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Application in Process Industry of the Solid Particles Displacement on a Flat Oscillating Surface

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Abstract: *In this paper we present a series of obtained results from the analysis of the behavior of a solid particle on a flat oscillating surface, a process that is found in separation operations of a heterogeneous mixture of solid particles. In this study, the inclination angle of the flat surface (7 or 10 degrees) and the eccentric device speed (91, 244 and 405 rpm) were varied. The results are extracted from video analysis using two commercial video cameras (Sony DCR-SR 36) with a recording speed of 25 frames per second, using the SynthEyes and Mathcad processing software. The obtained results from the analysis helped us to extract data showing the movement on the three axes OX, OY and OZ, average travel distance, average moving time of the solid particle on working surface and average velocity of the solid particle displacement.*

Keywords*: oscillating surface, inclination angle, solid particle, eccentric device speed*

1. Introduction

The researches applied in process industries are very complex and refers to many aspects, from the particle size reduction, heterogeneous mixtures separation and up to energy consumption and processes optimizing [1-3].

Within the processing industry there are numerous ways to achieve the separation of components of a heterogeneous mix into distinct fractions. One of the oldest but also the most used method of separation is the separation according to size, method taking into account the three dimensional elements of a solid body: length, width and thickness [4]. This method is can be found in the facilities used in different processing industries, but also in analysis laboratories for solid granular products [5, 6].

This separation method is influenced by a series of factors with regard to the characteristics of the mix undergoing the separation process, as well as to the type of equipment carrying on this process, its operating mode and functional features [7-9].

Being aware of the travelling mode of solid particle on flat surface is the key element helping to optimize the mechanical separation process of a heterogeneous mix of solid particles [10, 11].

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The behavior of a solid particle on a flat oscillating surface, due to its complexity, is studied theoretically, by using different types of software to achieve the simulation of this process [9-12] or using different mathematical methods [4, 13, 14], as well as practically, by making experimental determinations for different working conditions or for different facilities [12-14].

This article proposes to study the behaviour of a single solid particle on an oscillating surface. The experimental determinations took place on a laboratory stand, and a video camera has been uses to observe the behaviour of the solid particles.

2. Materials and methods

In order to identify the behaviour of a single solid particle on an oscillating surface, we used a laboratory stand having a blind sieve as working surface. The laboratory stand can vary the inclination angle of the working surface (Figure 1) [15-17].

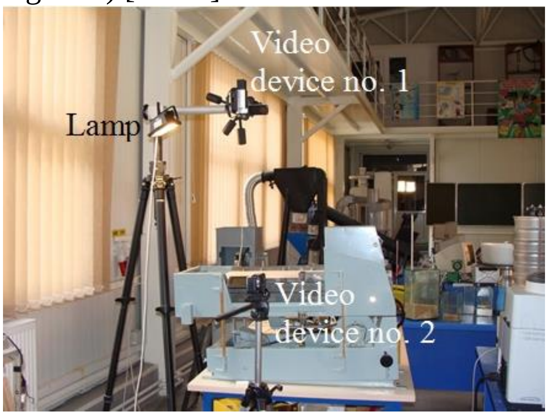

Figure 1. Laboratory stand and positioning of the two video cameras [15-18]

The working surface used in this set of experiments is 265 de mm². In order to extend the working parameters, we also used a rotation speed variator, thus modifying the rotation speed of the crank gear generating the oscillatory movement of the sieve block.

The behaviour of the solid particle was monitored with two Sony commercial video cameras with a recording speed of 25 frames/s. These cameras have been placed in two perpendicular planes xOy and xOz (Figure 2) [15-18].

