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Mathematical Model and the Simulation of Electrical Arc Welding as Moving Source in Protector Gas Welding

The works presents the mathematical model of electrical arc welding, simulation of the electrical arc as a moving source with help programs software Ansys, passing through three stage of simulation: pre- processing, processing (solution) and post-processing.

1. Introduction

The development of welding as a technological process of combining the metallic material in the latest 10 – 15 years is undoubtedly connected to the development of welding of protective gases generally, and the GMA welding.

During an electrical arch welding operation, there are four types of processes activated:

a) thermal processes
b) mechanical processes
c) metallurgical processes
d) electromagnetically processes

2. The thermal analysis.

Generally, to a thermal analysis, as input size used caloric power of in the areas where transformations of a type of inner energy occur or values imposed by the temperatures in special areas of the considered domain (in discussion). Since this is obtained from the electrical conduction analysis, it can be said that any thermal analysis is a coupled analysis.

3. Modeling of moving source

The movement of the electrical arc welding as a moving source is reported to the replacing of a point P regarding a mobile system of reference $Ox_1y_1z_1$ rapported to the cartesian system of referrence Oxyz.

As an entrance measure it is used the heating developed in the time and volume unity which is called the specific caloric power (P).

This is distributed permanently in a volume of components placed all around the momentary position of the electrical arc and is move towards the welding seam during the welding process.

As a result, the variation in time and space of the caloric power must be known:

$$p = p(x, y, z, t) \quad (1)$$

Where:

x, y, z = the coordinators of the points where the electrical arc is placed within the time t. The problem raised here is of determining this function of the specific caloric power, considering the shape and the dimension of the welding Zone fusion.

There are many variants in the specialised literature.

The theoretical study of the welding bath shape has been by many researchers, including the Russian researchers Rikalin and Prohorov, who made equations of the isothermal surface corresponding to the melting temperature, surface that defines in fact the shape of the welding bath (Figure 1).

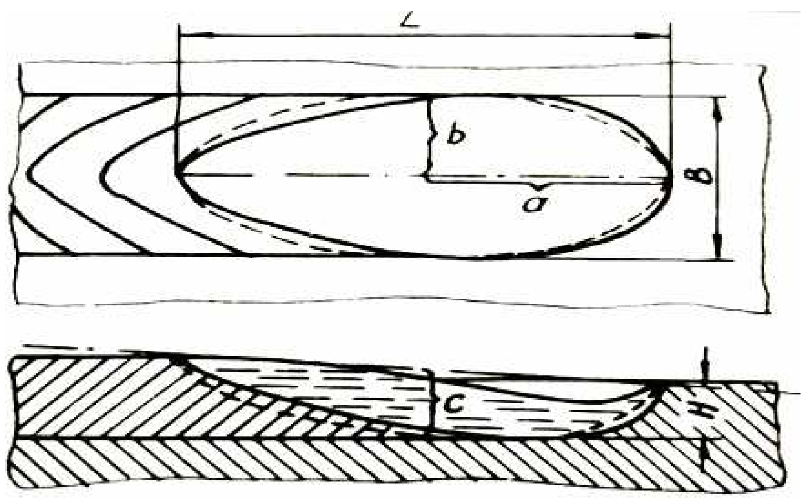

Fig.1 The shape of the welding bath

——— real - - - - - roughly, ellipse

The problem is very complex, since each welding process needs a special research, the profile in longitudinal and transversal section of the welding bath, be-ing determined by a series of factors connected to the characteristics of the process, the basis metal and the adding metal, the nature of the wire, the way of movement of the source.

However, many authors use a double ellipsoid proposed by the English researcher Goldak as a *tri-dimensional* model presented in Figure 2. The moving of the heating source has a double shape, permitting this way the absorption of heating in the area thermally influenced. The heating source consists of two elliptic areas called double *ellipsoid*, in which occur transformations from the solid phase to the liquid phase.

