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Arc Welding Workspace Risk Factors Evaluation and Monitoring

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ABSTRACT

For increasing the productivity and the quality of the beam welded joint is necessary the replacement of the manual welding methods with the semi automated and automated GMAW welding methods. Because the value of the welding current is high, the electromagnetic radiations, UV radiations, noise level and smoke are high as well. The European quality requirements for welding are very restricted. For this reason, we need to do a rigorous analysis of the working conditions of the operators. In this paper we make an evaluation of the risk factors and of the monitoring modalities at GMAW welding.

Keywords: *arc welding, safety assurance, Zig-Bee, wireless system, monitoring*

1. Introduction

Romania had to cope a period of major transformations, as regards the society as a whole. The scientific research has a very well defined role in this process of renovation, of the quality improvement and reducing of costs in all industrial areas. The industrial production should be based on modern equipments and ecological technologies, quality materials and qualified labour force able to work in safe conditions.

The products manufactured by welding processes are widespread in industry. The welding domain has been increasing transformed and developed.

In the past few years, Romania has undergone a very difficult crisis of a dramatic shortage of welders, no longer able to meet the market demand, on the one hand, and on the other hand because the welder profession, is suite difficult and applicable in very hard working conditions.

Along with the modernization of the equipment and technologies, a particular attention must be paid to the conditions of the working place, an attempt to protect and meet the very strict standards environment and safety.

As a conclusion a qualified/shielded welder, trained according to the international legislations and regulations, using modern technologies, will work in safe and quality conditions.

The paper makes an evaluation of the risk factors having an impact on the health of the welders, who work in MAG and MAG-P welding processes environments. Some considerations about the international regulations and legislation, the evolution and reduction of risk factors are also presented. The paper advances the welding space wireless monitoring system - WSW.

2. Motivation

In 2003, the Robotic and Welding Department, from "Dunarea de Jos" University of Galati, has begun a project dedicated to the investigation of the welding arc physical phenomena from. In this respect a complex system based on a high speed camera (for filming the welding arc phenomena) synchronized with the measurement of the welding parameters was developed. A first step was the analysis of the welding process (GMAW-P). [1]

In order to achieve better results, it was necessary to identify the action of disturbance forces and the way they can affect the fidelity of recordings and system integrity as well.

Therefore, the disturbances resulting from combined actions of thermal, electric, magnetic, UV, infrared and visible spectres radiations in the welding arc and as well of the smoke and the metal splatters, were noticed during this phase of our research.

It was conducted a documentation research concerning the actions of all these factors that act in the work space of the welding arc. All above stated factors had obviously a harmful action against the human body. Step by step, these emerged a new direction of research development so the focus on the field of equipment protection and recording's accuracy, was changed to the research of risk factors for welders.

3. Standards

The problems regarding the occupational health and safety and also about risk assessment in welding are the objectives of many projects, researches and papers and also are bring under regulation by different standards.

In Romania the general standards of health and safety, emitted by Labour Ministry Decision - PS no. 508/20.11.2003 and Health and Family Ministry Decision no. 933/25.11.2002, contains general principles for preventing accidents and professional disease. The aims of these standards are to preserve life and integrating man in the work process preventing accidents and professional diseases. The general standards of health and safety protection is regulate by law no. 90/1996 and are harmonized with European Union legislation, in particular with article 16 of Decision No. 89/391/CEE of the European Parliament and of the Council. [13]

At international level institution, agencies and organizations occupies with all the aspects about occupational health and safety in welding.

So in Europe exists-EU-OSHA (European Agency for Safety and Health at Work), in United States of America- OSHA (Occupational Safety and Health Administration), NIOSH (National Institute for Occupational Safety and Health) and at international level - ICOH (International Commission on Occupational Health), WHO(World Health Organisation), International Occupational Hygiene Association (IOHA), ILO (International Labour Organisation), IEA (International Ergonomics Association), International Institute of Welding - Commission VIII - Health and safety.

These institutions monitor permanently issues regarding health and safety and modifies the standards in operation. For the European Union the welding health and safety regulations are presented in the table no. 1.

