Corrosion Effects on High Strength Duplex Stainless Steel Nets for Offshore Fish Farming

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Abstract

As a result of increasing needs and shrinking resources, aquaculture is gaining progressively significance in the recent years. Ecological issues such as negative effects on the ecological system due to the high fish density in the farms, the use of copper as antifouling strategy etc. are very present, particularly regarding the increasing number of fish going to be produced in farms in the future. Current trends focus on larger farms operated offshore. To make these farms working safe and economical, reliability has to be improved and maintenance costs need to be reduced. Also, alternatives with higher mechanical strength compared to current textile net materials as well as common metal wires might be necessary.

In the last years, a new net system made of high strength duplex stainless steel wires with environmentally friendly antifouling properties suitable for offshore applications was developed. The first nets are operating for one year now as predator protection (i.e. seals) for fish farms and show a good performance in cleaning capability and predator protection. But in the real usage, some corrosion effects in the contact points of the net made of duplex stainless steel 1.4362 occur which were not observed in preliminary tests in laboratory and at different test sites around the world. These corrosion effects endanger the sustainable success of the net system.

In this work, the observed corrosion effects are investigated. A laboratory test, which simulates the movement in the contact points of the net, was developed. Two pieces of wire are bent in the middle and get stucked into each other. One wire is fixed at both ends and the second wire is fixed on one end. On the other end, a circular movement with 1-2 rps and a 1 cm displacement is applied. The movement generates friction between the wires and the passive layer will be locally damaged. When the movement stops, a repassivation starts. The passivity breakdown and the repassivation were measured with electrochemical techniques.

During the friction phase, when the surface will be activated, the open circuit potential breaks down. When the friction stops, the OCP increases. Between the movement phases, measurements of critical pitting potential were done. Thereby the quality of repassivation was investigated.

The tests were done in a 3% sodium chloride solution. Different temperatures were tested as well as the influence of air saturation and low oxygen content.

Keywords

Duplex Stainless Steel, High Strength, Offshore Fish Farming, Tribocorrosion

Introduction

Fish farming is a growing market which is becoming more and more important to provide fish for the increasing world population. The farms get larger and larger and it is necessary to enlarge the distance to coast. The requirements to the used materials are also increasing. On the one hand, the mechanical stress increases, on the other hand the maintenance of the farms gets more difficult, when the farm goes offshore.

Mostly used material for the cages in fish farms are polymers. To protect the nets against biofouling, copper containing coatings are used for the polymer nets. The usage of copper is an additional pollution for environment beside the excrements of fishes.

Due to these facts, a new net system was developed within the framework of a research project. Details to the developing of the net systems are described other where [1, 2, 3].

The first net systems, used under real conditions, show corrosion effects, which were not observed during the development phase and the preliminary tests in laboratory and different offshore immersion tests.

In this work, the corrosion effects should be described and investigated. An additional laboratory test method was developed to simulate the corrosion effects for a systematically investigation.

Materials

The used duplex stainless steels for net system are 1.4362 and 1.4462, cold worked to a high tensile strength. The diameter of the wires is 2 mm.

Corrosion effects under real conditions

The test cages for real condition tests are installed in Chile. Here, the stainless steel nets are used for predator protection of fish farms. The used net system is schematically shown in Figure 1. After one year testing under real conditions, the contact points show mostly more or less erosion without a corrosion attack, see Figure 2 & Figure 3. The corrosion products around the contact points come from the abrasion. At some contact points corrosion occurs additionally to erosion. Figure 4 & Figure 5 show corrosion on a 1.4362 sample. The corrosion attack is deep and reduces the wire diameter clearly. A corrosion attack in contact points of 1.4462 samples is very rare and when it appears, the attack is circular, see Figure 6 & Figure 7.

