PLINOVI ZA ZAVARIVANJE I REZANJE – UTJECAJ NA VELIČINE ZAGAĐENJA

WELDING AND CUTTING GASES – INFLUENCE ON THE VALUES OF POLLUTANTS

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Ključne riječi: lučno zavarivanje metala sa zaštitnim plinom, zaštitni plinovi, emisije, udio prašine koji se može udisati, alveolarni udio prašine, čestice, maksimalna dopuštena koncentracija, glavne komponente

Key words: gas metal arc welding, shielding gases, emissions, breathable dust fraction, alveolar dust fraction, maximum allowable concentration, particulate matter, guide components

Sažetak: Zavarivanje i rezanje su najčešće sretane tehnologije spajanja i razdvajanja. Većinu procesa zavarivanja i rezanja prate određene količine različitih emisija. Te emisije, kao što su prašina dim i pare imaju različite izvore i različite utjecaje na okoliš i zdravlje ljudi. Stoga je vrlo važno imati pregled opasnosti koje mogu biti izazvane različitim tehnologijama. Cilj je ovog rada formirati pregled različitih vrsta emisija, njihovih izvora i učinka te mjera njihovog smanjenja. Od brojnih primjena zavarivanja i rezanja ovaj se rad koncentrira na elektrolučno zavarivanje u zaštitnom plinu i njegove varijante, a osobito na elektrolučno zavarivanje niskougljičnih čelika u zaštitnom plinu. Europska je zajednica usvojila norme za radna mjesta. Postavljene su samo tri granice za svaku primjenu: udio prašine koji se može udisati, alveolarni udio prašine i glavnu komponentu. Suvremeni zaštitni plin utječe na proces zavarivanja ali i na emisije (smanjivanje količina ugljik-dioksida, dušik-oksida i čestica).

Abstract: Welding and cutting are the most common joining and separating technologies. Most of the processes of welding and cutting have a certain amount of different emissions. These emissions as there are dust; smoke and fumes have different sources and different effects to our environment and human health. So it's very important to have a view to the hazards witch can be caused by the different technologies. This publication wants to give an overview to the different kinds of emissions their sources the effects and what can be done to reduce them. With regard to the numerous welding and cutting applications this article will be concentrated to gas shielded arc welding and its variations and especially to gas metal arc welding of mild steel. European communities arrogate regulations for a human arrangement for workplaces. We have only three limits, the breathable fraction, the alveolar fraction and the guide component of each application. Modern shielding gases are an instrument to take influence to the welding process and finally to the emissions (reduction of carbon dioxide, nitrogen oxides and particulate matter).

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1. INTRODUCTION

Welding is one of the most popular joining technologies. This wide field of technologies contains numerous variations. As there are:

- Manuel metal arc welding
- Gas shielded arc welding
- Laser welding
- Plasma welding
- Resistance welding
- Friction welding
- …

All these welding procedures have different emissions. The differences may consist of different particle sizes, different materials, rays, sound or different amounts of emission. They get also influenced by the process parameters. Depending on the material thickness, the thickness of the welding wire or the required welding speed, a different welding current, voltage or laser energy is necessary. The friction welding needs different friction speed or pressure. The kind of arc is even crucial. A spray arc has much more emissions than a short arc. Last but not least the base material and the welding material take an important place in the chain of all these separate links.

This publication is concentrated to gas metal arc welding of mild steel.

2. EMISSIONS – DEFINITIONS

The emissions caused by welding are numerous beginning with sound, magnetic and ultra violet rays etc. This publication is restricted to:

- Gases
- Fumes
- Dust

These emissions result from the shielding gas itself from residual pollutions on the surface of the base or welding material and of chemical compounds or decomposition products of the air. The appropriate chemical reactions will be described as followed.

2.1 Vaporization

The energy of the arc causes the vaporization of the base metal, the filler metal and their alloying additions: Cu, Ni, Cr, Mo, Mn, V, …. (Figure 1) The source for copper is the coating and the amount depends on the thickness. All these metals can be found fine dispersed as components of the dust.

