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NEW APPROACH FOR MODELLING OF THE WELDING PROCESSES

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ABSTRACT
The applying of new technologies is connected with considerable outlays to receive the optimal welding regimes, metallographic research of welding seams, joint quality control and other facilities, which can be considerable lowered, using modelling of the welding processes.
We propose to use new approach for modelling – analogue modelling, which is based on process investigation, using logical functions. Some practical applying examples of the analogue modelling are offered in this paper. The analogue model of the heat input during resistance welding of wires with coating is described in detail. Using analogue modelling we can solve direct problems of thermal conductivity, it mean that we can predict temperature field, obtained as a result of influence of welding source of heat. The effectiveness of analogue modelling using is proven.
Keywords: welding, analogue modelling, temperature field

1. INTRODUCTION
The development of instrument engineering and industries, where welding processes are widely used, demands the elaboration of new technological solutions. It must be noticed that applying of traditional procedures for elaboration of new solutions such as intuitive method, statistical approach, fragmentary logic analysis, and optimization on the basis of the system analysis can take the significant time and capital inputs and may be unsecussful.
Analogue (non-discrete) modelling is a new approach for modelling of the welding processes. This method was proposed by R.B.Rudzit [1] and was successfully used by authors and other researches, for example:
1. In research of process of cold shear soldering of copper plate through easily Melted metal coatings [2].
2. In optimization of resistance welding of copper wire with kovar tube [3].
3. In investigation of the contact resistance in contact microwelding [4].
4. In modelling of the dynamic contact resistance in resistance microwelding [5].
The main advantage of this method is that the application of system analysis by logical functions allows describing the causal and effect relationships between large numbers of parameters of the welding technological process. Performing the modelling we can predict the quality level of goal

function of the modelling without testing, in result the outlays for receiving the optimal welding regimes, metallographic research of welding seams, joint quality control and other facilities, considerable lowered. That's why for investigation of the heat input during resistance welding of wires with coating we decide to use analogue modelling. Using analogue modelling we can solve direct problems of thermal conductivity, it mean that we can predict temperature field, obtained as a result of influence of welding source of heat.

2. ANALOGUE MODEL OF THE HEAT INPUT DURING THE RESISTANCE WELDING OF WIRES WITH COATING

The analogue modelling of the heat input during the resistance welding (Q) of wires with coating was elaborated [6]. The structural logical analysis scheme of Q characteristic is shown in Figure 1. The logical analysis is performed until the stage, where the function's arguments are variable parameters we are interested in.

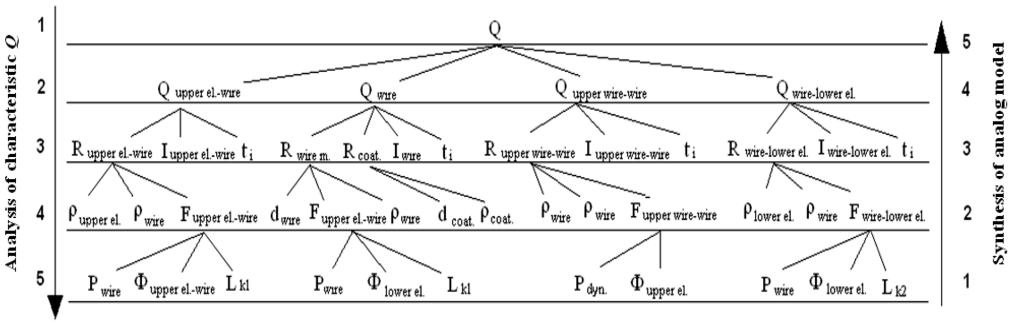

Figure 1. Structural logical analysis scheme of Q characteristic.

