Determining Microparticle Concentration in the Workplace Atmosphere during Plasma Gouging

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Abstract
In this paper, we will present the result of our experimental research on measuring the microparticle concentration in the workplace atmosphere during plasma gouging. The results were compared to those of other measurements carried out at other arc-air and coated electrode gouging procedures. The microparticle concentration was measured with the MicroDust 880 nm detector. Following the measurements carried out, the results were also compared to the maximum permissible limit value regulated by the Government Decision No. 1218 of September 6, 2006.

Keywords
microparticles, plasma gouging, permissible limit value

1. Introduction

Over the last decade, there has been an increase in the demand for metal structures, both industrial and civil. With the increase in the metal structure volume, the requirements for environmental and human health protection have increased, too [2]. This required finding and applying processing and manufacturing technologies as eco-friendly as possible. The gouging technologies known in the metal-structure building industry include plasma gouging or scooping, which is an environmentally friendly technology, if compressed air is used as a plasmagen gas.

As basic material, we used a structural steel, namely S275JR + AR steel. This is a low carbon content steel that behaves very well in welded structures, which are subjected to moderate stress. This steel has a ferrite-pearlite microstructure, with ferrite prevailing. The specimen that we subjected to plasma gouging is a rolled steel strip of 10 mm thickness and 100×250 mm length × width.

In the experimental framework, we used the MicroDust Pro 880nm microparticle detector [1]. This device measures the concentration of the airborne microparticles, using 880 nm wave length infrared light, which is projected through a sensor, where it comes into contact with the particles suspended in the atmosphere to be tested, causing light deviation. The light deviation rate is compared to the amount of airborne particles, which is measured by a detector.

2. Experimental Framework

In the experimental framework, we used the S275JR steel, whose chemical composition is indicated in Table 1.

Table 1. Chemical composition of the basic material [%] [3]

Grade	C	Mn	S	P	Si	Cu	N
S275JR	0.12	0.65	0.019	0.015	0.20	0.33	0.008

The gouging equipment is a Powermax 45 plasma cutting/gouging equipment.

This equipment can provide a 20-45-A cutting or gouging current. The equipment is small, which is ideal for use in a workshop or at home.

After the setting of the gouging device and the fastening of the specimens onto a working table, we performed the gouging operation and, at the same time, measured the microparticle concentration with a MicroDust 880 nm detector. The microparticle detector has four measurement ranges: 0-2.5

mg/m³, 0-25 mg/m³, 0-250 mg/m³ and 0-2500 mg/m³. The measurement range 0-250 mg/m³ was chosen. The microparticle detector was connected to a laptop and calibrated with the aid of the WinDust software, and a measurement was carried out by means of the programme. That measurement was necessary in order to show that, before the gouging process, the workplace atmosphere was free of microparticle traces.

Gouging parameters [3]:

- Basic material: S275JR + AR, according to standard SR EN 10025/2-2004
- Material thickness: 10 mm
- Gouging speed: ≈ 865 mm/min
- Gouging interval / measuring time: 600 seconds
- Intensity of gouging current: 40 A
- Plasmagen gas: compressed air
- Compressed air flow rate: 165 l/min
- Compressed air pressure: 0.5 MPa

The diagram in Figure 1 shows there curves. The violet one, which is drawn as a horizontal line, represents the first measurement before the beginning of the gouging operation. The red horizontal line at 5 mg/m³ represents the permissible limit value regulated by the Government Decision no. 1218 of 2006 [4] and the blue one represents the airborne microparticle concentration measured during the plasma gouging. One can see that, after two minutes, the value of the microparticle concentration begins to grow exponentially, up to the maximum value of 4.2 mg/m³, and afterwards, it decreases gradually. The fluctuations of microparticle concentration values are caused by the fact that the location of the gouging gun changes in relation to the sensor of the microparticle measuring device.

