Application of Sorting Processes in the Method DEM

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Summary

Due to the global increase of population the volume of waste that needs to be processed as fast as possible. There are situations in current practice where transport facilities are designed for certain, precisely specified bulk materials. Due to this fact the progress of modernization is advancing very rapidly. Companies are forced to use the new bulk materials with non-standard mechanical and physical properties. This implies the fact that companies have to also adapt to transport equipment for these new bulk materials. To optimize the transport system we need to know the exact parameters of the conveyed bulk material and also parameters transport equipment. To avoid economically challenging design of the prototype transport equipment that may not work reliably we use a software method of DEM (discrete element method). Using this method we are able to simulate the entire transport route and verify design changes in the traffic flow of the material before the production phase. We can also try non-standard construction design of the transport equipment or storage equipment. We can see how the bulk material behaves on our designed equipment. The simulation shows to us places of disturbances flow of bulk material on transport equipment or storage equipment. The aim of this article is to describe the use of simulation modelling using the DEM method (discrete element method) in a sorting process application in the field of processing and handling wastes. A wide range of application options of this method is available. The DEM method can be used to create a computer simulation of any transport process for specific waste materials or waste mixtures. In this way it is possible to determine how the given material will behave on specific transport or storage equipment.

Keywords: DEM method, sorting processes, material

Introduction

Searching for new technologies and methods to achieve savings in any form is a modern global trend. The required savings might include energy, finances, time, human resources, technological or process savings. This phenomenon is visible everywhere on an everyday basis, both in the work process and in personal life. A typical example would be the replacement of manual labour by automated lines. Automated lines can operate 24 hours a day, they do not require human operators and save time, i.e. also money. It goes without saying that these changes have many disadvantages as well, for instance, the high initial costs for successful implementation of the change or an increase in the unemployment rate.

The main impulse for economic solutions is scientific research in the given field.

Our research team at the Laboratory of Bulk Materials, part of the VSB-Technical University of Ostrava, focuses on research and development in the field of designing transport and storage equipment for bulk materials. All designs are based on knowledge of the mechanical and physical properties of the conveyed material. For this purpose we use state-of-the-art laboratory equipment, measuring equipment and other tools. A dominant tool is the DEM method (discrete element method), which enables a simulation environment for process applications to be created. It consists of a calculation software method used to obtain detailed information about the behaviour of conveyed material on transport routes and storage equipment.

The subject of this article is monitoring of a sorting process using the DEM simulation method.

The sorting is realized on sieves with different mesh sizes. The sorting process itself is done by specific circular vibrations. The sorted material consisted of glass of different sizes and shapes.

Materials and methods

Description of the DEM method

The DEM method is based on the mutual interactions of individual particles with each other, and particles with the transport equipment, in our case, the vibrating sorting sieve. Force interaction of individual particles at each contact joint also plays a significant role. An important function of the DEM method is also the option to define the mechanical and physical properties measured on our state-of-the-art laboratory equipment for the generated particles. This ensures that the material defined in the EDEM Academic software has comparable properties to the actual material to be verified by the simulation. Input parameters of the EDEM Academic software consist of the above-mentioned mechanical and physical properties of the conveyed material. The second dominant part is the insertion of the 3D model of the transport or storage equipment that we wish to monitor (4-10).

Conveyed material

In order to come as close as possible to the actual sorting process, it is necessary to program material in the EDEM Academic software with comparable mechanical and physical properties (1) as the actual particles. For the sorting process we selected a mix of glass particles of the same shape but with differing sizes. Particles created in the EDEM Academic environment are shown in Fig. 1.

Number of generated particles of individual sizes for the sorting process:

Size 12 – 1000 pieces; Weight - 0.498 kg
Size 18 – 1000 pieces; Weight - 1.683 kg
Size 24 – 1000 pieces; Weight - 3.986 kg

Mechanical and physical properties of glass particles:

Density ρ=2478kg/m3
Poisson's ratio: μ=0,25
Shear modulus: G=33GPa

Properties related to mutual contacts of particles with the steel sorting sieve:

Restitution coefficient kr= 0.5
Static friction coefficient kst=0.3
Rolling friction coefficient kvt=0.01

3D model of the sorting equipment

The sorting equipment consists of three basic parts: a frame, elastic elements and the vibrating element. The vibrating element is further equipped with a pair of drive that