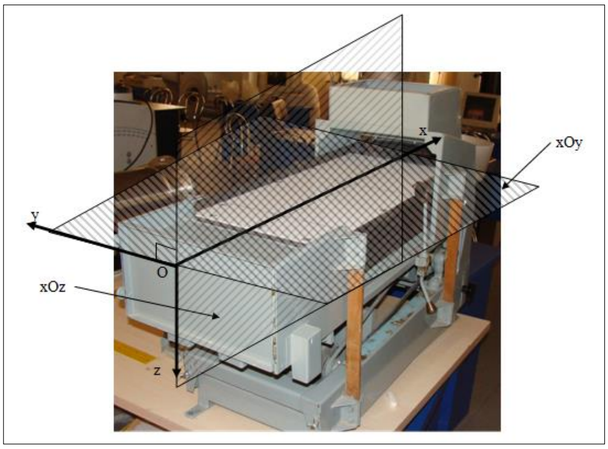

Figure 2. The working surfaces monitored by the two cameras [15-18]

The position of the two cameras aims to generate a three-dimensional trajectory of the solid particle on the oscillating surface. This can be obtained by combining the two final footages as they have the Ox axis in common.

The material used for this study, i.e. the material moved on the oscillating surface, was real soy particles. A specific feature of these particles is the almost spherical shape (Figure 3) [18]. This viewing was made possible through the Excel Tri-plot v1.4.2.xls file [19, 20] by using the dimensional features of the solid particle: length, width and thickness [18].

For a more conclusive analysis of the behaviour of a solid particle on an oscillating surface, a set of experiments have been carried out in which varied series of work parameters of the stand operation mode (Figure 4).

For the experimental determinations we followed the working methodology showed in Figure 5.

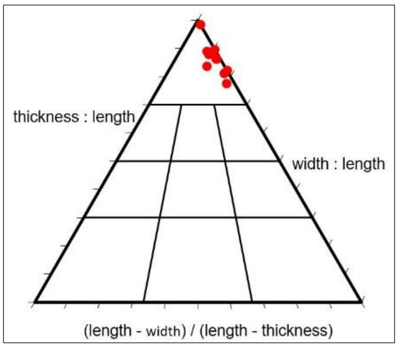

Figure 3. Graphical representation of the soy particles shape [18, 20]

