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REMOVAL OF BARNACLES IN MARINE ENVIRONMENT, USING IMPRESSED CURRENT ANTI FOULING (ICAF) SYSTEM

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ABSTRACT

FPSO (Floating Production Storage and Offloading) is an oil and gas transportation vessel, currently considered effective in the oil sector. However, the vessel possesses several limitations, including corrosion on the material steel. ICAF (Impressed Current Anti-Fouling) is a suitable preventive method for biological corrosion. The study of biofouling-causing macroalgae was performedona laboratory scale with a simple ICAF system, using the variables of operating time, as well as 10, 20 and 30 cm anode-cathode distances. Furthermore,physical observation was conducted to ascertain Barnacle removal, while the Cu ion concentration was determined using AAS (Atomic Absorption Spectrophotometry). This study aimed to determine the removal of Barnacle macroalgae, using a simple Impressed Current Anti-Fouling system. According to the results, the highest removal of 100% was obtained at all anode-cathode distances used. However, the fastest removal was attained using a 10 cm anode-cathode distance and 9 A of electrical current. Meanwhile, the highest Cu ion concentration produced while operating the simple ICAF system was about 81.85 ±3.04 mg/l. Therefore, the Cu ions generated during the system's operation were able to remove Barnacles from adhering media.

KEY WORDS : Barnacles, Biofouling, Biocorrosion, Cu ion, Impressed current anti-fouling, Macroalgae.

INTRODUCTION

Oil and natural gas are one of the most important human needs, with a constantly increasing demand for production. Thus, there is a need for technological advancement for the transportation of these products, as well as for maintenance of existing infrastructure. The two ways to transport oil and gas in offshore drilling are ship transportation and submarine pipeline distribution (Adegboye *et al*., 2019). FPSO (Floating Production Storage and Offloading) is an oil and gas transportation vessel currently considered effective in the sector. However, the vessel had several limitations and is most often made of steel metal. This material has several benefits, including being stronger, compared to material of iron, aluminum, copper (Passarini *et al*., 2018). In addition, steel also has disadvantages, particularly the problem of corrosion or rusting, caused by various factors, including sea water. The corrosion rate of steel metals in seawater environments is quite rapid, because the water contains acidic compounds, as well as organic compounds in organisms, leading to rapid rusting in metals (Refait *et al*., 2020).

According to Vinagre *et al*., (2020), ICAF (Impressed Current Anti Fouling) is a technology used to avert the spread of biofouling, often due to marine life, including algae and other marine plants, barnacles, and shellfish. This fouling is highly unfavourable because sticking to the ship's hull increases the vessel's resistance (Mauludin *et al*., 2018), and is categorized into two. The first, microfouling refers to biofilm formation or bacteria and microalgae colonization, for instance, bacteria and fungi (biofilms) and diatoms (periphyton) (Railkin, 2004). Meanwhile, the second, macrofouling is the attachment of organisms or colonization by invertebrates and macroalgae with destructive properties, for instance, algae as well as invertebrate larvae (Railkin, 2004), and is caused by the presence of identical microfouling, known as biofouling (Marhaeni, 2012). This is influenced by several factors, for instance, physical and chemical factors. These factors are bound to produce several complex layers of microorganism adhesion or microfouling as well as macro-organisms or macrofouling (Ruslan, 2014). The process of forming a biofouling community involves several procedures, where colonization on a new surface occurs as the final result of several stages. Initially, a layer is formed biochemically on a clean surface, followed by microbial attachment or microfouling (bacterial and diatom colonization) and macrofouling as the final stage (colonization of macroalgae and invertebrates) (Mujiyanto and Satria, 2011).

A study by Schultz *et al*., (2011) reported anti-corrosion cooling systemshave not been developed in ship engines due to high maintenance and inspection costs. In principle, the ICAF system's application is very simple, only using an anode and a cathode as well as an electric current. However, In Indonesia, the system is generally rarely used on ships. The ICAF principle uses an artificially triggered voltage difference a copper (Cu) anode, and a steel plate cathode. Copper as a heavy metal Cu has been shown to reducegrowth rate, reproductive success and abundance in many species (Hall *et al*., 1998).

