Assessment of Electromagnetic Fields in Arc and Resistance Welding

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ABSTRACT: Welding is used in a wide range of heavy and light industry, construction and maintenance, including vehicle construction. Workers using welding processes are exposed to electromagnetic fields (EMF). The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published guidelines on limits of the exposure to static magnetic fields and on guidelines limiting the exposure to time-varying electric, magnetic and electromagnetic fields. Moreover, the European legislation is based on these guidelines being the most recent and updated limits published in the Directive 2013/35/EU. The ICNIRP reference levels for magnetic fields may be exceeded in both arc and resistance welding. This study aims to assess the workers exposure to EMF in arc and resistance welding and compare the results with legal limits. Several measurements of EMF were carried out in different industries at workplaces using welding processes. The maximum measured field was near the cables with 1065 μT for single sided spot welding; 761,7 μT for arc welding (MIG) and 646,7 μT with resistance welding using a pneumatic "C" clamp. In some cases, the results were above the action levels (ALs) of the Directive 2013/35/EU.

1 INTRODUCTION

Electromagnetic fields (EMF) are present everywhere but they are invisible to the human eye. The electromagnetic field can be understood as a combination of an electric field and a magnetic field that can be emitted as waves by many natural and artificial sources such as electricity.

With the industrialization, the increasing of the mobility and communications, the human exposure to electromagnetic radiations has also increased.

Since the publication of the study of Wertheimer and Leeper (1979) "Electrical wiring configurations and childhood cancer" alleging that childhood leukemia was higher in households located near electric power lines, the international scientific community and general population began to look at this issue and to the associated adverse effects. Since then, several studies have been carried out, and in 2002 the International Agency for Research on Cancer (IARC, 2002) classified the magnetic fields with extremely low frequency (ELF: 1Hz – 100 kHz) as possibly carcinogenic to humans (Group 2B), the static fields (electric and magnetic) and the electric fields with frequency extremely low as not classifiable regarding its carcinogenicity to humans (Group 3). In 2011, IARC (2011) classified the electromagnetic field in the range of radiofrequency (RF: 100 kHz - 300 GHz) as possibly carcinogenic to humans (Group 2B).

Welding is widely used in industry, construction, maintenance and in particular in vehicle construction. Workers performing welding tasks are exposed to magnetic fields from the welding processes. There are many different welding processes, however the most used are arc welding (MMA: Manual Metal Arc; MIG/MAG: Metal Inert Gas/Metal Active Gas; TIG: Tungsten Inert Gas; Plasma; SMAW: Shielded metal arc welding) and resistance welding.

Depending on the specific process and technology used, the fundamental frequency ranges from 0 Hz to some hundreds of kHz (Grassi et al., 2012).

There are several internationally accepted guidelines concerning the exposure to electromagnetic fields. The most known are those from the ICNIRP (International Commission on Non Ionizing Radiation Protection), in which the European legislation is based.

A review of the literature in this field (Melton, 2005) shows that the ICNIRP reference levels for magnetic fields may be exceeded in both arc and resistance welding.

Recently, the Directive 2013/35/EU (EU, 2013) was published concerning the minimum health and safety requirements regarding the exposure of workers to risks arising from electromagnetic fields and repeal the Directive 2004/40/EC.

The aim of the present study is to provide satisfactory understanding of the magnetic fields which are present in the immediate vicinity of some arc and resistance welding processes, measuring the exposure to magnetic fields and comparing these values with the limits established in the Directive 2013/35/EU.

2 MATERIAL AND METHODS

This study was performed in three different companies from different sectors of activity.

Company A is a small enterprise in the light metalworking, which works with two similar MIG welding machines: ESAB MIG C280. This company has 2 welders; one does welding tasks during approximately 4 h/day and the other during 1 h/ day. The first one has about 24 years of welding experience, and the second about 10 years.

Company B is a medium-sized company with 70 employees, of which 31 are welders. They work in three shifts of 8 hours, with 11 similar MIG welding machines: ESAB MIG 5004i. All do welding tasks during 6 h/day. Concerning the 31 welders, 20 perform welding processes since 10 years ago in this company, 3 started their professional work as welders 4 years ago and 4 were already welders when they joined the company.