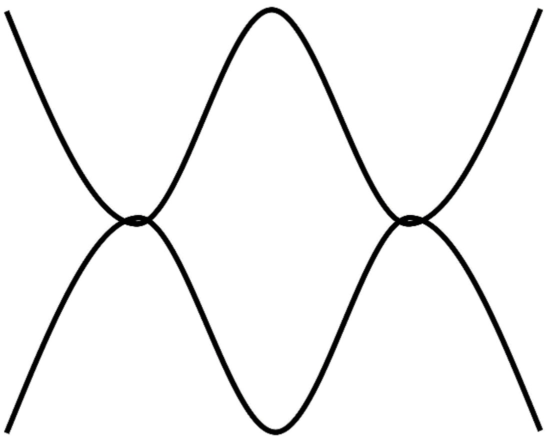

Figure 1 : schematic structure of the net

Figure 2 : erosion in contact point

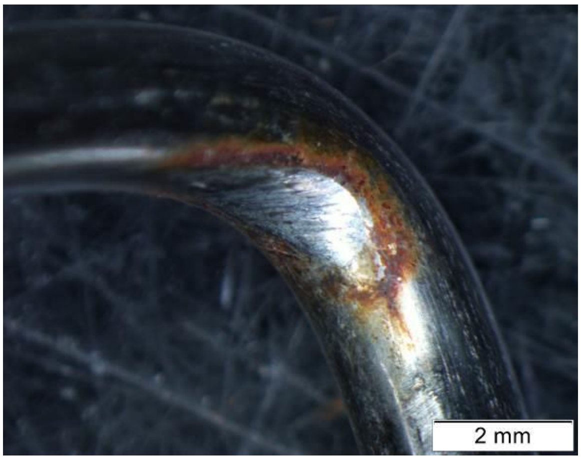

Figure 3 : erosion in contact point

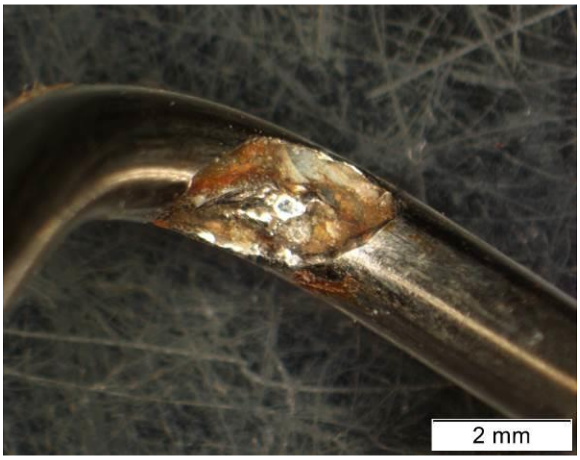

Figure 4 : erosion and corrosion in contact point, 1.4362

Figure 5 : erosion and corrosion in contact point, 1.4362

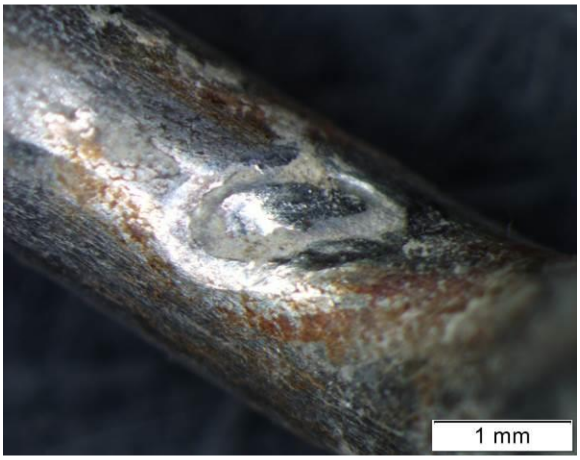

Figure 6 : erosion and corrosion in contact point, 1.4462

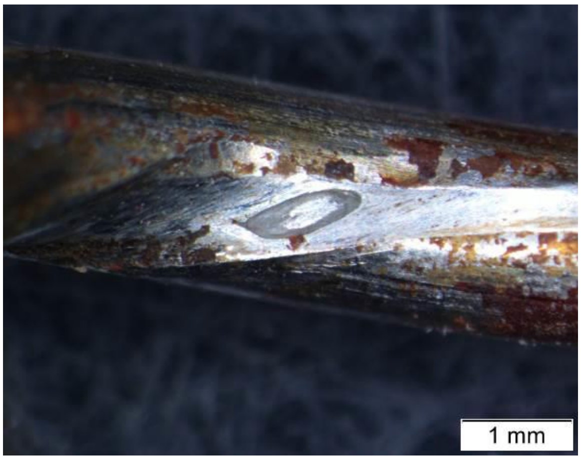

Figure 7 : erosion and corrosion in contact point, 1.4462

Laboratory test method

For investigation of these effects, a test method was developed, which simulates a friction in the contact point and also allows electrochemical measurements during the friction. Techniques for triboelectrochemical measurements are described for example by Mischler [4].
The test setup is schematically shown in Figure 8. A part of the net with one contact point is fixed in a frame on three points. A fourth point is fixed with a spring to an eccentric disc, which moves the wire and produces a small movement in the contact point. The frame stands in a tank, filled up with a 3% NaCl-solution, so that the contact point is dipped in the electrolyte. An Ag/AgCl reference electrode and a platin counter electrode was used for electrochemical measurements.

