Characteristics of the aerosol produced by thermal metal spraying

Thermal metal spraying refers to a process, in which metals are melted and sprayed onto a surface by compressed air to form a coating. Thermal metal spraying is a cause of multiple health and safety hazards for the operator and any other person in the vicinity: metal fumes and gases, noise, UV radiation and many other hazards (electrical, mechanical, fire, etc.).

An understanding of fume emissions is important in determining the ventilation air flow rate of the cabin, in which metal spraying is performed, or for assessing exposure near the process. It is also a useful parameter in designing a downstream dust filtration unit. Two thermal metal spraying processes were studied to characterize fume emission: flame spraying and electric arc spraying. Three metals (wires) were studied: Zn, Al, and a Zn/Al alloy.

Fume emission was extracted by a semi-circular hood placed inside a ventilated cabin at about 50 cm from the source; the volumetric air flow was 4000 $m^3.h^{-1}$. Aerosol concentration was measured inside the exhaust ductwork using various instruments: an ELPI impactor (Dekati), a CNC 3022A (TSI), a TEOM microbalance (R&P) and sampling filters. The aerosol was sampled using isokinetic probes placed at the centre of the duct (see fig.1). CNC 3022A measurement featured 100x dilution stage (Grimm 1159). Particles were collected on Nuclepore filters (15 nm and 80 nm pore diameters) for observation using a scanning electron microscope (SEM). We examined the influence of a number of parameters on aerosol emission: distance between the spray gun and surface, compressed air pressure, stream intensity, etc.

Measurements show very strong aerosol emissions for electric arc spraying (100 to 500 $mg.s^{-1}$ mass emission rates). Electric arc spraying also produced more fumes than flame spraying (factor of 8 between respective mass emission rates). Aluminium spraying produces large fume quantities (500 to 800 $mg.s^{-1}$) compared to the Zn spraying (100 to 200 $mg.s^{-1}$) under the same conditions. CNC-derived aerosol number concentration was between 10^9 and 10^{10} $particles.cm^{-3}$ (diameter > 7 – 15 nm).

The aerosol comprised submicron particles and 95% of the numerical particle size distribution was less than 100 nm. The nanometric nature of the fume particles was confirmed by observations on the SEM, which revealed that fume particles deposited on a large metal particle were also generated by the spraying process (Fig.2). These larger particles are formed by nanoparticle agglomeration, but most of the agglomerates are very small, probably due to high dilution in the compressed air at the time of spraying. This dilution has the effect of strongly limiting particle coagulation and, in turn, the size of the agglomerated particles. Great care must be taken, when performing this process, in view of the very high emission rates (especially in electric arc spraying) and the very small-size of the agglomerated particles produced.

