Biblid: 1821-4487 (2014) 18; 3; p 111-114
UDK: 621.86

Original Scientific Paper
Originalni naučni rad

UTILIZATION OF SCREW CONVEYOR AS PRE-MIXER: DISCRETE ELEMENT MODEL
KORIŠĆENJE PUŽNOG TRANSPORTERA KAO PREDMEŠAČA: MODEL DISKRETNIH ELEMENATA

Aca JOVANOVIĆ[*], *Milada PEZO*[**], *Lato PEZO*[*], *Sanja STANOJLOVIĆ*[*],
Biljana LONČAR[***], *Milica NIĆETIN*[***], *Ljubinko LEVIĆ*[***]
[*]*University of Belgrade, Institute of General and Physical Chemistry, 11000 Belgrade,Studentski trg 12/V, Serbia*
[**]*University of Belgrade, Institute of Nuclear Sciences Vinča, Laboratory for Thermal Engineering and Energy, 11001 Belgrade, P. O. Box 522, Serbia*
[***]*University of Novi Sad, Faculty of Technology, 21000 Novi Sad, Bulevar Cara Lazara 1, Serbia*
e-mail: akiyov@gmail.com

ABSTRACT

Single pitch screw conveyors are commonly used equipment in industry, used for transport of bulk materials. In this paper, several horizontal single-pitch screw conveyors with modifications in helices geometry were investigated for mixing action during transport, using Discrete Element Method. The influence of geometry variations on the performance of screw conveyor was examined, different designs were compared, and their effects on mixing performances were investigated. During the transport, the particle tumbles down from the top of the helix to the next free surface and that segment of the path was used for auxiliary mixing action. According to results, the addition of three complementary helices or blades, oriented in the same, or the opposite direction of screw helix, enlarges the particle path within the screw conveyor 3 - 5 times.

Key words: *Screw conveyor, Transport, Pre-mixer, Discrete Element Model.*

REZIME

Pužni transporteri su dobro poznata procesna oprema, koja se veoma intenzivno koristi u različitim granama industrije, uglavnom za podizanje i/ili transport rasutih materijala na kratkim i srednjim rastojanjima. Pužni transporteri se koriste u proizvodnji i preradi hrane, u industriji plastike, preradi mineralnih sirovina, u poljoprivrednoj proizvodnji kao i u prerađivačkoj industriji. Uprkos veoma jednostavnoj konstrukciji, sam transport materijala pužnim transporterom je veoma složen za razumevanje i optimizaciju (korišćenjem matematičkih modela) i konstruktori se veoma često oslanjaju na iskustvene podatke pri konstruisanju i izradi. U ovom radu je opisano nekoliko horizontalnih puževa, konstantne dužine koraka puža, sa izvesnim izmenama u geometriji pužnih spirala, kod kojih su testirane mogućnosti mešanja tokom transporta materijala, korišćenjem „Metode diskretnih elemenata“.Ispitivani su uticaji ovih izmena u geometriji na transportne performanse pužnog transportera, različita konstrukciona rešenja su međusobno poređena, kao i efekti ovih izmena u geometriji na mešanje u toku transporta.Tokom transporta u pužnom transporteru, čestice padaju sa vrha pužne spirale na prvu sledeću slobodnu površinu pužne spirale i taj segment putanje čestice može da bude iskorišćen za dopunsko mešanje materijala tokom transporta. Putanja čestice se drastično povećava ugradnjom tri dodatne zavojne površine usmerene u isom pravcu kao i pužna spirala. Skraćivanjem dodatnih zavojnica, koje su usmerene u istom smeru kao i pužna spirala, unekoliko se smanjuje putanja čestice (usled prekidanja zavojnice na sredini pužnog transportera). Putanja čestice se produžava, kada se ugrade dodatne zavojne površine koje su usmerene u suprotnom pravcu od pravca pužne spirale. Ugradnjom tri dodatna pravolinijske letve, dobijena je najduža putanja čestice.

