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# THE INFLUENCE OF THE WELDING CURRENT ON THE AIR POLLUTION EMISSIONS

**Summary**: This paper presents a statistical analysis of the influence of the welding current on the air pollution emissions. It contains the presentation of test conditions and design of a test rig. Station tests was performed on the basis of binding standards with reference to the quality of air on welding stations. The statistical analysis was carried out on the basis of R software.

**Key words**: welding process, air quality condition, inhaled fraction, respirable fraction, welding parameters

## 1. INTRODUCTION

The subject of tests in this paper is the process of air pollution emissions ongoing during the welding time visible in the form of welding smoke. This smoke contains different pollutants which depend on many factors, inter alia the grade of material of welded elements, welding method, type of applied welding appliances. Depending on the size of particles the welding smoke is divided into:

- inhaled fraction (inhaled through the nose and mouths),
- respirable fraction of particle size less than 0.001 mm.

In order to ascertain the course of pollution emissions process, station tests were performed. The test objects were elements made of S235JR steel with the thickness of 4 mm. The type of weld performed – fillet weld.

## 2. TEST CONDITIONS

The test of air pollution emissions during the welding process was carried out as per standard PN-Z-04008-7:2002 + Az 1:2004 [4]. Air cleanliness protection. Samples collection. The principles of samples collection in the work environment and interpretation of results.

With the use of a calibrator, type Giblator 2, proper flows of aspirators were set for both inhaled and respirable fractions. A calibrated aspirator was connected via a conductor to the measuring head. Samplers were placed in the head (Fig. 5 and 6). An individual set prepared in this way was fitted to the welder's overalls belt (Figs 1, 2).

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Physical and chemical analyses were carried out of filters collected during the welder's work. The amount of compounds deposited on filters is the measure of air pollution.

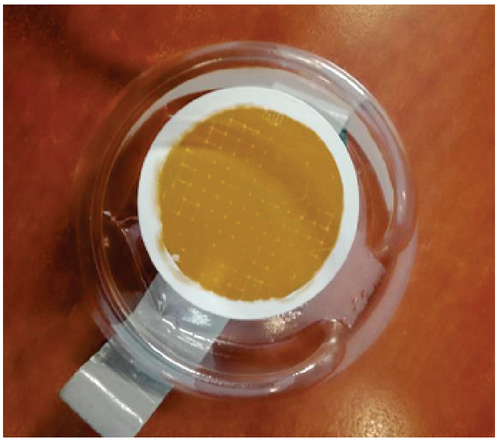

Fig. 1. An example of a filter of the diameter Ø37 mm intended for testing the respirable fraction (photo K. Pikulik)
Rys. 1. Przykładowy filtr o średnicy Ø37 mm przeznaczony do badania frakcji respirabilnej (fot. K. Pikulik)


Fig. 2. An example of a membrane filter of cellulose esters of the diameter Ø25 mm intended for testing the inhaled fraction (photo K. Pikulik)
Rys. 2. Przykładowy filtr membranowy z estrów celulozy o średnicy Ø25 mm przeznaczony do badania frakcji wdychalnej (fot. K. Pikulik)

The appliance of GILIAN GilAir3 type was used as an individual aspirator with a built-in flow stabilizer, system of pulsation suppression and a flow disturbance index (Figs 3, 4).

Each time before collecting samples the adjustment of aspirator was made. And each time after collecting samples the flow of air in the aspirator was checked in the plant laboratory [3].


Fig. 3. A set for checking the flow of air in the aspirator together with the aspirator type GilAir3 (photo K. Pikulik)

Rys. 3. Zestaw do sprawdzania przepływu powietrza w aspiratorze wraz z aspiratorem typu GilAir3 (fot. K. Pikulik)

In order to assess the air pollution during the welding process the following chemical substances were tested:

- manganese and its inorganic compounds calculated on Mn – inhaled fraction,
- manganese and its inorganic compounds calculated on Mn – respirable fraction,
- iron oxides calculated on Fe – iron (III) oxide, iron (II) oxide, tri iron tetroxide – inhaled fraction,
- iron oxides calculated on Fe – iron (III) oxide, iron (II) oxide, tri iron tetroxide – respirable fraction.

The above chemical substances were specified based on the following standards:

- PN-Z-04472:2015-10 Ap 1: 2015-12 [6]. Air cleanliness protection. Determination of manganese and its compounds on work stations with the method of flame atomic adsorption spectrometry;
- PN-Z-04469:2015-10 [5]. Air cleanliness protection. Determination of iron oxides in aerosol respirable fraction on work stations with the method of flame atomic adsorption spectrometry.


