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Project Code	
Project Type	

FINAL REPORT 2021

Applicants must read the *SAGIT Project Funding Guidelines 2021* prior to completing this form. These guidelines can be downloaded from www.sagit.com.au

Final reports must be emailed to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.

PROJECT CODE :	**USA120**

PROJECT TITLE (10 words maximum)
Novel bulk grain modelling, for contamination, using computer simulation.

PROJECT DURATION

*These dates **must** be the same as those stated in the Funding Agreement*

Project Start date	1st July 2020					
Project End date	30th June 2021					
SAGIT Funding Request	(year)	$	(year)	$	(year)	$

PROJECT SUPERVISOR CONTACT DETAILS

The project supervisor is the person responsible for the overall project

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Organisation:
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Mailing address:

Telephone:	**Facsimile:**	**Mobile:**	**Email:**

ADMINISTRATION CONTACT DETAILS

The Administration Contact is the person responsible for all administrative matters relating to the project

Title:	First Name:	Surname:

Organisation:
University of South Australia
Mailing address:

Telephone:	Facsimile:	Mobile:	Email:

PROJECT REPORT

Provide clear description of the following:

Executive Summary (200 words maximum)

A few paragraphs covering what was discovered, written in a manner that is easily understood and relevant to SA growers. A number of key dot points should be included which can be used in SAGIT communication programs

This preliminary study investigated novel techniques of understanding the behavior and movement of contaminates such as chaff in bulk grain during motion. Physical testing of grain and contaminants in a container was carried out at the University of South Australia on a specialised motion platform, aimed at low frequency bulk container motion.

- This testing highlighted the anecdotal evidence that grain, chaff and other contaminants move differently under motion and the MOG tends to segregate and congregate on the surface and edges of the grain bulk.

The second part of the project was to use novel Discrete Element Method (DEM) simulation to replicate the physical testing and validate that this simulation method can represent the movement behavior of bulk grain and contaminants under motion.

- The DEM simulations were able to replicate the different grain and chaff movements showing similar segregation of the MOG to the grain using the same container and grain quantities as the physical testing.

Limitations in size and scale of both physical testing and DEM simulations were realized during the project, but DEM simulations were proved to be a useful tool in understanding the movement of grain and chaff during potion.

- Modification of the bulk container size relative to the quantity of grain was able to modify the movement of grain and chaff and reduce the tendency for the chaff to segregate and congregate in the container.

Project Objectives

A concise statement of the aims of the project in outcome terms should be provided.

The aim of this project was to investigate how contaminants (MOG) congregate or segregate in grain during motion aiming to minimize congregation of residues at the surface during transport. With the objective to determine the nature and understand the movement of grain contaminants within the grain bulk, physical testing was carried out on a ship motion simulator platform. Small bulk quantities of grain were treated with chaff material both collected at harvest. Testing was carried out for periods of around 30 mins to determine if any difference in material movement could be established. Photos from the top and the side of the container were taken to enable measurement or quantification of this material movement.

Bulk material measurements of both grain and chaff were carried out to calibrate a computer simulation model using Discrete Element Method (DEM) particle based simulation approach. These simulations were then used to replicate the physical testing with actual size particles making up the same mass of material, in the same size container and ran for the same duration to determine if the simulation could replicate the bulk material movement. Particle tracking in computer the simulation was used to determine the starting position and the end position (after testing period) of all the chaff particles which could be compared to quantify the extent of movement.

Once simulations are validated to show appropriate particle movement, variables such as container size can be investigated to determine if a change/reduction in movement can be achieved.

Overall Performance

A concise statement indicating the extent to which the Project objectives were achieved, a list of personnel who participated in the Research Project including co-operators, and any difficulties encountered and the reasons for these difficulties.

The two main objectives of this project were to conduct physical testing and validate that DEM simulations can be calibrated and represent the movement and behavior of grain and other contaminants during motion. With these two aspects conducted a better understanding of how chaff and MOG moves in the grain bulk during motion will be achieved and the ability and usefulness of DEM computer simulations will be gained. This could provide a powerful tool to test novel ways of separating this material or ways to reduce the congregation on the surface during bulk transportation.

Thanks to the availability of a ship motion platform based as Mawson Lakes and UniSA staff with previous experience in running the motion platform physical testing was able to be carried out. Initial planning around the ship motion platform was that the testing would be carried out as if it were a real bulk container ship, but this was not possible due to a number of reasons, firstly obtaining the motion profiles of a bulk ship on the open ocean was not possible and quite tightly held sets of data. Secondly the mass and angle limitations of the platform and thirdly the ability to then simulation large bulks of grain in the DEM space.

The physical testing was a means to validating the ability of the DEM to simulate grain and MOG movement under motion, so the size of the testing did not represent a true ship size. As the simulation and physical testing were set-up the same, then the simulation can be validated against the physical test. As the motion platform had mass and angle limits and considering appropriate amounts of grain and chaff to be handled physical testing was limited to a small container and small mass of grain. A container of 800mm long, 200mm high and 200mm wide was built from clear Perspex. A layer of grain and chaff was put into the container and was allowed to run for approx. 30 minutes. After a 30min testing period the chaff had started to move differently to the grain and a segregation was seen to occur, each time the motion platform moved in one direction the grain moved but the chaff moved more slowly and pushed upward and to the end of the container by grain pushing in the direction of motion. It was clear to see a difference in the movement and positions of the chaff particles after testing.

Discrete Element Method Simulations are a capacity that UniSA has developed over the last 10 years with a focus on soil and soil engaging equipment. The application of DEM for grains is not completely novel, but investigating how grain and other particles such as chaff and MOG move differently during motion has not been found in the literature. A key to DEM simulations is calibration the discrete particles that are used to build up the bulk (Mass) of the product of interest. This calibration is done using some regular static tests such as the Angle of Repose. This is a test where a quantity of the material of interest is poured through funnel or pipe into a pile until the pile reaches a natural stable angle. This angle is measured and used to vary the contact model parameters in the simulation to achieve the same angle when the test is replicated in the simulation space. Calibration testes were caried out for Wheat, Barley and Lentils as well as chaff, short straws and snails.

Once a material is calibrated the method of validating a simulation is to set-up a replica of the physical test in the simulation space and compare the results. A 1:1CAD model of the motion platform was created along with the Perspex container and the grain and chaff particles added to the same quantities as the physical test. The simulation was set-up with Wheat grains and chaff to the same pass as the physical test and the motion platform was moved with the same modified sinusoidal input and leave it run for the 30mins as physical testing. It was found that the simulation with 1:1 particle sizes was processor intensive and took more than 4 weeks to complete 400secs (6.6 mins) of simulation time so it was decided to increase the particles to double size.

The longer than expected simulation times were due to a number of factors, the calculation environment had to be large enough to encompass the whole motion platform to cover its full range of motion. The material (Grain and Chaff) were clumps made up of a number of spherical particles (7 spheres for Wheat & 4 spheres for chaff) this increased the number of contact calculations significantly over a purely spherical particle simulation. Doubling, or using larger than actual size particles is a common approach in DEM to deal with simulation sizes and computation times, with double size particles the simulation completed 1800sec (30mins) after about 2 weeks and was able to be compared with the physical tests. The chaff particles started off spread randomly through the grain bulk and after 30 mins of motion were found to be congregating at the ends of the container in similar ways to what was found during the physical testing.

Once the DEM simulations were complete it was possible to try and quantify the movement of chaff from both the physical testing and the DEM simulation. It was found that wheat chaff in a bulk of wheat does move differently and tend to congregate near the end of the container.

Snails were initially considered as a contaminant of interest, but due to a number of reasons were not simulated using DEM. Collection of a good range of representative snails was difficult due to COVID field travel restriction. 3D scanning of collected snails was not as successful as hoped, where shell reflectance made it difficult to create a whole solid body and simulation times for the relatively small bulk of grain used for testing and simulation quickly used up allocated simulation resources.

Personnel and Co-operators who assisted in the project

- Francois Fraysse – Motion platform training input signal support
- Simon Modra – Building access and support during physical testing
- Phil Dixon – Technical workshop assistance to build grain containers
- Mustafa Ucgul – DEM simulation expertise, running simulations and exporting data

Key Performance Indicators (KPI)

*Please indicate whether KPI's were achieved. The KPI's **must** be the same as those stated in the Application for Funding and a brief explanation provided as to how they were achieved or why they were not achieved.*

KPI	*Achieved (Y/N)*	*If not achieved, please state reason.*
Bulk grain contaminant movement baseline testing	Y	
Development of a validated grain, chaff simulation to show movement of contaminants in grain.	Y	Snails were of limited focus due to access and availability and complexity in creating an appropriate shape and size in the simulation.

Technical Information (Not to exceed <u>**three**</u> pages)

Provide sufficient data and short clear statements of outcomes.

An appendix attached to the mid year progress report covered a summary of physical testing. An additional document is attached with more detail of the physical testing and also a document attached to this report which covers the DEM simulation component of this project.

Conclusions Reached &/or Discoveries Made (Not to exceed <u>one</u> page)

Please provide concise statement of any conclusions reached &/or discoveries made.

