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FUME EMISSION DURING THE ARC AND LASER WELDING OF CAST STAINLESS AUSTENITIC STEEL

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The article presents results of research on fume emission in relation to various arc welding methods (MAG standard, CMT, ColdArc and ColdArc Puls) and laser welding techniques (heat conduction and deep penetration welding). Research - related tests involved manifold elements and a turbine housing made of cast stainless steel. The shielding gas used during arc welding was a mixture containing 97,5 % of Ar and 2,5 % of CO_2. In turn, laser welding processes were shielded by argon. The analysis of test results aimed to identify the effect of arc/laser welding methods on the total emission of welding fume.

Keywords: stainless steel, technological parameters, arc welding, laser welding, fume emission

INTRODUCTION

The welding of metals entails the formation of hazardous substances, posing a threat to human health and classified as highly toxic, toxic, harmful, irritant, allergenic, carcinogenic and mutagenic. During welding processes, base materials, filler metals, protective coatings of base materials, shielding gases and ambient air affected by welding arc or laser beam give rise to the formation of welding fume (dual - phase condensing aerosol) [1 - 9]. The aerosol is the mixture of fine dispersive solid particles (welding fume) and various gases constituting a dispersion medium. Fume enters the human body primarily through the respiratory tract. The aforesaid route allows the passage of only very small, and also the most harmful, particles. The long-lasting irritant effect of welding fume leads to irreversible changes in the respiratory tract and, as a result, enables hazardous particles to penetrate pulmonary alveoli. Protracted exposure to welding fume leads to various diseases of the respiratory tract [2 - 9].

The chemical composition of welding fume depends on types of materials being joined as well as on welding methods and technological parameters. The welding of stainless steel usually entails the emission of iron, manganese, silicon, chromium and nickel compounds [3, 5, 7].

THE SCOPE OF RESEARCH

The primary purpose of the research involved the identification of the effect of arc and laser welding methods on the emission of fume. The tests included the MAG method and its low-energy variants, i.e. ColdArc, CMT and ColdArc Puls, as well as two laser welding techniques, i.e. heat conduction and deep penetration methods [8].

The base material used in the tests was cast stainless austenitic steel 1.4848 (GX40CrNiSi25-20) (in the form of a manifold). The chemical composition of the base material included 50,95 % of Fe; 25,06 % of Cr; 20,37 % of Ni; 1,18 % of Nb; 0,46 % of C; 0,21 % of Mn; 0,04 % of Mo; 0,02 % of Cu and 0,01 % of Ti. In turn, the chemical composition of the filler metal (i.e. wire 24.13 L Si Sandvik ER 309LSi having a diameter of 1 mm and used in arc welding methods) included 23,5 % of Cr; 13,5 % of Ni; 1,8 % of Mn; 0,9 % of Si; <0,4 % of Mo; 0,1 % of N, as well as < 0,025 % of C and P. The shielding gas mixture used in arc welding contained 97,5 % of Ar and 2,5 % of CO_2. The laser welding process was shielded by Ar.

The tests involving arc welding were performed in relation to three sets of technological parameters including welding current, arc voltage, filler metal wire feed rate and a welding speed (Table 1).

The tests involving laser welding were performed in relation to three sets of technological parameters including laser beam power and a welding speed (Table 2).

Table 1 **Technological parameters of arc welding processes [8]**

Welding method	Process technological parameters			
	I / A	U / V	V_w / m/min	V_{ws} / m/min
MAG standard	90 -120	18,0 – 20,0	4,4 - 6,0	0,40 -0,42
ColdArc	90 -137	17,0 – 22,0	4,5 - 7,5	0,4 -1,0
CMT	80 -143	11,6 – 14,0	4,0 - 8,0	0,4
ColdArc Puls	90 -140	20,5 - 24,5	5,4 - 8,4	0,4

Designations: I – welding current, U - arc voltage, V_w – filler metal wire feed rate and V_{ws} - welding speed

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Table 2 **Technological parameters of laser welding processes [10]**

Welding technique	Process technological parameters		
	V_{ws} / m/min	*f* / mm	*P* / W
Heat conduction welding	1,08	20	2 500 3 000 3 500
Deep penetration welding	1,50	0	2 500 3 000 3 500

Designations: V_{ws} - welding speed, *f* – defocusing, *P* – laser beam power

Figure 1 Testing station for fume emission measurements during arc welding [10]

