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Effect of Parameters on the Screw Feeder Performance using Discrete Element Method

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Abstract - **A computational particle flow simulation of a Screw feeder which transports bulk material from a Hopper by a turning screw is presented. The objective is to investigate the screw feeder performance by simulation assistance. The performance of the screw feeder system is assisted by number of parameters in which "Through Shape" also plays a vital role.[10] Through Shape is the shape of the casing in which screw is rotating. Such systems are used in industry to produce a continuous flow of the used bulk material. In this paper we examine how these Parameters influence the performance of a screw feeder by applying the Discrete Element Method (DEM) with periodic boundary conditions. The DEM modelling gives predictions of screw feeder performance in terms of variations of particle speeds, mass flow rate, due to changes in the parameters. The geometrical and operational parameters of the system are adjusted to a real feeder system with the help of past literature.**

I. INTRODUCTION

Screw feeders are used extensively to draw bulk materials from hoppers or bins in all chemical, pharmaceutical, food or mining industries. They generally provide good output control and facilitate a level of environmental protection not possible with belt conveyors [7]. The typical configuration consists of a bin and hopper coupled to a screw casing and a screw within. As the screw rotates material is drawn from the hopper and transported along the casing. The screw feeder has a helicoidal surface fitted on a shaft that rotates inside a fixed tube [5]. The material which comes out of the silo is pushed by the helicoids flight along the base of the tube in the direction of transport [3]. The advantages of the screw feeder include the possibility of having different openings, each with its own shut-off organ for unloading the material.[2] While mechanically simple in principle, the behaviour of material during the drawdown process and transport can be complex [3]. The basic design of a typical screw conveyor has three major components [6]:

(1) Hopper or bin;
(2) Stationary screw casing (tubular, open or covered trough);
(3) Rotating screw.

The considerable amount of research work has been carried out in the design and sizing of screw feeders and analysis of inside material flow using discrete element modelling approach. Justin W. Fernandez, Paul W. Cleary , William McBride studied about DEM approach to describe particle transport in hopper and screw feeder system.[1] They found that screw design influences the mass flow rate, drawdown rate, power consumption, screw wear, etc. by considering commonly used screw designs in industry. Lato Pezo, Aca Jovanovic, Milada Pezo, Radmilo C olovic, Biljana Loncar investigate Modified screw conveyor-mixers.[2] They studied modified screw geometries and lengths experimentally and numerically Using DEM. Geometry of the screw is changed by adding complimentary helices in screw blades. They found that the segment of helix can be used for additional mixing action [4]. P.J Owen and P. W. Cleary studied operational performance of a screw conveyor including quantitative variation of flow characteristics with fill level, angle of inclination and rotational speed.[8] Yongqin Yu investigates about the theoretical modelling and experimental investigation of the performance of the screw feeders.[10] They studied performance of single and twin screw feeder for volumetric efficiency, drawdown performance and torque or power requirements. Here we extend this work to look at the detailed performance of a screw feeder including quantitative variation of flow characteristics with mass flow rate, particle velocity.

II. MODEL DESCRIPTION

DEM simulates granular flow by tracking individual particles and predicting their interactions between each other and external objects such as the screw and hopper. The boundary geometry is created using a CAD package and imported as a triangular surface mesh into the DEM package. This provides unlimited flexibility in specifying the three dimensional geometries with which the particles interact. Here the particles are modelled as spheres. The laboratory scale screw feeder configuration used in this work. This is suitable for investigating of the effects of changes in configuration. For industrial scale hoppers, the magnitude and extent of variation in the solids stresses will be much larger with greater loads acting on the feeders leading also to greater torque and power requirements. It is assumed that the screw feeder behaviours investigated here do not differ much from the laboratory to the industrial scale. The hopper bin, screw casing and screw used for this study are shown in Fig 1 and Fig 2. The key geometric dimensions of the screw are given in Table 1. The screw used in this study was a variable pitch, expanding flight, tapered core screw. This screw will give the most even drawdown pattern.[1]