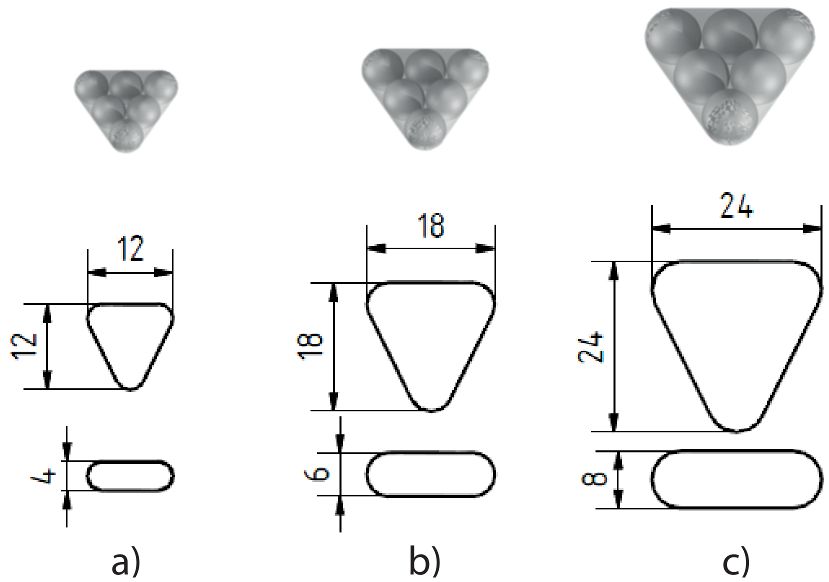

Fig. 1 Representation of aggregate particles in the EDEM Academic software a) size of 12 mm; b) size of 18 mm; c) size of 24 mm

Rys. 1 Reprezentacja ziaren kruszywa w oprogramowaniu EDEM Akademic dla wielkości ziren a) 12 mm; b) 18 mm; c) 24 mm

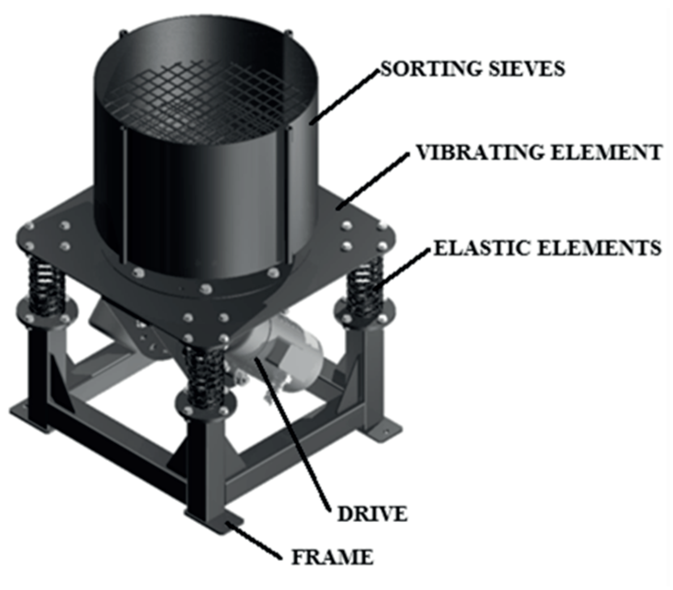

Fig. 2 Representation of the 3D model of the sorting equipment

Rys. 2 Prezentacja modelu 3D dla układu sortowania together create a vibrating spiral harmonic motion when turned on. The sorting process itself is realized on three circular square-meshed sieves arranged one on top of the other. A complete model of the sorting equipment is shown in Fig. 2. In the EDEM Academic application, individual contact and non-contact parts of the system are assigned the physical properties of the material to be used for the production of the actual equipment.

Fig. 3 shows the used square-meshed sieves with differing sizes. The bottom sieve has the smallest mesh size, 10x10 mm. The middle size is 15x15mm and the upper sieve has a mesh size of 20x20mm. The figure includes the size across the mesh, which is always 1.41*a, where "a" is the length of the mesh side. This fact causes inaccuracies in sorting of the material. Fig. 1 clearly shows that the perimeter of glass particles is always bigger than the sieve mesh size but due to the larger size of the mesh diagonal, some of the particles fall through.

