that uses the interface to measure the length of the product occupies 24 bytes and takes $197\,\mu\text{s}$. Total memory usage is 864 bytes. The maximum duration of the loop for processing the output control $u(t)$ is $270\,\mu\text{s}$.

At the maximum speed of $1.66\,\frac{\text{m}}{\text{s}}$, the period of the pulse generator is $600\,\mu\text{s}$. The total time for processing the interrupt that measures the length of the product and for outputting the control output is $470\,\mu\text{s}$. Since the system is speed limited, the oscillator period O_1 is chosen to be $2.5\,\text{ms}$.

It is concluded that the microcomputer has a margin of time between two successively generated outputs.

In the normal mode of operation of the system, it is observed that the response often does not have the desired value in the steady state. This occurs due to varying static gain where pressures and fluid flows are variable. A detailed analysis of transmission and response is given in [1]. Therefore, a new feedback loop shown in Fig. 3. Feedback cannot be performed in a classical way because a pure delay has been identified in the system. Since the exact parameters of the system, form the system model of Fig. P3 of the attachment [32].

If the response decreases k times, due to the reduction of static gain, then the input is increased k times through the feedback loop and the multiplier, whereby the output is established

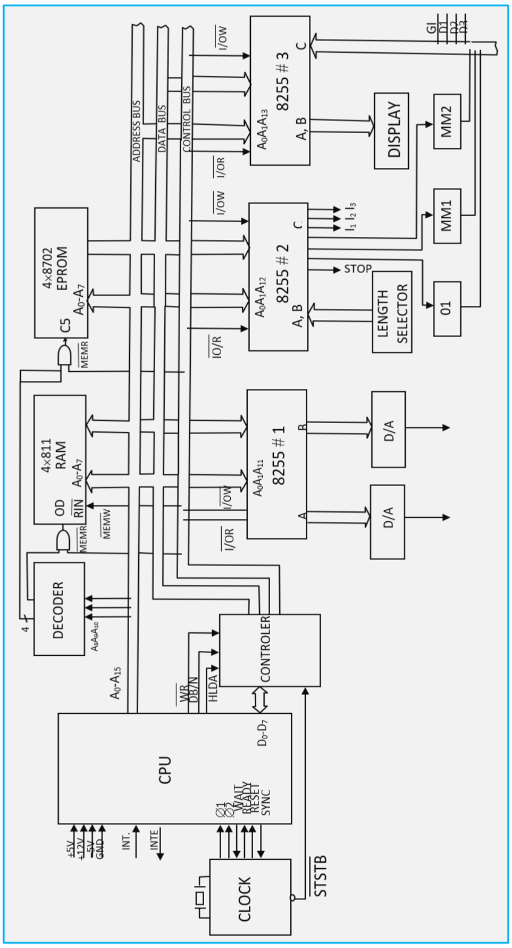

Fig. 4. Block diagram of a microcomputer system.

at the desired level. To implement this control, it is necessary to tune another speed meter that will measure the speed of the cutting tool. The cutting tool is mounted on the carriage of the flying saw which is rigidly connected to a large hydraulic cylinder. Translation is performed by changing the flow through the cylinder with a servo pump. The result is a change in line speed.

An optical pulse generator is chosen for the meter, which will generate 1000 pulses for one full revolution. Those pulses are converted by a frequency voltage converter into an analog DC voltage. The electrical diagram of the model is shown in Fig. P3 of the attachment [32]. The values of the components are selected based on the identification results.

Now the following relations can be written in order

$$U_4 = -\frac{1}{sC_2}\left(\frac{\alpha_2 U_3}{R_3} + \frac{\alpha_3 U_4}{R_4}\right), \quad U_3 = -\frac{1}{sC_1}\left(\frac{\alpha_1 U_1}{R_1} + \frac{U_2}{R_2}\right), \quad U_2 = -\frac{R_6}{R_5}U_4,$$

$$U_5 = -\frac{R_8}{R_7}U_2 \quad \text{and} \quad \frac{U_5}{U_1} = \frac{k}{T^2 s^2 + 2\vartheta T s + 1}.$$

By introducing the values of the electronic components $R_3 = R_4 = R_5 = R_7 = R_8 = 100\,\mathrm{k}\Omega, R_1 = R_2 = R_6 = 1\,\mathrm{M}\Omega, \quad C_1 = 1\,\mu\mathrm{F}, \quad C_2 = 0.1\,\mu\mathrm{F}$ and $\alpha_1 = 0.16667, \quad \alpha_2 = 0.11865, \quad \alpha_3 = 0.15$, finally, a transfer function of the following form is obtained

$$W(s) = \frac{0.166667}{0.008427s^2 + 0.127237s + 1}. \tag{18}$$

Since the values of the components were determined, the system model needed to realize the feedback loop is fully defined. The input control delay is given in Fig. P7 of the attachment [32]. By introducing this kind of feedback loop, the cutting of steel pipes at a right angle is achieved. To this should be added the increased accuracy of cut pipes.

