Initial trials of underwater wet flux-cored wire cutting at shallow water

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Abstract: Underwater cutting technology is commonly used in repairing and removement of damaged offshore steel structures. In this paper, arc stability and cut quality of flux-cored arc cutting process were investigated at shallow water. Gas-forming flux-cored wire and exothermic flux-cored wire were selected to evaluate its future potential use in underwater cutting process. Underwater flux-cored arc cutting process was realized using the two types of wires. Acceptable cut appearances were obtained and no local bridge emerged in two cuts. Arc stability of FCAC process for exothermic wires was superior to that for gas-forming wires because exothermic wires contain more arc stabilizers.

Key words: underwater cutting; flux-cored arc cutting; arc stability; cutting ability

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Introduction

Repairing and removement of damaged offshore steel structures require the development of underwater cutting technology[1]. Underwater cutting can be classified into underwater cold and thermal cutting. Underwater cold cutting free of thermal stress and heat-affected zone possess a wide range of cutting capacity and high cutting quality[2]. But cold cutting was used in special condition to obtain high quality cuts because of its relatively huge costs. Underwater thermal cutting featured by high cutting speed and high cutting efficiency is a promising cutting method although it produces thermal effects and rough cuts. Underwater thermal cutting methods typically include flame cutting, oxy-arc cutting, plasma cutting and consumable electrode water jet cutting, and only manual oxy-arc cutting method is now an established technique for practical application[3-5]. But this method is slow in cutting speed and require high-skilled operation techniques[6].

Researchers worldwide work on the development of underwater laser cutting technique for steel and alloys for nuclear applications using local-dry-zone creating nozzle[7-10]. During dry laser cutting process, a high-power laser beam is focused on the job so that the material reaches its melting temperature and a high-pressure active or inert gas is used to remove the molten material. This information indicated that underwater laser cutting could be used as a high-performance tool for remote cutting in dismantling and repairs of ship and pipe lines in water. For such operations, it is highly useful to deliver the laser beam through optical fiber because of its flexibility. However, this method is urgent for local dry conditions because laser beam was significantly sensitive to water. Particularly, it is difficult to form completely dry space under great depth. What’s more, Germany researchers investigated the contact arc metal cutting (CAMC) process and pointed out that CAMC could compete in cutting efficiency and pollution emission rate with other underwater cutting processes[11]. This method requires extremely high energy (single power source 1000 A) and is favorable for steel plates with great thickness. Therefore, it is essential to develop underwater thermal cutting processes of easy automation and high efficiency.
The E.O. Paton Welding Institute has developed a method of underwater electric arc cutting with flux-cored wires \[12\]. The flux core contains gas-forming and arc stabilizing components. The cutting mechanism of underwater flux-cored wire arc cutting (FCAC) without additional supply of oxygen is that resultant thermochemically highly active gas-flame jet melts, oxidizes and removes the molten metal from the cutting surface \[13\]. In contrast to the existing methods of electric oxygen cutting, air-plasma cutting and electric water jet cutting, this method does not require any additional feed of gas or water into the arcing zone. Comprehensive underwater flux-cored wire cutting results were obtained using this technique \[14\].

Overall, literatures on underwater thermal cutting were very little. It is very important to dedicate special attention to this process. In this article, cutting arc stability and cutting quality of FCAC process were analyzed to characterize the potential of this process using two types of flux-cored wires.

1 Material and Experiments

Welding experiments were conducted in a 1000 mm×1000 mm×600 mm water tank with Higerman Hi800 CNC operating system in flat position. Aotai NBC 630 as a power source and YW-50KB3HAE wire feeder were used for all experiments. The power source has an open circuit voltage of 70 V with a current limit of typically 630 A. DCEN current polarity was used in all welds at a depth of 0.3 m. The welding current and voltage signals were acquired in real time by Hall sensors and NI 6210 USB data acquisition cards at a frequency of 10 kHz/s.

