Effect of Metal Ions on Electrical Insulation Paper Properties

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ABSTRACT

Paper made from pure cellulose permits transmission of larger power loads through given size of ducts in cables compared to other insulations. Based on use, the electrical insulation paper may be categorized as high-tension cable paper, telephone cable paper, and capacitor tissue paper. These papers have distinct levels of metal ion purity in pulp depending on end use. Present paper aims at studying the effect of thickness of paper and metal ion concentration on electrical properties of paper. This study will help for developing various insulation papers.

Key words- Insulation paper, Metal ions, Conductivity, Break down voltage, Physical strength properties

INTRODUCTION

Electrical insulation papers have wide application in the most different branches of engineering viz., high tension cable paper, telephone cable, wire winding and capacitor or condenser. Pure cellulose has outstanding electrical properties. It is a good insulation material and is also polar, having proper dielectric constant. Paper is the cheapest and has traditionally been used for electrical insulation in many applications[1]. However, technological development has now surpassed them, and other materials are gradually replacing them. Further, petroleum cost and availability conditions may make the use of intermediate voltage paper insulated and sheathed cables advantageous again. One of the drawbacks of cellulosic raw materials of Indian origin is that they consist of high inorganic contents. The metals are initially present in wood and are also introduced from the process water and equipment. Of the common transition metals such as Cu, Mn, Zn and Fe are often harmful and affect oxygen based bleaching such as O_2, H_2O_2 and O_3 by catalyzing their decomposition and often initiating the formation of intermediate free radicals such as OH^-, which degrades the pulp. Also these d block element present in paper cause electric break down due to a voltage level which is reached wherein the electron impact with atoms and molecular dislodging other electrons[3,4] chelants are polydentate legands molecule, which binds metal cations between donor atoms. The use of Sodium salt of diethylenetriamine tetra acidic acid or diethylenetriamine pentaacetic acid effectively removes ions from the pulp[5,6&7].

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Present study focuses at studying the effect of metal ions concentration and sheet thickness on mechanical strength and electrical properties required for electrical insulation paper.

Experimental Morphology

Pulp Collection and Analysis— Unbleached pulp was collected from Ballarpur Industries Limited Yamuna Nagar located on the bank of East Yamuna Canal, Haryana. The pulp was evaluated for kappa number, brightness, conductivity, dichloromeths-ane extract, pH, viscosity, fiber length index and ash content and mechanical strength properties. The results are reported in Table 1 and 2.

EDTA Treatment and Metal Ions Detection— The pulp was treated with EDTA as per condition mentioned in table 3 in three distinct subsequent stages. Transition metals were detected from the pulp sample by ash method as this method provided highly accurate results. A known weight of sample was incinerated at 575^{0}C in Muffle furnace. After complete burning of organic matter the crucible was taken out. It was treated with 5 mL of 6M HCl and heated till the ash-acid mixture was evaporated to dryness. This process was repeated twice in the same way. Finally, the solution was transferred to a volumetric flask of 50 ml capacity and was made-up with deionized water up to the mark. The spectrophotometer was set at 325 nm for copper and 248 for iron. The spectrophotometer was calibrated with standard solution of salt of copper and iron at three different concentrations i.e., 2, 3 and 6 ppm for Cu and 2, 4 and 6 for Fe respectively. The results are reported in Table 3.

Pulp beating, sheet making and evaluation— Untreated and EDTA treated pulps were beaten in WEVERK valley beater at consistency of 1.57 percent at different CSF levels using deionized water. Laboratory hand sheets of 75 g/m^2 were prepared on Messmer semi automatic sheet former. The sheet were dried, conditioned and tested for various physical and electrical properties. The results are reported in table 4 and 5.

RESULTS AND DISCUSSION

Table 1 shows the analysis of unbleached pulp. The brightness of pulp at kappa no. 29.8 is 29.8 per cent (ISO). Dichloro methane, which gives an estimation of metals, is 0.231 percent. The conductivity of pulp at pH 7.5 is 42 µmho/cm. The fibers length index and pulp viscosity are 0.35 and 28.00 cps respectively.

Table 2 shows the mechanical properties of unbleached pulp beaten in PFI mill at different revolutions. All the properties like burst factor, breaking length, and per cent elongation increases with increase in pulp freeness where as tear factor and bulk decreases with increasing freeness.

Table 3 and figure 1 show that copper and iron in EDTA treated pulp decreases by 24.14 and 27.27 percent respectively compared to blank sample in the first stage. The EDTA treatment in 2nd stage reduces copper and iron by 61.94 and 45.45 per cent respectively. Copper and iron in the 3rd stage of EDTA treatment decreasesby 86.78 and 72.73 percent respectively compared to untreated pulp.

