PROMPT RATIONING OF MIG/MAG WELDING WORKS IN SERIES PRODUCTION

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Abstract The research on welding work in the conditions when products of different sizes, shapes and complexity are manufactured in series is performed in the work. The professional skills and abilities of welders of various qualifications in the production of parts with MIG/MAG technology have been tested. Video recordings of welding processes of various products have been collected and analyzed. The results of the observations were used to determine the time capacity of the welding work elements and to model the course of welding work. The aim is to find out the possibilities to calculate the time required for welding a specific product, using the test results and the technical documentation of the product. The dependence of individual elements of welding work on various factors is analyzed. An algorithm for calculating the welding time of different types of products has been developed. A method for determining the welding time for groups of products of different complexity by the welding angle and joint seams with MIG/MAG technologies has been developed. Theoretical calculations for the welding time of various parts have been made. Time consumption for analog parts was determined experimentally. The results were compared using mathematical statistical methods. It has been found that the technology used for the standardization of welding work allows to calculate the time required for welding the product with acceptable accuracy, using data from the technical documentation on the length of the seam, the number of parts and the cross-sectional area of the seam.

Keywords: welding works, modeling, rationing, calculations, video observations.

Introduction

Welding with MAG or MIG technology is used in the production of three-dimensional parts and assemblies in agricultural, utility and specialized machinery manufacturing companies with series production. The time required for the welding process can be determined by several methods. By recording the welding-related work with a stopwatch, it is possible to accurately determine and estimate the required welding time, the basic elements of the process, maintenance and other time required for the production of the current product [1]. The process is labour intensive, and the results obtained are not generalizable. The database management system software (SAP) [2] and the developed work plans include a description and sequence of individual activities, help identify business requirements, can automate and control business processes, but the use of the defined welding time is determined with too much error [3]. The work rationing methodology [4-6] is universal, developed for all life situations and is not applicable to such a specific technology as welding. The calculation algorithm for welding costs is also offered by a calculator [7], but it is product-specific and requires a large number of output parameters. A more specific methodology is proposed by the REFA group [8; 9]. The most commonly used REFA rationing methods are MTM (Methods – Time Measurement) [17] and instantaneous time recording. The aim of the work is to develop a methodology for operational rationing of welding work.

The duration of certain components of the welding process can be judged from observations during operation, such as video surveillance, which allows the exact duration of all elements of the use of the working time to be determined. The time norm N is determined by the formula [4]: $N = MH + MN + MZ + MP + ME$. The basic time in MH welding is summed from the seam formation time $MH1$ and the weld time $MH2$. The forming time $MH1$ depends on the length of the joints, the cross-sectional area and the melting rate of the additive. The time required for the welder to weld $MH2$ is estimated as the base time. The auxiliary time MN is inevitably associated with the basic time and is summed from the part movement time $MN1$, the part fixing time $MN2$, the working position change time $MN3$, the start assessment time $MN5$, the part processing time $MN6$, the welding surface preparation $MN7$, the machine maintenance time $MN8$. The welding downtime MZ, physiological needs MP and rest time ME are regulated by laboratory legislation [10; 11] and do not depend on the welder's qualifications. The time required to produce the product N is summed from the lead times of the individual working elements and can be expressed by formula 1 [12].

$$N = [(MH1 + MH2) + (MN1 + MN2 + MN3 + MN4 + MN5) + (MN6 + MN7 + MN8) + MZ] \; x \; 1.0714, \quad (1)$$

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where the rest on the production of one product is valued at a product of 1.0714 [13].

In order to calculate the time norm, it is necessary to have data on the production characteristics of different types of products, which can be obtained as a result of experiments.

