FLIGHT DESIGN FOR ROTARY BAGASSE DRYER

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Abstract - *In this study, Discrete Element Method (DEM) is used in order to calculate the motion of bagasse in rotating dryers. We are particularly interested in analyzing the effect of flight shape on the behavior of particles in the cross section of the dryer. We will be using segments of flights and five different profiles : a straight flight, inclined flight, a right angled flight (90◦), an angled flight (with an angle of 120◦) and a angled hook flight . The results show that the profile of the flight affects significantly the motion of the particles in the cross section of the dryer. By varying the angle between the flight's segments, changes the flight loading and thus the material hold-up which leads to different discharging profiles of the flight. Holdup in the flights rotary dryers can be classified according to its loading state as either over, under or at design load. For a angled hook flight, the range of the discharge angle increases leading to a more uniform cascade pattern in time and an enlarging of the area occupied by the curtains of particles.*

***Key Words*:** **Bagasse, dryer, flights, discrete element method and hold-up.**

1.INTRODUCTION

Drying fibrous materials can be defined as the removal of moisture from a solid product. The moisture commonly consists of water. Materials are dried to ease handling, to preserve materials for storage and shipment and mostly they must be dried to bring their moisture content to a specific value before being sold [1]. Rotary dryers are more widely used in a drying processing plant than any other type of dryer. This is understandable of the wide range of materials which can be dried in them and if they are correctly designed and operated high thermal efficiencies are obtained. They consist of long drum driven at low speed. The rotation speed, ω, is selected according to the desired mode of bed motion which is characterized by the Froude number ω2R/g [2], where R is the inside radius of the drum and g is the acceleration due to gravity. In direct heated rotary dryer the heat-transfer coefficient is determined by assuming the heat is transferred mainly by convection from the hot gases to the wet surface of the product. The model of the dryer studied consists of a slightly inclined rotating shell, provided with internal lifters in order to promote agitation of the solids, with feed entering at the high end of the dryer, and hot gases flowing parallel or counter current to the material flow. The most important factors influencing dryer design and performance are examined from a practical point of view to be optimized under some specified operating conditions. The dryers are usually fit with flights, which consist of slab made of steel distributed on the periphery of the cross section and periodically along the tube. Flights carry the solid particles and cascade them into the hot gas flow. Flights used in industrial dryers can have complex shape. However, for theoretical and experimental purposes, simple flight shapes are frequently considered composed by one , two or three segments ([5], [6], [7]). Several topics that interest scientists and engineers in connection with heat and mass transfer arise in the problem of rotary dryers. The most important of them are the behavior of the material bed, the holdup of the material by the flights, the material curtains and the mean residence time. Experiments also showed that the mean residence time is affected by the flight's shape. A drum fitted with right-angled flights has a higher residence time than a drum fitted with straight flights. In order to study the effect of flight shape on the behavior of the fibrous material, we use EDEM, a high performance software for bulk material flow simulation based on the Discrete Element Method. This study is conducted to investigate the influence of the flight shape on the holdup. And it is also extended to the analysis of the falling length and falling time of particles in the cross section of the dryer. The flight profiles chosen are: straight flight, inclined flight, large angled flight, right angled flight and hook shaped flight.

2. DESCRIPTION OF PROBLEM AND SIMULATION PARAMETERS

We are interested to study the fibrous material motion in a transverse cross section of the drum. Due to the periodicity of the fiber motion along the tube, we have used a portion of the rotating drum with thickness a of 0.02 m. The diameter is also reduced in order to minimize the particles number. The diameter, D, is equal to 0.1m. This portion is driven with rotation speed ω = 10 rpm. In industry, the number of the flights is calculated to ensure a maximum holdup. In the present study, in order to avoid interaction between the flights, we have used only single flight. The angle α_0 of fixation of the flights on the drum wall is 90◦. Each flight is drawn in at θ = 0◦, where the flight is supposed to be filled at its maximum hold-up. These lifters are illustrated in Fig.1-5 and comprise of a flat horizontal lifter, a flat inclined lifter, and three lifters where other segments are added to produce a hook formation. Fig.1-5 illustrates the different lifters, while Table provides details of the size and angles of the different segments of each lifter.

