16th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2012, Dubai, UAE, 10-12 September 2012

SOFTWARE APPLICATION IN ANALOG MODELING OF SPOT RESISTANCE WELDING

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ABSTRACT
Research is connected with elaboration of the calculating module VarWELD, using MS Excel software, for item-by-item examination of various combinations of variable parameters of spot resistance welding as well as analysis of possible solutions for managing the characteristics of the process. Mentioned examination is one of the main stages of analogue modeling. Analogue modeling is new perspective approach for modeling of welding processes, based on process investigation, using logical functions. Application of analogue modeling in investigation of welding process allows predicting the quality level of goal function of the modeling 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. The procedure of analogue modeling using calculating module VarWELD is offered. The effectiveness of analogue modeling using VarWELD is proven.
Keywords: spot resistance welding, analogue modeling, software

1. INTRODUCTION
Resistance Spot Welding (RSW) is widely used in industry for its high speed, relatively low cost and good applicability for automation. One of the main problems is the predictable and stable quality of the welds. To solve this problem welding specialists have to optimize and improve used welding procedures or elaborate more effective procedures.
In these activities the experimental (trial and error) as well as experience and statistical approaches steel dominate in practice [1,2]. But such approach in the case of solving technical problem which need the elaboration of more effective procedures can take the significant time and capital inputs and may be unsuccessful. That's why use, for example, of artificial intelligence applications like the artificial neural networks are been used to model the RSW process [3]. Finite Element Method (FEM) is widely used for prediction, for example, the weld nugget size and nugget formation for RSW [4,5] or to analyze the transient thermal behaviors of RSW process and to predict the temperature distributions as a function of time and location for any position in the weldment using the FEM [6]. Also in predicting stress distribution, stress concentration and failure modes of a weld-bonded or a spot welded nugget, finite element (FE) modeling was employed [7,8]. Also modeling and fuzzy control of the welding process were used in practice [9,10]. For the optimization of the RSW process the Taguchi method is widely used, for example, in work [11]. However, with this method the desired results can only be obtained with the use of very discrete control factors, thus leading to uncertainty about the real optimum [12].
We propose to use a new perspective approach for modeling of welding processes, based on process investigation, using logical functions: the analogue modeling. This method was proposed by

R.B.Rudzit [13] and was successfully used by authors earlier [14-16]. 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. Application of analogue modeling in investigation of welding process allows predicting the quality level of goal function of the modeling without testing.

2. ANALOGUE MODELLING

In general the sequence in analogue modeling is the following (Fig.1):

1. Analysis of the characteristics of the RSW process in the manner, when each characteristic is described as analogue logical function of two (or more) nearest parameters (characteristics). The logical analysis is performed until the stage, where the function's arguments are variable parameters we are interested in.
2. The kind of analog logical function is defined by tabulation and analysis of the truth-value tables.
3. 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. Analogue model contains all quality information about changes of level of output (goal function) during any changes of level of input variable parameters.
4. At the next stage the enumeration of possible situations using analogue model must be done. Then the choosing of strategic decisions from table of enumeration of possibilities can be easily done: from all possible situations the situations with increased value of output should be choosed and analyzed.
5. Based on choosed strategic decision(s) the experimental testing must be done, using any method of planning of the experiments. Amount of experiments will be very low, because principal optimal solution was finding earlier during analogue modeling.

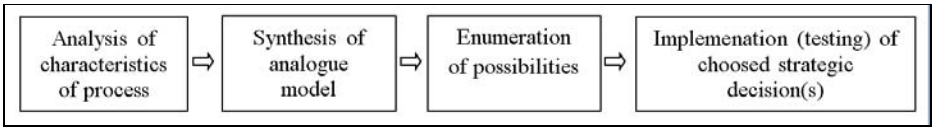

Figure 1. Basic stages of analogue modeling

The method of analogue modeling used in this study can be easily extended to many kinds of welding processes and others manufacturing technologies.

3. SOFTWARE APPLICATION FOR EXAMINATION OF ANALOGUE MODEL

The elaboration of the analogue model of the heat input during resistance welding of wires with coating is described in details in [15,16]. The fragment of the structural logical analysis scheme of *Q* characteristic is shown in Figure 2.