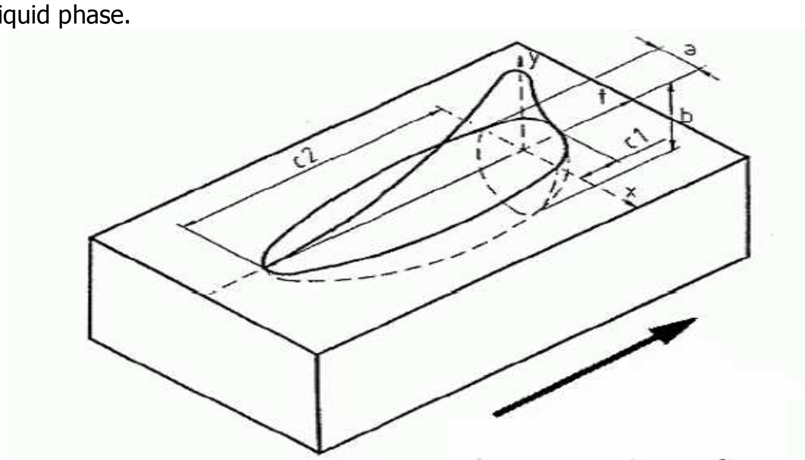

Figure 2 The model of the double ellipsoid

For the axis towards the welded seam, in the plan Oyz, the caloric power has a distribution of the Gaussian type:

$$p(x,y,z)=\frac{6\sqrt{3}f\cdot Q}{abc\pi^{3/2}}\cdot e^{-3\left(\frac{x}{a}\right)^2}\cdot e^{-3\left(\frac{y}{b}\right)^2}\cdot e^{-3\left(\frac{z}{c}\right)^2} \quad (2)$$

On the surface of the components the distribution is under the shape of an ellipsoid, that after the axis Ox has the semi-axis „a" and after the axis Oz has the semi-axis c_f, for the part in front of the welding arc, and c_r, for the part behind the arc

In the normal plan on the seam, that is the thickness of the piece(plan Oxy), after axis Ox the ellipsoid has the semi-axis a, and on Oy it has the semi-axis b.

It is also considered that, behind the source the maximum value of p, is p_{mr}, and in front of the source, the maximum value is p_{mf}. At the same time it is admitted that behind the source is developed a quantity of heating bigger than in the front.

For the points in front of the source, for z >0,

$$p = p_{mf} \cdot e^{-3\left(\frac{x}{a}\right)^2} \cdot e^{-3\left(\frac{y}{b}\right)^2} \cdot e^{-3\left(\frac{z}{c_f}\right)^2} \quad (3)$$

Where:

$$p_{mf} = \frac{6\sqrt{3}P_{f_f}}{a \cdot b \cdot c_f \cdot \pi\sqrt{\pi}} \quad (4)$$

For the points in the back of the source, for z ≤0

$$p = p_{mr} \cdot e^{-3\left(\frac{x}{a}\right)^2} \cdot e^{-3\left(\frac{y}{b}\right)^2} \cdot e^{-3\left(\frac{z}{c_r}\right)^2} \quad (5)$$

Where:

$$p_{mf} = \frac{6\sqrt{3}P_{fr}}{a \cdot b \cdot c_r \cdot \pi\sqrt{\pi}} \quad (6)$$

Equations where p, is that part developed in the electrical arc that contributed directly at the bath of the melted metal. f_f, f_r represent the fractions from P, which develop in the front, respectively behind the electrical arc.

At the same time, in order for the two expressions to be raccorded, for z=0, the following conditions must be met:

$$f_f + f_r = 2 \quad (7)$$

or: $f_f = \frac{2c_r}{c_f + c_r}$ (8)

or: $f_r = \frac{2c_f}{c_f + c_r}$ (9)

Since, $c_r > c_f$ results that $f_r > f_f$, that is it is supposed that behind the electrical is developed a quantity of heating bigger than in the front.

However, generally, the axes may be chosen arbitrary, so the expressions are considering the way these axes may be chosen.