- DEM simulation can be calibrated to model the movement of a range of types of grain seeds as well as Material other than grain (MOG) that may be found within a bulk of grain.
- Calibrated DEM simulations were able to represent the physical movement and segregation of grain and MOG at the size and quantities tested.
- DEM Simulations will be limited by the number of particles that can be used in a simulation, meaning full scale bulk container ship simulation is unlikely to be possible.
- In initial simulations, changes in the container size/shape have been shown to have an effect on the movement of the chaff particles within the bulk of grain.
- Smaller grain movement vessels such as chaser bins and trucks may be a potential for future studies

Intellectual Property

Please provide concise statement of any intellectual property generated and potential for commercialisation.

N/A

Research software was used to conduct the simulation which can not be used to generate commercial outcomes. All DEM contact model parameters are common to what has been published in literature

Application / Communication of Results

A concise statement describing activities undertaken to communicate the results of the project to the grains industry. This should include:

- *Main findings of the project in a dot point form suitable for use in communications to farmers;*
- *A statement of potential industry impact*
- *Publications and extension articles delivered as part of the project; and,*
- *Suggested path to market for the results including barriers to adoption.*

Note that SAGIT may directly extend information from Final reports to growers. If applicable, attach a list of published material.

- Grain and chaff move differently under slow ship like sinusoidal motion and chaff tend to congregate together at the edges
- Discrete Element Method computer simulations were able to replicate the movement of grain and chaff which was validated against physical testing
- DEM showed that a change in the size of container for a given mass of grain can affect the movement of particles and reduce the congregation.

If chaff and MOG contamination can be stopped from congregating together in grain bulk, this will limit the chances of spear type sampling from collecting overly dirty samples at the end of transportation.

POSSIBLE FUTURE WORK

Provide possible future directions for the research arising from the project including potential for further work and partnerships.

Computer Simulation using Discrete Element Method has great potential in many areas of agriculture, especially the grains industry. Simulation times were longer than first expected and computer resources would need to be increased to tackle larger bulk grain simulations. Both software and computer hardware does develop quickly and these limitations may be removed or reduced in the near future. The work did quickly show that MOG and grain do move differently under motion and the DEM was able to replicate this behavior. The DEM also showed that a simple change in the geometry of the container changed the movement behavior which would be an interesting avenue to explore at both on-farm and grain export level. In addition to this, other types of movement and motion could also be investigated for its effect on grain and chaff segregation.

Novel bulk grain modelling for contamination sorting and separation, using computer simulation.

DEM Simulation results

Background

Discrete element method (DEM) was developed to simulate the bulk behavior of the granular materials (Cundall and Strack, 1971). It is a numerical modeling technique that simulates dynamic motion and mechanical interactions of each particle using Newton's second law of motion and a force displacement law (Boac et al 2010). In DEM modelling, particle interactions are treated as a dynamic process, which assumes that equilibrium states develop whenever internal forces in the system balance (Theuerkauf et al., 2007). This process has been used widely in industries such as powder technology and mining for many years. In recent years the approaches and techniques have been used for agricultural research processes such as soil flow around tillage machines (ucgul et al., 2014, 2015, 2020) and grain postharvest operations (Boac et al 2014).

Calibration

Accurate determination of the DEM parameters is of utmost important to carry out accurate simulations. DEM parameters can be determined by performing laboratory tests and then mimicking these tests in the simulation environment. DEM parameters can be determined either by trial and error method or using a statistical method of DOE (design of experiment). When the motion of the particle is going to be simulated using an angle of repose test is a preferable method. The angle of repose of a granular material is the steepest angle of descent relative to the horizontal plane to which a material can be piled without slumping. In this study, DEM parameters have been determined using angle of repose tests (conducted using barley and chaff particles). Some material parameters were also taken from literature. Hertz-Mindlin contact model has been employed to model the interaction between barley and chaff particles.

AOR – Angle of Repose.

The angle of repose of a bulk material is a way of determining the behaviour of a material when creating a static pile. This is a method used to help calibrate particles parameters, (shape, size, density etc) and contact model variables, (friction, shear and yield strength) for a wide range of bulk material simulated in DEM. To measure the angle of repose of a granular grain material, firstly a sample was placed in a pipe (100mm diameter and 300mm long). After that the pipe was lifted upward and the grain material flowed onto a cylindrical tray (200mm diameter with 22.5 mm high edges) until the grain overflowed and formed a pile (with a base of grain to minimize surface material interaction). When at rest an image of the angle of repose was captured. Subsequently the image was processed using digital image processing to determine the angle of repose (MATLAB ™ R2019a). The experimental methodology was replicated in DEM until the simulated angle of repose reached a close match of 26.68° (Figure 2). The DEM parameters of chaff particles were also determined using the same approach to achieve the angle of repose of 48.05°. The grain and chaff shapes were created using clump particles as suggested by Liu et al (2016) (Figure 4). After the calibration process DEM parameters determined are presented in Table 1.

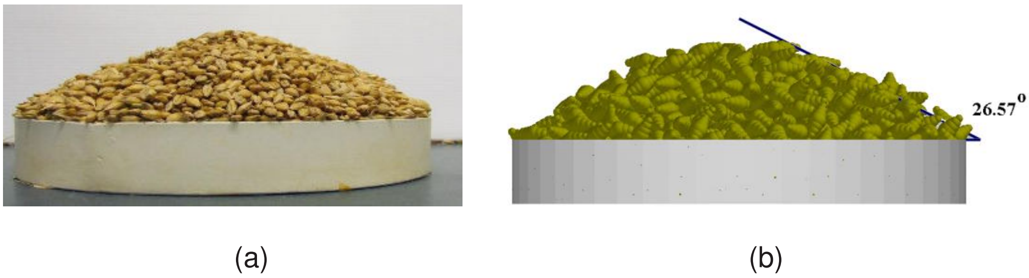


Figure 1 Angle of repose of barley (a) test and (b) DEM simulation

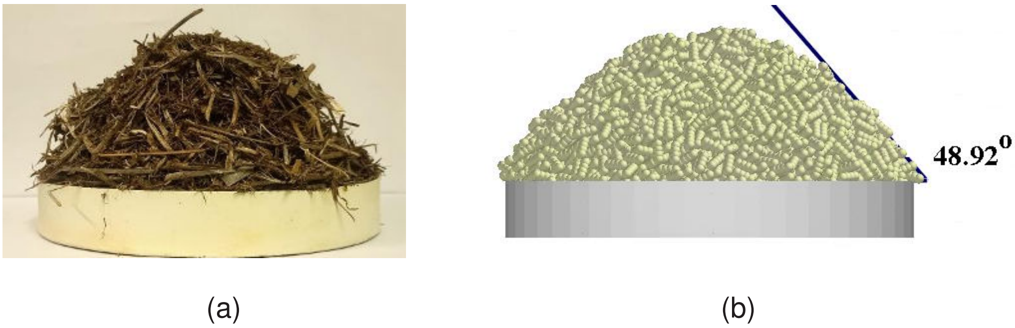
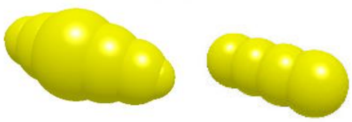
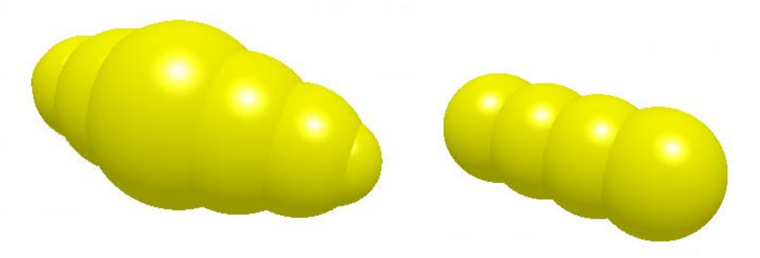


Figure 2 Angle of repose of chaff (a) test and (b) DEM simulation



Actual size



Double size

(a) (b)

Figure 3 Particle generation of (a) barley and (b) chaff

Table 1 DEM parameters used in the simulations

Property	Value
Density of barley particles (kgm^{-3})	1380
Density of chaff particles (kgm^{-3})	100
Density of perspex (kgm^{-3})	1190
Shear modulus of barley (Pa)	2.6 x 10^6
Shear modulus of chaff (Pa)	1 x 10^6
Shear modulus of perspex (Pa)	7.97 x 10^8
Poisson's ratio of barley	0.3
Poisson's ratio of chaff	0.4
Poisson's ratio of perspex	0.38
Coefficient of restitution of chaff-chaff	0.5
Coefficient of friction of chaff-chaff	0.58
Coefficient of rolling friction of chaff-chaff	0.08
Coefficient of restitution of chaff-barley	0.2
Coefficient of friction of chaff-barley	0.3
Coefficient of rolling friction of chaff-barley	0.01
Coefficient of restitution of chaff-perspex	0.1
Coefficient of friction of chaff-perspex	0.3
Coefficient of rolling friction of chaff-perspex	0.01
Coefficient of restitution of barley-barley	0.5
Coefficient of friction of barley-barley	0.35
Coefficient of rolling friction of barley-barley	0.08
Coefficient of restitution of barley-perspex	0.5
Coefficient of friction of barley-perspex	0.25
Coefficient of rolling friction of barley-perspex	0.01

Simulation set-up

After the calibration process a DEM simulation of the test rig was carried out. To do so, firstly a 1:1 CAD model of the test rig was imported into EDEM software along with the Perspex container. This was then filled with different rates of chaff and grain particles. 3.5 kg of grain particles (with a rate of 5kg/s) in 2s. Chaff particles were generated at 0.025s and 0.35s, at the rate of 0.1kg/s. After that the speed and rotation cycle of the test rig was replicated at the 0.1 Hz modified sinusoidal motion.

