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Processing conditions vs selected properties of mouldings made of ABS with the addiction of flame retardant

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The scope of application of polymers is gradually expanding, thanks to the possibility of their modification. The most common choice is dyeing. Regardless of the colour of used colouring agent, titanium white is always applied. It gives white colour or is used as an optical brightener. At the same time, TiO_2 is recommended as a flame retardant. Mostly it is used in the form of a pigment (powder). However, there are no studies where TiO_2 is used as a colourbatch.

The aim of the work was to investigate the effect of titanium dioxide in the form of colourbatch on the flammability and selected properties of mouldings manufactured in various processing conditions. Colourbatch on ABS matrix, was used in the research. The variable processing conditions were: injection temperature Tw, injection velocity Vw, plasticization delay and the addition of a colourbatch. It was found that the processing conditions and the addition of the colourbatch did not have a significant effect on the hardness, which was in the range from 72.81°Sh (Shore) to 75.95°Sh (Shore). It was also noted that the addition of a colourbatch and increasing Tw reduces impact strength even by several dozen percent. Moreover, it was noted that use of colourbatch with TiO_2 causes a delay in the ignitability of the samples in selected cases. It is difficult to determine whether the variable processing conditions or the addition of colourbatch have a greater impact on the ignitability of the mouldings.

2. Materials and research methods

Acrylonitrile-butadiene-styrene (ABS) by BASF under the trade name Terluran GP 35 Natur, was used for the tests. As flame retardant, a colouring agent containing titanium dioxide (TiO_2) in the form of a colourbatch on an ABS matrix was used (the mass fraction of TiO_2 was 20%). The concentrate was dosed in the amount of 3% (mass fraction). ABS and the concentrate were not pre-dried as they were stored in sealed, original bags. The test specimens, in the shape of A-type paddles in accordance with standard were made on a KM65-160 C4 injection moulding machine by Krauss-Maffei. The mouldings were produced under various injection conditions according to the research plan (Tab.1). The remaining injection parameters were as follows: mould temperature T_f=50°C, pressing time t_d=20s, cooling time t_c=20s, injection pressure P_w=100 MPa, holding pressure P_d=60MPa. The processing parameters were selected on the basis of the recommendations and literature

The hardness tests were performed using a Shore type D hardness tester in accordance with the standard. In turn, for impact tests, bars were cut from the paddles, and then an A-notch was incised in the samples. Charpy impact tests, with the use of a 1J hammer, were performed in accordance with standard. Another test was the measurement of the gloss with an Elcometer 406 glossmeter in accordance with the standard. Basic gloss tests were performed at an angle of light incidence 60°. Samples in the form of cuboids with dimensions of 150x23x4mm were made in accordance with the research plan (Tab.1). Results were presented in Table 2. The colour tests were carried out with the use of the spherical spectrophotometer SP60 by X-rite. Colour was determined using the CIE *Lab* independent model where *L* is luminance (brightness, black to white), *a* denotes green to purple, and *b* denotes a colour from blue to yellow. The obtained results were averaged. The last was the flammability test by UL 94-5VA method, which allows to determine the flammability class of the material.

Table 1. Research plan

Series	Plasticization delay [s]	Injection temperature Tw [°C]	Injection velocity Vw [cm³/s]	Colourbatch [%]
1	1	260	25	0
				3
2	1	280	25	0
				3
3	1	260	85	0
				3
4	1	280	85	0
				3
5	20	260	25	0
				3
6	20	280	25	0
				3
7	20	260	85	0
				3
8	20	280	85	0
				3

3. Research output

The results of hardness measurements of the mouldings are shown in Figure 1 (ABS means samples made of undyed ABS and ABS+CB ABS means dyed ones).