4. Results and Discussion

As part of the production lines for the production of steel pipes, the final section of the cut-off saw. The pipe length error occurs because the cut-off point and cut-off system paths are not the same. Further refinement of the lines led to the idea of prematurely starting the saw in the last meter of the pipe for cutting. The paths traveled at different speeds of the pipe were roughly calculated graphically. An additional identification process in the simulation process finds the right parameters.

As a result of these problems, this paper came up with the idea of applying an adaptive system so that the acceleration of the saw will be proportional to the speed of the steel pipe. On this occasion, a linear curve is obtained that can be easily fine-tuned using an external potentiometer. Since the parametersof the hydraulic servo system change over time, the application of one model is introduced, which will automatically perform the correction.

A big problem and stoppage were caused by the Vickers servo valve, because it got dirty because it was located in the oil. The problem was solved by using a new Moog servo valve that was of the flow type.

By using a microcomputer, the shortcomings that appeared in the original solution were overcome. The total error for cut products is below $1\,\mathrm{mm}$. Comparing the errors of the old system, which ranged up to $50\,\mathrm{mm}$, the application of the new system is economically justified.

5. Conclusions

A system for cutting profiles in motion with a microcomputer was designed. The application of this system allows significantly greater accuracy of the lengths of the cut products as well as cutting at right angles. By reducing the second class of products, productivity also increases, which contributes to an increase in total income.

Here is a presentation of the first innovative system of automatic regulation for the purpose of pedagogical presentation, where new sensors are introduced, the computer system for which the program is designed is designed in assembler, new adaptive control introduced to increase accuracy.

Therefore, this work is intended for students, engineers, and researchers, sharing practical engineering experiences that can inspire them to creatively design similar systems.

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References

[1] M.-R. STOJIĆ, *Continuous automatic control systems*, Gradjevinska knjiga, Belgrade, 2003.

[2] N. PAŠALIĆ, *Fundamentals of regulation techniques for electric drives*, Faculty of Electrical Engineering, Department of Electrical Engineering, Zagreb, 1977.

[3] V. POTKONJAK, *Robotics*, Naučna knjiga, Beograd, 1989.

[4] V. NIKOLIĆ, Ž. ČOJBAŠIĆ and D. PAJOVIĆ, *Automatic Control, System Analysis*, Faculty of Mechanical Engineering, University of Niš, Niš, 1996.

[5] V. STOILJKOVIĆ, *Measurement of Mechanical Quantities Electrically*, Faculty of Mechanical Engineering, University of Niš, Niš, 2005.

[6] K. K. TAN, H. T. LEE, H. DOU and S. HUANG, *Precision Motion Control*, Springer-Verlag, London, 2001.

[7] R. F. COUGHLIN and F. F. DRISCOL, *Operational Amplifiers and Linear Integrated Circuits*, Prentice-Hall, Upper Saddle River, NJ, 1977.

[8] J. G. GRAEME, *Designing with Operational Amplifiers*, McGraw Hill - Burr Brown, New York, 1977.

[9] M. B. DIMIĆ, *Automatic control of the rolling flat*, Ph.D. thesis, Department of Electrical Engineering, University of Belgrade, Belgrade, 1970.

[10] V. A. BESEKERSKIJ, *Teorija Sistem Avtomaticeskogo Regulirovanija*, Nauka, Moskva, 1975.

[11] R. DAVIS and G. MAURICE, *Electronically controlled pumps*, National Conference on Fluid Power, Chicago, 1964, vol. XVIII.

[12] RACINE and VICKERS ARMSTRONGS, *Electronically controlled axial piston pumps*, RVA - Bulletin **S204**, paper L-15.

[13] D. F. NETTALL, *Cut to length devices*, Measurement and Control, 1969.

[14] R. PEKLY, *Debitmetre turbiflow, mesureur à helice et convertisseur electronique*, Argenteuil, 1979.

[15] TRINDEL, *Mesure de vitesse et longeur par correlation optique*, Division Automatisme, Paris, 1979.

[16] ARC, *Electronique, Equipements de Programmation*, Livry-Fargan, 1979.

[17] MCB, *Departement capteurs et codeurs*, Generateur d'impulsions – optique, Courbevoie, 1974.

[18] THE OILGEAR COMPANY, *Typical Die Accelerator System with Digital Control*.

[19] INTEL, *Microcomputer Systems*, User's Manual, 1975.

[20] G. J. WESTER, *Software Design for Microprocessors*, Texas Instruments, London.

[21] H. LILEN, *Du microprocesseur au micro-ordinateur*, Editions Radio, Paris, 1977.

