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Reduction of weld metal diffusible hydrogen content by adding colloidal nanosilica to the electrode coating

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ABSTRACT

In the present study, a novel method for reducing diffusible hydrogen in the weld metals was developed by adding colloidal nanosilica to the electrode coating. Shielded metal arc weld deposits were prepared by varying colloidal nanosilica content in the range of 0–30 wt.%. The diffusible hydrogen and metallographic tests were carried out on the weld metals to evaluate the effect of colloidal nanosilica addition on the weld metal properties. The test results showed that the weld metal diffusible hydrogen content was greatly decreased when using the coated electrodes containing colloidal nanosilica.

Introduction

Low hydrogen coated electrodes have been widely used in petroleum, gas and petrochemical industries. One problem encountered in these types of electrodes is the absorption of moisture by the electrode coating from the surroundings. It is well known that the moisture in the electrode coating is mainly responsible for the hydrogen in the weld metal. Hydrogen in the weld metals exists as residual and diffusible hydrogen. At a given temperature, while the residual hydrogen is permanently trapped in the weld metal and plays no role in hydrogen-induced cracking (HIC), the diffusible hydrogen (H_D) is able to diffuse within or out of the weld metal and is responsible for HIC [1–5].

In general, it is accepted that HIC in ferritic steel weld metals occurs at temperatures in the range of −50 °C to 150 °C as a result of three main interrelated factors: sufficient H_D content, crack susceptible microstructure and tensile residual stresses acting on the weld metal [1]. The hardenability of weld metal and the tensile residual stresses is difficult to control. Therefore, reduction of H_D content in the weld metal is considered as the best way of reducing the risk of HIC. The major source of H_D in the weld metals produced by low

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hydrogen coated electrodes is the moisture absorbed by the electrode coating during welding [2,3]. The flux binders in the electrode coating are very hygroscopic and quickly absorb moisture from the ambient when exposed to a humid environment. The absorbed moisture depends upon the humidity of the atmosphere and the exposure duration [6].

With the advent and fast development of nanotechnology, various types of nanomaterials have been developed recently. The application of nanotechnology to welding science opens up new opportunity and research direction for the development of novel welding consumables [7,8]. Colloidal nanosilica sols are stable water-based suspensions, containing up to 50 wt.% of spherical amorphous silica nanoparticles. The addition of colloidal nanosilica to the flux binders has been found to decrease the weld metal H_D content by reducing the hygroscopicity of the electrode coating. No research dealing with weld metals produced by coated electrodes containing colloidal nanosilica appears in the literature. Therefore, the aim of this research is to identify the effect of colloidal nanosilica in the electrode coating on the H_D content of AWS E7018 weld metal.

Experimental procedure

To prepare the experimental AWS E7018 coated electrodes, the liquid flux binders containing 0, 10, 20 and 30 wt.% colloidal nanosilica (with an average particle size of 50 nm) were stirred for 2 h at 1200 rpm and then the mixtures were ultrasonicated for 30 min at 50 °C. The transmission electron microscopy (TEM) micrograph of colloidal nanosilica is shown in Fig. 1a. When the colloidal nanosilica was uniformly dispersed into the mixtures, the binders were added to the fluxes. Finally, four experimental coated electrodes with a diameter of 4 mm and coating factor of 1.63 were produced with these fluxes. The coated electrodes were air dried for 24 h, followed by baking at 450 °C. A bead-on-plate technique was used to deposit the weld metal on the test specimen assemblies according to AWS A4.3–93 [9]. Fig. 2 schematically illustrates the test specimen assembly after deposition of the bead. The test specimen assembly consists of three pieces, the run-on tab, run-off tab and test specimen. The arc is initiated on the run-on tab and continued until reaching in the run-off tab for the arc extinction. Therefore, a stable arc and uniform shape of the deposit can be obtained on the test specimen. All the test assemblies were degassed for 3 h in air at 400 °C to remove any residual hydrogen in the base metal. Welding was carried out by placing the test specimen assembly on a copper clamping fixture. Immediately after welding, the test specimen assemblies were placed into a low temperature liquid bath of acetone with dry ice and quenched down to −60 °C. Then, the cleaning of the test specimen assemblies was done

