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CONTENTS

PREFACE

This volume contains papers of the **XXI International Waste Recycling Conference**.

This conference series is being organised by academic and research institutions of Visegrad 4 countries:

- Institute of Raw Material Preparation and Environmental Processing, University of Miskolc, Hungary;
- Institute of Geotechnics, Slovak Academy of Sciences, Kosice, Slovakia;
- Institute of Environmental Engineering, VSB-Technical University, Ostrava, Czech Republic;
- AGH-University of Science and Technology, Cracow, Poland;
- Cracow University of Technology, Cracow, Poland.

The V4 WR21 Internationl Conference (22–23 November, 2018, University of Miskolc, Hungary) was organised in cooperation with the

- Mining Scientific Committee, Hungarian Academy of Sciences,
- Sub-committee on Mining, Earth- and Environmental Sciences, Sub-Commission on Preparation, Environmental Processing ,
- Mining and Energy and Association of Environmental Enterprises as well as
- „Sustainable Raw Material Management Thematic Network–RING 2017", EFOP-3.6.2-16-2017-00010 PROJECT.

The papers presented covers all the topics of waste recycling science, technology and innovation:

- Recycling and utilisation of industrial wastes (metallurgical, power-engineering, mechanical engineering, chemical industrial, WEEE, end-of-life vehicles, plastics, demolishing waste, mining waste and tailings etc.);
- Treatment and recycling of municipal solid waste and biowaste;
- Recycling of critical raw materials from secondary sources;
- Decontamination and remediation of contaminated areas;
- Waste water treatment and air quality control;
- Business activities in waste recycling;
- Legislation issues of recycling and waste utilization.

The valuable contribution of all the authors, as well as organisers is highly appreciated.

Miskolc, November, 2018.

Dr. Ljudmilla Bokányi
editor
chair of the conference

THE EFFECT OF SIEVE LOADING AND PARTICLES SHAPE ON THE RESULTS OF POLYMER SIEVE KINETICS

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Abstract

An experimental investigation has been made into the effects of different factors on the results of screening efficiency of polymer samples. The used polyvinyl chloride (PVC) samples have equal content of `small`, `large` and `small-to large` particles and filled the whole area of the sieve in one, two and four characteristic layers during the screening. Visual examination showed that the particle shape was similar in whole particle size distribution in the one sample tested. In addition to the aforementioned variable, the other factors studied included samples shape, vibrating amplitude and the duration of screening. Analysis of the obtained results of the screening rate in laboratory conditions was performed by applying the classical and modified model of the first order screening kinetics. The results showed that high loading of the sieve requires a larger vibrating amplitude for good classification and that the high layer reduction of sample is a more effective remedy for good efficiency than prolongation of sieving time. It has also been shown that the particles shape has a significant impact on the screening rate. The modified kinetics model (Magdalinović–Trumić) of the first order describes polymer screening kinetics with very good correlation coefficient in all cases. The application of the classical model is not adequate for determining a screening rate constant since the correlation coefficients are smaller than the minimum correlation coefficient.

Keywords: *polymer, screening, kinetic model, screening rate constant*

1. INTRODUCTION

Sieving or screening is the process which separate materials usually according to its particle sizes using a perforated area, so that small particle sizes (undersize product - between particle with average size smaller than average aperture size) pass through and larger sizes (oversize product - particles larger in size than average apreture size) stay on the surface perforated area (LIU 2009; YEKELER et al. 2014). TRUMIĆ and MAGDALINOVIĆ (2011) was give the definition of mentioned particles: 'small', (particles with the middle, diameter *(ds)* smaller than 0.75*a*, where *a* is the aperture size, $0 < ds < 0.75a$), 'small-to-large' (particles with mean diameter *(dsl)* larger than 0.75*a* and smaller than a, $0.75a < a$), and 'large' (particles with the middle diameter *(d1)* larger than *a* and smaller than 1.5*a*, $a < d1 < 1.5a$). One can observe that there is not sharp cut between particle size classes because some larger particles may have passed through the aperature and some smaller particles than apreture size remain in the oversize product. The explanation can be found in the analysis of the influence parameters that determine the efficiency of screening, like proportions of small and small to large particles in the particle size range (TRUMIĆ and MAGDALINOVIĆ 2011), particle shape (BEUNDER and REM 1999; KRUGGEL-EMDEN and ELSKAMP 2014; ELSKAMP, et al. 2017), and the density of raw materials (TRUMIC et al. 2016). It is also important to take into account the operating parameters (vibrating amplitude, duration of sieving, sieve loading) of the device in which the screening is done.

