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Corrosion Resistance of Fishing Hooks with Different Surface Coatings

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Corrosion of fishing hooks is a major problem faced by hook and line fishing industry. This communication presents the results of a study taken up to assess the corrosion resistance of round bent, flatted hook no. 7 with two different surface coatings; *viz.*, tinned and blued. The hooks were exposed to 300 h of salt spray as per ASTM B 117. The tinned hooks exhibited excellent performance in salt spray exposure in comparison to the blued fishing hooks. The exposure of the hooks to salt spray resulted in an appreciable weight loss *viz.*, the tinned hooks incurred a loss of 5.37% from the initial weight while the blued hooks lost 20.54% of weight. The corrosion rates of the tinned and blued hooks were found to be 26.934 mpy (mills per year) and 106.298 mpy respectively.

Keywords: Corrosion rate, salt spray, fishing hooks, coatings

Corrosion is a perpetual problem of metallic fishing hooks as they are operated in seawater which is highly corrosive medium. Seawater is a complex mixture of inorganic salts, dissolved gases, suspended solids, organic matter and organisms (Todd, 1986). Corrosion poses a serious problem for the fishermen in terms of hook failures leading to escapement of their valuable catch apart from the depreciation incurred to the fishing hooks. Besides, the fishermen are required to 're-sharpen' or replace the fishing hooks at regular intervals involving a lot of human effort and cost (Kitano *et al.*, 1990).

Fishermen resort to various methods to prevent or minimize corrosion of the hooks. Baranov (1976) mentioned about coating the spears of 're-sharpened' hooks with solid lubricants like tar, grease and cerolin to prevent corrosion. Modern hook manufacturers use special anticorrosive coatings to tackle this problem. The performance of these coatings often varies among manufacturers and in many cases, high costs are involved for applying the coatings (Cottis, 1982). Cathodic protection of fishing hooks using sacrificial anodes as experimented by Kitano *et al.* (1990) could lead to reduced fishing efficiency as the hook becomes bulkier making it more perceivable to the fish.

Modern day fishing hooks are manufactured from high carbon steel wire (Anon, 2002). The formed hook is given a suitable surface 'finish' or protective coating by lacquering or electroplating. The hooks are usually tinned, nickeled, blued, Japanned black, red and bronzed. In blued, Japanned black, red and bronzed fishing hooks, the surface finish is given by coating it with alkyd resin based preparations.

Only very few studies have been carried out on the different properties of fishing hooks, as most studies were focused on the fishing efficiency of the hooks (Varghese *et al.*, 1997; Thomas *et al.*, 2007). The corrosion resistance of different fishing hook has been studied by Kitano *et al.* (1990) and Varghese *et al.* (1997).

The corrosion performance of fishing hooks can be evaluated using accelerated

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corrosion tests. The purpose of an accelerated corrosion test is to evaluate the corrosion performance of a product in the laboratory within a very short period. Varghese *et al.* (1997) reported that 98 h of salt spray exposure is equivalent to 365 days of exposure in sea. The salt spray test is an accelerated corrosion test by which different samples exposed to the same condition can be compared and ranked based on the relative corrosion resistance. It is considered as a suitable method for evaluating general corrosion resistance (Basu *et al.*, 1977; Natishan *et al.*, 2000; Papadopoulos *et al.*, 2007).

The purpose of the present study was to evaluate the corrosion resistance of two common surface finishes *viz.*, tinned and blued applied to fishing hooks.

Materials and Methods

The most common hook finishes *viz.* the tinned (Quality No. 1100) and blued (Quality No. 1000) were selected for this study. These sets were drawn from, round bent flatted hooks number 7 of a Japanese hook manufacturer obtained from commercial sources. Ten samples (n=10) were used for each set. The physical dimensions of the hooks were measured following IS: 9860 (Part I) – 1981. Wire diameter was measured on the round unforged shank portion (the long unbent portion of a hook) of the hook using a micrometer (Mitutoyo, d = 0.01 mm). Weight of the hooks was recorded using a high accuracy electronic balance (Sartorius BP211D, d = 0.01mg), weighing ten hooks and taking the mean value. Carbon (C), nickel (Ni), manganese (Mn), copper (Cu), and chromium (Cr) content in the core material of the hooks was analysed. Chemical composition of core material of the hooks except the carbon content was analysed as per ASTM E 415 - 99 (2005). The carbon content was analysed by the combustion gravimetrical method as per ASTM E 352 - 93 (2000).