A previous study recorded a 98.5% reduction in *Pseudomonas fluorescens* population, using 0.1 A electric current and a 3 minute operation time (Pratikno and Titah, 2016). This reduction is due to the presence of Cu ions discharged into the saline solution from the ICAF system's anode, copper ions have the ability to kill microorganisms, including *Pseudomonas fluorescens*. Meanwhile, a 99.4% and 90% reduction in *Vibrio algynoliticus* and *Escherichia coli* population, respectively, were obtained using this system, anda Cu ion concentration of about 17.85 ± 0.01 mg/l to 20.9 ± 0.03 mg/l (Pratikno *et al*., 2019a; Pratikno and Titah, 2017). This shows a simple ICAF system has the ability to reduce *Vibrio algynoliticus*, *Pseudomonas fluorescens* as well as *Escherichia coli*, by varying the operation time and magnitude of electric current. Pratikno *et al*. (2019b) reported a 99.98% reduction in *Chrorella vulgaris* algae population, at 1 A, 10 minutes operation time, and a 17.9 ± 0.07 mg/l Cu concentration, while the least reduction of 97.57% was obtained using 0.3 A, a 5 minute operation time, as well as a 15.52 ± 0.25 mg/l Cu concentration. Meanwhile, the maximum reductions of 77.5% and 50% in *Isochrysis galbana* and *Botryococcus* sp, respectively, were obtained using this system, with a maximum Cu concentration of 4.08 ± mg/l (Pratikno *et al*., 2020).

However, there are no known reports on the use of simple ICAF system in Barnacle removal. The sea underwater surface is strongly influenced by the attachment of fouling organisms, especially barnacles, known as *Teritip*, in Indonesia. Barnacles are marine animals belonging to the group of crustaceans from the sub class *Cirripedia*, spending the entire life as an adult in the same place, and very easy to attached to the bodies of marine animals, including shrimp, lobsters, crabs, and whales. Based on the report by Thaeraniza *et al*. (2020), barnacles dominate the composition of attached macroinvertebrates at coral reefs in Damas Beach, Trenggalek, by 66%. In addition, these organisms prefer to live in shallow waters, have shells, and often to stick to rocks, ships, boats as well as dock masts. Young barnacles are often found swimming in the water, while the adult counterparts are sessile, and tend to stick constantly to solid objects in water. The organisms have a strong resistance to environmental changes and the ability to breed in any place of choice, as well as the ability to survive, despite exposure to air, rain, heat from the sun or even the threat of drought. Furthermore, after seawater has receded and barnacles are above the water's surface, the organisms seal a part of the body called the operculum, to stay in the shell and fast temporarily. Barnacles usually filter out current-washed plankton as food.

This study was conducted based on the previous research on the use of simple ICAF in microfouling reduction, as well as the limited available data on barnacle removal from sea vessels. The study's aim was therefore to discover the most effective distance and current in removing fouling of Barnacle soften attached to the FPSO box cooler.

MATERIALS AND METHODS

Anode and Cathode Preparation

For the cathode, steelmaterial was applied in a marine building or ship's field, while Copper (Cu) metal was applied as the anode, both with a dimension of 15 x 15 x 1 cm.

Acclimatization of Barnacles

For this experiment, barnacles were obtained from ship hulls at Pasuruan Beach, East Java, and acclimatized out using 35% artificial saline water, due to the similarity with sea water salinity.

Fig. 1. Appearance of Barnacles after collection.

Preparation of Simple ICAF

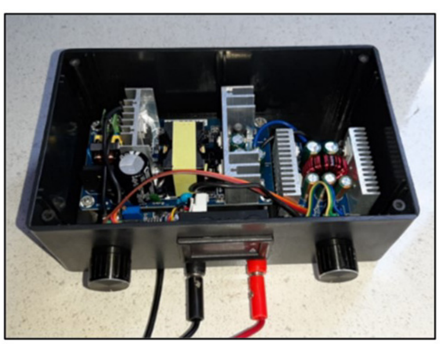
The simple ICAF system is shaped to resemble a power supply, using an electronic Surface Mount Device (SMD) component, placed directly on the solder side (the term "Solder Side") of the Printed Circuit Board (PCB). This means the SMD component was directly in contact with the PCB's copper surface. Contrary to ordinary conventional electronic components with special wires or metals for legs, SMD has two or more sides/parts, in addition to a smaller size and a special metal surface with a function similar to the legs of conventional components. Meanwhile, the power supply was a device or system consisting of a transformer, diode and capacitor/condensator functioning to transmit electrical energy from high-voltage AC to low-current DC voltage, or direct current, to stabilize the DC voltage (Sudarmaji, 2017).

