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Assessment of the Destruction Degree of the Quartz Matrix in the REGMAS Reclaimer

M. Skrzyński [a*], R. Dańko [a]
[a] AGH University of Science and Technology, Faculty of Foundry Engineering, Department of Foundry Processes Engineering, Reymonta 23 St., 30-059 Crakow, Poland
* Corresponding author's e-mail: e-mail: mskrzyns@agh.edu.pl

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Abstract

The results of investigations of the influence of operation parameters of the prototype vibratory REGMAS reclaimer on matrix grains refinement (destruction) are presented in the paper. Fresh quartz sand 'Szczakowa' –1K 0.40/0.32/0.20, J88, >1400^0C, W_K= 1.20 was subjected to the treatment. Examinations were performed in three stages differing in the frequency of electrovibrators operations (which was: 40 Hz, 50 Hz and 60 Hz). For each frequency two settings of the exciting force of the rotodynamic drives were applied. They were equal 42% and 75% of the maximal exciting force. The sand batch placed in the bottom part of the REGMAS reclaimer was, in individual stages, subjected to elementary operations of grinding, rubbing and crushing. The destruction ratio was determined by means of the classic sieve analysis and grain size analysis performed in the Analysette 22NanoTec apparatus.

Key words: Reclamation, Moulding sand, Grain size analysis, Destruction

1. Introduction

Investigations aimed at finding the mechanism of liberating matrix grains from coatings of spent binding agents in dry reclamation processes (mechanical and pneumatic), initiated by H.W. Zimnawoda [1], were later on undertaken in several research centres. Publications of D. Boenisch [2], W. Tilch [3], D. Leidel [4], R. Dańko [5-6] and others [7], consider the mechanical reclamation processes as the treatment processes, realising elementary operations of grinding, rubbing and crushing aimed at liberating the matrix moulding sands from coatings of spent binding agents, regardless of the reclamation method.

A lot of attention is devoted - in publications - to investigations of the spent moulding and core sands reclamation, to influences of operation parameters of reclaiming devices on the quartz matrix purification quality and significantly less to the negative influence of this type of device operations on the destruction (crushing) of the quartz matrix.

During the dry reclamation process, especially mechanical, the mentioned above elementary operations occur, which from the one side cause the removal of spent binding agents from matrix grains, however from the other side can be the reason of the matrix grains destruction. They can change the matrix grains shape from spherical to edged, can decrease their average diameter as well as the main fraction content or increase the powdery fraction amount.

2. Introduction range

The preliminary investigations of the influence of the prototype vibratory REGMAS reclaimer on the matrix destruction ratio were performed with using the quartz moulding sand 'Szczakowa' –1K 0.40/0.32/0.20, J88, >1400^0C, W_K= 1.20 .

Investigations were performed in the secondary reclamation chamber of the REGMAS reclaimer [8-10], presented in Figure 1.

Fig. 1. Prototype vibratory REGMAS reclaimer.

The device interaction force on the material was controlled by changes of the mutual position of flywheels of electrovibrators (Fig. 2), which can be set-up in various positions. On the basis of preliminary tests the reclamation process of the moulding sand with organic binder allowed to obtain the representative results for two settings of unbalanced masses: setting 1 - corresponding to 42% of the maximal excitation force and setting 2 - corresponding to 75% of the maximal excitation force.

Materials destined for tests were placed in the lower part of the reclaimer, in which there are additional crushing elements (balls) (Fig. 3), increasing reclamation influences of the device. The secondary reclamation of spent moulding sand, it means the removal of spent binding agents from refined grains, occurs in this part of the device.

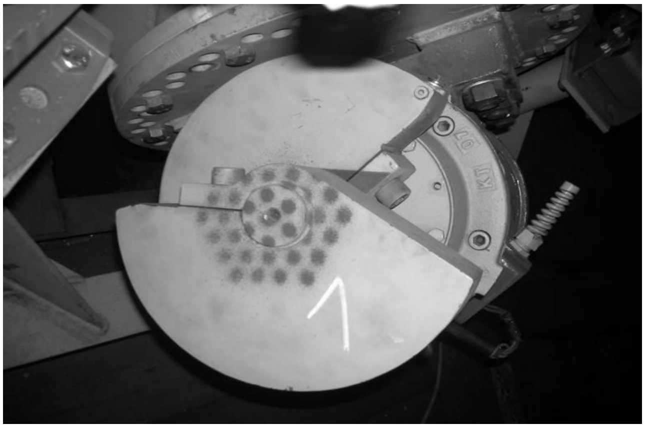

Fig. 2. Example of mutual positioning of flywheels (unbalanced masses) of the electrovibrator.