Results and discussion

Sorting process

Parameters of sinusoidal repetitive motions configured in the EDEM Academic software

Rotation around the "x" axis. 0.32˚

Shift in the direction of the "x" axis. 0.81mm

Shift in the direction of the "y" axis. 0.78mm

Frequency: 25Hz

Fig. 5 shows the final form of the sorting process for 10

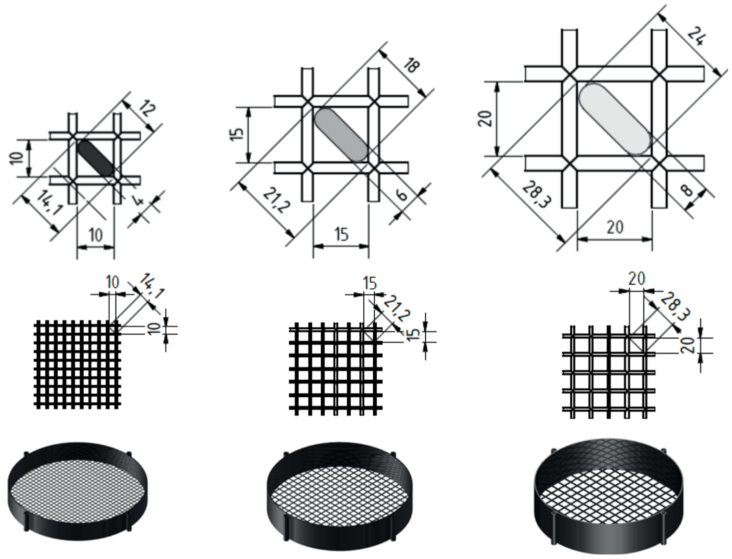

Fig. 3 Representation of used sieves

Rys. 3 Prezentacja użytych sit

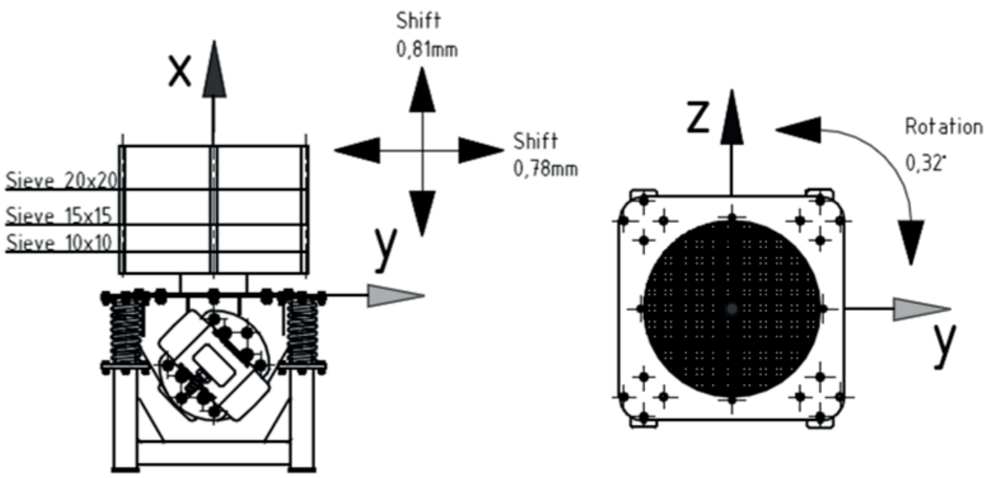

Fig. 4 Representation of individual components of the vibration motion

Rys. 4 Prezentacja pojedynczych składowych ruchu wibracyjnego

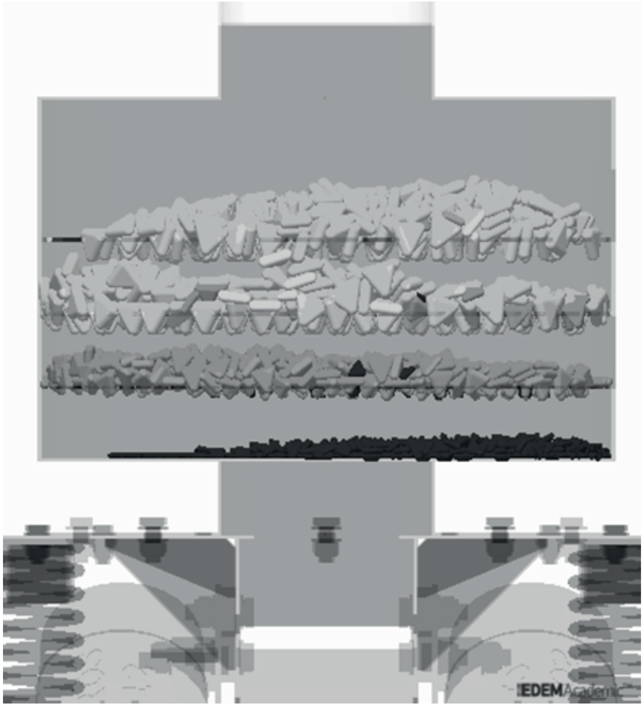

Fig. 5 Representation of the proportion of individual particles in sieves

Rys. 5 Prezentacja proporcji pojedynczych ziaren w przesiewaniu

Tab. 1 Shares of particles on each sieve

Tab. 1 Udział ziaren w każdym przesiewie

		Plate	Sieve 10x10	Sieve 15x15	Sieve 20x20
Mass [kg]	Size 12	0,465	0,032	0,001	0
	Size 18	0	1,453	0,199	0,031
	Size 24	0	0	1,85	2,136
Total mass [kg]		0,465	1,485	2,05	2,167
Number of particle [ks]	Size 12	934	64	2	0
	Size 18	0	864	118	18
	Size 24	0	0	462	538
Total number of particle [ks]		934	928	582	556

seconds. The black colour represents particles with a size of 12mm that are located under the 10x10mm sieve, as well as above the 12x12mm sieve. The gray colour represents particles with a size of 18 mm that are located under and above the 15x15mm sieve. The light gray colour represents particles with a size of 24mm that are located under and above the 20x20mm sieve. From this it follows that the sorting is not perfect and that square-meshed sieves are not suitable for glass particles with the shapes stated in the "Materials and methods" section.

In the Table 1, are shown shares of particles on each sieve. Table shows us the disposition of particles on each sieve in a steady state after a sorting process. We can also see the particle distribution to each part of the separator and the weight.

Conclusion

Using the DEM method, we reached the conclusion that the final sorting state of glass particles of differing sizes (resembling glass splinters) using square-meshed sieves is not ideal. Particles with a size of 12mm and width of 4 mm fall through sieves with a 10x10mm mesh size due to the diagonal size of 1.41*a, where "a" is the length of the mesh side. This fall-through also applies for other particle sizes.

