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EXPERIMENTAL STUDIES ON STABILITY OF POWER SOURCE – ARC SYSTEM OF MAG WELDING PROCESSES

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***Abstract*—** The physical phenomena taking place in the arc column during various processes of MAG and MIG welding depend on both the welding conditions and the electrical parameters of the power source – arc system. This paper presents some results of the experimental studies on the stability of power source – arc system under controlled, artificially simulated disturbances of a welding process, similar to such, that might have occurred under real welding conditions. An advanced method of registration of such data as the pictures of the metal transfer modes across the arc column with the use of high-speed camera synchronized with the current and voltage waveforms in the welding circuit has been applied during the course of experiments. Basic technical details of the advanced method of data acquisition as well as the analysis of obtained results are also presented.

***Keywords*—** arc stability, artificial disturbances, GMA welding, welding monitoring.

I. INTRODUCTION

Physical phenomena taking place in the welding arc strongly depend on electrical parameters of the welding power source – the arc system. This dependence is particularly significant while new processes of MAG (Metal Active Gas) welding method, such as low-energy ones and a suitable equipment for their application is used. Since those processes such as CMT (Cold Metal Transfer, low energy welding with pulsed electrode wire feeding) or pulsed current welding have been applied in industrial practice for the last few years all phenomena and mutual relation between arc stability and process parameters are not well known. At a given welding conditions determined by the kind of base metal, type and diameter of electrode wire, chemical composition of shielding gas and wire extension phenomena taking place in the arc column influencing its stability depends strongly on the static and the dynamic characteristics of the power source being used. Assessment of the arc stability determining the process stability with the use of conventional methods based on both output static and dynamic characteristics assessment [1], [4], [9], [10] shows usually good power source properties. In many cases this is not in a good relation with the quality of the joint being welded. It results probably from the complexity of the equipment structures and properties of output parameters regulator devices that can control entire process of molten metal transfer across the arc column. Some problems with the identification of the correlation between electric parameters of welding circuit and stability of welding process may result from the assessment methods.

Therefore, new methods of assessment of process stability as well as properties of equipment applied with the reference to modern welding processes should be found. Such research activities have been carried on in the Welding Engineering Division of Warsaw University of Technology. In order to fulfill research requirements, an innovative computer controlled apparatus for static and dynamic characteristic of welding power supplies as well as power source - arc systems has been designed and implemented [2], [3], [6], [7], [8]. The apparatus controller was designed on the base of LabVIEW software applications. The example of measuring results obtained with the use of the described apparatus of a welding power source output static characteristics is shown in fig. 1 and a dynamic characteristics with advanced transformation of acquired data in fig. 2.

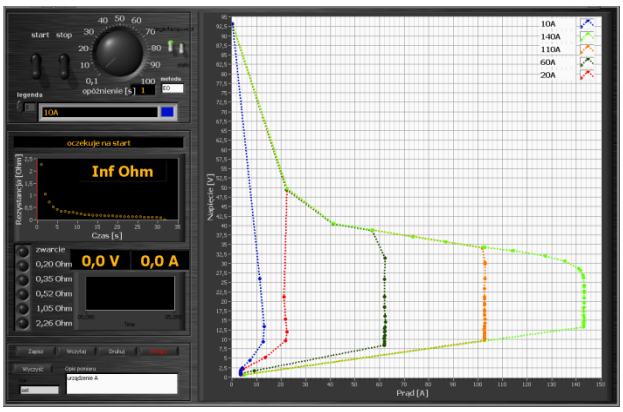


Fig. 1. An exemplary window of the designed application for output static characteristics measurement of an inveter type welding power source.