Company C is from the sector of vehicle repair and maintenance. In this sector of activity, welders usually perform welding tasks for a short period of time. They used to use arc welding (MIG/MAG, SMAW, plasma and oxyfuel) and resistance welding. Nowadays, the most used are MIG/MAG and spot welding. In this company, some measurements of the EMF were carried out in a resistance welding machine using a single sided spot weld and a “C” clamp: Blackhawk/CompuSpot WEL 750. This company has 8 welders who weld on average 1 hour per day, distributed approximately as follows: 10 minutes with resistance spot welding, 10 minutes with MIG/MAG, 10 minutes with oxyfuel and 30 minutes with small sop welder.

The measurements were performed in each company for 5 shifts of 8 hours each one. The welders were also observed during one shift without disturbing their jobs to analyze the welding process, the type of pieces welded and to check the periods in which the welding tasks were performed.

The magnetic field data was acquired using a isotropic and triaxis magnetic sensor (Aaronia NF5035). This instrument measures magnetic fields in the range of 0,1 nT to 2 mT, from 0 Hz to 30 MHz and with an accuracy of 3%.

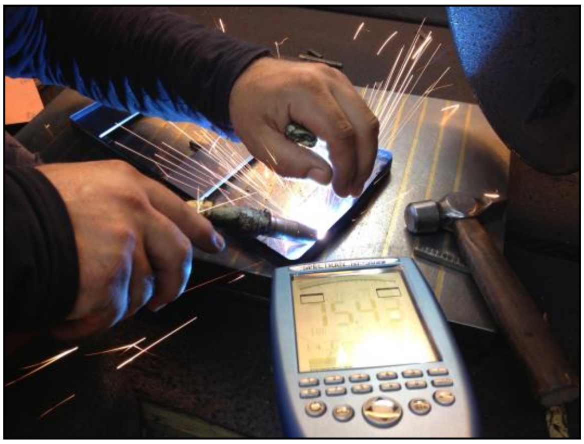

Figure 1: Spectrum analyzer of the isotropic magnetic field (Aaronia).

The measurements were conducted at several positions, close to the welders head, chest, waist and hand/electrodes and also near the welding cables and machine. In addition, a few measurements were carried out at distances of 20 cm, 50 cm, 1 m and 2 m from the welding cables and machine.

Each measurement was carried out with a minimum period of 1 minute. The electric field was also measured, but the registered values were very low compared to the action levels defined in the Directive 2013/35/EU.

3 RESULTS

All measurements were performed in a real work environment, during typical welding processes with usual welded parts and using habitual specifications.

The measurements were done in the range 0 Hz – 30 MHz, according the manufacture recommendations concerning band width.

For each machine, the magnetic fields were measured at several positions (Meas. Posit.): near welding cables (1); welding machine (laterals without cables-2, lateral with cables-3); electrodes (4); welder head (5); and welder chest/waist (6). Concerning the welding cables and the machine, some measurements were done at distances of 20 cm, 50 cm, 1 m and 2 m from these 2 positions (Table 1, Table 2, Table 3 and Table 4).

The results of the measurements conducted in company A with ESAB MIG C280 welding machine are presented in Table 1. The measurements were registered with a welding current of 140-175 A, a wire diameter of 0,8 mm, a wire speed of 9-10 m.min^{-1} and a shielding gas with 98% Argon + 2% CO_2. The welding cables were 3 m long.