Table 1 - European and International Standards on Health and Safety in Welding and allied processes [15]

Sampling of airborne particles and gases sampling in the operator's breathing zone	EN ISO 10882-1 and-2
Laboratory method for sampling fume and gases, ozone	EN ISO 15011-1 till-4 CEN ISO TR 15011-5c
Equipment for air filtration	EN ISO 15012-1 and-2
Eye protection	EN 167:2002
Protective clothing	EN 470-1:2001, EN 12477:2001
Transport welding curtains, strips and screens for arc welding processes	EN 1598:1997
Wordless precautionary labels for equipment and consumables	EN ISO 17846:2004

ISO/TC 44 produces standards in the field of welding, by all processes, as well as allied processes; these standards include terminology, definitions and the symbolic representation of welds on drawings, apparatus and equipment for welding, raw materials (gas, parent and filler metals) welding processes and rules, methods of test and control, calculations and design of welded assemblies, welders' qualifications, as well as safety and health.

Electrical safety matters related to welding are excluded from the scope of ISO/TC 44 (under the responsibility of IEC/TC 26).

In the United States of America the most important standards in the area are:

- ANSI Z49.1-2005 - Safety in welding, cutting, and allied processes; [14]
- ANSI Z87.1-2003 - Occupational and Educational Personal Eye and Face Protective Devices.

4. Welding risk factors

Welding was the most hazardous occupation. The welding processes have an unique exposure, extreme heat, high radiant energy, high electromagnetic fields, molten metal splatter and smoke. There are several reasons why welding is a dangerous occupation:

- there are a multiplicity of factors that can endanger the health of a welder, such as heat, burns, radiation, noise, fumes, gases, electrocution, and even the uncomfortable postures involved in the work;

- the high variability in chemical composition of welding fumes which differs according to the workpiece, method employed, and surrounding environment; and

- the routes of entry through which these harmful agents access the body

The adverse health effects of welding come from chemical, physical, and radiation hazards (see Table 2). [9]

Common chemical hazards include metal particulates and noxious gases. Physical hazards include electrical energy, heat, noise, and vibration. Electromagnetic radiation occurs at visible, ultraviolet, and infrared wavelengths.

Welding is associated with a number of non-respiratory health hazards. Most common among them are the effects of electricity, heat, and electromagnetic radiation.

Table 2 Risk factors in welding

Fume	Gases	Radiant Energy	Other Hazards
Al, Cd, Cr, Cu, F, Fe, Pb, Mg, Mn, Mb, Ni, Si,	CO2, CO, NO2, NO, Ozone	Ultraviolet – UV, Visible, Infrared – IR	Heat, Noise, Vibration

For risk factors, occupational exposure standard (OEL) and maximal exposure limits (MEL)/permissible exposure limits (PEL) are finding in standards also with the measure for occupational health and safety. [7,8,9]

4.1. Arc welding processes

- Manual Metal Arc (MMA) MMA consumables consist of a metal core wire and a flux/metal powder coating. The coatings can incorporate metallic alloying additions and rutile, carbonates, fluorides, silicates and other minerals bound together with a silicate binder and dried. When chromium is present, much of the fume chromium is in the hexavalent form (Cr^{VI}), due to reactions with flux constituents. [2]

- Flux and Metal Cored Tubular Wires (FCW/MCW) Tubular wires consist of a metallic sheath and a core consisting of metal powders and/or minerals similar to the coating of an MMA electrode. The fume could vary depending on whether a shielding gas is used and with the composition of the gas. When present, the ratio of Cr^{VI} to Cr^{III} is lower with FCW than MMA, although total Cr may be higher. With MCW, all Cr is Cr^{III}.

- Metal Inert Gas (MIG/MAG) MIG welding utilises a solid wire electrode protected by a shielding gas, either inert (eg. Ar, He) or active (CO2) or a mixture. As the shielding gas becomes more oxidising the particulate fume emission rate increases. The process parameters determine the transfer mode (dip, globular or spray), these do not generally affect the fume composition but can significantly alter the rate of fume generation. When present, fume Cr is always Cr^{III}. [2]

-Tungsten Inert Gas (TIG) TIG welding utilises a solid filler wire which is fed directly into a molten weld pool formed by the TIG arc. Welding fume composition is equivalent to the MIG process but negligible fume is generated by the TIG process as there is no metal transfer across the arc. As with other gas-shielded processes, displacement of breathing zone air by shielding gas must be considered in confined spaces. Ozone formation may reach significant levels, especially when welding aluminium or stainless steel.

- Submerged Arc Welding (SAW) SAW utilises a solid wire which is fed through a layer of granulated flux which shields the arc from the atmosphere. Because the arc is submerged, the emission of fume and gases does not reach hygienically significant levels. Submerged arc fluxes are inert and handling them may involve a minor dust nuisance only.