Prior to salt spray exposure, the tinned hook samples were degreased using acetone to remove any dirt and oil that might be present on the surface. The blued hook samples were cleaned in distilled water. After drying, the weight of the hook was recorded. The hooks were then subjected to salt spray (salt fog) in a salt spray cabinet as per ASTM B117 (2003). The hooks were suspended inside the cabinet using thin plastic string and a uniform saturated salt spray *viz.* sodium chloride (NaCl) solution sprayed as very fine mist, was maintained throughout the test.

The hooks were exposed to three hundred hours of salt spray. The exposure time was fixed as 300 h, based on a preliminary study in which hooks were exposed up to 500 h of salt spray. The results when statistically analysed, 300 h was found to be the optimum exposure period ($P < 0.01$). The hooks were visually observed for the extent of corrosion at every 100 hours. After the exposure for 300 h, the hooks were washed with clean running water to remove any salt deposits on their surface. The corrosion product buildup on the hook surface was removed as per the ASTM G1 – 90 (1994) specification and the specimens were then weighed and the percent weight loss (W) was calculated.

Exact estimation of the surface area of fishing hooks is difficult by virtue of their irregular/complex geometrical shape. Since the hooks used for the investigation were of the same type and size/number, the percentage weight loss over the exposure period in salt spray was taken as the measure of their corrosion resistance.

From the weight loss, the corrosion rate was calculated using the formula

$$\text{Corrosion rate} = \frac{K \times W}{D \times A \times T}$$

where: K = A constant *

W = Weight loss in gram

D = Density in g/cm^3
A = Surface area in cm^2
D = Time in hours.

*The value for the constant 'K' is 3.45 x 10^6 for corrosion rate calculation in terms of 'mils per year' (mpy) (ASTM G1 – 90, 1994).

The surface characteristics of the specimens were examined by optical microscopy (OM) (Leica MZ16 A). The change in wire diameter after every 100 h of salt spray exposure was also measured by calibrated optical microscope.

Statistical analyses were performed and differences in the weight loss and corrosion resistance between the two types of hook finishes were analysed by analysis of variance (ANOVA) using SPSS 12.0.

Results and Discussion

The physical characteristics of fishing hooks and the chemical composition of core material of the hooks are given in Table 1.

Signs of corrosion started to appear from the third day in the form of rust stains on the surface of hooks. The surface morphology of the samples before and after exposure is depicted in Fig. 1. All the samples on exposure showed signs of corrosion *viz.*, rust stains, blisters and corrosion product buildup on the surface. The tinned hook exhibited good performance as comparatively less general corrosion and pitting was noted on the surface of the samples after salt spray exposure (Fig. 1).

Table 1. Physical characteristics of the hooks and chemical composition of core material of fishing hooks studied.

Physical characteristics	Tinned hook	Blued hook
Wire Diameter (mm)	1.74 ± 0.01	1.73 ± 0.01
Gape (mm)	15.00 ± 0	16.00 ± 0
Bite Length (mm)	16.80 ± 0.422	17.80 ± 0.422
Total Length (mm)	41.00 ± 0	40.00 ± 0
Weight (g)	1.264 ± 0.005	1.258 ± 0.009
Chemical composition	**Tinned hook (wt. %)**	**Blued hook (wt. %)**
Manganese (Mn)	0.32	0.41
Nickel (Ni)	0.05	0.04
Copper (Cu)	0.06	0.05
Chromium (Cr)	0.09	0.08
Carbon (C)	0.65	0.69
Iron (Fe)	98.83	98.73
Total	**100.00**	**100.00**

The tinned hooks had rust stains on the shanks and barbs which were visible only when magnified under an Optical Microscope. Within five days of exposure blisters were developed on the shank portion of the blued hook. The core substrate beneath the blisters also started corroding. Corrosion was more pronounced along the eye, point and barbs in most of the samples. Similar observation was also made by Kitano *et al.* (1990) where in, severe corrosion was seen at the eye portion of tuna long line fish hook. Some samples completely lost the barbs after 300 h of salt spray. This is due to the accumulation of corrosive medium in the bends and nooks at these parts.

