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Editors:
Grozdanka Bogdanović
Milan Trumić

Hotel Jezero, Bor Lake, Serbia
13 – 15 September 2017

University of Belgrade

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FLOTATION SEPARATION OF THERMAL HEAT TREATED ABS AND PS PLASTICS

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ABSTRACT *– Flotation is a process that can be used for separation primary and secondary materials. The paper presents the results of a laboratory study separation of plastics waste. The aim is to extract the PS plastic from the PS/ABS mixture. Experiments were carried out in Denver cell at pH 7 in presence of MIBC as frother. The plastics were thermal threated at 100° C in order to increase the hidrophilicity of ABS surface. The results showed that PS plastics has higher flotation rate constant value, but low quality value (under 90 %) for both plastics, indicates that ABS and PS could not be successfully separated by froth flotation and which is not the case in other manuscript. Obtained results were represent by the classical model of first-order to try to describe the kinetics of plastics flotation with good correlation coefficient.*

Keywords*: PS, ABS, thermal treatment, flotation, kinetic model*

INTRODUCTION

Plastics is one of the most widespread materials in everyday life. The rapid increase in the use of these materials has been in the past 20-30 years. Plastics is a synthetically bio non-biodegradable material that has wide application and use in industry. Research has shown that these materials have a lifetime of up to 4500 years [1,2]. The accumulation of this waste is a major problem due to limited space in

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landfills since most polymers are decomposed by several hundred years [3]. Different polymers can't be recycled together because of their different characteristics (melting temperature, density, compose...), so the particles of different plastics must be separated because contamination of the main product with other polymers can limit the quality of recycled plastics [4].

According to the American Society of Plastic Industry (ASPI) differs seven category of polymers which are different in their chemical composition are shown in Table 1[5].

Table 1. Classification of plastics [5]

Material	Symbol	Aplication
Polyethylene Terephthalate	1 PET	Packaging for water, juices, carbonated drinks, food packaging
High Density Polyethylene	2 HDPE	Packaging for milk, yoghurt, juices, detergents
Polyvinyl chloride	3 PVC	Packaging for detergents, shampoos and other chemicals, cables, building materials
Low Density Polyethylene	4 LDPE	Slim films, packaging, flexible bottles, bread bags, frozen foods
Polypropylene	5 PP	Packaging for yoghurt, syrups, ketchup, medical bottles, packaging closures
Polystyrene	6 PS	Strong packaging, plastic cups, glasses, plates, medicine boxes
Others	7 Other	Mixed plastics

Electrical and electronic equipment waste (WEEE) is one of the most complex stream waste therefore EEE makes the wide variety of products (irons, vacuum cleaners, refrigerators, freezers, computers, telephones etc...) contained on 30 % of plastics. ABS in combination with others types of pastics (PS, PP, PC, PVC, SAN, PMMA, PBT...) is widely used [6].

ABS is a thermoplastic resin commonly used for injection molding applications. It is non biodagradable hazardous material because it can containing brominated atoms wich is used for fire protection. ABS is tough, hard and rigid and has good chemical resistance and dimensional stability [7].

PS is a vinyl polymer that structurally represents a long hydrocarbon chain with a phenyl group on every second carbon atom. It is produced from free radicals by the polymerization of styrene monomer [5].

These two types of plastics have approximately the same density value and can't be separated by gravity separation processes.

Froth flotation is used for plastic separation of two different produsts, approximately the same density values but a sufficient difference in the wettability of particle surface. The plastic naturally has a hydrophobic surface so polymeric materials represent challeging for flotation process. When using this

separation method, one of the products should become hydrophilic, which can be obtained through lowering liquid–vapor surface tension, chemical conditioning and surface treatment [8,9].

Combination of thermal treatment and froth flotation it aims to make the surface of ABS plastic hydrophilic for selectively separation [9,10].