Table -1: Details of the different segments of flights

Lifters	Inclinations
Lifter A	α_1-180°
Lifter B	α_1-150°
Lifter C	α_1-180°, α_2-90°
Lifter D	α_1-180°, α_2-120°
Lifter E	α_1-180°,α_2-120°, α_3- 90°, α_4-60°

Fig -1: Lifter A

Fig -2: Lifter B

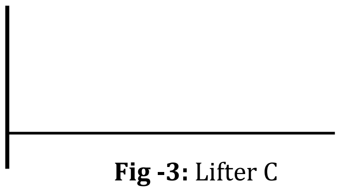

Fig -3: Lifter C

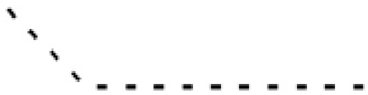

Fig -4: Lifter D

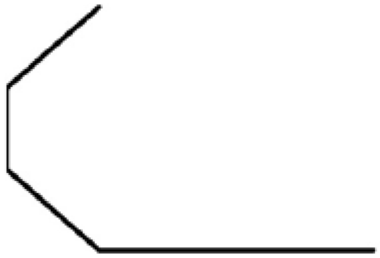

Fig -5: Lifter E

It is assumed that the right end of the lifter is the point where it is attached to the wall of the cascading dryer. In our simulations, the particle-particle and particle wall collision are modeled through the soft-sphere approach. This was used to simulate particle-to-particle and particle-to-wall contact interaction. Particles are considered fiber and the dryer is made of cast iron. Particles have a radius of r = 0.0001m resulting in the use of 1000 particles, corresponding to a random loose packing. This value has been verified later on with an image analysis software on some images of our configuration obtained by EDEM. Characteristics of the materials used are shown in table.

Table -2: Characteristics of the materials

Characteristics	Particle	Tube
Poisson's Ratio	0.3	0.26
Density (kg/m^3)	180	7500
Co-efficient of restitution	0.1	0.25
Co-efficient of static friction	0.5	0.5
Co-efficient of rolling friction	0.01	0.01

3. RESULTS AND DISCUSSION

In order to increase the drying efficiency, it is recommended to increase the density of material in the airborne phase (particles cascading through the cross-section of the drum) particularly in the upper half of the drum. Thus most of the studies consider the quantity of particles in the upper half of the drum as a design criterion [5] [7]. The range of the lifter is defined as the angle of rotation where that lifter empties completely. The initial volume of the lifters increases from Lifter A to Lifter E. However, it is interesting to note that an inclined lifter B has a higher hold up compared to one perpendicular to the dryer wall that is lifter A. Attaching some other segments to the lifter also increases the total hold up of the lifter and increases the distribution of material across the cross-section of dryer. It will increase both the amount of material held up by lifters, as well as the distribution of material along the cross-section of the drum. It is interesting to note that Lifter A, which had the largest hold up and the smallest range has the highest flux, over a short range. The sharp drop in flux for Lifter A around 40◦ represents the last bit of material being discharged from the lifter.