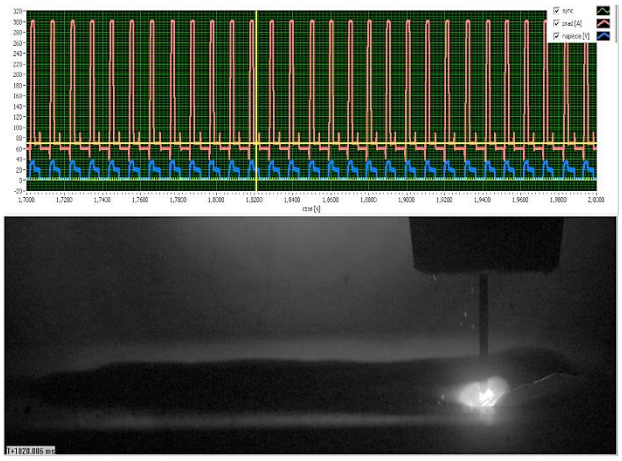


Fig. 2. An exemplary window of the designed application for the analysis of recorded waveforms with reference to welding process image registered by high speed camera.

Experiments and measurements being carried on with the use of the apparatus show that properly reckoned output static characteristics of power source may be still an important source of information concerning welding power source properties either of conventional and inverter structure. Good results of experiments have been achieved due to very fast, precise measurements of electric parameters values under controlled resistance load [6].

An application of high speed camera allowed for better observation of all phenomena taking place in the arc column during welding process (fig. 3).

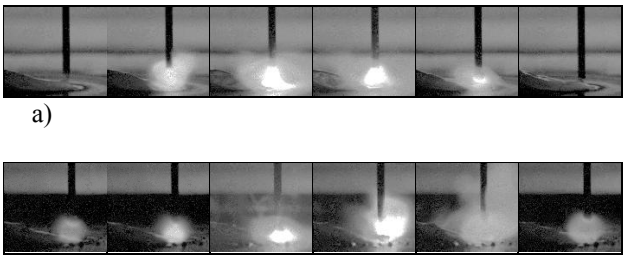
Reported here experimental studies on welding arc – power supply system stability were aimed to find relation between a disturbance of the process and the dynamic values of electric parameters in the welding circuit.

II. EXPERIMENT

A number of beads on plate welds have been done under controlled artificially introduced disturbances similar to such, which can occur under real welding conditions. Welding current, arc voltage waveforms have been recorded as well as the view of arc column has been observed with the use of high speed camera. All recordings were synchronized respectively as a function of time. The overall view of experimental set-up is shown in fig. 4. Two series of recordings were done as follows.

First one during bead on plate welding with the application of various MAG processes, four using numerically controlled inverter power supplies: MAG Pulse (synergic controlled pulsed current welding), CMT (Cold Metal Transfer), SYN (welding with non controlled arc but with synergic controlled output parameters of power source) and MAN (welding with non controlled arc and manually adjusted output parameters of analog controlled power source).

Second one during bead on plate welding with the application of three various MAG processes, one signed MAN from the first series and two of the same output power and with manually adjusted output parameters but different type of structure: diode rectifier and inverter.



a)

b)

Fig. 3. Cycle of metal drop transfer during CMT a) and MAG Pulse b)

Bead on plate welds of 60mm length on base metal – mild steel S235 specimens of 3.0mm thickness and dimensions 100.0 x 100.0mm were used. The shielding gas used was mixture of 82% Ar and 18%CO_2, electrode wire ESAB OK Autrod 12.51 dia. 1.0mm. Since bead on plate welds were done, the set of welding parameters was chosen as for welding the same thickness of base metal with full penetration.

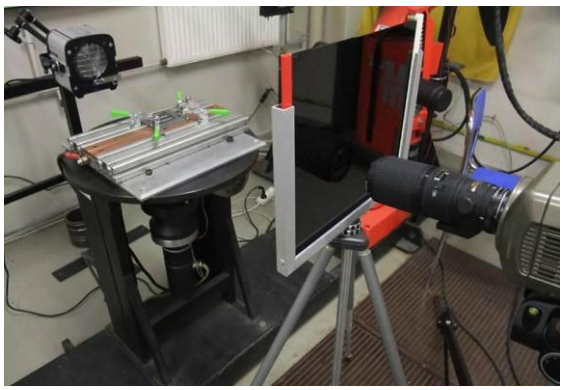


Fig. 4. Experimental set-up with high-speed camera

In order to obtained comparable results it was necessary to keep comparable welding conditions for all power sources being tested. Due to different types of power sources structure, different types of control systems, different procedures of control devices in inverters, the values of selected welding parameters were different for each of them. Therefore, it has been decided to keep two of all welding parameters constant, i.e. the speed of electrode wire feeding – Vdr and the speed of welding – Vsp. Welding parameters used in experiments are specified in table 1.