In this paper, the focus is on experimental studies on separation of ABS and PS plastics after thermal heat treatment and for mathematical interpolation of flotation kinetic the classical model of first order is used

$$\ln \frac{1}{1-I_t} = kt \qquad (1)$$

where I_t is flotation recovery, k is flotation rate constant, t the time of flotation. The Eq. (1) presents the equation of a straight line in the coordinate system [t; $\ln \frac{1}{1-I_t}$].

MATERIALS AND METHODS

The ABS and PS samples were collected from recycling compania in Ćuprija. The plastics differed on shape which facilitated separation through manual sorting at the end of each flotation test. The sample are shown at Fig. 1. The density of these plastics, measured by an pycnometer, ranged from 1024 kg/m^3 (PS) to 1034 kg/m^3 (ABS). The both plastics were screened to obtained size fraction -3,35+2,36 mm. Before each flotation test, the sample was thermal treated on the 100ºC by 60 s and 120 s, which was defined as a mild heat treatment during the given length of treatment after which the sample was cooled down at room temperature. The sample (10 g of each polymer) was then introduced in the Denver cell with a volume of 2,2 l and agitated at rotational speed of 1100 rpm for 5 min with 6,6 ml Methyl Isobutyl Carbinol (MIBC)[10,11,12] as frothing agent. The pH in the flotation cell was approximately constant, about 7. In each flotation test, the floated product was collected after a certain time, from 1 to 15 min, hence 7 float and 1 sink products were collected. Both float and sink products were collected, dried, manually separated and weighed.

Fig.1. The sample of PS (left) and ABS (right)

RESULTS AND DISCUSSION

Table 2. shows the recovery and quality of both polymers in the floated and sink product obtained in kinetic tests carried out under the same conditions, with the exception of thermal heat treatment, which were 60 or 120 s.

Table 2. The results of obtained recoveries after flotation tests

	Time of thermal treatment before flotation tests							
	60 s				120 s			
Flotation time (min)	*It ABS* (%)	*It PS* (%)	k_{pABS} (%)	k_{pPS} (%)	*It ABS* (%)	*It PS* (%)	k_{pABS} (%)	k_{pPS} (%)
0.5	41.80	56.80	42.39	57.61	34.60	44.80	43.58	56.42
1	61.40	76.80	44.43	55.57	62.20	75.20	45.27	54.73
2	80.60	92.80	46.48	53.52	78.60	90.60	46.45	53.55
4	89.60	96.80	48.22	51.78	87.40	96.60	47.50	52.50
7	90.80	97.00	48.35	51.65	92.60	98.80	48.38	51.62
10	90.80	97.00	48.35	51.65	94.20	98.80	48.81	51.19
15	90.80	97.00	48.35	51.65	94.20	98.80	49.23	50.77

*kp quality of product, *It* recovery of the PS or ABS in the floated or sink product

There is no significant difference in the achieved results after a different thermal treatment of the sample.

Results in the Table 2. shows that the recovery of boat polymers has higher value with increasing flotation time, and that the shorter thermal treated sample achieve the same recovery value for a shorter time in the first flotation period (1 min). With an extension of flotation time, effect of thermal treatment on flotation recovery becomes negligible.

ABS and PS quality value are very low, which indicates that ABS and PS could't be successfully separated by froth flotation with such thermal treatment.

The scientists Truc et all [10,12], have done research with the similar polymers and thermal treatment, but with different mixing speed and obtained the results which shows good separation of these materials. In his research he pointed out that this combined technique can be a simple, effective, economic method for selective separation of ABS with BFRs from heavy plastic wastes.

In order to explain the obtained results, further research should focus on determining the content of BFRs (brominated flame-retardants) compounds in used polymers and analyze the hydrophilic and hydrophobic groups on the plastic surfaces before and after treatments because under the interacting environmental conditions, the plastics surfaces are rearranged to respond to the change in the environment.

In the literature [4], mainly flotation kinetics are represented by the classical model of first-order. The extent of fitting the kinetic responses to Eq. (1) can be seen in Fig. 2. and Fig. 3.

