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MODELING OF THE DYNAMIC CONTACT RESISTANCE IN RESISTANCE MICRO WELDING

Irina Boyko
Riga Technical University, Mechanical Engineering Institute
Ezermalas 6, LV-1006, Riga
Latvia
Tel./Fax +371 7089701
e-mail: irinaboyko2000@yahoo.co.uk

Alexander Filipov
Riga Technical University, Mechanical Engineering Institute
Ezermalas 6, LV-1006, Riga
Latvia

ABSTRACT
The non-discrete logical model of the dynamic resistance in resistance micro welding is offered. The dynamic characteristic of contact resistance reflects the changes of contact resistance during heating process and deformation of the contact zone.
The investigation of the dynamic characteristic of contact resistance was made by the method of the non-discrete logical modeling. In the non-discrete logical modeling the complicated multiparametric process (micro welding) considered as system of elementary physical phenomena combined by the causal and effect relationships. Here the elementary physical phenomena were distinguished by the system analysis, for describing of causal and effect relationships between large numbers of parameters of the welding technological process the logical functions were used.
It is shown, that the dynamic characteristic of contact resistance depends on the surface quality parameters, the welding conditions (welding current and dynamic pressing effort), characteristics of diffusion process and the physical properties of welded materials as well.
The acquired NL-model can be used as separate model to qualitative a priori analyzing the changes of the dynamic characteristic of contact resistance or can be used in subsequent investigation of resistance welding process. The goal of integrated study of resistance micro welding is the optimization of existing processes and elaboration of new summarized solutions that could provide the welds of high quality.
Keywords: non-discrete logical modeling, micro welding, contact resistance

1. INTRODUCTION
Resistance spot welding is a commonly used resistance welding process. Resistance welding and micro welding uses the application of electric current and mechanical pressure to create a weld between two pieces of metal. Weld electrodes conduct the electric current to the two pieces of metal as they are forged together. The welding cycle must first develop sufficient heat to raise a small volume of metal to the molten state. This metal then cools while under pressure until it has adequate strength to hold the parts together. The current density and pressure must be sufficient to produce a weld nugget, but not so high as to expel molten metal from the weld zone.
The main advantages of resistance welding are: easily automated process; economical; suitable for high rate production; high productivity etc. One of the main problem that we have to solve is the investigation of junction formation mechanism with goal to search the possibilities to weld dissimilar

materials by resistance welding – hence, to the future resistance welding using extension.
The process of resistance spot micro welding is a very complicated object to research, that's why integrated investigation and description of characteristics of resistance spot micro welding by existing mathematical methods is quite complicated and not achieved at this time.
One of the main factors in the formation of the weld is the contact resistance that directly influences on thermal field. If the thickness of details is smaller then the contact resistance significantly influences on welding process (especially in micro welding), on weld quality.
Existing formulas do not reflect physics of welding process, for example:

- Holm's formula:

$$R_C = \frac{2\rho K_{a+b}^{a-b}}{\pi(a+b)}, \tag{1}$$

where ρ – specific electrical resistance of material; a and b – axes of elliptic contact patch; K_{a+b}^{a-b} – first elliptic integral.

- Empiric formula

$$R_C = \frac{R_{1C}}{P^{\alpha}}, \tag{2}$$

where R_{1C} – contact resistance at unit pressing force P ; α – coefficient inclusive the influence of all variable parameters!
So, now we can more or less precisely calculate the contact resistance, but we don't now which contact resistance value is optimal in concrete case, how the contact resistance influence on weld quality.

2. NON-DISCRETE LOGICAL MODELLING

We decide to use the method of the non-discrete logical modelling (NL-modelling) for describing contact resistance characteristics [1-3]. 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.
Principles of NL-modelling (Fig.1.):

- Complicated multiparametric process considered as system of elementary physical phenomena combined by the causal and effect relationships.
- Elementary physical phenomena distinguished by the system analysis.
- Logical functions are used for describing of causal and effect relationships between large numbers of parameters of the welding technological process use. Function is the immediate corollary, but logical arguments – causes.
- Non-discrete logical functions describe qualitative 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.

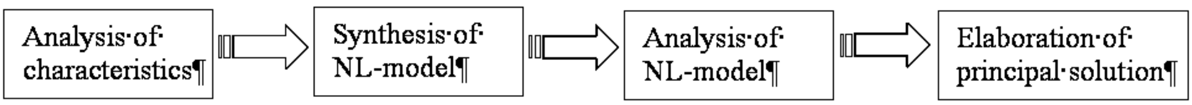

Figure 1. Sequence of non-discrete logical (NL) modeling

So, at the first step of analysis the contact resistance R_c is described as NL-function of two nearest characteristics: static (initial) characteristic of contact resistance R_{st} and dynamic characteristic of contact resistance R_d:

$$R_c = f\Big|\ R_{st} /+/ \exists_{R_{st}-1} R_d\ \Big|. \qquad (3)$$

The NL-formula of static characteristic of contact resistance R_{st} were determined by the authors earlier [4]:

$$R_{st} = \Big|^{1}_{6}\Big|^{1}_{5}\Big|^{1}_{4}\Big|^{1}_{3}\Big|^{1}_{2} R_a /\cdot/ \Big|^{1}_{1} S /\cdot/ \bar{S}_m \Big|_{1}\Big|_{2} /+/ \Big|^{2}_{2} L /\cdot/ R /\cdot/ R_a /\cdot/ \bar{\gamma} \Big|_{2}\Big|_{3}\Big|_{4} /\cdot/ \Big|^{2}_{4} \bar{P}_{st} /\cdot/ \sigma_{cond} \Big|_{4}\Big|_{5} /+/$$
$$/+/ \Big|^{2}_{5}\Big|^{3}_{4} h_a \Big|_{4} /\cdot/ \Big|^{4}_{4} \bar{P}_{st} /\cdot/ \sigma_{ad} \Big|_{4} /\cdot/ \Big|^{5}_{4} \rho_{ad} \Big|_{4}\Big|_{5} /+/ \Big|^{3}_{5} \varepsilon \Big|_{5}\Big|_{6} \qquad (4)$$

The goal of this work is elaboration of NL-formula for dynamic characteristic of contact resistance.