Most of the works regarding screening and sieving kinetics, i.e. the rate process, were studied from a different point of view. Generally it has been studied in terms of the rate of sieving of near-aperture particles for the terminal stages of sieving when the total load on the sieve does not change appreciably with time (STANDISH, 1985). For this condition for mathematical interpolation of screening and sieving kinetics, several models are proposed in literature.

The models used in this paper are the first order rate low given by Eq.(1) and Eq.(2) (STANDISH, 1985; TRUMIĆ and MAGDALINOVIĆ, 2011) and the modified first order rate low - model Magdalinović-Trumić (TRUMIĆ and MAGDALINOVIĆ, 2011) given by Eq.(3) and Eq.(4).

The first order screening kinetics:

$$dm / dt = - km \qquad (1)$$

where dm / dt is the rate particles of size $(–a + 0)$ pass through the screen in time t, k the screening rate constant, m the mass of the particles of size $(–a + 0)$ on the screen at time t, and a is the aperture size.

The Eq.(2) represents a straight line in the coordinate system [$t; ln 1/ 1-E$]

$$ln (1 /1 - E) = - kt \qquad (2)$$

where E is screening efficiency- undersize recovery.

The modified first order screening kinetics:

$$dm / dt = - kmk_p \qquad (3)$$

where dm / dt is the rate particles of size $(–a + 0)$ pass through the screen in time t, k the screening rate constant, m the mass of the particles of size $(–a + 0)$ on the screen at time t, and a is the aperture size and k_p is the change of the probability of screening coefficient.

The Eq.(4) represents a straight line in the coordinate system [$t; E/ 1-E$]

$$ln (1 /1 - E) = - kt \qquad (4)$$

where E is screening efficiency- undersize recovery wich may be given by the following formula:

$$E = 1 - m / m_0 \qquad (5)$$

where m is the mass of particles of size $(–a + 0)$ on the screen at time t, a the aperture size, m_0 the initial mass of a particle $(–a + 0)$.

2. MATERIALS AND METHODS

Experiments of sieving kinetics were carried out on PVC pipe and PVC insulation with equal content of `small`, `large` and `small-to large` particles. The samples filled the whole area of the sieve in one, two and four characteristic layers during the experiments. The density of PVC pipe is 1400 kg/m^3 and PVC insulation is 1350 kg/m^3. As can be seen on the *Figure 1a*, 1b, PVC raw materials differ in particles shape. The PVC pipe has mostly cubical, while PVC insulation has a mostly needle shape particles. Experiments were performed using a sieve and sieve shaker ‚Retsch' *(Figure 2a, 2b)*. The sieving surface used in the experiments was square with openings of 1,7 mm. Mass of sample in one layer was 80 g. Particle size distribution of samples is given in Table 1. The variable operating parameters were vibrating amplitude in range 0.2 to 1.4, duration of sieving – 180 s total, sieve loading from 80g to 320 g.

a) b)

Figure 1
PVC samples a) insulation and b) pipe

a) b)

Figure 2
Laboratory Retsh devices: a) sieve shaker b) sieve

Table 1
Particle size distribution of PVC samples

d (mm)	Samples
–3.35 + 2.36	10
–2.36 + 1.7	30
–1.7 + 1.18	30
–1.18 + 0.85	20
–0.85 + 0.60	10
∑	100%