After the analysis of the characteristic of welding process the analogue model synthesis is executed by consecutive substitutions of parameters-arguments of the subsequent step of analysis in directly determinated by them parameters-functions of the previous step of analysis. In result complicated multiparametric process considered as system of elementary physical phenomena combined by the causal and effect relationships. As a result of all substitutions, the analogue formula of Q characteristic is defined:

$$
\begin{aligned}
Q = f\Big(&\Big|_5^1\Big|_4^1\Big|_3^1\Big|_2^1\Big|_1^1 P_{wire} /+/ \underset{P_{wire\text{-}0}}{\exists}\Phi_{upper\ el.} /+/ L_{K_1}\Big|_1 /+/ \rho_{upper\ el.} /+/ \rho_{wire}\Big|_2 /\cdot/ J_{upper\ el.-wire} /\cdot/ t_i\Big|_3\Big|_4 /+/ \\
&/+/\Big|_4^2\Big|_3^2\Big|_2^2\Big|_1^2 P_{wire} /+/ \underset{P_{wire\text{-}0}}{\exists}\Phi_{upper\ el.} /+/ L_{K_1}\Big|_1 /+/ d_{wire} /\cdot/ \rho_{wire}\Big|_2 /+/ b_{coat} /\cdot/ \rho_{coat}\Big|_2^3 /\cdot/ J_{wire} /\cdot/ t_i\Big|_3\Big|_4 /+/ \\
&/+/\Big|_4^3\Big|_4^3\Big|_2^4\Big|_1^3 P_{dyn} /+/ \Phi_{upper\ el.}\Big|_1 /+/ \rho_{wire} /+/ \rho_{wire}\Big|_2 /\cdot/ J_{upper\ wire\text{-}wire} /\cdot/ t_i\Big|_3\Big|_4 /+/\Big|_4^4\Big|_3^4\Big|_2^5\Big|_1^4 P_{wire} /+/ \\
&/+/ \Phi_{lower\ el.} /+/ L_{K_2}\Big|_1 /+/ \rho_{wire} /+/ \rho_{lower\ el.}\Big|_2 /\cdot/ J_{wire\text{-}lower\ el.} /\cdot/ t_i\Big|_3\Big|_4\Big|_5\Big).
\end{aligned}
\tag{1}
$$

where P_{wire} – static pressure on the wire; $\Phi_{upper\ el.}$, $\Phi_{lower\ el.}$ – shape parameters of upper and lower electrodes; Lk_1, Lk_2 – the length of contact surface between upper and lower electrodes and wire; $I_{upper\ el.\text{-}wire}$, I_{wire}, $I_{upper\ wire\text{-}wire}$, $I_{lower\ el.\text{-}wire}$ – the current passing through resistance of upper electrode - wire contact, wire, resistance of wire - wire contact, resistance of wire - lower electrode contact; t_i – welding current impulse time; $P_{dyn.}$ – dynamic pressure.

Item-by-item examination of various combinations of variable parameters as well as analysis of possible solutions for managing the characteristics $Q_{upper\ el.\text{-}wire}$, Q_{wire}, $Q_{upper\ wire\text{-}wire}$, $Q_{lower\ el.\text{-}wire}$ allows finding the optimal solution for regulation and projecting the amount of heat Q. So, the choosing of strategic decisions from table of enumeration of possibilities was made. During examination the 131076 possible solutions were analyzed. The fragment of graph with compared situations, which have levels of *Q* characteristic different from previous, is shown in Figure 2.

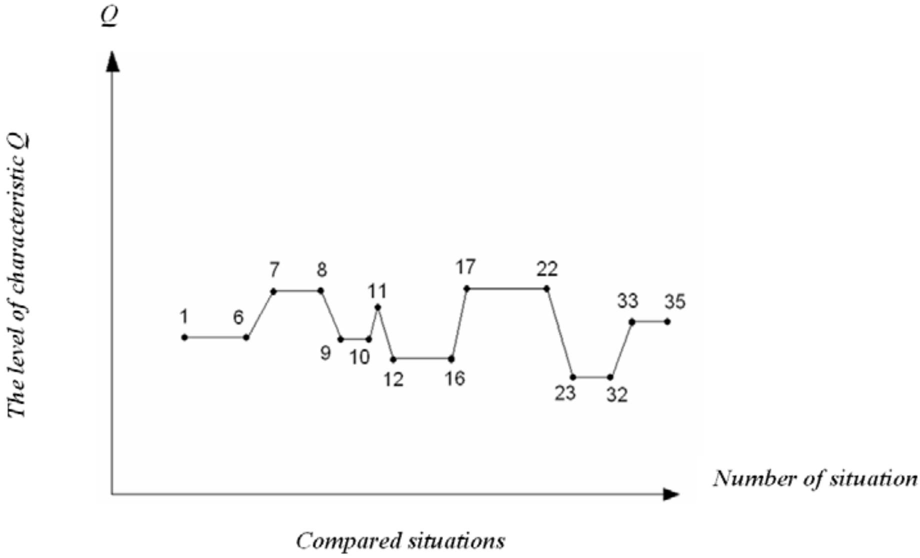

Figure 2. Graph of compared situations (fragment).

