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Influence of weld imperfection on short circuit GMA welding arc stability

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Monitoring of welding process can play important role in on line quality control of welding process. It is very important to find quick and save method of analysing recorded, during monitoring, data. Two signals: momentary arc power and momentary arc resistance were included into analyse and results of analyse were compared with the results of statistic analyse of welding current and welding voltage. Sensitivity of signals to artificial disturbances of welding arc was tested. The results show that it is possible to detect applied disturbance in analysed signals.

1. INTRODUCTION

Welding process can be characterised by four sets of parameters: set of parameters that describes the property of base metals and consumables, set of parameters that describes burning of welding arc, set of parameters that describes configuration of welding electrode - base metal system and set of parameters that describes property of welding machine. Some of welding parameters, that are thought to be input parameters for welding process, as a result of interaction with welding process receive new feature and can be treated as signals carrying information about welding process. Welding voltage, welding current and welding wire speed in the case of short circuit metal transfer are examples of those parameters. Those parameters are modulated by through the arc metal transfer during short circuit GMA welding process.. Simplicity of welding voltage and current measurement is the reason why those parameters are the most frequently used for monitoring and evaluation of welding process quality. Recording and analysing of welding parameters let us test directly conditions of welding arc burning and also process of molten metal transfer from electrode to weld pool. We can assume that properties of base metal, consumables and also properties of welding machine do not change during execution of welding, whereas changes in geometrical configuration between an electrode and welded metal influence the condition of welding arc. In that case we can simplify the welding process to model in which quality of welded joint first of all depends on stability of arc.

2. STABILITY OF GMA WELDING ARC

Welding arc can be thought as a cylinder like shape bounded by barrier of temperature gradient. It is kept in equilibrium if all acting forces are in equilibrium [1]. Three main forces which control over the equilibrium in the arc region are: surface tension force, electromagnetic force and gravitational force. Leaving the state of equilibrium can be caused by liquid metal transport through the welding arc or disturbance of gaseous shield of welding arc. At the beginning of metal transfer the surface tension force resist detachment of molten droplet hanging at welding wire and when the droplet touches the welding pool the force change their direction. The electromagnetic power results in flow and rotation of medium that conduct the electric current. Influence of electromagnetic force in the surrounding of molten electrode tip is known as a Pinch effect that supports detachment of liquid droplet from wire.

Intensive spatter, frequent arc stubbing and resistant-explosive melting of wire are the external symptoms of welding arc stability loss. The energy balance during gas metal arc welding with short circuit metal transfer is negative. The temperature of molten welding pool and surrounding material goes down during short circuit. When the short circuit is too long the temperature of arc area is too low for supporting emission of electrons and following welding arc ignition. Conditions of arc ignition are strongly influenced by chemical composition of the shielding gas and presence of oxide film on welded metal surface. The areas rich of oxide films have low emission work.

Research of welding process stability are curried on by testing characteristics of signals recorded during welding. Testing of mean value and standard deviation of welding voltage and welding current is in common use [2,3]. Some researchers [4] test statistic characteristics of short circuit and arc burning time, for example standard deviation of instantaneous short circuit frequency can be used as a measure of welding arc stability. Authors [4] admit that expressed in that way criterion of arc stability depends on other welding parameters.