Ključne reči: *pužni transporter, transport, predmešač, model diskretnih elemenata.*

INTRODUCTION

Screw conveyors are widely used for process equipment, utilized for transport and/or elevate particles continuously, at controlled rates. A summary of current design methods and problems experienced for screw conveyors can be found in *Bortolamasi and Fottner (2001)*. The description of the theoretical behavior of screw conveyors can be found in articles by *Yu and Arnold (1997)*, and *Roberts (1999)*. Screw conveyors are also used for metering (measuring the flow rate) from storage bins and adding small controlled amounts of trace materials (dosing) such as pigments to granular materials or powders, (*Roberts and Willis, 1962, Cleary, 1998a,* Cleary, *1998b*).

Discrete element modeling (DEM), of particulate flow in a screw conveyor was first reported by *Shimizu and Cundall (2001)*. They examined the performance of horizontal and vertical screw conveyors and compared their results with previous work and empirical equations. *Owen et al. (2003)* introduced the use of a periodic slice model to explore the performance of a long screw conveyor. *Cleary (2004)* used DEM to study draw down patterns from a hopper by a 45° inclined screw conveyor. This work was extended by *Cleary (2007)* to examine the effect of particle shape on the draw down flow from the hopper and on the transport characteristics of the screw conveyor.

Screw transporters are frequently used to remove powder or grain material from silos, and transport it to the mixer. Before the mixing process is performed, it is often practice that some premixing action is done, using some type of the auxiliary mixer. The main aim of this paper is to consider the possibility of prolonging particle transport path from the moment of entering to the moment of leaving the screw conveyor, with addition of new elements welded on the helix of screw conveyor, in order to increase the effect of auxiliary mixing along with the transport of particles. In this way a screw transporter could be considered as transporter and also the continous pre-mixer. Discrete Element Method (DEM) was used to explore the modifications in screw geometry and the influence on transport path, during the transport of just one particle, with the intention to keep the material flow unspoiled.

MATERIAL AND METHOD

Model description

DEM simulation involves following the motion of every particle involved in the model definition, and modeling each collision: inter-particle and between the particles and their environment (e.g. the internal surface of the screw casing and the surface of the rotating screw). The boundary geometry is built using a CAD package and imported as a small sized triangular surfaces mesh into the DEM package. This provides unlimited flexibility in specifying the three dimensional geometries with which the particles interact. Here the particles are modeled as spheres (also as small sized triangular surfaces). The modeling technique is based on the assumption that the particle is soft (soft particle method), and that particles are allowed to overlap. The amount of overlap is labeled as Δx, and the normal and tangential relative velocities determine the collisional forces. The normal force is considered as the repulsive force that pushes the particles apart (or particle from bounding geometry), depicted as the action of the spring, and also dissipation action, resulting in an effective coefficient of restitution, shown as dashpot action. Tangential component is considered as an incrementing spring action and dashpot action that is subject to frictional limit.

In this article, DEM analysis was used to investigate the path of single particle, during transport, considering the differences in helix of the screw conveyor. Here applied DEM analysis can be summarized as follows: neighboring interaction list is based on the used grid (defined by used triangular surface mesh), and the boundary objects (also defined by triangular surface mesh), which are treated as virtual, non-moving particles. The collisional forces on the specific particle and boundaries are evaluated efficiently using the neighboring list and the spring-dashpot interaction model, (*Cleary, 1997*). All the forces on the boundary objects and specific particles are summed and the resulting equations of motion are integrated using DEM package. The particle velocities and their axial and tangential (swirl) components were invariant to changes of particle–wall friction.

RESULTS AND DISCUSSION

In this work the influence of helix geometry on single spherical particle trajectory is investigated. Applied DEM analysis the mutual influence of different configuration of helix geometry and observed particle is focused to inspect the possibility of prolonging single particle path during transport. The basic screw conveyor used in this study was a standard pitch, single flight screw conveyor with no additional helices, which is commonly used in processing industry. The pitch of the screw is defined as the length, along the drive shaft, of one turn of the helical blade, as shown in Figure 1. A standard pitch screw has its pitch equal to the outer diameter of the helical blade. The DEM model was simplified (and the CPU time is significantly reduced) by applying periodic boundary conditions to a single pitch of the screw as shown in Figure 1.