From optical microscopic analysis it was found that there was a substantial reduction in the average wire diameter of blued hooks after 300 h of salt spray exposure, while this reduction was minimal in tinned hooks. The average wire diameter of blued hook reduced from 1.73 to 1.48 mm (14.45% reduction) while in tinned hook the reduction was only 6.90% *viz.*, from 1.74 to 1.62 mm (Table 2).

After 300 h of exposure, a weight loss of 0.063 to 0.073 g was observed in the tinned

Table 2. Reduction in the average wire diameter of hooks exposed to salt spray.

Salt spray exposure	Tinned hook Wire diameter (mm)	Blued hook Wire diameter (mm)
Before exposure	1.74	1.73
After 100 h	1.70	1.61
After 200 h	1.66	1.55
After 300 h	1.62	1.48

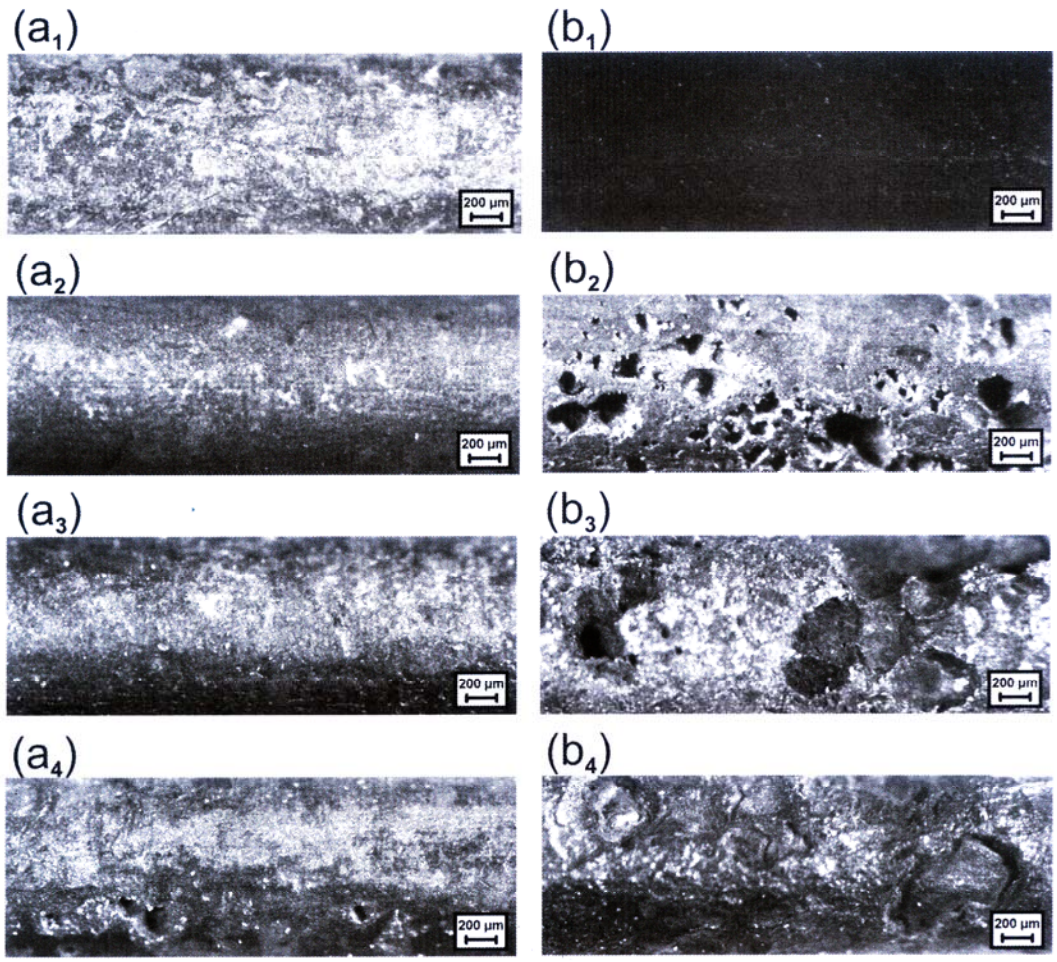

Fig. 1. Morphology of hook surfaces exposed to salt spray environment.
(a1. Tinned - Unexposed specimen, a2. Tinned - after 100 h, a3. Tinned - after 200 h, a4. Tinned - after 300 h, b1. Blued - Unexposed specimen, b2. Blued - after 100 h, b3. Blued - after 200 h and b4. Blued - after 300 h)

hooks, while 0.228 to 0.306 g loss was observed in blued hooks. The tinned hooks recorded a mean weight loss of 5.37 ± 0.54% while the blue finished hook showed significantly high weight loss of 20.54 ± 3.30% ($P<0.05$). Weight loss of such a high magnitude in the blued hooks will seriously affect the overall performance of the fishing hook.