Fig. 4. Individual aspirator, type GILIAN GilAir3, applied in these tests (photo K. Pikulik)
Rys. 4. Aspirator indywidualny typu GILIAN GilAir3, zastosowany w badaniach (fot. K. Pikulik)

As constant factors in these tests taken were:

- the grade of welded material – non-alloyed construction steel S235JR,
- shielding gas mixture – symbol M21 with the content of Ar + 18% $CO_2$ acc. PN-EN ISO 14175,
- sheet thickness – 4 mm,
- type of weld – fillet weld,
- type of applied ventilation – natural (gravitational),
- welding electrode diameter – Ø1.2 mm,
- copper coated welding wire applied, classification EN400-G4Si1,
- electrode wire feed – 2.0 $m \cdot min^{-1}$,
- arc voltage,
- welding appliance – semi-automatic welder make LINCOLN POWERTEC 305C,
- welding method – type MAG (Metal Active Gas),
- sample collection time.

Random, uncontrolled input factors – disturbances include inter alia:

- pollution of welded surfaces,
- fluctuation in the flow of shielding gases mixture;
- drop of welding current strength,
- noise,
- optic radiation.

Fig. 5. Head for collecting inhaled fraction (photo K. Pikulik)
Rys. 5. Głowica do pobierania frakcji wdychalnej (fot. K. Pikulik)

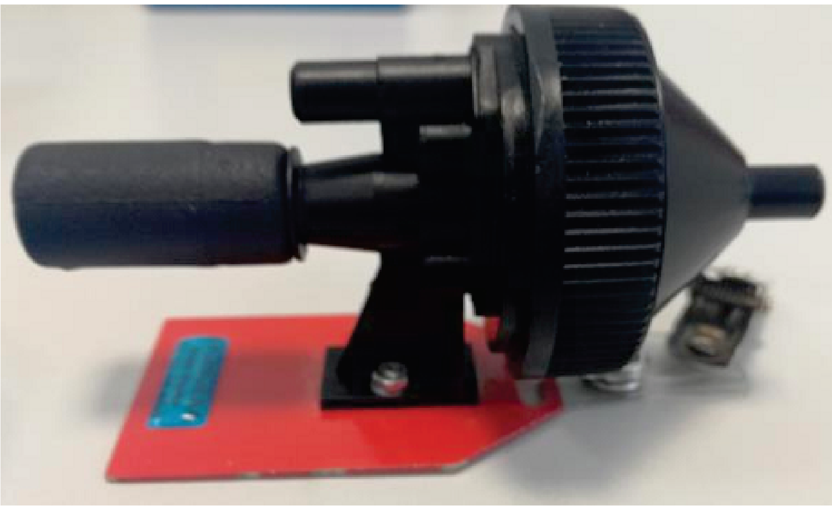

Fig. 6. Head for collecting respirable fraction (photo K. Pikulik)
Rys. 6. Głowica do pobierania frakcji respirabilnej (fot. K. Pikulik)

## 3. TEST RESULTS

Emissions of manganese and its inorganic compounds calculated on Mn-inhaled fraction were assessed as first chemical substances influencing the air pollution. The data obtained is presented in Table 1. Next, the data was implemented into R software for the purpose of generating a box plot (Fig. 7) and selected statistical parameters were calculated which are presented in Table 2 [1, 2].

Table 1. Manganese and its inorganic compounds – inhaled fraction [mg·m$^{-3}$] (own study)
Tabela 1. Mangan i jego związki nieorganiczne – frakcja wdychana [mg·m$^{-3}$] (opracowanie własne)

| No. | I = 110 A; v = 2,0 m·min$^{-1}$ | I = 130 A; v = 2,0 m·min$^{-1}$ | I = 150 A; v = 2,0 m·min$^{-1}$ |
|---|---|---|---|
| 1 | 0.08 | 0.11 | 0.18 |
| 2 | 0.08 | 0.12 | 0.17 |
| 3 | 0.09 | 0.13 | 0.15 |
| 4 | 0.07 | 0.11 | 0.17 |
| 5 | 0.10 | 0.14 | 0.16 |
| 6 | 0.09 | 0.12 | 0.18 |
| 7 | 0.09 | 0.14 | 0.17 |
| 8 | 0.10 | 0.13 | 0.15 |
| 9 | 0.08 | 0.11 | 0.17 |
| 10 | 0.09 | 0.12 | 0.17 |

