Standardization of Polyethylene Treatment Level Using a Mathematical Model

McLean Bhala*, Lobengula Dube

Department of Applied Chemistry, National University of Science and Technology
P.O. Box: AC9393 Ascot, Bulawayo, Zimbabwe

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ABSTRACT

A corona discharge treatment of low-density polyethylene film (LDPE) was carried out in preparation for flexographic printing. Such treatment of the PE film is necessary if maximum adhesion of ink is to be achieved. This project involved three different treating machines for which the current had to be manipulated in all the machines so that a standard treatment could be accomplished. Using a mathematical relation, current requirements for each machine were calculated and used to standardize treatment level of PE films. Standardization was achieved by controlling input current in all the three machines so as to attain a treatment level of 38 dynes/cm. This level of treatment showed the best results in adhesion of ink to the PE film during printing. The exercise also confirmed that printing must be carried out within 24 h of treatment since the level of treatment deteriorates with time.

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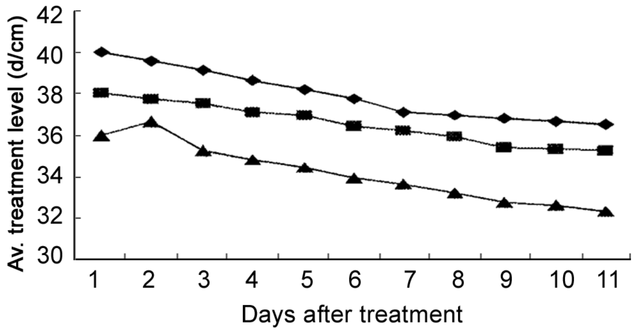
Key Words:
treatment level;
standard treatment;
treatment loss;
operating current;
line speed.

INTRODUCTION

The surface of polyethylene (PE) film which, is inherently non-polar when manufactured, does not provide satisfactory adhesion for printing inks most of which are polar in nature. Printing of PE films is very necessary to satisfy the diverse applications in the packaging industry through which commodities are easily identified. When a surface is too smooth or ‘unfriendly’ for ink, there is always a need to break the surface tension and increase the surface area for a better interfacial con-

(*)To whom correspondence should be addressed.
E-mail: mibhala@nust.ac.zw



(◆)Initial treatment 40 d/cm; (▬)Initial treatment 38 d/cm;(▲)Initial treatment 36 d/cm

Figure 1. Treatment level loss observed in ten days.

nection between the film surface and the ink [1].

The ink must initially wet the surface after which adhesion is expected. If the PE film to be printed is not treated to achieve ultimate results, both wetting and adhesion are not accomplished irrespective of the nature of the ink being used. Treatment of PE film in preparation for printing involves the modification of the film surface with an objective to creating more bonding sites for the polar ink being used. Among the many possible methods of film treatment used in industry today, the corona treatment is the most preferred because of its comparative simplicity, flexibility and effectiveness [2].

The objective of the current exercise is to evaluate treatment levels of polyethylene films so as to standardize general treatment by using a mathematical model relating machine power and speed to treatment level. Both extremes on treatment, i.e. over-treatment and under-treatment have cost Treger Plastics losses in thousands of dollars in scraped products and returns from customers who claim rebates. The lack of a specified unit of treatment has meant that film treatment has been left to chance (experience of operative) resulting in poor finishing of products.

Table 1. Concentration of wetting solutions used in measuring surface tension [3].

Formamide volume (%)	Ethyl cellosolve volume (%)	Wetting tension (dynes/cm)
0.0	100.0	30
2.5	97.5	31
10.5	89.5	32
19.0	81.0	33
26.5	73.5	34
35.0	65.0	35
42.5	57.5	36
48.5	51.5	37
54.0	46.0	38
59.0	41.0	39
63.5	36.5	40
67.5	32.5	41
71.5	28.5	42
74.7	25.3	43

EXPERIMENTAL

Methodology

Corona Discharge Treatment: The film to be treated is passed under electrode discharge energy, ionizing the gap between the film and the electrode. The ionized air creates excited particles that introduce oxygen functional polar groups into the inherently non-polar polyethylene surface.