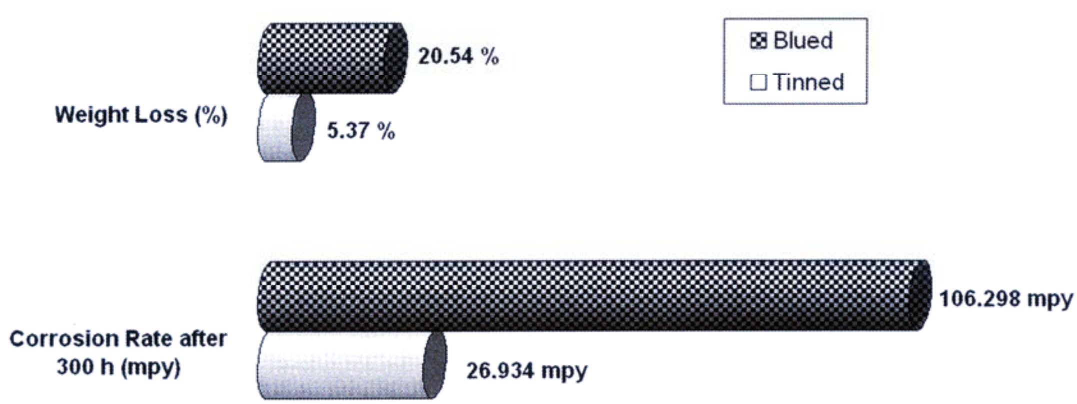

Fig. 2. Performance of fishing hooks after 300 h salt spray exposure

The tinned fishing hooks had a mean corrosion rate of 26.934 ± 2.741 mpy, whereas the blued hooks had shown a significantly high ($P<0.05$) corrosion rate of 106.298 ± 4.122 mpy (Fig. 2). In cases where tin coating is worn away or scratched, the presence of tin actually accelerates the corrosion of the underlying iron. Since the tin (Sn) has a lower redox potential than iron (Fe), the iron is preferentially oxidized over tin (Blaber, 2000). However, if this coating remains undamaged, it acts as an excellent oxygen barrier for iron. Varghese *et al.* (1997) have also reported good performance of fishing hooks coated with nickel and tin in salt spray tests.

The blue finish apparently had poor barrier property in comparison to the tin finish and was more prone to scratches resulting from handling. Further, the blistering observed in the case of blued hooks is indicative of poor adhesion with the base metal which aggravated the corrosion rate.

It is clear from the study that the tinned fishing hooks are better in resisting corrosion than blue finish hooks. Since the tinned fishing hooks performed well in highly corrosive salt spray environment, it can be preferentially used in marine fishing.

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