Fig. 3. Cast iron balls, additional grinding-crushing elements of the prototype reclaimer.

Tests were performed according to the schematic diagram presented in Fig. 4. 70 kg batches of fresh sand were subjected to the secondary reclamation in the lower part of the reclaimer.
Investigations were performed in three stages differing in frequencies of electrovibrators operations (40 Hz, 50 Hz and 60 Hz). Two settings of the excitation force, being 42% and 75% of the maximal force, were applied for each frequency. The influence time of the device on the tested material was: 5, 10 and 15 minutes for each setting.
The obtained material was subjected to the classic sieve analyses and laser analysis, which data served for the determination of the grain composition function.

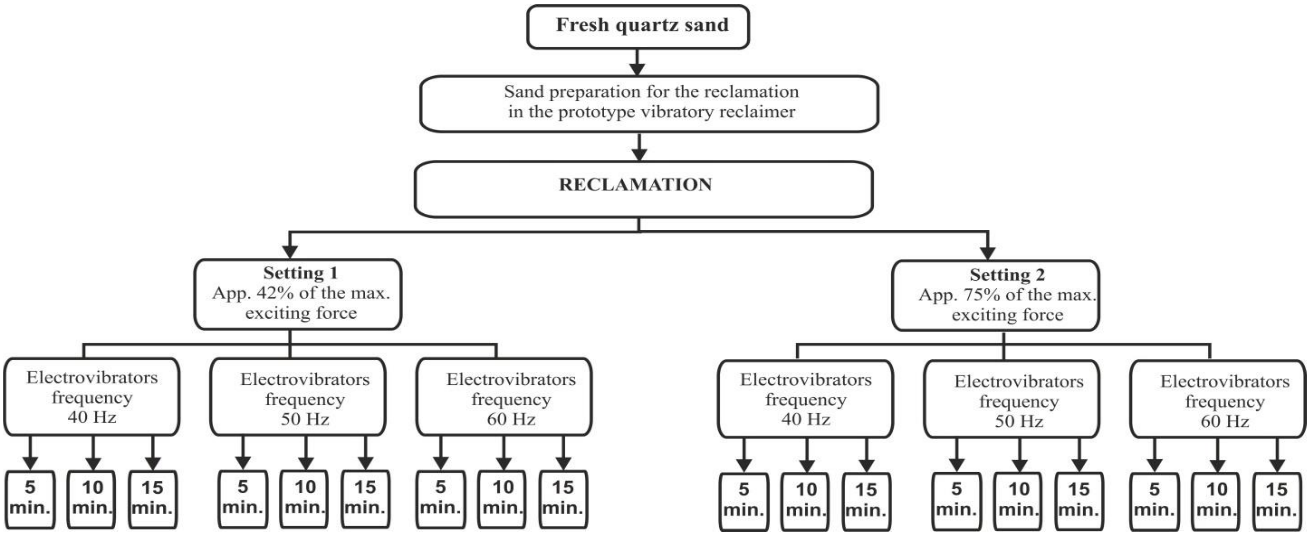

Fig. 4. Schematic presentation of the performed tests

3. Theories of the material crushing process

The complexity of the reclamation processes, combined of spent sand treatment processes, from its preliminary preparation via the secondary reclamation up to the final treatment of the reclaimed material, is the reason of the lack of the total and complete solution of these topics in scientific publications.

Energy problems of the matrix reclamation and crushing can be considered from the point of view of energy hypotheses, such as:

- Rittinger's deterministic hypothesis of material crushing,
- Kick's volumetric hypothesis.

There are also other methods of determining crushing operations , however the majority of them is based on these two hypothesis, properly modified [11].

The chronologically oldest hypothesis concerning the material crushing process is the Rittinger's hypothesis [12], who assumed as the basis of his theory the observed effect of a proportionality of energy used for the brittle material fragmentation to the obtained - in this process - increased surface of the grains set. He stated that for the given brittle materials: 'crushing works are to each other nearly the same as degrees of fineness'.

According to Rittinger the right work equals:

$$L_R = L_0 \cdot \Delta F \ , \qquad (1)$$

where:

L_0 - work necessary for obtaining the increased surface unit; J/m^2 (J/cm^2),

ΔF – increased material surface as a crushing result; m^2 (cm^2).

