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Empirical assessment of the MAG welder's exposure to an electromagnetic field

Abstract. *The papers presents the results of the electromagnetic field measurements at the welder's workplace. Welding was carried out by means of the MAG (Metal Active Gas) method (according to PN-EN ISO 4063: 2002 standard). Measurements have been made of the ESM 100 meter working within from 5 Hz to 400 kHz frequency band. Results obtained were compared with the requirements of the current 2013/35/EU Directive*

Streszczenie*. W pracy zaprezentowano wyniki pomiarów pola elektromagnetycznego na stanowisku pracy spawacza. Spawanie było wykonywane w metodzie MAG (Metal Active Gas), (zgodnie z normą PN-EN ISO 4063:2002). Pomiary prowadzono miernikiem ESM 100, pracującym w pasmie częstotliwości od 5 Hz do 400 kHz. Uzyskane wyniki porównano z obowiązującą dyrektywą 2013/35/UE.* ***(Ocena empiryczna narażenia spawalnika pracującego w metodzie MAG na pole elektromagnetyczne).***

Keywords: electromagnetic field, MAG welding, occupational exposure
Słowa kluczowe: pole elektromagnetyczne, spawanie metodą MAG, ekspozycja zawodowa

Introduction

The impact of an electromagnetic field on human organisms has been studied in numerous scientific centres around the world. So far, there has been no clear answer as to the assessment of the impact. The negative impact of electromagnetic fields on humans depends on various factors such as: field strength, frequency, exposure time. The direct influence of an electromagnetic field is associated with the presence of magnetic fields in organisms and an induction of the electric field which causes the induction of electric currents. Another effect of electromagnetic fields may be an interference with the operation of electronic devices [1-4, 7].

The presence of electromagnetic fields is associated with risks connected with their impact upon the working environment. For example, a welder is exposed to such an effect during his work (an 8-hour exposure throughout the shift). The effect may cause undesirable changes in the functioning of the organism. Among others, the changes include disorders in the functioning of organs, changes in tissue structure and nervous system, cancer and infertility. Therefore, the monitoring of electromagnetic field parameters at the is a very important issue [12-15, 30-31].

Materials and Methods

Metal active gas (MAG) welding determined/marked in the standard as the 135 symbol, is the form of arc welding. In this method, the electric arc is surrounded by a carbon dioxide atmosphere, or a mixture of carbon dioxide and argon. In addition, argon or helium are used as the shielding gas. The arc glows between the fusible electrode, which is a bare wire, and the workpiece. Importantly, the shielding gas has a degree of oxidizing activity. The method is suitable for welding most materials. The selection of appropriate electrode wires and shielding gas suitable for various metals is vital [10].

Method 135 and its automated varieties are suitable for welding most of the materials by selecting the electrode and shielding wires suitable for various metals. It is very often used in the industry to join materials in a 1 - 30 mm thickness range. The uncoated wire is less expensive than the shielded metal arc welding (SMAW) electrodes, where interruptions caused by the necessity of replacing the electrode and the removal of slag are eliminated by the use of semi-automated feeders. The 135 method generally uses the voltage range of 14 - 30 V with a retained electrode positive. From the welding source to the MAG method, the static flat rate and current characteristics (depending on the thickness of the welded components), 40 - 500 A are required for the MAG electrode, 0.6 mm to 4 mm of diameter. The gas shield is supplied in a flow rate of 8 - 32 dm^3 per minute. The process is characterized by high efficiency of joining materials (0.2 - 0.6 m/min) with high quality of the resulting weld [6, 9].

In the previous century, semi-automatic machines with mains transformers and diode bridge rectifiers were commonly used for CO_2 welding. In order to eliminate the pulsations of the welding current, chokes on plate cores, often with taps, were used for step adjusting of the choking induction. Currently, the main inverters in semi-automatic welders convert the energy at a frequency of several dozen kHz [8, 21, 25]. Processing the electrical energy in the welding power source in the MAG method usually takes place in the following conversion chain: the voltage is supplied to the rectifier system with filtration in the form of a battery of capacitors and a pre-charging system. The active power factor correctors are also used (PFC) [17-20].

