Multi Stage High Current Resistance Welding Control

Bertalan Beszédes
Óbuda University
Alba Regia Technical Faculty
Székesfehérvár, Hungary
beszedes.bertalan@uni-obuda.hu
https://orcid.org/0000-0002-9350-1802

***Abstract* - This article describes the most important aspects of the design, manufacture and operation of microcontroller-controlled spot welding machines, with a particular focus on the application and benefits of recyclable components. The study presents the electrical and mechanical parameters of the equipment, as well as the operation of the electrical control electronics and regulators, as well as the process of regulation.**

***Keywords* - spot welder, transformer control, welding current control, recyclable electrical components, reuse electronic components**

I. INTRODUCTION

Welding is a bond that can be dissolved by destruction where many factors influence quality, c would like to mention only a few of the most important ones: for example, the composition of the material to be welded, its thickness, the design of the electrode. On the electrical side, the voltage (U) and current (A) of the welder. Knowledge of the listed characteristics is essential for the formation of a high-quality and durable welding joint.

II. BASICS IN RELATION TO A WELD

A. Spot welding

Spot welding is a type of resistance welding [1] and its process may consist of the following steps. The workpiece is held between two electrodes with a very high current, without protective gas and other auxiliary substances, carried out only with the help of clamping force. In this way, they ensure adequate transition resistance and avoid unnecessary arcing. The current flowing between the affected points causes the metal to glow up and form some level of bonding. In terms of size and design, there are many different types and types, from DIY ones that are easy to use and no bigger than a shoebox to serious industrial machines, which are already human-sized equipment with serious cooling and control units. It is important to know what and how you want to use the welder, so the main parameters should always be taken into account before buying or building a machine. How many pieces, how thick, how large workpieces we want to weld with it, from these data we can determine the approximate size and required performance of the machine [2].

B. Specifications and steps to build

The planned equipment was produced in smaller series and was designed to produce several different metal parts in size, all parts were designed accordingly. A block diagram of the equipment can be found in Fig. 1.

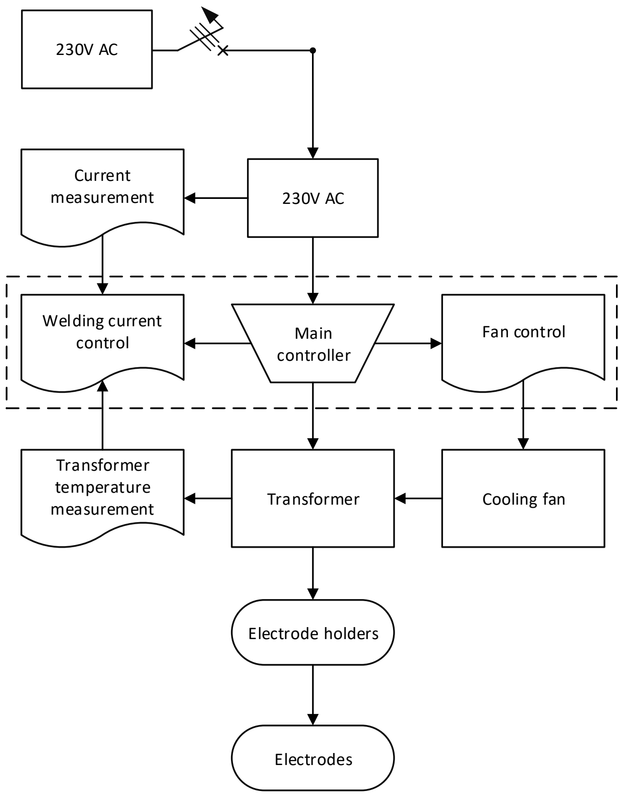


Figure 1: System design

The main steps of construction:

-Dismantling the winding of the transformer to be reused and making a new one

-Enclosure design

-Construction of electrode support and clamping device

-Preparation and programming of control and measurement system

III. HARDWARE AND SOFTWARE IMPLEMENTATION

In the following chapter, it can be find a more detailed description of the preparation of certain parts of the equipment and some of the defects that have occurred during production, and how to repair them. The description has been divided into two parts, the hardware solutions and the software implementation, due to the order of construction, the control electronics are also detailed here.

