ing of rope wires often observed during service.

Interface ratio, (denoted I.R.) is the ratio of the specimen immersed in the electrolyte, to area exposed above the electrolyte, for an air-corrodant interface. For lubricant corrodant interface, it is the ratio of the specimen length immersed without lubricant to that with lubricant. Weight of lubricant used was 2% of the weight of the specimens.

Procedure

Corrosion Tests: Specimens of cold-drawn rope wires(polished with extrafine emery paper and degreased with trichloroethylene) are kept fully immersed in the solution at 30°C for the required exposure time. The weight loss of the specimens are then determined after cleaning in Clarke's solution

Polarization Measurements: Specimens in electrolytes like 0.04 M NaOH and 1% acetic acid with different chloride content are anodically polarized by passing a constant current from a power source and the corresponding potential followed using a VTVM (Phillips GM 6020) as a function of time. A stable passive film is formed on the surface with resultant passive potentials. The chloride-ions, cause the dislodgement of the passive film formed thereby making the potential more negative. Potential values are obtained by using a printing voltmeter (Make, IEC/141M/ India and IEC/1435/Md./ India) with maximum measurable voltage of 2 volts using reference calomel electrode and a platinum foil counter electrode.

Thickness measurements for corrosion products: The film is produced on the cylindrical rope wire specimen, 5 cms length by immersing in 10 cc 20% H_2SO_4 solution for a period of 2 hrs in a specially designed petridish. Film thicknesses are measured by using pencil type magnetic thickness-meter and the mean values are reported.

Adhesion test for the film formed on the surface: Treatment of the film formed on rope wire surface (as per previous paragraph) in 20 cc 10% HCl solution, simulates the resistance of the adhering coating against film dissolution and dislodgement. The weight loss after the HCl treatment is then expressed per unit area of the coated surface and per unit thickness of the coating. These values are then considered to be proportional to the relative adhesivity value between the film and the substrate.

Short-term immersion and long term exposure tests: Short term immersion test is conducted in a beaker for a period not exceeding 100 hours, where dissolution reactions are important. Long term exposure tests are conducted with lubricated specimens for a period of eight months, inside a humidity chamber, where the formation of corrosion crust is controlled by its subsequent spalling action. Lubricant weight used was 2% of the weight of the specimens.

RESULTS AND DISCUSSION

Results are given in Tables 1 to 6.

The values in Table 1 reveal that corrosion is more for 1% H_2SO_4, followed by 1% HNO_3, 1% HCl and 1% CH_3COOH acid solution for short term immersion tests. Increase in acetic acid results in an increase in corrosion-effect, followed by a drastic fall at 15% acetic acid-solution. It is to be noted that organic acids are more common in the environments of wire rope machine than inorganic acids. Table 2 reveals that the corrosion rates in 3% CH_3COOH acid and 5% HNO_3 acid increase with increase in deformation of rope wire specimens and become maximum at 84% deformation. The potential time relationship of rope wire materials having 0%, 69% and 84% deformation (from manufacture) revealed that the potentials, in 3% acetic acid solution with reference to SCE move to negative values in all the cases. The depressions are respectively 3 units, 32 units and 41 units for total span of 290 minutes.

Table 3 shows the variation in the thickness of the film formed in contact with H_2SO_4 and its dissolution and dislodgement in 10% HCl solution, as a function of percentage deformation (from manufacture). It is seen that film thickness increases with increase in percentage deformation and becomes maximum at 84% deformation. It is well known that with increase in deformation (from manufacture) the strength and toughness of the material increases upto a certain point and become maximum at a certain percentage deformation for a given composition of the material. Deformation, above that value, only increases the brittleness, as there is no ductility [3] left in the specimen to counteract the strengthening action. Increase in the toughness of the rope wire materials at 84% deformation (from manufacture) results in increased adhesion between the film formed on the surface and the substrate. Exposure data for a period of 8 months in a humid atmosphere for the lubricated specimens, revealed that corrosion rate values

TABLE 1

CORROSION RATE AS A FUNCTION OF CORRODANT COMPOSITION

Percentage deformation of the specimen 84%
volume of corrodant 50 ml
period of immersion 20 hrs

S.No.	Corrodant Solution	Corrosion rate X 10^5 (gms/mm^2)
1	1% HCl	31.0
2	1% H_2SO_4	205.0
3	1% HNO_3	51.0
4	1% CH_3COOH	9.3
5	3% CH_3COOH	14.3
6	5% CH_3COOH	27.4
7	7% CH_3COOH	46.1
8	15% CH_3COOH	26.2

TABLE 2

CORROSION RATE AS A FUNCTION OF THE DEFORMATION STRESS

Sl. No.	Corrodant solution (volume)	Period of immersion	Deformation percentage from manufacture	Corrosion rate X 10^{-5} (gms/mm^2)
1	3% CH_3COOH (30 ml)	90 hour	0%	35.9
2	"	"	69%	41.92
3	"	"	84%	63.4
4	5% HNO_3 (50 ml)	25 mins.	0%	6.64
5	"	"	44%	11.9
6	"	"	69%	14.7
7	"	"	84%	21.4

decrease with increase in percentage deformation and become maximum at 84% deformation. The decrease in corrosion rate values is attributed to the lower spalling loss of the corrosion products formed on mine rope wire surface. The lower spalling loss is due to the increased adhesion between the film of corrosion product and the substrate as a result of increased toughness. The corrosion rate value of 3.3×10^{-3} gm/sq.m. at 44% deformation came down to 0.003×10^{-3} gm/sq.m. at 84% deformation.

TABLE 3

FILM THICKNESS AND RELATIVE ADHESIVITY OF THE FILM AS A FUNCTION OF DEFORMATION-STRESS

Length of specimen 20 mm; Film formed in contact with H_2SO_4 solution; It is dissolved and dislodged in 10% HCl solution.