The appropriate matching of voltages and currents is carried out with the use of a full bridge converter. The bridge, usually composed of fully controlled insulated-gate bipolar transistor (IGBT), switches the current in the transformer's primary coil. Switching in both directions in one pulse period results in a fast-changing magnetic flux in the transformer core without a gap. Cores made of powdered ferrite are used. Similarly, the primary and secondary windings are wound with a facing weave that reduces the skin effect. Bridge converters, by using coils configured in series, are capable of working with soft commutation and resonance [26-28]. In the rectifying output circuits, fast diodes are used. However, circuits controlled with MOSFET transistors, and glands on powder cores are also frequently employed [29].

Welding Trial

The experiment was carried out at a standard welding station equipped with a table with a mobile fume extractor. As a tool (source), a popular semi-automatic inverter Magnum Midimig 200 was used. Welding was done with a SG2 welding wire in a carbon dioxide sheath according to PN-EN ISO 14175, fed in a stream of volume of 12 l/min. DIN: ST37.2 (EN: S235JRG2) steel with a thickness of 5 mm was welded. Fillet weld was performed on a T-joint in the down position [22-24]. Measurements of the electric and magnetic field strength emitted during MAG welding were carried out in accordance with PN-T-06580-3: 2002. The test stand with the measuring points is shown in Figures 1 and 2.

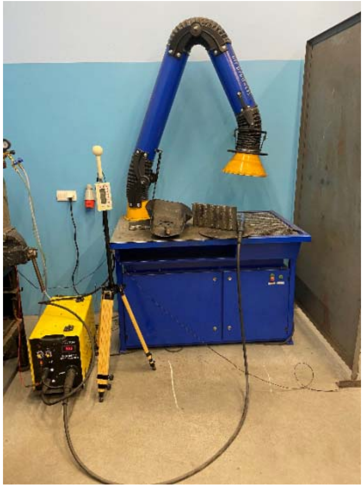

Fig.1. MAG welding measuring position

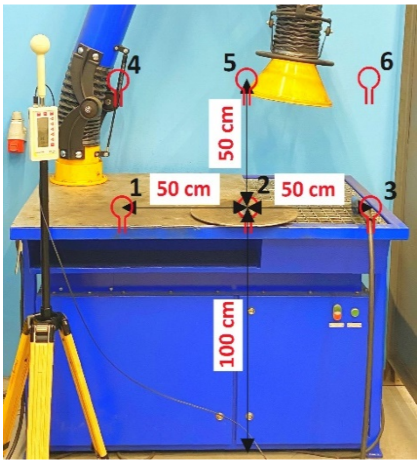

Fig.2. Presentation of the positioning of welding measuring points

Emissivity tests were carried out using Maschek's ESM-100 electromagnetic field meter. Operation parameters and meter settings are described in [11-16]. The welding current was measured with a UT207 clamp meter (UNI-T). A 87 V multimeter (FLUKE) was used to measure voltage. Measurements were made according to a plot of three vertical and two horizontal measurement levels at a height of 100 cm (point 1, 2, 3) and 150 cm (point 4, 5, 6), where the measuring instrument (ESM-100) was located, with welding being carried out directly after the working point marked 2 (Fig. 2). The location of the lines at which the intensity levels were observed was chosen at the height of 150 cm - to study the exposure of the welder's head working in an inclined position, and 100 cm - as the area of exposure of soft tissues: the lower abdomen and reproductive organs of the welder. Table 1 contains welding parameters collected during the experiment.

Table. 1 Welding parameters

No.	Current *I*, (A)	Current density *J*, (MA/ m^2)	Voltage *U*, (V)	Wire feed speed *v*, (cm/s)
1	200	399	23.6	3.5
2	150	299	20.8	3.2
3	100	199.5	16.9	3.0

At each measuring point, three measurements were made for each of the welding parameters. Average value was taken as the result.

