Quality of boat building steel: Story from the field

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Mechanization of fishing sector fuelled the construction of steel boats as it ensures ease of construction and operation. Globalization has enabled import of steels from countries like China and the sector is flooded with different grades of steels. The lack of an effective quality control

system to evaluate the materials imported and very poor awareness among the users about the quality of the material used aggravate the situation. On the steel plates there is no marking of quality, manufacturer or other details which further denies the availability of quality material. Testing facility for quality assessment of the material is very meager in the Indian scenario. A group of fishermen from Kollam, Keala constructed fishing boats using steels procured from local markets and the same had undergone severe pitting corrosion within few weeks of service. The fishermen approached ICAR-CIFT to evaluate the steel used for boat construction. We tested the material to find out the reasons behind this atypical corrosion problem.

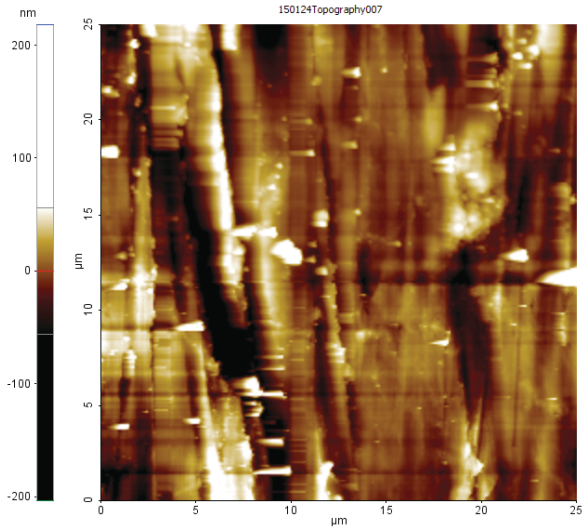
Two sets of samples of steel plates supplied by the fishing boat owners *viz*., corroded plate cut from the hull of the vessel (marked as 'a') and unused part of the plate (marked as 'b') were used for quality evaluation. The sample plates were cut in to 5 × 3 cm sizes and were cleaned to remove paint and dirt through mechanical means as per ASTM standards. The surface of the plate was ground upto 600 grits. For AFM studies, it was ground upto 1500 grits. The panels were cleaned by sonicating in acetone and washed with Milli Q gradient water.

Surface morphology of the material

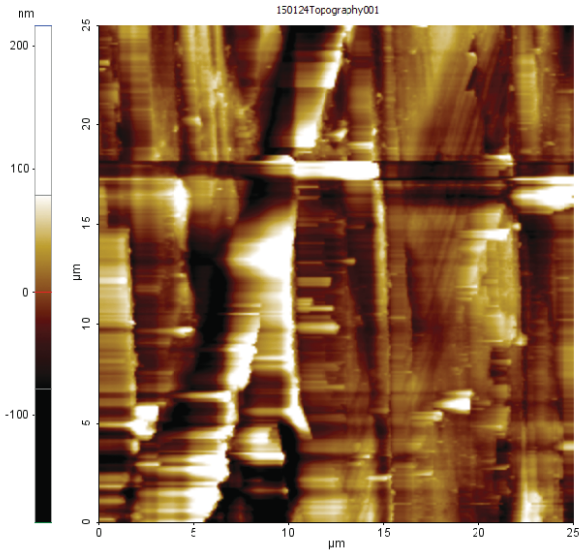
The panels were polished using sand papers upto1500 grits and the surface morphology was analyzed using Park Systems MX100 Atomic force microscope. The horizontal and vertical surfaces of the panels were analyzed. The micrographs exhibited thin cracks and surface roughness of about 19.93 nm and 29.44 nm, respectively for surface and vertical height in the 25 µm scanned region (Fig 1).