A. *The hardware*

The basic data of the transformer used DAYKIN TS4981 is the primary and secondary voltage is 400/230V and the power is 1500VA. After the resistance measurements made, it can be determined that the outer winding is 400V and the inner winding is 230V. Then the outer winding had to be dismantled, due to the strong varnishing and impregnation, this had to be done with special care not to damage the secondary winding, which was kept in its original state. After idle and load measurements, the following data can be measured on the completed transformer.

Idle voltages U1=236V, U2=4.7V

Load currents I1=17.8A, I2=889A,

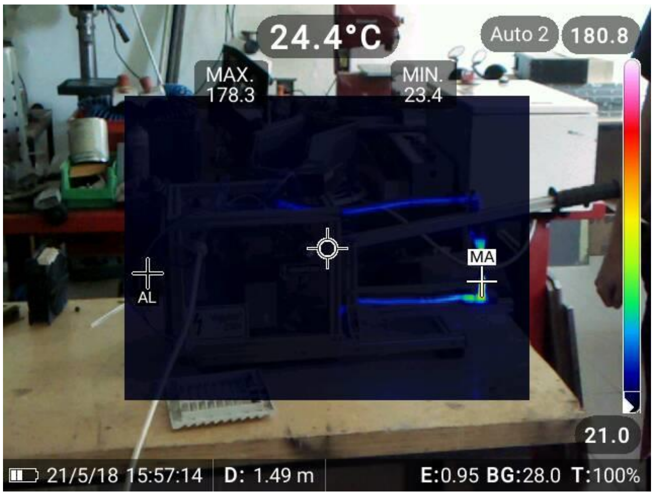
where U1 and I1 are the primary electrical parameters of the transformer, U2 and I2 are the secondary electrical parameters of the transformer.

The gear ratio is calculated: a=U1/U2 =50.2 a=I2/I1=49.9 after the calculations the gear ratio of the transformer a≈50 There is about 1% error in the calculations due to the inaccuracy of the instruments used.

The next step is the preparation of the frame, for this a 20x20 mm ITEM aluminum profile was used from out-of-plant production machines (Fig. 2.). The goal was to create a protective cover and support structure that is able to withstand mechanical stress and ensure safe use.

When making the electrode support structure and the clamping mechanism, several aspects had to be taken into account. The size of the workpiece determines the length of the clampers. And welding technology gives the type and design of electrodes. The finished clamping device is suitable for welding a workpiece up to 25 cm long. And for the clamping arm, a simple spring mechanism was made. For the electrodes, the available 8 mm diameter piece of bronze was used, with an M6 thread on the bottom 7 mm and M8 thread on the rest to properly secure the terminals. For these, a supporting structure had to be made, which was first solved with rail bollards. During testing, after the seventh weld, the holder melted and the electrode fell out. Alternatively, textile bakelite was used, it insulates heat-resistant and tolerates mechanical stresses well (Fig. 3.), after which the only limits of long-term use were the heating of the equipment, to avoid which a cooling fan was installed, which was later controlled.

Figure 2: The finished equipment



3. Figure Thermal image of the electrodes after welding

B. *Software & Control*

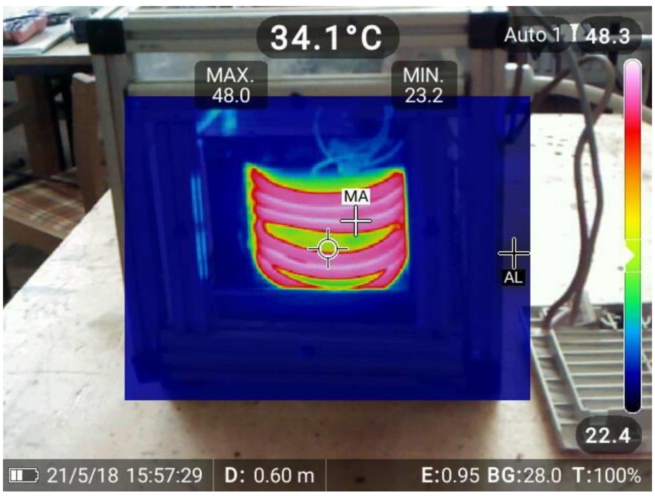
A microcontroller has been selected to control the device [3], this type has sufficient digital and analog inputs and outputs to perform control tasks properly. For communication with the user, a 16x2 line LCD display has been installed.