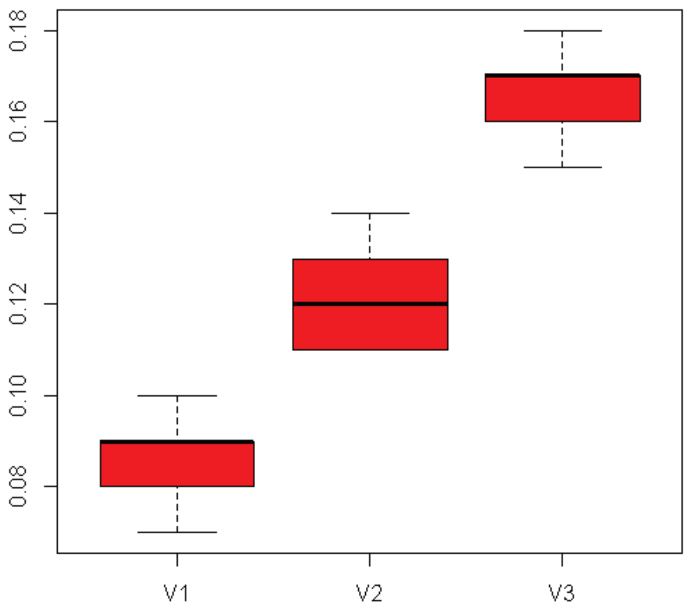


Fig. 7. A box plot generated in R software pertaining to the emission of manganese – inhaled fraction during the welding process; wire diameter – Ø1.2 mm, wire feed v = 2.0 m·min$^{-1}$. On the vertical axis – volume of manganese emission of inhaled fraction [mg·m$^{-3}$]. V1 – for the welding current I = 110 A; V2 – for the welding current I = 130 A; V3 – for the welding current I = 150 A (own study)

Rys. 7. Wykres pudełkowy wygenerowany w programie R, dotyczący emisji manganu – frakcji wdychanej w czasie procesu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 m·min$^{-1}$; na osi pionowej – wielkość emisji frakcji wdychanej [mg·m$^{-3}$], V1 – dla prądu spawania I = 110 A; V2 – dla prądu spawania I = 130 A; V3 – dla prądu spawania I = 150 A (opracowanie własne)

For measured values of manganese and its inorganic compounds calculated on Mn-inhaled fraction the following statistical parameters were measured using R software for the purpose of analyzing the results obtained:

- Min – minimum value,
- 1stQu. – lower (first) sample quartile ($Q_1$),
- Median – median (‘medial value’ $Q_2$),
- Mean – arithmetic mean,
- 3rdQu. – upper (third) sample quartile ($Q_3$),
- Max – maximum value,
- IQR – interquartile range,
- R – sample range,
- s – standard deviation,
- $d_1$ – average deviation from the mean value.

Table 2. A set of selected statistical parameters for measured emissions of manganese and its compounds calculated on Mn-inhaled fraction during the welding process; wire diameter Ø1.2 mm, wire feed v = 2.0 m·min$^{-1}$, welding current value I: 110 A; 130 A; 150 A (own study)

Tabela 2. Zestawienie wybranych parametrów statystycznych dla zmierzonych emisji manganu frakcji wdychanej w czasie procesu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 m·min$^{-1}$, wartość prądu spawania I: 110 A; 130 A; 150 A (opracowanie własne)

| Current I [A] | Min | 1stQu. | Median | 3rdQu. | Max | IQr | R | s | $d_1$ | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 0.07 | 0.08 | 0.09 | 0.09 | 0.10 | 0.01 | 0.03 | 0.009 | 0.0076 | 0.087 |
| 130 | 0.11 | 0.11 | 0.12 | 0.13 | 0.14 | 0.01 | 0.03 | 0.011 | 0.0096 | 0.123 |
| 150 | 0.15 | 0.16 | 0.17 | 0.17 | 0.18 | 0.0075 | 0.03 | 0.010 | 0.0082 | 0.167 |

For the purpose of defining a possible dependence between individual values of manganese emissions of inhaled fraction during the welding process, for selected values of the welding current, correlations were calculated using the Pearson’s and Spearman’s method. It was assumed at the same time that results have a normal distribution. If correlation values are close to 1 or -1 value, then variables are dependent. If correlation values are close to 0 value, then we deal with independent variables. Results are presented in Table 3.