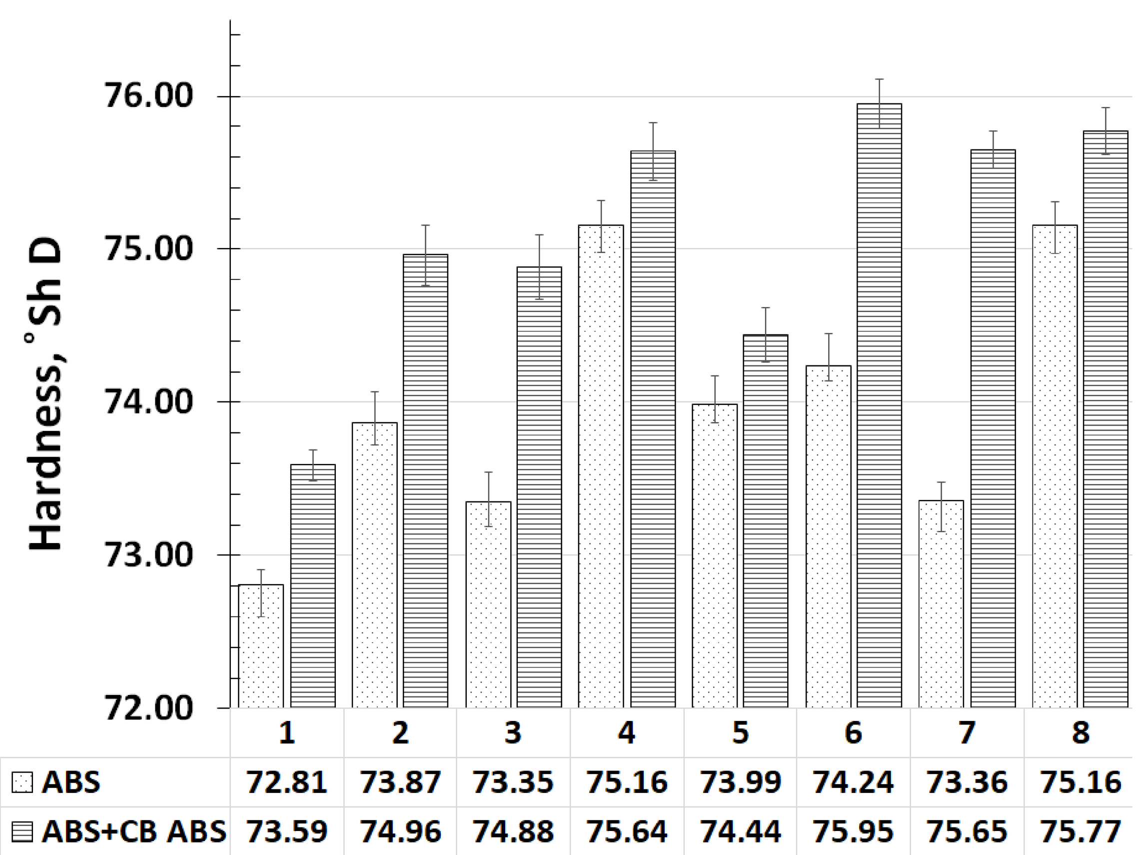

Figure 1. Results of measurement of hardness

It was found that samples made of ABS with addiction of 3% of colourbatch, produced in series 6, had the highest hardness (75.95°Sh D). The lowest hardness have (72.81°Sh D) mouldings from series 1. The addition of a colouring agent, regardless of the processing conditions, increased the hardness by about 0.63% to 3%. For mouldings made of undyed ABS, it was observed that increasing injection temperature T_w to 280°C in all cases resulted in an increase in hardness. Also, increasing the plasticization delay to 20s (series 5÷8) and the low injection velocity V_w 25cm³/s usually contributed to the increase of hardness. In turn, increasing V_w did not change the hardness. Similar trends were observed for mouldings made of ABS with colourbatch addition.

The results of the gloss and colour tests were presented in Table 2. For samples made of undyed ABS, it was found that mouldings produced at low T_w and high V_w had the highest gloss (series 3; 67.54GU). Lowest gloss was noticed for the mouldings manufactured in series 7 (54.19 GU). Extending the plasticization delay to 20s results in a lower gloss of the surface. The addition of colourbatch reduces gloss, in some cases by up to 30% (e.g. series 7). The highest value was obtained for mouldings from series 1 (49.66 GU), and the lowest for series 7 (16.40 GU). Also extending the plasticization delay to 20s contributed to a lower gloss. Increasing the T_w to 280° C, mostly, reduces the gloss.

