DETERMINATION OF EMISSION RATE AND SAMPLING FOR ANALYSIS OF PARTICULATE WELDING FUME

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ABSTRACT
Before entering the market, coated electrodes, as an additional material in the MMAW welding process, must meet the existing regulations and requirements regarding the quality of welds, permissible harmful emissions into the environment and market requirements. In the MMAW welding process, welding fume is generated by the welding process. The emission level or production of welding fume, the method of collecting particles from welding fume and the method of chemical analysis are determined by the standard EN ISO 150011-1. The aim is to obtain a coated electrode with the lowest emission of harmful welding fumes into the environment and with the best welding characteristics. Tests of commercial and experimental electrodes of the same class were performed for the MMAW welding process of carbon and alloy steel. The production of welding fume particles was measured, and the welding fume particles were analyzed by the recommended methods of chemical analysis. These activities were fully carried out according to the standard EN ISO 150011-1.

Keywords: *MMAW, welding fumes, particles, chemical analysis, EN ISO 150011-1*

1. INTRODUCTION
For a quality assessment of the actual state of exposure to welding fumes of welders and workers in the workplace in such an environment and assessment of the level of evaporation into the atmosphere, detailed knowledge of causal mechanisms of welding fumes, which may be due to specific environmental conditions as well as consequence of used consumers and welding parameters. The electrode, which with its chemical composition during operation can provide qualitatively and quantitatively lower emission of harmful particles of welding fume into the environment, and also provides quality welds, is an economic guarantee for the manufacturer of successful production and marketing. Consumers who use such electrodes in their production process secure a place among those who meet the legal regulations on harmful emission levels. The basic intention, as well as the ultimate goal, is that the results of this research can fit into the concept of preserving the health of welders and the environment, through standards and regulations that imply the reduction of harmful emissions. The whole series of tests is designed in such a way as to connect and combine the parameters for which it is desired to define the influence on the chemical composition of welding fume particles. Systematic experimental work was carried out in laboratory conditions, during which samples were made, the testing of which will provide elementary input information for later statistical processing and analysis, and drawing conclusions.[1]

Protection and measures to improve the health protection of welders during operation date back to the 1930s. The first research on welding fumes began around 1945, after the war events that initiated the development of new welding procedures and their large application, and thus an increase in the number of welders and harmful side effects on their health. The leader in research on the problem of welding fumes is the American Welding Society (AWS), which reaffirmed its activities in 1972. In the period of accelerated technological development, the last thirty years, an increasing number of researchers from all over the world are working on research on this issue, when a large number of papers on this topic appear.[1]

2. DETERMINATION OF EMISSION LEVELS AND SAMPLING FOR ANALYSIS OF WELDING FUME PARTICLES

During the welding process and related processes, a complex mixture of organic gases and particles is created that can be harmful to human health and the environment. The emission level depends on the welding process, welding parameters, base and additional material, and materials that can be coated on the metal surface. Knowledge of fume and gas emission levels and the amount, composition and particle size of welding fumes is necessary if a favorable air atmosphere in the working environment is to be provided so that the necessary measures can be taken to reduce them if they exceed the permitted values. Evaporation emission levels, without chemical analysis, cannot be used directly to assess welder exposure levels, but processes, consumers and low emission welding parameters are expected to result in lower welder exposure than high emission processes under the same operating conditions. [1]

2.1. Welding fume sampling

In the field of occupational safety, there are a number of standards that prescribe workplace conditions that employers must adhere to in order to protect the worker and the environment. Standard EN 1540 prescribes the conditions for the degree of cleanliness of the atmosphere in the workplace, standard EN 482 prescribes the basic requirements for performing procedures for measuring chemical agents in the workplace, etc. There are also standards that precisely define the problem of welding fumes, methods of measuring production and methods of sampling welding fume particles.

The ISO 10882-2 standard deals with the health and safety of welding and allied processes, the collection of particulate and gas samples in the welder's breathing zone, and the methods of gas collection [2]. Standard EN ISO 10882-1 deals with health and safety in welding and allied processes, collection of particles and gases in the breathing zone of welders and methods of collecting particles of welding fumes [3]. Standard EN 1598 refers to the health and safety of welding and allied processes and protective equipment during welding [4].