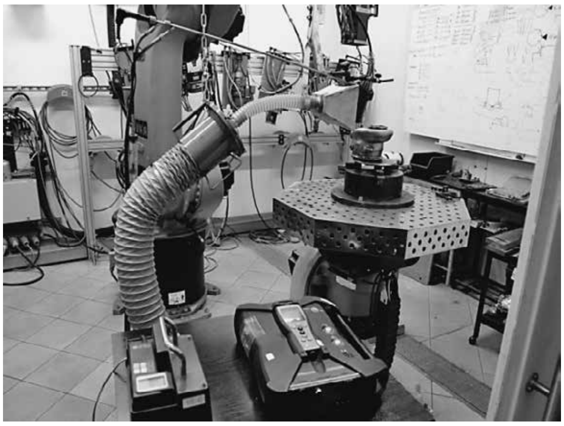


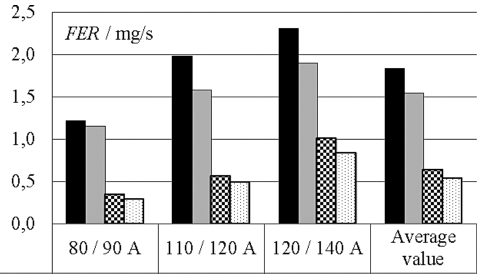
Figure 2 Testing station for fume emission measurements during laser welding [10]

Testing stations examining fume emission rates during arc and laser welding are presented in Figures 1 and 2.

INFLUENCE OF ARC WELDING METHOD ON FUME EMISSION RATE

The analysis of measurement results concerning total fume emitted during arc welding aimed to identify the correlation between fume emission rates and the use of MAG standard, ColdArc, CMT and ColdArc Puls welding methods.

Figure 3 contains a bar chart presenting information concerning the emission of pollutants in relation to three current parameters subjected to examination (80 / 90, 110 / 120 and 120 / 140 A) as well as the comparison of mean arithmetic values of pollutant emission in relation to the entire range of current parameters.



	80 / 90 A	110 / 120 A	120 / 140 A	Average value
■ MAG	1,22	1,98	2,31	1,84
▒ ColdArc Puls	1,15	1,58	1,90	1,54
⊠ ColdArc	0,35	0,56	1,01	0,64
□ CMT	0,29	0,49	0,84	0,54

Figure 3 Fume emission rates in relation to arc welding methods [8]

The analysis of test results revealed the effect of the arc welding method on the emission of fume pollutants in time.

The highest values of total fume emission were determined when the cast elements were welded using the MAG standard method. In relation to a welding current of 90 A, the emission of welding fume amounted to 1,22 mg/s, in turn, relation to a welding current of 110 A, the emission of welding fume 1,98 mg/s, whereas relation to a welding current of 120 A, the emission of welding fume amounted to 2,31 mg/s. In relation to the entire set of parameters, the average value of emission amounted to 1,84 mg/s.

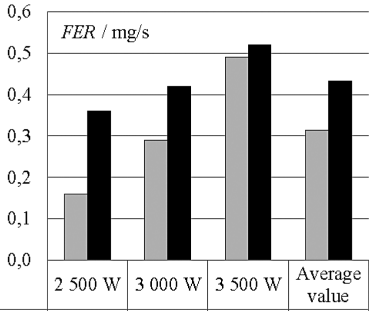
The lowest emission of total fume within the entire range of parameters was that related to the use of the CMT method, where emission amounted to 0,29 mg/s in relation to a current of 80 A, 0,49 mg/s in relation to a current of 125 A and 0,84 mg/s in relation to a current of 143 A. The ColdArc and ColdArc Puls methods were characterised by higher emission rates in terms of total fume (in comparison with that related to the CMT method). As regards the average values, the emission of total fume during the CMT welding process (0,54 mg/s) was by 15 % lower than that related to the ColdArc method (0,64 mg/s). The CMT and ColdArc methods belong to low-energy methods and are characterised by the reduced emission of pollutants into the work environment.

The analysis of the average values concerning the emission of total fume in relation to the entire range of tested current parameters revealed that the replacement of the traditional MAG method with the ColdArc Puls variant reduced the emission of total fume by more than 15 %. The use of the ColdArc method reduced emission nearly by thrice, whereas the use of the CMT reduced the emission of total fume by 3,5 times.

INFLUENCE OF LASER WELDING TECHNIQUE ON FUME EMISSION RATE

The analysis of test results aimed to identify the effect of laser welding technique (heat conduction and deep penetration welding) on the total fume emission.