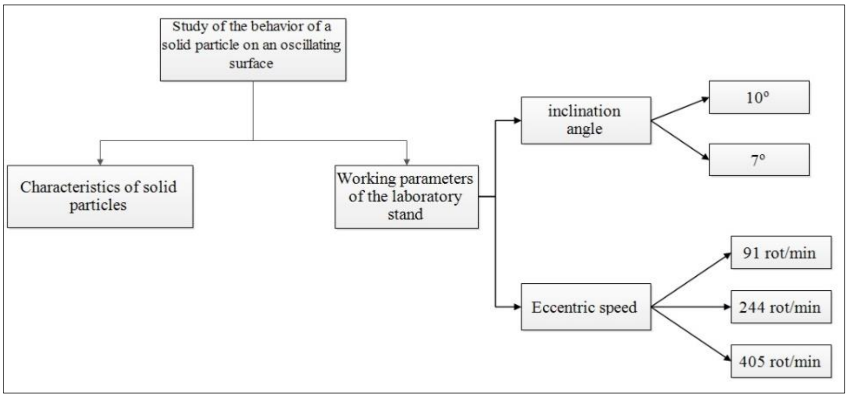

Figure 4. Working parameters

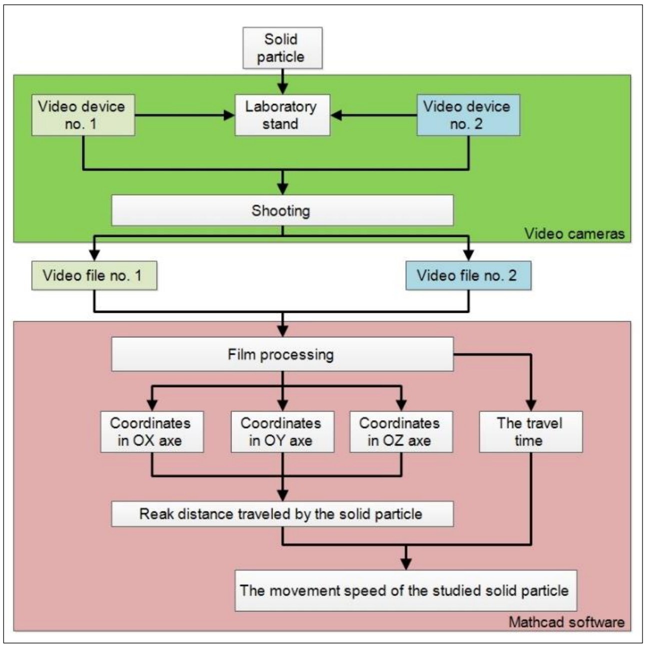

Figure 5. Working methodology [18]

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For the processing the data obtained by the two video cameras, we followed the diagram in Figure 6, by using the following software:

- To extract the date from video files we used SynthEyes software, thus obtaining a *.txt file with the data required by the analysis.

- To process the data, to identify the analyzed parameters, to achieve the conversion and to determine the different characteristics, we used Mathcad software.

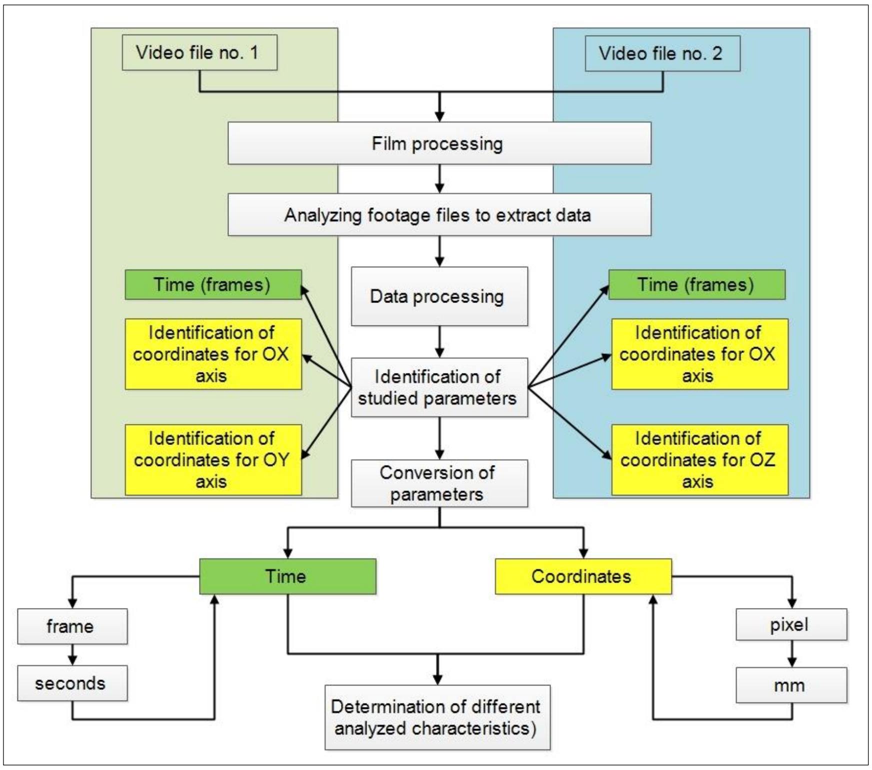


Figure 6. Data processing diagram

3. Results and discussions

Following the experimental determinations, the obtained results have been analyzed and a series of graphical representations have been drawn in order to view the influence exerted by:

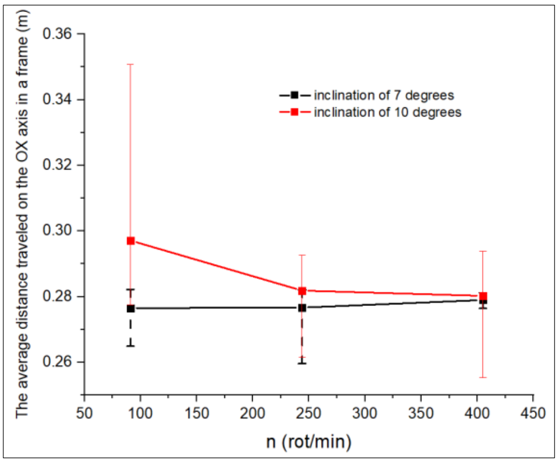
- variation of the inclination angle of the working surface.