2.2 Oxidation

By using shielding gases with oxygen or carbon dioxide the elements of the base material and the filler material gets oxidized. 90 % of these oxides are generated by the filler material.

2.3 Decomposition

Carbon monoxide is a decomposition product of the carbon dioxide contained in the shielding gas mixtures. Carbon dioxide gets generated by high temperatures following the Boudoir's balance. The generated oxygen is use for metallurgical needs and the remaining carbon monoxide gets emitted.

Vaporisation
- metals Fe, Ni, Cr, Mn, Cu, …

Oxidation
- metals FeO, Fe_2O_3, CuO, SiO_2, Mn_2O_3
- $N_2 + O_2 \Rightarrow 2NO \qquad 2NO + O_2 \Rightarrow 2NO_2$

Decomposition
- $CO2 \Rightarrow CO + O$

Pyrolysis
- $C_xH_y \Rightarrow C_{x1}H_{y1}$

Combustion
- $C_xH_y + O_2 \Rightarrow \begin{matrix} CO + H_2O \\ CO_2 + H_2O \end{matrix}$

Figure 1 Vaporization of metals and chemical reactions

2.4 Fumes / Dust

In General dust is a name for minute solid particles witch are able to float in air or gases for a long time after being raised. Dust may be classified on the particle sizes such as coarse dust with a diameter > 10µm or particulate matter < 10 µm. Particles with a diameter < 5 µm are alveolar. Altogether is called respirable fraction.

Otherwise the chemical composition makes a difference. The possible components are metal oxides and chemical compounds. The different sources of dust are mechanical removal or chemical or thermal processes.

Fumes occur from chemical or thermal processes. They content gases, aerosol and fine dust. Most of the particles have a diameter less than 1 µm.

3. SOURCES

To reduce the emissions of a welding process we have to look to all possible influences (Figure 2). In this case we have to start at the beginning that means the construction itself. There is a difference between but or fillet welds with regard to the heat input for example. And the more heat is put into the process the more material gets vaporized. Vertical up welding causes more heat input than flat position welding. Last but not least the longer them seams the emissions are produced. The surface of base material and filler material may be polluted by any dirt or coated by residual oil, impregnating agents or coatings. In these cases we have different emissions. The emissions out of these pollutions getting vaporized by the heat effected zone of the base metal the heat of the arc and the heat of the spatters.

Spatters have a relative big surface with regard to their volume and a very high content of heat. This causes relative high emissions. Reducing spatters means reducing the emissions out of pollutions of the surface of the base material and out of the spatters themselves. The filler metal produces 90 % of the pollutions. The emissions rise with an increasing diameter of the wire.

The shielding gas is mainly responsible for the emission of carbon monoxide. So it is very effective reducing the content of carbon dioxide in the shielding gas.

Stainless steel is alloyed with chromium, nickel, vanadium, molybdenum and some more components. They are helpful inside but outside they are dangerous for the welder's health. Especially oxides of chromium, cobalt and nickel are harmful because of their carcinogen effect. Last but not least the influence of the chosen welding procedure and the parameters is even very high. The welding procedures also have an influence to the construction and here we are at the beginning again.

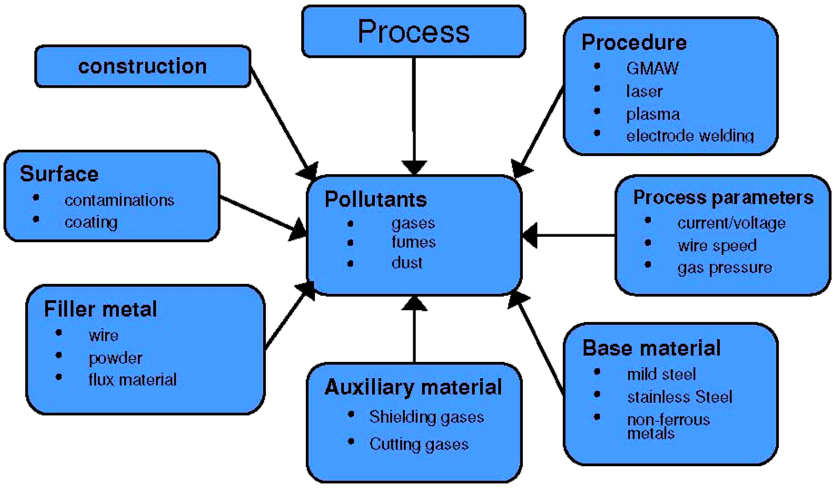

Figure 2 Influences of the welding process

4. EMISSION RATES

The emission rate of each welding application is different and depends on:

