

Determination of Parameters of Electrode Metal Transported Drops by Simulation and Visualization

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Abstract

The nature of the molten electrode metal melting and transfer is the main process parameter of manual metal arc welding (MMA) with coated electrodes. It significantly affects the efficiency of the welding process. For this reason the relevant task is to identify the parameters of the transferred molten electrode metal drops and their further transfer into the weld pool with maximum accuracy. The aim of the given paper is to develop a method and visual representation of the form and the geometrics (volume, area, mass) of a molten electrode metal drop.

We have developed the method of simulation modeling and visualization for molten electrode metal drops transfer and their parameters. It allows obtaining highly reliable input data to be used for developing and verification of mathematical models for the thermal fields distribution along the welded item surface. The algorithm is realized as the calculation programs for specifying the molten metal drop parameters and means of its geometrics and space form visualization.

We used this method to specify a number of molten electrode metal drop parameters: volume, mass, center-of-gravity position, surface area.

We have established that it is possible to conduct the measurements with maximum

The suggested method significantly decreases the labor intensity of experimental studies aimed at specifying the size of electrode metal drops in comparison to the standard methods. When we know the size of the drops under certain welding conditions we can control the drop transfer process, i. e. reduce the heat input into the welded item and produce weld joints with the tailored performance characteristics.

Keywords: MMA, a drop of molten electrode metal, parameters, simulation method, visualization.

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Определение параметров переносимых капель электродного металла методом имитационного моделирования и визуализации

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Основным технологическим параметром процесса ручной дуговой сварки, покрытым электродами, существенно влияющим на эффективность его протекания, является характер плавления и переноса расплавленного электродного металла. Поэтому актуальным является вопрос максимально точного определения параметров переносимых капель расплавленного электродного металла и их последующего перехода в сварочную ванну. Целью данной работы являлась разработка методики и визуального представления формы и геометрических параметров (объём, площадь, масса) капли расплавленного электродного металла.

Разработан метод имитационного моделирования и визуализации переноса капель расплавленного электродного металла и их параметров, что позволит получить входные данные с высокой степенью достоверности для разработки математических моделей распределения температурных полей по поверхности свариваемого изделия и её верификации. Алгоритм реализован в виде расчётных программ для определения параметров капли расплавленного металла и средств визуального представления её геометрии и пространственной формы.

С помощью данного метода определён ряд параметров капель расплавленного электродного металла: объём, масса, положение центра масс, площадь поверхности.

Установлено, что возможно с максимальной достоверностью производить измерения, увеличить число измеряемых параметров, а также наглядно представить происходящие процессы.

Предложенный метод значительно упрощает трудоёмкость проведения экспериментальных исследований по определению размера капель электродного металла в сравнении со стандартными методами. Зная размер капель при определённых режимах сварки, можно управлять процессом каплепереноса, т. е. уменьшать тепло-вложение в свариваемое изделие и получать сварные соединения с заданными эксплуатационными свойствами.

Ключевые слова: ручная дуговая сварка, капля расплавленного электродного металла, метод имитационного моделирования, визуализация.

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Introduction

The main technological parameter of the process of manual arc welding (MMA) with coated electrodes, which significantly affects the efficiency of its flow, is the nature of melting and transfer of molten electrode metal from the end of the electrode to the weld pool. The geometric parameters of the transferred droplets of molten electrode metal have a significant effect on the mechanical and operational properties of the welded joint. Determination of the regularities of the droplet transfer process, such as the formation and size of a drop at the edge of the electrode, makes it possible to create methods for controlling the volume of drops, choose the optimal options for implementing the technological process and serves as the basis for solving a wide range of practical problems.

Now, methods are used to study the transfer of electrode metal [1]: direct (separation and weighing of drops and X-ray and video filming) and indirect (oscillography of current and voltage), which are significantly laborious.