Other criterion of GMA arc stability was presented in [5]. At first authors present results of earlier research in which as a criterion of arc stability were proposed the variation of time intervals between transfer of succeeding molten droplets from a wire to welding pool [6], or standard deviation of welding current maximum values [7]. Other research results are also cited [8], in which probability density plots of welding parameters are used for estimation of welding process stability. Similar criterions of arc stability are presented in [9]. For analysis of metal transportation through the welding arc the theory of welding pool oscillation was exploit [5]. The theory was presented in [10] and also exploit in [11]. The most important conclusion coming from that theory is, that the most favourable condition for welding can be observe when the standard deviation of short circuit frequency reach the minimum value [10]. In the same article two conditions of stable arc burning are put into words: wire velocity equal to wire feed velocity and transport of molten metal from electrode to welding pool should not disturb the burning of welding arc. In the work [12] time of short circuit and time of arc burning were investigated by calculation of their mean values and standard deviations. The coefficient of variation was defined as quotient of standard deviation value and mean value. Range of welding parameters in which coefficient of variation riches its minimum value is recognise as range that corresponds to the most stable arc. In following paper [13] authors changed their opinion, and proposed [13,14] different approach to this problem. Standard deviation of each loop at U-I plot that correspond to cycle of each droplet transfer from electrode to welding pool was proposed as a measure of welding arc stability. Plot of defined in this way stability factor against welding parameters have a minimum value. It helps to evaluate the state of the welding arc and distance from actual parameters to optimal parameters.

3. EXPERIMENTS

Artificial disturbance of welding arc stability were introduced during weld execution. Welding current and welding voltage were recorded with a speed 4000 samples per second to detect influence of disturbance on welding parameters. Four artificial disturbances were tested:

- the lack of shielding gas
- the layer of grease on the top surface of joint
- the layer of paint on the top surface of joint
- too narrow root gap
- too wide root gap

Tests were made on butt weld joints made of S235 structure steel. Each test joint was 250 mm long, 90 mm wide and 5 mm thick. Angle of V bevel was 45 degree and width of root gap was 1.2 mm. Each disturbance was applied two ore three times at the same joint and the length of disturbance was 30 mm each time. Distance between disturbances was 40 mm. Joints were welded by gas metal arc welding with shielding gas M21 and G382CG3Si1 wire of diameter 1.2 mm. Welding parameters were the same for all joints: welding current 120 - 130 A, welding voltage 18 V, welding speed 266 – 275 mm/min and wire extension 15 mm.

4. RESULTS AND DISCUSSION

For each test joint four signals were analysed: welding current (I) , welding voltage (U), momentary power of arc (UMI) and momentary arc resistance (UDI). Welding voltage signal was used to calculate time of short circuit (TZ), time of arc burning (TJ) and frequency of short circuit (FZW). Statistical features of each signal were calculated separately for area of weld with disturbances and area of weld free of disturbances. Two coefficients were calculated. The first coefficient (WWBW) expresses quotient of mean value of statistical feature in the area of weld where disturbance was applied and mean value of statistical feature in the area of weld free of disturbance. The second coefficient (WWC) expresses quotient of mean value of statistical feature in the area of weld where disturbance was applied and mean value of statistical feature calculated for all length of weld. Results of that calculation are presented in table 1.

GMA is a welding process in which heat for melting the base metal and wire is transferred form arc where electrical energy is changed to thermal energy. Monitoring of welding current and welding voltage does not represent completely thermal processes which are essential for evaluation of welding process stability. UMI and UDI signals, that represent

Table 1.
Relative change of statistic features of tested signals in the weld area with disturbances

	Relative values						
	Variance of welding voltage	Variance of welding current	Variance of arc burning time	Variance of arc short circuit time	Frequency of short circuit	Variance of UMI	Variance of UDI
Disturbance: lack of gas shield							
WWC[1]	1.85	1.64	0.15	1.38	1.55	1.50	2.12
WWBW[2]	4.09	2.88	0.18	4.15	2.40	2.78	307.90
Disturbance: layer of paint							
WWC[1]	1.53	1.39	0.66	3.25	1.06	1.00	1.52
WWBW[2]	2.04	2.96	7.63	130.80	1.01	1.91	1065.76
Disturbance: layer of grease							
WWC[1]	1.22	1.48	4.29	4.57	1.03	1.18	0.93
WWBW[2]	1.35	2.90	35.95	81.48	0.96	2.15	634.51
Disturbance: too narrow root gap							
WWC[1]	1.00	1.01	1.11	0.86	0.96	1.01	1.02
WWBW[2]	0.97	1.04	1.65	0.81	0,89	1.00	1.01
Disturbance: too wide root gap							
WWC[1]	1.37	2.13	4.27	6.25	0.63	1.63	2.62
WWBW[2]	1.49	4.97	70.22	326.70	0.51	2.99	1274.82

[1] WWC expresses quotient of mean value of statistical feature in the area where disturbance was applied and mean value of statistical feature calculated for all length of joint.
[2] WWBW expresses quotient of mean value of statistical feature in the area where disturbance was applied and mean value of statistical feature in the area free of disturbance.