- Welding application
- Base material
- Thickness
- Filler material
- …

Using self-shielding cored wire produces the highest emission rate. The shielding material is nearly identical to the material of electrodes for manual metal arc welding.

The following tables show the typical emissions of the different GMAW and some comparable.

Table 1: Emission rates of different welding applications

mild steel						
welding process					Emission rate mg/s	
Electrode welding					4-18	
GMAW	**solid wire**				**2-12**	
	Cored wire				**6,7-54**	
	Self shielding cored wire				**up to 97**	
Stainless steel						
Welding process	Emission rate mg/s					
	Welding	Chrome	Chrome-VI	Nickel	Mangan	
Electrode welding	2-16	0,04-1,3	0,01-1,2	0,03-0,5	0,04-1,1	
GMAW	**1,5-8**	**0,1-1,3**	**0-0,05**	**0,05-0,6**	**0,1-1,2**	
Laser welding	1,3-2,0	0,16-0,26	0,003-0,007	0,05-0,08	0,09-0,16	

5. EUROPEAN STANDARDS AND REGULATIONS

Welding fumes, dust and gases are subject to the "Ordinance on Hazardous Substances" and so they have to be handled. Additional the arrangement of a working place is regulated by the labor protection laws. This leads to some essential facts. The emissions have to be disposed in a correct way and the concentration at the working place has to be controlled and reduced to a given limit. To simplify the regulations with regard to the numerous emissions once has created the guide component. The guide component is the component with the highest health risk in a special application. Now there are only three limits witch have to be observed.

- Breathable dust fraction < 10 mg/m³
- Alveolar dust fraction < 3 mg/m³
- Guide component < MAC limit (maximum allowable concentration).

Table 2 Guide components for GMAW

Application	Filler metal	Guide component
GMAWC	Mild steel	Welding fume, carbon monoxide
GMAWM	Mild steel	Welding fume
	Stainless steel solid wire	Welding fume, nickel oxide
	Stainless steel cored wire	Welding fume, chrome-VI-compounds

To arrange a healthy working place it is necessary to keep emissions to a certain concentration. Even if the lowest level of emission of a welding process is reached the concentration at the working place will rise continuously if the emitted material doesn't get removed. So some kind of ventilation is necessary.

Now we have to make a difference between risk assessment and protection measures. To choose the right ventilation we don't have to know the kinds and amounts of emissions but the application. Depending on the welding procedure, the base material and the filler material a certain kind of ventilation is required:

- Natural airing
- Technical ventilation
- An fume exhaust at the point of origin

Table 3 Exhausting of applications with filler material

Application	Filler material		Welding of coated material
	Mild steel, aluminium	Stainless steel, non ferrous metal (except aluminum)	
Gas welding	T	E	E
MMAW	E	E	E
GMAW	E	E	E
TIG welding:			
• Thorium oxide free electrode	T	E/T	T
• Thorium oxide containing electrode	E	E	E
Submerged arc welding	T	T	T
T – Technical ventilation, E – Exhaust at the point of origin			

6. INFLUENCE OF SHIELDING GASES

The influence of the shielding gases to the kind and amount of emissions is complex. Carbon dioxide is responsible for the production of carbon monoxide. The exchange of carbon dioxide against argon enables the use of a spray arc. To reach a stabile spray arc it is necessary to go below a limit of 20 % carbon dioxide. The use of a spray arc in connection with a less carbon dioxide gas mixture influences the production of fumes, carbon monoxide and nitrogen oxides. Latest welding test have shown the correlations between shielding, welding application, fumes, carbon monoxide and nitrogen oxides. The following welding parameters have been used for the welding tests.

