Synthetic Reference Materials Based on Polymer Films for the Control of Welding Fumes Composition

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Abstract. Analysis of the current hygienic situation in the welding production showed that the intensification of welding processes involves the deterioration of air quality, which negatively affects the welders health. Welders are exposed to a variety of metal fumes, including manganese that may elevate the risk for neurological diseases. The control of metals concentration in the air of the working area is difficult due to the lack of reference materials. The creation of reference materials of welding fumes composition is a challenge due to chemical characteristics of their physical properties. Synthetic samples in a form of the polymer film containing powder particles of welding fumes were create. Studies on the selection of the polymer were done. Experiments proved that the qualitative materials of synthetic welding fumes are obtained by using polyvinyl alcohol. The metals concentration in the samples was determined by X-ray fluorescence analysis. The obtained data demonstrates indirectly the uniform distribution of welding fumes powder particles on the polymer film.

1. Introduction

Welding as a process of high-performance production of permanent joints is widely used in the manufacture of metallurgical, chemical and energetic equipment, the installation of various piping, mechanical engineering, shipbuilding, manufacturing of building and other structures. In spite of the achievements in the development of high-performance equipment and the introduction of automated and robotic lines, the proportion of welding performed manually is not reduced, and as a result, the welder is exposed to welding fumes. Elevated concentrations of fumes in the air of a working area can cause deviations in a health status and at a certain duration and intensity of exposure it can lead to the development of occupational diseases, such as bronchitis, respiratory tract irritation, fibrosis, pulmonary cancer [1]. The greatest risk for the occurrence of a respiratory disease is a solid component of welding fumes (SCWF), toxic compounds containing metals such as manganese, iron, chromium, nickel [1, 2]. Therefore, the problem of qualitative laboratory control for the condition of air in the working area is very relevant, and its role is increasing with the wear and tear of processing facilities and with the introduction of modern technologies.

The introduction of rapid methods of SCWF analysis is limited to the absence of national reference materials (RM) of welding fumes composition collected on a filter. There are only a few copies of reference materials found in the foreign analytic practice, for example, BCR-545 (IRMM, Belgium), HSL MSWF–1 and HSL SSWF 1 (UK). BCR–545 material [3–4] is a glass fiber filter loaded with weld dust; it is certified only on the content of total Cr and Cr (VI). HSL MSWF–1 [5] and HSL SSWF–1 materials [6] are welding fumes powder particles collected during welding of soft steel and
stainless steel respectively, packed in glass bottles 1 g each; they are standardized on the content of Fe, Mn and Zn.

The specific complexity when creating RM of welding fumes is a wide variation in particle size and the complexity of phase and chemical composition of SCWF. Solid particles of welding fumes have mostly sizes of 10⁻¹ to 1 micron regardless of the welding technique [7]. The phase and chemical composition of SCWF depends on conditions of a welding work conduction; therefore, the creation of reference materials for each welding type separately is required.

The certification of RM as real materials collected on the filter is not possible, as it is required to produce a large number of samples copies with the same composition, in order to use a part of them for certification analyses and to use the remaining ones as certified RM. However, uneven distribution of pollutants in the controlled object does not provide a sample group of similar chemical composition. Thus, the problem solution is seen only through the creation of synthetic reference materials, which would be adequate to real materials by their physical and chemical characteristics.

Filters, on which solutions of analyzed elements applied, are used mostly as parts of the analysis of welding fumes as synthetic materials of SCWF composition. For example, in determining the Cr (VI) [8], there were materials used, obtained by applying K₂Cr₂O₇ solution on the filter. It should be noted that the filter material may contain varying amounts of different metals [9], so that for samples preparation it is expedient to use the same type and commercial batch of filters as for the sampling. The advantage of this method is the simplicity of preparation, but the main disadvantage is the inadequacy of such SCWF samples to real samples by physico-chemical properties. Therefore, it is more promising to use materials prepared by precipitation of compounds particles of controlled components on the filter. However, such materials are unsuitable for long-term storage and transportation, as well as during the operation in a vacuum, because of the possible crumbling of particles.

The samples, prepared using a specially designed air samplers or fumes generators, are closer to real SCWF samples, loaded onto aspiration filters. In the works [10–11] etc. to manufacture the materials of SCWF composition, the parallel selection of a large number of welding fumes materials was carried out, then part of the materials was analyzed by different methods and there was an installation of contents parameters settings of the filter components. The remaining part of samples was used as RM. The authors [10] have found that there are differences in weight of fumes on the filter and hence the content of elements in the sample, so there was an additional analysis of loaded filters done using an X-ray fluorescence spectrometer with the wave dispersion to eliminate different copies. In works [12–14] for the control of metal content in the working area when welding steel structures using fumes generator, synthetic samples of generated fume from the metal wire using a robotic system was prepared. It should be noted that these techniques make it difficult to prepare a large number of identical materials with different variations of the chemical composition, specific to SCWF samples.