According the Rittinger's theory [12], the measure of work used for the material fragmentation to the grain form, which in case of the presented mechanical reclamation model is used for crushing of spent binder covering matrix, is the area in between integral curves of the feed and product grain composition drawn in the system: 1/d, Φ(d). Curve Φ(1/d) in Fig. 5 marks the value of the integral function of the grain composition for grains of a diameter d. The axis of ordinates is scaled in inverse values of a grain size of a diameter d, it means in 1/d. In this case, the spent moulding sand of the average diameter d_N - is the feed, while the reclaim of the average diameter d_p - is the product.

The Rittinger's theory is applied, in practice, for designing the crushing devices and for predicting the effects of treatment processes.

The argument in favour of the application of this hypothesis for the mechanical reclamation processes is the physical similarity of the matrix grains liberation from binding agent coatings to the crushing process, as well as the broadly used and normalised in foundry practice, the grain composition analysis, allowing to determine changes in the specific surface of the reclaimed matrix on the sieve analysis basis.

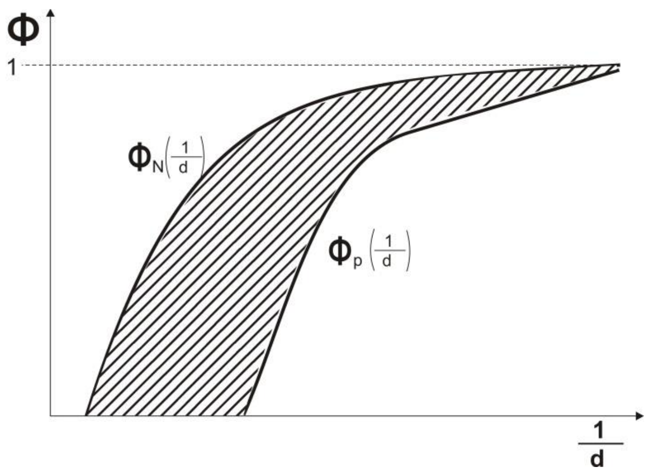

Fig. 5. Interpretation of the work used for the fragmentation of the feed of a diameter d_N to the product of a diameter dp - according to the Rittinger's theory [5]

According to the Kick's theory the crushing work is proportional to the material volume, it means to the third power of the linear measure characterising the grain size.
The volumetric Kick's hypothesis is based on the work of deformation under an influence of compressive force of a material particle of a diameter dz, which is expressed as:

$$L = \frac{d_Z^3 \cdot \sigma^2}{2 \cdot E} \cdot \rho_m \cdot g \, , \qquad (2)$$

where:
d_Z– diameter of the particle subjected to crushing,
σ – compressive stress,
E – modulus of elasticity,
ρ_m - density of the crushed material,
g – acceleration of gravity.
The lack of the dependence of the crushing work on the initial and final grain dimensions (it means on the degree of fineness), resulting from equation (2), limits this theory application to problems of the spent moulding sands reclamation. Therefore the crushing process was examined according to the Rittinger's hypothesis.

4. The obtained results

The results of examinations of changes of the average characteristic diameters, the main fraction content and specific theoretical surface, obtained by means of the classic sieve analysis, before and after the reclamation process performed in the prototype reclaimer, are listed in Table 1.

Table 1. List of the material geometrical parameters before and after the reclamation process in the prototype reclaimer

		Time of proces	d_L	d_a	d_g	d_h	S_t
		min	mm	mm	mm	mm	cm^2/g
Fresh quartz sand		0	0,327	0,407	0,388	0,367	61,75
42% of the excitation force	40Hz	5	0,327	0,41	0,391	0,37	61,8
		10	0,326	0,407	0,388	0,366	61,8
		15	0,32	0,4	0,38	0,357	63,42
	50Hz	5	0,307	0,393	0,37	0,339	66,69
		10	0,277	0,371	0,342	0,3	75,53
		15	0,259	0,362	0,328	0,277	81,6
	60Hz	5	0,303	0,39	0,367	0,334	67,74
		10	0,263	0,363	0,331	0,282	80,33
		15	0,247	0,349	0,315	0,262	86,36
75% of the excitation force	40Hz	5	0,328	0,409	0,39	0,368	61,51
		10	0,322	0,407	0,386	0,36	62,89
		15	0,315	0,397	0,376	0,351	64,56
	50Hz	5	0,307	0,393	0,37	0,339	66,69
		10	0,277	0,371	0,341	0,3	75,35
		15	0,259	0,362	0,328	0,277	81,6
	60Hz	5	0,303	0,39	0,367	0,334	67,74
		10	0,263	0,363	0,331	0,282	80,33
		15	0,243	0,346	0,311	0,258	87,77