*screening was done in one (1L), two (2L) and four (4L) layers

3. RESULTS AND DISCUSSIONS

The results of the screening kinetics investigation of the PVC pipes were analyzed using classic and modified model of the first order. The application of the classical model is not adequate for determining a screening rate constant since the correlation coefficients are smaller than the minimum correlation coefficient. The modified kinetics model (Magdalinović-Trumić) of the first order describes PVC pipe screening kinetics with a very good correlation coefficient for all tasted variables. Due to a reliable analysis of the vibrating amplitude value influence on the screening rate constant and the height of the raw material layer on the sieve, the obtained results will be shown only using a modified model.

The depedance of vibrating amplitude value and screening rate constant for one, two and four characteristic layers during the sieving are shown in *Table 2* and *Figure 3*.

Table 2
Depedance of vibrating amplitude and screening rate constant value for PVC pipe

	one layer 1L	**two layers 2L**	**four layers 4L**
Vibrating amplitude, A	**Screening rate constant, k**		
0.20	0.009	0.006	0.001
0.40	0.231	0.049	0.007
0.60	0.799	0.373	0.024
0.80	0.493	0.408	0.047
1.00	0.18	0.15	0.04
1.20	0.134	0.095	0.034
1.40	0.108	0.058	0.027

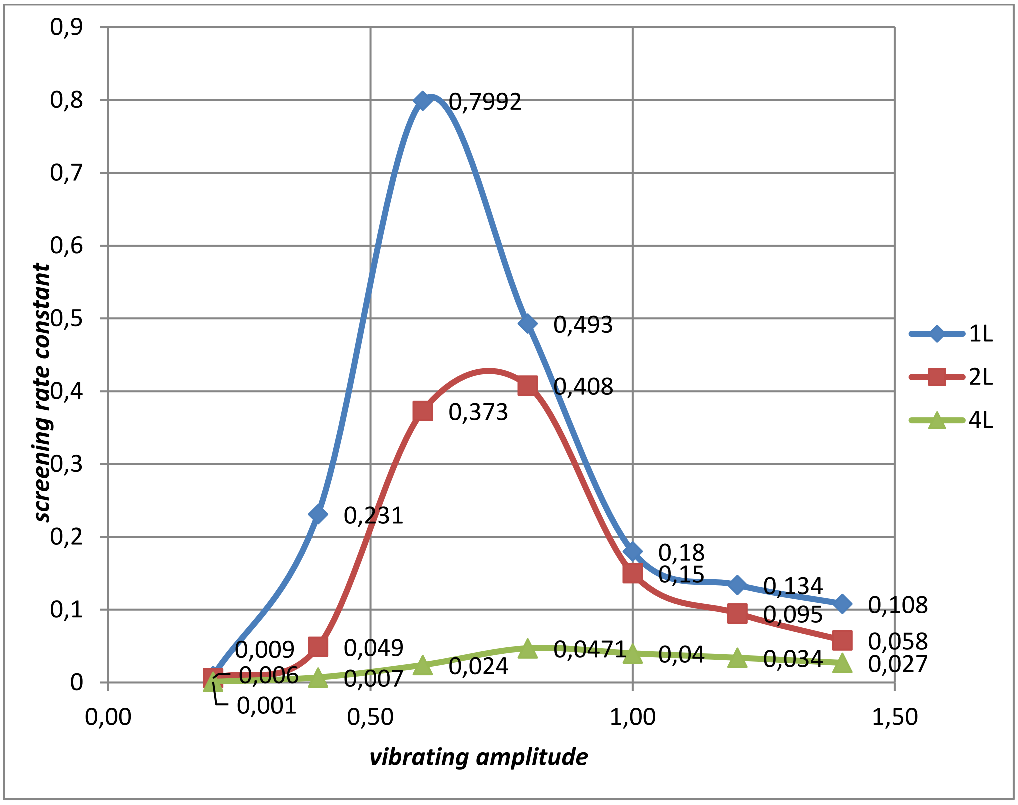

Figure 3
Depedance of vibrating amplitude and screening rate constant value for PVC pipe

It can be clearly seen that there is an optimal range of vibrating amplitude at which the screening rate constant has maximum value. If the screening is done in one characteristic layer, the optimal amplitude value is 0.6. With the increase in the height of the layer on the sieve, the value of the optimal amplitude increases, and for two and four layer it is value of 0.8.