In order to ensure the required sorting, different technology needs to be used or a different mesh shape, e.g. circular-meshed sieves, must be used. Application of the DEM method for transport processes has significant benefits for the industrial sector. Simulation procedures allow us to try even non-standard solutions that could not be realized in practice. Another significant advantage is the already mentioned financial savings of not designing a prototype that might not ultimately work. This is associated with the high financial costs for activation modifications of the designed prototype.

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Zastosowanie procesu sortowania w metodzie DEM

Z powodu globalnego zwiększania się populacji rośnie objętość odpadów, które muszą zostać przetworzone tak szybko jak to możliwe. Aktualnie, w praktyce zdarzają się sytuacje gdzie urządzenia służące do transportu zaprojektowane są dla pewnego, precyzyjnie określonego materiału masowego. Z tego powodu postęp w modernizacji rozwija się bardzo gwałtownie. Firmy zmuszone są do używania nowych materiałów masowych o niestandardowych mechanicznych i fizycznych właściwościach. Powoduje to, że firmy muszą również dostosować sprzęt transportowy na potrzeby nowych materiałów. Aby zoptymalizować system transportowy musimy znać dokładne parametry przewożonego materiału masowego jak i również parametry urządzeń transportowych. Aby uniknąć wyzwania ekonomicznego związanego z budową prototypowego urządzenia transportowego, który mógłby być zawodny, używa się metody programowania DEM (discrete element metod – metoda elementów dyskretnych). Użycie tej metody umożliwia symulację całej trasy transportu i zweryfikowanie zmian w projektowaniu natężenia ruchu przed fazą produkcji. Można również przetestować niestandardowe projekty konstrukcyjne urządzeń transportowych lub urządzeń do przechowywania. Możliwe jest również zobaczenie jak materiał masowy zachowuje się na zaprojektowanym wyposażeniu. Symulacje te pokazują miejsca gdzie przepływ materiału masowego, na urządzeniach transportowych lub do przechowywania, jest zakłócony. Celem artykułu było opisanie użycia modelowania symulacji, z użyciem metody DEM, stosowanego w obszarze obróbki i operowania odpadami. Dostępny jest szeroki zakres zastosowań dla tej metody. Metoda DEM może być użyta do stworzenia symulacji komputerowych jakiegokolwiek procesu transportu specyficznych materiałów odpadowych lub mieszanin odpadów. Tym sposobem możliwe jest określenie jak dany materiał będzie zachowywał się podczas transportu lub na określonych urządzeniach do przechowywania.

Słowa kluczowe: metoda DEM, proces klasyfikacji, materiał