TABLE 1.
WELDING PARAMETERS APPLIED IN EXPERIMENTS

Parameter	value	unit
Welding velocity	4,6	m/min
Voltage	11,1	V
Current	110	A
Wire feed rate	6,8	m/min
Gas flow rate	17	l/min

III. RESULTS

Each of the welding parameters influences the welding process as well as the quality of welded joint. If only the average or RMS (Root Mean Square) values of welding parameters are taken into account, some significant information concerning stability of the process can be lost. Monitoring of the welding process is strongly related to the mode of molten metal transfer across the arc column. In short circuiting transfer, that is most typical for low energy MAG processes, each droplet caused dynamic change of current and voltage or is a result of controlled change (pulse) of current and voltage generated by the control device of power source. The example of the current pulse causing one drop transfer is shown in fig. 5, while real current and voltage waveform recorded for different MAG processes applied in described experiments are shown in fig. 7 to 10. The only problem to be solved is the choice of proper parameter or the component of the parameter obtained by processing recorded data related to arc and/or process stability.

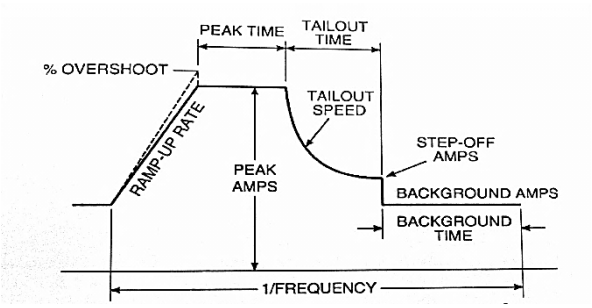


Fig. 5. Example of controlled welding current pulse in one pulse – one drop transfer [17]

The real waveforms of electrical signals strongly depend on the welding process being performed, type of power supply used, particularly its characteristics and control system as well as process parameters. Each of welding process as well as each of welding power supply requires an another attitude to be used for analysis. An exemplary welding current pulse of CMT process and corresponded arc space image from high speed camera are shown in fig. 6.

Detailed analysis of electrical signals recorded during welding process allow for identification the criteria for recognition phases of metal transfer across the arc column. Next, they allow for an algorithm to be designed for an automatic identification of particular phases of metal drops transfer. An analysis of electrical parameters of each phase allow in further studies for an assessment of welding process stability and might be a complementary method with regards to already existing methods.

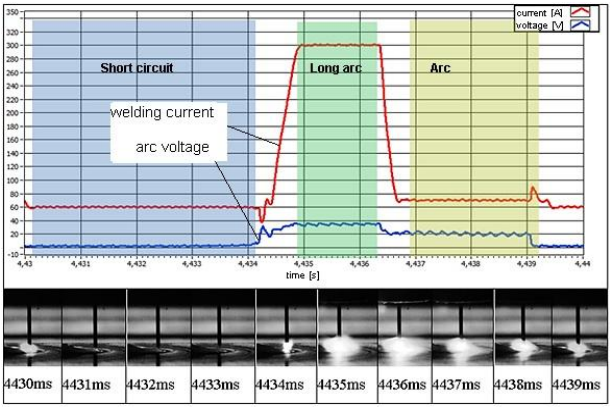


Fig 6. Detailed analysis of single cycle drop transfer for CMT welding [18]

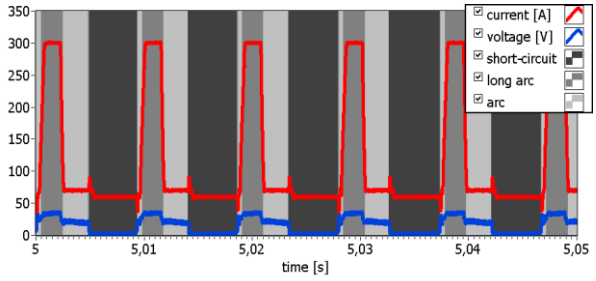


Fig. 7. Current and voltage waveforms recorded during CMT welding with marked phases of cycles of each droplet transfer