Actual size particles (6.7mm barley and 5mm chaff - Figure 4) caused the simulation to run slower than expected (400s simulation took 4 weeks) therefore larger than actual size grain and chaff particles (13.4mm barley and 10mm chaff-Figure 4) were used in the simulations to reduce simulation time (400s simulation took 2.5 days) and a simulation comparable to the physical testing of 1800 sec (30mins) took around 2 weeks. The side view and top view of the motion platform simulation can be seen in Figure 4 & Figure 5.

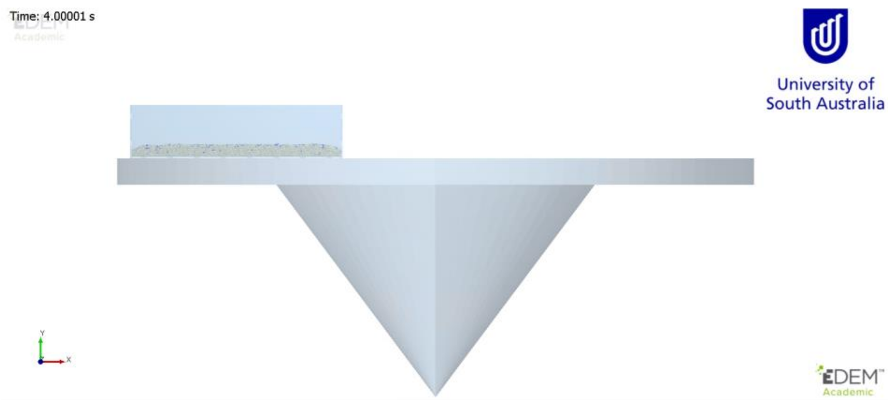


Figure 4 . Side view of DEM simulation of grain motion test rig

Figure 5 Top View of DEM simulation of grain motion test rig.

Results

Within the DEM software it is possible to track each particle's location during each time step of the simulation. Taking coordinates of each chaff particle and plotting the original position with the position at the last time step of the simulation allows for the positions to be compared. If this is expressed as a percentage of the total number of chaff particles in the simulation the difference in distribution can be seen in Figure 11. Using the wheat and chaff simulation results the simulation can be investigated before and after the simulation time. Simulations run with actual grain particles sizes were only run for 6.6 mins due to the simulation time needed but were starting to show some particle segregation.

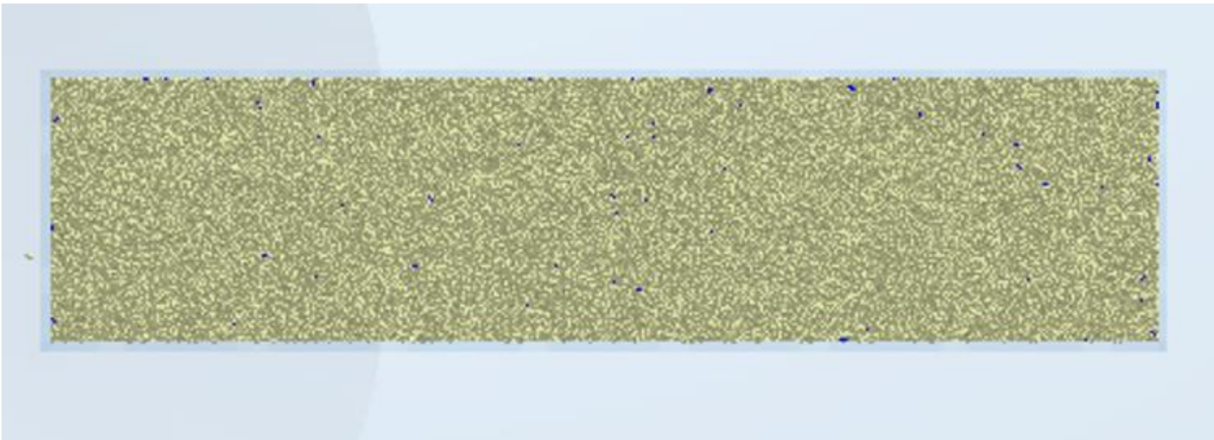


Figure 6 Actual grain particle sizes before simulation

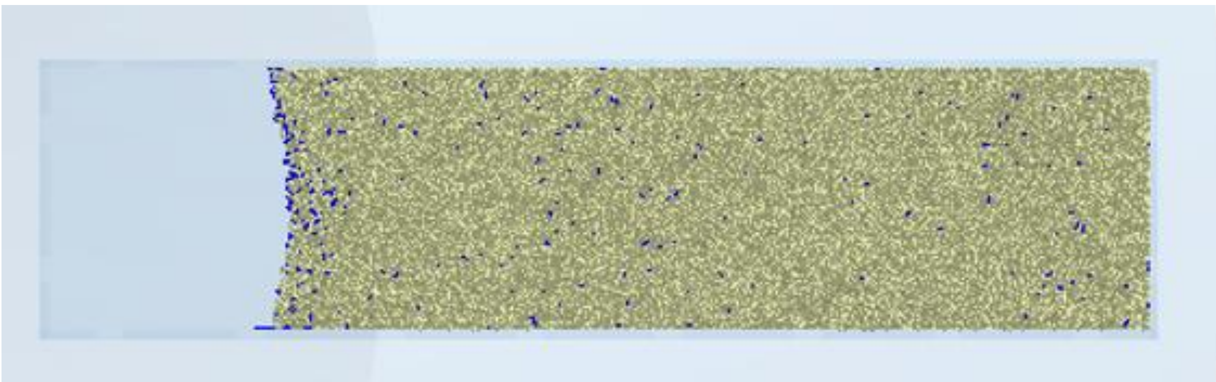


Figure 7 Actual grain particle sizes after 6.6mins simulation, Top view

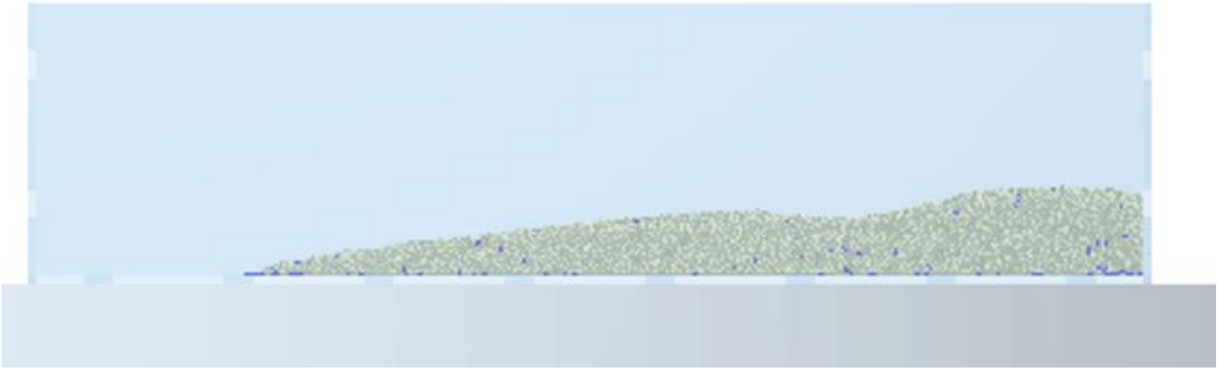


Figure 8 Actual grain particle sizes 6.6 mins simulation side view

It is difficult to identify where the chaff particles are within the grain bulk, but in the DEM simulation it is possible to isolate the grain and the chaff and just display the particles of interest.