Table 3. Results of correlation between individual values of emissions of manganese and its inorganic compounds calculated on Mn-inhaled fraction [mg·m$^{-3}$] during the welding process for individual values I of the welding current; wire diameter Ø1.2 mm, wire feed v = 2.0 m·min$^{-1}$ (own study)

Tabela 3. Wyniki korelacji pomiędzy poszczególnymi wartościami emisji manganu frakcji wdychanej [mg·m$^{-3}$] w czasie procesu spawania dla poszczególnych wartości I prądu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 m·min$^{-1}$ (opracowanie własne)

<table>
<tr><th></th><th colspan="2">Pearson</th><th colspan="2">Spearman</th></tr>
<tr><td>110 [A]</td><td rowspan="2">0.79</td><td></td><td rowspan="2">0.83</td><td></td></tr>
<tr><td>130 [A]</td><td rowspan="2">-0.55</td><td rowspan="2">-0.59</td></tr>
<tr><td>150 [A]</td><td></td><td></td></tr>
</table>

Another chemical substances influencing the air pollution in the welding process were assessed emission of manganese and its inorganic compounds calculated on Mn-respirable fraction. The data obtained is presented in Table 4, which was also implemented into R software for the purpose of generating a box plot (Fig. 8) and selected statistical parameters were calculated (Table 5) [1, 2].

Table 4. Manganese and its inorganic compounds calculated on Mn-respirable fraction [$mg \cdot m^{-3}$] (own study)

Tabela 4. Mangan i jego związki nieorganiczne – frakcja respirabilna [$mg \cdot m^{-3}$] (opracowanie własne)

| No. | I = 110A; v = 2,0 $m \cdot min^{-1}$ | I = 130 A; v = 2,0 $m \cdot min^{-1}$ | I = 150 A; v = 2,0 $m \cdot min^{-1}$ |
|---|---|---|---|
| 1 | 0.06 | 0.09 | 0.15 |
| 2 | 0.07 | 0.11 | 0.16 |
| 3 | 0.06 | 0.10 | 0.14 |
| 4 | 0.07 | 0.09 | 0.15 |
| 5 | 0.07 | 0.11 | 0.14 |
| 6 | 0.07 | 0.09 | 0.16 |
| 7 | 0.07 | 0.10 | 0.16 |
| 8 | 0.05 | 0.11 | 0.15 |
| 9 | 0.07 | 0.09 | 0.15 |
| 10 | 0.06 | 0.09 | 0.15 |

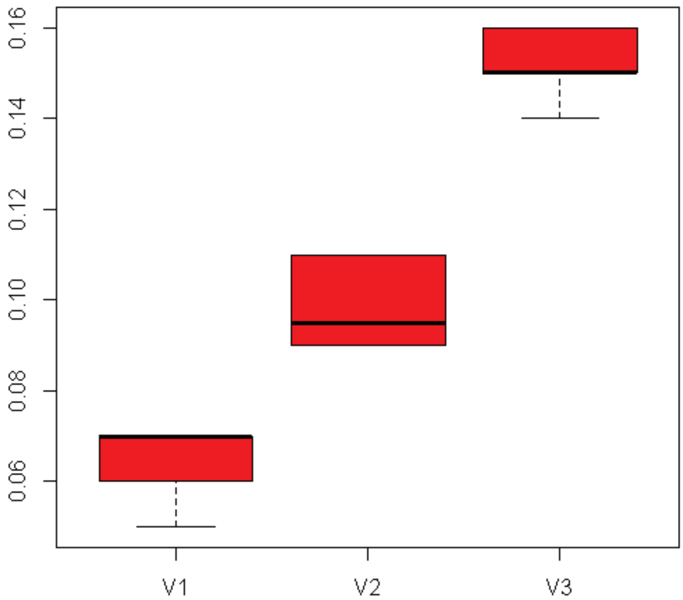


Fig. 8. A box plot generated in R software pertaining to the emission of manganese – respirable fraction during the welding process; wire diameter – Ø1.2 mm, wire feed v = 2.0 $m \cdot min^{-1}$; on the vertical axis – volume of manganese emission of respirable fraction [$mg \cdot m^{-3}$], V1 – for the welding current I = 110 A, V2 – for the welding current I = 130 A, V3 – for the welding current I = 150 A (own study)

Rys. 8. Wykres pudełkowy, wygenerowany w programie R, dotyczący emisji manganu – frakcji repirabilnej w czasie procesu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 $m \cdot min^{-1}$; na osi pionowej – wielkość emisji manganu frakcji respirabilnej [$mg \cdot m^{-3}$], V1 – dla prądu spawania I = 110 A, V2 – dla prądu spawania I = 130 A, V3 – dla prądu spawania I = 150 A (opracowanie własne)

As previously, in order to analyze obtained results, the selected statistical parameters were calculated, using R software [1, 2], for measured values of the mass decrement of samples. Above mentioned statistical parameters for the manganese emission of inhaled fraction for selected values of welding current are presented in Table 5.