There are various methods for determining the size of drops of electrode metal based on the construction of mathematical models [2–4]. These methods used with various simplifications (assumptions), for example, the arc column is stationary and coaxial with the electrode, and a drop of molten metal has the shape of a segment or a glob, etc., which significantly reduce the reliability of the results obtained. The use of modern computational and graphic programs [5–7] makes it possible to perform calculations with a high degree of reliability and reduces the processing time of experimental data.

The aim of this work is to develop a method for determining the parameters (volume, surface area and mass) of the transferred drops of electrode metal through the arc gap of the MMA process using a software package.

Visualization of the manual metal arc welding with coated electrodes

We applied a numerical algorithm, visualization of molten electrode metal droplets transfer and specification of their dimensional parameters (volume, area, mass) to develop a simulation model of a molten electrode metal. The method of simulation and visualization will allow predicting heat input into the welded metal, as well as predicting the mechanical and operational properties of welded joints.

The construction of a spatial model of a liquid droplet of molten electrode metal was carried out on the basis of frames of high-speed video filming carried out earlier [8] using the Kompas 3D software package from ASCON.

An experimental setup for high-speed shooting and process oscillography shown in Figure 1.

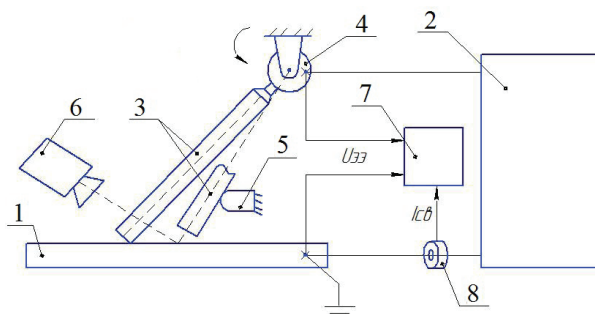


Figure 1 – The experimental setup for high-speed shooting and oscillography of the welding process: 1 – metal plate; 2 – power source; 3 – coated electrode, 4 – rotating electrode holder, 5 – electrode movement limiter, 6 – digital high-speed video camera, 7 – electronic oscilloscope, 8 – current sensor

A visual representation of the welding process and the transition of molten electrode metal droplets from the end of the electrode into the liquid weld pool presented in the form of filming and oscillograms shown in Figures 2 and 3, respectively.

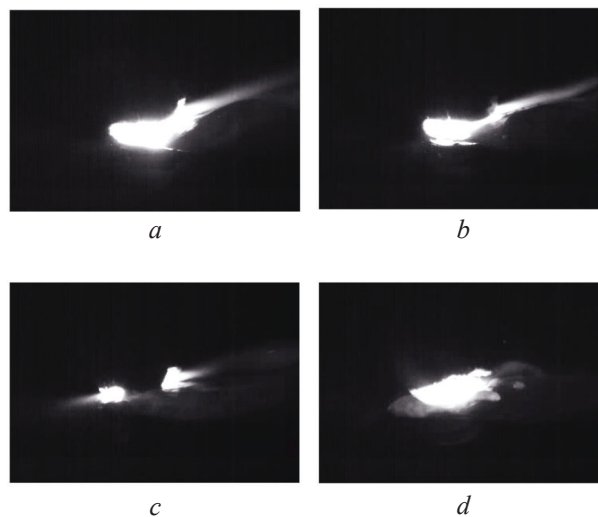


Figure 2 – Filming of the process of transferring drops of electrode metal during MMA: *a* – the beginning of the formation of a drop on the surface of the coated electrode; *b* – the growth of a drop of liquid metal on the surface of the electrode; *c* – drop transition from the electrode surface to the weld pool with the closure of the arc gap; *d* – the process of the onset of nucleation of the subsequent drop

