

ABSTRACT

The welding of corrosion-resistant austenitic steels involves the emission of welding fume, which poses a significant risk to the environment, health and safety of workers. According to the International Agency for Research on Cancer guidelines, welding fume has been a proven carcinogen since 2018. The main alloying elements of these steels are chromium and nickel. Their compounds are also included in the substances with proven carcinogenic effects.

Welding technologies are the most commonly used joining technologies for corrosion-resistant steels. The basic welding method for austenitic steels is the arc welding process, but increasing demands for improved productivity and quality of welded joints and the efficiency of the welding process have increased the use of laser techniques in industry. In addition to laser welding, a process that uses a laser beam is hybrid laser arc welding (HLAW). This process involves the simultaneous use of two heat sources (a laser beam and an electric arc).

Within the framework of doctoral thesis, a methodology for the assessment of welding fume hazard was developed. This methodology includes the determination of total fume emission rate expressed in mg/s; defined as the amount of fume generated over time. In order to determine which chemical elements are present in the fume, a chemical composition analysis was performed using the SEM-EDS method. The chemical composition analysis was complemented by a phase analysis of the fume using the XRD method, making it possible to determine the phases present in the fume. A study of fume morphology was also carried out, determining particle size, shape and structure. The laser diffraction (LD) technique was used to assess particle size.

The developed methodology provided a complete characterization of the fume including the emission rate, its chemical and phase composition and morphology. This enabled a fume hazard assessment to be carried out during laser, hybrid and arc welding of 1.4301 and 1.4828 steel grades.

The study results demonstrated that arc MIG welding had the highest fume emission rate compared to laser and hybrid welding. For an arc energy of 0.54 kJ/mm, the fume emission rate from arc welding was 3.5 times that of laser welding and more than twice that of hybrid welding. The chemical analysis of fume from laser and hybrid welding of corrosion-resistant steels revealed the presence of iron (55-63%), chromium (20-28%), manganese (3-14%), nickel (4-9%) and silicon (0.1-6%). These elements are in the form of iron, manganese, chromium and nickel oxides (spinels) - Cr_2FeO_4 , MnFe_2O_4 i NiFe_2O_4 . The analysis of the particle size of fume from laser and hybrid welding of corrosion-resistant steels showed that more than 20% of the fume particles were part of the respirable and tracheal fraction (i.e. with a dimension of less than 10 μm), posing the greatest health risks.

Keywords: welding fume emission, laser welding, hybrid laser arc welding (HLAW), arc welding, corrosion-resistant steels