"the thermal element" of welding process are included in to the analyse to check if they are more suitable for finding areas of joint where imperfections are expected. It is necessary to notice that lack of shielding gas is a disturbance which influences recorded signals all the time, in the contrary to too wide root gap which influences recorded signals only at beginning and end of disturbance. Analysis of result presented in table 1 shows that in most cases signals of UMI and UDI better indicate areas where disturbances were applied, especially when WWBW coefficient is investigated.

Different approach to analyse of signals emitted by welding process is presented in fig. 2. In this case recorded signals are divided into samples. Each sample represent 500 recorded values (0.125 sec.). Mean value of statistical features of samples were smoothed by moving average method. Similar to previous result area in which arc disturbances were applied are revealed better in UMI UDI signals.

5. CONCLUSIONS

Monitoring of GMA welding process by digital recording and analysis of welding parameter enable to detect imperfection related to phenomena that take place in welding arc. There are two types of disturbances that meet mentioned requirements: imperfections that affect gas shield of arc and disturbances that affect length of wire extension. Lack of shielding gas, layer of grease, layer of paint affect the gas shield of welding arc. Oxygen, nitrogen and hydrogen as components of air or decomposition products of grease and paint change the welding arc shield properties. They influence the ionisation potential, surface tension, condition of arc ignition, power of arc and other essential conditions of arc burning. Imperfections that influence the wire extension are related to electrode – base metal system. This type of imperfections ,for example burn through, change the resistance of welding circuit. Unfortunately it is more difficult to find this kind of imperfection because they effect recorded signals only at start and end of imperfection.