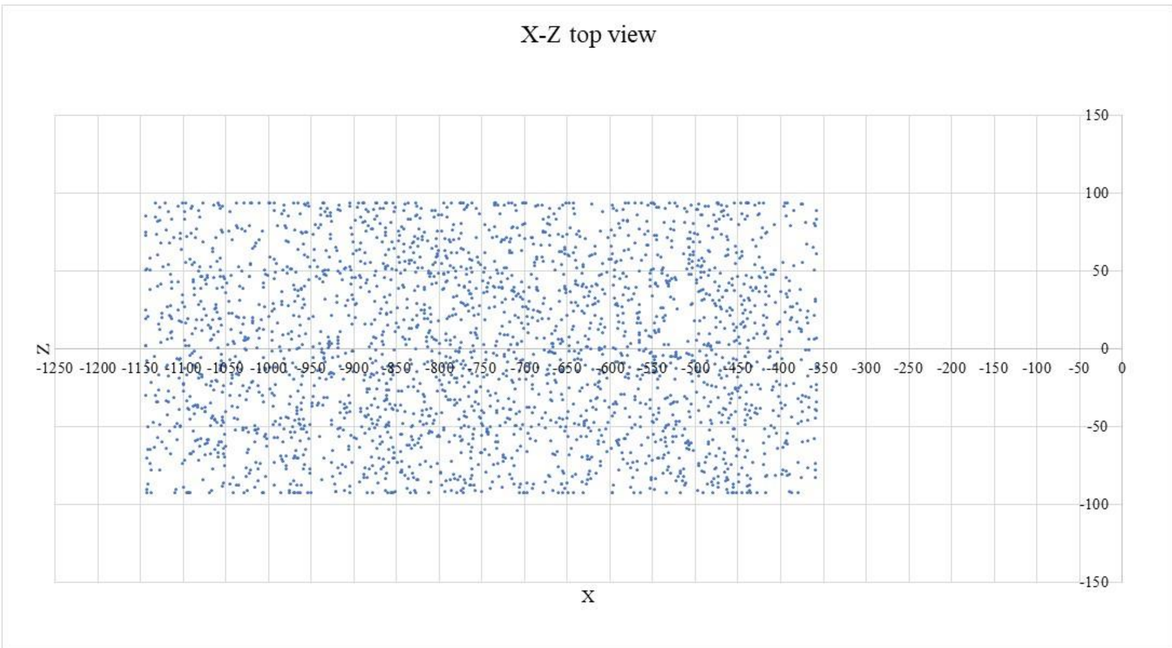


Figure 9 Top view of initial chaff particle locations

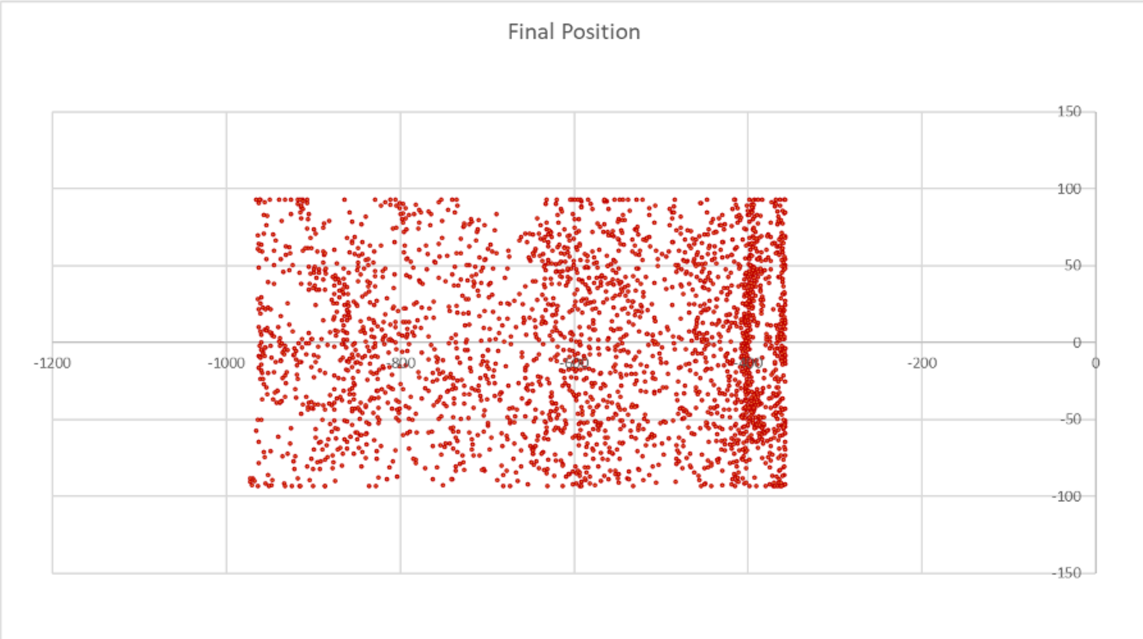


Figure 10 Top view of Final Chaff particle locations

To quantify the particle positions the simulation space was split into approx. 50mm slices and the particles counted for each slice, this can be plotted as a histogram over the length of the bin

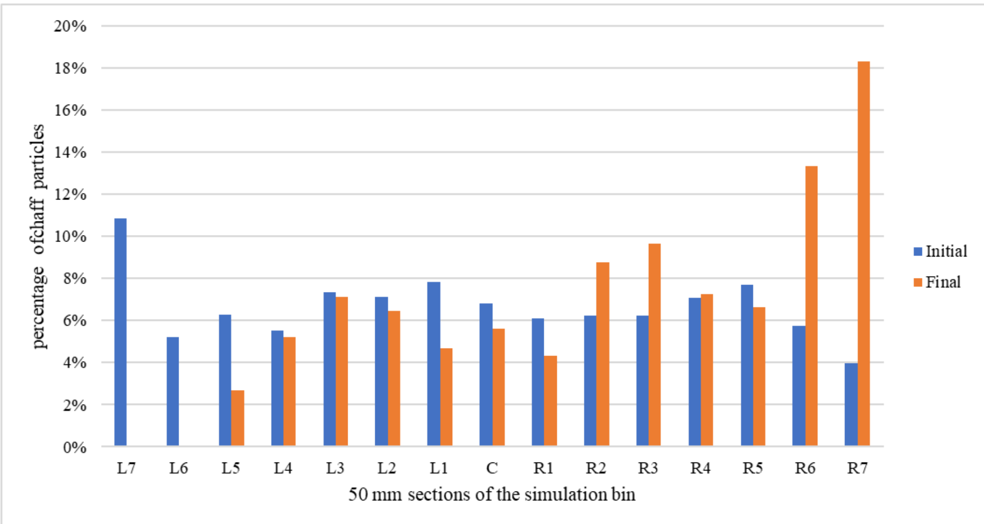


Figure 11 Chaff particle position tracking at initial and final positions for actual particles sizes after 6.6mins

It can be seen from Figure 11 that the final positions of the chaff particles is starting to move away from where they were originally and the percentages are increasing at the ends of the moving bulk of grain, where more than double the percentage of chaff particles are in the right hand 100mm of the grain .

Using double size grain and chaff particles allowed the simulations to run more quickly and complete the same simulation time (30 mins) as the physical testing

