Optimisation of Geometry of the Chain Conveyor Carriers by DEM Method

Martin ZIDEK[1)], Jiri ZEGZULKA[1)2)], Lucie JEZERSKA[2)], Jakub HLOSTA[1)], Jan NECAS[1)2)]

[1)] VSB – Technical University of Ostrava, Faculty of Mechanical Engineering,Institute of Transportation, 17. listopadu 15, 708 33 Ostrava, Czech Republic; email: martin.zidek@vsb.cz
[2)] VSB – Technical University of Ostrava, ENET Centre, Laboratory of Bulk Materials, 17. listopadu 15, 708 33 Ostrava, Czech Republic; email: lucie.jezerska@vsb.cz

DOI: 10.29227/IM-2015-02-24

Abstract

The article presents the results of simulation of the Discreet Elements Method (DEM) applied to the chain conveyor model with regard to optimisation of its carriers´ geometry. The work is focused on the impact pulses of carriers in the first part of the chain conveyor´s transport cycle and the influence of a change in the carrier element´s geometry on vector motion of particles and velocity differences of motion of the transported material. The issue is solved by the DEM method, where a 3D model of the tested equipment and a simulation of material transportation in the transport system is created. Virtual 3D models of equipment can be easily adjusted such as changes in the structure dimensions. In the text, it is the approach to testing the influence of the chain conveyors carrier´s geometry on the character of motion of particles. The results show that the carrier´s geometry changes the trajectory of motion and velocity of the transported material particles during their transport on the chain conveyors.

Keywords: DEM, particle movement, chain conveyor, spherical particles

Introduction

A system of chain conveyors with carriers is the usual transport equipment method used in the industry for transportation of bulk materials [1, 2]. Design of chain conveyors is relatively simple [3, 4]. They consist of a measuring trough in which material is transported and an endless towing element with carriers. They are also equipped with a driving station, return station and tension equipment. The trough contains the upper and lower sections which are divided by an intermediate bottom or simply by guiding of the upper section. The device [5] has a driving unit for changing the transport speed as shown Fig. 1.

In the scope of the study, a solution to the influence of the change of the carriers´ geometry on transport of bulk materials in the transport was proposed. In Fig. 2, two types of carriers´ geometry solutions are shown. The first type of carrier (Fig. 2a) presents geometry commonly used in practice [6]. The second type of carrier in Fig. 2b, shows cylindrical convex geometry which is currently the alternative option in the phase of development and testing.

The carriers are fastened to the towing element with a spacing distance “t”. The value of 100 mm was used for this study. Movement of the carriers causes the material to start moving and shifting in the trough occurs. Material movement is thus influenced by the motion of the carriers [7]. For the purpose of assessing the influence of change in carriers´ geometry on the transport of bulk material spherical parts by using the DEM method was chosen impact leap of thereby forwarded kinetic impulse to particles. Discreet Elements Method (DEM) uses software interface to simulate a flow of bulk material in the engineering parts [8, 9]. Model material is defined by input parameters, mechanical and physical properties which can be determined by means of laboratory equipment. The basic data includes friction parameters of transported material, particle density, shear modulus and Poisson's constants [10, 11].

Influence of the change of carriers geometry on transported material

Movement of particles in the bulk material is dependent on the following factors - placement of the particles in the measuring trough, the number of surfaces contact, the particles segregation and the compaction of material [12, 7].

In theory, when sorting the particles, many differently and chaotically sorted particle systems occur in the trough. The different arrangements of particles in the trough are shown in Fig. 3. For comparison reasons, the theoretical arrangement of particles was done such that the particles contain as many surfaces contact as possible in order to minimize inter-particle spaces. The two different arrangements of the particles are apparent depending on the particular shape of the carrier. In the starting phase of the chain conveyor, the par-

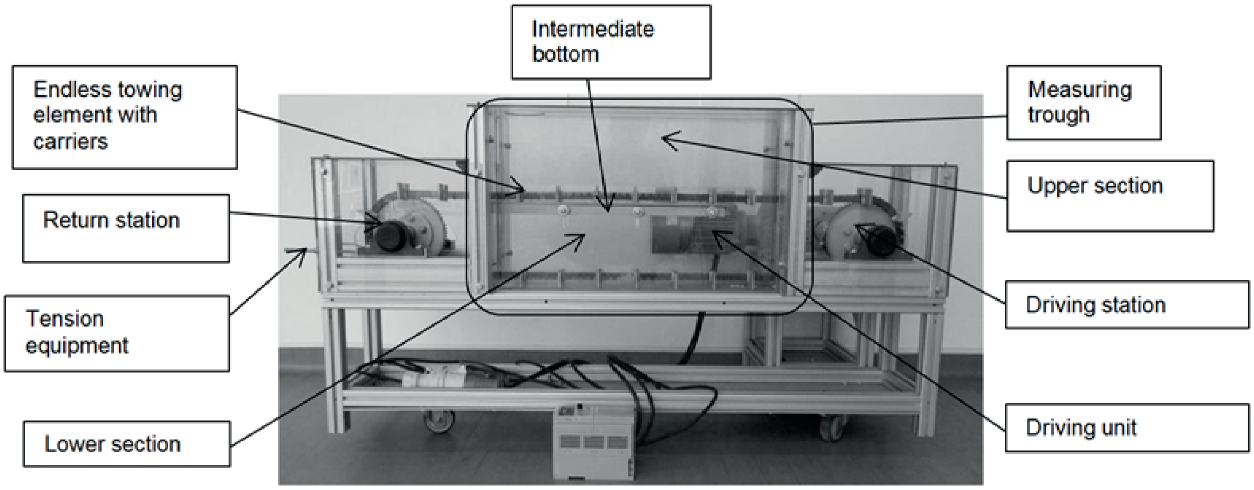

Fig. 1. The real model of the chain conveyor with carriers

Rys. 1. Model rzeczywisty przenośnika łańcuchowego

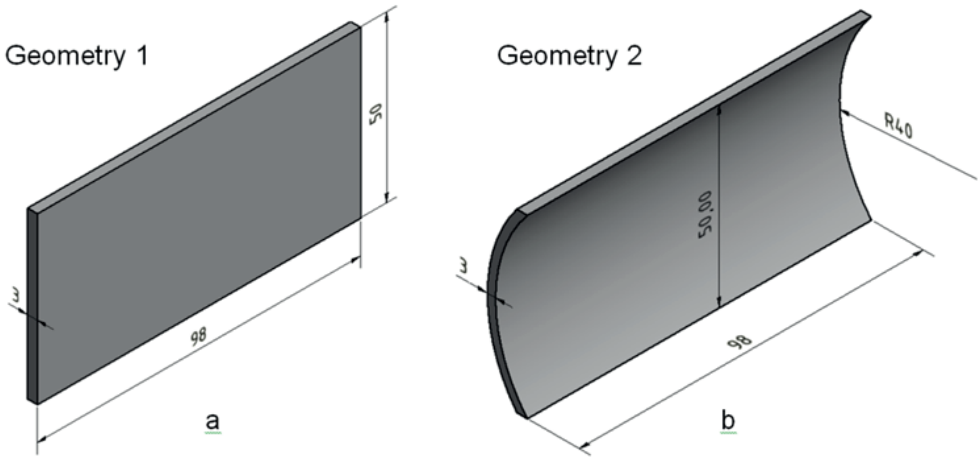

Fig. 2. Designs of the carrier geometry

Rys. 2. Geometria przenośnika

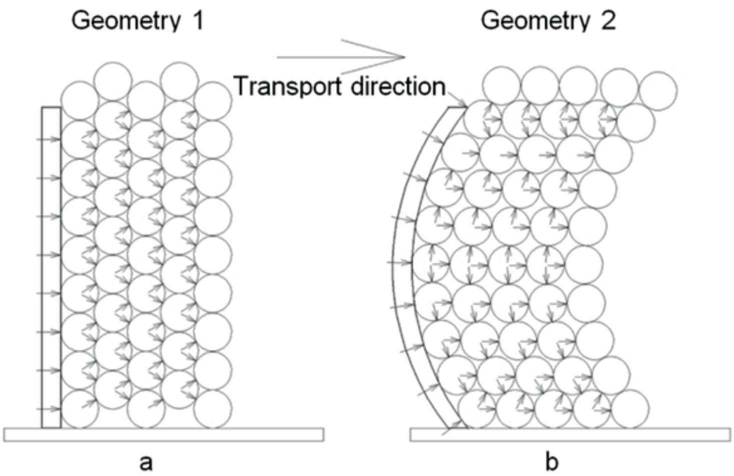

Fig. 3 Representation of spherically shaped particle contact surfaces occurring in the continuous flow of materials of the same type but with either of two alternative carrier geometries.

Rys. 3. Reprezentacja kulistych powierzchni styku ziaren występujących w ciągłym przepływie materiału na różne kształty przenośnika

Tab. 1. Basic simulation data used during simulation by the DEM

Tab. 1. Podstawowe dane do symulacji DEM

Particle density, kg·m^{-3}	1780
The coefficient of static friction for the particles – particles, -	0.35
The coefficient of static friction for the particles – geometry, -	0.44
The coefficient of rolling friction for particles – particles, -	0.014
The coefficient of rolling friction for particles – geometry, -	0.013
The coefficient of restitution for particle – particle, -	0.48
The coefficient of restitution for particle - geometry, -	0.82
Speed of chains with carriers, m·s^{-1}	0.063
Acceleration time of chains with carriers, s^{-2}	63

ticles start moving due to emerging mutual surfaces contacts which are able to transfer velocity and motion vectors from particle to particle. As a result of the different shape of the carrier, the size of velocity vectors changes (see Fig. 3).

In case of geometry 1 (Fig. 3a), the particles move continually during the entire transport cycle with roughly identically big contact surfaces which shift material similarly in all planes. Owing to the carrier geometry change, particles´ velocity vectors change their direction and move differently in the given planes. In simulations, we mainly deal with changing the direction and motion of velocity vectors.

For creation of mathematical models describing the influence on the particles´ motion by changing the carriers geometry basic simulation data was used (see Table 1 and Fig. 2) and particle arrangement was selected so that it contains a minimum number of contact surfaces (see Fig. 3).

Discrete element analysis

The model of chain conveyor has been created using simplification conditions. Into the measuring trough of given sizes (see Fig. 1) has been modelled one branch of the conveyor with fixed parameters carriers (see Tab. 1, Fig. 2).

The spherical shape particles with 5.96 mm diameter were selected for simulation. Some 25 000 particles were spontaneously poured in to the measuring trough with dimensions, see Tab. 1 and Fig. 2. This was performed for both geometries of the carriers where this same quantity of material was used. Input parameters were bulk density of material, friction coefficient and restitution coefficient (Tab. 1).

After pouring the material, the carriers´ velocity was 0.063 m s^{-1} (direction is shown in Fig. 3). Thus was created the impact kinetic energy exchange between the carrier and particles and the leap of particles was created. In the above mentioned material of airsoft balls with the size of 5.96 mm were measured in the Laboratory of Bulk Materials at VSB-TU of Ostrava all mechanical and physical properties necessary for design of the model and calibration of the material in the EDEM program. The calibration of the material was performed by comparing the resulting experimental value of the angle of repose that is the angle of slope of the bulk material with the value generated from the EDEM program [13].

Results

The analysis of the transport process showed a formation of strokes of the particles on the transport system. Mathematic models confirmed the influence of the carriers shape on direction of the particles motion and velocity of the particles motion.

Fig. 4 represents a set of five time intervals when the cycles of material transport starts. Fig. 4 (a–g) show motion of particles under the influence of the carrier with geometry 1 and (h–n) geometry 2. In order to come close to the real situation the carriers were placed in the trough and covered with material before simulation. Due to research, the appearance of particles was changed by the EDEM programme Academic to the velocity vector fields and particles motion. The vectors recorded by this method are easily assessable and provide also information about direction of the simulated particles motion. Range of colours states magnitude of the particles velocity is shown in Fig. 5.

Immediately after the start a sharp stroke of the carrier and material occurs, this gives material kinetic energy and sets it in motion. Kinetic energy is transferred by the particles and it results in setting material in motion. Modification of geometry concentrates velocity vectors to the places where material is carried by the carriers thus it transfers bigger stroke velocity energy to the particles before the carrier.

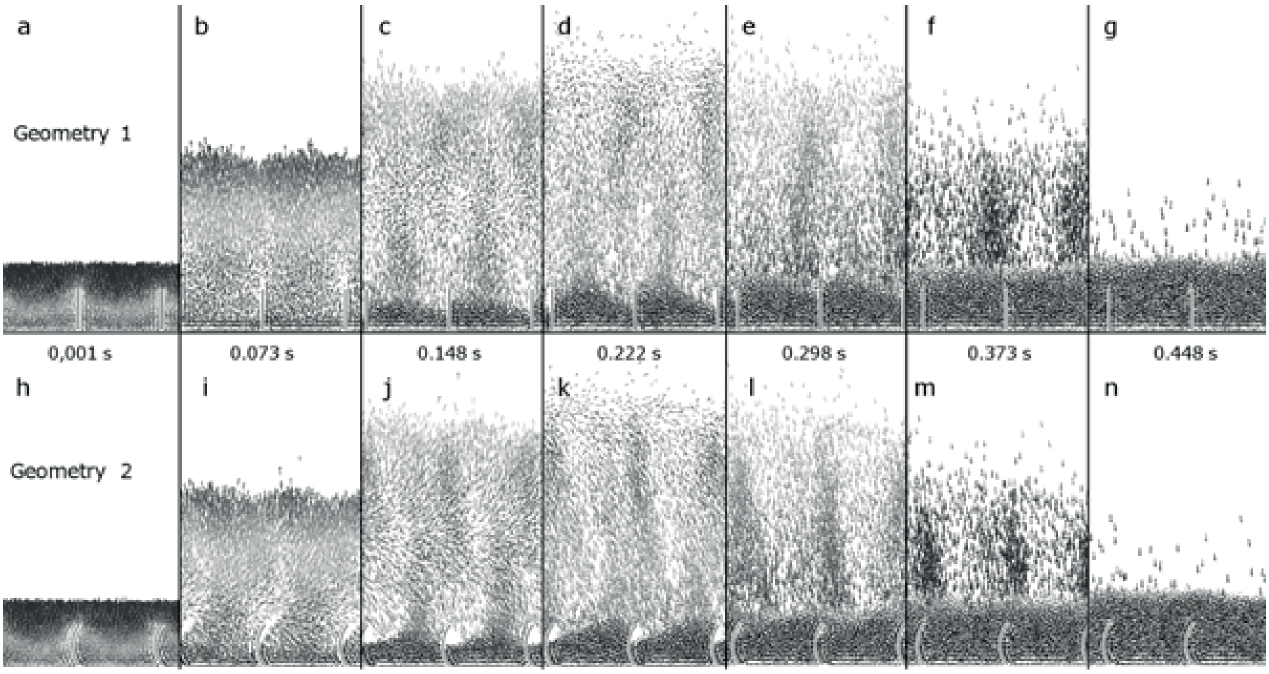

Fig. 4. Starting of the carriers of different geometries

Rys. 4. Uruchamianie przenośników o różnej geometrii

Fig. 5. Legend of velocity of transported material

Rys. 5. Opis prędkości transportowanego materiału

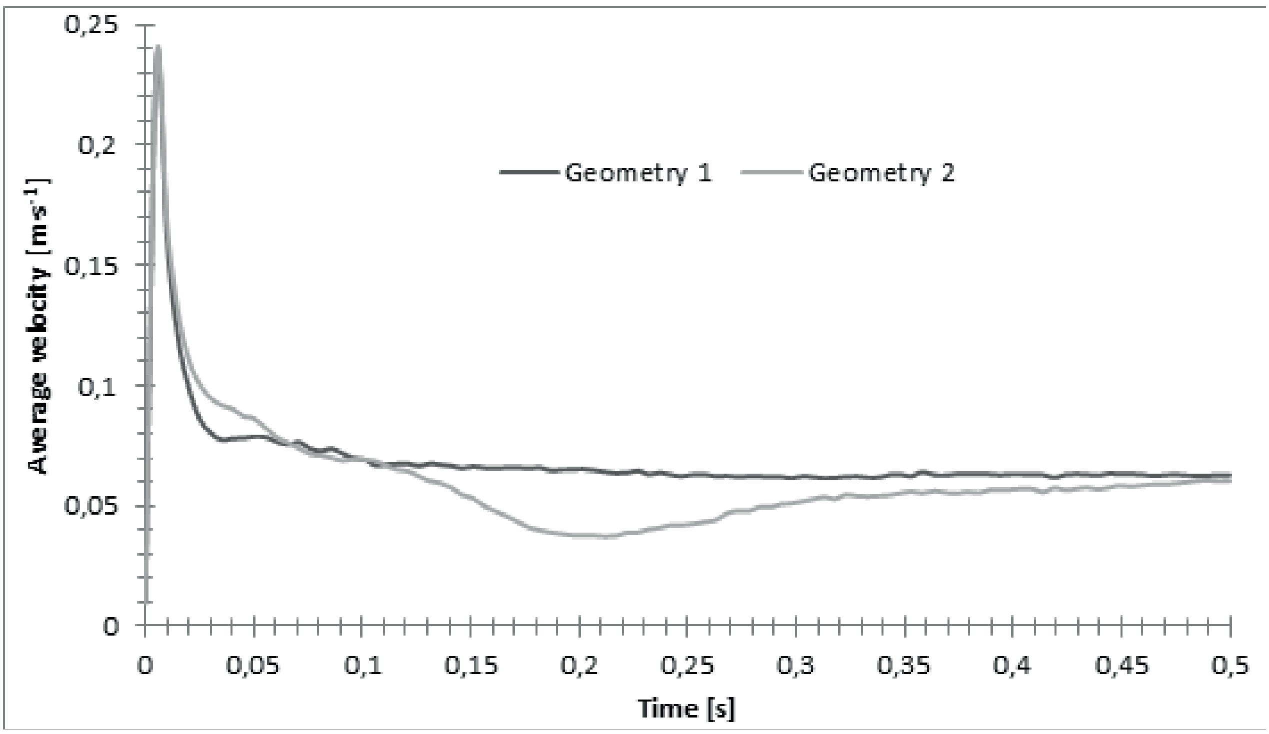

Fig. 6. The average velocity of the particles in the lowest scanning plane of conveyor

Rys. 6. Średnia prędkość ziaren na najniższej płaszczyźnie przenośnika

The particles moving above the carriers are transferred by geometry 2 mainly above the carrier head. In the upper layer of material the stroke waves originate by the influence of the carriers and they cast material and create flight parabolas. Velocities of these parabolas come from the initial impulse of the carriers and their geometry.

