ChuteMaven®

MATERIAL FLOW MODELING

Software for Modeling Conveyor Transfer Points

Version 0.4

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Introduction

Originally developed in 1995 by Dr. Andrew I. Hustrulid to model material flow in conveyor belt transfer chutes, ChuteMaven TM, a model based on the discrete element method is now available for use by engineering firms. This program allows the user to easily interface AutoCAD drawings into the DEM MavenTM for running simulations of different material flow capacities and chute designs before committing large resources to building transfer stations that may have some "unforeseen" problems.

Features:

- Quickly and easily import chute, belt and injection point geometry from AutoCAD DXF files.
- 3D Faces, lines, and circles are used to define required geometry.
- Use AutoCAD mesh surfaces to create complex surfaces.
- Handle AutoCAD drawings in US units (inches) and international units (mm).
- Frozen AutoCAD layers are not imported. Off layers are imported and can be displayed but are not modeled in the simulation. This allows the designer to maintain other construction geometries in the AutoCAD file.
- Specify material properties, belt speeds, and friction coefficients. Boundaries can be turned on and off during the simulation allowing the designer to start flows from feed chutes.
- Maximum and minimum particle diameter, particle density, contact friction, contact restitution and the percentage of particles allowed to rotate (from 0-100%) are easily defined.
- The time starts and stops for material injection are defined. This allows the designer to quickly fill rock boxes.
- The time boundaries are present and disappear are defined allowing the designer to open chute boxes.
- While the simulation is running a temporary file is output so the designer can review the simulation progress without interrupting the simulation.
- An estimated simulation completion time is continuously updated so the designer can plan future simulation runs.
- In reviewing the results the speed and particle pressure can be displayed.
- Cut and paste to a spreadsheet the particle positions, speeds, and forces for any frame. Also export the maximum speeds, kinetic energy, and potential energy to a spreadsheet.
- Create a restart file from any point in the simulation to "seed" the next design iteration.
- Velocities automatically assigned to belt surface.

- Unlimited number of injection locations.
- Output average forces on each boundary.
- Three-dimensional review of the results in a professional viewer. Step through the results one frame at a time or quickly get to the information needed by stepping forward and backward in 1 second intervals.
- Pan, Rotate, and Zoom the model in 3 dimensions to see exactly the vantage point needed.
- Create videos (AVIs) and capture bitmap images from any vantage point.

Design Steps

The design steps are logical and easy to complete. If the chute is already designed in 3 dimensions in AutoCAD, the additional work required to run a simulation is minimal. Typical simulation steps are:

1. Draw chute, pulley, and belt geometry in AutoCAD using 3D Faces, lines, and circles in inches.
2. Import into Chute Maven™ software.
3. Select material properties, tonnage, belt speed, friction coefficients in easy to use dialog boxes.
4. Save files and run the simulation.
5. Step through the results in 3 dimensions, create AVI's of the material flow and decide on improvements to the chute design.

Entering the Model Geometry

The transfer chute geometry is created and maintained in AutoCAD. The belts, pulleys, chutes, and material load points are all defined. How these different items are defined is discussed in this section.

Different layers are used in AutoCAD to identify separate items and group them together. Reserved layer identifiers include "Belt", "Pulley", and "Injection". The use of these identifiers is discussed in this section.

Layers that are Frozen in the AutoCAD model are not imported into the Chute Maven™ software. Layers that are Off are imported but not modeled in the simulation. The user has the ability to toggle the display of Off layers in the Chute Maven™ software.

The DEM Maven™ software assumes that the z axis is up. Gravity will act in a negative z direction. The geometry dimensions of the model should be in inches.

Care should be taken that points properly match up between surfaces and are not just "close enough". "Close enough" can cause material spill in the model and material to bounce as it encounters the artificial discontinuity in the model.

Defining the Belt

In a simulation you may have one or more belts with material entering the model and one or more belts taking material away. There is no limit to the number of belts the simulation can handle. However, since we are primarily interested in the flow through the chute, only the end of the conveyor belt should be modeled.

Each conveyor belt in the simulation must be defined with unique layers in AutoCAD. The name of the layers with the belts must start with the word "Belt" followed by a space. For example "Belt 1" or "Belt Incoming".

Incoming belts should be modeled with six "3D Face" surfaces. Three surfaces make up the belt at full trough depth and three surfaces represent the transition from full trough depth to being flat on the pulley.

3D Face surfaces are defined in AutoCAD and can have 3 or 4 vertices.