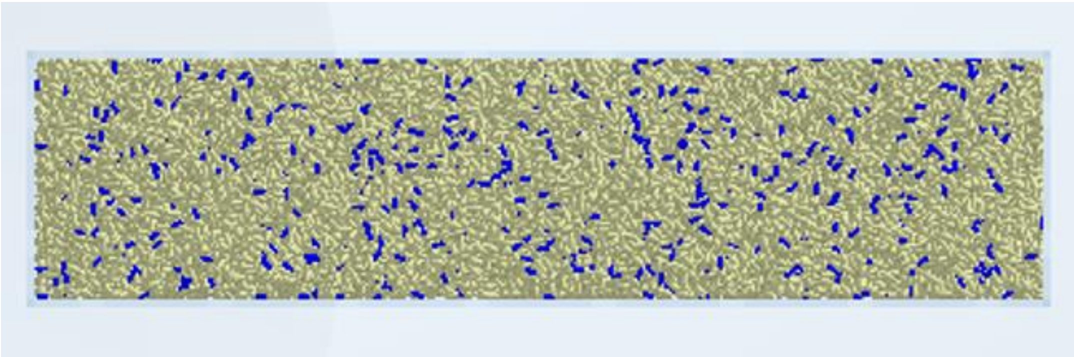


Figure 12 Double size Wheat and chaff in 800mm container before simulation

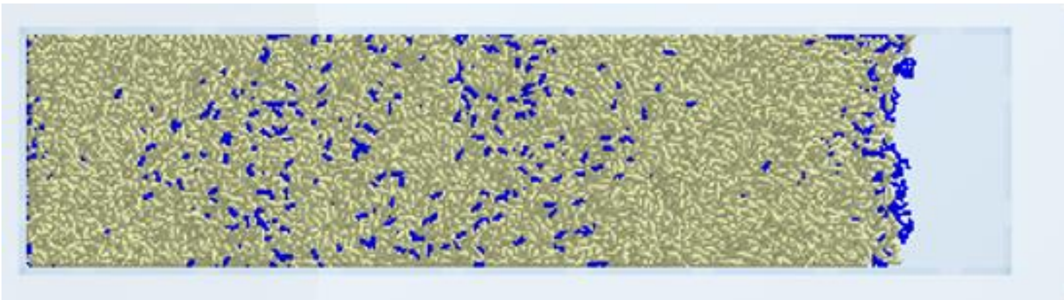


Figure 13 Double size Wheat and Chaff in 800mm container after 30 mins

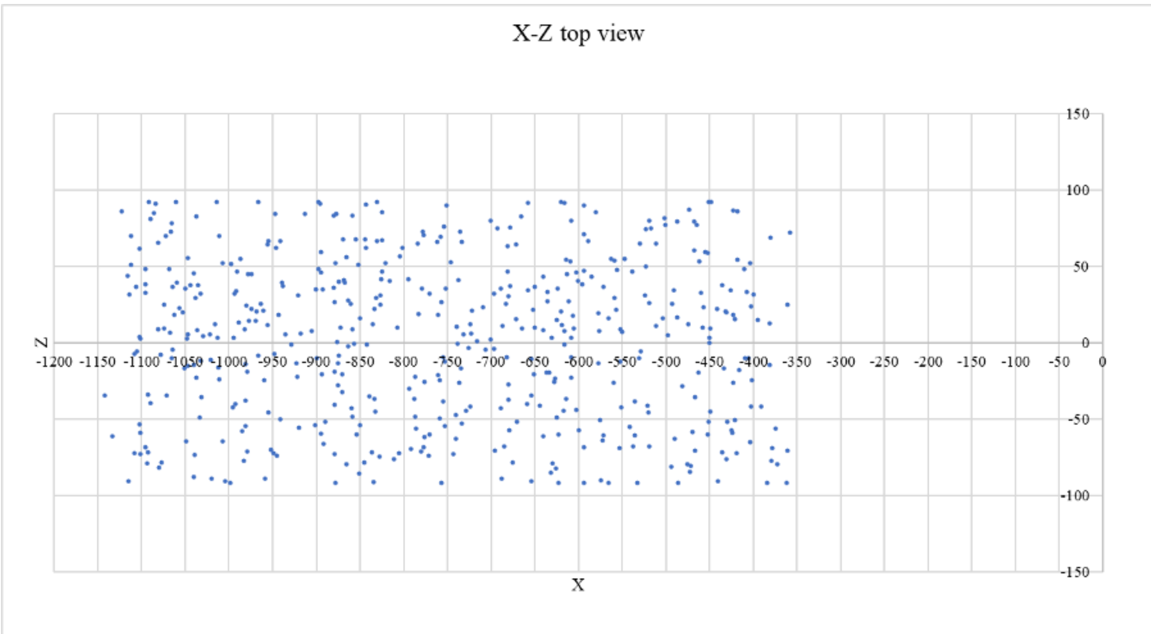


Figure 14 Top view of initial chaff positions for double size particles

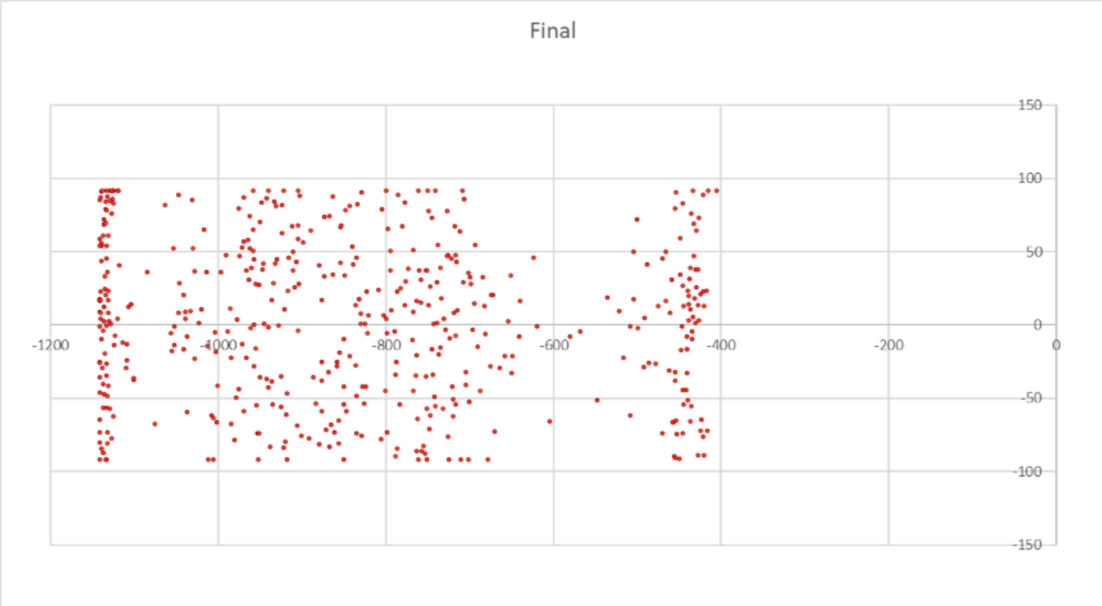
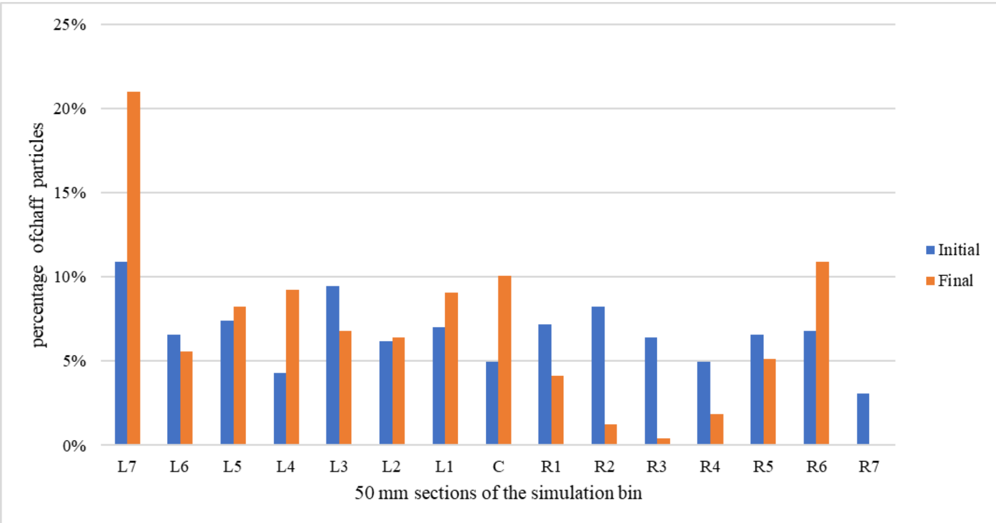


Figure 15 Top view of final chaff positions for double size particles



From these validation simulations it can be seen that the DEM is able to determine the difference in particle movement between grain and chaff and shows a similar concentrations of the chaff and lighter particles segregating to the end of the bulk container and clustering together. The numbers will not be exactly the same due to the methods used in quantifying the physical testing and the simulation results, but the trends are similar.

Once a DEM simulation is validated for a material and contact model, it is possible to change the container geometries and investigate if the material movement is altered. Everything else in the simulation, contact model, particles and total mass stays the same, but the container is varied. This was done by simply splitting the length of the container in half, reducing it from 800mm to 2x 400mm containers side by side.