4.2. Fume and gases

More often over 90% of the particulate fume arises from the vaporisation of the consumable. The base material does not normally contribute significantly to the particulate fume except for certain operations. Depending on the welding process, there may also be gases present. These may be shielding gases (eg. Ar, He, CO_2 or mixtures) or there may be gases formed by the action of the welding process on the flux (eg. CO_2/CO) or the surrounding atmosphere (NO, NO_2, ozone). Ozone formation can be a particular problem in gas-shielded processes, especially MIG welding of aluminium. Ozone can be generated by reaction between UV light from the arc and oxygen in the air. At the levels of exposure to ozone found in welding the main concern is irritation of the upper airways, characterised by coughing and tightness in the chest, but uncontrolled exposure may lead to more severe effects, including lung damage. [3]

Primary stage of poisoning by gases indicate the following symptoms: Irritation of the eyes, nose and trachea, narrowness in breathing, dizzines and headache, sickness and fatigue, intensive cough.

Normally, good local or general ventilation for controling exposures to the metal fumes and gases of welding operations is required. The most effective control is local exhaust ventilation in which an exhaust hood is placed near the welding arc or flame, and the contaminants are drawn away from the welder's breathing zone. The system may consist of moveable exhaust hoods, flexible and stationary ducts, a powered fan, and a fume or dust collector. Exhausted air should be discharged to the outdoors, if possible, it is important that, during the welding operation, the exhaust hoods are placed or set so that welding fumes are not drawn across the worker's face or into the breathing zone.

Considering that the major causes of the fume generation are due to the auxiliary material (gases or filler metal) for each material used in the welding process must be elaborated a document entitled “Material Safety Data Sheet” (MSDS) that describes the type of fumes produced, the hazard during their use, first aid measures, exposure prevention/control/personal protection etc.

The careful study of these MSDS’s leads to a cautious selection of the auxiliary materials, in terms of risk factors. [14]

4.3. Arc welding radiations

Radiation is electromagnetic energy given off by the arc or flame that can injure eyes and burn skin.

• Intensity and wavelength of energy produced depend on the process, welding parameters, electrode and base metal composition, fluxes, and any coatings or plating on the base material.

• Ultraviolet radiation increases approximately as the square of the welding current.

• Visible brightness (luminance) of the arc increases at a much lower rate.

Processes using argon produce larger amounts of ultraviolet radiation than those using most other shielding gases. Welding and cutting operations can cause acute effects such as severe “sunburn” (erythema) of the skin and painful “welder’s flash” (photokeratitis) of the cornea of the eye. Ultraviolet light is produced by the electric arc and often causes welders to experience an eye condition called acute photo kerato-conjunctivitis or “arc eye”.

Nowadays, the protection against these radiations is realised using special and performant filters (auto darkening lens). This kind of filters suppresses UV and IR radiations in a proportion of 99% and limits the visible spectrum radiation at an acceptable level.

These filters have a very short change-over time (milliseconds or even shorter). Also, they have a very small mechanical impact resistance and a very good resistance when increasing the temperature.

A very large number of autodarkening filters also exists on the market. Obviously, these filters assure a very broad range of protection and optical comfort as compared to the classical ones. The question is if these are in compliance with the technical characteristic described on the manufacturer prospects.

A change-over time evaluation and autodarkening methodology was realised. It was used to test no-name filter that are find on the Romanian market. The tests were run on all types of MAG welding processes and for different values of the welding current. Filters were successively mounted on a high speed camera that took frames at a speed of 10000 frames/sec, taking images of the welding arc, concurrently with measuring the current and power supply. [1]

The frames were subsequently analysed and, knowing exactly the value of filming speed, the reaction response during switching on and off has been found for each operation/sequence. Deviations were found to be high, as compared to those in the manufacturer’s prospects. Also, after successive filtering and transformation of the acquired images, those were compared with other images previously taken by using standards lenses, in order to determine the darkening degree of the darkening lenses.

This situation also showed great variation as compared to those recorded in the manufacturer’s prospects, according to ANSI Z87.1-2003 standard. Using high speed filming method can be determined also the mechanical impact resistance of the filters. [14]

To conclude with it is recommended the use of those lenses made by manufacturers that offer warranty for product quality and characteristics.

4.4. Electric and magnetic fields

Electric and magnetic fields are often referred to as “electromagnetic fields,” or EMF. There is concern that EMF may affect your health. Many scientific tests have been and are still being conducted by governmental and private agencies to determine if EMF is harmful to our health. Most studies to date indicate that there is no evidence of significant health problems from EMF.