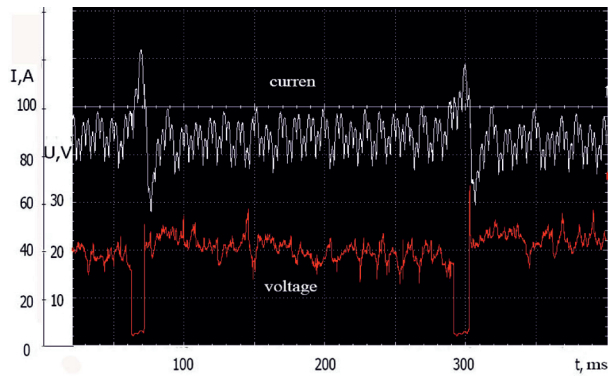


Figure 3 – Oscillograms of current and voltage (electrodes of the TsL-11 brand with a diameter of 3 mm, power supply VD-306)

Simulation modeling

In order to simplify the simulation, it was assumed, that in any section of the drop, by a plane perpendicular to the axis of the electrode, a simple geometric figure is obtained – a circle. In this case, the sequence of constructing the calculated visual model was as follows:

1. The image obtained during high-speed video filming (Figure 2) was opened in the program window, "Kompas 3D", where using the "spline" command, the contour of the liquid drop was visualized (Figure 4). At this stage, the scale of the construction is determined based on the actual size of the electrode (an electrode diameter of 3 mm was used).

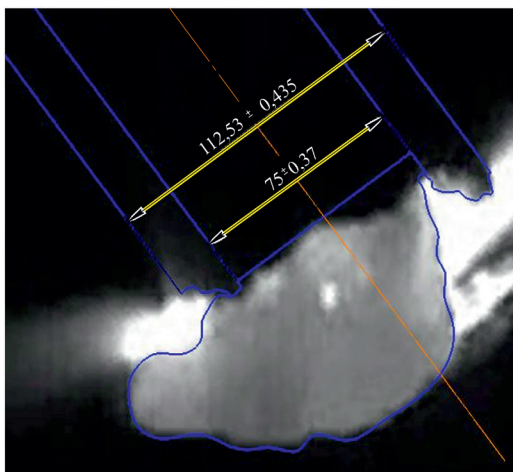


Figure 4 – Liquid drop contour

2. On the rendered contour of the drop, lines were drawn corresponding to the position of the future secant planes. At the same time, the lines were initially drawn in places where the direction

of the contour changed, then with the same interval between them.

3. The obtained image (Figure 5) was used to determine the diameters of the section circles and the position of the circle center relative to the axis coinciding with the electrode axis.

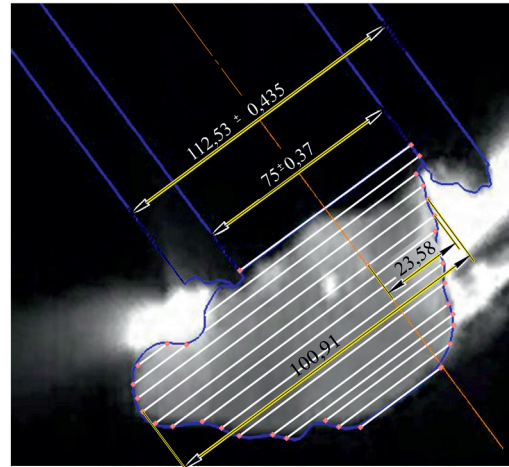


Figure 5 – Placement of secant planes

4. Simulation of the droplet volume was carried out in three-dimensional modeling mode in the "Kompas 3D" application. For this, a number of parallel planes were built (their position was determined in point 2) in which the droplet sections were constructed (according to the sizes determined in point 3). Then, using the "Lines" function, a volumetric body corresponding to the shape of a liquid drop was built (Figure 6).

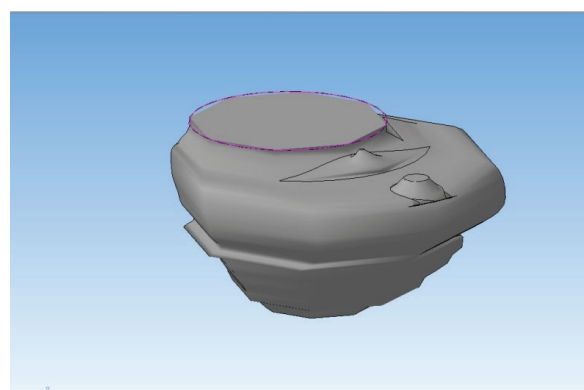


Figure 6 – Solid modeling of the spatial shape of a drop

5. Measurements were made of various parameters of the spatial model of the drop (volume, mass, position of the center of mass, surface area, etc., Figure 7) using the "MCM model" function presented in the "Kompas 3D" program.