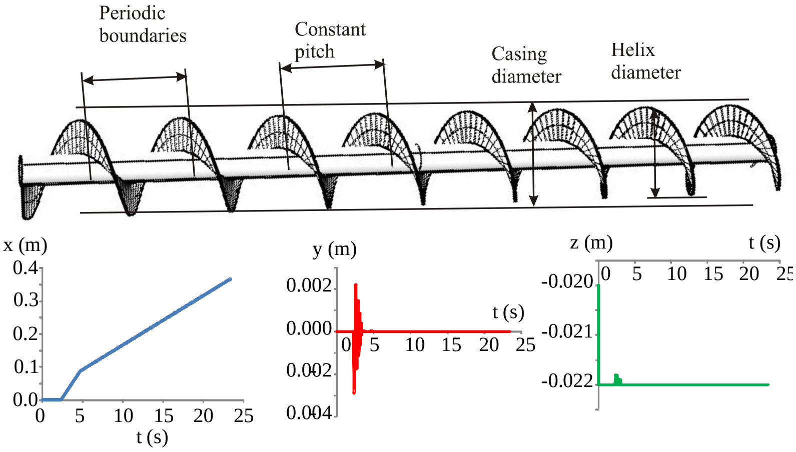

Fig. 1. Standard pitch, single flight screw conveyor, with Cartesian coordinate changes over time t

The pitch of the screw was 50 mm, the diameter of the screw shaft was 15 mm, and the blade thickness was approximately 1 mm. The internal diameter for tubular case was 47 mm, giving a gap of about 1.5 mm between the outer edge of screw blade and the internal surface of the casing. Screw conveyor length was 400 mm. All simulations used the same rotational speed of 20 rpm.

DEM particles are modeled as spheres in three dimensions. Small-sized triangular surfaces mesh was used for geometrical modeling of seed, (grain that is very close to spherical shape), and for the DEM calculation, and the size of the particles used was 4.0 mm, with a density of 500 kg/m^3. The particle–boundary frictions used for the DEM (base case) simulations were 0.3, and particle–boundary coefficients of restitution were 0.3. The maximum overlap between particle and boundary is determined by the normal spring stiffness. Typically, average overlaps of 0.1–0.5% are desirable, requiring a spring constant of 1000 N/m for this type of simulation.

A series of DEM simulations was performed for various screw conveyor-mixer geometry. Examined modified screw conveyor-mixers used in this article were:

1. Screw conveyor-mixer with three additional helices oriented in the same direction as screw transporting helix, welded on the periphery of the helix, Fig. 2,
2. Screw conveyor-mixer with three additional helices oriented in the opposite direction from transporting helix, welded on the periphery of the helix, Fig. 3,

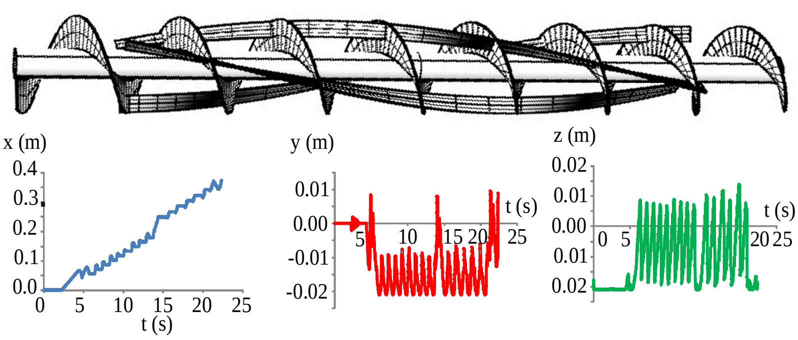

Fig. 2. Screw conveyor-mixer with three additional helices oriented in the same direction as screw blades, with Cartesian coordinate changes over time t

3. Screw conveyor-mixer with three truncated additional helices oriented in the same direction as transporting helix, welded on the periphery of the helix, Fig. 4,

4. Screw conveyor-mixer with additional straight line blades, welded on the periphery of the helix, Fig. 5.

The movement of granular particles, modeled as spheres in DEM simulation, was observed from the initial moment, the entering in screw transporter-mixer to the moment of leaving the

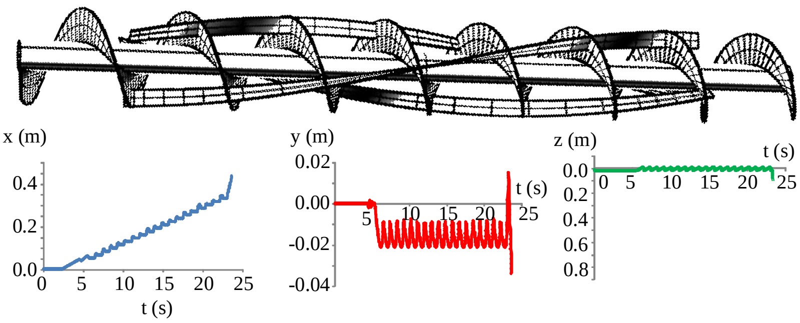

Fig. 3. Screw conveyor-mixer with three additional helices oriented i the opposite direction from screw blades, , with Cartesian coordinate changes over time t

external tube, and the motion path was analyzed. The purpose of this analysis is to improve the geometry of the standard screw transporter with additional elements, welded on the perifery of the helix that enable prolonging of particle path within the screw conveyer. It is well known, that the screw conveyor fill level should be less than 50%, i. e. much of the volume above the helix blade is empty during transport, and this volume can be used for additional mixing action during transport. Using DEM simulation of the particle trajectories, single particle coordinates x = f (t), y = f (t) and z = f (t) have been obtained, and plotted (Fig. 1-5), from the moment of entering until the moment of leaving the screw conveyor.

The effect of single path prolonging leads to enhance the interferences between observed particles and increase probability of particles being mixed during the transport (in case that screw conveyor is transporting several different components and/or different particle sizes). The movement of just one single particle has been observed in order to show possible solutions that would increase the particle path by adding elements to the screw conveyor, not changing the basic dimensions of the screw conveyor.

In the first case, when the screw transporter works only as a conveyor, particle path is almost a straight line (Fig. 1), while in

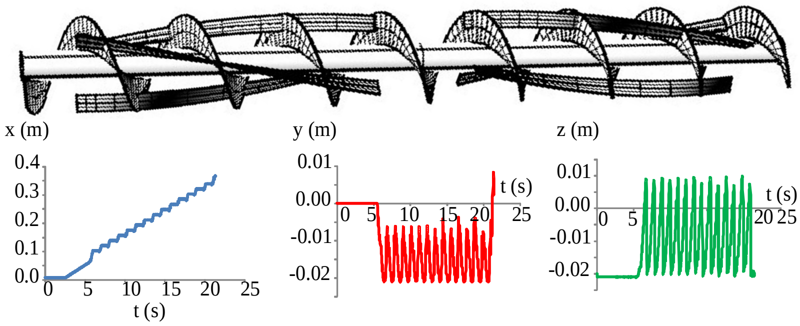

Fig. 4. Screw conveyor-mixer with three truncated additional helices oriented in the same direction as screw blades, , with Cartesian coordinate changes over time t

all other cases the particle is moving on a much longer path which was particularly evident in the case of screw conveyor-mixer with additional straight line blade (Fig. 5).

In case of single flight screw conveyor (Fig. 1), the total particle path is only 397.6 mm, according to DEM simulation. Initial small perturbation was observed, and afterward straight lined path, caused by screw conveyor transporting action

Screw conveyor-mixer with three additional helices oriented in the same direction as screw blades (Fig. 2), strongly enlarges the total particle path, calculating more than a three times longer trajectory of 1458.2 mm, for equal transport time of 23.5s.

After reaching the top of the screw the particle tumbles down from the top of the helix. The particle tumbling down to the next free surface on the heap and that segment of path can be used for auxiliary mixing action.

When using screw conveyor-mixer with three additional helices oriented in the opposite direction from screw blades (Fig. 3) for transporting and auxiliary mixing action, transporting path enlarges even more, to 1764.4 mm, which was expected, because opposite oriented helices return the single particle a bit backward, as can be seen from Fig. 3.

