APPLICATION OF A CONTROL BANDING TOOL FOR RISK LEVEL ASSESSMENT AND CONTROL OF NANOPARTICLES EXPOSURE IN WELDING OPERATIONS

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APPLICATION OF A CONTROL BANDING TOOL FOR RISK LEVEL ASSESSMENT AND CONTROL OF NANOPARTICLES EXPOSURE IN WELDING OPERATIONS

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Porto, 26 Sept., 2014
Scope of study

✓ Welding operations result in harmful emissions of nanoparticles [1-2];

✓ The aim of emissions monitorisation is to evaluate exposure levels and to derive protection measures in order to protect exposed workers;

✓ However, the traditional approach of comparing measured concentrations with exposure limits cannot be used;

✓ But risk levels can be quantified by using Control Banding Strategies [3];

Welding process: MAG (metal active gas)

- Uses an electric arc between wire filler material and plate to be welded, a gas protection mixture, and can proceed by three different electrical current transfer modes:

  - Short-circuit
  - Globular
  - Spray
Exposure Assessment – MAG process

Monitoring equipment: NSAM

Working bench for welding

Sampling location during welding
Materials used for MAG welding

Chemical composition of steel plates

<table>
<thead>
<tr>
<th>Steel plates</th>
<th>Chemical composition of base material (% weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Mild steel</td>
<td>0,017</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>≤ 0,08</td>
</tr>
</tbody>
</table>

- **MAG** welding: using different wire filler materials;
- **MAG** welding using different gas mixtures:
  - **mild steel**: Ar+10%CO₂; Ar+18%CO₂; 100% CO₂
  - **stainless steel**: Ar+5%CO₂; 81%Ar+18%He+1%CO₂; 91%Ar+5%He+2%CO₂+2%N₂
- **Welding parameters**: different wire feeding velocities, different welding tensions and 3 different electric current transfer modes: globular, spray and short-circuit
MAG welding – NSAM results for mild steel

Nanoparticles as ADSA for ARCAL 21 (Ar+10%CO₂)

<table>
<thead>
<tr>
<th>Transfer mode</th>
<th>Average ADSA nanoparticles (μm²/cm³s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arcal 21</td>
</tr>
<tr>
<td>Short-circuit</td>
<td>8 325</td>
</tr>
<tr>
<td>Globular</td>
<td>13 306</td>
</tr>
<tr>
<td>Spray</td>
<td>17 574</td>
</tr>
</tbody>
</table>

Nanoparticles as ADSA for ATAL 5 (Ar+18%CO₂)
MAG welding – NSAM results for stainless steel

Nanoparticles as ADSA for ARCAL129 (91%Ar+5%He+2%CO₂+2%N₂)

Nanoparticles as ADSA for ARCAL121 (81%Ar+18%He+1%CO₂)

<table>
<thead>
<tr>
<th>Transfer mode</th>
<th>Average ADSA nanoparticles (µm²/cm³s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arcal 12</td>
</tr>
<tr>
<td>Short-circuit</td>
<td>23 637</td>
</tr>
<tr>
<td>Globular</td>
<td>37 054</td>
</tr>
<tr>
<td>Spray</td>
<td>39 376</td>
</tr>
</tbody>
</table>
Nanoparticles characterisation - TEM and EDS

Nanoparticles EDS analysis for MAG welding: mild steel and ARCAL 21

Nanoparticles by TEM: mild steel

Nanoparticles EDS analysis for MAG welding: stainless steel and ARCAL 129

Nanoparticles by TEM: stainless steel
NanoTool, was developed for qualitative risk assessment studies in order to control nanoparticle exposure.

CB is a qualitative approach defining risk as equal to probability x severity and established adequate control measures.

The tool considers several criteria:

- **Punctuation for SEVERITY** (sum of all severity factors):
  
  0-25: Low severity ; 26-50: Medium severity ; 51-75: High severity ; 76-100: Very high severity.

  Example:
  - Nanoparticle shape: Tubular or fibrous: 10 ; Irregular: 5 ; Compact or spheric: 0 ; Unknown: 7,5.
  - Carcinogenic material: Yes: 6 ; No: 0 ; Unknown: 4,5.

- **Punctuation for PROBABILITY** (sum of all exposure factors):
  
  0-25: Extremely unlikely ; 26-50: Less likely ; 51-75: Likely ; 76-100: Probable.