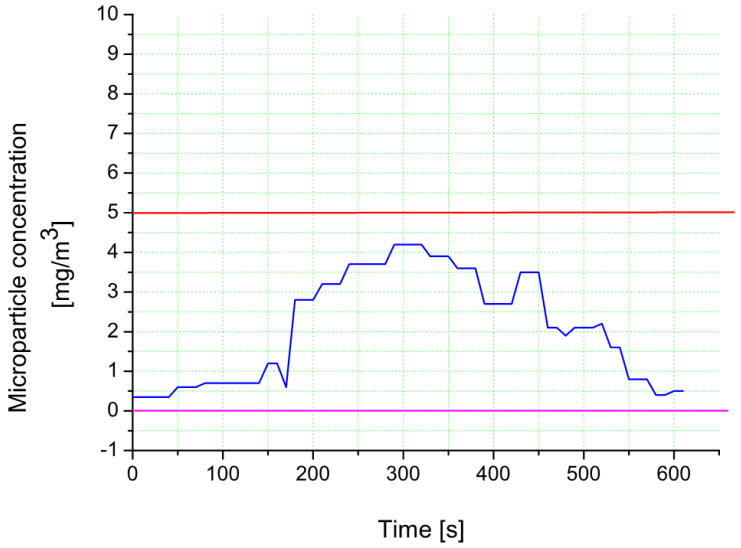

Fig. 1. Diagram of microparticle concentration measured during manual plasma gouging

A summarization of the measured data is presented below:

- Gouging interval / measuring time: 600 seconds
- Minimum microparticle concentration determined by the sensor of the device: 0.35 mg/m³
- Maximum microparticle concentration determined by the sensor of the device: 4.2 mg/m³
- Average microparticle concentration in the measured time interval, determined by the sensor of the device: 2.094 mg/m³

The second measurement was carried out for the plasma mechanized gouging procedure. The same type of steel was used as a basic material and the same specimen size. At this specimen, the microparticle concentration was measured only during the gouging operation.

Gouging parameters [3]:

- Basic material: S275JR + AR, according to standard SR EN 10025/2-2004

- Material thickness: 10 mm
- Gouging speed: 1050 mm/min
- Gouging interval / measuring time: 600 seconds
- Intensity of the gouging current: 40 A
- Plasmagen gas: compressed air
- Compressed air flow rate: 165 l/min
- Compressed air pressure: 0.5 MPa

The microparticle concentration measured during the mechanized plasma gouging and presented in Figure 2. One can see that the concentration value increases exponentially from the first minutes after the beginning of the gouging process. As can be seen in Figure 2, the particle concentration does not exceed the maximum permissible value of 5 mg/m^3.

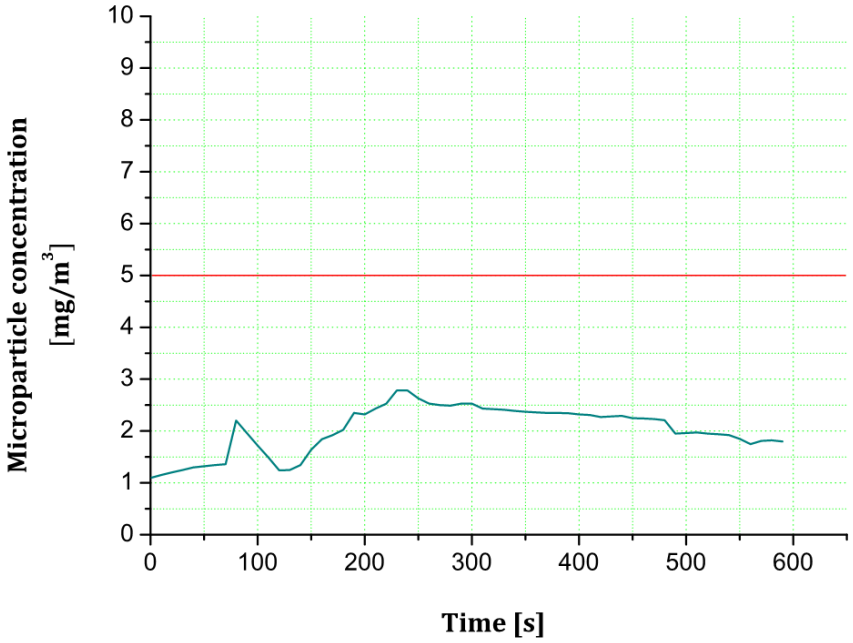

Fig. 2. Diagram of microparticle concentration measured during the mechanized plasma gouging