[22] H. LILEN, *Programmation des microprocesseurs*, Editions Radio, Paris, 1979.

[23] H. LILEN, *36 programmes pour votre micro-ordinateur*, Editions Radio, Paris, 1979.

[24] B. SOUČEK, *Microprocessors and microcomputers*, Tehnička knjiga, Zagreb, 1978.

[25] *The Memory and Microprocessor* , Data Book, Texas Instruments, London.

[26] A. SAMARDŽIĆ, *Microprocessor Systems*, Akademska misao, Beograd, 2003.

[27] B. DRNDAREVIĆ, *Personal computer in measurement and control systems*, Akademska misao, Beograd, 2003.

[28] M. PROKIN, *Microprocessor electronics*, Akademska misao, Beograd, 2004.

[29] M. MILIĆEVIĆ, *Proektirovanie mikro-vyčisletelnoi mašiny dlja avtomatičeskogo upravlenija letučoi piloi*, VII Meždunarodnaja konferencija stran členov SEV i SFRJ po avtomatizacii proizvodstvenyh procesov i upravlenija v černoi metalurgii, SRR, Bucharest, Romania, 1984, pp 1–6.

[30] M. MILIĆEVIĆ, *Automatic control of the flying saw on seam pipe production lines*, Proceedings of ETAN-1979, Maribor, Yugoslavia, 1979.

[31] M. MILIĆEVIĆ, T. JOVANOVIĆ and V. NEJKOVIĆ, *Electric Actuators*, Beograd, 2013.

[32] M. MILIĆEVIĆ and V. NEJKOVIĆ, Supplement files for work: Design of a Microcomputer for Controlling a Servo System for Cutting Steel Pipes: `https://github.com/valentinanejkovic/milicevic-romjist2024/blob/main/New%20attachment.pdf`.

[33] R.-E. PRECUP and S. PREITL, *PI-fuzzy controllers for integral plants to ensure robust stability*, Information Sciences **177**(20), 2007, pp. 4410–4429.

[34] C. ALEXANDRU and M. BODEA, *Analysis and design of a high efficiency current mode buck converter with I2C controlled output voltage*, Romanian Journal of Information Science and Technology **23**(2), 2020, pp. 188–203.

[35] R.-C. ROMAN, R.-E. PRECUP, S. PREITL, A.-I. SZEDLAK-STINEAN, C.-A. BOJAN-DRAGOS, E.-L. HEDREA and E. M. PETRIU, *PI controller tuning via data-driven algorithms for shape memory alloy systems*, IFAC-PapersOnLine **55**(40), 2022, pp. 181–186.

[36] R.-E. PRECUP, S. PREITL, E. M. PETRIU, J.-K. TAR, M.-L. TOMESCU and C. POZNA, *Generic two-degree-of-freedom linear and fuzzy controllers for integral processes*, Journal of the Franklin Institute **346**(10), 2009, pp. 980–1003.

[37] T.-M. VU, R. MOEZZI, J. CYRUS and J. HLAVA, *Model predictive control for automated vehicle steering*, Acta Polytechnica Hungarica **17**(7), 2020, pp. 163–182.

[38] I. A. ZAMFIRACHE, R.-E. PRECUP and E. M. PETRIU, *Safe reinforcement learning-based control using deep deterministic policy gradient algorithm and slime mould algorithm with experimental tower crane system validation*, Information Sciences **692**, 2025, paper 121640.

[39] R.-E. PRECUP, E.-L. HEDREA, R.-C. ROMAN, E. M. PETRIU, A.-I. SZEDLAK-STINEAN and C.-A. BOJAN-DRAGOS, *Experiment-based approach to teach optimization techniques*, IEEE Transactions on Education **64**(2), 2021, pp. 88–94.

[40] T. LU, G. LI, Y. FAN and D. CHEN, *Error-free tracking control of discrete-time systems by combining data-driven control with model-based ILC*, Proceedings of the Romanian Academy Series A **25**(3), 2024, pp. 225–240.

[41] R.-C. ROMAN, R.-E. PRECUP and E. M. PETRIU, *Hybrid data-driven active disturbance rejection sliding mode control with tower crane systems validation*, Romanian Journal of Information Science and Technology **27**(1), 2024, pp. 50–64.

[42] J. WEN and F. WANG, *Stable levitation of single-point levitation systems for maglev trains by improved cascade control*, Romanian Journal of Information Science and Technology **27**(3–4), 2024, pp. 348–361.

[43] I. A. ZAMFIRACHE, R.-E. PRECUP and E. M. PETRIU, *Adaptive reinforcement learning-based control using proximal policy optimization and slime mould algorithm with experimental tower crane system validation*, Applied Soft Computing **160**, 2024, paper 111687.