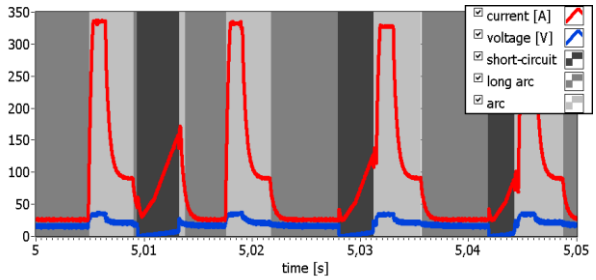


Fig. 8. Current and voltage waveforms recorded during PULSE welding with marked phases of cycles of each droplet transfer

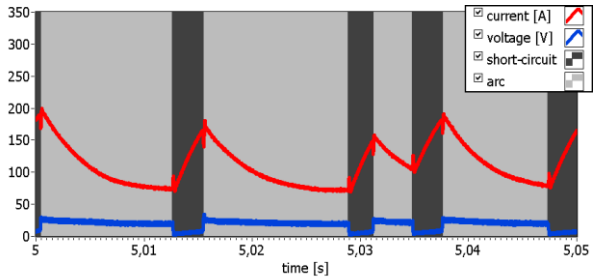


Fig. 9. Current and voltage waveforms recorded during welding with the use of synergic controlled power source and marked phases of short circuiting by molten droplet and arcing time periods.

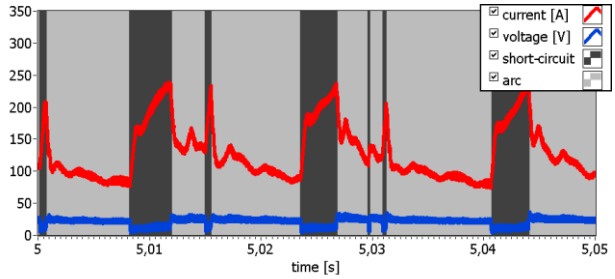


Fig. 10. Current and voltage waveforms recorded during welding with the use of analog controlled power source and marked phases of short circuiting by molten droplet and arcing time periods

The exact analysis of recorded waveforms and split recorded values into components related to successive phases of every cycle of droplet transfer allow to assess the welding process stability. From recorded current and voltage waveforms within the time period of 0.05s can be observed that the frequency of metal transfer is highest for CMT process, lower for PULSE and the lowest for MAG welding with the use of synergic controlled power source. Any irregularities in metal transfer and/or welding parameters disturbances which may affect arc or process stability can be also identified. The stable process is characterized by stable values of all process parameters or ability for fast recovery after any disturbances, if occurred. If stability of welding process depends not only on current and voltage values but also on the shape of current waveforms, they also should be monitored.

IV. CONCLUSION

The course of experiments described here has proven a good performance of the computer controlled apparatus with measuring and recording application in LabView software for static and dynamic characteristic of welding power supplies as well as power source - arc systems analysis, designed and implemented to practice in the Welding Engineering Division of Warsaw University of Technology. It can be easily synchronized with high speed camera for full determination of welding process stability. The obtained results of the welding process stability and quality of welded joints done by various MAG processes being a first stage of the investigation program allow to find the correlation between welding process disturbance that may cause a weld imperfection and dynamic values of welding current and/or arc voltage. This requires advanced methods of welding parameters waveforms registration and application of proper method of recorded data processing. Identification of such correlation might be used for on line monitoring of welded joint quality as well as pointing out the type and the location of possible weld imperfection. Both kind of MAG welding process and kind of disturbance of welding process requires different method of process instability identification. The described here results of the experimental studies of welding arc – power supply systems stability proves the possibility of such identification. For this purpose a catalog showing the probable disturbance and coresponding signal should be identified and proposeed for any of welding proceess.

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