Standard EN ISO 15011–1, together with Appendices A, B, C and D, deals with health and safety in welding and allied processes, a laboratory method for collecting evaporation samples and gases from arc welding. All actions and activities were performed according to this standard, and part 1 of this standard was particularly interesting, which determines the level of welding fume production, sampling for chemical analysis of welding fume particles and recommends methods of chemical analysis of welding fume particles.[5]

Welding fumes contain various gases and particles. European standards prescribe, among other things, laboratory procedures for determining methods of collecting fumes and gases for chemical analysis and procedures for determining their emission levels. The "evaporation chamber" technique is used, and the standard describes the principle of the test, the possible options of the welding chambers and the methods for sampling and analysis. The test chambers for the collection of welding fumes can be intended for the collection of welding fume particles and for the collection of welding gases, as well as for performing both of the above functions simultaneously. The subject of this paper is, in addition to determining the production of welding fume, collection and chemical analysis of fume particles generated by MMAW welding, for this reason the paper uses a chamber with a filter for collecting fume particles shown in EN ISO 15011-1. The semi-closed ventilated chamber, with a shrink filter, is suitable for collecting fume particles generated by welding by the MMAW welding process. The vapors generated during the test can be continuously extracted from the chamber by means of a fan (pump). The complex composition of the mixture of particles and gases in welding fumes requires confirmation of the sampling and measurement method in order for the process to be successfully used for other applications.[5]

It is very important to accurately measure the air flow. The air flow in the evaporation chamber can be measured directly with a flow meter or indirectly as a product of the air velocity and the area of the ventilation pipe.[5]

The test welding chamber for collecting welding fume should have a process part of the chamber and a ventilation drain in which the filter is located. The process chamber should be suitable for the selected welding process, which means that it must enclose the entire process (in this case the MMAW process) and be large enough to allow the collection of total welding fume emissions during welding. The ventilation flow through the process chamber must enhance the thermal movement of air which means that the ventilation outlet should be above the welding process to enhance the natural flow of heated air flow, while the air inlet should be below the welding process. The air flow capacity of the pump or fan should be sufficient to capture the total emitted gases from the chamber but should not affect the integrity of the process. Sampling of welding fumes is performed at the outlet part of the evaporation chamber where the appropriate filter should be located. The filter should be placed at a distance from the welding process or air inlet at 5 × the distance from the diameter of the air outlet from the chamber. All equipment that comes into contact with welding fumes must be made of inert metals to prevent absorption, accumulation or chemical reaction with fume components. PVC pipes are also suitable for use. It is not necessary to use heat-resistant materials or to use cooling devices. It is necessary to regularly clean the inside of the chamber.[5]
Also the ambient air in the room where the chamber is located should meet the quality requirements prescribed by ISO 8756, which provides a procedure for adjusting air quality with changes in temperature, pressure and humidity during the sampling period and provides references to temperature, pressure and humidity used in the results report. The requirements of this standard should be considered in the measurement methods specified in this standard. Execution of the given measures given in the standard and interpretation of the obtained results can be performed only by qualified and experienced persons.[5]

2.2. Equipment and procedure for conducting tests for the collection of welding fume particles

Standard EN ISO 15011-1, in the first part, defines a method for taking evaporation samples and describes a laboratory procedure for determining the emission levels of corrections generated during arc welding and proposes possible analytical techniques or chemical analysis to determine the chemical composition of consumer-generated evaporation during welding. The emission level and evaporation composition depend on the welding process, welding parameters, coatings, work surface size, etc.[5]

Test equipment (evaporation chamber, filters and pump, measuring equipment, base material and other welding consumables depending on the welding process) were completed and tested before the start of the test experiments. The evaporation chamber is designed to reduce the deposition of the rectification on the inner surface of the chamber.[5]

Standard glass fiber filters are used to collect welding fume particles. The filters must be able to withstand the air pressure of the pump and allow the collection of vapors of 0.4÷1.2 mg / cm2. The minimum filter efficiency must be 99.5%. The diameter of the filter should be approximately 250 mm. When determining emission levels, the stability of the filter weight depending on humidity is essential and therefore quartz and glass fiber filters, which are not sensitive to moisture, are recommended. The filter holder should allow the filter to be easily mounted and removed and there should be no leakage of vapor between the filter holder and the chamber body. The filters are kept on a steel wire mesh, and the recommended dimension for the openings on the mesh is 0.5÷2.0 mm. In tests used to collect welding fume particles to determine hexavalent chromium, all vapors should be removed from the filter. The pump must not interfere with welding and should clean the chamber after welding. The pump should have an air flow level of 25÷30 l / s at a pressure of 0.1 bar at the beginning of the test, which is in accordance with the resistance of the filter to 0 mg of evaporation, while at the end of the test the air flow level should be at least 5 l / s at a pressure of 0.16÷0.2 bar.[5]

During welding, the required welding current is set and the arc duration is measured. Before starting the test, make sure that the inside of the chamber and the base material on which the test is performed are cleaned and that they are both at ambient temperature and that there is no splashing in the chamber. Filters should be handled with great care and care should be taken not to contaminate them with dust or grease from your fingers.[5]