Results and Discussion

In order to present the value of the electromagnetic field intensity which occurs in the room without the welder's work, a background measurement was made (Fig. 3).

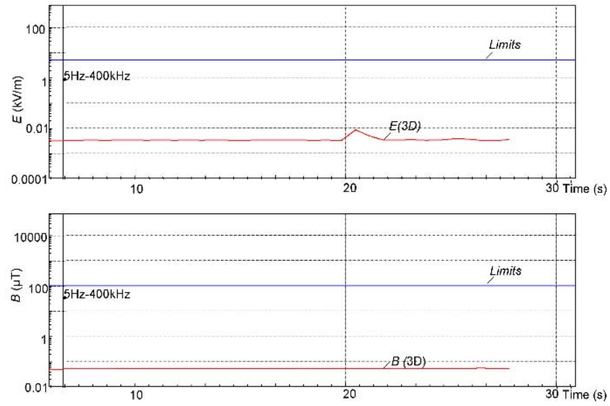

Fig. 3 Distribution of the electromagnetic field intensity in the workshop (background).

The paper contains selected results for which the maximum values of the magnetic component of the electromagnetic field were observed. Figure 3 presents the course of the intensity of the magnetic induction and electric component of the electromagnetic field for measuring point 2. Welding parameters are I = 100 A, U = 23.6 V.

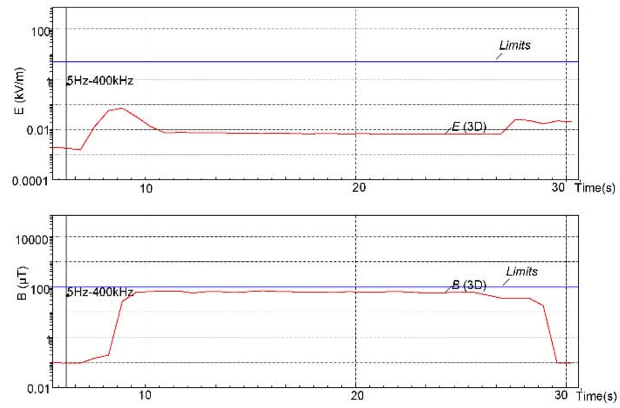

Fig. 4. Distribution of the electromagnetic field intensity at the measuring point no. 2 at a height of 100 cm.

The statistical analysis involved the introduction of the values of the electromagnetic field intensity recorded by the ESM 100 meter into the Statistical 13.0 software. The values of the analysed variables are determined by the mean value, median, standard deviation and range of variation. The researchers assumed the error of inference which equals 5% and the level of significance was $p < 0.05$.

The variation of the magnetic induction is shown in Figure 5.

The variation in the intensity of the electric field observed in the authors' own research proved to be statistically significant and ranged from 79.09 nT to 80.38 μT. Mean value in time function ranged from a minimum of 95.56 nT to maximum of 49.89 μT. The differences described are reflected in the values of the test function for the maximum value of the point (table 2).

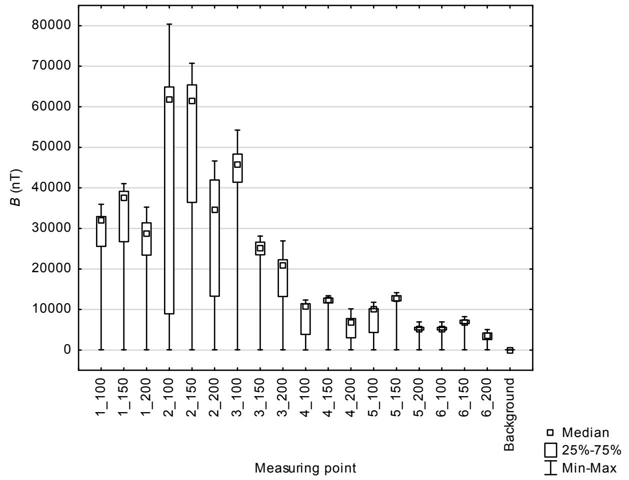

Fig. 5 Range of variability and median during MAG welding for the magnetic induction.

