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New Poly(vinyl chloride)-Based Blends: Aspects of Processability (Part II)

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ABSTRACT

Starting from the characteristics of the parameters specific to Brabender plastograms, the concurrent influence of the nature and ratio of some impact modifiers, of the processing aid ratio and of the carbon black upon the fusion and lubricating characteristics of some PVC- based unplasticized compounds has been evaluated.

There has been also put into evidence the anti-lubricating action of the above components, the intensity of which depends on their ratio in the blends composition.

Key Words

poly (vinyl chloride) compounds, impact modifier, processing aid, carbon black, processability

INTRODUCTION

In a previous paper [1], the simultaneous influence of some impact modifiers (CPE 3615, Kane Ace B 56 A) of a processing aid (Paraloid K 120 N) and of carbon black upon the main parameters characterizing the Brabender plastograms of some unplasticized poly (vinyl chloride) - based blends was studied in order to obtain a better appreciation of the processability of such compounds. The results discussed [1], as well as other literature data [2-8], have revealed the complex role played by such components, the idea being stressed that, for a better explanation of their influence on the processability of the studied compounds, the analysis should also include their influence on the blends lubrication characteristics.

EXPERIMENTAL

The aim of this study was to determine the simultaneous influence of both nature and ratio of the impact modifiers, processing aid and carbon black on the fusion and lubricating characteristics derived from parameters characterizing the Brabender plastograms, namely:

- fusion ratio Q, $Q = M_2/M_1$;
- fusion yield L, $L = M_2/t_1$;
- the Brabender lubrication number F, $F = Q.L$;
- the Böttner-Rosenthal lubrication number G;

$$G = 1000 \frac{E}{T.M_3}$$

where: M_1 = maximum torque, N.m;
M_2 = minimum torque, N.m;
M_3 = regime torque, N.m;
t_1 = fusion time, min;
T = temperature of the mixture melt, °C;
E = total amount of addition (expressed as %) compared to PVC.

The components characteristics, composition used for the obtaining of the blends are given in [1].The significance and variation domain of the independent variables, as well as the values of the features calculated from the parameters characterizing the Brabender plastograms, are given in Table 1.

The results were processed by the regression method, on a PC-compatible IBM computer and the following regression equation of the form:

$$y = a_o + \sum a_i x_i + \sum a_{ij} x_i x_j + \sum a_{ii} x^2_i \; ; \; i \leq j,$$

where: y = dependent variables;
$a_i a_j$ = regression coefficients;
x_i, x_j = independent variables.

The value of the regression coefficients, as well as the other characteristics involved in their calculation are listed in Tables 2 and 3.

The computer has been programmed for plotting the response surfaces in x_1-x_3 coordinates for only three levels, kept constant, of the content of carbon black - x_2 (surface 1, x_2 = 0.0 p; surface 2, x_2 = 2.5 p; surface 3, x_2 = 5.0 p). The response surfaces thus obtained are plotted in Figures 1-4.

RESULTS AND DISCUSSION

The fusion ratio (Q) indicates the difference between the materials behavior during and at the end of fusion process. Influence of the nature and ratio of the blends components upon the fusion ratio may be established by using the response surfaces plotted in Figure 1.