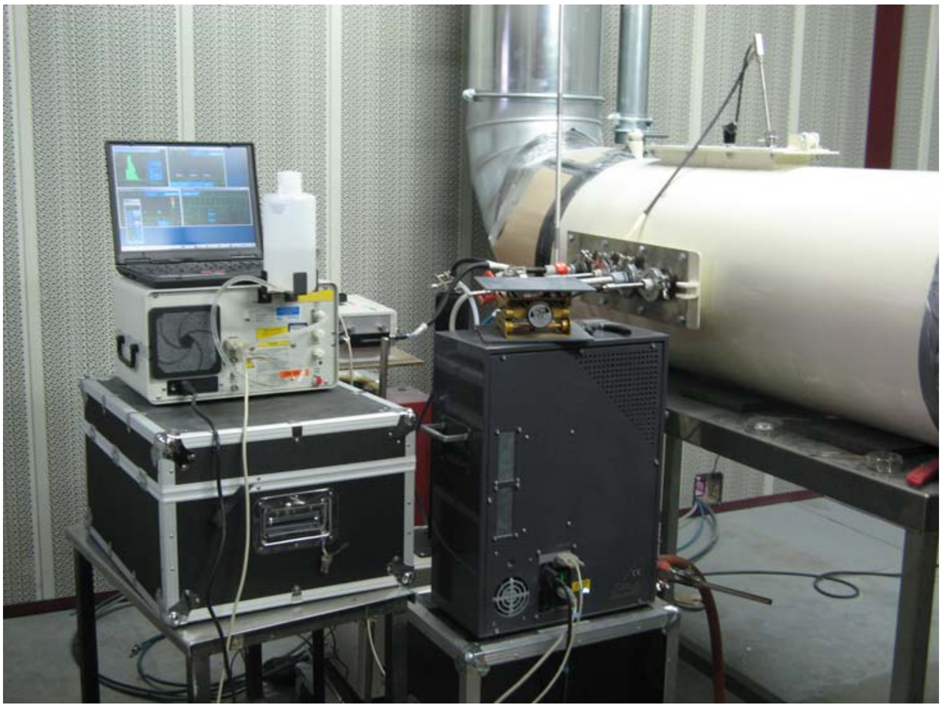

Fig.1 Experimental set-up showing the sampling section.

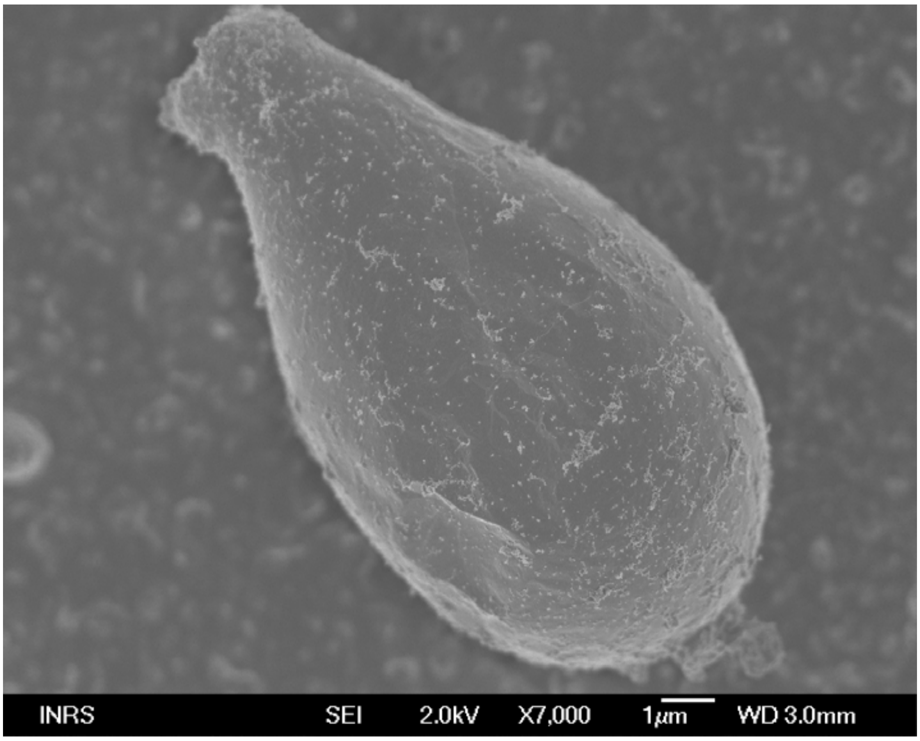

Fig.2 SEM view showing the fume particles deposited on the surface of a metal particle ($d_p \approx$ 10 µm).