Electrochemical Evaluation

Linear polarization measurements: The samples were cut to 10 × 115 cm sizes and polished upto 1000 grits after removing all dirts and paints from the panels. The panels were subjected to linear polarization studies using AUTOLAB PGSTAT 30 corrosion measurement system. The linear polarization studies were performed in 3.5% NaCl as electrolyte using Ag/AgCl (3M KCl) reference electrode, Platinum as counter electrode and



Horizontal section view



Vertical section view

Fig. 1. Atomic force micrographs of steel plates

sample as working electrode. The results are shown in Table 1 and Fig. 2. The results showed large variation in corrosion current density and polarization resistance within the sample itself. This indicates that the material is more prone to corrosion due to the varied currents showed by the specimen. A comparative evaluation with recommended boat building steel, IS 2062, is also given in Table 1. The results showed that the supplied material had lower polarization resistance and higher corrosion density. When the material is having higher Rp value, it indicates lower corrosion current density and higher corrosion resistance. In the present case, compared to the IS 2062, the material is less

Table 1. Linear polarization characteristics of steel samples supplied by the fishermen of Kollam in comparison to the recommended IS 2062 steel

Specimen	Linear polarization parameters	Steel sample supplied by Kollam boat owners	IS 2062 steel
Unused steel	Corrosion Current Density I_{corr} (A/cm^2)	1.54×10^{-05}	3.25×10^{-06}
	Polarization Resistance R_p (Ohm cm^2)	4480	10620
	Corrosion potential E_{corr} (V)	-0.488	-0.600 to 0.860
Corroded or used steel	Corrosion Current Density I_{corr} (A/cm^2)	8.22×10^{-06}	3.576×10^{-06}
	Polarization Resistance R_p (Ohm cm^2)	6390	9209
	Corrosion potential E_{corr} (V)	-0.567	-0.609 to -0.800

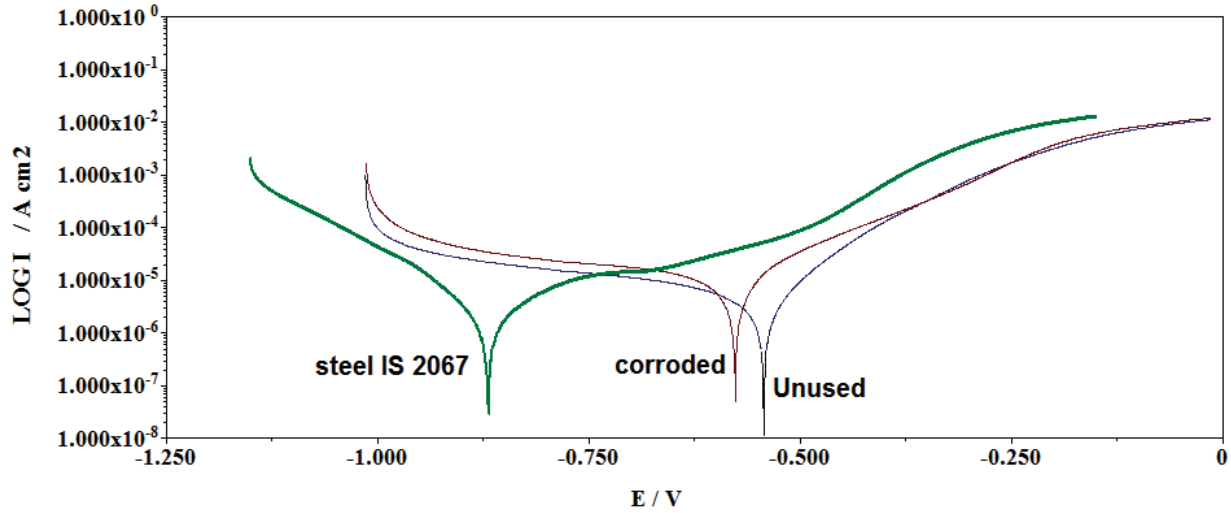


Fig 2. The Tafel plot of IS 2062 steel, unused and corroded steel supplied by the Kollam fishermen

resistant to corrosion and the higher standard deviation further highlights the instability of the material in seawater.

Electrochemical impedance spectroscopic (EIS) analysis: The impedance measurements were done by scanning 1MHz to 0.1Hz frequency with 5 decades at open circuit potential and the results are shown in Table 2 and Figure 3. The EIS data was fitted with simple Randle's Equivalent circuit models using FRA 2 software available with Autolab FRA2 module.