Table 1: Measurements of the magnetic field [μT] for ESAB MIG C280 welding machine

Meas. Posit.	Freq. [Hz]	Distance [cm] 1	20	50	100	200
1	0	760,3	463,9	141,0	79,2	75,6
	53	225,7	-	-	-	-
	98	95,0	-	-	-	-
	204,4	48,6	-	-	-	-
2	0	108,5	-	-	-	-
3	0	496,0	477,9	71,8	62,3	-
4	0	480,0	-	-	-	-
5	0	322,3	-	-	-	-
6	0	231,0	-	-	-	-

The results of the measurements carried out in company B with ESAB MIG 5004i welding machine are presented in Table 2. The measurements were taken with a welding current of 265-285 A, a welding voltage of 26,2-29 V, a wire diameter of 1,2 mm, a wire speed of 10-12 $m.min^{-1}$ and a shielding gas with 75% Argon + 25% CO_2. The welding cables were 5 m long.

Table 2: Measurements of the magnetic field [μT] for ESAB MIG 5004i welding machine

Meas. Posit.	Freq. [Hz]	Distance [cm] 1	20	50	100	200
1	0	761,7	185,0	105,0	76,5	66,1
	45	133,0	-	70,9	-	-
	50,2	111,1	-	-	-	-
	53,4	116,3	77,85	-	-	-
	56,2	104,4	-	-	-	-
	80	1,6	-	-	-	-
	98	6,4	-	-	-	-
	132	60,0	-	-	-	-
	154	49,3	-	-	-	-
	281,8	26,2	-	-	-	-
2	0	214,9	-	-	-	-
3	0	485,0	477,9	71,8	62,3	-
4	0	635,5	-	-	-	-
	53,4	82,2	-	-	-	-
5	0	105,0	-	-	-	-
6	0	495,0	-	-	-	-

The results of the measurements performed in company C with Blackhawk/CompuSpot WEL 750 resistance welding machine, using a "C" clamp are given in Table 3. The measurements were taken with a welding current of 8100 A, a welding time of 300 ms and a welding pneumatic force of 400 daN. The cables and the torch were cooled with a fluid consisting of 50% ethyl glycol and 50% water. The welding cables were 2,5 m long.

Table 3: Measurements of the magnetic field [μT] for a resistance welding WEL 750 with "C" clamp

Meas. Posit.	Freq. [Hz]	Distance [cm] 1	20	50	100	200
1	0	646,8	-	-	-	-
	53,8	95,5	-	-	-	-
2	0	190,0	-	-	-	-
	53,8	115,7	-	-	-	-
3	0	591,0	-	-	-	-
4	0	590,4	-	-	-	-
	53,8	111,2	-	-	-	-
5	0	95,0	-	-	-	-
6	53,8	108,0	-	-	-	-

The results of the measurements carried out in company C with Blackhawk/CompuSpot WEL 750 resistance welding machine, using a single point spot welding are given in Table 4. The measurements were performed with a welding current of 8600 A and a welding time of 70 ms. The cables were air cooled and were 2,5 m long.

Table 4: Measurements of the magnetic field [μT] for a single point spot welding Blackhawk/CompuSpot WEL 750

Meas. Posit.	Freq. [Hz]	Distance [cm] 1	20	50	100	200
1	0	1064,5	510,0	494,5	-	-
3	0	237,5	-	-	-	-
4	0	375,9	247,0	-	-	-

4 DISCUSSION

From the obtained results it is possible to observe that the magnetic field is higher near the cables, for all cases studied. The results also show that the magnetic field is predominantly at one frequency with harmonics at other frequencies.

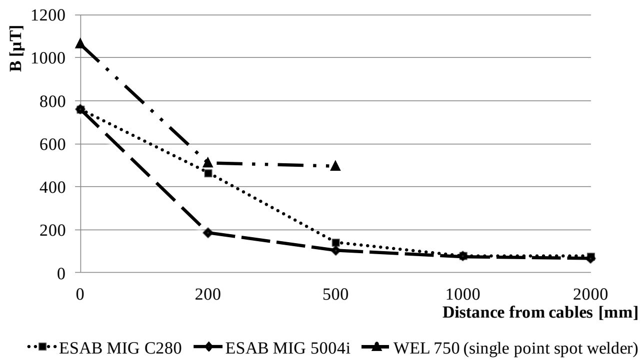

Figure 2: Variation of the magnetic field (B) with the distance to the cables.