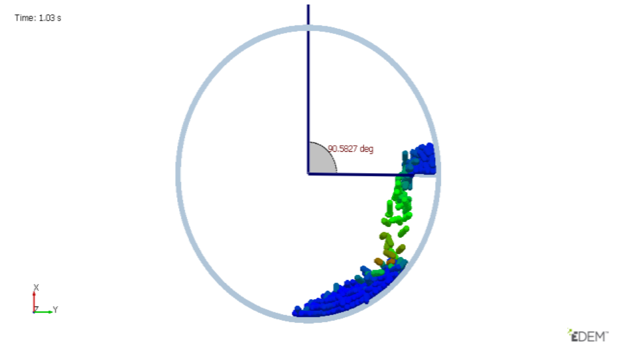

Fig -6: Lifter A at 0°

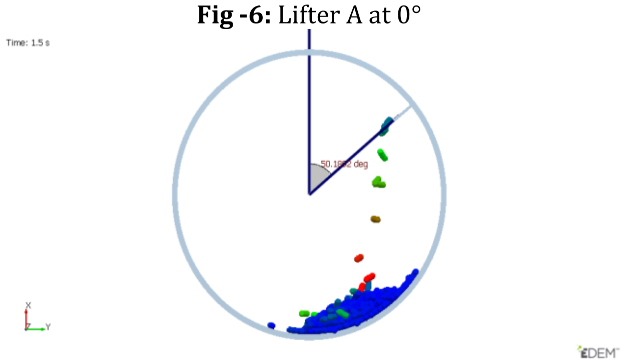

Fig -7: Lifter A at 40°

In Fig.6-7, we see the change of volume of material on the flight from θ = 0◦ up to complete discharge. The angle α1 between the two segments influences the discharging profile of the flight. The time the flight takes to be completely empty is more important for an angle. This favors the presence of particles in the cross section of the drum for a longer time. Even though straight flight carries more particles initially but its angular discharging angle, for which the flight is completely empty, is small. The above snapshots shows the dryer with straight flight cascading particles over the cross-section of the drum. The volume of material carried by the flights reduces gradually as the flights rotates through 180°. Lifter B, which is the similar to Lifter A but is inclined at angle has a higher hold up, a larger range but a smaller flux. This reflects that the apex of Lifter B is closer to the dryer wall during rotation so the amount of material lost during a small angle of rotation is smaller than that lost by Lifter A, which has a larger distance between the apex and the dryer wall. Hence the triangular sections for Lifter B are smaller than those for Lifter A during rotation.

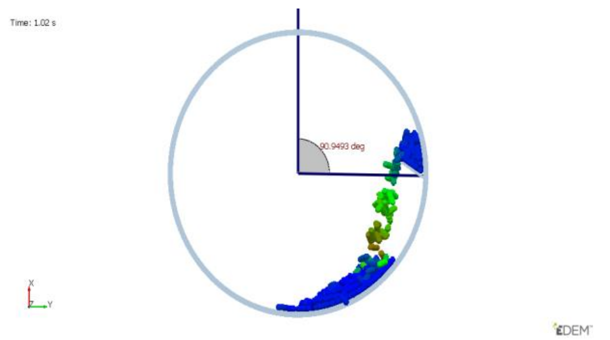

Fig -8: Lifter B at 0°

The number of particles leaving the flight is more or less constant over time for a right angled and a large angled flight, snapshots of the behavior of the material in the drum are presented in Fig. 10-13. These snapshots show that the flight profile affects the behavior in the cross-section of the drum. However for the right angled flight, a more extended zone is observed.

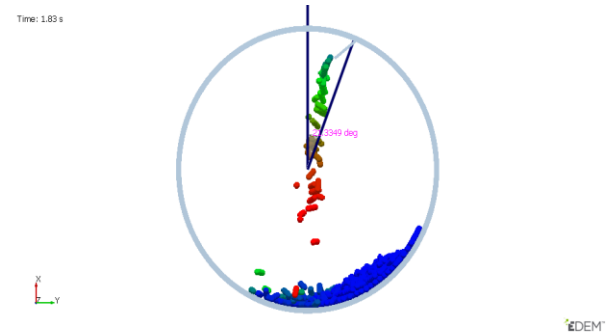

Fig -9: Lifter B at 70°

It also illustrate both the hold-up in the flight and the particle curtain, which appear to have a constant width for angled flights and change shape for a straight flight. A straight flight will have the maximum initial volume, but an angled flight carries the particles higher. So for further characterization of the dispersion of the falling length and the falling time is not the same from one flight shape to another, leading to different discharging patterns. Since the number of particles leaving the flight is important and depends on the angular position of the flight, we calculate the average falling length and falling time over an angular range to present the results and to ease the comparison between the flight's shapes.