Also, it is can be seen from the *Figure 3*. that in the entire tested amplitude range, the highest values for screening rate constant *k*, are achieved when the PVC pipe is screened in one layer, and at the optimum amplitude $k = 0.7992$. The doubly less absolute values for screening rate constant are achieved when the screening is done in two layers and at the optimal amplitude value $k = 0.408$. Drastically lower values for screening rate constant are achieved in the case of four-layer screening, and the maximum value for *k* in this case is 0.0471. Generally, based on the analysis, it can be said that screening in four layers on the sieve is not efficient because of the low rate of screening. It should also be noted that the influence of the height of the raw material layer on the sieve is not negligible.

On *Figure 4* and *Figure 5* are showen the screening kinetics for optimum amplitude values at the characteristic layer heights of PVC pipe on the sieve, by classical and modified model of the first order.

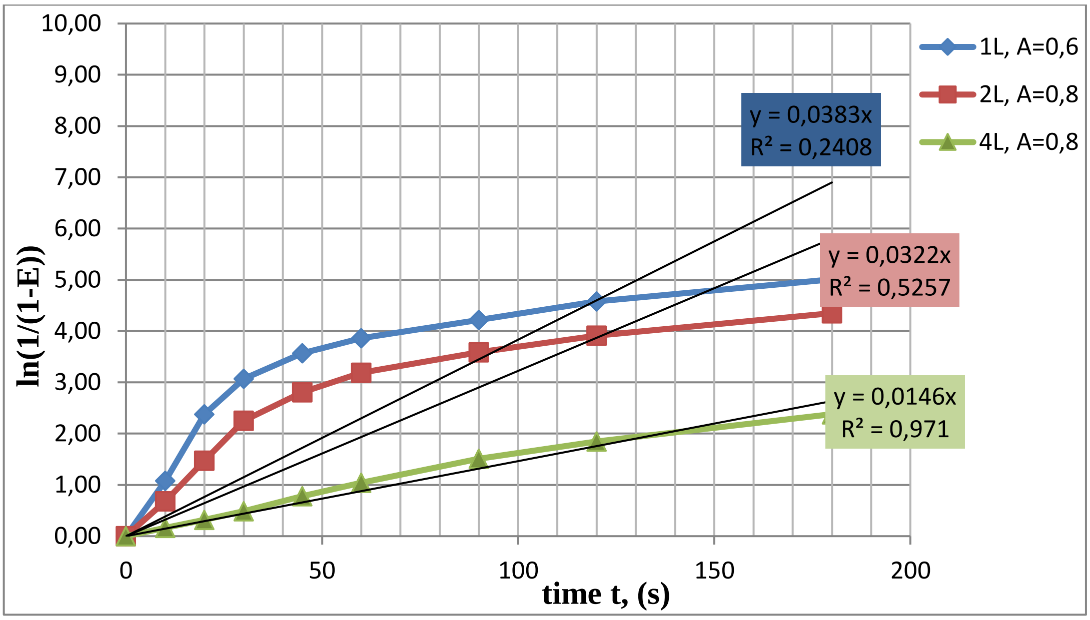

Figure 4
PVC pipe screening kinetics by classical model of the first order