The highest magnetic field is measured near the cables for a single point spot welding, 1 064,5 μT. As the higher the current intensity, the higher the magnetic field, it is expectable that the magnetic field obtained with this spot welding machine will be greater if we use higher welding current (maximum 12 000 A). However, in this kind of applications, this is not usual the case.

Concerning the resistance welding machine with "C" clamp, the magnetic field is 646,8 μT near the cables, 591,0 μT near the machine in the side with cables and 590,4 μT near the electrodes.

For MIG welding machines (C280 and 5004i) the results were very similar. The highest values are obtained near the cables, 761,7 μT and 760 μT, for the ESAB MIG 5004i and ESAB MIG C280, respectively.

Although the measurements were carried out at various positions, from the point of view of occupational safety and health, the most important measurement is the one that usually presents higher values (near welding cables). In fact, in practice and for all manual welding processes the contact between the welder and the cables is inevitable; therefore the compliance with the action levels (ALs) near the cables will ensure worker protection.

According to the Directive 2013/35/EU, the exposure limit values (ELV's) applied to the sensory effects and health effects for external magnetic flux density (B_0) were not exceeded. However, the action levels for magnetic flux density of static magnetic fields (ALs(B_0)), concerning interference with active implanted devices, e.g. cardiac pacemakers, were exceeded near the cables, for all cases. In particular, for the case of a single point spot welder WEL 750, the ALs(B_0) were exceeded up to 50 cm away from the welding cables. Although the magnetic field is predominant at 0 Hz, we could verify that the ALs were not exceeded for the harmonics.

For each welding equipment and process, the reduced data set has been tabulated showing the individual significant frequency of the magnetic field. These values have been compared with the Directive 2013/35/EU action levels (ALs). According to the ICNIRP (1998a; 2010b), the ratio of the measured value (B_n) and the reference level (R_n, which in this case is the action level AL_n) will be calculated and the sum of these individual contributions should be less than or equal to 1 (Equation 1).

$$\sum_n \frac{B_n}{AL_n} \leq 1 \tag{1}$$

In spite of the results obtained in this study, it should be noted that in the considered exposure conditions, the reference levels set by the Council Recommendation (EC, 1999) concerning the exposure of the general public to electromagnetic fields (0 Hz to 300 GHZ) were exceeded, meaning that the access to these areas should be limited to welders.

The risk assessment concerning the exposure to magnetic fields by the welders should consider the lifelong exposure (LE) for each individual, as some welders work (almost) the whole day (like in company B), other welders may perform the welding task for certain periods in a day (like in company A), and others weld only just a few hours in some days of the week (like company C). According to Man et al. (2007), the LE to magnetic fields (B) is calculated by LE = B[μT] x the average usage in hours per day x the number of days in a year where welding tasks were performed x the number of years in which welding tasks were performed.

According to the data collected during the measurements it is possible to conclude that different LE can be found for the workers of the same company, with a similar welding machine. So the cumulative exposure can be very different for each welder. This is a very important aspect to be considered in the risk assessment to EMF exposure and most probably has influence in the potential adverse health effects.

5 CONCLUSION

From the measurements of the magnetic fields carried out in the vicinity of an arc and resistance spot welding equipment, in addition to an exhaustive literature review, the following conclusions may be drawn:

- Different processes produced different magnetic fields strengths;
- The highest values measured were close to the welding cables for all cases;
- In manual welding processes the permanent contact between the welder and cables is inevitable, whereby it is acceptable to use these exposure values as the welder exposure;
- In some conditions the action levels (ALs) of the Directive 2013/35/EU (EU, 2013) are likely to be exceeded;
- The access to welding areas should be limited to welders;
- People with active implanted devices (e.g. pacemakers) should be kept away from the welding areas;
- In some cases, it may be important to consider the contribution of the fundamental frequency and the most important harmonics, concerning the exposure to EMF;
- The lifelong exposure should be considered in the analysis of cumulative and potential adverse health effects;
- Further investigation is required to assess the exposure if the Directive 2013/35/EU (EU, 2013) action levels (ALs) are exceeded.

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