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Effect of boric acid on metal transfer mode of underwater flux-cored wire wet welding

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ABSTRACT

For obtaining high quality of underwater welding repairing for nuclear power equipments, the influence of boric acid on metal transfer process of underwater flux-cored wire wet welding in boric acid solution is explored by an X-ray transmission system. The research results show that the mixed repelled globular transfer and solid short circuit transfer mode and the mixed repelled globular transfer and surface tension transfer mode are two kinds of main metal transfer modes during underwater welding in boric acid solution. The proportion of the mixed repelled globular transfer and surface tension transfer mode is increasing with the increasing of concentration of boric acid solution, which is caused by the difference of force condition of the droplet.

1. Introduction

Safety is always the main theme during the nuclear power plants service. The regular inspections and maintenances of the equipments in nuclear power plants are very necessary, as reported by Wang et al. (2013). In general, water is always used as coolant and moderator in the nuclear power plant, and it is forbidden to be drained due to the prevention of nuclear radiation pollution during the maintenance of nuclear power equipments. Therefore, according to the studies of Yurioka and Horii (2006) and Rowe and Liu (2001), the underwater wet welding technology has widespread application in the field of nuclear equipments repairing. In addition, Verbeke et al. (2000) have expounded the boron's strong ability of absorbing neutrons. So the boric acid is dissolved into water in nuclear power plant reactor to control the reaction rate and make the nuclear reactor run stably and safely. Therefore, compared with normal underwater wet welding, the distinctiveness of underwater wet welding technology adopted for repairing nuclear power equipments are reflected in the welding surrounding of boric acid solution. Haidar and Lowke (1996) and Pires et al. (2007) have studied metal transfer process, and they concluded that metal transfer has decisive effect on the welding arc stability, weld formation and welding quality. Lots of works have been carried out to study the droplet transfer process in various welding techniques, especially GMAW and FCAW. Most of them focus on the metal transfer classification and the influence of welding parameters on the metal transfer. About droplet transfer process of GMAW, Iordachescu and Quintino (2008) overviewed and defined the basic concepts of fundamental transfer modes to help the specialists involved in the study, design and industrial applications. Scotti et al. (2014) have explored the relationship between arc-length and metal transfer's mode on the basis of conventional transfer map represented by arc voltage plotted against welding current. As a result, they have succeeded to describe the influence of arc-length on metal transfer more realistically. Comparing with GMAW, the droplet transfer process of FCAW presents more complexities due to the additional welding metallurgical factors. Liu et al. (2008) have defined three different modes of metal transfer for FCAW as bridging transfer without arc interruption, repelled globular transfer and globular transfer, while the former two modes played a key role in the welding metal transfer process. However, another study of Li et al. (2000) argues that explosive transfer can also be observed and the bridging transfer consisted of different phenomena. Although there have been many studies concerning metal transfer, almost all of these researches are just conducted for in-air welding, and few of the works are related with the metal transfer of underwater wet welding. In fact, the shortage of suitable methods and equipments for these works is the main reason for this issue.

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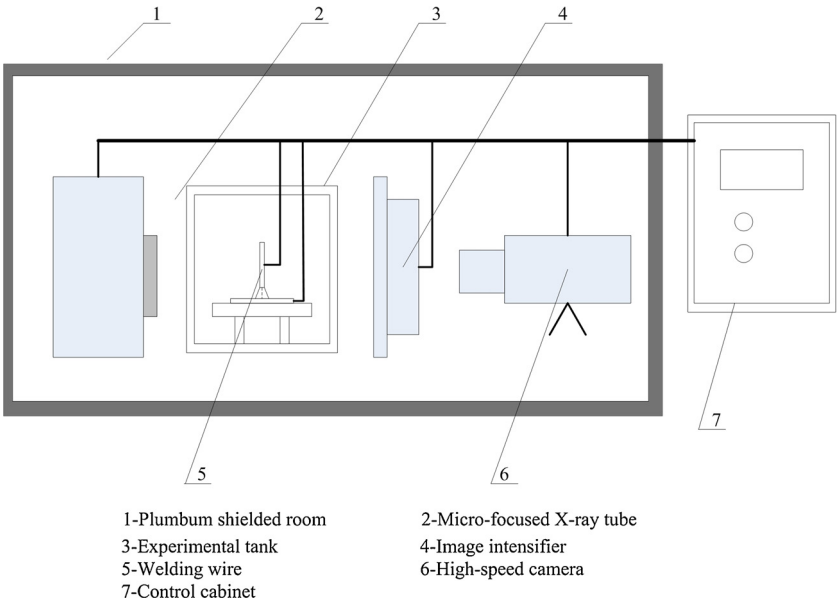

Fig. 1. Schematic of X-ray imaging system.