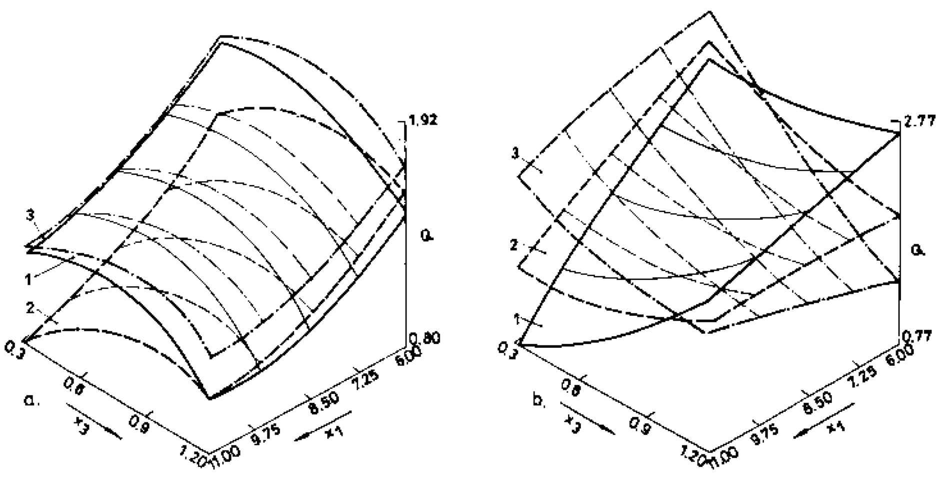

Fig.1. Aspect of the response surfaces within the experimental domain x_1-x_3, for the fusion ratio (Q).

Table 1. Domains of variation of independent variables and experimental results obtained.

Sample number	PVC	Impact modifier, x_1 CPE 3615	Impact modifier, x_1 Kane Ace B 56 A	Processing aid, x_2	Carbon black, x_3	Q	L, N.m/min	F, N.m/min	G, %/N.m°C
0	1	2	3	4	5	6	7	8	9
1	92.38	7.62	-	1.01	0.48	1.627	4.39	7.15	24.289
2	87.62	12.38	-	1.01	0.48	1.464	3.42	5.01	25.456
3	92.38	7.62	-	3.90	0.40	1.577	4.94	7.80	30.897
4	87.62	12.38	-	3.99	0.40	1.177	22.6	26.6	30.022
5	92.38	7.62	-	1.01	1.02	1.608	4.14	6.65	24.028
6	87.62	12.38	-	1.01	1.02	1.284	7.12	9.14	25.067
7	92.38	7.62	-	3.99	1.02	1.529	6.32	9.67	30.997
8	87.62	12.38	-	3.99	1.02	1.364	7.02	9.58	31.779
9	94.00	6.00	-	2.50	0.75	1.973	1.99	3.93	26.801
10	86.00	14.00	-	2.50	0.75	1.463	4.53	6.63	30.151
11	90.00	10.00	-	0.00	0.75	1.503	3.38	5.08	21.792
12	90.00	10.00	-	5.00	0.75	1.299	6.01	7.81	32.854
13	90.00	10.00	-	2.50	0.30	1.408	3.58	5.05	27.444
14	90.00	10.00	-	2.50	1.20	1.457	4.62	6.73	26.845
15	90.00	10.00	-	2.50	0.75	1.720	4.26	7.33	29.917
16	90.00	10.00	-	2.50	0.75	1.683	3.71	6.25	30.569
17	90.00	10.00	-	2.50	0.75	1.465	4.85	7.10	28.171
18	90.00	10.00	-	2.50	0.75	1.521	6.64	7.09	26.434
19	90.00	10.00	-	2.50	0.75	1.366	5.90	8.06	28.119
20	90.00	10.00	-	2.50	0.75	1.682	4.40	7.39	29.237
21	92.38	-	7.62	1.01	0.48	2.026	6.82	13.84	21.772
22	87.62	-	12.38	1.01	0.48	1.272	24.22	30.82	20.241
23	92.38	-	7.62	3.99	0.48	2.166	8.40	18.59	27.183
24	87.62	-	12.38	3.99	0.48	1.947	8.65	16.84	26.136
25	92.38	-	7.62	1.01	1.02	2.084	11.93	24.87	26.105
26	87.62	-	12.38	1.01	1.02	1.865	11.83	22.08	21.371
27	92.38	-	7.62	3.99	1.02	1.723	11.83	31.63	24.029
28	87.62	-	12.38	3.99	1.02	1.747	21.59	37.73	24.029
29	94.00	-	6.00	2.50	0.75	2.133	9.95	21.23	23.497
30	86.00	-	14.00	2.50	0.75	1.587	25.57	40.59	21.561
31	90.00	-	10.00	0.00	0.75	1.974	7.41	14.63	20.251
32	90.00	-	10.00	5.00	0.75	1.941	17.14	33.27	25.781
33	90.00	-	10.00	2.50	0.30	2.069	6.16	12.76	24.874
34	90.00	-	10.00	2.50	1.20	2.000	12.59	25.18	23.529
35	90.00	-	10.00	2.50	0.75	1.806	12.42	22.43	21.804
36	90.00	-	10.00	2.50	0.75	1.953	12.00	23.44	22.972
37	90.00	-	10.00	2.50	0.75	1.929	12.86	24.82	23.533
38	90.00	-	10.00	2.50	0.75	1.831	16.49	30.20	22.836
39	90.00	-	10.00	2.50	0.75	1.921	15.20	29.03	22.569
40	90.00	-	10.00	2.50	0.75	1.522	16.64	25.32	23.856