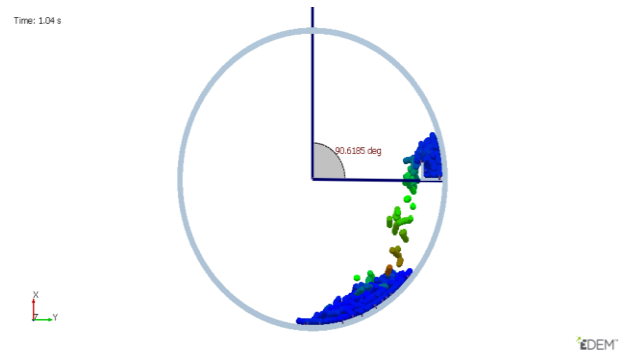

Fig -10: Lifter C at 0°

The more we reduce the angle α1 between the segments of the flight, the greater the range of the discharging flight. Moreover, when calculating the average falling length and falling time of all particles leaving each the flight, the results show an increase in the falling length and the falling time up to 50% and 70%, respectively, when using a angled flight instead of a straight one.

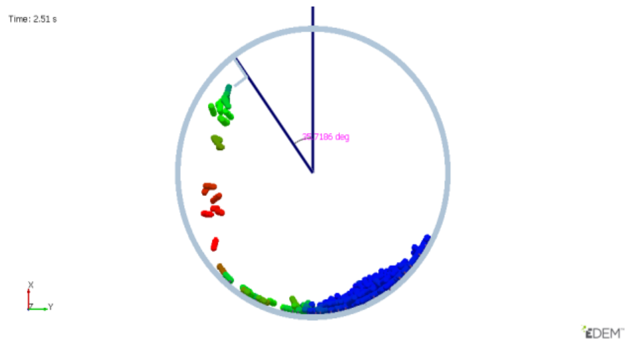

Fig -11: Lifter C at 125°

Finally, Lifter E has a third segment beyond the perpendicular segment from the dryer wall. This forms a partly closed lifter and has the advantage of producing a range of nearly 163°.

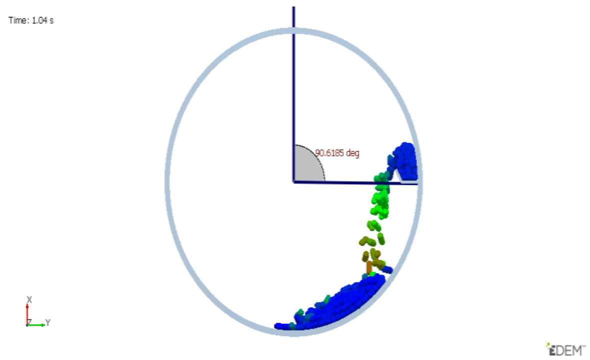

Fig -12: Lifter D at 0°

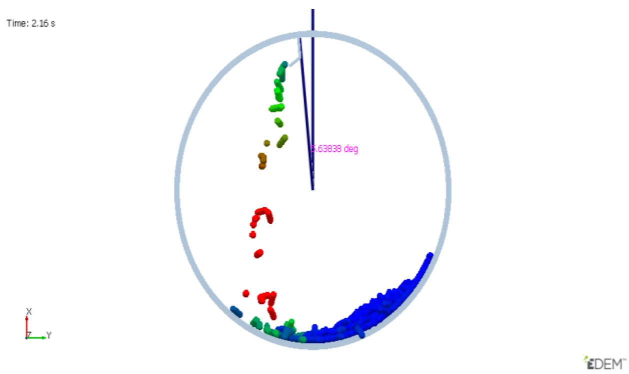

Fig -13: Lifter D at 95°

However, the flux of this lifter, compared to that of Lifter A, is quite low at the initial angles of rotation and as the range is approached. This indicates that the highest rate of losing material from the lifter occurs at the highest position of the lifter and produces the largest vertical distance of the curtain that returns the material to the bottom of the dryer.

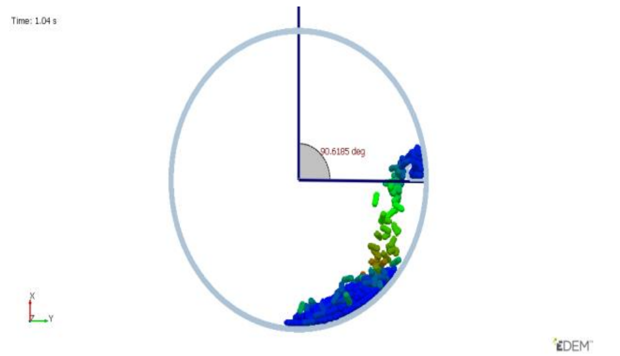

Fig -14: Lifter E at 0°

The above analysis assumes that the lifters will be filled to their maximum capacity at a rotation of 0◦. This depends on the total fill of the cascading dryer, and the type and number of lifters.