Generally, most of the researchers employ the high-speed photography with a visible light back-lighted shadowgraphic method to analyze the metal transfer, such as Lin et al. (2001), Wong and Ling (2014) and Heald et al. (1994). However, because the visible light can be reflected and refracted by the surrounding water mightily, it is very different to apply it to explore the metal transfer process of underwater wet welding. Therefore, the traditional method is not able to achieve clear images of the metal transfer during underwater welding. In this study, a valid method is introduced to obtain precise metal transfer images of underwater wet welding. In addition, aiming at the technology of underwater welding repairing in boric acid surrounding, the metal transfer characteristics of underwater wet welding in boric acid solution and the influence mechanism of boric acid on metal transfer modes are both explored in the present research.

2. Experimental procedure

The base metal prepared for this experiment is Q235 mild steel with dimensions of 200 mm × 60 mm × 15 mm. The welding material is a rutile type self-shielded flux-cored wire with diameter of 1.6 mm. Moreover, an automatic control platform for underwater welding, SAF-FRO DIGI@WAVE500 welder and a set of matched automatic wire feeding system are used in this experiment. The

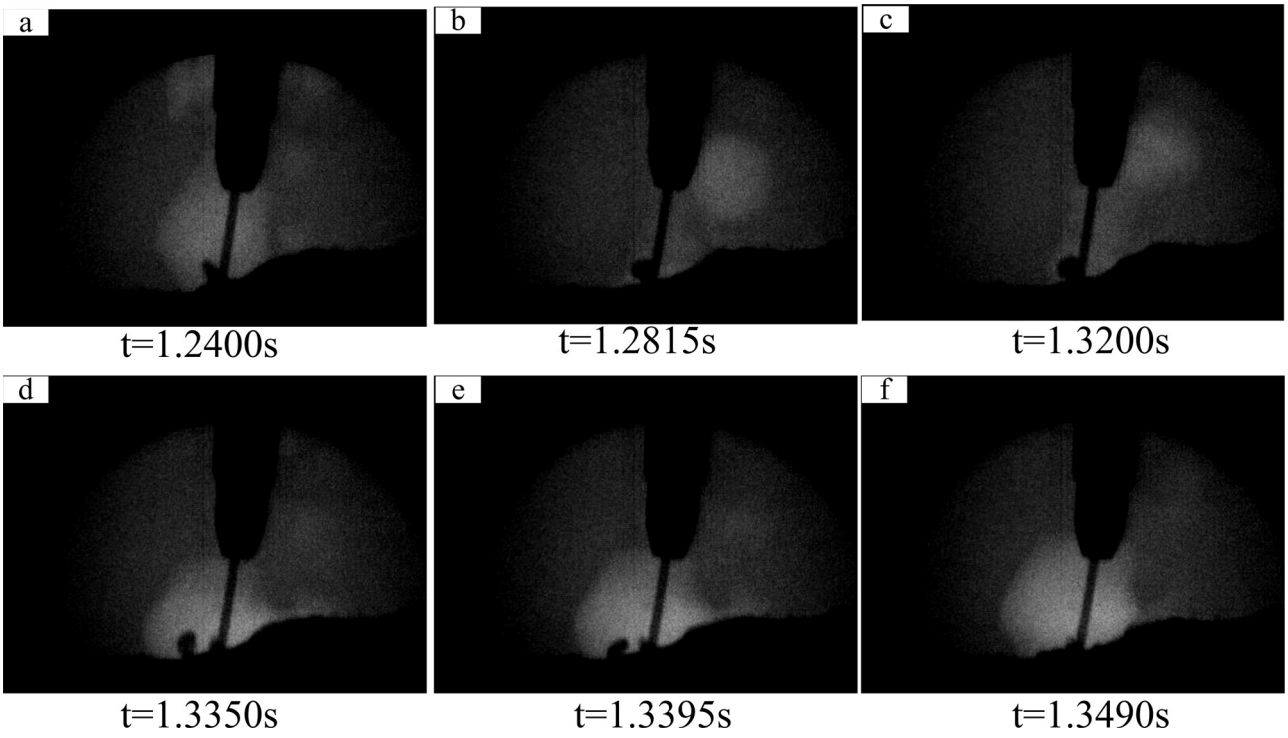

Fig. 2. A combination of repelled globular transfer and solid short circuit transfer.