There is a technology for manufacturing synthetic RM of atmospheric aerosols composition in the form of methylcellulose polymer film containing a finely divided powder carrier of identified components [14]. As a carrier of aerosols particles, there is a mixture of RM of soils composition and metal oxides. The developed technology allows preparing the required number of identical samples with wide chemical composition variations and mass of aerosols particles. The closest in physical and chemical properties to real fumes samples collected on the aspiration filter, are the samples in the form of polymer films containing powder – the carrier of identified elements, which is a homogenized finely dispersed SCWF material. The objective of this study is to develop manufacturing techniques of RM of welding fumes composition in the form of a polymer film containing SCWF particles.

2. Experimental

At the stage of polymer selection the use of the following polymers was evaluated: methylcellulose (MC), polyvinyl chloride (PVC), polyvinyl alcohol (PVA), polystyrene (PS), polyvinylbutyral (PVB), copolymer vinylglycide ester with vinylchloride (VGE-VC) after their dissolving in water, ethanol,
acetone, toluene, chloroform, dichloroethane, dimethylformamide. The resulting polymer solution was poured onto a cleaned horizontal glass surface and air-dried. Smooth films were received only from solutions of PVA and MC in water, PS in toluene, PVB and VGE-VC in dimethylformamide; in other cases, the dried polymer films contained crystalline inclusions and could not be separated from the glass surface. The films from VGE-VC solutions in dimethylformamide and PS in toluene were very brittle. In addition, it should be noted that toluene and dimethylformamide are toxic solvents. The films of MC solution in water are hygroscopic, which creates certain difficulties when working with them. The foregoing led to the choice of the polyvinyl alcohol as the polymer to create synthetic RM of welding fumes.

Further studies showed that the optimum ratio of thickness-elasticity are in films produced from the PVA solution in water with polymer concentration of 10% in the solution.

The main difficulty is the introduction of SCWF powder material into the polymer solution. The possibility of the powder introduction into the polymer solution with water suspension was studied. There was the uneven distribution of powder and many conglomerates because of the coagulation of fine SCWF particles in the resulting film. Qualitative films were obtained by the introduction of powder particles into the polymer solution with ethyl alcohol. For this purpose, a sample of a powdered material weighing 50 mg was placed in a beaker, 1 ml of alcohol was added, 50 ml of polymer solution was added to the resulting suspended material and it was mixed thoroughly with a glass rod, poured onto cleaned glass disposed on a horizontal surface, and dried. Individual samples with a diameter corresponding to aspiration filters on which SCWF samples selected, were stamped from the resulting film.

3. Results and considerations

According to the developed technology, the produced set of synthetic materials was based on polyvinyl alcohol to the mass range (mg) of the welding fumes powder 30 (films 1 and 2), 50 (films 3 and 4), 100 (films 5 and 6). Two samples were stamped from each film. The metals concentration in the samples was determined by XRF analysis. Studies were performed on an energy-dispersive X-ray fluorescence spectrometer EDX-8000 (Shimadzu, Japan) based on silicon drift detector with thermoelectrical cooling: an X-ray tube with an Rh-anode (work mode: air cooling, voltage 4-50 kV, current 1-1000 µA). Determination results of Mn, Cr, Zn, rationed by the Fe content in samples are shown in the Table 1.

Table 1. The concentrations of elements in the samples, rationed by the iron content.

| sample | Mn     | Cr     | Zn     |
|--------|--------|--------|--------|
| 1-1    | 0.0317 | 0.0106 | 0.00264|
| 1-2    | 0.0332 | 0.0091 | 0.00302|
| 2-1    | 0.0321 | 0.0058 | 0.00292|
| 2-2    | 0.0387 | 0.0060 | 0.00298|
| 3-1    | 0.0406 | 0.0070 | 0.00280|
| 3-2    | 0.0409 | 0.0073 | 0.00292|
| 4-1    | 0.0358 | 0.0076 | 0.00265|
| 4-2    | 0.0362 | 0.0081 | 0.00268|
| 5-1    | 0.0397 | 0.0048 | 0.00274|
| 5-2    | 0.0375 | 0.0056 | 0.00208|
| 6-1    | 0.0358 | 0.0064 | 0.00239|
| 6-2    | 0.0365 | 0.0046 | 0.00183|
| Mean value | 0.0366 ± 0.0020 | 0.0068 ± 0.0012 | 0.00264 ± 0.00023 |

Errors in the identification of elements were decided by the t-test (t(11, 0.95) = 2.20), they form 5±18%, depending on the element that meets the requirements for the analysis of welding fumes. It
should be noted that the obtained data (see Table 1) demonstrates indirectly the uniform distribution of SCWF powder particles on the polymer film.

4. Summary
Based on the foregoing, a method is provided of making synthetic RM of welding fumes composition that are adequate to real samples collected on a filter. Using SCWF material obtained at various types of welding, allows the creation of reference materials with wide variations of phase and chemical composition.

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