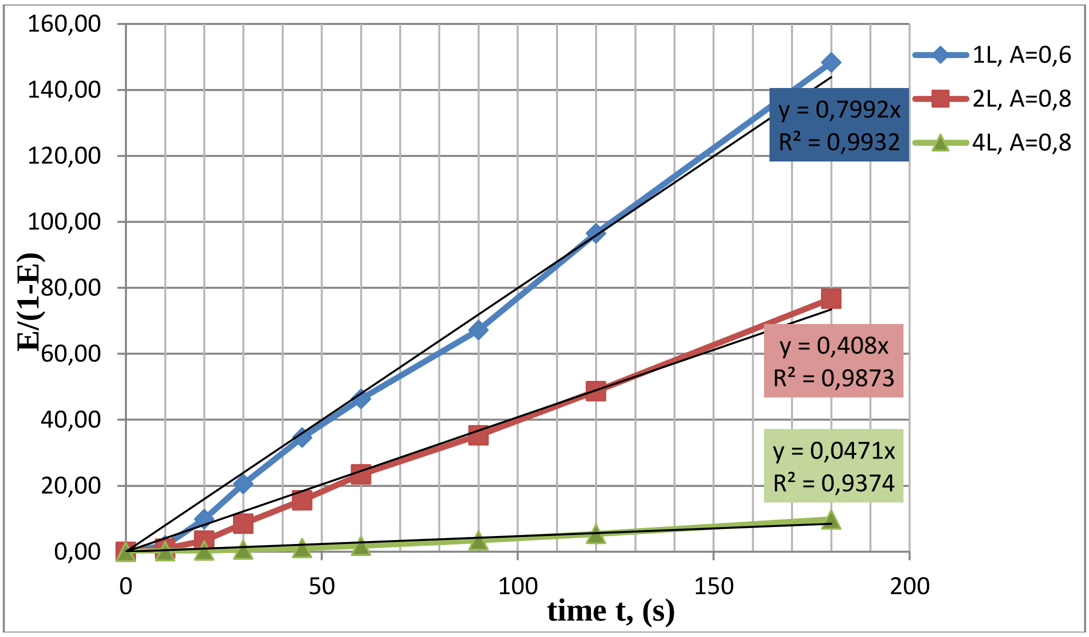

Figure 5
PVC pipe screening kinetics by modified model of the first order

Considering that the minimum value of correlation coefficient is R^2_{min} = 0,443 (VOLK 1965), it can be said that both models describes screening kinetics with good correlation coefficient for two and four characteristic layers. It should be emphasized that for the entire tested range of amplitude values, as well as for all tested characteristic heights of the material on the sieve, only the modified model has a very high correlation coefficient over 0.9. These results confirm previous research of testing modified model screening kinetics Magdalinović-Trumić (TRUMIĆ and MAGDALINOVIĆ 2011; STOJANOVIĆ et al. 2015a; STOJANOVIĆ et al. 2015b; TRUMIĆ et al. 2016).

The second part od investigation is based on analysis of particle shape influence on screening kinetics.

The results of the screening kinetics investigation of the PVC insulation were analyzed using classic and modified model of the first order only in optimal range of vibrating amplitude value and were showen on *Figure 6* and *Figure 7*.