Taking into account the generally accepted recommendations for the resistance welding of materials with low-melting coatings (for example, tin coating) we can conclude that the development of generalized solution is necessary to analyze the situations, which provide a decreasing of the level of *Q*. In the case of welding materials with high-melting coatings (for example, nickel coating) is necessary to analyze the situations, which provide an increasing of the level of *Q*.
Generalized solution:
1) For the resistance welding of materials with low-melting coatings we choose situation number 23 (Fig.2.), which provides a light mode of welding. The parameter of the coating thickness is recommended with higher level (i.e. thicker);
2) For the resistance welding of materials with high-melting coatings we choose situation number 76, which provides a heavy mode of welding. The parameter of the coating thickness is recommended with lower level (i.e. thinner).

3. EXPERIMENTAL

Experimental testing of elaborated generalized solution was made on experimental welding equipment for the widespread combination of cross-welded wires: 1) copper wires ∅ 0.2 mm coated with tin (thickness 3 mm); 2) copper wires ∅ 0.2 mm coated with nickel (thickness 5 mm).
The cross-welds of copper wires coated with tin is characterized by formation of a common welding zone in the contact zone with the disappearance of the interface (Fig.3a). The molten tin was displaced outside of the contact zone with the formation of fillets (Fig.3b,c). This formation mechanism is connected with a lower melting point of tin (232^0C) in comparison with the melting point of copper (1083^0C). The welded joints are characterized by a stable strength in a wide range of working capacity of capacitors.
Cross-welds of copper wires coated with nickel (melting point 1455^0C) is characterized by the formation of the compounds in the solid phase through the nickel coating with it partial melting (Fig.3d). However, in this case to achieve optimal results must strictly observe the welding mode - in case of any deviations the lack of penetration and splash were observed.

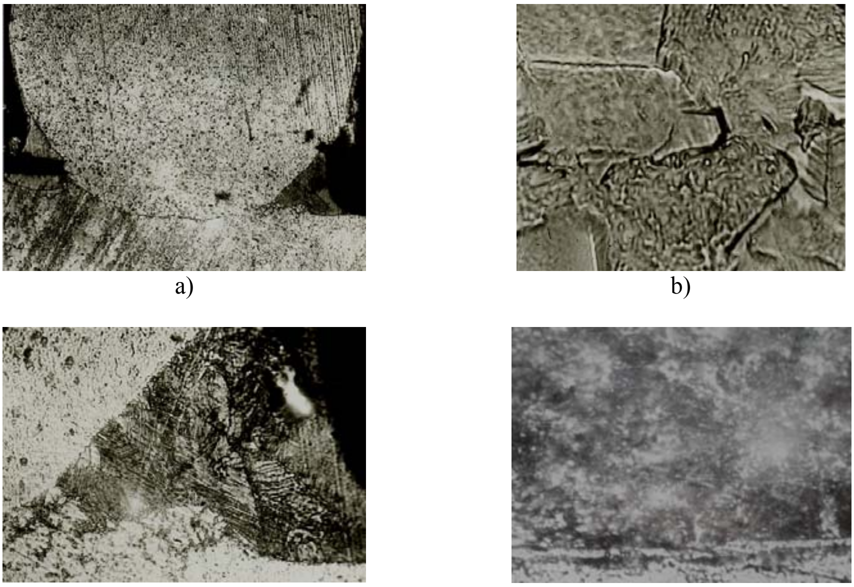

Figure 3. Micro section of welds of copper wires coated with tin: a) weld with fillet (x100); b) welding zone (fragment, x600); c) fragment with fillet (x600); d) micro section of welds of copper wires coated with nickel (x600).

4. CONCLUSION

A new approach for modeling of welding process, analogue modeling, is offered. The analogue model of the heat input during resistance welding of wires with coating is described. Based on an analogue model the generalized solution for optimal heat input during welding is developed that allows obtaining high quality welds. Experimental testing of model in the case of resistance welding of copper wires with tin and nickel coatings was prove the effectiveness of obtained analogue model.

5. ACKNOWLEDGEMENT

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