Care should be taken in determining (1) the tangent point with the pulley and (2) the proper trough depth relative to the pulley. This attention to detail is required to obtain the correct trajectory coming off the head pulley.

The geometry making up a typical incoming belt is shown in Figure 1.

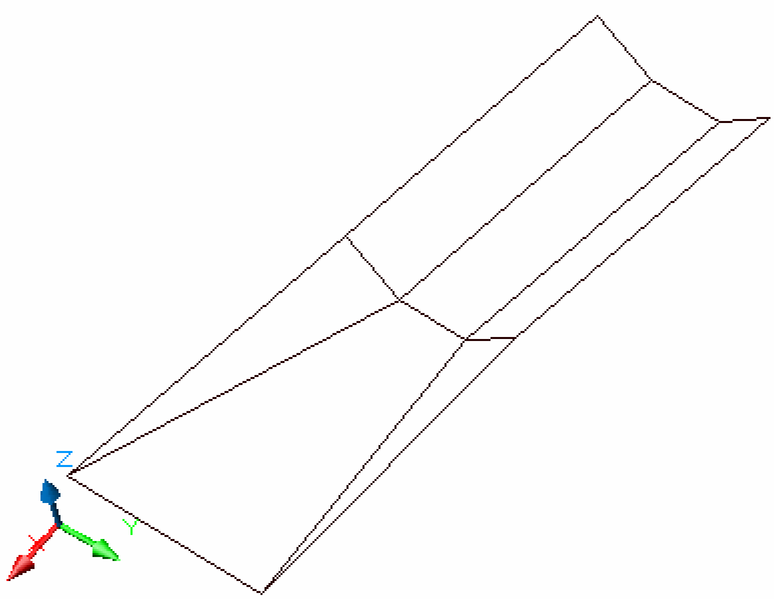


Figure 1 Example of Incoming Belt

The length at full trough depth needs to be long enough to get the material up to speed but not excessively long since this wastes simulation time.

Next a **line** in 3D space must be drawn on the layer representing the belt to define the direction the belt is traveling. The **line** should be defined in the direction of belt travel – starting at the load point and ending toward the discharge pulley. The direction in the XY plane will determine the direction of the velocity vectors on the flat surfaces. The Z coordinates of the velocity vectors will be determined from the planes of the surface making up the belt. This vector, defining the direction of the belt, will also be used together with the vector defining the center of the pulley to determine which direction the pulley is rotating. For the incoming belt it is recommended to define the direction vector in the transition region of the belt as shown in Figure 2.

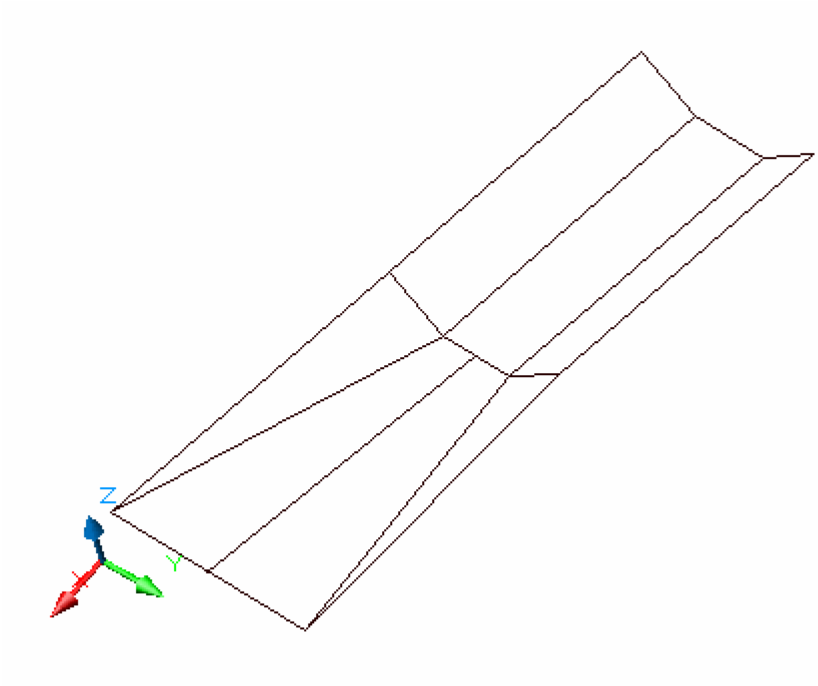


Figure 2 Belt with Direction Vector Defined

In summary to define an incoming belt the following items must be defined:

- All items defined on a layer named "Belt XXXX"
- Six – 3D Faces representing the belt at full trough depth and in the transition.
- One **line** defining the direction of belt travel in the XY plane and used to determine the rotation of the pulley.