3. NL-MODEL OF THE DYNAMIC CONTACT RESISTANCE

The dynamic characteristic of contact resistance reflects the changes of contact resistance during heating process and deformation of the contact zone. At the first step of analysis the dynamic characteristic of contact resistance R_d is described as NL-function of three nearest common parameters: dynamic parameter of form of contact F_d, dynamic parameter of electro resistance R_d and dynamic parameter of adsorbed coat resistance R_{coat}:

$$R_d = f\big|F_d /+/ R_d /+/ R_{coat}\big|. \qquad (5)$$

Then the parameter of form of contact F_d is represented as NL-function (6) of integrated form parameter, duration of surface roughness deformation and duration of contact zone heating up to melting.

The scheme of the analysis and synthesis of NL-model of the dynamic parameter of form of contact F_d is shown on Figure 2, where:

D_{heat} – parameter of duration of surface roughness deformation in contact;
D_{dur} – parameter of contact zone heating up to melting temperature;
P_{heat} – integrated form parameter;
T_m – melting temperature;
C_{heat} – specigic heat parameter;
λ – specific thermal conduction;
σ_{cond} – resistance to deformation of conductor material;
P_{st} – static pressure;
I – welding current;
ρ_{cond} – electroresisitivity of conductor material;
$\alpha_{\rho cond}$ – thermal coefficient of electroresistivity of conductor material;
α_{cond} – theraml coefficient of resistivity to deformation of conductor material;
R_a – surface roughness parameter.

$$F_d = \Big|^{1}_{4}\Big|^{1}_{3}\Big|^{1}_{2}\Big|^{1}_{1} I \Big|^{1}_{1} /+/ \Big|^{2}_{1} \rho_{cond} /\cdot/ \alpha_{\rho cond} \Big|_{1} /+/ \Big|^{3}_{1} \bar{L} \Big|_{1}\Big|_{2} /+/ \Big|^{2}_{2} \bar{C}_{heat} \Big|_{2} /+/ \Big|^{3}_{2} \bar{T}_m \Big|_{2} /+/ \Big|^{4}_{2} \bar{\lambda} \Big|_{2}\Big|_{3} /+/ \Big|^{2}_{3}\Big|^{4}_{1} R_a \Big|_{1} /+/$$
$$/+/ \Big|^{5}_{1} \bar{\sigma}_{cond} /+/ \bar{\alpha}_{cond} \Big|_{1} /+/ \Big|^{6}_{1} \bar{P}_{st} \Big|_{1}\Big|_{3} /+/ \Big|^{7}_{1} R_a \Big|_{1}\Big|_{4} \qquad (6)$$

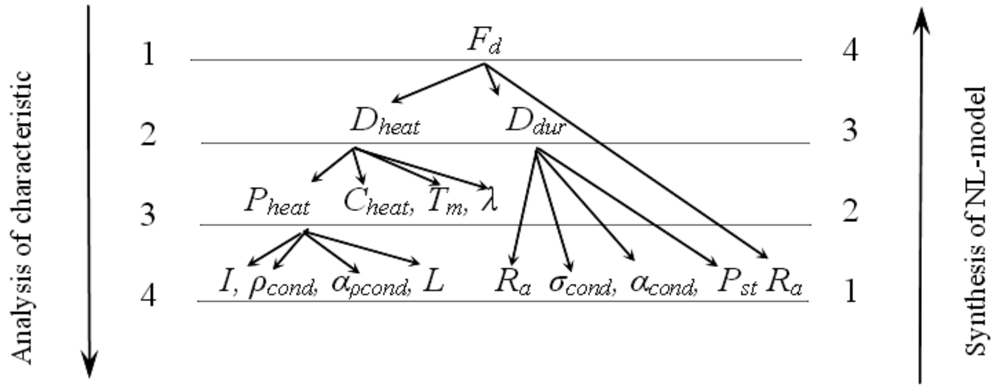

Figure 2. The scheme of the analysis of the parameter of form of contact F_d and synthesis of it's NL-model

The following step in integrated investigation will be the modeling of the dynamic parameter of electro resistance R_d and dynamic parameter of adsorbed coat resistance $R_{coat.}$ Preliminary investigations are shown that mentioned parameters depends on physical properties of welded materials, characteristics of diffusion process and welding conditions.

Then the investigation of the temperature field at resistance micro welding will be performed. The goal of integrated investigation is the optimization of existing processes and elaboration of new summarized solutions that could provide the welds of high quality.

4. CONCLUSIONS

1. The NL-model of dynamic parameter of form of contact F_d have been developed.
2. It is shown, that the dynamic characteristic of contact resistance depends on the surface quality parameters, the welding conditions (welding current and dynamic pressing effort), characteristics of diffusion process and the physical properties of welded materials as well.
3. The following step in integrated investigation could be the modeling of the temperature field at resistance micro welding. The goal of integrated investigation is the optimization of existing processes and elaboration of new summarized solutions that could provide the welds of high quality.

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