Table 2. Regression coefficients and regression analysis for CPE - containing blends.

Coefficient number	Coefficient expression	Properties			
		Q	L, N.m/min	F, N.m/min	G, %/N.m.°C
1	free term	1.5748	4.841	7.554	28.733
2	x_1	-0.1397	1.805	1.729	0.567
3	x_2	-0.04974	1.922	2.219	3.1835
4	x_3	0.001635	-0.6597	-0.6374	0.0147
5	x^2_1	0.03874	0.1461	0.08234	-0.04353
6	x_1x_2	-0.00975	2.043	2.295	-0.2873
7	x_1x_3	0.00925	-1.626	-1.782	0.1911
8	x^2_2	-0.07356	0.6545	0.4951	-0.452
9	x_2x_3	0.04225	-2.206	-2.347	0.3133
10	x^2_3	-0.0624	0.4437	0.2984	-0.5152
Minimum error, %		0.03	0.17	0.36	0.15
Maximum error, %		15.28	82.95	87.48	8.69
Correlation coefficients		0.88	0.777	0.748	0.957
F regression		3.836	1.696	1.413	12.095
Standard deviation of estimation		0.117	3.64	4.24	1.17

Table 3. Regression coefficients and regression analysis for AIM - containing blends.

Coefficient number	Coefficient expression	Properties			
		Q	L, N.m/min	F, N.m/min	G, %/N.m.°C
1	free term	1.8304	14.265	25.935	22.9086
2	x_1	-0.1526	3.923	4.343	-0.7742
3	x_2	0.0207	0.8799	2.660	1.5521
4	x_3	-0.008055	1.457	4.784	-0.1507
5	x^2_1	-0.01042	1.257	1.561	-0.01671
6	x_1x_2	0.0925	-0.910	-0.205	0.6522
7	x_1x_3	0.097	-0.9975	2.515	-0.2695
8	x_2^2	0.02411	-0.6862	-0.904	0.1558
9	x_2x_3	-0.162	2.957	4.980	-1.3405
10	x^2_3	0.0514	-1.713	-2.668	0.5758
Minimum error, %		0.4	4.56	0.64	0.01
Maximum error, %		20.26	57.21	39.39	5.06
Correlation coefficients		0.893	0.849	0.914	0.949
F regression		4.393	2.873	5.681	10.1993
Standard deviation of estimation		0.136	3.99	4.58	0.839

Analysis of these surfaces shows that, in the case of blends containing chlorinated polyethylene - CPE (Figure 1a) but no carbon black, the fusion ratio decreases with increasing the ratio of the impact modifier from compounds. With respect to this component, the aspect of the response surfaces is not modified, even after the introduction and subsequent increase of the carbon black ratio in blends.

Variation of the fusion ratio, depending on that of the processing aid, reveals the presence of a large maximum, whose position and height depend on the content of carbon black in compounds. Special mention is to be made of the fact that, in the case of blends containing no carbon black, as well as with those having 5.0 p carbon black, the fusion ratio is higher when the CPE ratio is lower, while for compounds containing 2.5 p carbon black, the reverse situation is found.