Table 4 Welding parameters

Shielding gas	Wire feed [m/min]		Voltage [V]		Current [A]	
	ShA	SpA/LA	ShA	SpA/La	ShA	SpA/La
CO_2	4,6	12,0	24,4	34,6	150	315
18 % CO_2 bal. argon	4,6	12,0	19,4	32	180	325
8 % CO_2 bal. argon	4,6	12,0	19,2	31,8	180	322
4 % O_2 bal. argon	4,6	12,0	19,0	31,6	180	330
3 % CO_2 1 % O_2 bal. argon	4,6	12,0	19,2	31,7	178	327
6 % CO_2 1 % O_2 bal. argon	4,6	12,0	19,2	31,8	179	325

6.1 Particulate matter

The use of a spray arc causes up to 200 % more solid particles than the use of a short arc (Figure 3). But generally the use of argon based gas mixtures with low contents of carbon dioxide or oxygen decreases the emissions. Welding with carbon dioxide by using the long arc is not typical. Welding with CO_2 causes a lot of spatters witch become more in the long arc. The spatters themselves produce emissions so it is the highest emission rate of all. The lowest emission of particulate matter is caused by short arc welding with low contents of oxygen in argon.

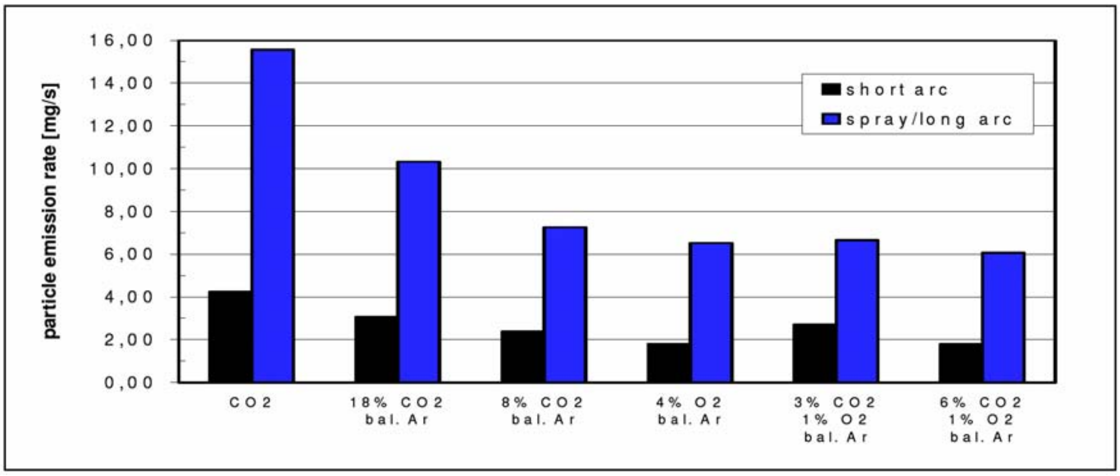

Figure 3 Particle emission rates of different gas mixtures

6.2 Carbon monoxide

Carbon monoxide (CO) is the guide component for gas metal arc welding with pure carbon dioxide. The reduction of carbon dioxide reduces the emission of carbon monoxide (Figure 4). The less carbon dioxide is included in the gas mixture the less carbon monoxide will be produced. The use of spray arc is a further possibility to reduce carbon monoxide between 30 % and 50 %.