Table 5. A set of selected statistical parameters for measured emissions of manganese and its compounds calculated on Mn-respirable fraction during the welding process; wire diameter – Ø1.2 mm, wire feed v = 2.0 m·min$^{-1}$, welding current value I: 110 A; 130 A; 150 A (own study)

Tabela 5. Zestawienie wybranych parametrów statystycznych dla zmierzonych emisji manganu frakcji respirabilnej w czasie procesu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 m·min$^{-1}$, wartości prądu spawania I: 110 A; 130 A; 150 A (opracowanie własne)

| Current I [A] | Min | 1stQu. | Median | 3rdQu. | Max | IQr | R | s | $d_l$ | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 0.05 | 0.06 | 0.070 | 0.070 | 0.07 | 0.010 | 0.02 | 0.007 | 0.006 | 0.065 |
| 130 | 0.09 | 0.09 | 0.095 | 0.1075 | 0.11 | 0.0175 | 0.02 | 0.091 | 0.008 | 0.098 |
| 150 | 0.14 | 0.15 | 0.150 | 0.1575 | 0.16 | 0.0075 | 0.02 | 0.007 | 0.005 | 0.151 |

For the purpose of defining a possible dependence between individual values of manganese emission of respirable fraction during the welding process, for selected values of the welding current, as previously, correlations were calculated using the Pearson's and Spearman's method. Results are presented in Table 6.

Table 6. Results of correlation between individual values of emissions of manganese and its inorganic compounds calculated on Mn-respirable fraction [mg·m$^{-3}$] during the welding process for individual values I of the welding current; wire diameter – Ø1.2 mm, wire feed v = 2.0 m·min$^{-1}$ (own study)

Tabela 6. Wyniki korelacji pomiędzy poszczególnymi wartościami emisji manganu frakcji respirabilnej [mg·m$^{-3}$] w czasie procesu spawania dla poszczególnych wartości I prądu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 m·min$^{-1}$ (opracowanie własne)

<table>
<tr><th></th><th colspan="2">Pearson</th><th colspan="2">Spearman</th></tr>
<tr><td>110 [A]</td><td rowspan="2">-0.17</td><td></td><td rowspan="2">-0.07</td><td></td></tr>
<tr><td>130 [A]</td><td rowspan="2">-0.13</td><td rowspan="2">-0.11</td></tr>
<tr><td>150 [A]</td><td></td><td></td></tr>
</table>

Another chemical substances influencing the air pollution, which were assessed, included iron oxides calculated on Fe-iron (III) oxide, iron (II) oxide, tri iron tetroxide – inhaled fraction. Results obtained are presented in Table 7. Next, the data was implemented into R software for the purpose of generating a box plot (Fig. 9) and selected statistical parameters were calculated which are presented in Table 8.

For the purpose of defining a possible dependence between individual values of iron oxides emission of inhaled fraction during the welding process, for selected values of the welding current, as previously, correlations were calculated using the Pearson's and Spearman's method. It was assumed at the same time that results have a normal distribution. Results are presented in Table 9.

Table 7. Iron oxides – inhaled fraction [mg·m$^{-3}$] (own study)
Tabela 7. Tlenki żelaza – frakcja wdychana [mg·m$^{-3}$] (opracowanie własne)

| No. | I = 110 A; v = 2,0 m·min$^{-1}$ | I = 130 A; v = 2,0 m·min$^{-1}$ | I = 150 A; v = 2,0 m·min$^{-1}$ |
|---|---|---|---|
| 1 | 1.17 | 1.27 | 1.54 |
| 2 | 1.19 | 1.24 | 1.50 |
| 3 | 1.15 | 1.29 | 1.49 |
| 4 | 1.18 | 1.23 | 1.51 |
| 5 | 1.16 | 1.30 | 1.54 |
| 6 | 1.21 | 1.25 | 1.58 |
| 7 | 1.20 | 1.29 | 1.55 |
| 8 | 1.19 | 1.28 | 1.49 |
| 9 | 1.18 | 1.24 | 1.54 |
| 10 | 1.16 | 1.25 | 1.45 |