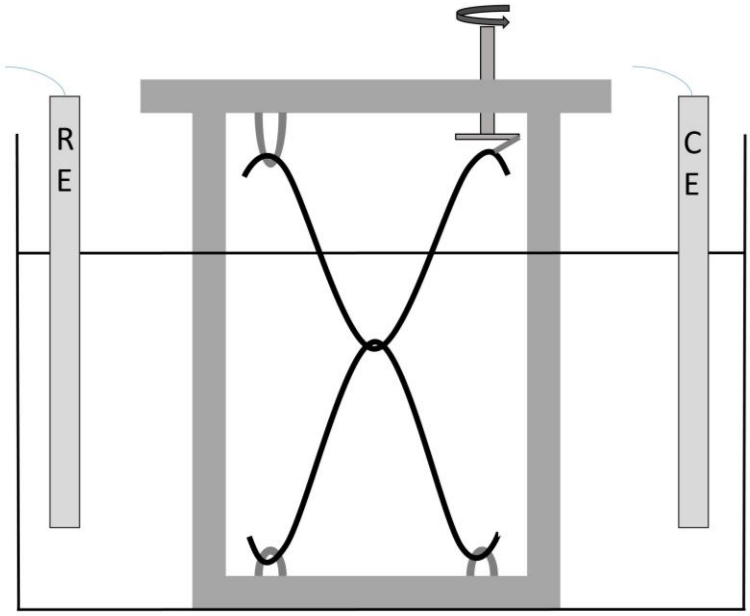

Figure 8 : schematic test setup

Experimental results

Measurements were done in three phases (see Table 1). For potentiodynamic scans, the scanspeed was 0,2 mV/s. In Table 1 only results for duplex stainless steel 1.4362 are shown. The measurements of 1.4462 are still in progress and will be reported later.
Figure 9 shows the potential drop during the first 30 minutes of movement. The OCP drops around 400 mV. The cycles of phase 2 & 3 show another drop during movement. In the rest period, the OCP increases again. Tendencially, a potential drop is visible over time (see Figure 10)
The first potentiodynamic scan before movement shows a flat curve till pitting potential at around 600 mV (see Figure 11). After first movement phase, the scan shows a similar trend but between 100 and 200 mV a short increase of current is visible. This increase of current is also more visible after phase 2 which ends in an increasing of current.

Phase 1	Potentiodynamic scan	OCP, 30 minutes movement
Phase 2	Potentiodynamic scan	OCP, 15 min movement, 30 min rest period, cycle repeats for 20 hours
Phase 3	Potentiodynamic scan	OCP, 15 min movement, 30 min rest period, cycle repeats for 96 hours