Figure 4 presents data concerning the total fume emission in relation to three values of laser beam power (2 500 W, 3 000 W and 3 500 W). The figure also presents the comparison of the mean arithmetic values of pollutant emissions in relation to the entire range of laser beam power.



	2 500 W	3 000 W	3 500 W	Average value
Heat conduction welding	0,16	0,29	0,49	0,31
Deep penetration welding	0,36	0,42	0,52	0,43

Figure 4 Fume emission rates in relation to laser welding [10]

The analysis of the test results revealed the effect of the applied laser welding technique on the fume emission during the Ar - shielded welding of the manifold elements and the turbine housing.

Higher values concerning the total fume emission were observed during the deep penetration welding technique. In relation to a laser beam power of 2 500 W, the emission of total fume amounted to 0,36 mg/s, in turn, in relation to a laser beam power of 3 000 W, the emission of total fume amounted to 0,42 mg/s, whereas in relation to a laser beam power of 3 500 W, the emission of total fume amounted to 0,52 mg/s. In terms of the same values of laser beam power applied during the heat conduction welding process, the values of fume emission amounted to 0,16 mg/s, 0,29 mg/s and 0,49 mg/s respectively.

The analysis of the average values of the total fume emission in relation to the entire range of parameters (i.e. 0,31 mg/s in relation to the heat conduction welding technique and 0,43 mg/s in relation to the deep penetration welding method) revealed that the use of the heat conduction welding technique reduced the total fume emission by more than ¼.

COMPARISON OF FUME EMISSION RATE DURING ARC AND LASER WELDING

Figure 5 presents the comparison of test results concerning the welding fume emission in relation to the arc welding methods (i.e. MAG standard, ColdArc, CMT and ColdArc Puls) and the laser welding techniques (i.e. heat conduction and deep penetration welding) used in the joining of the manifold element and the turbine housing.

The laser welding processes were characterised by lower rates of total fume emission in comparison with

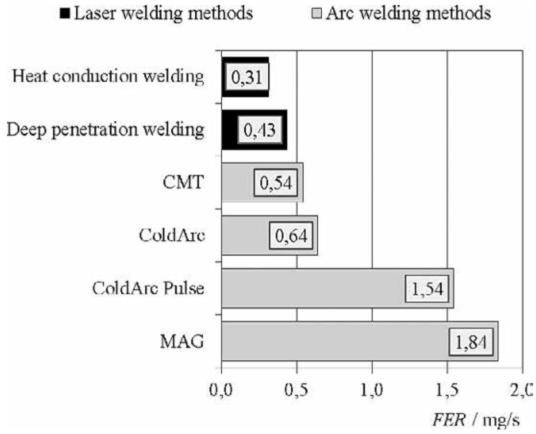


Figure 5 Comparison of average values of total fume emission during the arc welding and laser beam welding of the manifold and the turbine housing [10]

all arc welding methods investigated in the tests. The lowest total fume emission accompanied the heat conduction welding process - the average value of emission amounted to 0,31 mg/s and was 6 times lower than that accompanying the use of the MAG standard method, 5 times lower than during ColdArc Puls method, 2 times lower than in ColdArc method and by more than 40 % lower than during the CMT method. It should also be noted that in the arc welding processes, welding fume was formed as a result of arc affecting the base material and the filler metal (electrode wire), whereas during laser welding, the emission of pollutants resulted from the laser beam only affecting the base material.

CONCLUSIONS

The above-presented tests as well as the analysis of their results justified the formulation of the following concluding remarks [10]:

1 The tests revealed the effect of the 97,5 % Ar + 2,5 % CO_2 mix-shielded arc welding of the manifold elements with the turbine housing (grade 1.4848), using solid wire 24 13 LSi, on the emission of welding fume. As regards the reduction of total fume emission, the CMT appeared the most favourable, whereas the standard MAG process turned out to be the least advantageous method.

2 The replacement of the MAG standard method with the CMT technique reduced the emission of total fume by up to 3,5 times.

3 The tests also revealed the effect of the Ar - shielded laser welding of the manifold elements with the turbine housing (grade 1.4848) on the emission of fume pollutants. The heat conduction welding technique proved the most favourable as regards the total fume emission.

4 The use the heat conduction welding reduced the total fume emission by 25 % in relation to the use of the deep penetration welding technique.

5 The laser welding processes were characterised by lower rates of total fume emission than those related

to all arc welding methods. The lowest emission of total fume was observed during the heat conduction welding process.

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