In the area of the lowest part recording space it is possible to observe that motion of the carrier at the initial motion stroke gives the particles motion with the average velocity of 0.24 $m.s^{-1}$ and then the particle velocity decreases. It was found that particles carried by carriers with geometry 1 slow down to the approximate value of 0.063 m s^{-1} and then their speed stabilize. The carriers with geometry 2 slow down particles for a longer time to 0.037 s and then accelerate again to a steady value of 0.063 $m.s^{-1}$ (Fig. 6). This difference amounts to 0.026 $m.s^{-1}$ which is approximately 45% of the particle velocity when using geometry 1.

The results of the mathematic model show that the change of the carrier geometry affects particles velocity which occurs at the lowest scanning plane of conveyor.

Conclusion

The analysis of the particles motion by DEM method has shown how the movement of the particles during impact shift with two different geometries of the carriers is affected. It has shown that the change of the carrier's geometry affects trajectory of motion and velocity of the transported material particles. In the lowest area of conveyor the velocity of the particles motion is more affected by geometry 2 in comparison with geometry 1. Geometry 2 absorbs velocity impacts, streamlines the acceleration of conveyor, and therefore may also affect the lifespan of carriers. It was showed in the work how DEM method can be used in a proposal and innovations in the area of solution of the transport equipment design.