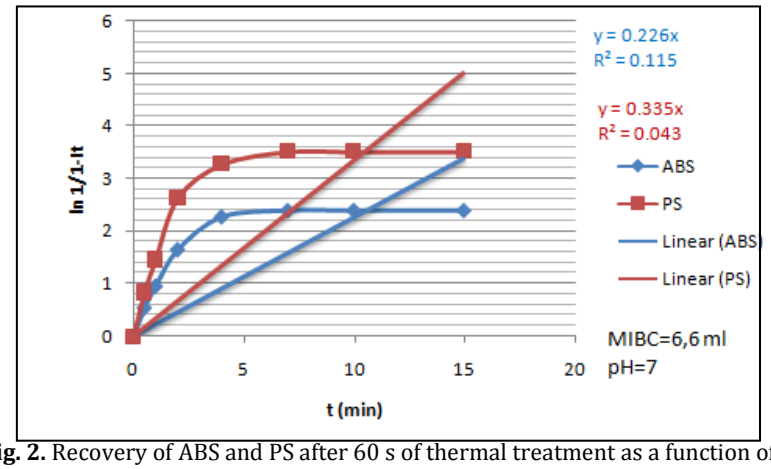

Fig. 2. Recovery of ABS and PS after 60 s of thermal treatment as a function of time

From Fig. 2 can be seen that correlation coefficient R^2 for ABS is 0,115 and for PS is 0,043. Considering that the correlation coefficient minimum value R^2_{min} is 0,44 [13], it can be said that this kinetic model can not describe the flotation kinetics of PS and ABS plastics.

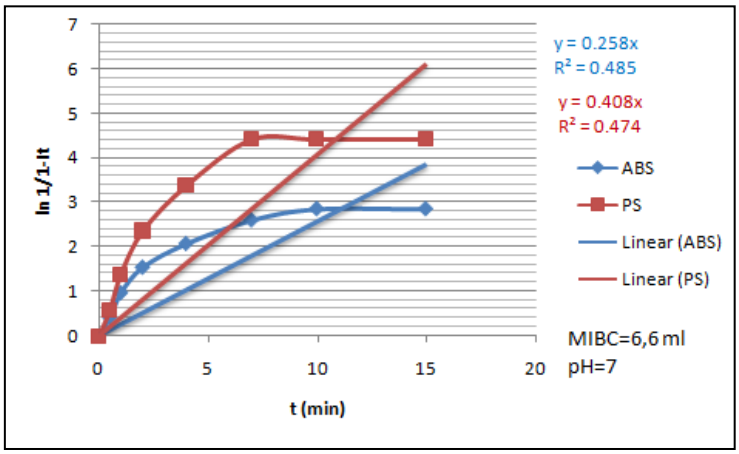

Fig. 3. Recovery of ABS and PS after 120 s of thermal treatment as a function of time

The results obtained by ABS and PS flotation shows that the both samples have the correlation coefficient higher than R^2_{min} and it amounts are 0,485 and 0,474 for ABS and PS respectively, and as well as in the first experiment, the flotation rate constant value, *k,* for PS is higher than for ABS. Based on this data it can be sad that classical model of first-order describes the kinetics of plastics flotation with correlation coefficient approximate values as minimum correlation coefficient.

The knowledge of the flotation kinetic of plastic separation is of great importance to evaluate the flotation results and the effect of flotation variables with influence on the process, and therefore further research should also focus on defining a model of flotation kinetics that will more accurately describe the flotation process with a more reliable correlation.

CONCLUSIONS

Kinetic flotation experiments were carried out with samples of ABS and PS where MIBC was used as frother. The aim of this study was the separation PS plastic from a mixture of ABS/PS on which the thermal heat treatment were performed for change the wettability of particle surface. Based on the literature reviewed, this treatment increases the hydrophilicity of ABS plastics which, based on the results of this research, showed that it did not happen. Also, the quality of the plastic is not satisfactory because k_p is less than 90% in all cases.

Further research should focus on determining and analyze the hydrophilic and hydrophobic groups on the plastic surfaces before and after treatments in order to attempt to explain the obtained results.

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