The studies were also extended to spot welding for electric arc welding with modern inverted sources. Significant increases were observed for magnetic fields during pulsed arc welding for frequencies of less than 150-200 Hz and high pulse current values. Mention must be made that the EU regulations are currently under preparation. [4]

5. Zig-Bee system monitoring

As we previously presented, at the welding arc process, the risk factors are very numerous and the mixed actions of those can lead to a substantial degradation of the welder's health and not the last, to other welders from the work space. For a complete image over the level of the most important risk factors, these must be monitored through a complex sensorial system – WSW. [5]

The idea is to develop a distributing sensorial network, which must permanently send information to a central unity of counting which processes, analyzes and stock the informations.

A sensorial network with the transmission of the information through the cable can use standard protocols used at the robot cells command of the solder. These cabled networks are more difficult to realise if the number of the sensors is high and the coverage is large.

An attractive way of communication would be the use of the wireless networks. The question is if, in the case of the welding arc processes, can be used such a wireless communication and which sort of the protocols is the best for the monitoring of the risk factors during the solder.

The wireless communications are sensitive to interferences and the disturbances produced by the welding arc. According to the protocols of communication, there are more variants of networks: WI-FI, Bluetooth, ZIG-BEE etc. [6]

Comparison of key features of complementary wireless protocols is presented in the table 3. [16]

Table 3 – Comparison of key features of complementary wireless protocol

Market Name Standard	ZigBee^{TM} 802.15.4	GPRS/GSM 1xRTT/CDA	Wi-Fi^{TM} 802.11b	Bluethooh^{TM} 802.15.1
Application Focus	Monitoring& Control	Wide area Voice & Data	Web, Email, Video	Cable replacement
System Resources	4-32Kb	16Mb+	1M+	250Kb
Battery life (days)	100-1000+	1-7	5-5	1-7
Network size	Unlimited (2^{64})	1	32	7
Bandwidth (KB/s)	20-250	64-128+	11,000 +	720
Transmission range (metres)	1-100+	1000+	1-100+	1-10+
Success Metrics	Reliability, Power, Cost	Research Quality	Speed, Flexibility	Cost, Convenience

The evolution of the wireless communication systems is presented in the figure 1 [6,16]

Analyzing the performances and the compatibilities, above presented, with the desired aim (to monitor the risk factors during the arc welding process) it was chosen the using of ZIG-BEE system.

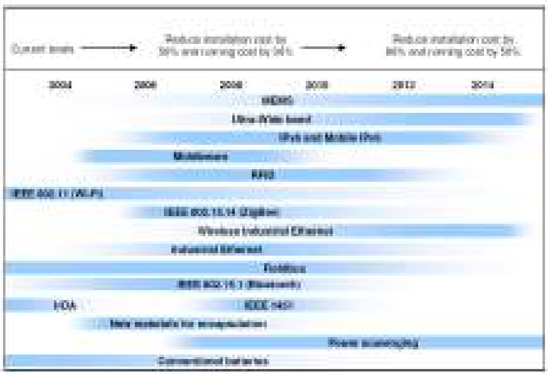

Figure 1 – The evolution of the wireless communication system

The ZigBee Alliance is a rapidly growing, non-profit industry consortium of leading semiconductor manufacturers, technology providers, OEMs and end-users worldwide. Membership is open to all. ZigBee Alliance members are defining a global specification for reliable, cost-effective, low power wireless applications based on the IEEE 802.15.4 standard. [16]

6. Wireless monitoring system for welding workspace

Our primary objective is to investigate the possibility of applying wireless sensor communication to the measurement and control of the indoor environment from welding workspace.

System Requirements

- User friendly and ease of data collection by user;
- ZIGBEE Wireless communication ;
- Accurate information transfer throughout the system;

– Low power wireless development board to convert sensors information;
– Capable of temporary data storage;
– Wireless communication between sensors and PC;
– Standard code format for versatile applications.

The importance of the system is to create wireless connection links between WSW and a computer.

6.1. System components

a. Freescale SARD ZIGBEE board-developer's Starter Kit (Figure 2) [10,12]

– Zigbee 802.15.4 standard;
– 100-300 m range;
– 128 bit encryption;
– 1000 days 9V battery life, low power;
– RS-232 complaint;
– 8 Analog to digital pins.