The simple ICAF tool was an upgrade from the previous one, with benefits in terms of specifications, particularlya 13 Ampere electric current, as well as smaller size and lighter weight, due to the component's use of two transformers (step down and step up transformers). Furthermore, the tool was equipped with short protection to minimize the occurrence of short circuit. The step down transformer was used to convert 220 VAC current to 24 volt voltage, while the step up transformer was used to increase the amperage currents. However, the current and voltage were limited to improve the tool's life-span and durability. Figure 3 shows some of the tool's electrical components (a) as well as the upgrade simple ICAF tool's physical appearance (b).

The Simple ICAF System's Operation

The simple ICAF system was designed as described in previous studies, and operated using a plastic reactor with dimension of 36,5 x 24 x 16 cm and 20 Barnacles added at each reactor (Pratikno and Titah, 2016; Pratikno and Titah, 2017; Pratikno *et al*., 2019a,b). In addition, cathode-anode distances of 10, 20 as well as 30 cm, and 1500 ml of 35% artificial saline water were used for the experiment. Figures 3 (a), (b) and (c) show the simple ICAF system's operation in Barnacle removal at different durations as well as anode-cathode distances.

Barnacles removal was determined through direct observation, while Cu ion concentration was



(a)

(b)

Fig. 2. Upgradesimple ICAF system tool
(a) some electrical components in simple ICAF tool (b) The physical appearance of upgrade simple ICAF tool

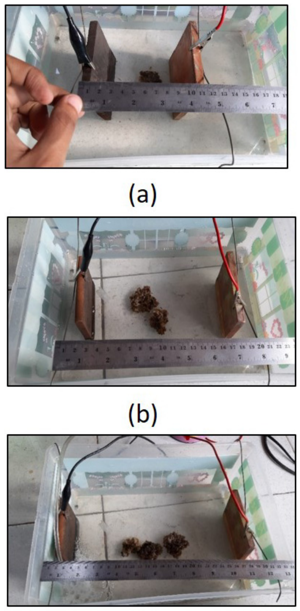


Fig. 3. The simple ICAF system's operationfor Barnacle removal using anode –cathode distances of 10 cm (a) 20 cm (b) and 30 cm (c).

determined with an Atomic Absorption Spectrophotometer (AAS), using a similar method as described in the previous study (Pratikno and Titah, 2016; Pratikno and Titah, 2017; Pratikno *et al*., 2019a,b). Meanwhile, saline water samples were collected form the simple ICAF system reactor, filtered with a filter paper, and subjected to analysis by Atomic Absorption Spectrophotometer (AAS) model Z-2000 Series Hitachi (Japan), at DRPM ITS' Laboratory of Energy.

Statistical Analysis

The experimental data obtained on Barnacle removal and concentration of Cu during the simple ICAF system reactor's operation were subjected to an analysis of variance (ANOVA), using SPSS Statistics, for Windows version 21.0 (SPSS, Inc., Chicago, IL), and statistical significance was designated to values with p value< 0.05.

RESULTS AND DISCUSSION

Barnacle Removal

Figure 4 shows the cumulative number of removed barnacles on 35% artificial seawater media. According to the diagram, all barnacles this experiment were attached to a material at the initial simple ICAF system. The highest cumulative barnacle number was obtained using a 10cm anode-cathode distance and a 9 Ampere electrical current, while 100% removal was obtained after 9 minutes of operation (Figure 5). However, all anode-cathode distance variation used showed the ability to release Barnacles with different durations.

According to the results of ANOVA, there was a significant difference ($p < 0.05$) between the extent of Barnacles removaland the anode-cathode distance, electrical current as well as duration. This shows these three variable factorsinfluence barnacle removal, during the simple ICAF system's operation.