Table 4 and figures 2-4 show the effect of EDTA treatment on mechanical strength properties of paper. It clearly

Table 1— Evaluation of unbleached pulp collected from BILT Yamuna Nagar (Pitkranta)

Sl No	Parameters	Results
1	Pulp brightness. ISO per cent	29.8
2	Permagnate number	17.7
3	Kappa number	26.2
4	Conductivity m mho/cm	42
5	Dichloromethane extract	0.231
6	pH	7.5
7	0.5 per cent CED viscosity, cps	28.88
8	Fiber length index g/10g	0.35
9	Ash content, per cent	2.30

Table 2— Mechanical strength properties of unbleached pulp collected from BILT Yamuna Nagar (Pitkranta)

Sl No	Parameters	Revolution, No.		
		00	6500	8000
1	Freeness, CSF	700	400	410
2	Bulk, Cm^3/g	1.79	1.28	1.27
3	Burst factor	16.6	76.4	83.3
4	Breaking length, Km	2.323	9.791	10.4
5	Double fold	24	2253	3146
6	Tear factor	154.2	87.4	80
7	Elongation, per cent	1.75	3.95	4.15
8		12	103.7	363.3

Table 3— Effect of EDTA on metal ion concentration

Metal ion	Untreated pulp	Pulp after 1st EDTA treatment	Pulp after 2nd EDTA treatment	Pulp after 3rd EDTA treatment
Copper, ppm	17.4	13.2	6.7	2.3
Per cent reduction	-	24.14	61.94	86.78
Iron, ppm	1.1	0.8	0.6	0.3
Per cent reduction	-	27.27	45.45	72.73

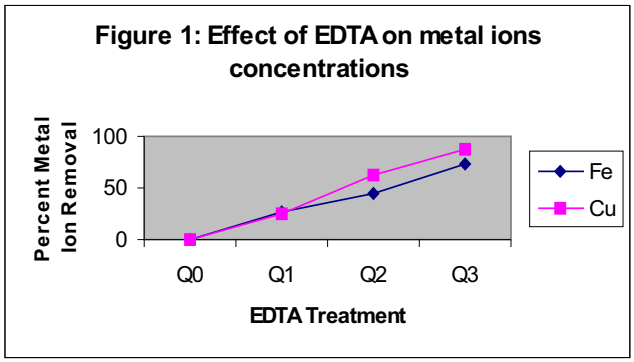
Conditions: 0.2 per cent EDTA, temp. 90^0C for 60 min and pH 6.0.

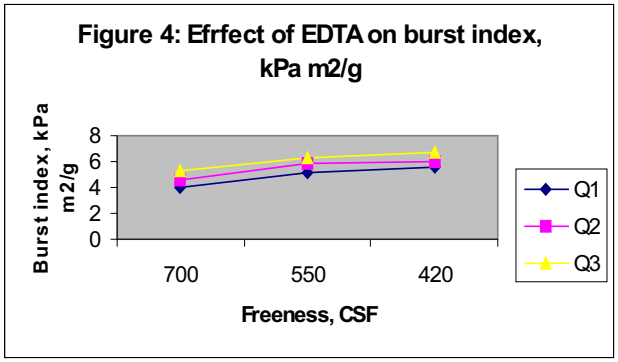
Table 4— Effect of EDTA treatment on mechanical strength properties of paper

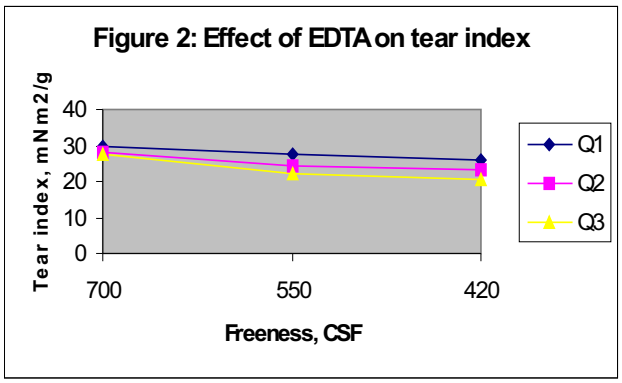
Parameters	EDTA treatment								
	1st stage			2nd stage			3rd stage		
Kappa no.	22.8			21.5			20.3		
CED viscosity	19.3			19.1			18.8		
CSF	700	550	420	700	550	420	700	550	420
Tensile Index, Nm^2/g	29.86	27.40	25.78	28.34	24.53	23.00	27.40	22.06	20.37
Tensile Index, Nm/g	16.67	44.59	68.50	19.98	48.80	71.54	21.56	51.94	76.44
Burst index Kpa m^2/g	40	5.10	5.51	4.6	5.8	6.04	5.25	6.28	6.72
Double fold, no.	24	1166	2279	30	1315	2405	38	1624	2672