In the case of blends with acrylic impact modifier (AIM - Figure 1b) without carbon black, increase of the ratio of Kane Ace induces a decrease of the fusion ratio, while an increase of processing aid increases the value of this characteristic. Introduction of 2.5 p carbon black lowers considerably the influence of the two independent factors (only a slight increase of the fusion ratio is observed concomitantly with increasing the content of Paraloid in the blends). Nevertheless, on increasing the ratio of carbon black to 5.0 p, the fusion ratio increases with the increase of the impact modifiers ratio, along with a slight decrease caused by the increase of the processing aid content in compounds.

In the case of blends containing CPE but no carbon black (Figure 2a), the fusion yield (L) does not depend on the processing aid ratio, yet it decreases with increasing the content of the impact modifier.

Introduction and subsequent increase of the carbon black ratio in these compounds modify considerably the shape of the response surfaces; thus, their analysis reveals that, in the case of carbon black - containing blends, the fusion yield decreases with increasing the processing aid ratio. This decrease is quite remarkable at higher CPE ratios and less significant for blends with lower contents of this impact modifier.

Another observation is that for a content of 2.5 p carbon black in the blends, the fusion yield depends only slightly on the impact modifier ratio, and also that by increasing the carbon black ratio to 5.0 p, the value of the fusion yield is observed to increase on increasing the CPE content in the blends.

In the case of AIM-containing compounds, the shape of the response surfaces shows that the variation of the fusion yield with ratio of the components in the system is much more complex (Figure 2b). Analysis of these surfaces shows that, with mixtures containing no carbon black, the fusion yield decreases with increasing the

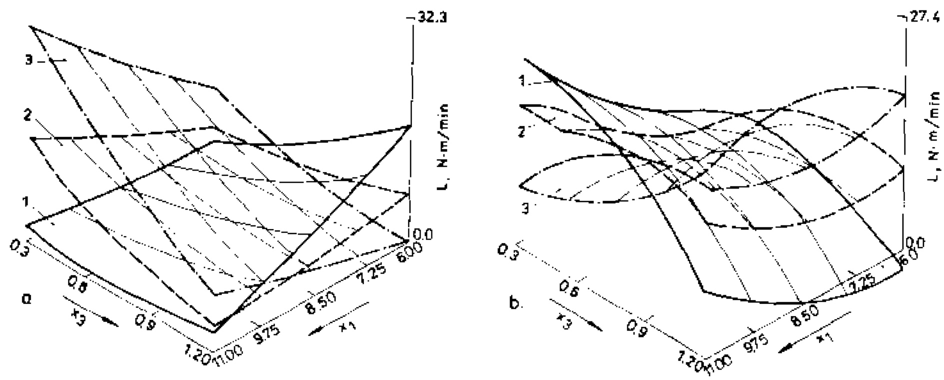

Fig.2. Aspect of the response surfaces within the experimental domain x_1-x_3, for the fusion ratio (L).

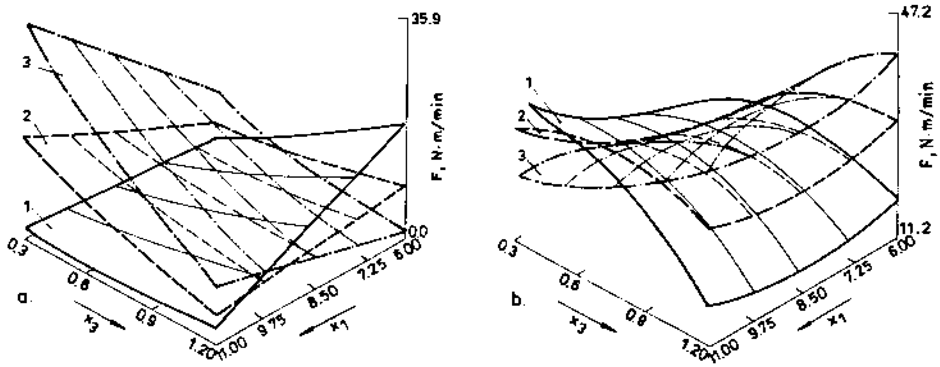

Fig.3. Aspect of the response surfaces within the experimental domain x_1-x_3, for the Brabender lubrication number (F).