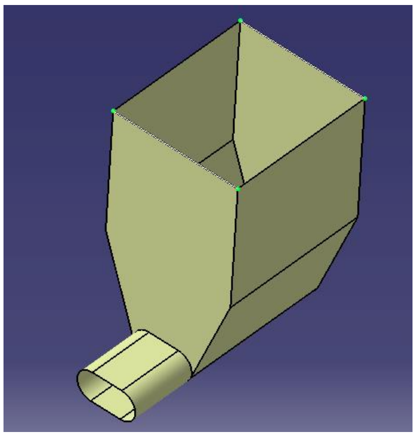


Fig 1The hopper bin, screw casing

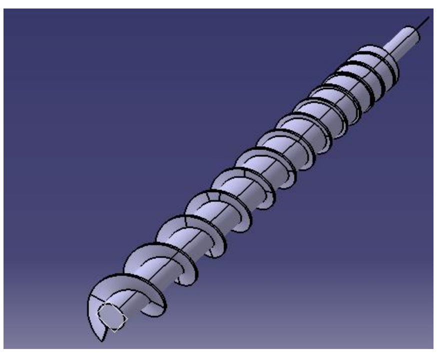
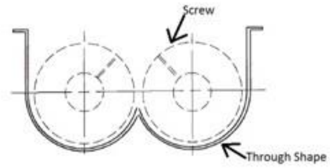


Fig 2 Screw

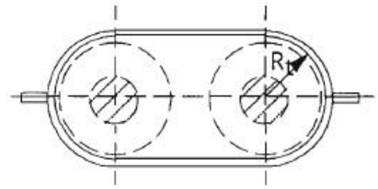
TABLE I
SCREW DIMENSIONS

Screw Dimensions	
Outside Blade Diameter (Do)(mm)	37.5-52.5
Outer shaft diameter (Di)(mm)	37.5-22.5
Pitch (P)(mm)	12.5-52.5
Maximum Screw Clearance (C)(mm)	8.25

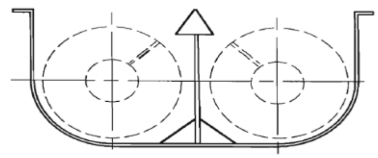
In this study, we investigated three typical Shapes of the Casing. Past literature indicates that Through Shape has strong influence on the performance of the screw feeders.[10] By changing shape of the casing the influence parameter on performance of the screw feeder could be observed. Fig 3 shows the types of Through Shapes consider for this study. The ‘‘optimal’’ shape was decide which could give better performance.



a) Through with curve Bottom



b) Through with straight bottom



c) Through with pup tent between screws

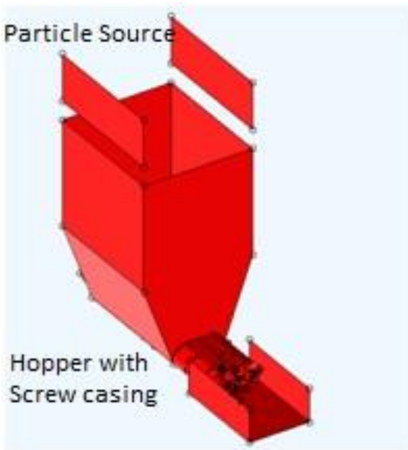
Fig. 3 Through Shapes

III. MATERIAL PROPERTIES

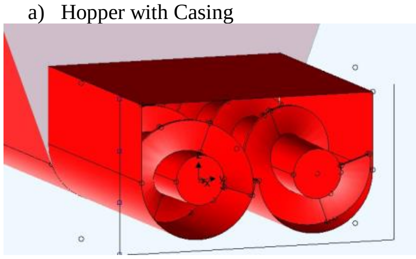
The hopper bin was filled to approximately 60% full with 5 mm diameter spherical grains. A 1% variation was used for the diameter range to prevent unrealistic crystallization from occurring. The solid density of the particles was 1400 kg/m3. These are generic simple type of material intended to be reasonably representative of bulk materials so that the analysis is not overly complex but the modelling conclusions are reasonably broadly applicable. The coefficient so friction between particles, hopper wall and screw face were 0.6, 0.45 and 0.364, respectively. In particular, the screw face friction (0.364) is often lower than the hopper wall friction (0.45) as the screw is polished either purposefully or by the flow of particles. These frictional coefficients were chosen based on typical values found in industry as measured using a Jenike shear tester. The maximum overlap between particles 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.

