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Application for beam time at ESRF – Experimental Method

Characterization of metal transfer process in underwater flux-cored wire wet welding

Proposal Summary (should state the aims and scientific basis of the proposal) :

The better understanding of the droplet transfer is very important for the development of a welding technique. Lots of works have been carried out to study the droplet transfer process in various welding techniques. Generally, analysis of metal transfer is performed using high-speed videography with a laser back-lighted shadow graphic method [1, 2], which is named “Visible light method” here. In this method, the image of droplet transfer is obtained only by the visible light videography system, where a spatial filter is located at the focal point of the objective lens and transmits most of the laser light and excludes most of the intense arc light. However, the traditional “Visible light method” is not able to achieve clear images of the droplet transfer process due to the reflection and refraction of visible light in water during underwater wet welding because of the many bubbles and water perturbation surrounding the arc burning area.

As known, X-ray has a wavelength in the range of 0.01 to 10 nm which is much shorter than those of visible light. X-ray can traverse relatively thick objects without being much absorbed or scattered. For this reason, X-ray is widely used to image the inside of visually opaque objects. The penetration depth can vary several orders of magnitude over the X-ray spectrum which allows the photon energy to be adjusted for the application so as to give sufficient transmission through the object and at the same time good contrast in the image. Based on these properties of X-ray, it is believed that X-ray may be able to overcome the effect of the water bubbles and perturbation on metal transfer imaging. The images of metal transfer process in underwater wet welding have been obtained at our home laboratory [3], shown in Fig.1 and Fig.2, while the clearer images are urged to character more details and to conduct in-depth researches. The better illuminant, like synchrotron radiation, is effective for completing the works mentioned above. In the proposed experiment we aim at obtaining clear images of metal transfer process via synchrotron radiation and clarifying the mechanism of mass transfer in underwater wet welding.

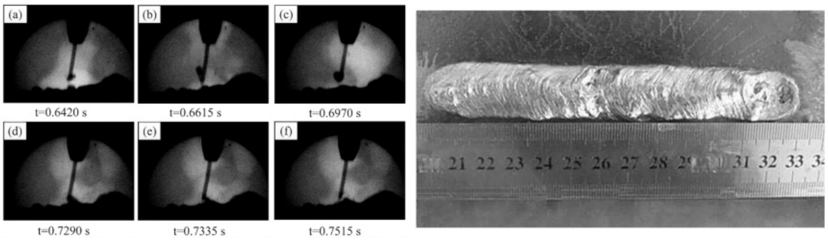

Fig.1 Metal transfer processes of the surface tension transfer mode and the weld appearance

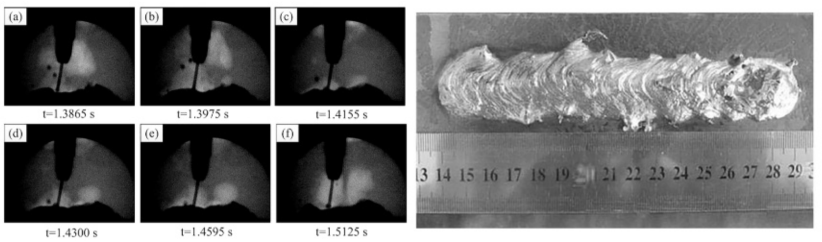

Fig.2 Metal transfer processes of the submerged arc transfer mode and the weld appearance

Scientific background :

Underwater welding is widely used in the repair and maintenance of marine constructions such as submerged pipelines, offshore oil platforms, nuclear power plants as well as harbor devices [4]. Underwater welding techniques can be divided into two main types, wet and dry method. In comparison to dry or habitat method, wet method does not require any complicated device such as diving bell, hyperbaric vessel, drainage device, etc. The welding process is conducted directly in the water, and the simplicity of the process makes it possible to weld even the most geometrically complex structures and its cost is extremely low. However, as wet method is performed at ambient pressure with no physical barrier between water and welding arc, the increased pressure makes welding arc unstable. Moreover, as the amount of oxygen and hydrogen present in the weld pool are higher due to water dissociation, increasing porosity and hydrogen-induced cracks are produced in underwater wet method [5]. All the issues mentioned above have close relation with the heat and mass transfer process which has unique characteristics in underwater wet method, because of the effect of the surrounding water. So the study of welding arc physics and metallurgy mechanism of wet method has great significance. Metal transfer process, as a main channel of mass transfer in welding process, has always been a concern owing to its importance of the effect on welding arc stability, molten pool behavior, weld formation and welding quality. For instance, comparing the weld appearance in Fig.1 and Fig.2 indicates the difference of weld appearance for diverse transfer modes. On the basis of the thorough understanding of the droplet transfer, it will be realizable to control metal transfer mode and acquire the perfect welds. Therefore, the research of the droplet transfer is crucial to the development of a welding technique.

Experimental technique(s), required set-up(s), measurement strategy, sample details (quantity...etc) :

Underwater wet welding is conducted in the experimental tank full of water. During the underwater welding process, the workpiece immersed in the water moves with the tank along the opposite direction of welding, while the wire is immobile. The X-ray source and detector are placed at two sides of the tank, and the X-ray propagates perpendicular to the direction of welding. The X-ray penetrate the two tank walls, the water and exposure the welding zone. The tank wall is made of glass and the thickness of two walls is more than 10 mm. The width of the tank, which equals to the thickness of the water penetrated by the X-ray, must be more than 80 mm to ensure the welding experiment conduct successfully. Consisting of wire tip, molten pool and area of metal transfer, the welding zone exposed to X-ray must be large enough to characterize whole features of metal transfer process. Therefore, the minimal diameter of the zone is 20 mm according to the previous researches. Otherwise, the wire, with a diameter of 1.6 mm, is made of nickel or mild steel. The diameter of droplet varies from 1 to 5 mm. The frame rate of capturing X-ray transmission images requires to be more than 1500 f/s.

The welding equipment, including an automatic control platform for underwater welding, a special underwater wet welding machine, a set of matched automatic wire feeding system, the experimental tank and the welding materials, is prepared by ourselves.

Beamline(s) and beam time requested with justification :

Required beamline: ID19 beamline with an energy between of ~ 120 keV –FOV of ~20 mm.

Required beamtime: 7 shifts including mounting and aligning of samples

Results expected and their significance in the respective field of research :

Anticipated results of the imaging metal transfer process experiments via synchrotron radiation are:

- clear images of droplet in the process of droplet growth and metal transfer, which are fundamental to gaining droplet size and structure, estimating the metal transfer mode and calculating the droplet transfer frequency.
- clear outline of molten pool which is essential to obtain molten pool behavior and clarify the influence of droplet on the molten pool.
- clear images of bubble and welding fume surrounding the wire which have large effect on the metal transfer.
- formation process of arc air sac existing in the process of underwater wet welding to guarantee the burning of welding arc, which is necessary to reveal the dynamics and thermodynamics principle of generation and overflow of the air sac and clarify the mechanism of action of welding arc in underwater wet welding and the environmental constraints of gas discharge in water.
- process of gas overflow from the droplet (It has been observed that the droplet is full of gas), which will be conducive to illustrate the metallurgical reaction process in the droplet.

References

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[5] V.R. Santos, M.J. Monteiro, F.C. Rizzo, A.Q. Bracarense, E.C.P. Peesoa, R.R. Marinho,et al. Weld. J 91(2012) 319–28.