The speed of the belt and coefficient of friction are defined later in the Chute Maven™ software.

The steps required for defining an exiting belt are nearly identical. In most cases it is unnecessary to define the transition distance from the tail pulley to full trough depth as typically the material is loaded on the belt after it is troughed and the material is not trajecting off of the tail pulley.

Defining Pulleys

The pulleys associated with the incoming belts should be modeled to help accurately calculate the trajectory of material coming off of the head of the conveyor. Each pulley must be defined on a separate layer and the layer's name should correspond to the associated belt. For example if the incoming belt is on a layer called "Belt A" the associated pulley must be defined on a layer "Pulley A". This nomenclature is essential as the pulley rotational direction and speed are directly tied to the belt speed.

In AutoCAD the pulley is defined by two circles representing the ends of the pulley and a single line drawn between the center of the two circles. All three of these elements must be drawn on a layer "Pulley XXX". No other drawing items can be included on this layer. An example of a pulley drawn in AutoCAD is shown in Figure 3.

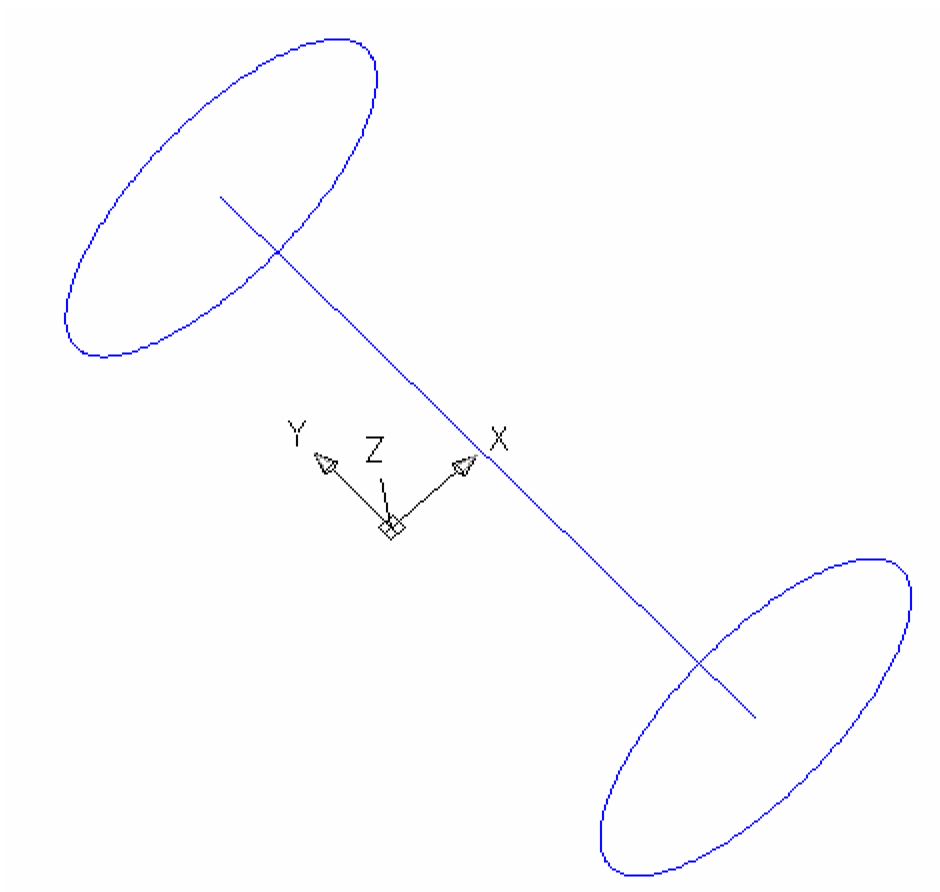


Figure 3 Pulley Drawn in AutoCAD

Defining the Belt Loading Points

To load the material on the incoming belt, particles are randomly created in a defined box. Then under the action of gravity the particles are allowed to drop onto the belt where they are brought up to speed.

To define the location of the injection boundary in AutoCAD a unique layer must be created with the name of the format "Injection xxx." A single line is drawn on the layer from opposite corners of the box (for example: the lower left hand corner to the upper right hand corner) of the injection region. See Figure 4. The injection volume is defined from the Xmin to Xmax, Ymin to Ymax, and Zmin to Zmax locations. While not mandatory, the injection layer should be named to correspond with the associated belt. In this example if the belt is on layer "Belt A" and the pulley on layer "Pulley A" then the injection point should be on layer "Injection A". No other graphic items should be included on the injection layer.

There is no limit to the number of injection locations that can be handled by the model.

In laying out the model it is convenient to locate the incoming belt along the x or y axis. An injection point drawn over the incoming belt is shown in Figure 4.

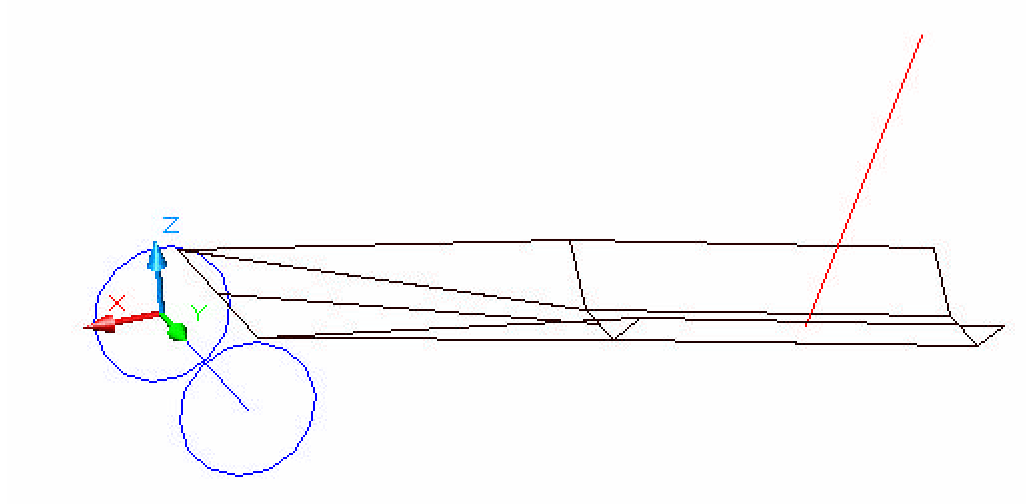


Figure 4 Injection Loading Point

If the injection box is too small it will "plug" up. Each time step that the program is required to inject a particle to meet the specified tonnage, the program randomly looks for an empty space to inject the particle. If it can't find one in 20,000 attempts it gives up, generates an error and continues. You will see this in the output of the program as the simulation is running. Make the injection point larger than you expect to need.

The goal of the load point on the incoming belt is to get the material loaded onto the incoming belt and up to the belt speed without spillage. To actually get material to load onto the incoming belt and keep it from spilling before the material gets up to speed, you need to include some skirting. It is also helpful to define surfaces around the injection loading point. These surfaces should NOT be defined on the same layer as the Injection boundary. An example of the injection point and skirting is shown in Figure 5.

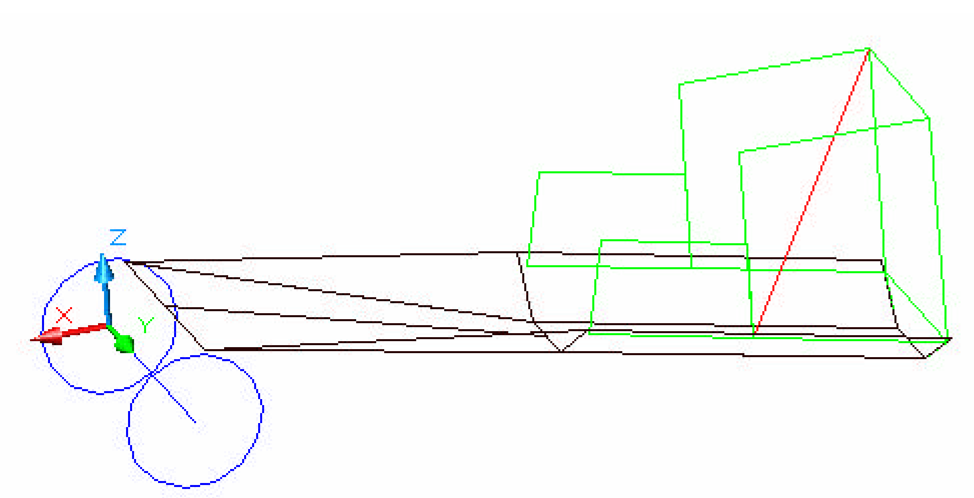


Figure 5 Injection Point with Skirting Defined

The injection regions can also be used to quickly fill rock boxes. Instead of only loading the material on the belt and allowing it to flow through the chute, gradually filling up the rock boxes, it is more economical to position an injection location directly over the rock box, and allow it to fill up directly for a few seconds.