The main steps of control:

- current measurement
- temperature measurement
- welding current control
- welding duration control

Among several options for current measurement, a hall sensor current measuring module [4] was selected and installed on the primary side of the transformer (see on Fig. 4.), the reason for this was to detect current changes with as little delay as possible. For temperature measurement, a DS18B20 type component was selected, which facilitates the programming part and the result is obtained in degrees Celsius [5].

The data in Table I. shows welding temperature results of 3 seconds in every 30 seconds.



4. Figure Temperature change of coils and

TABLE I. TRANSFORMER TEMPERATURE CHANGE

1. Welding	15°C
2. Welding	19°C
3. Welding	24°C
4. Welding	26°C
5. Welding	35°C
6. Welding	41°C
7. Welding	49°C
8. Welding	53°C
9. Welding	55°C
10. Welding	56°C

In the userinterface, a simple potentiometer is used to select welding options. Welding times are assigned to resistance values in the program to ensure that the material does not burn through, but still creates a durable bond.

Frequent use of equipment containing transformers creates a lot of disturbance and noise in the network (Fig. 5.), in order to reduce this, a mains filter has been installed and so that the disturbance at startup is not too great (Fig. 6.), so the transformer is continuously pre-excited through a resistor after switching on, when welding starts and the current increases, then with the SSR2 solid-state relay, the resistance will be discharged and the current will flow through the relay.

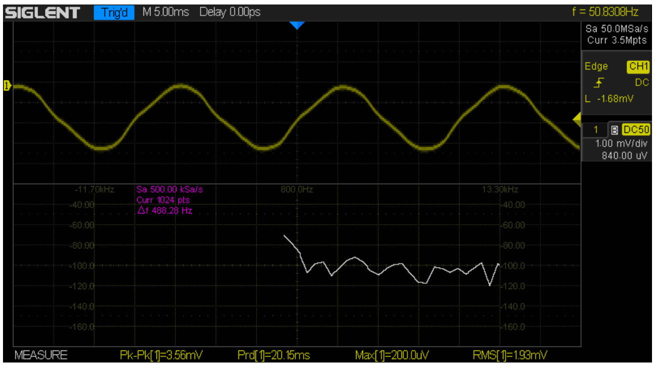


Figure 5: Noise spectrum before filtering

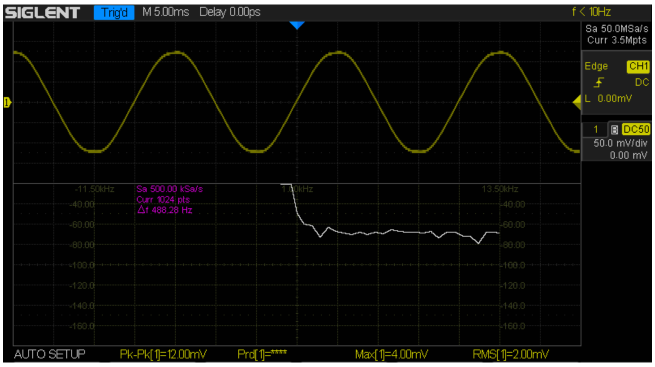


Figure 6: Noise spectrum after filtering

Description of the operation of the program can be follow at Fig. 7. At start-up, it is checked under one condition whether this is the first start, and with it current measurement is also performed, excluding the device from starting with burnt electrodes, if current does occur, it turns off the SSR1 relay and writes "Shor circuit" on the display.