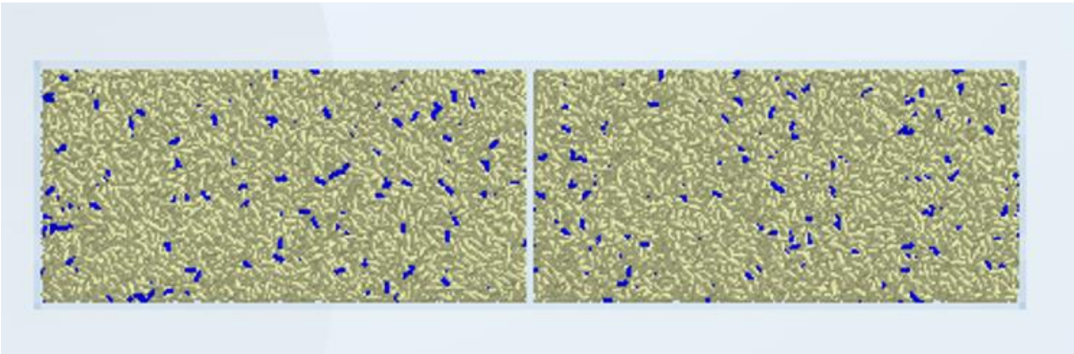


Figure 16 Top view of initial particle position in a split container

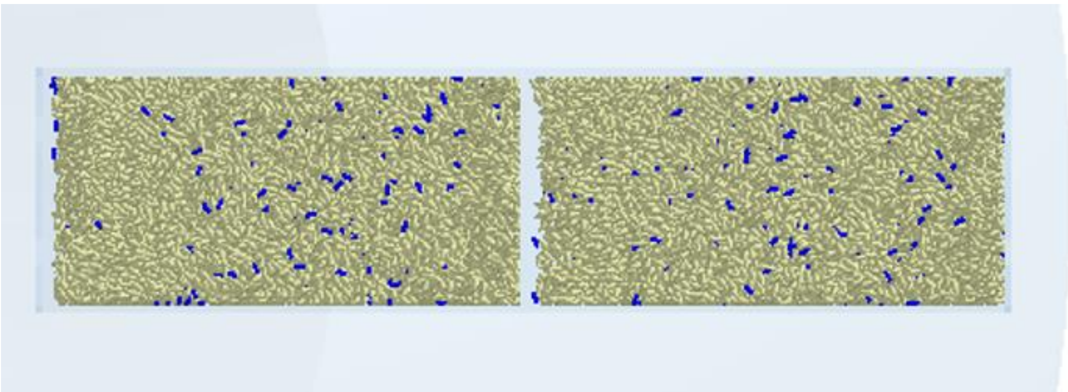


Figure 17 Top view of the final particle position in a split bin

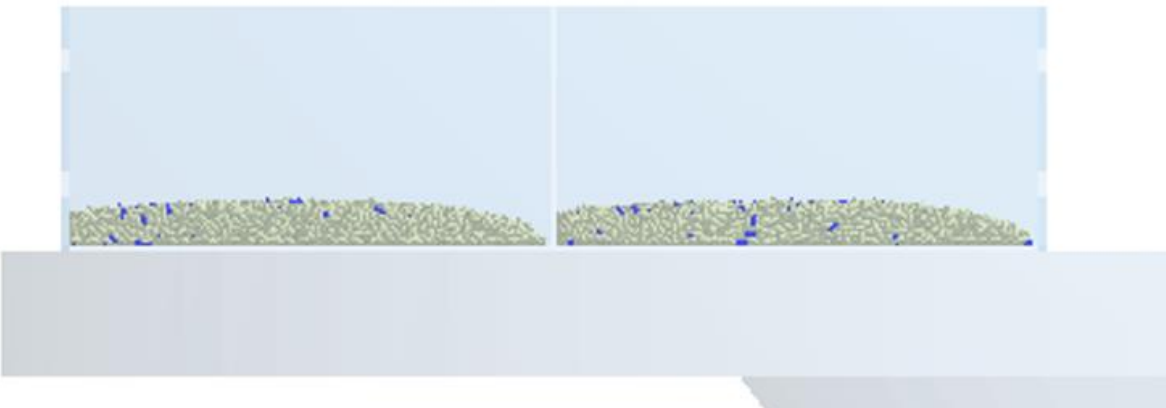
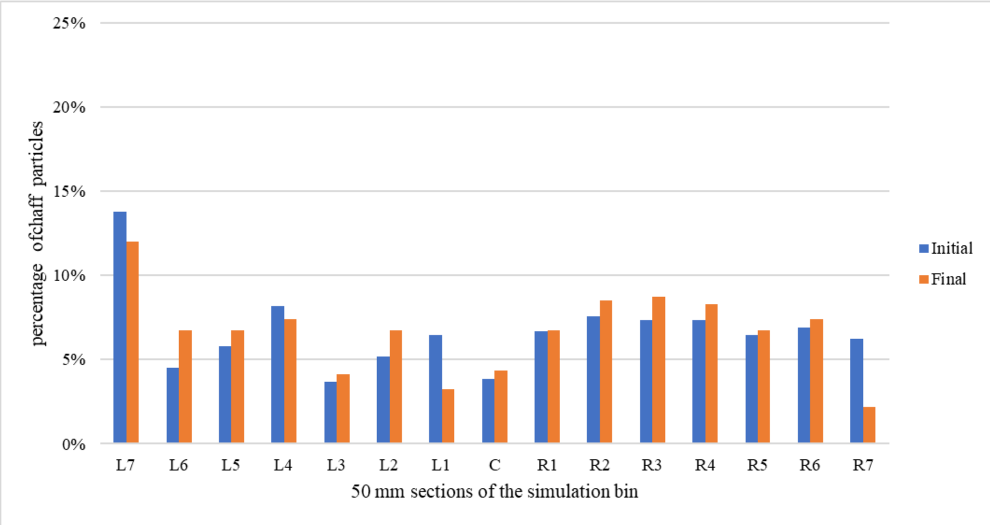


Figure 18 Side view of final particle position in a split container



With the reduced size container there is still some variation between the initial and the final chaff positions as the bulk of grain still has some movement, but the congregation of chaff particles at the end has been reduced and the distribution of chaff is more uniform over the container.

This highlights the potential of DEM as a tool to investigate improved container designs, but also solutions to minimise the segregation of chaff during transport motion.

Conclusions

- DEM simulation can be calibrated to model the movement of a range of types of grain seeds as well as Material other than grain (MOG) within a moving bulk.
- Calibrated DEM simulations were able to represent the physical movement and segregation of grain and MOG at the same container and grain quantities as the physical testing.
- DEM Simulations will be limited on the number of particles that can be used in a simulation
- In initial simulations, changes in the container size/shape have been shown to have an effect on the movement of the chaff particles within the bulk of grain.
- Smaller grain movement vessels such as chaser bins and trucks may be a potential for future studies

References

Boac JM, Casada ME, Maghirang RG, Harner JP (2010) Material and interaction properties of selected grains and oilseeds for modeling discrete particles. Transactions of the ASABE 53(4):1201–1216

Cundall, P.A. & Strack, O.D.L. (1971). A discrete numerical model for granular assemblies. Geotechnique, 29, No.1, 47-65.

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Ucgul, M., Fielke, J.M., Saunders, C. (2015). Three-dimensional discrete element modelling (DEM) of tillage: Accounting for soil cohesion and adhesion. Biosyst Eng. 129: 298-306.

Ucgul, M., Saunders, C., (2020). Simulation of tillage forces and furrow profile during soil-mouldboard plough interaction using discrete element modelling. Biosyst Eng, 190, 58-70.

Novel bulk grain modelling for contamination sorting and separation, using computer simulation.

Experimental results

Calibration using AOR – Angle of Repose.

The AOR is a physical test used to determine the nature internal friction angles of a bulk material, this can be used as a calibration method for the particle contact model of a DEM simulation. Figure 1, Figure 2 and Figure 3 show samples used to measure the Angle of repose of three grains used for testing.

Figure 1, Wheat Sample

Figure 2, Barley Sample

Figure 3, Lentil Sample

Table of grain sample properties

Sample Measured	Moisture Content	AOR	1000 grain-weight	Ave Seed Size
Wheat	10.4 %	23.13 deg	38.69 g	6.7x3.3 mm
Barley	9.9 %	26.67 deg	31.87 g	7.9 x 3.5 mm
Lentils	9.3 %	26.41 deg	33.89 g	4.8 x 2.5 mm

Figure 4, Example of contaminant AOR testing

Sample Measured	Moisture Content	AOR
Chaff/straw	N/A	61.24 deg
Round Snails	N/A	38.52 deg

Physical testing on the motion platform

Physical testing of bulk grain under low frequency motion was carried out on the University CKAS motion platform. Initially a 500x500x500 container was used and placed in the centre of the motion platform, due to this being above the neutral axis of the motion

Figure 5, Initial testing container

It was found that the motion at this point above the neutral axis did not provide enough motion to the grain in the container and that the small size also limited the movement. An improvement to this was to increase the size of the box to 800mm long in the direction of motion and 200mmx200mm in the other two dimensions. This container was also placed at the edge of the platform so as to increase the motion experienced by the container

Figure 6, Updated testing container

Figure 7 Improved location of testing container

Tests were carried out with Wheat, Barley and Lentils, but the focus of the results were based around wheat and chaff movement. The tests were run for 30mins until a visual difference in the location and distribution of chaff on the surface could be seen.

Although the motion platform had 3-axis of rotation, testing was only done over one axis with a modified 0.1 Hz sine wave incorporating a 4 second pause at either end of the motion. The platform had a maximum tilt angle of 24degrees