- variation of rotation speed of the eccentric device which gives the oscillation movement to the working surface.

The obtained parameters took into consideration the distance of displacement by the solid particle on the working surface, regardless of its direction of movement.

Figure 7 shows the average values of the distances travelled by the solid particle on each individual axis.

For the Ox axis we notice that the average value of the distance travelled by the solid particle on the 10° inclination oscillating surface is higher than the average value of the distance travelled by the solid particle on the 7° inclination oscillating surface. It was also found that at the 7° inclination of the working surface, the distance travelled by the solid particle increases as the rotation speed of the eccentric device increases from 0.276 m to 0.278 m, while at 10° inclination it was found a decrease of the value from 0.281 m to 0.278m followed by an increment up to 0.28 m.



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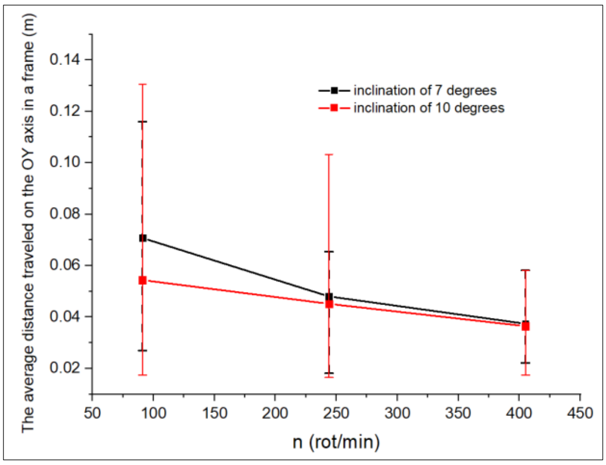

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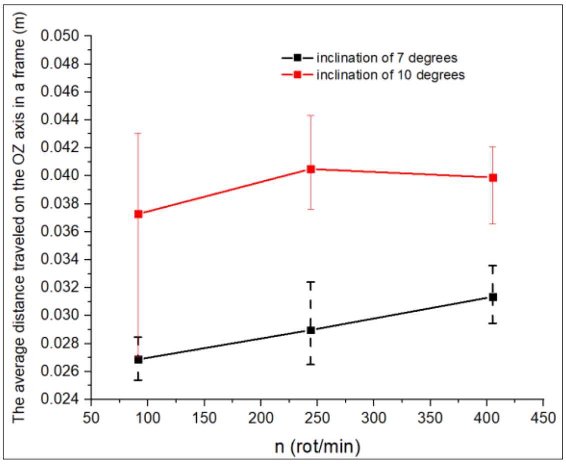

c

Figure 7. Variation of the average distance travelled by the solid particle on the oscillating surface according to the variation of the inclination angle of the working surface and the variation of the eccentric speed (rot/min): a) OX axis; b) OY axis; c) OZ axis

For the Oy axis it was found that at 91 rot/min the difference between the two average values of the distance travelled by the solid particle is 0.02 m. We must consider the fact that the values of the average distance corresponding to the 7° inclination are higher than the values obtained for the 10o inclination. The difference between the values decreases with the increase of the value of eccentric rotation speed, reaching the value of 0.001m at the speed of 405 rot/min. Regardless of the value of the inclination angle of the working surface, the distance travelled by the solid particle decreases with the increase of the eccentric speed.

For the Oz axis, the highest average values of the travelling correspond to the 10o inclination surface. From the analysis of the graphical representation, it was found that the value of this parameter increases directly proportional to the increase of the value of the eccentric speed for the two values of the inclination angle of the working surface.