Solutions for measuring wetting tension of PE films were prepared from formamide with ethyl cellusolve using ASTM D2578-84 specification [3] with levels as shown in the Table 1. All film samples for testing treatment levels were cut from across the entire width of a specified PE film roll so as to obtain representative values. Three sets of ten samples of PE film from different extrusion machines were tested for wetting tension using the prepared wetting solutions. A cotton applicator was used to spread a small amount of a wetting mixture onto a PE film specimen so as to cover an area approximately 6.5 cm^2 with a continuous liquid film. Retention time for the continuous liquid film on the PE film was recorded.

For each of the three different extrusion machines, a record of treatment power factors, machine line speed and general power input to the machine was kept. Tests were also carried out to assess loss of treatment level based on the length of time after the initial treatment process. Such tests were carried out over a period of ten days. Specimens from three different machines were tested and the results were compared.

RESULTS AND DISCUSSION

Results on initial treatment tests from the three sets (machines) show that, samples from machine (a) recorded an average wetting tension of 40 dynes/cm

Table 2. Current (Amps) requirements for machine (a).

Line	Treatment Widths (mm)								
Speed	500	550	600	650	700	750	800	850	900
38				9.2	10.0	10.7	11.4	12.1	12.8
39			8.8	9.5	10.2	10.9	11.7	12.4	13.1
40			9.0	9.7	10.5	11.2	12.0	12.8	13.5
41			9.2	10.0	10.7	11.5	12.3	13.0	13.8
42			9.4	10.2	11.0	11.8	12.6	13.4	14.1
43		8.8	9.7	10.5	11.3	12.1	12.9	13.7	14.5
44		9.1	9.9	10.7	11.5	12.3	13.2	14.0	14.8
45		9.3	10.1	11.0	11.8	12.6	13.5	14.3	15.2
46		9.5	10.3	11.2	12.0	12.9	13.8	14.6	15.5
47	8.8	9.7	10.5	11.4	12.3	13.3	14.1	14.9	15.8
48	9.0	9.9	10.6	11.7	12.6	13.5	14.4	15.3	16.2
49	9.2	10.1	10.8	11.9	12.8	13.8	14.7	15.6	16.5
50	9.4	10.3	11.2	12.1	13.1	14.1	15.1	16.1	16.8

which, is proportional to the surface tension of a specific solution mixture on Table 1, while samples from machines (b) and (c) recorded average levels of 38 and 36 dynes/cm, respectively.

Tests to assess loss of treatment on PE films from the three machines revealed that the longer a film was kept after initial treatment, the higher the loss of treatment compared with the initial treatment levels (Figure 1).

The recommended treatment level for tubular PE films used in commercial flexographic printing is 35 dynes/cm [4]. Incidentally all the three machines used in the current research exercise produced results indicating that excessive treatment of films was the practice in the plant.

In order to standardize the treatment process and also accommodate for treatment loss, level 38 dynes/cm was used in the calculations of the power factors of the respective extrusion machines. Analysis of results were made using the following power formulae [5]:

$$P = S \times W \times Pf(\alpha) \times 2 \qquad (1)$$

where: P, the power input on the machine
S, the machine line speed
W, the treatment width
Pf, the power factor
α, the treatment level (dynes/cm)

and; 2 is the number of sides being treated.

$$P = VI \quad (kW) \qquad (2)$$

where: P, power output on the machine
V, voltage (220V)
I is current

From eqns (1) and (2) the following relation is achieved:

$$VI = S \times W \times Pf(a) \times 2 \qquad (3)$$

$$Pf(38) = VI/(S \times W \times 2)$$
$$= 220 \times 9.4/(31.4 \times 0.8 \times 2)$$
$$= 41.16\ W/m^2 \times min^{-1}$$

Since parameters like Pf(38), voltage (220V) and the number of sides to be treated (2) remained constant throughout the treatment process, the operating current (I) remained the only measurable parameter on the machine that could be manipulated with any line speed and treatment width to produce a treatment level of 38 dynes/cm. The linearity of the function, therefore, depended on the value changes of the line speed and treatment width.

$$I = S \times W \times Pf(38) \times 2 / V \times 1000 \qquad (4)$$

$$I = S \times W \times (41.16 \times 2) / 220$$

$$I = 0.337 \times S \times W \qquad (5)$$

Using the above formula, tables of data on current (I) requirements to achieve 38 dynes/cm for each of the three machines were prepared. Tables 2, 3 and 4 below show data requirements for machine (a) to achieve the set treatment level. All three machines achieved a stan-

Table 3. Current (A) requirements for machine (b) to achieve 38 dynes/cm.