Table 2. Results of measurement of selected properties

Series	Colourbatch [%]	Colour L [cd/m²]	Colour a [--]	Colour b [--]	Gloss [GU]	Flame retardant [s]
1	0	79.93	-3.36	2.35	61.72	7
	3	95.42	-1.04	6.67	49.66	10
2	0	84.88	-4.35	1.82	66.31	8
	3	95.39	-1.09	6.85	46.16	8
3	0	82.36	-4.20	3.54	67.54	9
	3	95.34	-1.12	6.89	47.00	9
4	0	80.96	-3.99	3.21	60.10	7
	3	95.40	-1.06	6.61	39.43	9
5	0	79.88	-4.25	5.21	57.90	7
	3	95.05	-1.20	7.28	24.93	13
6	0	79.56	-3.57	4.59	55.81	8
	3	95.01	-1.26	7.86	23.03	12
7	0	79.07	-3.48	5.34	54.19	8
	3	95.29	-1.23	7.27	16.40	11
8	0	79.45	-4.01	4.98	58.28	7
	3	95.42	-1.13	7.07	38.43	11

In the case of colour tests, it should be noted that undyed ABS has a milky white colour, while the colouring agent can be described as the so-called “snow white”. The addition of colourbatch contributes to an increase in *L* luminance (up to 17%, series 1). Samples from virgin ABS are characterized by luminance *L* ranging from 79.07 to 84.88cd/m², however, it is difficult to indicate trends between changes in processing parameters and the luminance *L*. All moulded parts made of coloured ABS have a similar luminance *L* (about 95cd/m²), regardless of the processing conditions. For the parameter *a*, it was found that for undyed mouldings, its value is in the "green" part of the CIE *Lab* system. Due to the addition of colourbatch, it is moved towards the center of the array, although it still remains in the "green" part. The value of parameter *b* for samples made of undyed ABS is located closer to the center of the CIE *Lab* system, in the "yellow" part. The addition of colourabtach shifted it towards yellow.

The results of the measurements of the impact strength of mouldings undyed and dyed are presented in Figure 2. It can be seen that the addition of colourbatch generally contributed to the reduction of the impact strength. The impact strength value was reduced by 23% to 37% after application of colourbatch. The exception are mouldings from 5 series, where a slight increase was noted. The lowest value (6.08 kJ/m²) was found for samples made of coloured ABS, in series 6–made with high T_w=280°C, low V_w=25cm³/s and plasticization delay 20s. The highest impact strength was characteristic for the mouldings made of undyed ABS manufactured in series 1.

For undyed mouldings, it was found that in most cases, extending the plasticization delay to 20s contributed to the reduction of impact strength (e.g. series 1 or 5). But increasing the V_w to 85cm³/s with the simultaneous use of a low T_w 260°C allows to obtain samples with high value of impact strength (series 3 and 7). Increasing the T_w while maintaining high V_w reduces the impact strength. For mouldings made of ABS with addiction of colourbatch, it was noted that the highest impact strength was characteristic for samples made at low T_w and low V_w. Change in the plasticization delay time to 20s also contributed to the reduction of impact strength. By using a higher V_w and a higher T_w, samples with lower impact strength are produced.