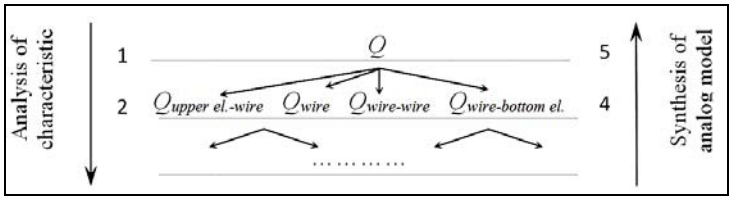

Figure 2. Structural logical analysis scheme of Q characteristic (fragment)

The calculating module VarWELD, using MS Excel software, was elaborated for item-by-item examination of various combinations of variable parameters of RSW as well as analysis of possible

solutions for managing the characteristics of the process. The procedure of analogue modeling using calculating module VarWELD is the following:

1. Analysis of the characteristics of the RSW process.
2. Synthesis of analogue model (formula).
3. Input the achieved formula into the VarWELD.
4. Item-by-item examination of various combinations of variable parameters (Fig.3). In analogue modeling logical functions describe qualitative not quantitative relationships between parameters: symbol "0" interpreted not as "no", but as "decreased value" and symbol "1" interpreted not as "yes", but as "increased value". By this way it is possible to describe non-discrete process with logical functions [13].

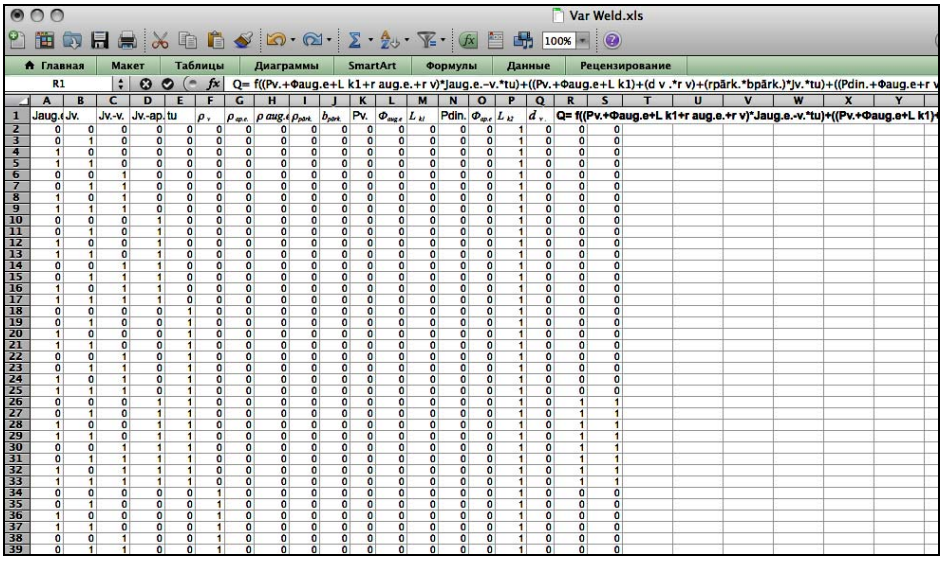

Figure 3. View of working sheet of the calculating module VarWELD (fragment)

5. After examination of possible situations (in these case were 131076 possible situations) calculating module choose the situations, which provide a decreasing (or increasing) of the level of output characteristic of process (Fig.4).

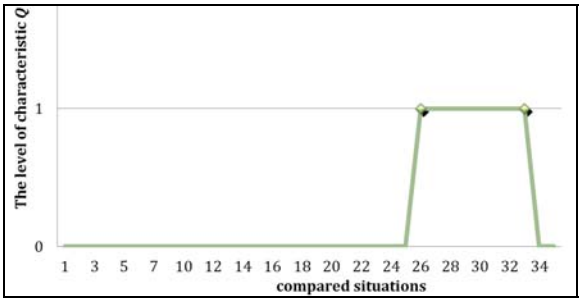

Figure 4. Graph of compared situations (fragment)

6. Chosen situations, which provide the desired level of goal function of analogue modeling, must be analyzed. As a result of analysis the logically verified original solution will be developed.
7. Experimental testing for optimization of the parameters of welding process within the elaborated strategic solution.

The significant decreasing of the time of analogue modeling could be achieved by using of calculating module VarWELD. In the future it is planned to supplement this module with additional functions, which will help in the beginning stages of analogue modeling: in analysis of the characteristics of the process and in the synthesis of analogue model (formula).

4. CONCLUSION

Analogue modeling is especially efficient in development of new welding technological processes and in optimization of known processes. The procedure of analogue modeling using calculating module VarWELD is offered. This calculation module allows fast realization of the item-by-item examination of various combinations of variable parameters of the RSW process. After examination of all possible situations the calculating module VarWELD automatically choose the situations, which provide a decreasing (or increasing, if necessary) of the level of output characteristic of process. Chosen situations serve as a basis of elaboration of the justified strategic solution, which provide the welding joints of high quality.

5. ACKNOWLEDGEMENT

This work has been supported by the European Social Fund within the Project Nr. 2009/0201/1DP/1.1.1.2.0/09/APIA/VIAA/112 “Nanotechnological research of the mechanical element surface and internal structure in mechanical engineering”.

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