IV. DEM SIMULATION

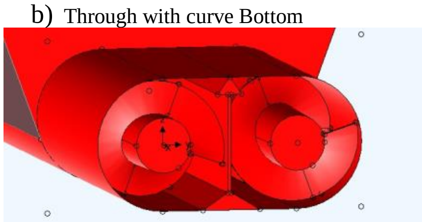
A series of DEM simulations was carried out for a range of different Through Shapes. Five different rotational speeds and three different Through Shapes were used. The DEM modelling gave predictions of the changes in the screw feeder performance due to changes in the parameters in terms of variations of: particle speed, mass flow rate [9]. DEM model used in the study are demonstrated in Fig 4. It was assume that after some time system reaches to steady state & giving constant output. The DEM results are in excellent agreement with the experimental results giving error approximately 5 to 10%.



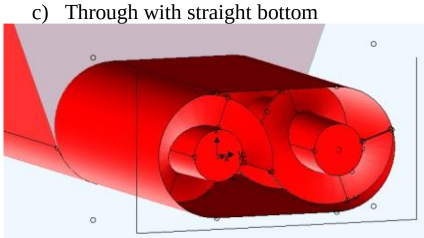
a) Hopper with Casing



b) Through with curve Bottom



c) Through with straight bottom



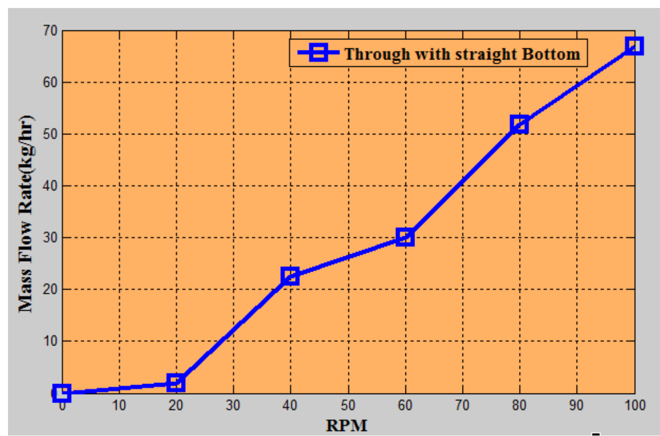
d) Through with pup tent between screws

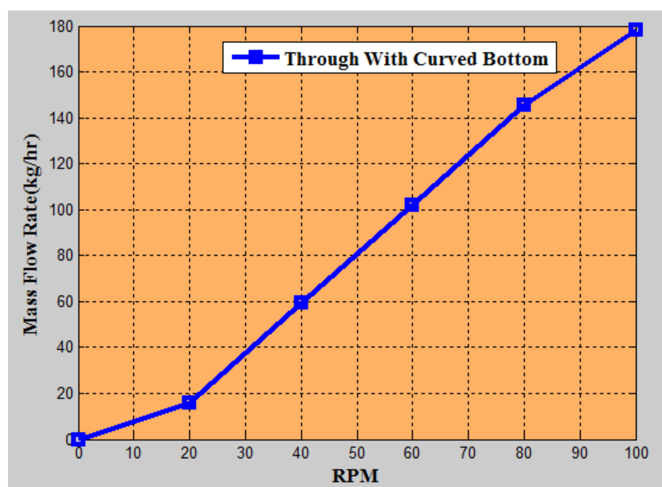
Fig 4 DEM model

V. RESULT AND DISCUSSION

A. Average Mass Flow Rate

The flow behaviour inside the screw conveyor examine quantitatively by measuring the mass flow rates of the particles when they are transported along the screw feeder. The mass Flow rate was determined by recording the mass of each particle that has passed through a plane perpendicular to the axis of the screw[8]. This plane was located half-way between the two periodic boundaries. The average mass flow rate of the particles versus rotational speed of the screw feeder for various shape of the casing i.e. Through Shape is presented in the graphical format in Fig. 5.