Materials and methods

The REFA time standardization method is used to obtain the data. The welding process is monitored and recorded in a company with 50 welders, using video surveillance. Fronius welding TPS 320i semi-automatic machines, shielding gas M21, welding wire G46 4 M G4 Si, standardized welding processes 131/135 have been used for MIG/MAG welding [14]. DAHUA Technology video surveillance camera IPC-HFW1320S and Video Lan computer program have been used. This method allows data to be processed repeatedly without being at the workstation. The use of the working time is recorded with a stopwatch to the nearest second. The timed data shall be recorded on a time record form, recording the article number, name, date, time of the material, the time elements used and the timed time. "Regression" is used for the analysis of the work norms and Fisher's statistical data processing methods are divided into four groups: *K*001 – simple welding compound, an auxiliary device is used in the welding process; *K*002 – welding connection of a complex construction from many parts, an auxiliary device is used in the welding process; *K*003 – simple welding connection, no auxiliary device is used in the welding process; *K*004 – a complex welding connection from several parts, an auxiliary device Jig is used in the welding process. Complex welding joints are characterized by a joint length of more than 1000 mm, the number of tolerances of more than 4, the weight of more than 4 kg, the use of welding accessories, the need to grind welds, the number of parts is at least 5 and the joint is at least 4 dm^3. Typical video recordings of the welding process for typical products in each group. For repeated measurements in MS Excel, statistical data processing "correlation" is performed [15; 16]. The mean and standard deviation for each element at 95% confidence using the "Descriptive Statistics" function in MS Excel is calculated. From the data obtained in practice and the average use of the working time for products of different complexity, a table comparing the use of the average working time and the established working time norms shall be calculated.

Results and discussion

The experimentally determined seam formation time $MH1$ is 10… 38% of the total welding time. The size of $MH1$ is directly related to the seam length L and the seam cross-sectional area S. This makes it possible to determine the time $MH1$ for seams with different cross-sectional area sizes. The relationship between the seam volume and the seam formation time in minutes when welding 3… 6 mm thick non-alloy steel is expressed as: $MH1 = 0.0004.LS$; $R^2 = 0.9962$. The coefficient 0.0004 is determined, assuming that the amount of molten joint material per minute is 2700 mm^3 [12]. The welding time $MH2$ correlates well with the number of parts in the product n: $MH2 = 0.0107n^2 + 0.0564n$, $R^2 = 0.9998$. The part movement time $MN1$ correlates with the number of parts in the product n: $MN1 = 0.042n^2 + 0.0375n$; $R^2 = 0.9944$. The fixation time of parts $MN2$ also correlates well with the number of parts in the product: $MN2 = 0{,}055n^2 + 0.1543n$ -0,023; $R^2 = 0.998$. The time for change of the welding position $MN3$ is closely related to the number of parts n: $MN3 = 0.0046n^2 + 0.2492n – 0.245$; $R^2 = 0.9976$. The part quality evaluation time MN4 is related to the working time consumption Nf and depends on whether a welding conductor is used or not. If a conductor is used, $MN4 = 2\%\ Nf$; if no conductor is used, $MN4 = 5\%\ Nf$. The use of the working time Nf is determined from the expression [4]:

$$Nf = (MH1 + MH2 + MN1 + MN2 + MN3 + MN4 + MZ). \qquad (2)$$

Preparation for the work process takes place during $MN5$ and it depends on the seam length L: $MN5 = 0.002L + 0.1352$; $R^2 = 0.8471$. The part processing time $MN6$ depends on the use of the working time: $MN6 = 0.25\%\ Nf$. Aerosol application time $MN7$ depends on the use of the working time: $MN7 = 8\%\ Nf$. The operating time of the machine $MN8$ depends on the use of the working time: $MN8 = 0.53\%\ Nf$. The welding cleaning time $MZ3$ depends on the seam length L: $MZ3 = 1.25\ ln\ L – 3.62$; $R^2 = 0.9975$. The rest time in ME, physiological MP and conditional waiting time in MS are included in the multiplier 1.07. It can be seen from the expression in Table 1 that 1 is used only to determine the production time of a complex product with many joints with a large seam length *K*002.

$$N_{002} = (MH1 + MH2 + MN1 + MN2 + MN3 + MN4 + MN5 + MZ)\ x\ 1.16, \quad (3)$$

where (*MN*6 + *MN*7 + *MN*8) is 9% of *Nf* and is in the multiplier of 1.16.