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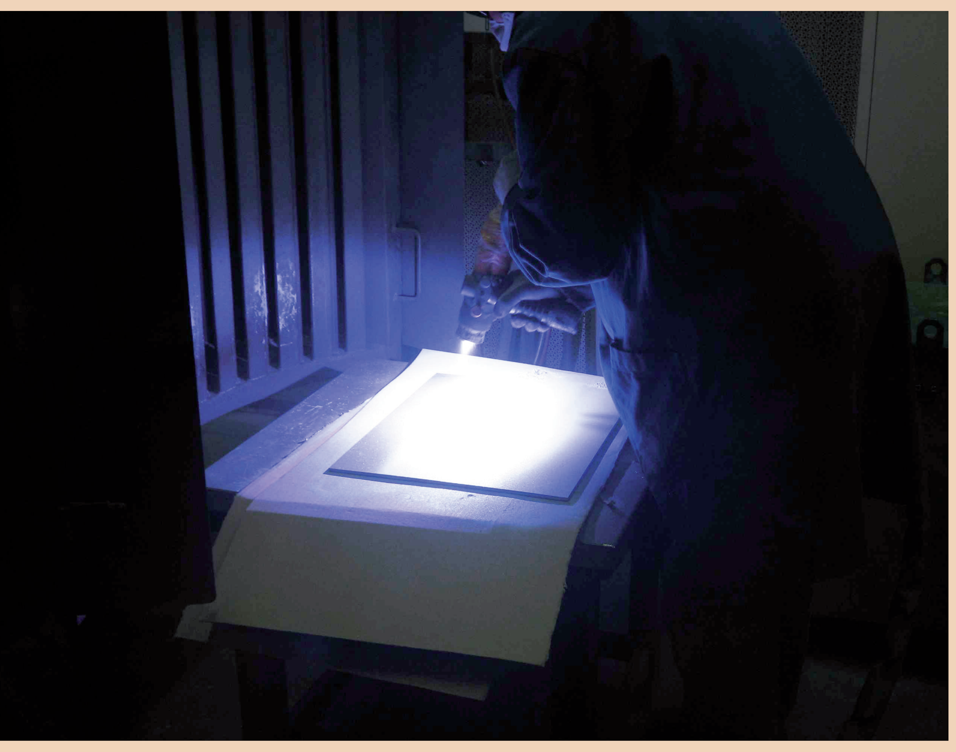