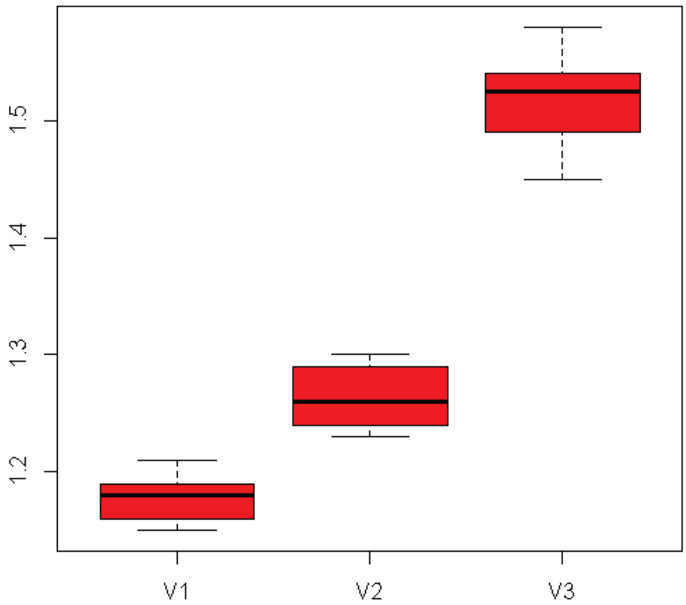


Fig. 9. A box plot generated in R software pertaining to the emission of iron oxides – inhaled fraction during the welding process; wire diameter – Ø1.2 mm, wire feed v = 2.0 m·min$^{-1}$; on the vertical axis – volume of iron oxides emission of inhaled fraction [mg·m$^{-3}$], V1 – for the welding current I = 110 A, V2 – for the welding current I = 130 A, V3 – for the welding current I = 150 A (own study)

Rys. 9. Wykres pudełkowy wygenerowany w programie R, dotyczący emisji tlenków żelaza – frakcji wdychanej – w czasie procesu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 m·min$^{-1}$; na osi pionowej – wielkość emisji tlenków żelaza frakcji wdychanej [mg·m$^{-3}$], V1 – dla prądu spawania I = 110 A, V2 = dla prądu spawania I = 130 A, V3 – dla prądu spawania I = 150 A (opracowanie własne)

Table 8. A set of selected statistical parameters for measured emissions of iron oxides and its compounds calculated on Fe-inhaled fraction during the welding process; wire diameter – Ø1.2 mm, wire feed v = 2.0 m·min$^{-1}$, welding current value I: 110 A; 130 A; 150 A (own study)

Tabela 8. Zestawienie wybranych parametrów statystycznych dla zmierzonych emisji tlenków żelaza – frakcja wdychalna w czasie procesu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 m·min$^{-1}$, wartość prądu spawania I: 110 A; 130 A; 150 A (opracowanie własne)

| Current I [A] | Min | 1stQu. | Median | 3rdQu. | Max | IQr | R | s | $d_1$ | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 1.15 | 1.163 | 1.180 | 1.190 | 1.21 | 0.0275 | 0.06 | 0.019 | 0.015 | 1.179 |
| 130 | 1.23 | 1.242 | 1.260 | 1.288 | 1.30 | 0.0450 | 0.07 | 0.025 | 0.022 | 1.264 |
| 150 | 1.45 | 1.492 | 1.525 | 1.540 | 1.58 | 0.0475 | 0.13 | 0.037 | 0.031 | 1.519 |

Table 9. Results of correlation between individual values of emissions of iron oxides and its compounds calculated on Fe-inhaled fraction [mg·m$^{-3}$] during the welding process for individual values I of the welding current; wire diameter – Ø1.2 mm, wire feed v = 2.0 m·min$^{-1}$ (own study)

Tabela 9. Wyniki korelacji pomiędzy poszczególnymi wartościami emisji tlenków żelaza – frakcji wdychalnej [mg·m$^{-3}$] – w czasie procesu spawania dla poszczególnych wartości I prądu spawania; średnica drutu Ø1,2 mm, posuw v = 2,0 m·min$^{-1}$ (opracowanie własne)

<table>
<tr><th></th><th colspan="2">Pearson</th><th colspan="2">Spearman</th></tr>
<tr><td>110 [A]</td><td rowspan="2">- 0.29</td><td></td><td rowspan="2">-0.26</td><td></td></tr>
<tr><td>130 [A]</td><td rowspan="2">0.09</td><td rowspan="2">0.08</td></tr>
<tr><td>150 [A]</td><td></td><td></td></tr>
</table>

The last chemical substances, which were assessed, were iron oxides calculated on Fe-iron (III) oxide, iron (II) oxide, tri iron tetroxide – respirable fraction. The data obtained is presented in Table 10. These data were also implemented into R software in order to generate a box plot (Fig. 10) and selected statistical parameters were calculated (Table 11).