The summarization of the measured data is presented below:

- Gouging interval / measuring time: 600 seconds
- The minimum microparticle concentration determined by the sensor of the device is 1.12 mg/m^3
- The maximum microparticle concentration determined by the sensor of the device is 2.78 mg/m^3
- The average microparticle concentration in the measuring interval, determined by the sensor of the device is 1.96 mg/m^3

The third measurement was carried out for the arc-air gouging procedure. In this case, the measurement was carried out during the gouging process. This procedure was used, as well as the coated electrode gouging procedure, in order for us to make a comparison between the results of the measurements obtained for the plasma gouging procedure.

Gouging parameters [3]:

- Basic material: S275JR + AR, according to standard SR EN 10025/2-2004
- Material thickness: 10 mm
- Gouging speed: ≈780 mm/min
- Gouging interval / measuring time: 600 seconds
- Intensity of the gouging current: 270 A
- Auxiliary gas: compressed air
- Compressed air pressure: 0.7 MPa

The value of the microparticle concentration measured during the arc-air gouging is indicated in Figure 3. As can be seen, the microparticle concentration increases exponentially and exceeds the permissible limit threshold of 5 mg/m^3, indicated on the diagram by a red horizontal line. The value maintains itself at a constant high level throughout the entire gouging process.

A summarization of the measured data is presented below, as follows:

- Gouging interval / measuring time: 600 seconds
- The minimum microparticle concentration determined by the sensor of the device is 1.25 mg/m^3
- The maximum microparticle concentration determined by the sensor of the device is 14.62 mg/m^3
- The average microparticle concentration in the measured time interval, determined by the sensor of the device is 4.5024 mg/m^3

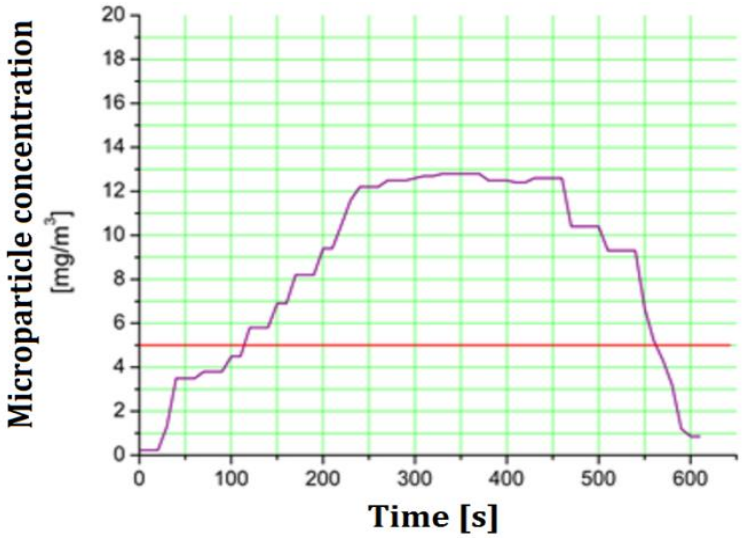

Fig. 3. Diagram of microparticle concentration measured during the arc-air gouging

The fourth measurement was carried out for the coated electrode gouging procedure and, this time, the measurements were carried out during the gouging process.

Gouging parameters [3]:

- Basic material: S275JR + AR, according to standard SR EN 10025/2-2004
- Material thickness: 10 mm
- Gouging speed: ≈ 860 mm/min
- Gouging interval / measuring time: 600 seconds
- Intensity of the gouging current: 185 A
- Gouging voltage: 60V

The value of the microparticle concentrations measured during coated electrode gouging is indicated in Figure 4. One can see that, from the very first minutes since the beginning of the gouging operation, the determined values grow exponentially, until they exceed the permissible limit threshold of 5 mg/m^3. The fluctuations of the microparticle concentration values are caused by the fact that, during the measurement, the position of the gouging electrode or of the gouging gun in relation to the sensor of the device is continuously changing. The high values of the measured microparticle concentration are caused by the molten material eliminated from the gouged channel, which rebounds from the workshop floor back into the breathable atmosphere, also carrying along other older particles existing inside the workshop.