Cu concentration during the upgrade simple ICAF tool's operation

A study by Juneja *et al*., (2013) reported heavy metal Cu as one of the most toxic metals, with toxicity towards barnacles. The organism's life cycle comprises four stages, nauplius, cyprid, juvenile, as

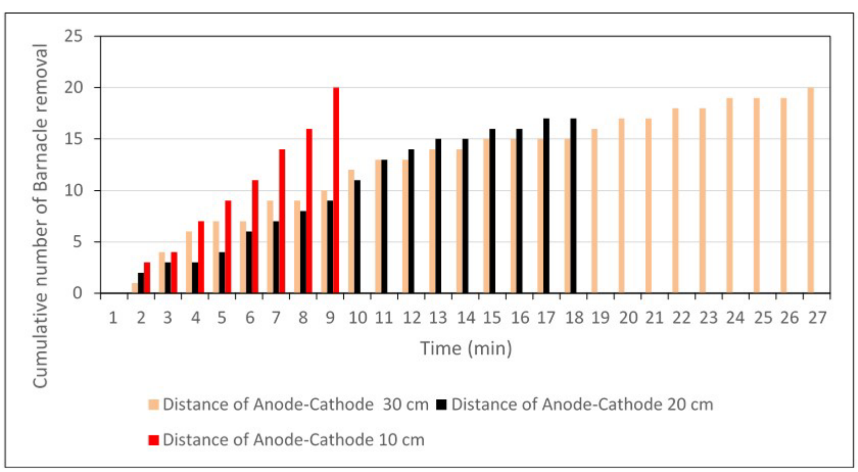


Fig. 4. The cumulative number of Barnacles released from attached material in different of anode-cathode distances

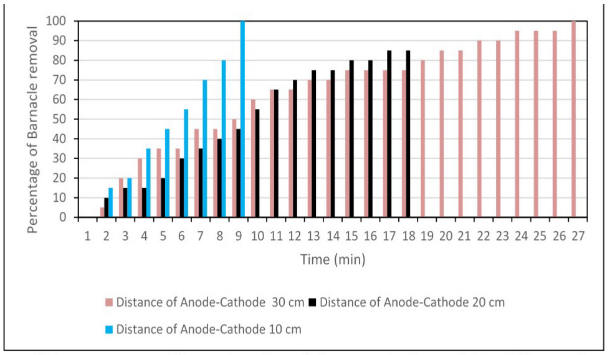


Fig. 5. The percentage of Barnacles released from attached material in different of anode-cathode distances.

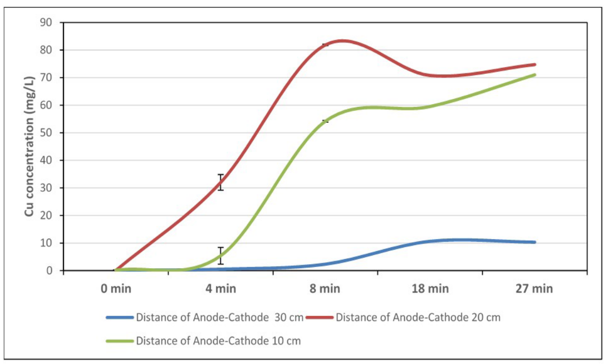


Fig. 6. Cu ion Concentration, duringthe operation of simple ICAF on Barnacles.

well as adult stage (Liang *et al*., 2019). Meanwhile, Wen-Qiu *et al*., (2005) stated copper had an inhibitory effect on barnacle (*Balanus amphitrite*) larval (nauplius) development at a concentration of 97 μg/l - 129 g/l. Figure 6 shows the Cu ion concentration during the operation of a simple ICAF system for Barnacle removal. The highest concentration of Cu ion was 81.85 ± 3.04 mg/l at a 20cm anode-cathode distance. Therefore, in this study, this distance produced the highest Cu ion concentration.

Liang *et al*. (2019) disclosed adult barnacle secrete a sort of cement periodically, to help secure underwater attachment. Meanwhile, Austin and Crisp (1960), reported copperoxide paints were unable to significantly inhibit settlement, and are only efficient antifouling agent due to copper metal's toxic action on cyprids as well as young barnacles, after initial attachment. These paints appearto inhibit the shell's cementing to the substratum in young barnacles surviving metamorphosis, thus the organisms become easily dislodged.

CONCLUSION

Based on the study's results, 100% barnacle removal was attained using aa 10 cm anode-cathode distance, 9 A electric current, as well as a 9 minute operation time. However, at a 30 cm distance, 100% barnacle removal was obtained after 27 minutes of operation. In addition, the highest Cu ion concentration obtained was 81.85 ±3.04 mg/l. In conclusion, Cu ions produced while operating a simple ICAF system has the capacity to remove barnacles.

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