Table 1 : Overview of measurement phases

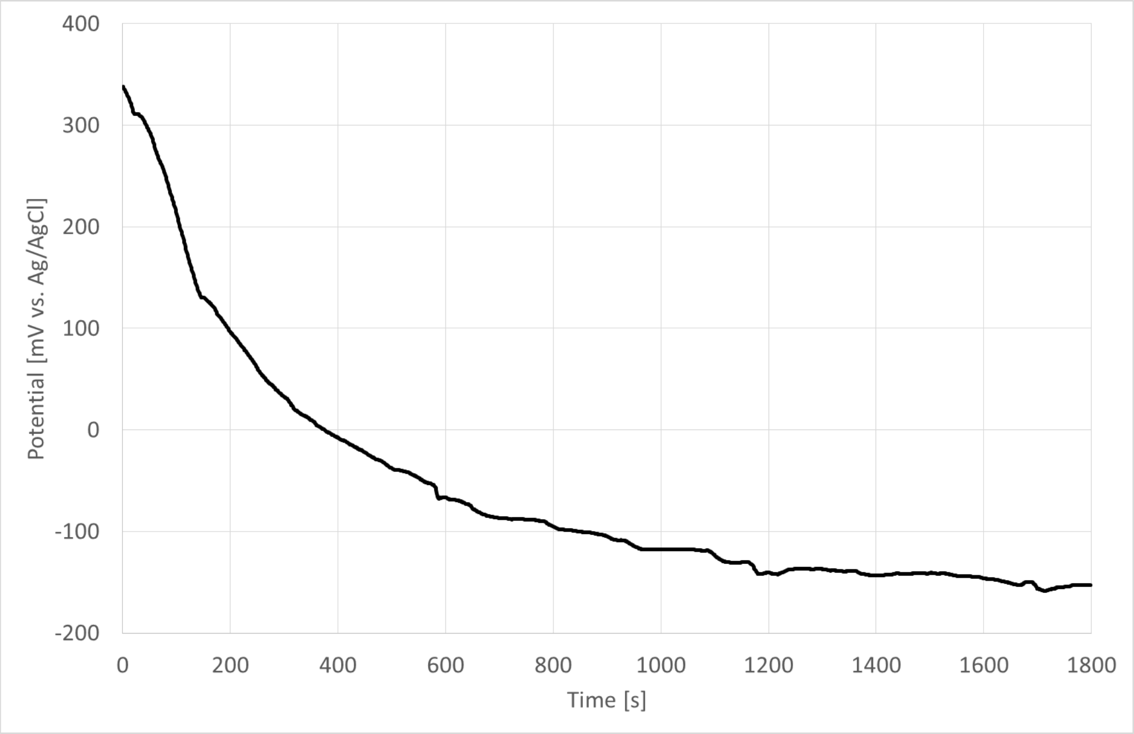

Figure 9 : Phase 1, OCP-potential, 1.4362

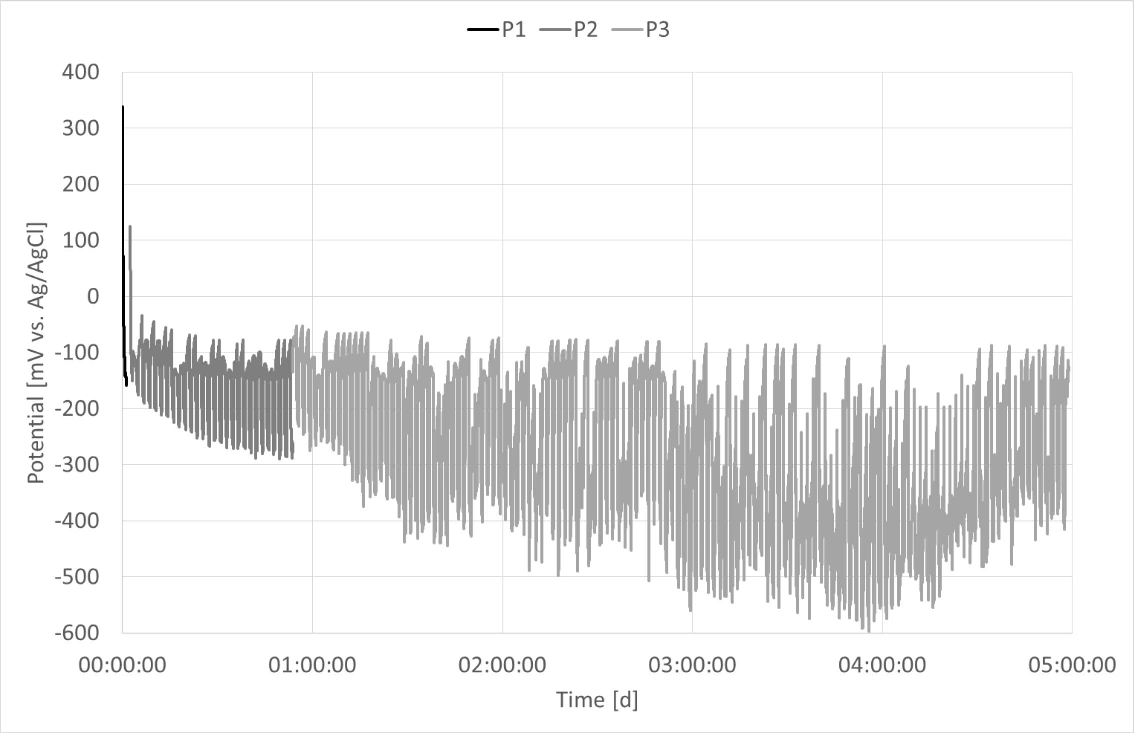

Figure 10 : Phase 1-3, OCP-potential, 1.4362

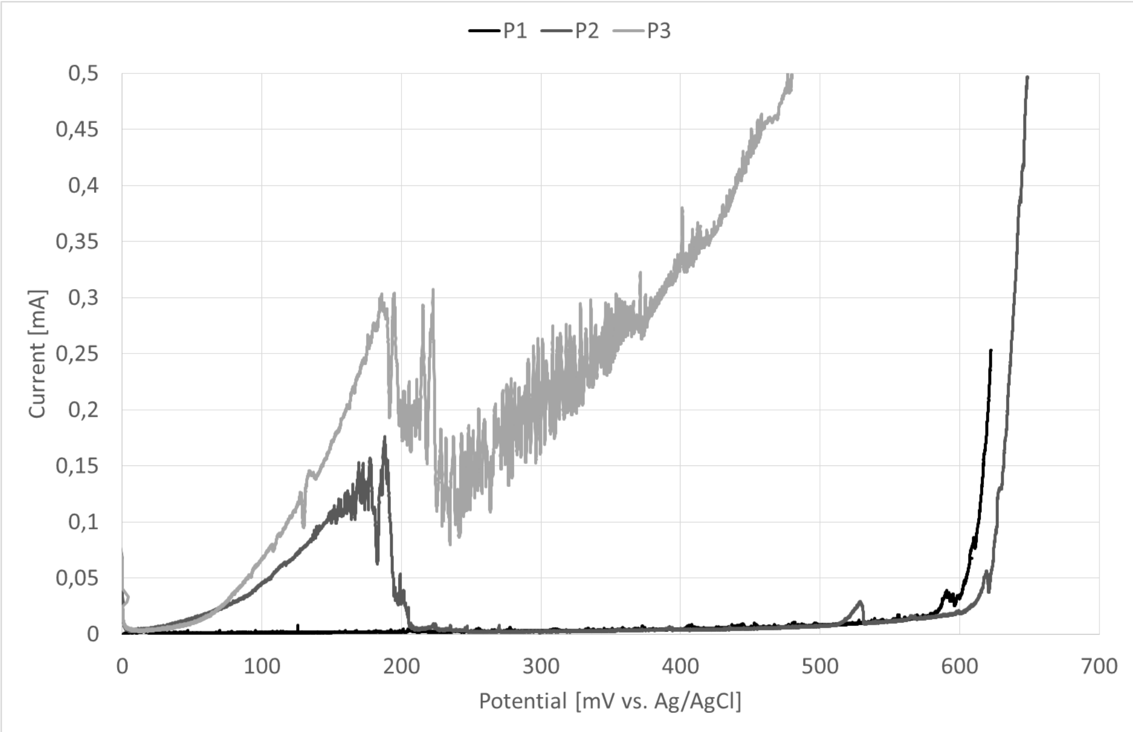

Figure 11 : Potentiodynamic scan before the three phases, 1.4362

Conclusions

The measurements show a potential drop during the movement phase. During the friction in the contact point, the passive layer would be removed and the surface becomes activated in this small area. This is also described for example by Sun & Rana [5].
For lifetime of the wires, the repassivation during the rest period is much more important. After short activation after phase 1, the active contact point can repassivate. The potentiodynamic scan shows this clearly. But after longer time of friction and rest period, the surface cannot repassivate anymore and the pitting potential drops significant. In phase 3 the OCP increases more and more and also the repassivation is more and more unstable.

The laboratory test method allows an investigation of repassivation ability over longer time for contact points of stainless steel nets which are used in seawater.

References

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