A general feature of the variation of the solid particle travelling on the oscillating surface is represented by the fact that the highest values are obtained for the travelling on the Ox axis, followed by the travelling on Oy, and the lowest value is obtained for the travelling on the Oz axis.

Following the analysis of the variation of the average travelled distance of the solid particle on the oscillating surface (Figure 8) it was found that:

- For the eccentric rotation speed of 91 rot/min., the highest values of the distance travelled is obtained for the 10o angle, i.e. 0.96 m, and for the 7° angle is 0.95.

- As we increased the speed up to 244 rot/min, we found that the value of the distance travelled on the working surface, for the 10° angle, decreased by 0.013 m, and for the 7° angle decreased by 0.059 m.

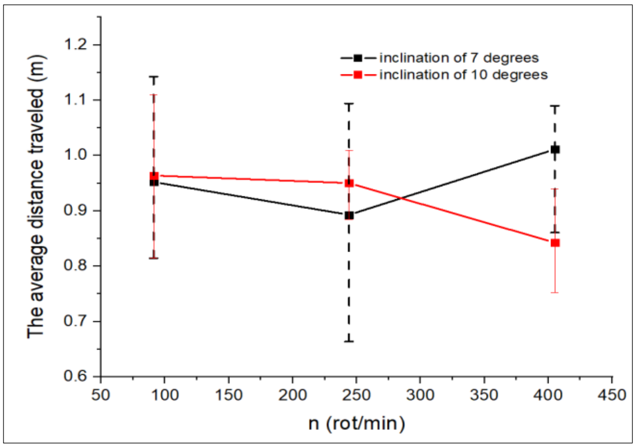

Figure 8. Variation of average distance travelled of the solid particle on the oscillating surface according to the variation of the inclination angle of the working surface and the variation of the eccentric speed

For the last value of the speed (405 rot/min) it was found that for the 10° angle the value of the average distance travelled by the particle decreases by 0.1 m compared to the previous value, and for the 7° inclination angle the value of the average distance travelled by the particle increases by 0.118 m compared to the previous value.

After analyzing the variation of the time needed by the solid particle to travel the 265 mm (Figure 9) it was found that:

- The highest values are obtained for the 7° inclination angle of the working surface.
- For the value of 91 rot/min it was obtained, for a 10° inclination angle, an average time in which the solid particle travels the monitored distance of 0.88 s, and for the 7° inclination angle the value is 1.11 s.
- For the 244 rot/min speed it was found that, regardless of the value of inclination angle of the working surface, the average time in which the particle travelled the 265 mm decreased by 0.08 s.
- For a 405 rot/min eccentric speed it was found that for the 7° inclination angle the time in which the solid particle travels the monitored distance increased by 0.112 s compared to the previous value, and in the case of the 10° inclination angle of the working surface the value of time decrease by 0.064 s compared to the previous value.

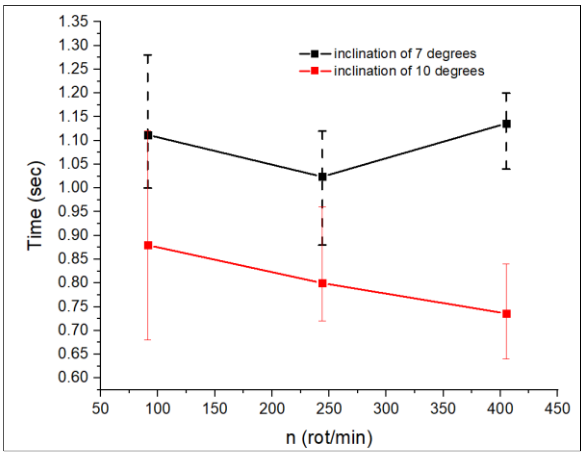

Figure 9. Variation of total travelling time of the solid particle on the oscillating surface according to the variation of the inclination angle of the working surface and the variation of the eccentric speed

Knowing the average value of the distance travelled by the solid particle and the time required by the travelling, we can determine the average travelling value. Analyzing the graphical representation in Figure 10, the following conclusions can be drawn:

- The highest values of the average travelling speed of the solid particle are obtained in the case of the 10° inclination angle of the working surface.