Two types of flux-cored wires were selected to conduct underwater cutting trials. A FCAC wire (#1) with 2.0 mm of diameter specially developed by E.O. Paton Welding Institute, called PPR-AN1, was used in the wet FCAC process. The flux-core of this wire mainly consists of gas-forming components. The flux core of the other wire (#2) is with exothermic addition (55% thermite) which was designed for underwater cutting application. Electrode wire (#2) was produced with (34~35) wt.% flux fill to steel sheath ratios. The cutting parameters applied are arc voltage of 30 V, wire feeding speed of 8.5 m/min, current of 400 A, and cutting speed of 300 mm/min. Q235 steel with the thickness of 8 mm was used in underwater wet cutting experiment.

2 Results and discussion

Fig.1 demonstrates the recorded typical electrical signals of underwater cutting process using wire #2. Obviously, the fluctuation trend of electrical signals of cutting process was similar to underwater welding process before the workpiece was pierced. The measured values of voltage and current were fluctuated greatly during cutting process. The time when the workpiece was pierced was a symbol of arc extinction. For underwater FCA cutting process, arc extinction was very common. Therefore, the ability for an arc to restart was important to realize a stable cutting process after the arc extinction. In fact, lots of gas-forming constituents and arc stabilizer in flux core helps to stabilize ignition and permit longest arc length discharge.

Arc stability of cutting process was altered due to the difference of flux core components between the two wires. The effect of two types of wires on probability density distribution of voltage is displayed in Fig.2. The probability density distribution of voltage with the addition of exothermic addition had less pronounced arc extinction region. This figures also illustrated a more intense and narrower large hump in the center was obtained for the exothermic addition, which implied a more steady cutting process.

To dynamically and clearly display the fluctuation of the electrical signal in the whole cutting process, cyclograms of arc voltage and cutting current (U-I) was selected for the two wires, as illustrated in Fig.3. It can be observed that the arc burning area for wire #2 became more concentrated than that for wire #1. Also, compared to wire #1, the intensity of the working point arc extinction area for wire #2 was small indicating that a more stable cutting process could be obtained for wire #2.

The arc burning through capacity, called pierce time, is considered to be space of time from arc ignition to full burning through of metal. The pierce time is important because the plate must be pierced prior
to cutting in practical decommissioning situations. The relationship of pierce time depending on plate thickness is displayed in Fig. 4. It can be seen that pierce time of wire #2 was shorter at different plate thickness than that of wire #1, which indicated the benefits of exothermic addition in wire #2. Here it should be mentioned that wire #1 could function well at greater depth because of arc compression.

![Fig. 3 Cyclogram for arc voltage and cutting current for the two wires](image)

![Fig. 4 Piercing time depending on plate thickness for two wires](image)

The cut quality was not of primary importance but it was essential that any dross produced did not cause a local bridge in the cut. Fig. 5 demonstrates that the typical flux-cored arc cutting appearances of the investigated two wires. It is visible that no local bridge emerged in two cuts. The back width of cut was larger than the front width of the cut. In addition, a smaller average cut width (6.1 mm) was obtained for wire #1 than that (7.8 mm) for wire #2. That is, for wire #2, a considerable amount of energy was conducted into the work piece resulting in changes in the material properties and the microstructure of the material leading to large heat affected zone (HAZ).

The flux-cored arc cutting process has the potential to be applied to decommissioning work since it can be easily started and operated automatically. However, it is essential to figure out the optimal cutting parameters (arc voltage, current and cutting speed) for FCAC process according to the practical conditions. If the unfitted cutting parameters were selected, the emergency of arc extinction or bridging between two edges may decrease the efficiency of FCAC process.

3 Conclusion

In this paper, gas-forming flux-cored wire and exothermic flux-cored wire were selected to evaluate its future potential use in underwater cutting process. Main conclusions are as follow,

1. Underwater flux-cored arc cutting process was realized using the two types of wires. Acceptable cut appearances were obtained and no local bridge emerged in two cuts.

2. Arc stability of FCAW process for exothermic wires was superior to that for gas-forming wires because exothermic wires contain more arc stabilizers.
(3) The flux-cored arc cutting process could be applied to decommissioning work since it can be easily started and operated automatically.

References: