Influence of Container Shape and Particulate Shape on the Behaviour of Bulk Material in Storage Devices Using the Edem Program

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Summary

This article describes application of the EDEM program to the design of the container shape. Modelling of the motion behaviour of the powder particles by using this software tool is an important step toward understanding the movement of the bulk material as a whole. This model enables us to examine the behaviour of the various parameters involved in the bulk material flow process in containers of different shapes and to develop new applications in this area.

Keywords: bulk material, EDEM program

Introduction

This paper concerns transport and handling equipment and the monitoring of partial parameters resulting in a qualitative evaluation of bulk material flow inside a container. The partial parameters include vector speed fields, segregation and flow profiles.

The comparison of experimental outcomes with a new simulation method opens the door to new applications in storage, but most importantly leads to a reduction in financial costs connected with the structures and greater efficiency of the bulk material flow.

Current condition of the matter

The age of drawing and designing on draughting tables has long gone.

Now we are entering a phase where we can virtually load the whole designed structure and simulate its weak points. This simulation means imitating a certain real object, the key properties or an abstract process. Simulation is a commonly used method for modelling of natural systems that aims to gain information on their functionEng. The application of simulations is expanding to safety engineering, testing, training courses, education and optimization.

Storage containers are vessels of geometric shapes used for the storage of bulk materials. They are commonly called containers or silos. They can be used as a store for a certain amount of material for a longer period or as equalizers of the subsequent transport, thus forming operative supplies.

Division according to the shape:
- rectangular (pyramidal)
- circular (conical)
- Imhoff tanks

Engineering works are often badly designed because of insufficient theoretical knowledge of the behaviour of bulk material. Consequently, the flow of bulk material in the container is often interrupted. Removing defects on a finished engineering work is fre-

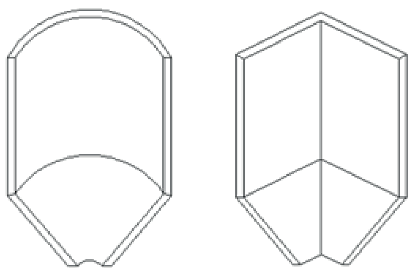

Fig. 1 Circular and Rectangular containers

Rys. 1 Przestrzeń robocza prostokątna i okrągła quently a costly problem; extension of the knowledge of bulk material behaviour is thus emphasised.

The first frequent problem is badly designed geometry of the container which does not respect the properties of the stored material. This particularly concerns the discharge hole. Its size, shape and position in the container walls is crucial. The position of the discharge hole entails other important aspects such as the angles of the walls, and the angles of the edges in the case of pyramidal containers.

Another problem is poorly chosen contact material for the container's inner walls.

Discharge of the container is a complicated process affected by various factors which complicate the actual flow of the bulk material. The basic mechanisms of bulk material flow include mass flow and core flow. In mass flow, the bulk material leaves the hopper in the sequence in which it was poured. In core flow, the first poured layer of the bulk material is the last to leave the hopper.

Loose material

The behaviour of the particular material reflects its structure, which depends on the shape and size of an individual particle that moves in the environment of other particles. The behaviour of the particular material is affected by border conditions, which affect the loose mass, particularly inter-particulate bonds. This is the reason why knowledge of the bulk material and its classification is the basic key to understanding the material's behaviour.

Classification of bulk materials as regards transport equipment was one of the suggestions for the classification of bulk materials by means of FEM (Fédération Européenne de la Manutention). According to this suggestion, a loose material is characterized by five factors (granularity, compactness, behaviour during transport, bulk density and temperature).

Besides the classification, it is also important to know the properties of the material as regards its internal structure, i.e. its mechanical-physical properties.

Mechanical-physical properties of loose materials

The behaviour of loose material is completely different to the behaviour of continual material and depends on its own structure and the movement of individual particles. The condition of loose material can change within relatively narrow limits. Consequently, the following parameters of loose material should be acknowledged when designing engineering works:

- granularity [%]
- moisture W [%]
- bulk density ρ_v [kg.m^{-3}]
- powder density ρ_s [kg.m^{-3}]
- natural repose angle ψs [°]
- angle of external friction φw [°]
- effective angle of internal friction φ_e [°]
- linearized angle of internal friction φ_{lin} [°]
- initial shear stress t τ_o [Pa]
- main vertical stress σ_1 [Pa]
- main horizontal stress σ_2 [Pa]
- pressure strength limit σ_c [Pa]
- flow factor $_{ffc}$ [-]

For a comparison with the EDEM simulation program, we chose glass beads 5 mm in diameter. This material was subjected to laboratory measurement of its mechanical-physical properties. Based on the knowledge of the loose material's properties, we were able to design experimental models and authentic virtual models for comparison in EDEM.

Recording of the experimental process

The process proceeding inside a closed vessel is subject to various influences and border conditions. Experimental models that allow a glimpse inside the container were made for a better understanding of the process. To better understand and analyse the process, it is necessary to make a quality recording for evaluation; a high-speed camera is suitable to capture the speed of particles in the loose material. The recording process was divided into individual steps for the individual records:

1) Composition of the experimental model
2) Filling the model with bulk material
3) Setting up the recording device (a high-speed camera)
4) Start of recording and subsequent opening of the discharge hole in the experimental model

Computer simulation in the EDEM program

We can make a model similar to the real model by computer simulation in the EDEM program to monitor and study the system's functionality. The behaviour of this system can then be anticipated by a change in the input shape parameters.

EDEM is a worldwide software platform. DEM (Discrete Element Method) is a method able to create simulations and analyses necessary for solutions to complicated problems in the design, prototyping and optimizing of bulk material handlEng. It is possible to make a model of a complex granular system by means of EDEM.

Conclusion

The behaviour of bulk materials can only be anticipated approximately. To overcome this problem, simulation programs which maximally approach the

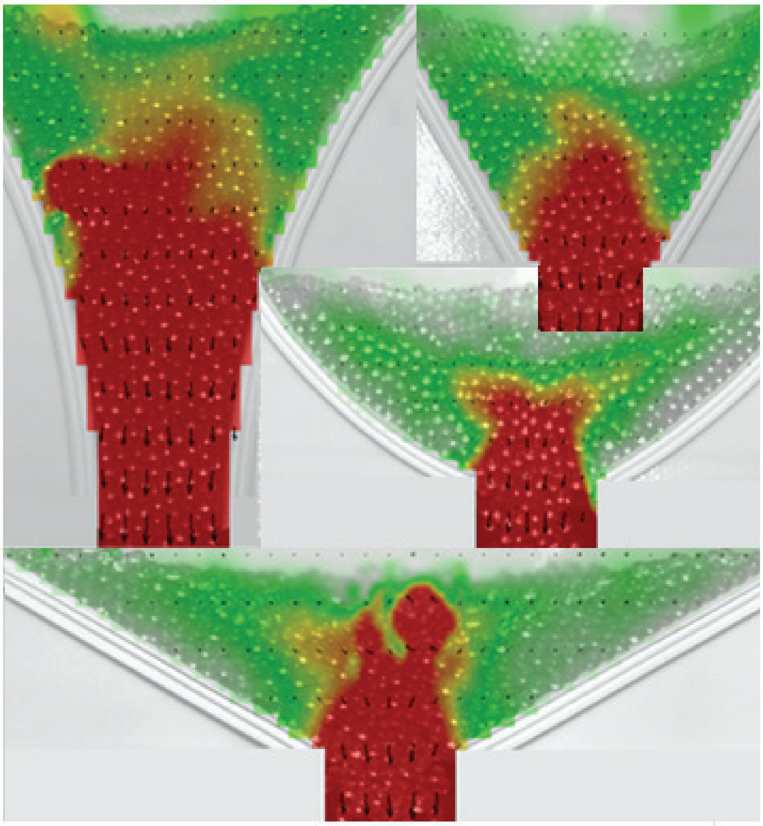

Fig. 2 Speed vector field of the particles during discharge of the container using the PIV method