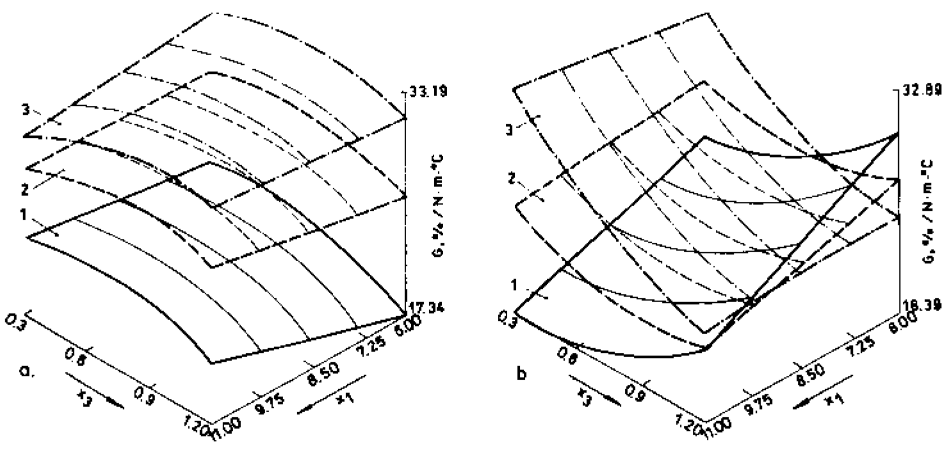

Fig.4. Aspect of the response surfaces within the experimental domain x_1-x_3, for the Böttner- Rosenthal lubrication number (G).

processing aid ratio, and increases with increasing the content of impact modifier in compounds.

With introduction of 2.5 p carbon black in the blends although the shape of the response surface remains the same; the fusion yield, that records higher values for small contents of Paraloid and, respectively lower ones for high processing aid ratios, is modified as compared with those recorded for blends without carbon black. By increasing the carbon black ratio to 5.0 p, the response surface becomes a pronounced saddle shape. For this mixture as well, the fusion yield records higher values when the processing aid content is high, and lower values for reduced Paraloid ratios, on taking as reference, blends containing no carbon black.

The way in which the Brabender lubrication number (F) varies, as a function of the nature and ratio of the various additions in compounds, does not differ essentially from the way in which the fusion yield varies (Figure 3), except for the values taken by this characteristic.

For blends containing CPE but no carbon black, the Böttner Rosenthal lubrication number (G), expressing the lubricating capacity of the components in the system, is not modified significantly with the increase of the processing aid ratio in compounds although increases are recorded when the content of impact modifier is increased (Figure 4a). With these blends, the introduction and subsequent increase of the carbon black induces appreciable increases of the Böttner-Rosenthal lubrication number, without significant modification in the shape of the response surfaces.

In the case of blends containing no carbon black but having AIM in their composition (Figure 4b), the Böttner-Rosenthal lubrication number increases with increasing the processing aid content and decreases on increasing the kane Ace ratio in compounds.

Introduction of carbon black in these compounds promotes further variation of the Böttner-Rosenthal lubrication number with the impact modifier ratio, although the value of this characteristic decreases with increasing the Paraloid content in the blends.

The situation is therefore reached in which, at lower contents of impact modifier and higher processing aid contents, the Böttner-Rosenthal lubrication number, corresponding to the carbon black - containing blends, is higher than for compounds that do not contain this component, while for lower ratios of processing aid the highest value of this characteristic is recorded with systems containing 5.0 p carbon black.

CONCLUSIONS

The concurrent influence of the ratio of additives used in the study (i.e., impact modifiers, processing aid and carbon black) on the fusion and lubricating characteristics of PVC-based unplasticized compounds is very complex, depending on the nature of the impact modifier. The assertion may be nevertheless made that all these additives manifest an anti-lubricating action, the intensity of which depends on their ratio within blends.

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