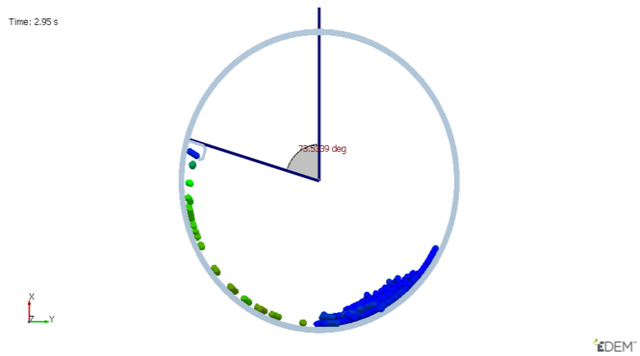

Fig -15: Lifter E at 163°

Lifter	Range
Lifter A	0°- 40°
Lifter B	0°- 70°
Lifter C	0°- 125°
Lifter D	0°- 95°
Lifter E	0°- 163°

Table -3: Range of lifters

4. CONCLUSION

The shape of the flight influences the discharging pattern of the material retained in the flight. Compared to the other flights an angled flight with hook shape offers a large angular discharging range while carrying an important quantity of material compared to a other flights. While more complex lifters were found to have a higher hold up and a larger range, the rate of material lost from these was generally less than simple perpendicular lifters, but more reflective of the height difference between the lifters and the bottom of the dryer in a cross-section.

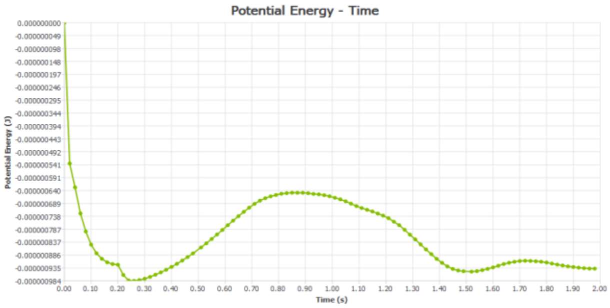

Fig -16 Lifter A

Fig. 16-20 indicates the potential energy curve that particles posses while they cascade through the upper half of the drum.

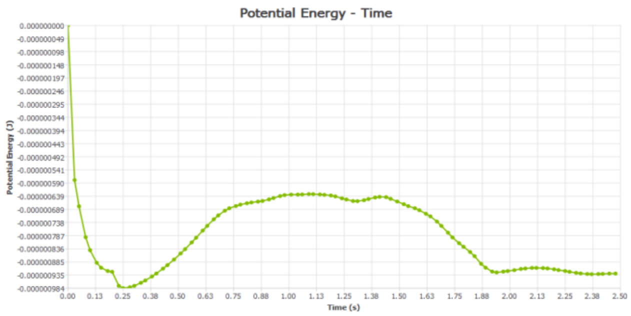

Fig -17: Lifter B

The falling length and the falling time of the particles also increases up to a maximum value then they start decreasing for a inclined flight and a straight flight. Compared to the other flight's shape, the angled flight offers a compromise between the angular discharging range and the falling length and falling time. It allows to get greatest falling length and time without decreasing afterwards as with a right-angled flight. The angular discharging rate is optimum compared to a straight flight. Nevertheless, the specific application of the dryer needs to be considered as this may dictate the type and range of distribution. The model described in this paper can be used to develop a lifter that best matches this distribution.