Table 10. Iron oxides – respirable fraction [mg·m$^{-3}$] (own study)

Tabela 10. Tlenki żelaza i jego związki nieorganiczne – frakcja respirabilna [mg·m$^{-3}$] (opracowanie własne)

| No. | I = 110 A; v = 2,0 m·min$^{-1}$ | I = 130 A; v = 2,0 m·min$^{-1}$ | I = 150A; v = 2,0 m·min$^{-1}$ |
|---|---|---|---|
| 1 | 0.93 | 1.07 | 1.38 |
| 2 | 0,91 | 1.05 | 1.34 |
| 3 | 0.90 | 1.11 | 1.35 |
| 4 | 0.94 | 1.09 | 1.39 |
| 5 | 0.95 | 1.13 | 1.37 |
| 6 | 0.96 | 1.06 | 1.43 |
| 7 | 0.94 | 1.10 | 1.40 |
| 8 | 0.95 | 1.09 | 1.34 |
| 9 | 0.95 | 1.06 | 1.42 |
| 10 | 0.94 | 1.09 | 1.36 |

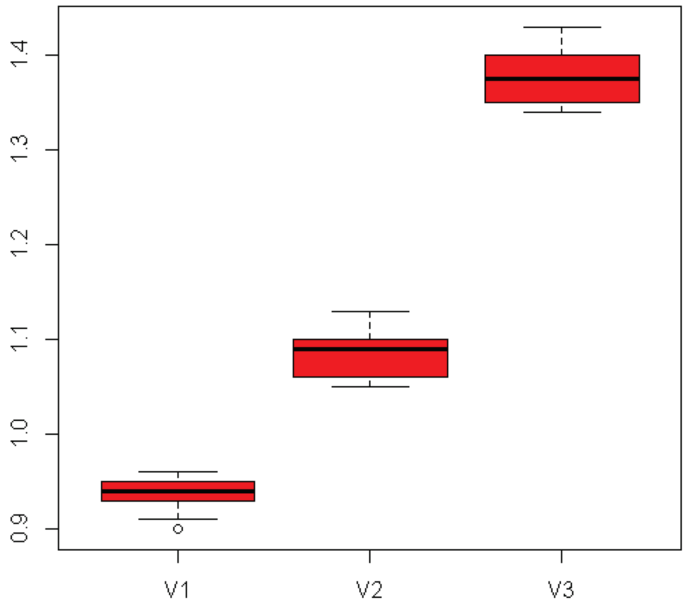


Fig. 10. A box plot generated in R software pertaining to the emission of iron oxides – respirable fraction during the welding process; wire diameter – Ø1.2 mm, wire feed v = 2.0 m·min$^{-1}$; on the vertical axis – volume of iron oxides emission of respirable fraction [mg·m$^{-3}$], V1 – for the welding current I = 110 A, V2 – for the welding current I = 130 A, V3 – for the welding current I = 150 A (own study)

Rys. 10. Wykres pudełkowy, wygenerowany w programie R, dotyczący emisji tlenków żelaza – frakcja respirabilna – w czasie procesu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 m·min$^{-1}$; na osi pionowej – wielkość emisji tlenków żelaza frakcji respirabilnje [mg·m$^{-3}$], V1 – dla prądu spawania I = 110 A, V2 – dla prądu spawania I = 130 A, V3 – dla prądu spawania I = 150 A (opracowanie własne)

Table 11. A set of selected statistical parameters for measured emissions of iron oxides and its compounds calculated on Fe-respirable fraction during the welding process; wire diameter – Ø1.2 mm; wire feed v = 2.0 m·min$^{-1}$, welding current value I: 110 A; 130 A; 150 A (own study)