Before each test, the filter is weighed, the obtained values are recorded and then the filter is placed on the grid. The base material to be welded is placed on a metal plate inside the chamber. The pump is switched on and welding inside the chamber begins. After the welding has stopped, the pump should run for at least 30 seconds, in order to collect all the vapors, and immediately after that the filter is removed and weighed again. The collected correction is removed from the filter and placed in an impermeable glass tube, after which it is ready for chemical analysis. The test is valid only if no evaporation comes out of the chamber, the temperature of the welding chamber does not become high enough to allow the deposition of the rectification on the inner surface of the chamber. All welding parameters should be recorded in the test report. The parameters must be constant during each measurement and for each test. The duration of the test is determined on the basis of pre-tests and corresponds to the minimum required amount of collected particles of 0.1 g, then the test is stopped before the filter becomes clogged.[5]
To estimate the production of welding fume particles, it is necessary to perform three tests and calculate the mean value. If the individual results differ by more than ± 10% from the mean, two more tests must be performed and the mean of the five test results calculated. The fume emission rate, E mg / s, is calculated as followsformula 1 [5]:

$$E = \frac{M_2 - M_1}{t} \left(\frac{mg}{s}\right) \qquad (1)$$

where:

M1 – is the mass of filter before welding (mg),
M2 – is the mass of filter after welding (mg),
t – is the arc time in seconds (s).

Model 1 of the collecting chamber, conical shape, intended for MMAW and MIG / MAG welding, has a base diameter of 600 mm, a height of 600 mm and an upper part for a filter with a diameter of 300 mm. The chamber is equipped with two openings lined with rubber for the welder working from the outside. A large window with a protective light filter allows visibility during the welding process. The base of the chamber rests on three supports and is raised 15 mm from the work table, which gives space through which air enters. The top of the section can be a pipe connected to the filter space and the suction system. A schematic representation of the welding chamber is given in Figure 1.[5]

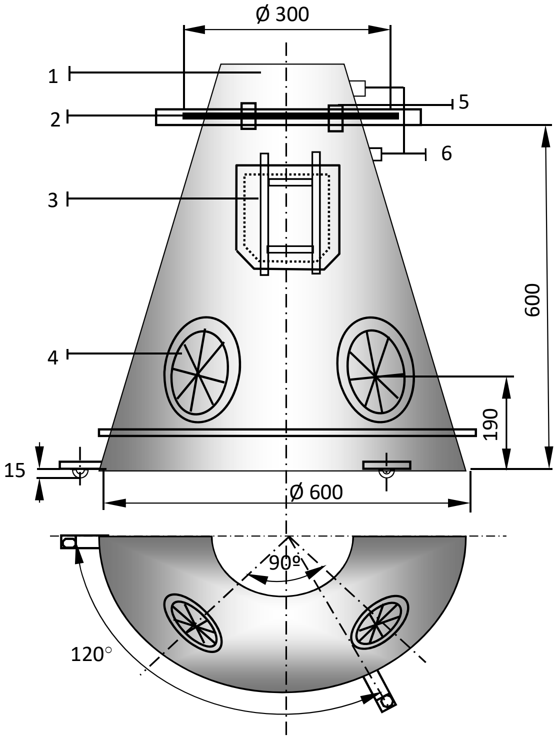

Figure 1. Schematic representation of the welding chamber

The chemical elements to be analyzed as well as the recommended analytical analysis techniques are given in Appendix C of the standard. The analysis should provide sufficient information on the basis of which measures will be taken to meet national health and safety rules. It is necessary to record complete information about the welding process, since the choice of welding parameters can significantly affect the amount of evaporation produced. As hexavalent chromium is considered to be one of the most dangerous constituents of welding fume particles, special attention has been paid to it in the standard. Total hexavalent chromium should be analyzed after collection according to the method given in Appendix D of standard EN ISO 15011-1, referring to IIS / IIW 744.82 document: "interlaboratory calibration, calibration, standardized analytical methods of hexavalent and total chromium in welding vapors" , established by Commission VIII "Health and Safety" of the International Welding Institute IIW. [5]

3. CONCLUSION

The problem of welding fumes is becoming part of the problem of harmful emissions, which is being talked about more and more and which should be reduced in the interest of protecting people and the environment. There has been an increase in the use of welding as a process of joining parts into structures that are increasingly made of alloy steels. Therefore, the production of welding fume is higher, and as it is about the increasing use of high-alloy electrodes, the chemical composition of welding fume is increasingly harmful. Any reduction of harmful emissions into the atmosphere has a positive impact on the protection of people and the environment. Experimental coated electrodes for REL welding process are made in the factory for the production of additional welding material "Elektroda Zagreb". The procedure prescribed by standard EN ISO 150011-1, sampling, welding chamber, sampling of welding fume particles, testing of chemical composition of particles according to the recommended methods (AAS, SEM-EDS, XPS, AES) in the verified laboratories of the institute "Kemal Kapetanović" Zenica, Faculty of Agromediterranean Mostar, Institute of Materials and Technologies IMT Ljubljana, was carried out in full according to EN ISO 150011-1, to make the results reproducible and comparable with data in the literature and papers on similar issues. The results and conclusions of this extensive experimental study are available in the doctoral thesis.

4. REFERENCES

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