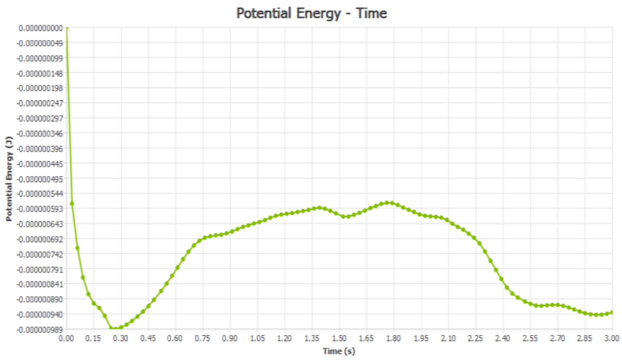

Fig -18: Lifter C

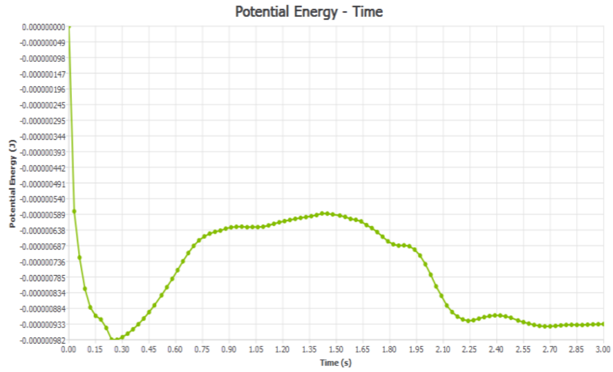

Fig -19: Lifter D

It is found that the drying performance can be improved in particular cases by using combination of lifter shape on the same dryer unit. For example, straight or single bend lifters could be used at the feed end where the product is relatively wet and sticky, where as double bend lifters could be used toward the discharge end where the product is sufficiently dry to be free flowing. This would result in improved heat transfer of the cascading dryer. However, DEM's simulations offer a more accurate calculations of the flight's hold-up since the DEM takes into account the interactions between particles and the particle's size unlike the bulk material's approach.

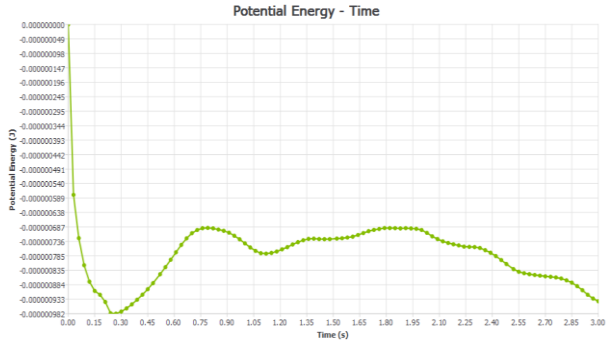

Fig -20: Lifter E

NOTATIONS

D - dryer diameter (m)
L - length of the dryer (m)
r - particle radius (m)
l - length of the flight segment (m)
ω - dryer rotational speed (rad/s)
τ - drum's filling degree (%)
θ - angular position of the tip of the flight
α_1- angle between drum and flight segment
α_2- angle between segment 1 and 2
α_3- angle between segment 2 and 3
α_4- angle between segment 3 and 4

REFERENCES

[1] R. B. Keey, Drying : Principles and practice (Pergamon Press, 1972)
[2] H. Henein and JK. Brimacombe and AP. Watkinson, Metallurgical transactions B 14, 191-205 (1983) S. Mujumdar, Handbook of industrial drying (Crc Press, 2014)
[3] C.G.J. Baker, Drying Technology 6, 631-653 (1988)
[4] P. G. Glikin, Chemical Engineering Research and Design 56a, 120-126 (1978)
[5] M. H. Lisboa and D. S. Vitorino and W. B. Delaiba and J. R. D. Finzer, and M. A. S. Barrozo. Brazilian Journal of Chemical Engineering, 24, 365-374 (2007)
[6] D. Revol and C.L. Briens and J.M. Chabagno, Chemical Powder Technology 121, 230-238 (2001)
[7] R. G. Sherritt, and R. Caple, The Canadian Journal of Chemical Engineering 71, 337-346 (1993)
[8] K. R. Sunkara and F. Herz, and E. Specht and J. Mellmann and R. Erpelding. Powder technology, 234, 107-116 (2013)
[9] Advanced Drying Technologies 2nd edition by Tadeusz Kudra, Arun S. Mujumdar.
[10] Bagasse drying by B. P. Edwards, Sugar research institute, Mackay.
[11] Rotary Drying by Magdalini Krokida, Dimitris Marinos-Kouris, and Arun S. Mujumdar.