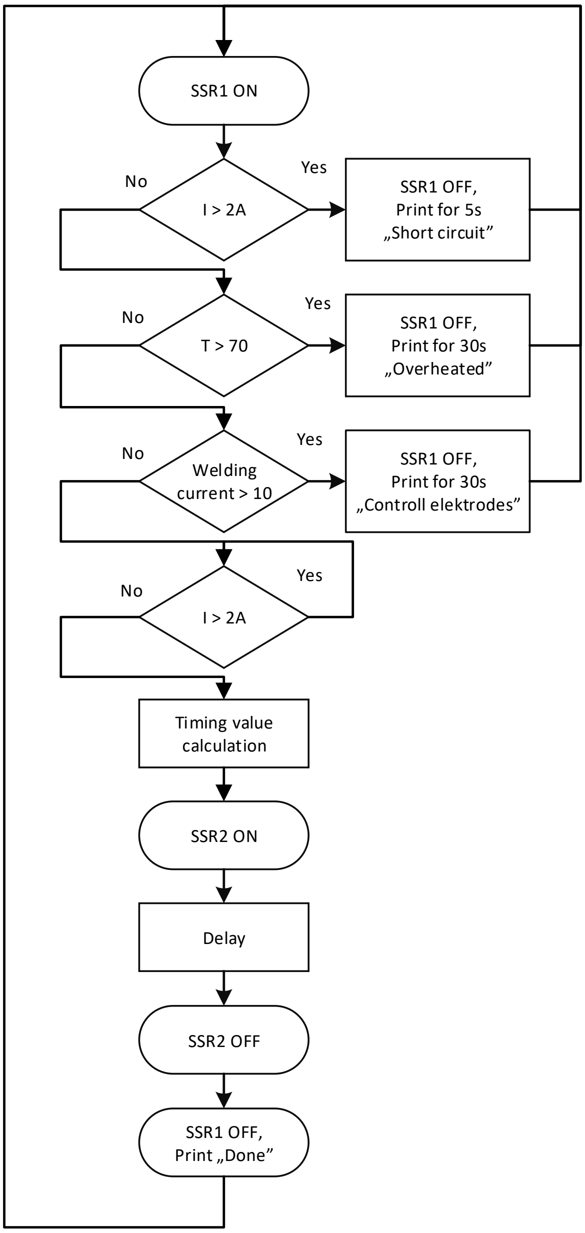


Figure 7: Flowchart of the program

In the next step, temperature measurement is performed to avoid overheating. if the set value is exceeded, it turns off the equipment and informs the user "Overheated".

In the third step, the number of welding cycles is checked. This step was installed because the condition of the electrodes can deteriorate quickly during high-current welds. After ten cycles, the operator receives a notification "Controll electrodes" and then shuts off the device for 30 seconds.

In the final step, the actual welding process is already started. After turning on the SSR1 relay, a current measurement is made, and if its value exceeds 2A, the SSR2 relay is turned on for the period that it was scanned from the potentiometer. See the system architecture in Fig. 8.

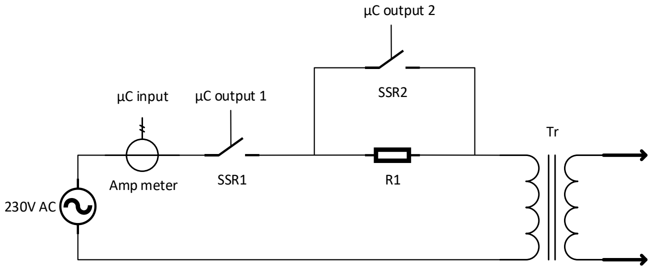


Figure 8: Primary side control elements

Similar control solutions can be seen in [6-10]. The microcontroller-based solutions presented here are also effective in cutting-edge technological areas [11-15]. These methodologies are well connecting for higher educational frameworks [16] and focusing on cutting-edge cybersecurity education logic [17].

IV. Reuse of electrical components

The reuse of dismantled, used electrical components can have a significant positive impact on both economic and sustainable industrial practices [18]. The following are some important positive effects.

The possibility of reusing components can reduce costs for new parts for manufacturers and companies. This can improve the profitability and competitiveness of companies in the market. Reuse can reduce the use of raw materials and energy required to manufacture new parts [19]. In doing so, it can contribute to the conservation of natural resources and reduce pressures on the environment.

