JTTEE5 13:155-157
DOI: 10.1361/10599630419643
1059-9630/$19.00 © ASM International

Editorial

Safety Issue in Thermal Spraying: The Need for a Collaborative Effort Within the Community?

Karlis Gross

Ghislain Montavon

Safety of both research and production thermal spray facilities is a major interest of managers, workers, and also environmental, health, and safety regulating bodies around the world. In this column, we would like to review the current status of regulations related to powder feedstock materials.

Thermal spray techniques are implemented on-site or in permanent spray booths, either manually or automatically. In every case, sprayers are exposed to several risks. Among them, respiratory ailments caused by feedstock materials appear as the major risk.

Depending on their average size, powder particles penetrate more or less deeply into the tracheobronchial tree after being inhaled where they accumulate. In the pharynx, the accumulation occurs especially in places where the direction of the respiratory tree changes abruptly and where the inhaled air velocity is high. In the trachea and in the bronchial tree, where the inhaled air velocity decreases, the accumulation occurs either by impact or by sedimentation. Finally, in the respiratory bronchioles, where the air velocity is close to zero, the accumulation occurs by diffusion. The particle size distribution, as well as their morphology, influences greatly their deposition into the respiratory tracts; that is, the "large" particles, of average diameters ranging from 5-30 μm, are stopped in the pharynx; the "medium" particles, of average diameters ranging from 1-5 μm, are deposited mostly in the trachea and the bronchi; the "small" particles, of average diameters lower than 1 μm, diffuse into the pulmonary alveoli, from which arises their harmfulness.

Several acute and secondary pathologies can potentially develop after short- or long-term exposure to powder substances, although to our personal knowledge, these have never been diagnosed among thermal sprayers. From irritation syndrome to pulmonary edema, from reactive airway dysfunction syndrome (RADS) to metal fume fever, from chronic bronchitis to lung cancer, the effects of exposure are numerous and varied, painful, and dangerous.

One of the major characteristics in terms of risk and in addition to the intrinsic toxicity of substances, especially the metallic ones (Table 1), relates to the intensity, or level of exposure. Several indexes relative to the permitted maximal exposure to harmful products are defined by organizations in charge of the occupational safety (Table 2, 3). One has to notice that these indexes vary from country to country. To develop similar pathologies, it seems that the average level of exposure to chromium is higher in the United States (i.e., 1 mg/m^3 according to PEL, OSHA) than in France (i.e., 0.5 mg/m^3 according to VME, INRS) and vice versa for lead. Beyond these differences, two exposure levels have to be carefully considered: the *Permissible Exposure Index* (PEL), corresponding to the maximum daily average concentration on an 8 day and 40 h week basis that must not be exceeded (i.e., Valeur Moyenne d'Exposition, VME, is the French equivalent index defined by Institut National de Recherche et de Sécurité, INRS for French National Institute of Research and Security) and the *Short-Term Exposure Limit* (STEL), corresponding to the maximal permitted concentration that cannot be exceeded during 15 min (i.e., Valeur Limite d'Exposition, VLE, is the French equivalent index).

While the awareness of the harmful risks is usually obvious to the sprayers when standing inside a spray booth, risks outside the spray booth are often underestimated. Nevertheless, major risks still exist—for example, the STEL may be exceeded when preparing the feedstock powders, especially when filling up the powder feeders.

To address these problems, the facility management in these conditions can take several actions. The first possibility is to impose the compulsory wearing of respiratory semidisposable half-facepiece masks, fitted with an expiratory valve and adequate filters for small diameter particles (i.e., about 1 μm size). Experience tells us that it is not always easy to prescribe and enforce the wearing of masks. A second possibility is to set up a ventilation system connected to filters in areas dedicated to filling up the powder feeders. This is generally possible only in permanent facilities and can be difficult to retrofit. In any case, it is important to stress health and safety issues to all personnel. It is imperative to provide all available personnel with protective devices and to take a proactive approach.

Some often argue, for example, that smoking represents similar or even a higher danger. However, such an argument is in no way acceptable for the management responsible for the health and safety of their employees. Such an argument would not be acceptable or defendable in any lawsuit against the facility and its management.

Numerous toxicological data are available. They remain, however, mysterious and confusing for anyone except health professionals and other specialists. We believe that it is necessary for the thermal spray community to develop comprehensive guidelines related to issues of this nature. Indeed, partial guidelines exist in many countries. We have recently been made aware—many thanks to

Dr. Stephan Siegmann, EMPA, Thun, Switzerland—of a very systematic guide written in German.[1] Other guides can be found, sometimes with difficulty, in other countries as well. Powder and spray system manufacturers have also made progress in this direction; such information is often available on their website. Also, the Committee on Health and Safety of TSS offers some interesting documents that can be downloaded from the Web. Combining these and other contributions within a collaborative work could benefit the spraying community around the world. Our association, TSS, could catalyze this work, for example under the auspices of an international committee. This is even more important, in our opinion, since we are facing a new challenge: the use of nanosized feedstock for which, as far as we know, no safety data or recommendations exist in any of the technical fields in which they are used.

A special issue of *Journal of Thermal Spray Technology—Safety Issues in Thermal Spraying*—is in preparation to cover specifically these important topics. It should be published next year.

These problems might appear as secondary in relation to the daily problems that we all face in our companies or research centers. However, the safety issue remains and will remain into the future—and neglecting it today may turn out to be very costly in the future.