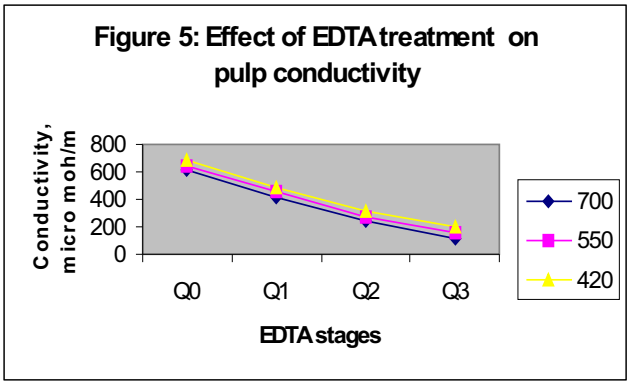
Table 5— Effect of EDTA treatment on electrical properties

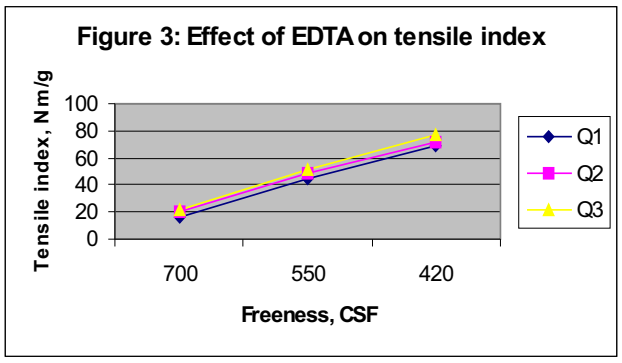
Parameters	Pulp before treatment	EDTA treatment									
		1st stage			2nd stage			3rd stage			
CSF	700	550	420	700	550	420	700	550	420	700	550	420
Thickness, µm	173	138	135	172	138	133	170	139	132	171	133	132
Grammage, g/m2	70.5	69	69	70	69	69.5	70.4	69	69.2	70.2	69.1	69.2
Conductivity, µs/m	610	640	680	420	460	420	240	270	310	120	150	200
pH	6.6	6.8	6.8	6.6	6.5	6.7	7.4	7.2	7.3	6.5	6.6	6
Breakdown Voltage, kv/mm	4.68	4.53	4.35	4.86	4.74	4.63	5.11	4.94	4.82	5.28	5.16	5.05

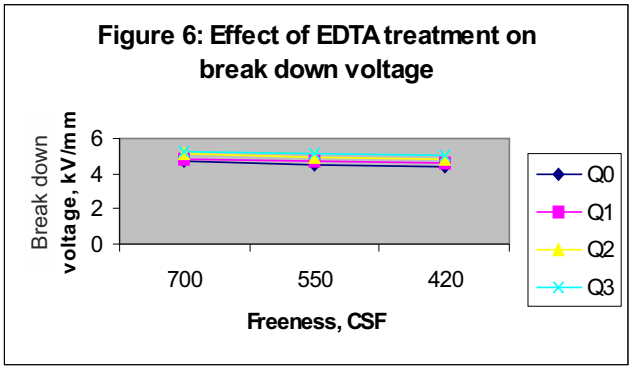












indicates that removal of lignin with metal ions in three subsequent stages of EDTA treatment improves all the mechanical strength properties like, tensile and burst index and double fold except tear index.

Table 5 shows the impact of EDTA on electrical properties of paper. Figure 5 show that the subsequent removal of transition metals with EDTA reduces the conductivity of pulp sharply. The conductivity of pulp after 2nd stage of chelation decline slowly. It is interesting to note that as the freeness of the pulp decreases the conductivity of pulp increases. The possible reason is that the surface area of pulp increases due to the beating effect and more reducing groups are introduced in to the pulp. Figure 6 shows that the subsequent removal of transition metals in three distinct stages with EDTA improves the breakdown voltage but it decreases with increasing pulp beating. The reason is that pulp beating reduces the thickness of sheet and breakdown voltage is inversely proportional to the sheet thickness.

CONCLUSION

1. EDTA treatment results about 5 per cent drop in kappa no, and it improves over all mechanical strength properties like burst and tensile index and double fold except tear index of insulation paper.

2. The subsequent removal of metal ions in three distinct EDTA stages progressively improves which sharply decreases the conductivity of pulp. On the other hand pulp beating increases the conductivity of pulp.

3. The electric breakdown voltage also progressively improves with EDTA treatment but pulp refining adversely affect the electrical break down voltage, which is due to the decreased thickness of the sheet.

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