Electric arc spraying

PROCESS

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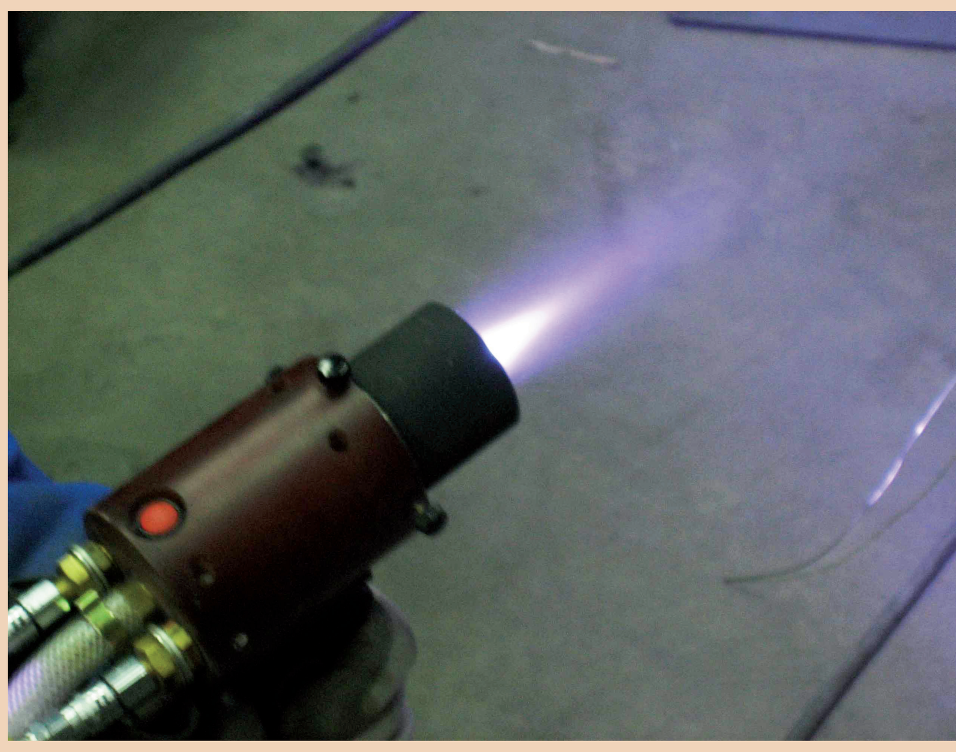
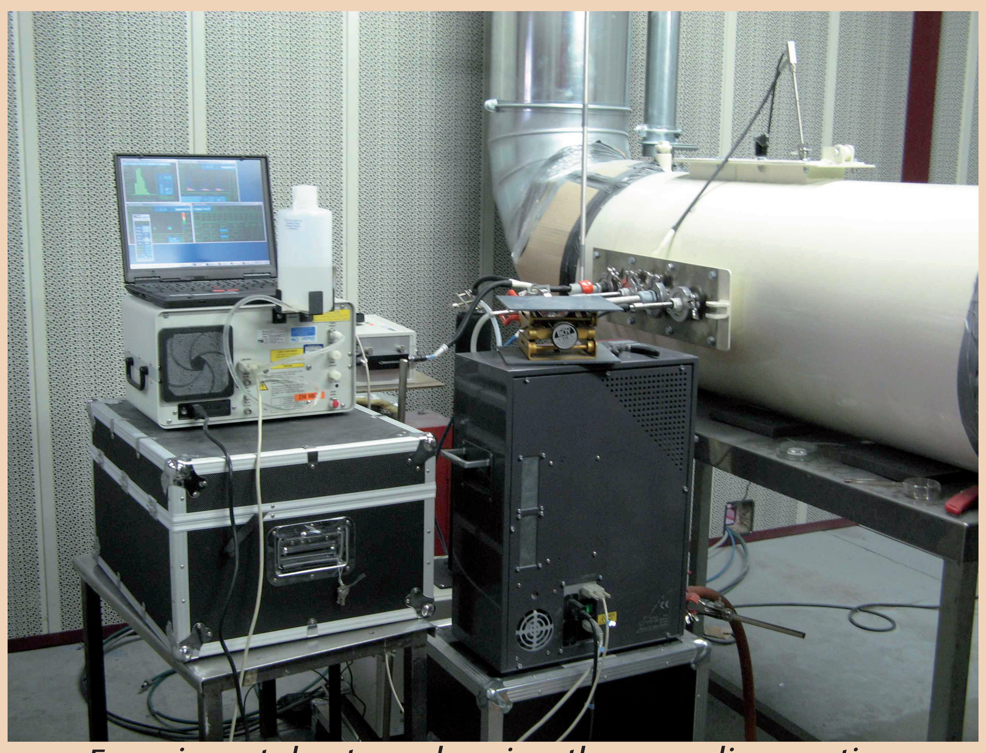


Electric arc spraying

EXPERIMENTAL SETUP



Experimental set-up showing the sampling section.