The data sensors are transmitted in to the Freescale Zigbee board. Using the HCS08 microprocessor the data will be formatted and stored. With proper user interaction the data will then be sent wirelessly to another Freescale board connected to a PC.

b. Sensors

Currently, sensors are available off the shelf for a wide variety of measurements, for example: [16]

– air temperature
– relative humidity
– motion (acceleration)
– ambient light
– smoke or dust
– toxic or asphyxiate gases, flammable
– radiation
– magnetic field
– electrical field
– wind speed/direction
– pressure
– battery health (voltage)

Figure 2 – SARD ZIGBEE board

The output is an analog signal that is sampled by the A/D converter on the Freescale Zigbee board. The data is formatted and sent wirelessly to a Freescale board connected to the PC.

c. Scalable software support:

– Proprietary point-to-point or star networking using Freescale's Simple Medium Access Control (SMAC) and TRIAX software (figure 3) [11]
– IEEE 802.15.4 Standard compliant networking using Freescale's MAC/PHY
– ZigBee™ networking using Freescale's Z-stack software

6.2. Testing

Using the above presented system that includes the demo software accompanying the development some kit more tests were run.

These tests followed the wireless communication behaviour in all the phases of the welding process. For MMA and MAG welding process and for different values of the welding current and metal transfer (spray, short arc and pulsed) few tests were also performed so as to determine if the system transmits information, if the communications are stable and it doesn't appear error messages. (Figure 4)

Figure 3 - TRIAX software panel

Figure 4 – Software test tool

6.3. Results

The capability of the wireless communication for the WSW was analyzed. This communication established was without errors in welding conditions. It was also maintained during the modification of the module distances, from 30 meters (working space and hall). Approaching under 0.5 meters from the arc welding zone, disturbances in communication has appeared.

6.4. Implementation Phases

1. Phase 1

1.1. Building a database with all the values of the monitored OEL and MEL factor risks for different types of materials and different arc welding processes

1.2. Sensors selection according to the monitored parameters and their level

1.3. Development kit sensors adaptation

1.4. Sensors optimal position settlement

1.5. Optimal assignment of the number of sensors

1.6. Establishment of optimal measurement domain

1.7. Monitoring application management software

2. Phase 2

2.1. Testing of the prototype system in industrial conditions (working area)

2.2. Analysis and processing of the monitored parameters values

2.3. Implementation of the online warning when admissible maximum values are exceeded

2.4. Analyses of the possibility of adapting the WSW system to the control system

3. Phase 3

3.1. Commercial Alternative for the WSW system

7. Conclusions

The paper makes an evaluation of the risk factors having an impact on the health of the welders, who work in MAG and MAG-P welding processes environments. Some considerations about the international regulations and legislation, the evolution and reduction of risk factors are also presented. The paper advances the welding space wireless monitoring system - WSW.

After the all the tests made this paper has demonstrated that we can use a wireless sensorial system for the monitoring of the welding areas.

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Evaluarea şi monitorizarea factorilor de risc la sudarea cu arc electric

Rezumat

Pentru creşterea productivităţii şi calităţii îmbinării sudate la sudarea MAG este necesară înlocuirea metodelor sudării manuale cu cele semi-automatizate sau automatizate. Datorită faptului că valoarea curentului de sudare este mare va fi, de asemenea, ridicată si valoarea radiaţiei electromagnetice. Radiaţiilor UV, nivelul de zgomot şi a noxelor. Normele europene de calitate în sudare sunt foarte restrictive. Din acest motiv, trebuie realizată o analiza riguroasă a condiţiilor de lucru a operatorului sudor.

Prin lucrarea de faţă ne propunem să efectuăm o evaluare a factorilor de risc şi a metodelor de monitorizare la sudarea MAG.

Qualité et assurance de la sécurité et prévenir le risque compte arc qui soude workspace

Résumé

Pour augmenter la productivité et la qualité de la poutre soudé le joint est nécessaire le remplacement des méthodes de la soudure manuelles avec le semi a automatisé et a automatisé MAG qui soude des méthodes. Parce que la valeur du courant de la soudure est haute, les radiations électromagnétiques, radiations UV, niveau du bruit et fumée sont hautes aussi. Les exigences de la qualité européennes pour souder sont très restreintes. Pour cette raison, nous avons besoin de faire une analyse rigoureuse des conditions actives des opérateurs. Dans ce papier nous faisons une évaluation du risque compte et des modalités de l'écoute à soudure MAG.