  Example:
  - Quantity of product used in each task:
    >100 mg: 25 ; 11-100 mg: 12.5 ; 0-10 mg: 6.25 ; Unknown: 18.75.
  - Number of exposed workers:
    >15: 15 ; 11-15: 10 ; 6-10: 5 ; 1-5: 0 ; Unknown: 11.25.
Criteria punctuation using an Excel file
**RL matrix as a function of severity and probability [3]**

<table>
<thead>
<tr>
<th>Severity</th>
<th>Probability</th>
<th>0-25</th>
<th>26-50</th>
<th>51-75</th>
<th>76-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>Extremely unlikely</td>
<td>RL3</td>
<td>RL3</td>
<td>RL4</td>
<td>RL4</td>
</tr>
<tr>
<td>(76-100)</td>
<td>Less likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Likely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(51-75)</td>
<td>Probable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(26-50)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0-25)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Control bands:**

**RL 1** – General ventilation

**RL 2** – Fume hoods or local exhaust ventilation

**RL 3** – Containment

**RL 4** – Seek specialist advice

Results of Risk Assessment

✓ Risk assessment was based on three criteria:

- Nature of wire filler material;
- Gas protection of fusion pool, droplets of wire filler material and welding surface obtained through the use of a gas protection mixture;
- Nature of base material (plate) to be welded.

✓ The description/classification of each material is based on Safety Material Data Sheets.

✓ Base characteristics: material description; nanomaterial description; CAS; activity classification; actual control engineering.
Results of risk assessment: MAG welding of mild steel using 100% CO₂

<table>
<thead>
<tr>
<th>Activity</th>
<th>Severity</th>
<th>Probability</th>
<th>Total</th>
<th>Control band</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Wire filler material - Lincoln ER70S-6)</td>
<td>Medium (35)</td>
<td>Likely (57.5)</td>
<td>RL2 (125)</td>
<td>Fume hoods or local ventilation</td>
</tr>
<tr>
<td>2 (Gas protection)</td>
<td>Medium (30.5)</td>
<td>Likely (57.5)</td>
<td>RL2 (125)</td>
<td>Fume hoods or local ventilation</td>
</tr>
<tr>
<td>3 (Base material – Mild steel)</td>
<td>High (62.5)</td>
<td>Likely (55)</td>
<td>RL3 (150)</td>
<td>Containment</td>
</tr>
</tbody>
</table>

In what concerns MAG welding of mild steel, efficient control of nanoparticles emissions is obtained with the use of fume hoods or local ventilation as well as the use of containment measures.
# Good working practices

<table>
<thead>
<tr>
<th>Preventive measures</th>
<th>Utilization of Individual Protection Equipment</th>
<th>Analysis/selection of materials/processes/parameters leading to lower fume emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Workplace ventilation and localized exhaust/containment</strong></td>
<td>- <strong>Welding torch equipped with fume extraction system</strong>;&lt;br&gt;- Masks with embedded ventilation;&lt;br&gt;- Improved welding torch design with the capability to collect more than 80% of emitted fume.</td>
<td>- Reduction of fume emissions at source: droplet source; electrode composition and gas mixture composition.&lt;br&gt;- Different type of current (pulsed MAG).&lt;br&gt;- Substitute conventional MAG welding for other processes: Surface Tension Transfer (STT), FastRoot and Cold Metal Transfer (CMT).</td>
</tr>
<tr>
<td>- Take into consideration the general principles of the ventilation system: total welding time, factors associated with the emission rates, chemical composition of welding protection gas, fume extracted as close as possible of source, etc.</td>
<td>- Ventilation systems: local (fume extracted directly from welding surface) or general.&lt;br&gt;- Operations organisation in order to optimise pollutant extraction efficiency.</td>
<td>- Allow to increase significantly the mobility of welding processes, as welding operations are not dependant from na extraction system difficult to handle.</td>
</tr>
<tr>
<td>- Ventilation systems: local (fume extracted directly from welding surface) or general.</td>
<td>- Allow to increase significantly the mobility of welding processes, as welding operations are not dependent from na extraction system difficult to handle.</td>
<td>- Use protection gases having low content of active gases (thus reducing the oxidizing potential).</td>
</tr>
</tbody>
</table>
Placement of suction device just above fume emission source

Rotating extraction arm suspended in order to cover a wide area of a welding workshop

Portable filtration system

Welding torch with embedded fume extraction system
## Conclusions

Welding processes, such as MAG, do produce considerable nanoparticle emissions which are potential harmful for exposed workers.

As traditional risk assessment is difficult to perform due to the inexistence of exposure limit values, control banding is an alternative to perform actual risk assessment and to derive protection measures.

However, this approach is qualitative and somewhat general.

Nevertheless, it can direct to protection measures such as exhaust hoods and local ventilation as well as containment.

One should always keep in mind that, the adoption of good working practices, must take into account the feasibility (both technological and economical) of altering the welding conditions.
Thanks for listening !!!

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