Businesses dealing with dismantled, reused components can create jobs in local communities. They can also support the local economy by providing opportunities for local trade and services to develop. The use of reused components can reduce the amount of electronic waste going to landfill, which can contribute to environmental protection and reduce the burden on landfills. The need for reuse encourages the development of new methods and technologies for more efficient recovery and recycling of components [20]. In doing so, it can promote innovation and development in the industry.

Together, these positive effects can contribute to a more economically sustainable and environmentally friendly industrial practice, benefiting both companies and society in the long term. Of course, while the reuse of dismantled, used electrical components can bring many benefits, it is also important to mention some potential drawbacks.

The quality and reliability of reused components may vary. Although some of the parts used still meet the technical requirements, others may already be outdated or damaged, which may reduce their performance and reliability [21]. The use of outdated or damaged components can pose safety risks, especially in critical applications such as medical devices or aviation systems. Failure or improper operation of these components can lead to serious consequences.

Reused components can cause compatibility issues with new systems or applications. This may be particularly true in cases where recycled components are not fully compatible with the technical requirements or interfaces of new systems.

Although reuse can reduce the use of raw materials and energy to manufacture new parts, recycling processes themselves can have environmental impacts. For example, the use of energy and chemicals for reuse processes can increase environmental pressure.

Reuse may often be limited for certain types of components, such as components used in complex or specialised systems for which there is no widespread market for reuse.

In addition, it is important to note that the effects of reusing dismantled, used electrical components depend on the specific industry, technologies used, and local regulations. Therefore, it is important to carefully weigh the pros and cons in each individual case and take appropriate measures to reduce any potential risks.

Conclusion

Microcontroller-controlled spot welding machines are an important component of today's industrial processes that perform precision welding tasks on various materials. In this study, the design and operational aspects of the equipment were reviewed, highlighting the possibilities of using recyclable components.

The equipment operates in accordance with its intended purpose. The user does not experience any operating difficulties on it, and the software also works reliably.

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References

[1] Németh György. Széchenyi University. Hegesztési eljárások

[2] Rozovits Zoltán. Ívhegesztés műveletei, alkalmazása és a varratok készítése. Javítástechnológiai feladatok. 2277-06 A

[3] S. Ardabili, B. Beszedes, L. Nadai, K. Szell, A. Mosavi and F. Imre, "Comparative Analysis of Single and Hybrid Neuro-Fuzzy-Based Models for an Industrial Heating Ventilation and Air Conditioning Control System," 2020 RIVF International Conference on Computing and Communication Technologies (RIVF), Ho Chi Minh City, Vietnam, 2020, pp. 1-6, doi: 10.1109/RIVF48685.2020.9140753.

[4] Alexander Baklanov, Svetlana Grigoryeva, György Györök. Control of LED Lighting Equipment with Robustness Elements, Acta Polytechnica Hungarica (1785-8860 1785-8860): 15 3 pp 105-119 (2016)

[5] G. Gyorok and M. Mako, "Configuration of EEG input-unit by electric circuit evolution," 2005 IEEE International Conference on Intelligent Engineering Systems, 2005. INES '05., Spain, 2005, pp. 255-258, doi: 10.1109/INES.2005.1555168.

[6] Aizhan Zhaparova, Dimitry Titov, Alexander Y. Baklanov, Gyorgy Gyorok. Study of the Effectiveness of Switching-on LED Illumination Devices and the Use of Low Voltage System in Lighting. Acta Polytechnica Hungarica (1785-8860 1785-8860): 12 5 pp 71-80 (2015)

[7] Mosavi Amirhosein, Bertalan Beszedes, Imre Felde, Nadai Laszlo, Gorji Nima E. Electrical characterization of CIGS thin-film solar cells by two- and four-wire probe technique. MODERN PHYSICS LETTERS B 2020 p. 2050102 , 16 p. (2020)

[8] S. Kimathi, B. Lantos. Modelling and Attitude Control of an Agile Fixed Wing UAV based on Nonlinear Dynamic Inversion, Periodica Polytechnica Electrical Engineering and Computer Science, Vol 66(3), 2022, pp. 227-235

[9] S. Kimathi, B. Lantos. Quaternion based attitude control of a maneuvering fixed wing UAV, IEEE 26th International Conference on Intelligent Engineering Systems (INES), pp. 261-266, 2022.