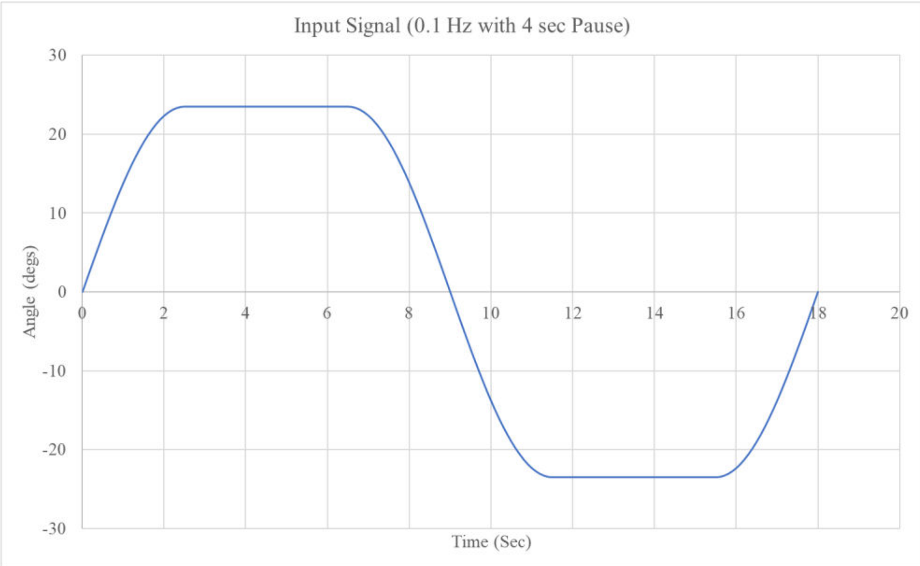


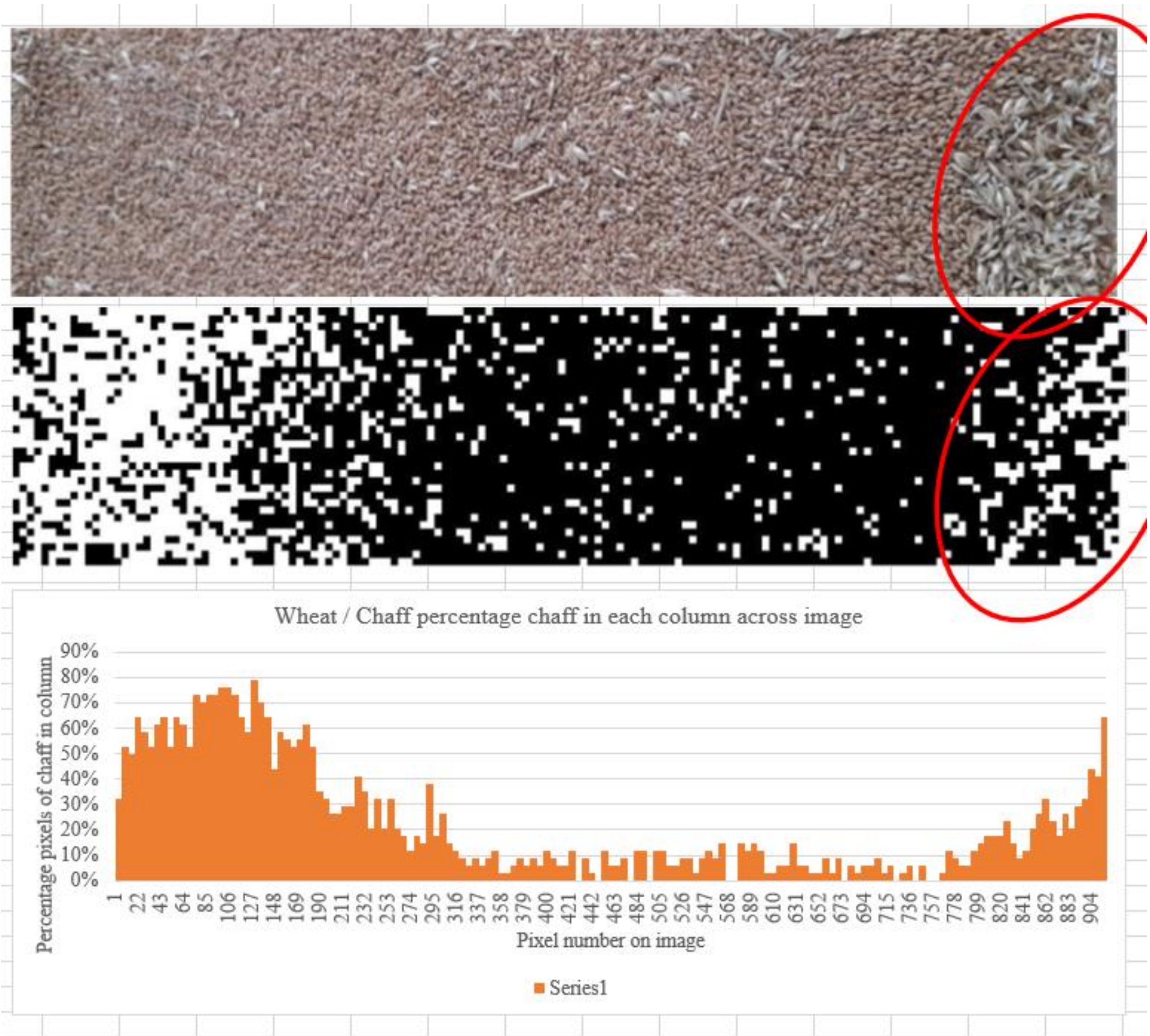
Figure 8 Motion platform input signal

Testing results:

Wheat and chaff

Figure 9, Before and after wheat testing

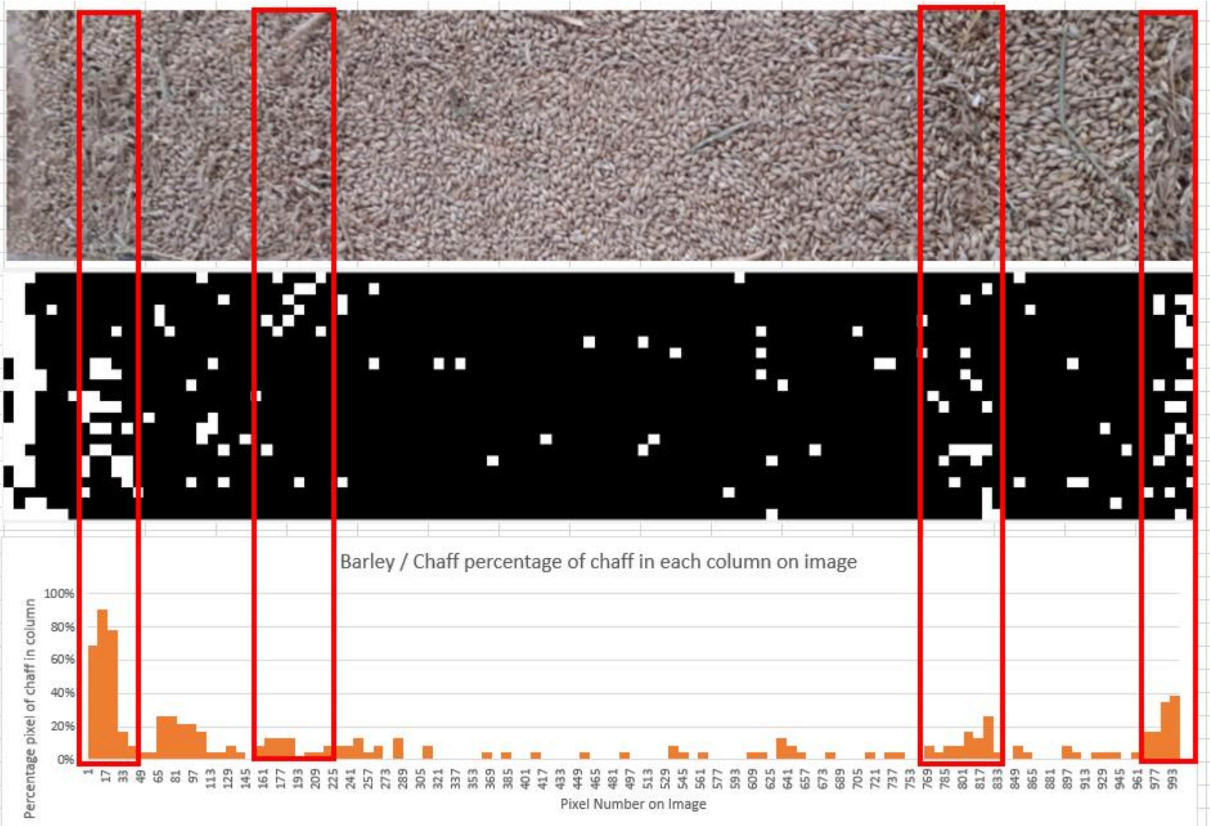
To attempt to quantify this movement, images were collected from above the container and then image processing was used to determine the number of pixels that contained chaff over the length of the container. It was found that in the center of the container there was as little as 10% pixels with light coloured chaff versus the ends where the chaff concentration increased to around 60%. This was not an extensive study and there were some issues with the lighting of the pictures and the contrast on the grain and chaff. The peak of high contrast and white pixels on the left hand side of the graph does not correctly represent high chaff loads, but the peak on the right hand side does.