The polarization resistance (Rp1) at high frequency indicates the electrochemical impedance behavior of the outer-most layer of the steel and the Rp2 at low frequency region indicates the behavior of inner layer of the material. In the present case the Rp1 values were comparatively higher showing that the surface is resistant to corrosion mainly due to the influence of iron oxide present on the surface. The Rp2 of internal layer was 1104 Ohms cm^2 indicating the internal iron matrix and the value is comparable. EIS data of IS 2062 steel done at ICAR-CIFT on earlier occasions is given in Table 2. The results showed that Rp1 was very low and Rp2 was comparatively high. This indicates that the surface layer of Kollam steel is resistant to corrosion but

Table 2. EIS data of steel samples supplied by the fishermen of Kollam

Specimen	Electrochemical impedance parameters steel	Kollam Boat steel	IS 2062
Unused	Rp at high frequency domain Rp1 (Ohm cm^2)	115.53	23.09
	Rp at low frequency domain Rp2 (Ohm cm^2)	1104.67	1131
	Constant phase Element at High frequency domain C1 (μF)	148.67	10.96
	Constant phase Element at Low frequency domain C2 (mF)	0.32	0.48
Corroded	Rp at high frequency domain Rp1 (Ohm cm^2)	110.75	-
	Rp at low frequency domain Rp2 (Ohm cm^2)	726.00	-
	Constant phase Element at High frequency domain C1 (μF)	42.17	-
	Constant phase Element at Low frequency domain C2 (mF)	152.40	-

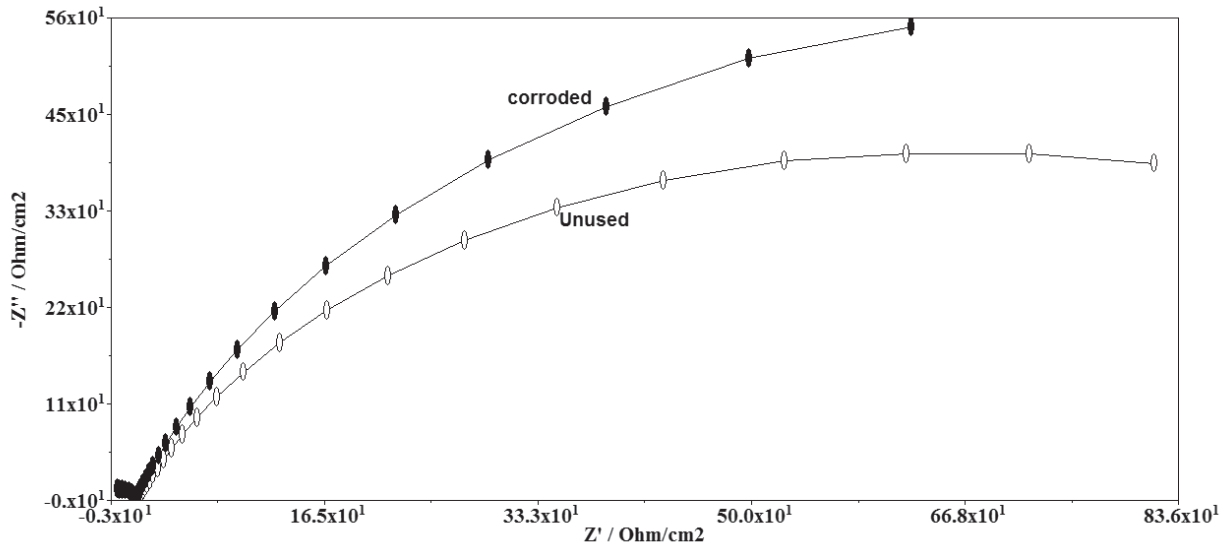


Fig. 3. Electrochemical impedance spectrograph of unused and corroded specimen of steel supplied by the fishermen of Kollam

easily ruptured under aggressive marine environments.