The obtained results of the average characteristic diameter d_L, at the settings of unbalanced masses of rotodynamic engines corresponding to 42% and 75% of the maximal excitation force are graphically presented in Figure 6 and 7. It can be noticed that in both cases the smallest changes of the tested diameters occur for the electrovibrators frequency being 40 Hz. When the device was operating with frequencies of 50 Hz and 60 Hz the matrix destruction process, at both values of the excitation force, is much faster.
These results are also confirmed by the analysis of changes of the theoretical specific surface (Figure 8 and 9) determined at the same operation parameters of the device. The crushing process causes an increase of the specific surface of the set of grains. Increasing of the crushing intensity by increasing the operation frequency of electrovibrators and changes of the mutual positioning of unbalanced masses causes an increased value of this geometric parameter.

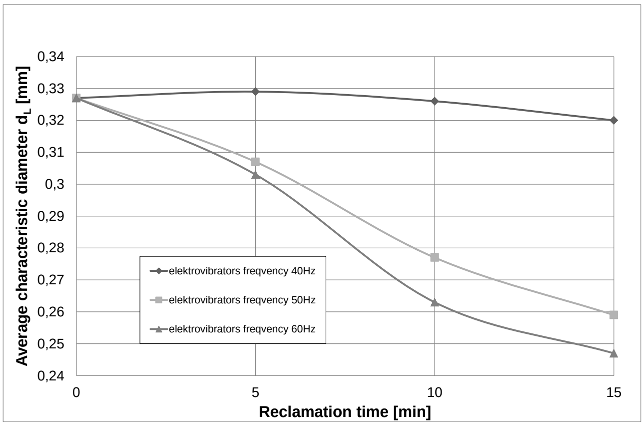

Fig. 6. Changes of the average characteristic diameter d_L as a function of the reclamation time at three frequencies: 40 Hz, 50 Hz, 60 Hz of electrovibrators operations and the setting of unbalanced masses corresponding to 42% of the maximal excitation force

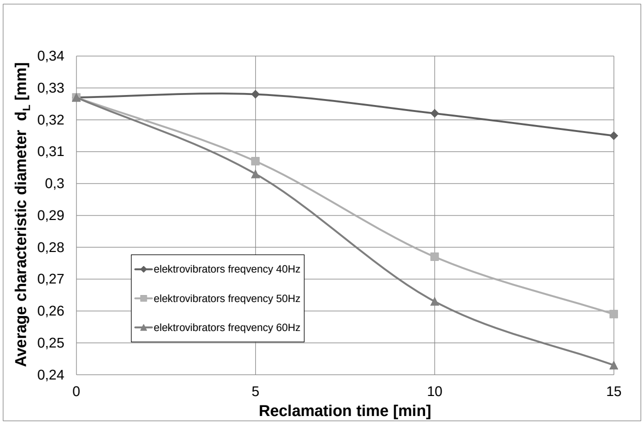

Fig. 7. Changes of the average characteristic diameter d_L as a function of the reclamation time at three frequencies: 40 Hz, 50 Hz, 60 Hz of electrovibrators operation and the setting of unbalanced masses corresponding to 75% of the maximal excitation force

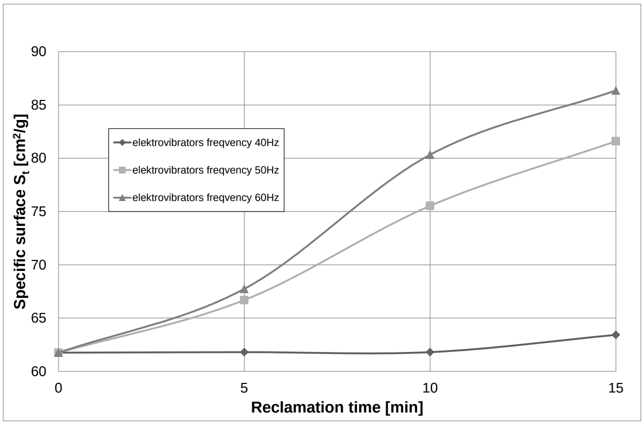

Fig. 8. Changes of the specific surface St as a function of the reclamation time at three frequencies of electrovibrators operations (40 Hz, 50 Hz, 60 Hz) and the setting of unbalanced masses corresponding to 42% of the maximal excitation force