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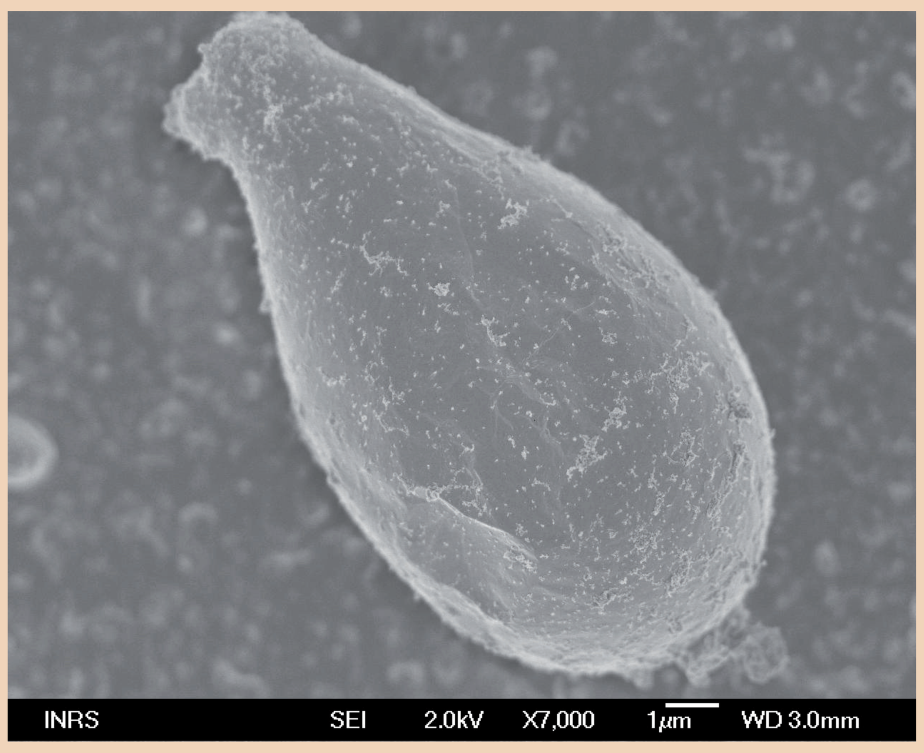
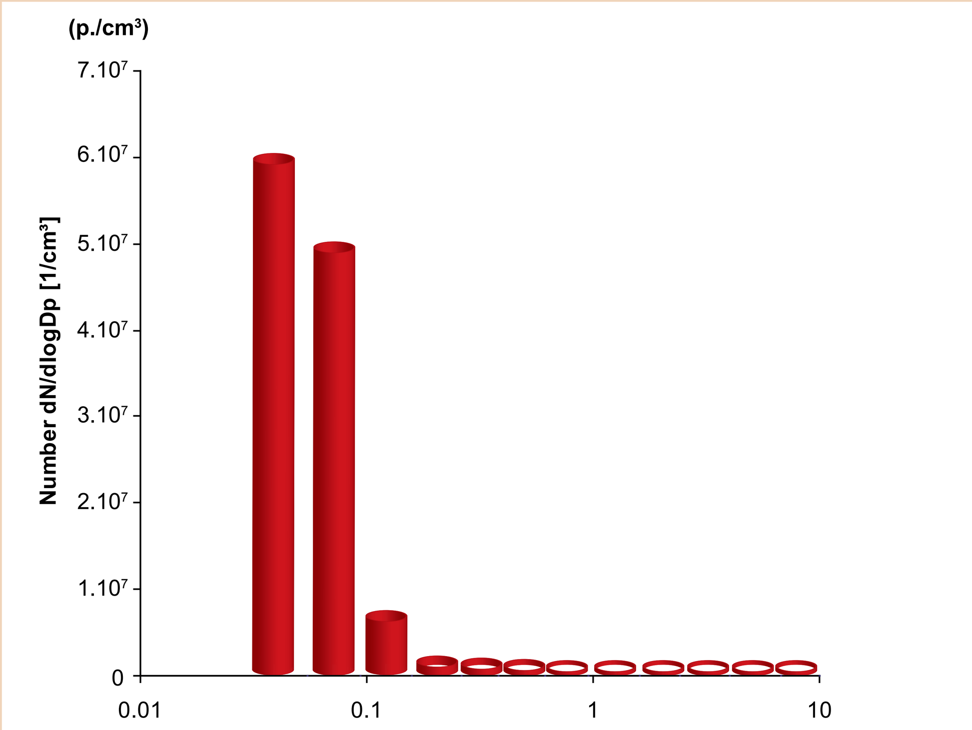
GENERETED AEROSOL

The high dilution caused by the compressed air at the time of spraying has the effect of strongly limiting particle coagulation and, in turn, the size of the agglomerated particles. 95% of the numerical particle size distribution was less than 100 nm. The nanometric nature of the fume particles was confirmed by observations on the SEM.