Chemical composition of steel

The steel samples were digested using conc. HCl and diluted to 100 ml. The samples were analyzed for metal composition using the Perkin Elmer Optima 2000DV Inductively coupled Plasma Optical emission Spectroscope and the results are shown in Table 3. The iron content was very low in the samples (about 80–82%). The elemental composition was compared with carbon steel specification from SAIL India brochure where the maximum Mn concentration was 1.5% (Table 4) while in the current samples it was only 1%. While digesting the sample, higher amount of undissolved particles and dirt were observed. Probably, the material had higher amount of iron oxides which was evident from the electrochemical impedance high frequency domain data.

Summary and conclusion

- The sample submitted by fishermen of Kollam was subjected to electrochemical, chemical and morphological studies. On AFM evaluation cracks were observed on the surface.
- The electrochemical evaluation showed that the steel had lower polarization resistance and higher current, indicating less resistance to corrosion in marine environments. Further evaluation with EIS also showed that the

Table 3. The chemical composition of carbon steel IS 2062

Grade	% Chemical Composition													Deoxidation
	C	Mn	Si	S	P	Al	Cr	Ni	Cu	Nb	V	Ti	N	
IS 1079 Gr O	0.15 max	0.6 max	-	0.055 max	0.055 max	-	-	-	-	-	-	-	-	Semi killed Killed
IS 1079 Gr D	0.12 max	0.5 max	-	0.04 max	0.04 max	-	-	-	-	-	-	-	-	Semi killed Killed
IS 1079 Gr DD	0.1 max	0.4 max	-	0.035 max	0.035 max	0.02 min	-	-	-	-	-	-	-	Al killed
IS 1079 Gr EDD	0.08 max	0.4 max	-	0.03 max	0.03 max	0.02 min	-	-	-	-	-	-	-	Al killed
IS 2062 E250 A	0.23 max	1.5 max	0.40 max	0.045 max	0.045 max	-	-	-	-	-	-	-	-	Semi killed Killed
IS 2062 E250 B	0.22 max	1.5 max	0.40 max	0.045 max	0.045 max	-	-	-	-	-	-	-	-	Killed
IS 2062 E250 C	0.2 max	1.5 max	0.40 max	0.04 max	0.04 max	-	-	-	-	-	-	-	-	Killed
IS 2062 E250 Cu C	0.22 max	1.6 max	0.45 max	0.04 max	0.04 max	-	-	-	0.2-0.35	-	-	-	-	Killed
IS 2062 E410	0.20 max	1.6 max	0.45 max	0.045 max	0.045 max	-	-	-	-	-	-	-	-	Killed
IS 2062 E450 D	0.22 max	1.6 max	0.45 max	0.045 max	0.045 max	-	-	-	-	-	-	-	-	Killed
IS 2062 E450 E	0.22 max	1.80 max	0.45 max	0.045 max	0.045 max	-	-	-	-	-	-	-	-	Killed

Source: http://www.sail.co.in/sites/default/files/plants/special-steel-plants/Salem_Userguide.pdf

Table 4. Chemical composition of steel supplied by fishermen of Kollam

Element	Unused (%)	Corroded (%)
Fe	80.09	82.48
Mn	1.092	0.996
Cr	0.011	0.012
Cu	0.007	0.005
Ni	0.006	0.005
Zn	0.014	0.007
Co	0.002	0.001

material was prone to corrosion in aggressive marine environments.

- The chemical composition of the material showed only about 80% of iron in the matrix.
- From our preliminary evaluation, the quality of the material was found inferior for use in aggressive environments. Finally, the steel used by the fishermen of Kollam for construction of boat is more prone to corrosion in the marine environments. Detailed evaluation is required from a metallurgical point of view to pinpoint the exact reasons for aggressive degradation and quality of the steel used.

Recommendations

- Detailed study on the quality of the steels used for boat construction needs to be carried out.
- There is an urgent need to make it mandatory to print the quality standards of the steel over the sheets.
- There is an immediate need to conduct awareness programmes for the boat owners regarding the standards of the steel and their properties.