Acknowledgements

This paper was conducted within the framework of the project LO1404: Sustainable development of ENET Centre.

Literatura – References

1. Y.J. JIA, D.Y. ZHANG, G.Z.. CHENG, et al. 2012. "Water Storage Bucket Chain Convey-Cleaning Machine for Cleaning Up Coal Mine Water Storage." *Applied Mechanics and Materials* 164: 497–500.
2. W.K. TALLEY, D.Y. ZHANG, G.Z. CHENG, et al. 2014. "Maritime transport chains: carrier, port and shipper choice effects." *International Journal of Production Economics* 151: 174–179.
3. R. SMITH, R.K. MOBLEY. 2003. *Conveyors. Industrial Machinery Repair, Industrial Machinery Repair, Best Maintenance Practices Pocket Guide*, Butterworth Heinemann. Burlington: Elsevier.
4. M.D. HOLLOWAY, C.N.WAOHA, O.A. ONYEWUENYI. 2012. *Process plant equipment operation, reliability and control*. Wiley: Hoboken.
5. M. ZIDEK, J. ZEGZULKA, J. NECAS, et al. 2012. "The validation chain conveyor with carriers." *Industrial design* 39211 (2013/35543).
6. W. WEINER. 2001."Test of a redler type conveyor with a plastic chain." *Powder handling and processing* 13: 373–377.
7. P. KRIZAN, L. SOOS, D. VUKELIC. 2009. "A study of impact technological parametres on the briquetting process." *The Scientific Journal Facta Universitatis* 6: 39–47.
8. D. HOHNER, S. WIRTZ, V. SCHIERER. 2014. "A study on the influence of particle shape and shape approximation on particle mechanics in a rotating drum using the discrete element method." *Powder Technology* 253: 256–265.
9. R. KOBYLKA, M. MOLENDA, V. SCHIERER. 2014. "DEM simulations of loads on obstruction attached to the wall of a model grain silo and of flow disturbance around the obstruction." *Powder Technology* 256: 210–216.
10. R.S. LAKES, A. WINEMAN. 2006. "On Poisson's Ratio in Linearly Viscoelastic Solids." *Journal of Elasticity* 85: 45–63.
11. E. SILVA, J.P. SOUSA, D. SPLENDOR, et al. 2013. "Note on the Measurement of Bulk Density and Tapped Density of Powders According to the European Pharmacopeia." *AAPS PharmSciTech* 14: 1098–1100.
12. J. ZEGZULKA. 2013. "The angle of internal friction as a measure of work loss in granular material flow." *Powder Technology* 233: 347–353.
13. J. ROZBROJ. 2013. *Motion simulation (DEM) of particulate matter in the screw conveyor in the contruction of vertical screw* [Ph.D. thesis], Ostrava: VSB-Technical University of Ostrava.

Optymalizacja geometrii łańcuchowych przenośników taśmowych metodą DEM

Artykuł przedstawia wyniki symulacji za pomocą Metody Elementów Dyskretnych (ang. skrót DEM) zastosowanej do modelu przenośnika łańcuchowego w celu optymalizacji geometrii taśm. W pracy skupiono się na wpływie impulsu w pierwszej części cyklu transportu przenośnika łańcuchowego oraz następstw jakie niesie ze sobą zmiana geometrii elementów taśmy na wektor ruchu ziaren oraz zmiany prędkości transportu użytego materiału. Problem rozwiązano metodą DEM, przy użyciu modelu 3D dla testowanego sprzętu oraz symulacji transportu materiału. Wirtualne trójwymiarowe modele sprzętu można łatwo dostosować, jak również wprowadzić zmiany w wymiarach konstrukcji. Takie podejście zastosowano w pracy, w celu zbadania wpływu geometrii łańcuchowych przenośników taśmowych na ruch ziaren. Wyniki wykazały, że zmiana w geometrii nośnika wpływa na trajektorię ruchu i szybkość transportowania cząsteczek materiału na przenośnikach łańcuchowych.

Słowa kluczowe: DEM, ruch ziaren, przenośnik łańcuchowy, ziarna sferyczne