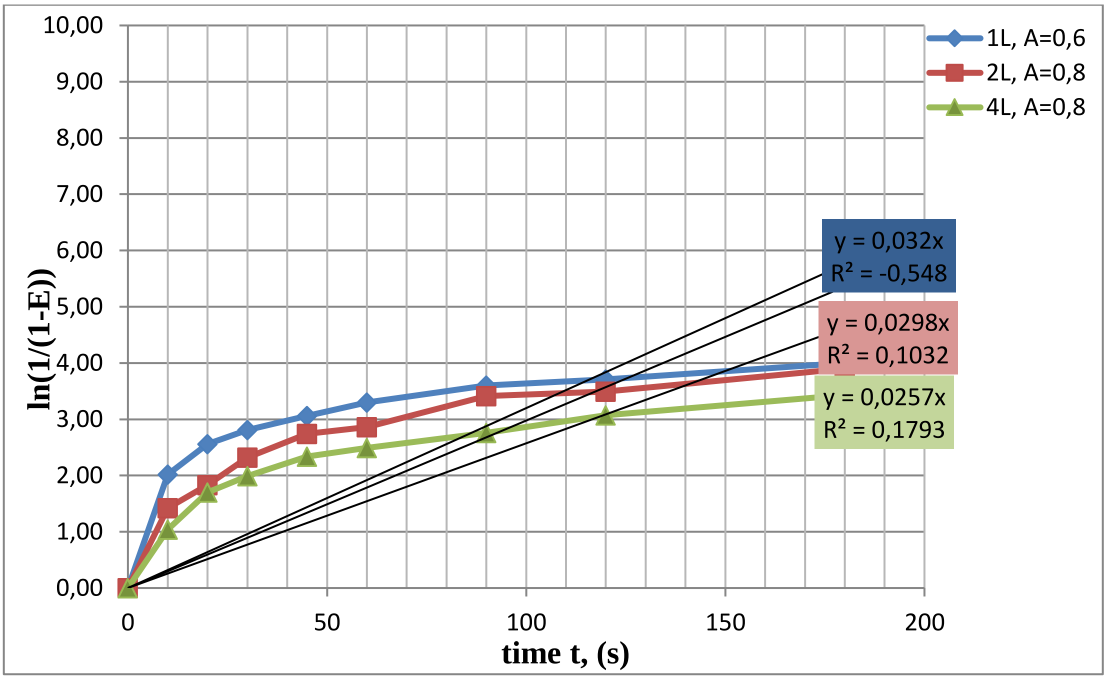

Figure 6
PVC insulation screening kinetics by classical model of the first order

Since the minimum value of the correlation coefficient is R^2min = 0.443, it can be concluded that the classical model does not describe the screening kinetics with a reliable correlation coefficient, even for optimal parameters. From the *Figure 7* can be seen that the modified model has a very high correlation coefficient over 0.9, which generally indicates that this modified model can be used for the reliable determination of the screening rate constant of raw materials of different shapes, in different loading of the sieve as well as in wide amplitude range.

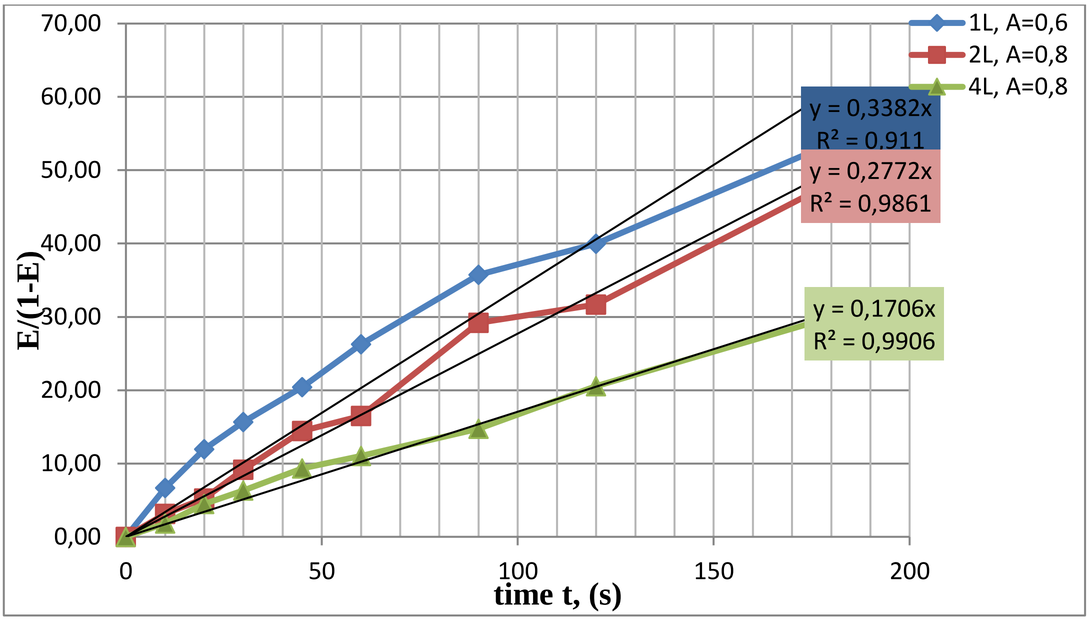

Figure 7
PVC insulation screening kinetics by modified model of the first order

Table 3
Values of screening rate constant for PVC pipe and PVC insulation using modified model