Rys. 2 Wektor prędkości cząstek podczas wyładowań, metoda PIV

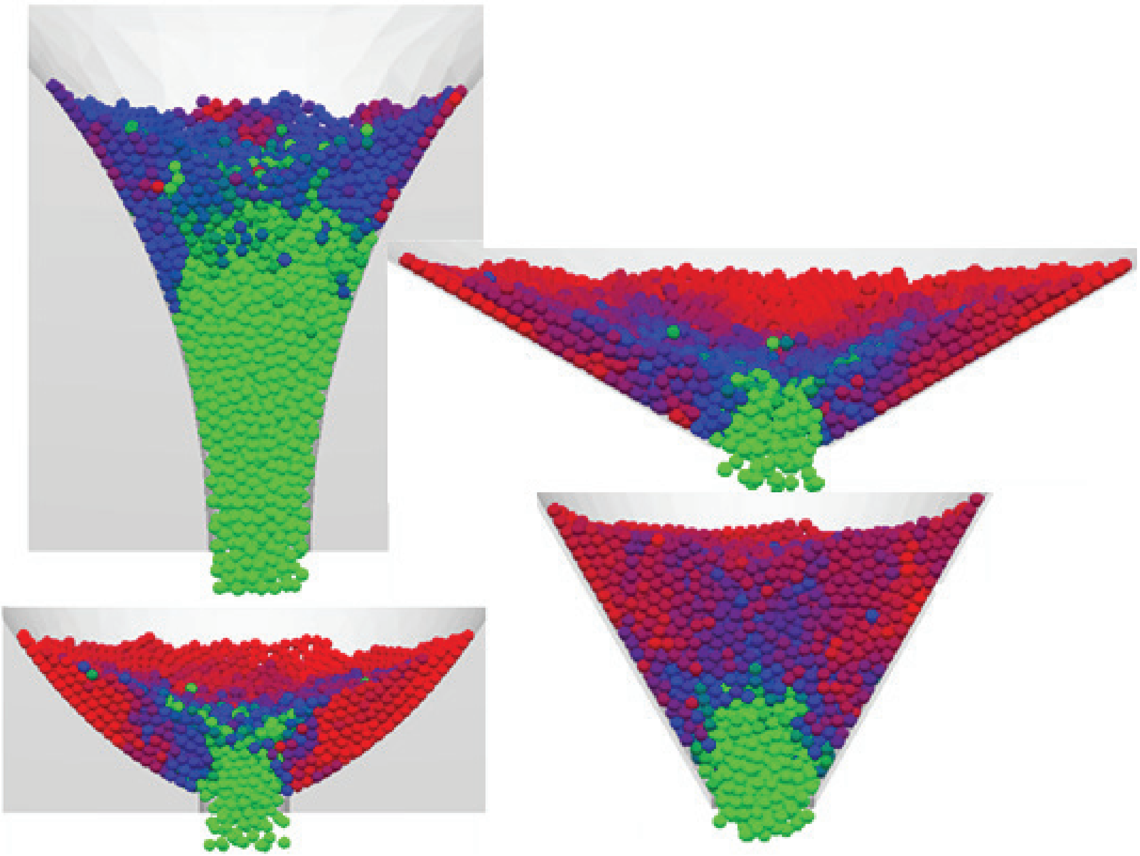

Fig. 3 Speed of the particles during the container's discharge in EDEM

Rys. 3 Prędkość cząstek w czasie wyładowania kontenera w EDEM actual physical condition representing the physical reality are developed. The EDEM simulation program, which utilizes the discreet element method, is used for simulations of the movement of a particular mass in our laboratory.

In this paper, the simulation concerns the speed of the container's discharge in relation to a change in the discharge hopper shape. The credibility of the simulation was validated by an experimental measurement by means of PIV using high-speed recording of the process.

The results obtained by the experimental measurement describe the fact that the fastest discharge of the container was achieved by the application of a concave hopper. It was also observed that the application of a concave hopper results in a mass flow mechanism. The same flow mechanism occurs in hoppers with a wall angle of 60°. Comparable discharge periods were measured in containers with hopper walls with a 30° angle and a hopper with a special convex shape.

Validation performed by the application of the EDEM program confirmed this fact with high accuracy, but calibration of the program was more time consuming because the simulation program does not use measured mechanical-physical properties applied in structural calculations for input of the material properties.

Simulation programs can prevent structural defects, thus saving costs connected with their removal.

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Streszczenie

Artykuł ten opisuje zastosowanie programu EDEM w projektowaniu kształtu pojemnika. Modelowanie zachowania ruchu cząstek proszku przy użyciu tego narzędzie jest ważnym krokiem w kierunku zrozumienia przepływu materiału sypkiego jako całości. Model ten pozwala na zbadanie zmiany różnych parametrów wpływających na proces przepływu materiałów w przestrzeniach roboczych o różnym kształcie i opracowanie nowych rowziązań w tej dziedzinie.

Słowa kluczowe: materiał masowy, program EDEM