S.No.	Dia. of specimen (mm)	Deformation percentage from manufacture %	Film thickness μm	Relative adhesivity of the film (gm/sq.mm/μm x 10^{-6})
1	7.0	0	2.65	17.0
2	5.0	44	2.25	21.0
3	3.8	69	4.25	11.0
4	2.8	84	10.00	0

Table 4 shows the metastability present on the rope wire surface which produces a stable passive film, even in the presence of 1300 ppm Cl^- ion. As the concentration of chloride ion increases, the film breaking mechanism is also enhanced resulting in the lowering of the positive potential values. Film breaking increases with time resulting in less positive values of the potential. However, the positive potential even in 1300 ppm Cl^- becoming asymptotic after 10 minutes, indicates the stability of the film formed in 1% acetic acid solution. It is wellknown that the rapid formation of a passive film is the criterion for metastability.

Table 5 indicates the effect of angular deformation on the formation and breaking of the passive film in 0.04N NaOH (with 6.5% NaCl) by passing an anodic current of 100 mA/sq.cm. It is seen that with decrease in angular deformation in degrees (increase in the amount of bending) from 180° to 30°, the initial positive potential changes from + 180 mV to + 90 mV and the final potential from + 250 mV to + 110 mV. Film breaking mechanism starts on 15th minute for the specimen without any bending. It starts on 8th minute for the 60°- bent specimen and on 5th minute for the 30°- bent specimen. This is in conformity with the amount of static stress imposed on

TABLE 4

POTENTIAL VS TIME IN 1% ACETIC ACID SOLUTION

Percentage deformation from manufacture 84%; Medium 1% acetic acid solution with specified concentration of chloride.

Pre-treatment 50 mA/sq.cm; anodic current is impressed.

S. No.	Time	Potential in mV w.r.t. SCE mV			
	(min)	100 ppm Cl^-	500 ppm Cl^-	1000 ppm Cl^-	1300 ppm Cl^-
1	1	+200	+110	+55	+20
2	3	+180	+110	+190	+25
3	5	+180	+110	+185	+25
4	10	+165	+105	+180	+15
5	13	+160	+100	+180	+15
6	15	+165	+105	+180	+15
7	18	+180	+105	+185	+15
8	19	+180	+105	+180	+15
9	20	+180	+105	+180	+15
10	30	+180	+105	+180	+15

TABLE 5

POTENTIAL VS TIME IN 0.04N NaOH WITH Cl^- ION (6.5% NaCl)

Deformation percentage from manufacture 84%; Anodic current of 100 mA/sq.cm is impressed

S.No.	Time	Potential in mV w.r.t SCE (mV) for angular deformations (bent in laboratory) in degrees		
	(min)	180° (No bending)	60°	30°
1	4	+180	+150	+90
2	5	+200	+150	+80
3	8	+260	+100	+70
4	10	+280	+160	+70
5	15	+250	+220	+70
6	18	+200	+190	+90
7	20	+250	+180	+110
8	30	+250	+180	+110

the rope wire. It shows that with increase in bending, there is a progressive decrease in corrosion resistance and film stability in 0.04N NaOH solution containing 6.5% NaCl. The electrolyte simulates the alkaline mine water with aggressive chloride ions. The formation of a stable passive film in terms of high positive potential, even in the + 30° -bent specimen, indicates that the rope wire surface is capable of forming a stable passive film.

It has been observed from prolonged exposure of mine rope wire specimens (with 84% deformation from manufacture) in mine water of pH 8.4 that corrosion increases from 0.100×10^{-3} gm/sq.mm. to 0.126×10^{-3} gm/sq.mm. when the interface ratio is decreased from 19.7 to 15.7. The specimens were exposed for a period of total six months. Potential-time correlation of the same specimens in distilled water reveals that potential values become more negative as I.R. (Interface ratio) is decreased from 2.5 to 0.9. Reduction in I.R. indicates higher length of specimen, exposed to air. Table 6 reveals the positive potential values in 1% acetic acid solution, containing 100 ppm of chloride-ion, after passing an anodic current of 50 mA/sq.cm. The rope wire specimens used have an interface ratio (I.R.) equal to 1 and an angluiar bending or deformation (in laboratory) of 110° The positive potential values have been shown against the type of interface created. Higher positive potential values are obtained for the specimen having air-corrodant interface with angle in air in

TABLE 6

POTENTIAL VS TIME IN 1% ACETIC ACID SOLUTION WITH Cl^- ION IN PRESENCE OF AN INTERFACE

Specimen with an angular bend of 110°
Deformation percentage from manufacture 84%
Medium 1% acetic acid with 100 ppm Cl^-
Anodic current 50 mA/sq.cm passed

S.No.	Time	Potential in mV w.r.t. SCE mV		
	(min)	Air corrodant I.R. = 1 Angle in air	Air corrodant I.R. = 1 Angle in corrodant	Lubricant-corrodant I.R. = 1 Angle in corrodant
1	1	+520	+270	+200
2	4	+530	+260	+180
3	5	+520	+240	+165
4	8	+520	+200	+165
5	10	+520	+200	+165
6	15	+520	+180	+165
7	18	+515	+180	+165
8	20	+520	+220	+160
9	30	+520	+220	+160

comparison to that having the angle in corrodant and with partial lubrication. The angular bend is the stress-concentration point. Therefore, the potential become more negative when the angle is immersed in the electrolyte. Presence of lubricant further depresses the potential. It may be due to the degeneration of the lubricant film, in presence of the acidic environment. The positive potentials shown in this table indicate that stable passive film is formed in these mine rope wire materials, even with the simultaneous presence of angular bending, interface and bending.

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