Line	Treatment width (mm)								
Speed	500	550	600	650	650	750	800	850	900
57		9.08	9.91	10.73	10.73	12.39	13.21	14.04	14.86
58		9.24	10.08	10.92	10.92	12.60	13.44	14.28	15.13
59		9.40	10.26	11.11	11.11	12.82	13.68	14.53	15.39
60		9.56	10.43	11.30	11.30	13.04	13.91	14.78	15.65
61	8.84	9.72	10.60	11.49	11.49	13.26	14.14	15.02	15.91
62	8.98	9.88	10.78	11.68	11.68	13.47	14.37	15.27	16.17
63	9.13	10.04	10.95	11.86	11.86	13.69	14.60	15.52	16.43
64	9.27	10.20	11.13	12.05	12.05	13.91	14.84	15.76	16.69
65	9.42	10.36	11.30	12.24	12.24	14.13	15.07	16.01	16.95
66	9.56	10.52	11.47	12.43	12.43	14.34	15.30	16.26	17.21
67	9.71	10.68	11.65	12.62	12.62	14.56	15.53	16.50	17.47
68	9.85	10.84	11.82	12.81	12.81	14.78	15.76	16.75	17.74
69	9.99	10.99	11.99	12.99	12.99	14.99	15.99	16.99	17.99

dard film treatment through the adjustment of current so as to attain the set treatment level. It must be noted that the amount of current used to achieve 38 dynes/cm for each individual machine was different for sets of similar treatment widths and line speeds. An increase in line speed from 31.4 m/min in machine (a) to 57.5 m/min in machine (b) meant that the required current for attaining a standard treatment of 38 dynes/cm had to be changed from 9.4 A to 13.5 A, respectively. This was mainly due to the fact that the machines used were of: (i) different makes, i.e. single phase treaters and three phase treaters; (ii) different operating systems, and (iii) different power generation systems. The three-phase treater machines (a) and (b) were calibrated to supply a minimum current of 8.80 A while the single-phase machine (c) supplied a minimum of 1.10 A. Generally line speeds of the three machines ranged from as little as18 m/min in machine (a) to as high as

Table 4. Current (A) requirements for machine (b) to achieve 38 dynes/cm.

Line	Treatment width (mm)								
Speed	500	550	600	650	700	750	800	850	900
38	2.54	2.79	3.04	3.30	3.55	3.81	4.06	4.32	4.57
39	2.60	2.86	3.13	3.39	3.65	3.91	4.17	4.43	4.69
40	2.67	2.94	3.21	3.47	3.74	4.01	4.28	4.54	4.81
41	2.74	3.01	3.29	3.56	3.83	4.11	4.38	4.66	4.93
42	2.80	3.08	3.37	3.65	3.93	4.21	4.38	4.77	5.05
43	2.87	3.16	3.45	3.73	4.02	4.31	4.60	4.88	5.17
44	2.94	3.23	3.53	3.82	4.11	4.41	4.70	5.00	5.29
45	3.00	3.31	3.61	3.91	4.21	4.51	4.81	5.11	5.41
46	3.07	3.38	3.69	3.99	4.30	4.61	4.92	5.23	5.53
47	3.14	3.45	3.77	4.08	4.40	4.71	5.02	5.34	5.65
48	3.21	3.57	3.85	4.17	4.49	4.81	5.13	5.45	5.77
49	3.27	3.60	3.93	4.26	4.58	4.91	5.24	5.57	5.89
50	3.34	3.67	4.01	4.34	4.68	5.01	5.35s	5.68	6.01

70 m/min in machine (b). Treatment widths on the other hand ranged from as little as 500 mm to as high as 1300 mm in all the three machines. Despite these differences standardization of treatment using current as a control measure was achieved.

CONCLUSION

Exercises carried out in this project revealed that it is indeed possible to standardize the general treatment of PE films by controlling the amount of current used in the process. Essentially, the work undertaken underlines the possible controls to be adhered to during film treatment if uniform treatment is to be achieved. With all procedures carefully followed, results of such film treatments can be improved and in the process cut down on amount of scrap.

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