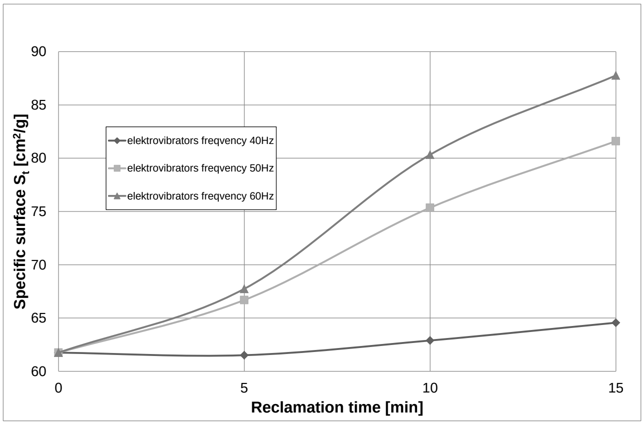

Fig. 9. Changes of the specific surface St as a function of the reclamation time at three frequencies of electrovibrators operations (40 Hz, 50 Hz, 60 Hz) and the setting of unbalanced masses corresponding to 75% of the maximal excitation force

Analysing the obtained results with the application of the Rittinger's theory it was found that the largest area between diagrams in the system (1/d, Φ(d)) was obtained for the following setting: 75% of the maximal excitation force, frequency 60 Hz and the longest influence of the device (15 minutes) on the sand (Fig. 10). At the electrovibrators operation frequency equal 40 Hz - regardless of the excitation force and the process duration time (Fig. 11) - diagrams nearly cover themselves, which means that the crushing process is minimal.

5. Conclusions

The performed investigations allow to present the following conclusions. The destruction process of matrix grains increases with the increase of the process intensity.

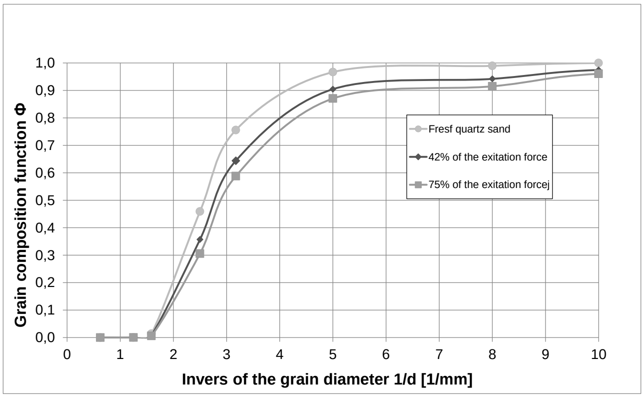

Fig. 10. Grain composition function, at a frequency of 60 Hz and the reclamation time equal 15min.

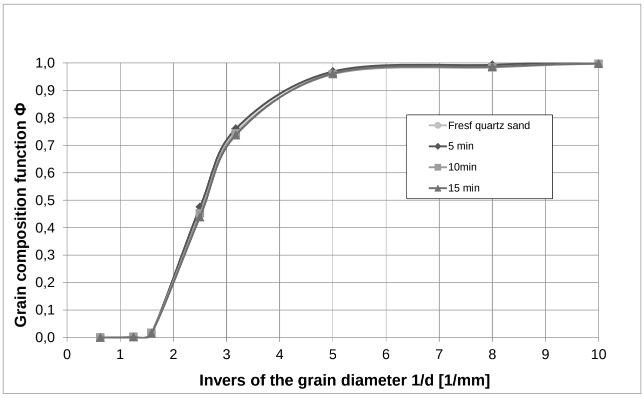

Fig. 11. Grain composition function at 75% of the maximal excitation force and a frequency of 40 Hz for the individual reclamation times

The highest destruction degree of the investigated quartz sand was obtained for thesetting of the unbalanced masses of rotodynamic engines corresponding to 75% of the maximal excitation force, at the operation frequency of these engines being 60 Hz and the process time of 15 minutes.

- The crushing process occurs in a minimal degree at the operation frequency of electrovibrators equal 40 Hz, regardless of the excitation force setting and the process time.

On the basis of these results the preliminary conclusions concerning the performing of the reclamation process of spent moulding sands in the REGMAS reclaimer, can be drawn. It seems, that in case of easily reclaiming sands the optimal reclamation effects can be obtained at the electrovibrators operation frequency equal 50 Hz. Moulding sands which are difficult for the reclamation, have more elastic and less susceptible to crushing coatings of spent binding agents and due to that, will require the device operation at higher frequencies of its rotodynamic engines.

Acknowledgements

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