	PVC pipe	**PVC insulation**
1L; A = 0.6	0.799	0.338
2L; A = 0.8	0.408	0.277
4L; A = 0.8	0.047	0.171

Table 3 shows the values of the rate constant of screening *k*, of tested PVC samples in 1L, 2L and 4L on the sieve. It can be observed that *k* decreases with increasing layers on the sieve, which further states that the effect of the height of the raw material layer on the sieve is not negligible.

Also, the data show that PVC insulation sample with mostly needle particles shape have the smaller value of *k* in comparation with the PVC pipe sample with mostly cubic particles shape, which points to the significant impact of the shape of the particles on on the screening rate.

4. Conclusion

Based on the experimental data presented in this paper and the analysis of screening kinetics of PVC samples – pipe and insolation, can be concluded:

- The modified kinetics model (Magdalinović–Trumić) of the first order describes polymer screening kinetics with very good correlation coefficient in all cases.
- The application of the classical model is not adequate for determining a screening rate constant since the correlation coefficients are smaller than the minimum correlation coefficient.
- There is an optimal range of vibrating amplitude at which the screening rate constant has maximum value.
- High loading of the sieve requires a larger vibrating amplitude for good classification.
- Secondary raw material with mostly needle particles shape has a smaller value of *k* in one and two characteristic layer, compared to secondary raw material with mostly cubic particles shape.

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REFERENCES

[1] BEUNDER, E. M.–REM, P. C. (1999): Screening kinetics of cylindical particles. *International Journal of Mineral Processing,* 57, pp. 1–81.

[2] ELSKAMP, F. et al. (2017): A strategy to determine DEM parameters for spherical and non-spherical particles. *Granular Matter,* 19 (3), p. 46.

[3] KRUGGEL-EMDEN, H.–ELSKAMP, F. (2014): Modeling of screening processes with the discrete element method involving non-spherical particles. *Chemical Engineering and Technology,* 37 (5), pp. 847–856.

[4] LIU, K. (2009): Some factors affecting sieving performance and efficiency. *Powder Technology,* 193 (2):25, pp. 208–213.

[5] STANDISH, N. (1985): The Kinetics of Battih sieving. *Powder Technogy*, 41, pp. 57–67.

[6] STOJANOVIĆ, A. et al. (2015a): Screening kinetics analysis of PVC insulation and copper wire. *X International Symposium on Recycling Technologies and Sustainable Development Proceedings*, Bor, Serbia, 04–07 November. pp. 80–85.

[7] STOJANOVIĆ, A. et al. (2015b): The influence of particle shape on screening kinetics, *47th International October Conference on Mining and Metallurgy Proceedings,* Bor Lake, Serbia, 04–06 October. pp. 95–100.

[8] TRUMIĆ, M.–MAGDALINOVIĆ, N. (2011): New model of screening kinetics. *Minerals Engineering,* 24 (1), pp. 42–49.

[9] TRUMIĆ, M. S. et al. (2016): Infuence of Secondary Raw Material Density and Grain Shatpe on Screening Kinetcs, *XI Internatonal Symtposium on Recycling Technologies and Sustainable Develotpment Proceedings,* Bor, Serbia, 02–04 November, pp. 171–176.

[10] VOLK, W. (1965): Statystyka stosowana dla inżynierów, *Wydawnictwa Naukowo – Techniczne*, Warszawa.

[11] YEKELER M. (2014): Correlation of the Particle Size Distribution Parameters with Sieving Rate Constant. *Particulate Science and Technology: An International Journal*, 32 (2), pp. 118–122.