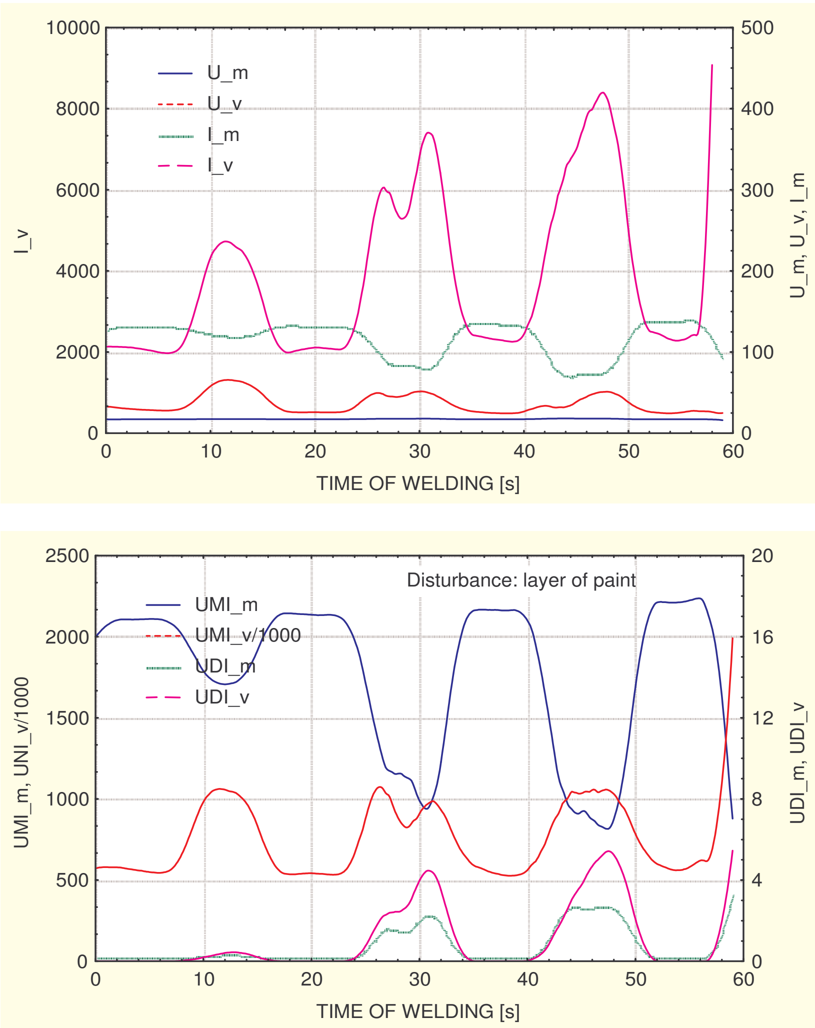
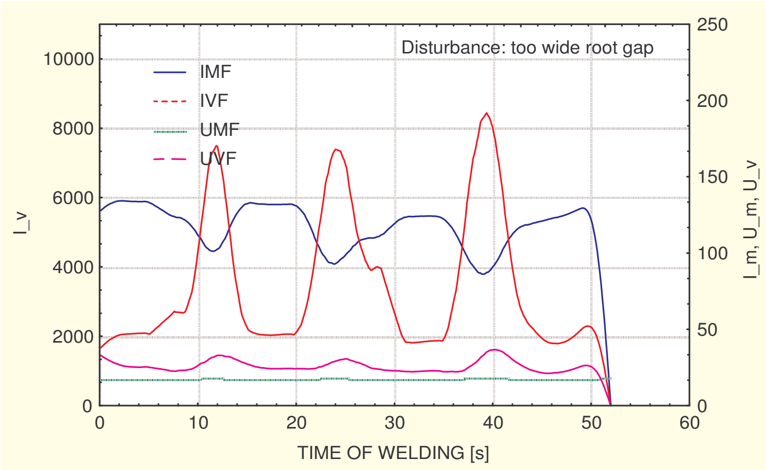


Fig. 1. Mean value (_m) and variance (_v) of welding voltage (U), welding current (I), momentary power of arc (UMI) and momentary arc resistance (UDI). Disturbance: layer of paint.

Two methods of detection of both types of imperfections was tested in the paper. Signals of welding current, welding voltage, arc power and arc resistance were tested. Artificial disturbance of welding arc stability were detected in tested signal. Not all signals react on arc disturbance in the same way and intensity. It means that it is better for full detection to analyse all signals for proper detection of welding imperfection, but there is a chance of identification the imperfections by using all signals simultaneously.



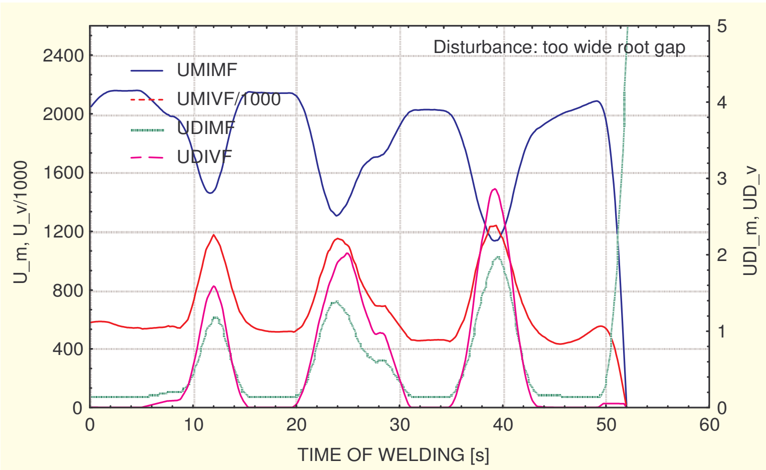


Fig. 2. Mean value(_m) and variance (_v) of welding voltage (U) welding current (I), momentary power of arc (UMI) and momentary arc resistance (UDI). Disturbance :

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