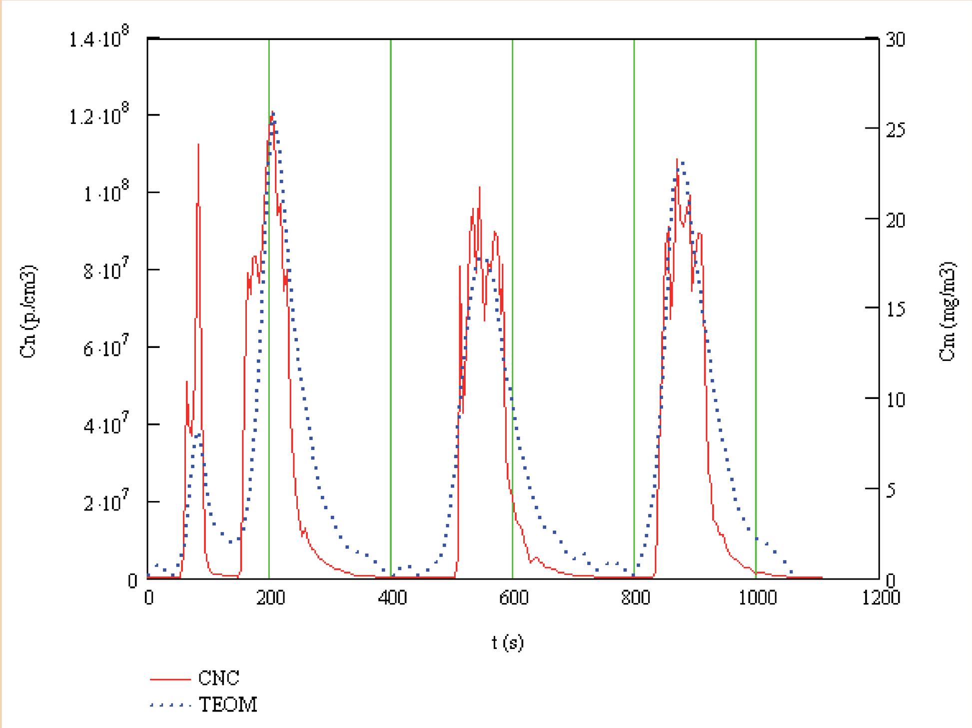
SEM views of fume particles deposited on the surface of a metal particle ($d_p \approx 10$ μm)



Particle number size distribution of the aerosol produced by flame spraying determined from ELPI impactor

FUME PRODUCTION

Electric arc spraying produced more fumes than flame spraying (factor of 8 between respective mass emission rates). Aluminium spraying produces large fume quantities (500 to 800 mg.s-1) compared to the Zn spraying (100 to 200 mg.s^{-1}) under the same conditions.



Variations in aerosol mass (TEOM) and number (CNC) concentrations during 3 operations of flame spraying.

RESULTS

Flame spraying Zn/Al (19/03)	øn×10^{13} (p.s^{-1}) ELPI	øn×1013 (p.s^{-1}) CNC	øm (mg.s^{-1}) TEOM
1	3,85	8,60	28,50
2	2,60	7,90	28,50
3	3,10	8,60	30,90
Electr. Arc spraying Zn (18/03)	**øn×1013 (p.s^{-1}) ELPI**	**øn×1013 (p.s^{-1}) CNC**	**øm (mg.s^{-1}) TEOM**
1	sat	>100	221,60
2	sat	>100	235,40
3	sat	>100	226,30

Øn *is the particle number emission rate* **Øm** *is the particle mass emission rate*

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