- In the case of a 7° inclination angle working surface, it is found that the value of the average speed increases directly proportional to the increase of the eccentric speed: from 0.88 m/s at 91 rot/min reaches 0.92 m/s for 405 rot/min.

- The shape of the variation of the average speed of the travelling of the solid particle on an oscillating surface is different in case of an inclination angle of the working surface of 10°. Initially, the value of the average speed increases from 1.18 m/s to 1.26 m/s corresponding to the interval 91-244 rot/min for the eccentric speed. For the last value of the eccentric speed we found a decrease of the average travelling speed, this reaching the value of 1.21 m/s.

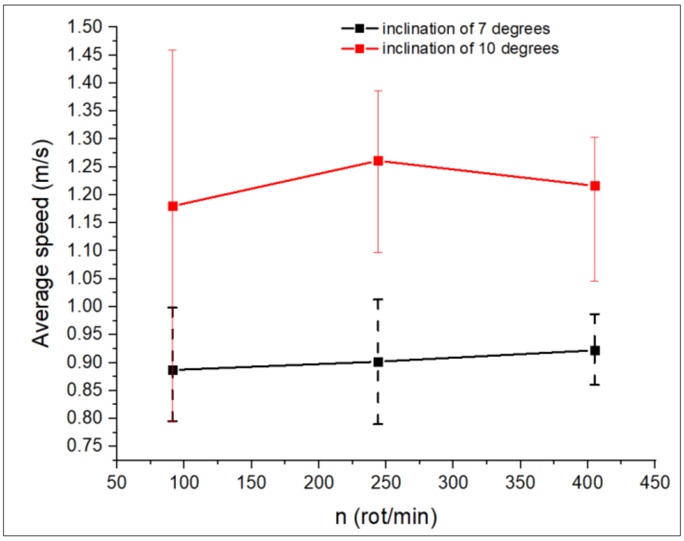

Figure 10. Variation of average travelling speed of the solid particle on the oscillating surface according to the variation of the inclination angle of the working surface and the variation of the eccentric speed

4. Conclusions

After the analysis of the experimental results, the following conclusions are to be drawn:

a) For the travelling on the OX axis: The inclination angle of the working surface plays an important part, but this decreases with the increase of the eccentric speed.

b) For the travelling on the OY axis: The values obtained do not represent a considerable difference, regardless of the inclination angle and the eccentric speed, as we observed a general decreasing tendency.

c) For the travelling on the OZ axis:

- We observed a considerable difference between the values obtained at the 7° inclination angle, where the lowest values have been obtained, and the 10° angle, where we obtained the highest values.

- The eccentric speed sets an increasing trend to the obtained values, regardless of the inclination angle of the working surface.

d) For the average travelling distance: Initially, from 91 rot/min to 244 rot/min we observe a decrease of this parameter, regardless of the inclination angle. At 405 rot/min we observe that the value of the average travelling increased significantly for a 7° angle, and for 10° angle the increasing trend is kept, thus obtaining a significantly lower value.

e) For the total average travelling time of the solid particle on the working surface:

- For the 7° inclination angle it was initially found that the travelling time of the solid particle on the working surface decreases with the increase of the eccentric speed, followed by a significant increase of the value of this parameter for the last value of the speed.

- In the case of the 10° angle it is found that the variation of the total travelling time of the solid particle on the working surface is inversely proportional to the variation of the working speed.

f) For the value of the average travelling speed of the solid particle:

- In the case of this parameter it was found that the inclination angle of the working surface plays an important part, this obtaining the highest values for the 10° angle, and for the 7 degrees angle the lowest values.

- The variation of the eccentric speed directly influences the variation of the average travelling speed.

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