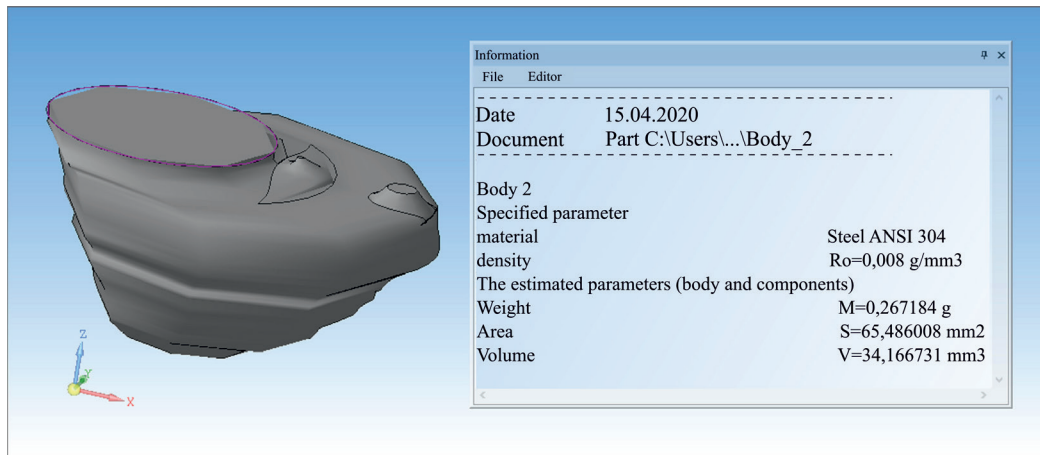


Figure 7 – Determination of the parameters of the spatial droplet model

Analysis of the method adequacy

The method of simulation modeling and visualization of a molten electrode metal droplet geometrics was tested by comparing the results obtained with the transferred drops parameters obtained by the indirect method [2] after oscillograms

processing (Figure 3) according to the following method [8].

The convergence of the results of theoretical studies and the amount of deposition recommended by the manufacturer of the electrode (table), according to: the proposed method – 5 %, the indirect method [8] – 23 %.

Table

Comparison of theoretical and experimental data of certain parameters of transferred drops

Data retrieval method	Electrode type, power supply	$t_{s.c} \cdot 10^{-3}$, sec	Drop weight m , g	Drop volume V , mm ³	Deposition coefficient a , g/A·h
Calculated, according to the methodology [8]	CL-11, diode rectifier	12 ± 3.8	0.37 ± 0.04	45.48 ± 4.9	13.6 ± 0.4
Visualization, according to the proposed method			0.264 ± 0.05	34.167 ± 2.5	10.5 ± 0.3
Manufacturer data*					11

*SpetsElectrode Company, <https://www.spetselectrode.ru/electrod/cl11.htm>

The proposed method will allow taking into account the peculiarities of the configuration of the transferred droplets when developing models: thermal processes during welding [9–11] and predicting the chemical composition and operational properties of the deposited weld metal [12], which increases its adequacy.

Conclusion

To determine the shape and size of a drop of molten electrode metal, a method of simulation and

visualization was developed, including a mathematical model, a spatial model of a drop of molten electrode metal using a computer program package. Using this method, a number of parameters of molten electrode metal droplets were determined: volume, mass, position of the center of mass, surface area. It was found, that the proposed method significantly simplifies the complexity of experimental studies to determine the size of drops of electrode metal in comparison with standard methods. Definition the droplet size for different welding modes allow to control the droplet transfer process, i. e. to reduce heat

input into the welded product and to obtain welded joints with specified operational properties.

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