If the seam length is less than 200 mm and a Jig is used, for example to determine the production time of a simple welding joint K001, only part of the expression is:

$$N_{001} = (MH1 + MH2 + MN1 + MN2 + MN3 + MN4 + MN5 + MZ3)\ x\ 1.07. \quad (4)$$

If the seam length is greater than 200 mm and no Jig is used, for example to determine the production time of a complete welded joint *K*003, taking into account also *MN*5 and *MN*7:

$$N_{003} = [(MH1 + MH2) + (MN1 + MN2 + MN3 + MN4 + MN5 + MN7) + MZ3]\ x\ 1.07. \quad (5)$$

Complex joints of several parts *K*004 in the welding process, and the accessory Jig is used and the length of the seam is approximately 1000 mm, including *MN*5 and *MN*6 to determine the production time:

$$N_{004} = [(MH1 + MH2) + (MN1 + MN2 + MN3 + MN4 + MN5 + MN6) + MZ3]\ x\ 1.16. \quad (6)$$

The obtained expressions are used to calculate the working time norms of different types of welding products in series production, varying with the seam length *L*, number of parts, seam cross-sectional area *S*. The obtained results for determining the production time of 16 different products with the proposed model are shown in the table. The effect of the number of parts on the duration of the welding process is modeled there, and the length of the seam is 5000 mm and the area is 8 mm^2.

The obtained results are compared with the data obtained experimentally with the video surveillance method by timing. In practice, for average *K*001 products, for which the corresponding product in the table 1 to 5 corresponds, 4 average consumers spend 18% more time and in one case 26% less time than expected. In practice, the average time taken to weld a *K*003 product, which corresponds to the products in the table 6 to 8, is 38% longer than expected.

For the reduction of the *K*004 type product, which corresponds to the products in the table 9 to 13, in practice the average consumer uses 53% more time and in 3 cases 17% less time than expected. In practice, the average time taken to weld a *K*002 product, which corresponds to the products in the table 14 to 17, is 92% longer than expected.

Table 1

Data obtained experimentally

No	*L*, mm	*n*	*S*, mm^2	*N*, min
1	50	1	4	2.55
2	63	2	15	3.48
3	96	4	4	3.71
4	100	6	4.5	7.60
5	145	3	8.5	5.45
6	180	2	25	7.08
7	256	2	8.5	6.96
8	268	5	8.5	10.8
9	507	4	8.5	10.56
10	614	4	2	7.61
11	733	3	4,5	10.3
12	900	9	8.5	22.04
13	1400	5	4.5	13.16
14	2589	7	4.5	26.45
15	4394	11	3	43.8
16	4400	22	8.5	113.7
17	5073	10	8.5	59.42
18	5000	9	8	53.27
19	5000	12	8	66.23
20	5000	15	8	81.64
21	5000	18	8	95.82

The analysis of the results shows that when calculating the duration of the welding process with the calculation method, the time most often consumed is less than that specified in practice. This is due to the fact that the model does not include all possible measures. For example, processing for products 14, 16, 17 after the joints have been formed, the product needs to be sanded to ensure the required surface quality.

More accurate results can be obtained by considering the manufacturing characteristics of each product, such as the time required to cool the seam if several seams need to be applied, or ensuring the dimensional stability of the products for three-dimensional parts by welding with short seams or checkered seams.

Modeling the effect of the number of parts on the duration of the welding process shows that increasing the number of parts to be welded doubles the welding time.

It is also possible to assess the effect of the cross-sectional area of the seam on the welding time, but in this case changes in the welding regime must be taken into account.

The proposed rationing model of the welding process allows to estimate approximately the required time quickly, using only the information about the length of the welds, the cross-sectional area, the number of welded parts and the amount of molten weld material per unit time.

The amount of molten joint material per unit time can be determined by a variety of methods: experimentally using the test method, using literature data, when making control samples.

The method allows to determine the welding time also in cases when seams of different profiles and sizes are used for the production of the product.

Conclusions

1. A fast MIG/MAG welding process rationing model for approximate time consumption is proposed.
2. The proposed modeling of the welding process allows to estimate the required time quickly, using only the information about the length of the welds, the cross-sectional area, the number of welded parts and the amount of molten weld material per unit time.
3. The method makes it possible to determine the welding time even in cases where seams of different profiles and sizes are used for the manufacture of the product.
4. Modeling the effect of the number of parts on the duration of the welding process shows that increasing twice the number of parts to be welded doubles the welding time.

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