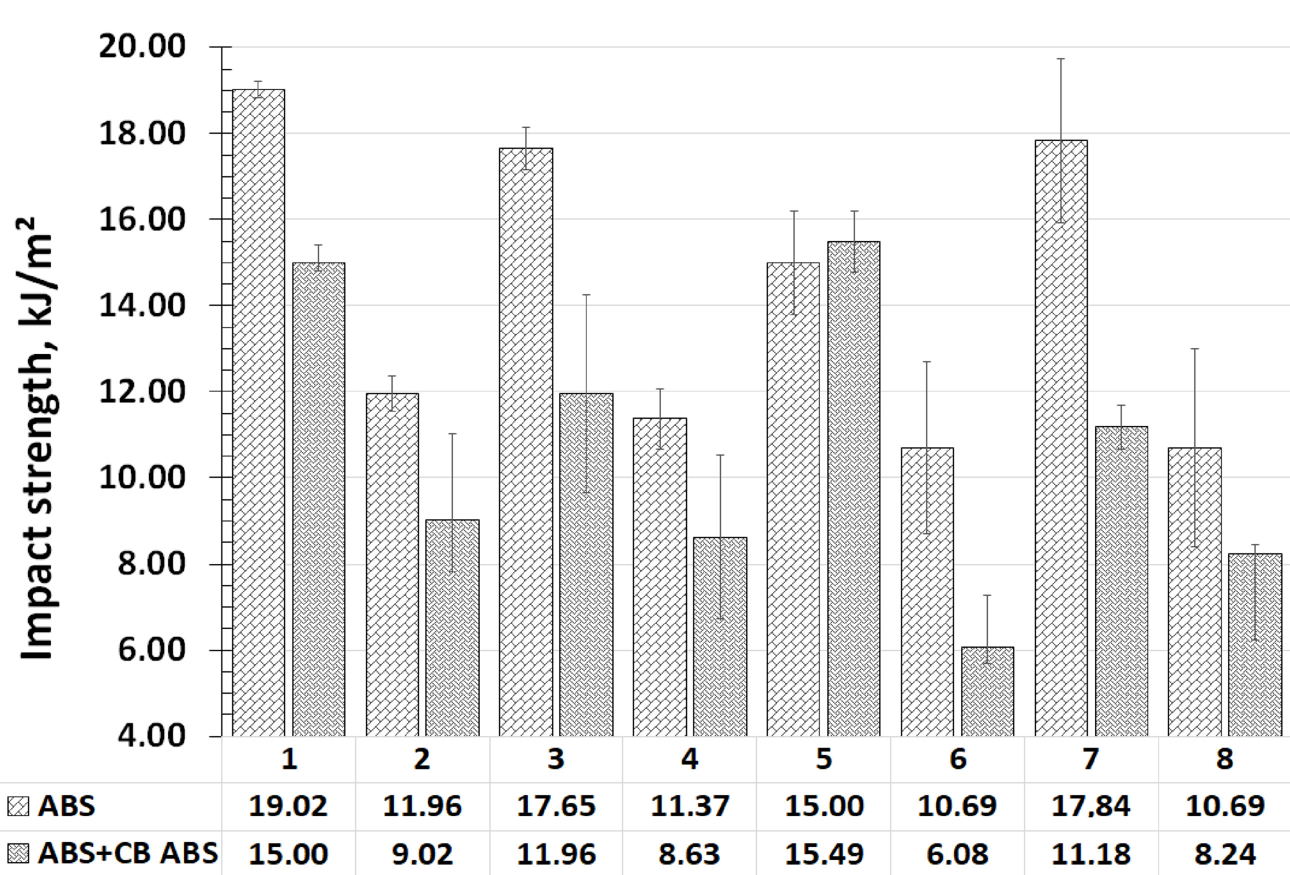

Figure 2. Results of measurement of impact strength

During the flammability test, it was noticed that the addition of a colourbatch with TiO_2 delayed the ignition of the samples by about 20s. Samples made of virgin ABS ignited after 10s, and those from dyed ABS–after 30s. Cotton placed under the undyed samples burns after 7 to 9s., regardless of the processing conditions. In turn, for samples made of ABS with colourbatch addition, this time was between 9 and 13s. The biggest change (from 7 to 13s) was found for series 5. Moreover, for mouldings made of coloured ABS, it was found that samples produced in a plasticization delay of 20s burn longer. Despite the changes in ignition, moulded parts without and with the addition of colourbatch still qualify for the V0 flammability class.

4. Conclusions

On the basis of research it was noticed that the addition of a colourbatch containing TiO_2 allows to obtain a white colour but also changes the properties of the samples. They may be due to the porous structure of pigment TiO_2 contained in colourbatch. Addiction of colourbatch increased hardness of mouldings, but at the same time, reduced impact strength and gloss. It caused also an increase in the ignition time, but do not allow included samples in the flammability class V1.