Table 1 Some Harmful Effects of a Few Metallic Materials

Material	Characteristics	Effects on Skin	Effects on Respiratory System
Nickel	Allergen Carcinogen?	Eczema, dermatitis	Asthma, pneumoconiosis
Cobalt	Allergen Carcinogen?	Eczema, dermatitis	Irritation, fibrosis
Chromium	…	Eczema, dermatitis	…
Hexavalent chromium	Carcinogen, leukocytosis	Ulcer, dermatitis	Perforation, bleeding
Titanium/tungsten carbides	Hyperplasia, fibrosis	…	Hyperplasia
Copper	Carcinogen?	…	Cough, dyspnea

Table 2 Several Indexes Describing Permitted Maximal Exposures to Harmful Products

	Legislation	Recommendations	
Exposure index	OSHA/INRS	NIOSH	ACGIH
Weekly average concentration	TWA	TWA	TWA
Daily average concentration	PEL/VME	REL	TLV
Maximal limited concentration	STEL/VLE	STEL	STEL
Maximal concentration	C	C	C
Dangerous for life	No index defined	IDLH	No index defined

ACGIH, American Conference of Governmental Industrial Hygienists, www.acgih.org; C, ceiling that defines that maximal concentration limit that never must be exceeded during a shift work; IDLH, Immediately Dangerous to Life and Health concentration, which is the maximal concentration that represents and immediate danger for life after a 30 min exposure; INRS, Institut National de Recherche et de Sécurité (French National Institute of Research and Security), www.inrs.fr; NIH, National Institutes of Health, U.S. Department of Health and Human Services, www.nih.gov; NIOSH, National Institute of Occupational Safety and Health, www.cdc.goc/niosh; OSHA, Occupational Safety and Health Administration, U.S. Department of Labor, www.osha.gov; PEL, Permissible Exposure Limit, which is the maximum TWA that must not be exceeded during an 8 h day shift and a maximum of 40 h week; REL, Recommended Exposure Limit, which corresponds to a TWA for a 10 h day shift and a maximum of 40 h week; STEL, Short-Term Exposure Limit, which is the maximal permitted concentration that cannot be exceeded during 15 min; TLV, Threshold Limit Value (TLV), which corresponds to a TWA for a shift work of 8 h day; TWA, Time-Weighted Average, which defines the daily average concentration on 8 h day and 40 h week basis; VLE, Valeur Limite d'Exposition (INRS value equivalent to OSHA STEL); VME, Valeur Moyenne d'Exposition (INRS value, equivalent to OSHA PEL).

Table 3 PEL and STEL and Other Indexes for Several Metallic Materials

Metal	PEL (OSHA)	VME (equivalent to PEL) (INRS)	STEL (OSHA)	VLE (equivalent to STEL) (INRS)	REL (NIOSH)	TLV (ACGIH)	IDLH (NIOSH)
Be	2 μg/m^3	2 μg/m^3	25 μg/m^3	NA	0.5 μg/m^3	NA	4 mg/m^3
Ni	1 mg/m^3	1 mg/m^3	0.30 mg/m^3	NA	15 μg/m^3	1 mg/m^3	10 mg/m^3
Fe	10 mg/m^3	NA	NA	NA	NA	NA	NA
Co	0.1 mg/m^3	NA	0.1 mg/m^3	NA	0.05 mg/m^3	NA	20 mg/m^3
Mo	15 mg/m^3	5 mg/m^3	20 mg/m^3	10 mg/m^3	NA	NA	5 000 mg/m^3
Cu	1 mg/m^3	1 mg/m^3	1 mg/m^3	2 mg/m^3	1 mg/m^3	NA	100 mg/m^3
Al	5 mg/m^3	10 mg/m^3	15 mg/m^3	NA	10 mg/m^3	NA	NA
W	NA	NA	10 mg/m^3	NA	5 mg/m^3	NA	NA
Zr	5 mg/m^3	NA	NA	NA	5 mg/m^3	NA	50 mg/m^3
Cr	1 mg/m^3	0.5 mg/m^3	15 mg/m^3	NA	0.5 mg/m^3	NA	250 mg/m^3
Cr^6	0.1 mg/m^3	50 μg/m^3	30 μg/m^3	NA	1 μg/m^3	50 μg/m^3	15 mg/m^3
Mg	10 mg/m^3	10 mg/m^3	20 mg/m^3	NA	NA	NA	NA
Ta	5 mg/m^3	5 mg/m^3	10 mg/m^3	NA	5 mg/m^3	NA	2 500 mg/m^3
Pb	50 μg/m^3	150 μg/m^3	50 μg/m^3	NA	50 μg/m^3	NA	100 mg/m^3

See Ref 2-4, from which this data have been accepted. NA, not available

References

1. J. Auffarth, S. Bredendiek-Kämper, N. Fröhlich, and C. Lampe, "Stoffbelastungen Beim Termischen Spritzen" (in German), transl. "Substance Harmful Effects in Thermal Spraying," Schriftenreihe der Bundesanstalt für Arbeitsschutz and Arbeitsmedizin, Gefährliche Arbeitsstoffe GA51, Dortmund, Berlin, Germany, 1997, 87 pages.
2. NIOSH Pocket Guide to Chemical Hazards for Nickel Metal and Other Compounds (as Ni at www.cdc.gov/niosh/npg/ngpd0445.html).
3. "Valeurs Limites d'Exposition Professionnelle aux Agents Chimiques en France" (in French), transl. "Occupational Exposure Limit Levels to Chemical Products in France," Cahier de Notes Documentaires, *Hygiène et Sécurité au Travail, 174*(1), 1999, pp. 59-77.
4. Hazardous Chemical Database at ull.chemistry.uakron.edu/erd/.

Ghislain Montavon
LERMPS
Université de Technologie de Belfort-Montbéliard
France

Karlis Gross
Department of Materials Engineering
Monash University
Clayton, Victoria, Australia