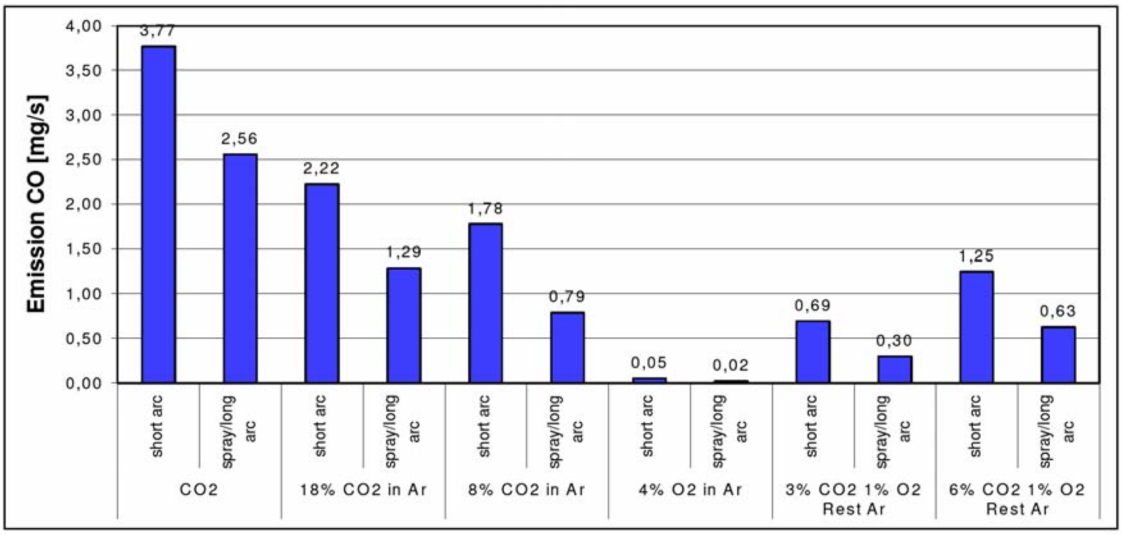

Figure 4 Carbon monoxide productions of different welding applications and gas mixtures

6.3 Nitrogen oxides

Nitrogen dioxide (NO_2) is limited to a working place concentration of 5 ml/m³ (9,5 mg/m³). The emission of nitrogen oxides also correlates with the contents of carbon dioxide and oxygen. In combination with the spray arc a very low level of nitrogen oxides is reachable. The best results could be obtained with oxygen content of 4 %. All in all, none of these applications emits enough nitrogen dioxide to become a guide component.

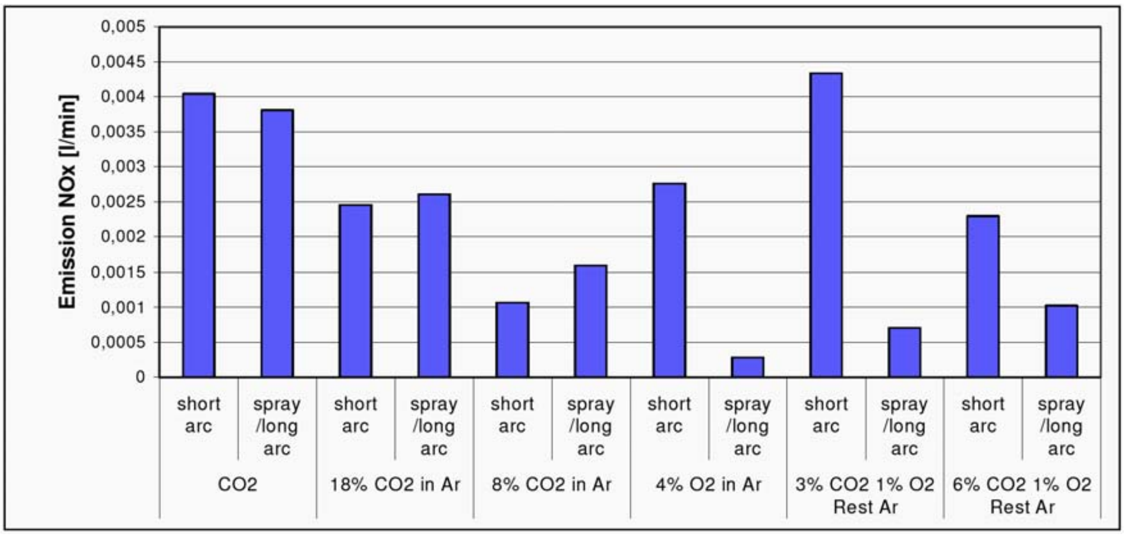

Figure 5 Nitrogen oxide emissions of different applications and gas mixtures

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