Therefore:

- Axis Oz is replaced by the notation chosen towards the seam
- Axis Ox is replaced by the notation chosen on the normal surface of the components on the seam.
- Axis Oy is replaced by the notation chosen on the thickness of the seam

In this case we have chosen:

- x, towards the seam,
- z, on the surface of the components, so the final form is:

$$p = p_{mf} \cdot e^{-3\left(\frac{x}{a_r}\right)^2} \cdot e^{-3\left(\frac{y}{b}\right)^2} \cdot e^{-3\left(\frac{z}{c}\right)^2} \quad (10)$$

$$p = p_{mr} \cdot e^{-3\left(\frac{x}{af}\right)^2} \cdot e^{-3\left(\frac{y}{b}\right)^2} \cdot e^{-3\left(\frac{z}{c}\right)^2} \quad (11)$$

And the fraction parts are:

$$p_{mf} = \frac{6\sqrt{3} \cdot P_{ff}}{a_r \cdot b \cdot c \cdot \pi\sqrt{\pi}} \quad (12)$$

$$p_{mr} = \frac{6\sqrt{3} \cdot P_{fr}}{a_f \cdot b \cdot c \cdot \pi\sqrt{\pi}} \quad (13)$$

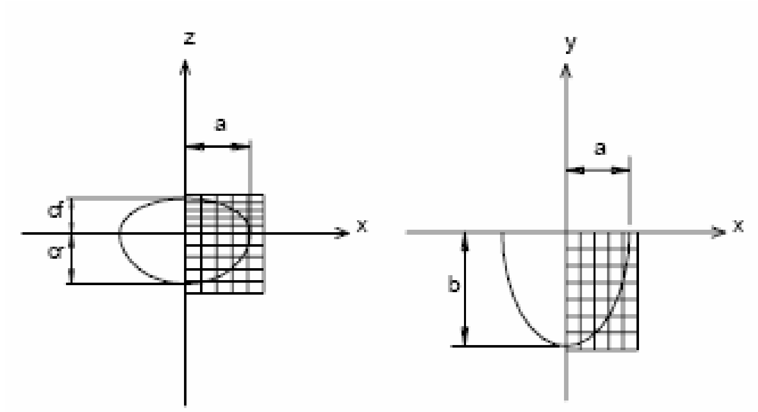

Figure 3. The discreditation of the thermic source

A special problem is the establishment of the values of the parameters of the semi-axes, a, b, c on which depend the maximum values p_{mf} şi p_{mr}. In the specialized literature it is stated that these values must be chosen so that after the simulation, on each position of the electrical arc, results the dimension of the melted metal bath, identical with that obtained experimentally.

But these parameters depend on many factors, which were mentioned previously. For this reason, through many attempts, we have established the following values for the parameters of the double ellipsoid, which can be seen in Table 1

Table 1. Parameters value of mathematical equation

Parameters	a_f	a_r	b	c	f_r	f_f
Value [m]	0,02	0,04	0,01	0,02	1,25	0,75

On the basis of the established values, we have passed to the simulation of the electrical arc as a moving source of welding.

The simulation of the heating flux of the front part of the model ellipsoid

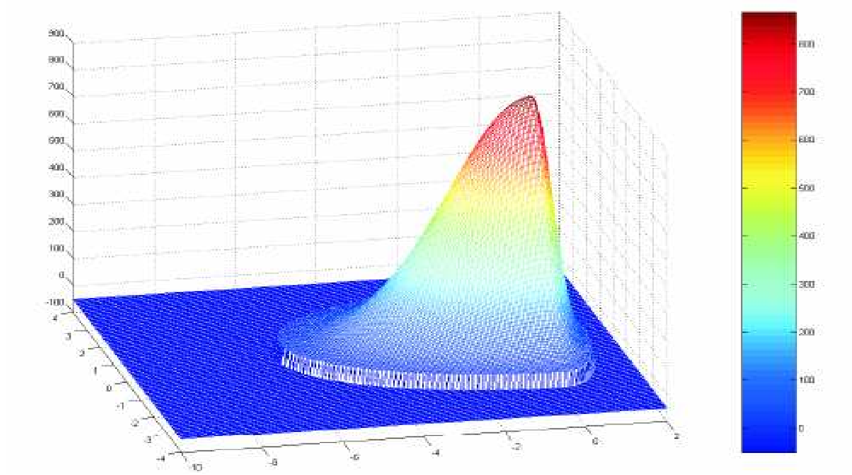

Figure 3. The distribution of the heating at the surface of the model source of the double ellipsoid

4. Conclusion

The validation of results was thoroughly satisfied by comparing the model with two experimental and analytical works, and can optimize the sequences of welding which have been specified for practical solutions.

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