A summarization of the measured data is presented below:

- Gouging interval / measuring time: 600 seconds
- The minimum microparticle concentration determined by the sensor of the device is 0.02 mg/m^3
- The maximum microparticle concentration determined by the sensor of the device is 22.7 mg/m^3

- The average microparticle concentration in the measured time interval, determined by the sensor of the device is 7.495 mg/m^3

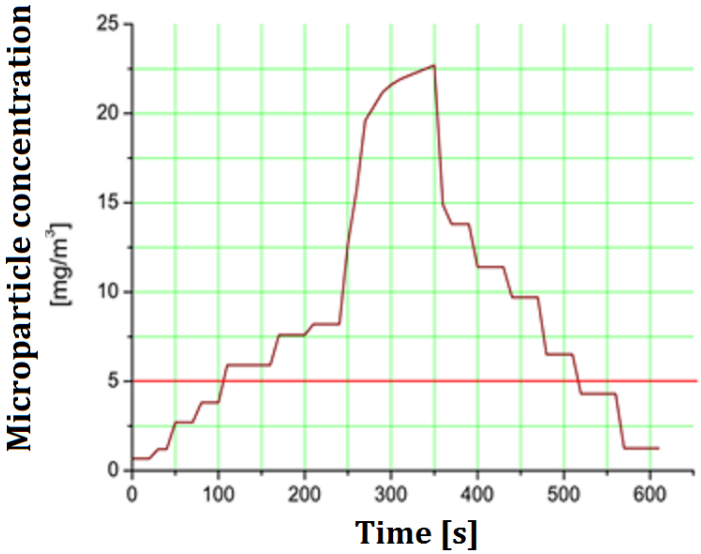

Fig. 4. Diagram of microparticle concentration measured during coated electrode gouging

The average values of the microparticle concentration during the actual gouging time interval (with various gouging procedures) are indicated in the following figure.

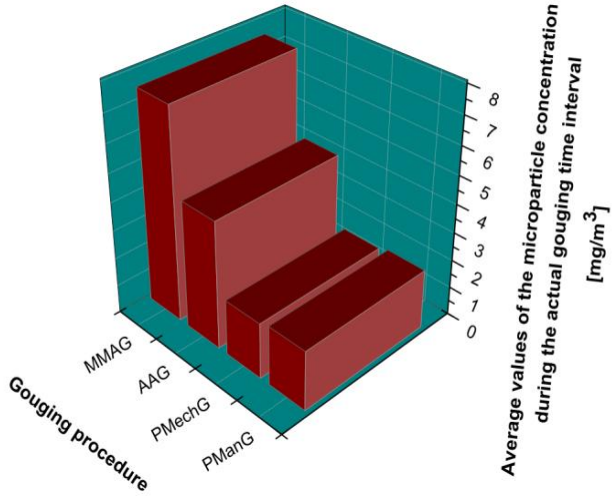

Fig. 5. Average values of the microparticle concentration during the actual gouging time interval with various gouging procedures

The values presented in the diagram above correspond to the average microparticle concentrations (Mpc), as follows:

- The plasma mechanized gouging procedure (PMechG) at the basic material S275JR+AR: Average Mpc = 1.96 mg/m^3
- The plasma manual gouging procedure (PManG) at the basic material S275JR+AR: Average Mpc = 2.094 mg/m^3
- The arc-air gouging procedure (AAG) at the basic material S275JR+AR: Average Mpc = 4.502 mg/m^3
- The coated electrode (manual metal arc) gouging procedure (MMAG) at the basic material S275JR+AR: Mpc = 7.495 mg/m^3

3. Conclusions

- According to the measurements carried out and presented in this scientific paper, the fact that the coated electrode gouging procedure has the highest level of microparticle concentration confirms our expectations. This is because the procedure using gas (from external sources) to eliminate the molten material is not used in this case.
- In the case of the coated electrode gouging, the average value of the microparticle concentration, too, exceeds the permissible limit value of 5 mg/m^3.
- The arc-air gouging procedure has a lower microparticle concentration, even if the intensity of the gouging current is higher than with the coated electrode gouging procedure.
- In the case of the plasma gouging procedure, especially the mechanized one, the microparticle concentrations are the lowest.

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