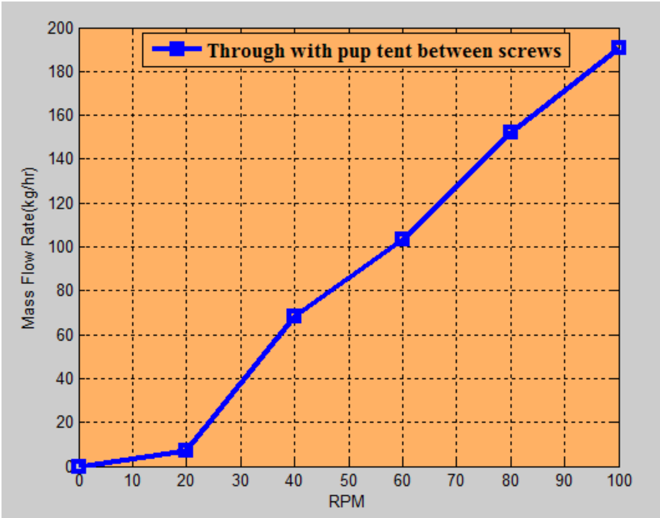


Fig 5 Mass Flow Rate versus Screw speed

For all the Through Shapes variation of a mass flow rate is observed for 20, 40, 60, 80 and 100 rpm. It was observed that with the increasing rotational speed, the average mass flow rate increases strongly but linearly.

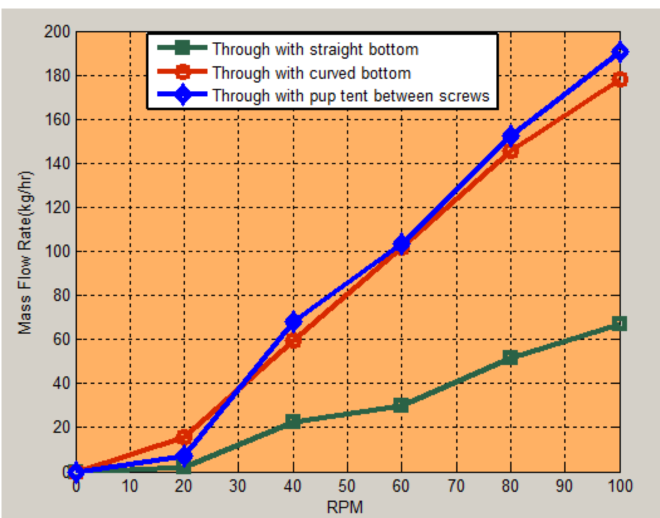


Fig 6
Mass Flow Rate versus Screw speed

Finally the comparative study on the mass flow rates for all the three shapes was done. For the comparative study all other parameters were constant except Through Shape. The average mass flow rate versus rotational speed for the various screw speed is presented in Fig 6. The trend shows that, for the "Through with pup tent between screws", the average mass flow rate is higher as compared to other two shapes. There was almost 45 % of increase in the average mass flow rate when as compared to two other two shapes. If we observed more closely it shows that the pattern of increase in the average mass flow rate for the 'Through with curve Bottom' & 'through with pup tent between screws' is almost similar. For the through with straight Bottom this trend is bit slowly. The reason behind this will be the topic of interest for the future work.

VI. CONCLUSION

DEM simulation shows that the nature of the particle flow in screw feeder is reasonably sensitive to the geometric & operating parameters. The mass flow rate for transport by the screw feeder for the different casing configuration was studied and it showed considerable variation in mass flow rate for the different Through Shapes. The increase in the mass flow rate with the rotational speed is almost linear. Ultimately through Shape governs the clearance between the tip of the screw and casing. It's an important construction feature affecting performance of the screw feeder. Clearance is necessary to prevent the metallic contact from taking place during rotation due to various adverse factors such as shaft deflection, minor manufacturing eccentricities, tolerance on the screw and through. It has been clearly seen from the investigation that increase in the output is directly proportional to the increase in the clearance.

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