[10] I. Bendiák and T. Sándor, "Possible Ways of Measuring and Calculating Waste Heat from a Machine Diagnostic Approach," 2023 IEEE 6th International Conference and Workshop Óbuda on Electrical and Power Engineering (CANDO-EPE), Budapest, Hungary, 2023, pp. 000259-000266, doi: 10.1109/CANDO-EPE60507.2023.10417972.

[11] I. Bendiák and S. Semperger, "Simplified Predictive Strategy of Mechanical Life Cycle Model in Three-Phase Asynchronous Motor," 2023 IEEE 6th International Conference and Workshop Óbuda on Electrical and Power Engineering (CANDO-EPE), Budapest, Hungary, 2023, pp. 000267-000274, doi: 10.1109/CANDO-EPE60507.2023.10417977.

[12] I. Bendiák and T. Sándor, "Comparison of the propulsion of electric vehicles for passenger cars and buses in terms of efficiency optimization," 2021 IEEE 4th International Conference and Workshop Óbuda on Electrical and Power Engineering (CANDO-EPE), Budapest, Hungary, 2021, pp. 173-176, doi: 10.1109/CANDO-EPE54223.2021.9667858.

[13] Thermo-dynamic Cycle Computation of a Micro Turbojet Engine. Fozo, L; Andoga, R and Kovacs, R. 17th IEEE International Symposium on Computational Intelligence and Informatics (CINTI). 2016 17TH IEEE International Symposium on Computational Intelligence and Informatics (CINTI 2016) , pp.75-79

[14] Pődör, A., & Kertész, K. (2023, November). Analysis of health data using geospatial methods in Székesfehérvár, Hungary. In *2023 IEEE 23rd International Symposium on Computational Intelligence and Informatics (CINTI)* (pp. 391-396). IEEE.

[15] Pődör, A., & Szabó, S. (2021). Geo-tagged environmental noise measurement with smartphones: Accuracy and perspectives of crowdsourced mapping. Environment and Planning B: Urban Analytics and City Science, 48(9), 2710-2725. https://doi.org/10.1177/2399808320987567

[16] Judit Módné Takács, Monika Pogátsnik. A Comprehensive Study on Cybersecurity Awareness: Adaptation and Validation of a Questionnaire in Hungarian Higher Technical Education. Acta Polytechnica Hungarica 21 : 10 pp. 533-552. , 20 p. (2024)

[17] Tóth Peter, Pogatsnik Monika. Advancement of inductive reasoning of engineering students. Hungarian Educational Research Journal (HERJ) 13 : 1 pp. 86-106. , 21 p. (2023)

[18] Biswajit Debnath, Priyankar Roychowdhury, Rayan Kundu. Electronic Components (EC) Reuse and Recycling – A New Approach towards WEEE Management. Procedia Environmental Sciences. Volume 35. 2016. Pages 656-668. ISSN 1878-0296. https://doi.org/10.1016/j.proenv.2016.07.060.

[19] Wang, H. (2002/09//). Using component knowledge base - a framework for building an electrical service system with reusable components. *Asia Pacific Management Review, 7*(3) Retrieved from https://www.proquest.com/scholarly-journals/using-component-knowledge-base-framework-building/docview/1115662723/se-2

[20] M. Tavakoli, P. AlhaisLopes, A. Hajalilou, A. F. Silva, M. ReisCarneiro, J. Carvalheiro, J. MarquesPereira, A. T. deAlmeida, 3R Electronics: Scalable Fabrication of Resilient, Repairable, and Recyclable Soft-Matter Electronics. Adv. Mater. 2022, 34, 2203266. https://doi.org/10.1002/adma.202203266

[21] Conti, Massimo, and Simone Orcioni. 2020. "Modeling of Failure Probability for Reliability and Component Reuse of Electric and Electronic Equipment" *Energies* 13, no. 11: 2843. https://doi.org/10.3390/en13112843