Tabela 11. Zestawienie wybranych parametrów statystycznych dla zmierzonych emisji tlenków żelaza – frakcji respirabilnej – w czasie procesu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 m·min$^{-1}$, wartości prądu spawania I: 110 A; 130 A; 150 A (opracowanie własne)

| Current I [A] | Min | 1stQu. | Median | 3rdQu. | Max | IQr | R | s | $d_1$ | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 0.90 | 0.932 | 0.940 | 0.950 | 0.96 | 0.017 | 0.06 | 0.018 | 0.014 | 0.937 |
| 130 | 1.05 | 1.062 | 1.090 | 1.097 | 1.13 | 0.035 | 0.08 | 0.025 | 0.020 | 1.085 |
| 150 | 1.34 | 1.353 | 1.375 | 1.397 | 1.43 | 0.045 | 0.09 | 0.031 | 0.026 | 1.378 |

For the purpose of defining a possible dependence between individual values of iron oxides emission of respirable fraction during the welding process, for selected values of the welding current, as previously, correlations were calculated using the Pearson's and Spearman's method. Results are presented in Table 12.

Table 12. Results of correlation between individual values of emissions of iron oxides and its compounds calculated on Fe-respirable fraction [mg·m$^{-3}$] during the welding process for individual values I of the welding current; wire diameter – Ø1.2 mm, vire feed v = 2.0 m·min$^{-1}$ (own study)

Tabela 12. Wyniki korelacji pomiędzy poszczególnymi wartościami emisji tlenków żelaza – frakcji respirabilnej [mg·m$^{-3}$] – w czasie procesu spawania dla poszczególnych wartości prądu spawania; średnica drutu Ø1,2 mm, posuw drutu v = 2,0 m·min$^{-1}$ (opracowanie własne)

<table>
<tr><th></th><th colspan="2">Pearson</th><th colspan="2">Spearman</th></tr>
<tr><td>110 [A]</td><td rowspan="2">-0.01</td><td></td><td rowspan="2">-0.08</td><td></td></tr>
<tr><td>130 [A]</td><td rowspan="2">-0.27</td><td rowspan="2">-0.16</td></tr>
<tr><td>150 [A]</td><td></td><td></td></tr>
</table>

## 4. SUMMARY

After the analysis of obtained test results for the air pollution emissions during the welding process the following conclusions can be formulated:

- along with the increase of the welding current, increases also the average value of manganese emission of inhaled fraction – from the value of 0.087 mg·m$^{-3}$ (for I = 110 A) to the value of 0.167 mg·m$^{-3}$ (for I = 150 A) – Table 2;
- for manganese emission of inhaled fraction no outliers were noted (Fig. 8);
- there is a strong correlation between the values of manganese emissions of inhaled fraction for individual welding currents (Table 3);
- along with the increase of the welding current, increases also the average value of manganese emission of respirable fraction – from the value of 0.065 mg·m$^{-3}$ (for I = 110 A) to the value of 0.151 mg·m$^{-3}$ (for I = 150 A)
- for manganese emission of respirable fraction no outliers were noted (Fig. 8);
- practically no correlation exists between values of manganese emissions of respirable fraction for individual welding currents (Table 6);
- along with the increase of the welding current, increases also the average value of iron oxides emission of inhaled fraction – from the value of 1.179 mg·m$^{-3}$ (for I = 110 A) to the value of 1.519 mg·m$^{-3}$ (for I = 150 A) – Table 8;
- for iron oxides emission of inhaled fraction no outliers were noted (Fig. 9);
- there is a certain correlation between values of iron oxides emission of inhaled fraction, especially for welding currents I = 110 A and I = 130 A (Table 9);
- along with the increase of the welding current, increases also the average value of iron oxides emission of respirable fraction – from the value of 0.937 mg·m$^{-3}$ (for I = 110 A) to the value of 1.378 mg·m$^{-3}$ (for I = 150A) – Table 11;
- for iron oxides emission of respirable fraction no outliers were noted (Fig. 10);
- there is a certain correlation between values of iron oxides emission of respirable fraction, especially for welding currents I = 130 A and I = 150 A (Table 12);
- R sample range of obtained results for respirable fraction is lower than for inhaled fraction.

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# WPŁYW PRĄDU SPAWANIA NA EMISJĘ ZANIECZYSZCZEŃ POWIETRZA

**Streszczenie**: W artykule przedstawiono analizę statystyczną wpływu prądu spawania na emisję zanieczyszczeń powietrza. Omówiono warunki badań oraz budowę stanowiska badawczego. Analizę statystyczną wykonano w oparciu o program R.

**Słowa kluczowe**: proces spawania, stan jakości powietrza, frakcja wdychana, frakcja respirabilna, parametry spawania