Table. 2 The characteristics of the electromagnetic field for the measuring point in which the maximum values are recorded

No.	Point 2 I [A]	Mean	Minimum	Maximum	SD
		B (nT)			
1	200	46041	85.9	80387	28822
2	150	49897	94.55	70747	23655
3	100	27551	92.41	46667	17209
4	0	95	94	96	0.81
		E (V/m)			
5	200	16.35	3.29	101	15.78
6	150	14.39	1.59	101	20.69
7	100	24.95	12.09	101	16.57
8	0	2.43	2.10	2.70	0.17

The variation of the electric field is shown in Figure 6.

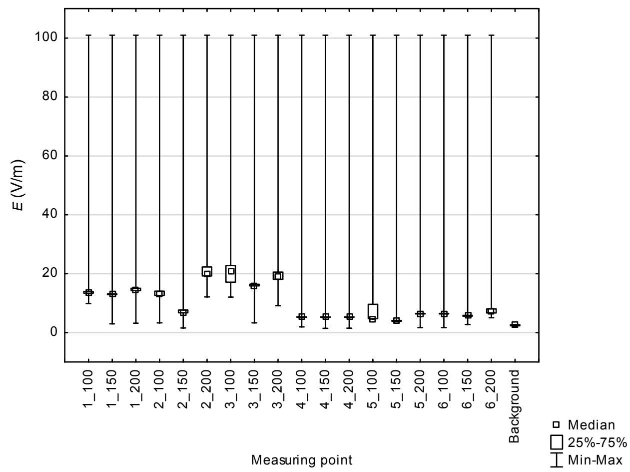

Fig. 6 Range of variability and median during MAG welding for the electrical component of the electromagnetic field.

Variation in the intensity of the electric field observed in the authors' own research proved to be statistically significant and ranged from 1.44 V/m to 138.8 V/m. Mean value in time function ranged from a minimum of 2.43 V/m to maximum of 27.76 V/m. The differences described are reflected in the values of the test function for the maximum of the point (table 3).

Student's t- test was performed in order to determine statistically significant differences between the values of the electromagnetic field intensity for measurements made in each of the welding measuring points (1, 2, 3, 4, 5, 6), compared to the values obtained for the background. Having compared the values of the electromagnetic field intensity compared to the background, statistically significant differences were observed (p=0.000).

Conclusions

Monitoring of the electromagnetic field is very important from the point of view of the negative effects of long-term exposure of people to the impact of the electric and magnetic induction intensity of the electromagnetic field. The highest values for the magnetic induction were recorded at measuring point 2, where the welder was in direct contact with the welded object. The maximum value of magnetic induction B was 80.38 μT. Comparing the results, representing two current and voltage settings and the associated two welding wire distribution speeds, for which field-tests were made at six measuring points, it can be seen that the largest values for the magnetic induction in each case were recorded for current I = 150 A and voltage U = 20.8 V. Investigating the correlation between welding current and observed values, it can be stated that a double increase in the current in the electric arc and fused additional material does not cause a proportional increase in the field interaction on the welder. It can therefore be assumed that by using 100, 150 and 200 A currents, changes in the value of the intensity of the electromagnetic field do not depend directly on these values. Similarly, the increased arc energy did not increase the level of the received electromagnetic field strength.

The maximum intensity of electric field E is 101 V/m. The values of the electrical component at each measuring point are of the same magnitude. During welding, the strength of the electromagnetic field for both the magnetic and electric components is several times higher, compared to the values measured without the welding machine (background). The analysis of the results indicates the electromagnetic processes of energy conversion in the main converter and the suppressor circuits of welders as the source for electromagnetic fields. The permissible values of the electric and magnetic components of the electromagnetic field were not exceeded (in relation to the requirements set in the current 2013/35/EU Directive) [5].

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