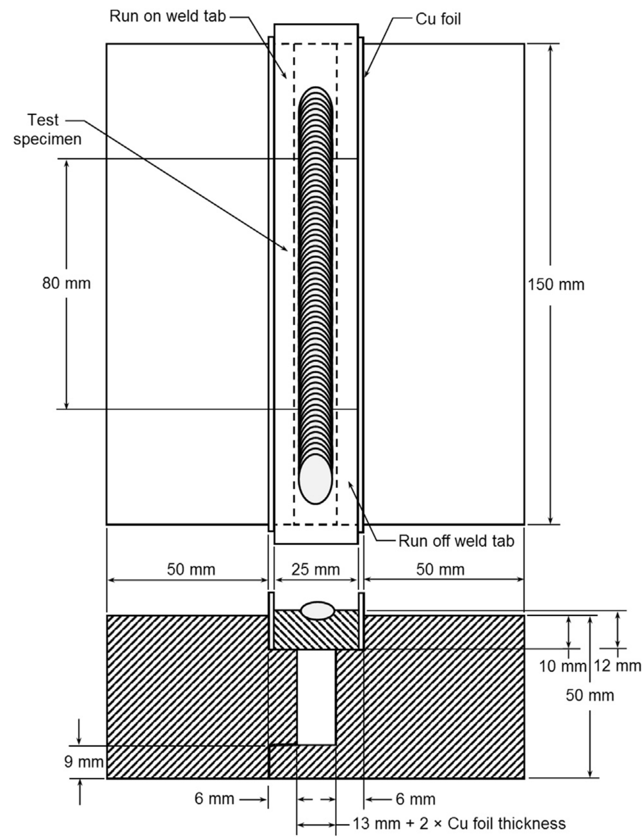

Fig. 2 – A diagram showing the test specimen assembly in the welding test jig and a single weld bead.

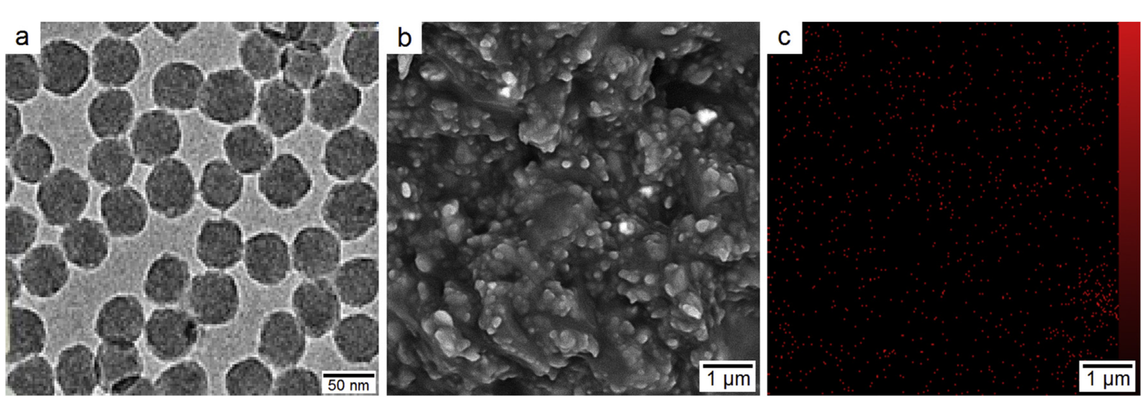

Fig. 1 – (a) TEM micrograph of the colloidal nanosilica, (b) and (c) SEM micrograph and silicon EDS mapping of electrode coating containing 30 wt.% colloidal nanosilica, respectively.