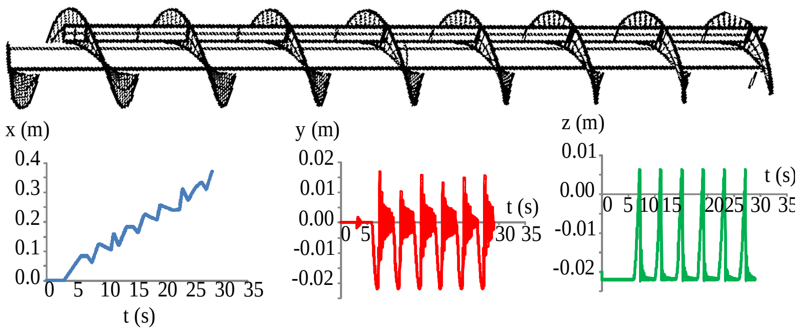

Figure 5. Screw conveyor-mixer with additional straight line blade,, with Cartesian coordinate changes over time t

By truncated additional helices oriented in the same direction as screw blades (Fig. 4), particle path is being shortened (due to broken helices at the middle of screw conveyor). In this case, total path is 1728.8 mm.

Screw conveyor-mixer with additional straight line blade exerts the longest single particle path in this simulation (Fig. 5): 2061.6 mm, which is a less more than five times compared with single flight screw conveyor.

CONCLUSION

Modified geometry screw conveyor, and its utilization in mixing action were analyzed. The transport action of single particle depends on the geometry of the helix, and the transporting path can be significantly prolonged by inserting these elements to the helix of screw transporter. Particle retention time remains constant, but the velocity is significantly increased, and the probability of mixing of two or more particles is also enhanced, in respect to distance traveled is much longer. Discrete Element Method (DEM) was used for an investigation of the effects of differences in screw geometry and the influence on transport path, during the transport of just one particle, with an intention to use a screw conveyor as transporter, but also as the continous pre-mixer.

The particle path is being extended by addition of complementary helices oriented in the same direction as screw blades (particle path is enlarged more then three times), or in the opposite direction of screw blades (when particle path is endured extended more then four times). The longest path result obtained in DEM simulation was with the screw conveyor with additional straight line blade, which is a less more than five times compared with single flight screw conveyor.

AKNOWLEDGEMENT:The authors wish to express their gratitude to the Ministry of Education and Science of the Republic of Serbia for the financial support, TR-31055, 2011-2014.

REFERENCES

Bortolamasi, M., Fottner, J. (2001). Design and sizing of screw feeders, Proc. Partec 2001, Int. Congress for Particle Technology, Nuremberg, Germany, March, 27–29, Paper 69.

Yu, Y., Arnold, P.C. (1997). Theoretical modelling of torque requirements for single screw feeders, Powder Technol. 93, 151–162.

Roberts, A.W. (1999). The influence of granular vortex motion on the volumetric performance of enclosed screw conveyors, Powder Technol. 104, 56–67.

Shimizu, Y., Cundall, P.A. (2001). Three-dimensional DEM simulation of bulk handling screw conveyors, J. Eng. Mech.,127(9), 864–872.

Owen, P.J., Cleary, P.W., McBride, B. (2003). Simulated granular flow in screw feeders using 3D Discrete Element Method (DEM), CHEMECA 2003, 31st Australian Chemical Engineering Conference, 2003, ISBN: 0-86396-829-5, Paper No. 203.

Cleary, P.W. (2004). Large scale industrial DEM modelling, Eng. Computation 21, 169–204.

Cleary, P.W. (2007). DEM modelling of particulate flow in a screw feeder, Progress in Computational Fluid Dynamics 7 (Nos. 2/3/4), 128–138.

Cleary, P.W. (1998). Predicting charge motion, power draw, segregation, wear and particle breakage in ball mills using discrete element methods”, Miner. Eng. 11, 1061–1080.

Cleary, P.W. (1998). Discrete Element Modelling of industrial granular flow applications”, TASK, Quarterly — Scientific Bulletin 2, 385–416.

Roberts, A.W., Willis, A.H. (1997). Performance of grain augers, Proceedings of the Institution of Mechanical Engineers 176 (8) (1962) 165–194.

Cleary, P.W., Metcalfe, G., Liffman, K. How well do discrete element granular flow models capture the essentials of mixing process?, Inter Conf on CFD in Mineral and Metal Processing and Power Generation, CSIRO, 149-156.

Received: 28. 02. 2014. Accepted: 26. 03. 2014.