Wheat / Chaff percentage chaff in each column across image
Percentage pixels of chaff in column
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1 22 43 64 85 106 127 148 169 190 211 232 253 274 295 316 337 358 379 400 421 442 463 484 505 526 547 568 589 610 631 652 673 694 715 736 757 778 799 820 841 862 883 904
Pixel number on image
Series1

Barley

Figure 10 before and after barley testing

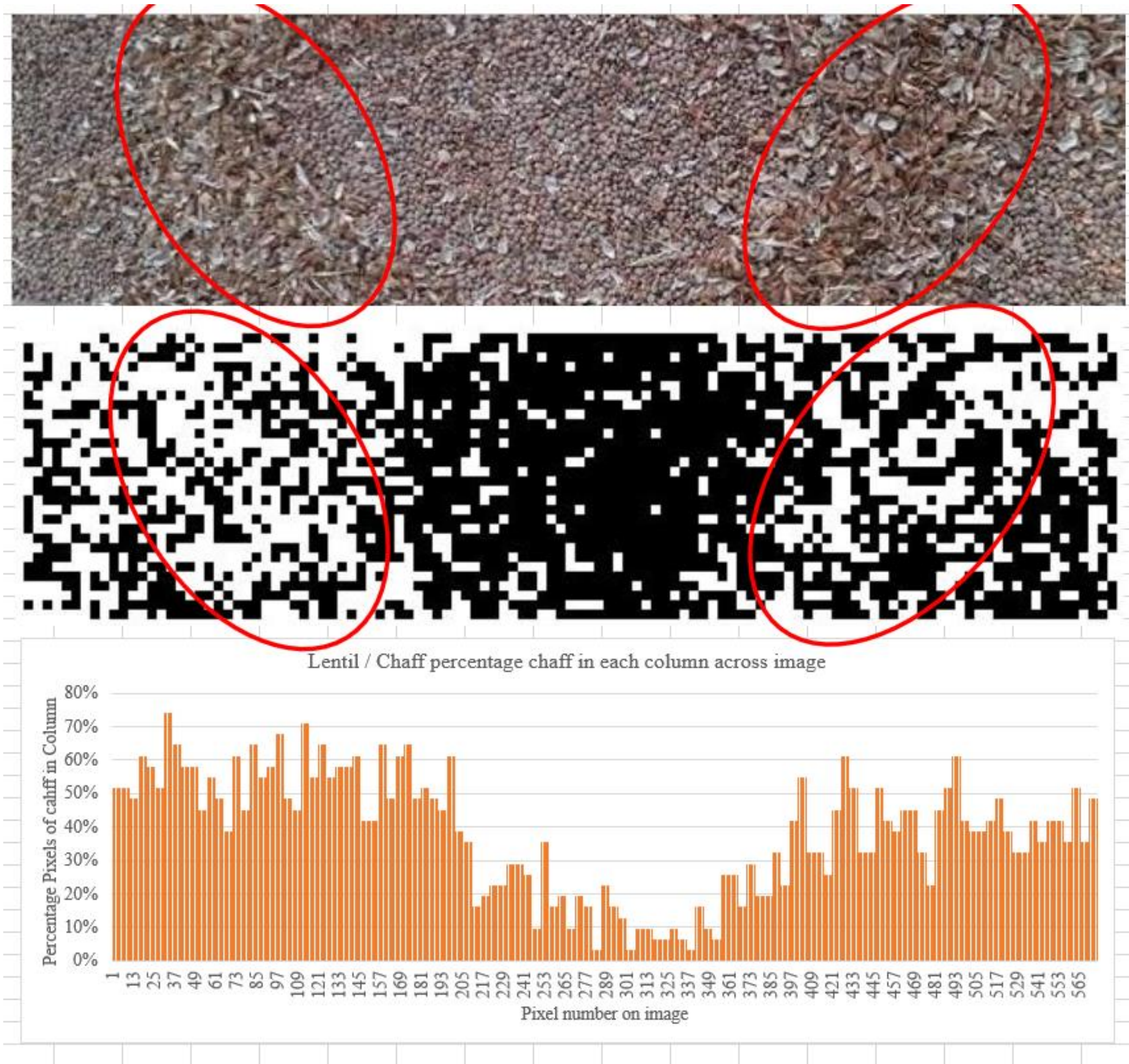


Barley / Chaff percentage of chaff in each column on image
Percentage pixel of chaff in column
Pixel Number on Image

Lentils

Figure 11 Before and after lentil testing

In a similar way to Wheat image processing to highlight contrast differences was carried out on the top view of the lentil testing and a similar trend of chaff movement was discovered. In the centre of the container chaff values in the pixels were less than 20% but nearer to the ends the percentage of chaff covered pixels increased to 50-60%. This is highlighted on the visual image with the enclosed red circles



In a range of crops and chaff types after 30 mins of physical motion there seems to be a trend of the chaff and lighter material congregating together in clumps on the grain bulk.

Physically characterising round snails

In addition to AOR for particle calibration a 3D scanner was used to try and scan a round snail. The top half of the snail could be scanned but when the snail was held up to enable scanning around the underside, the scanner was not able to detect the edge. Additionally, if the snail was flipped upside down and the top and bottom were scanned separately, there was trouble joining the two halves together.

This is an area that may need to addressed and improved in the future of creation of snails in the DEM simulation space is required.

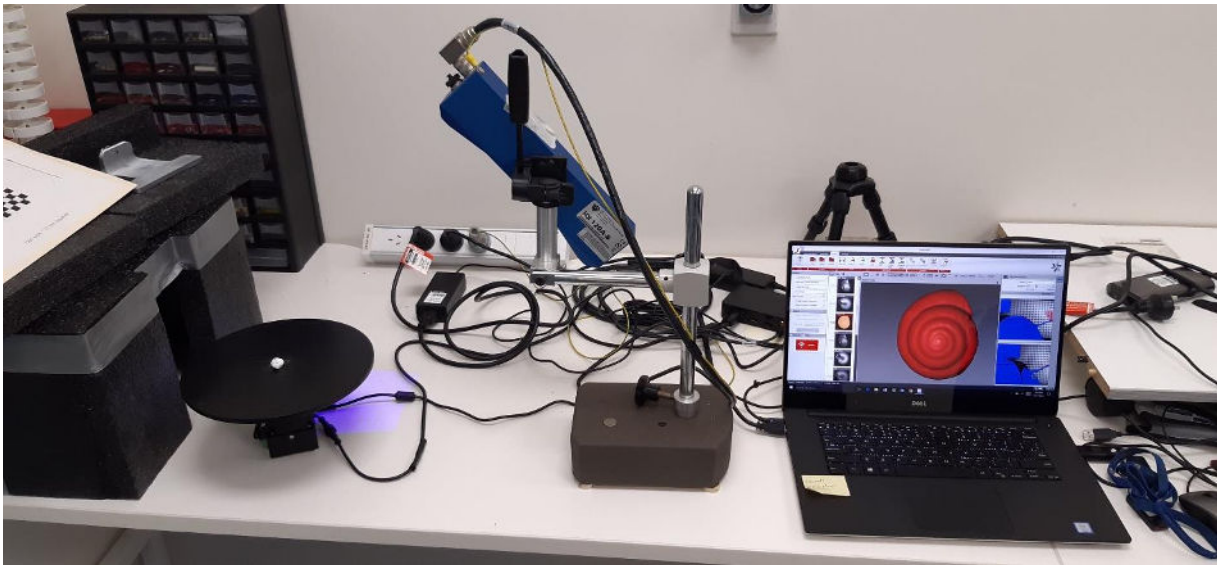


Figure 12 UniSA lab based 3D Scanner

Figure 13 A round snail on the scanner platform

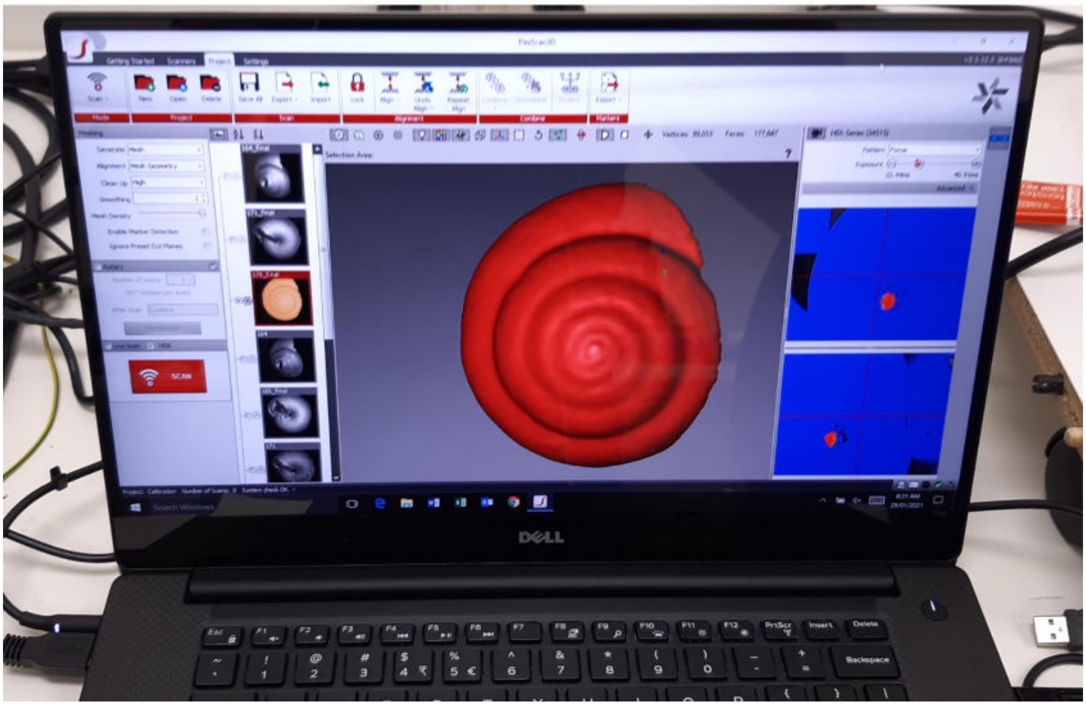


Figure 14 3D Scan of the top half of a round snail