Defining the Chute Geometry

The chute geometry is defined using 3DFaces in AutoCAD. Curved surfaces should be defined as a series of flat 3DFaces. **The file should be centered 0,0,0 in AutoCAD.**

The different sections of the chute should be defined on different layers. Typical examples of layer names include Chute Head, Left Pant Leg, Rock Box, Flop Gate 1, and Skirting. The only reserved layer names that should not be used are Belt, Injection, and Pulley. Care should be taken in the choice of what items are on each layer. Total forces acting on a particular boundary will be selected and summarized by layer. In addition, the time that a boundary comes on and off and the friction are also defined by layer. For example it would be appropriate to define the two positions of a flop gate on two separate layers – Flopgate Position A and Flopgate Position B.

An example of chute geometry is show in Figure 6.

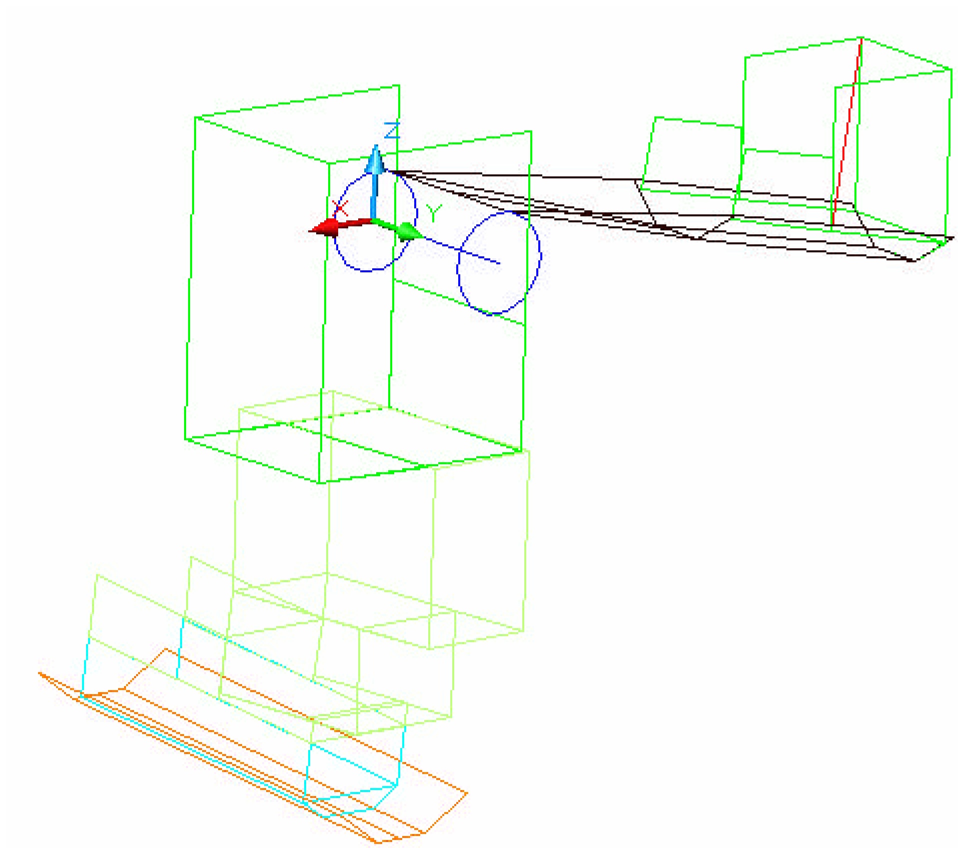


Figure 6 Complete AutoCAD Chute Geometry

Frozen and Off Layers

Layers that are Frozen in the AutoCAD model are not imported into the viewer. Layers that are Off are imported but unless turned On in the DEM Maven^{TM} software they will not be modeled in the simulation. In the DEM Maven^{TM} software you are able to toggle whether Off layers are to be displayed or not. Using Off layers is a good method for showing additional geometry or for taking measurements.

Saving in DXF Format

After the model geometry has been created in AutoCAD is should be saved in the dxf file formation so that it can be read by the Chute Maven^{TM} software program.

Creating the Chute Maven^{TM} Model

Once the AutoCAD model has been created it is time to generate the files required to run the DEM simulation. Start by running the DEM Viewer program. You should get the screen shown in Figure 7.

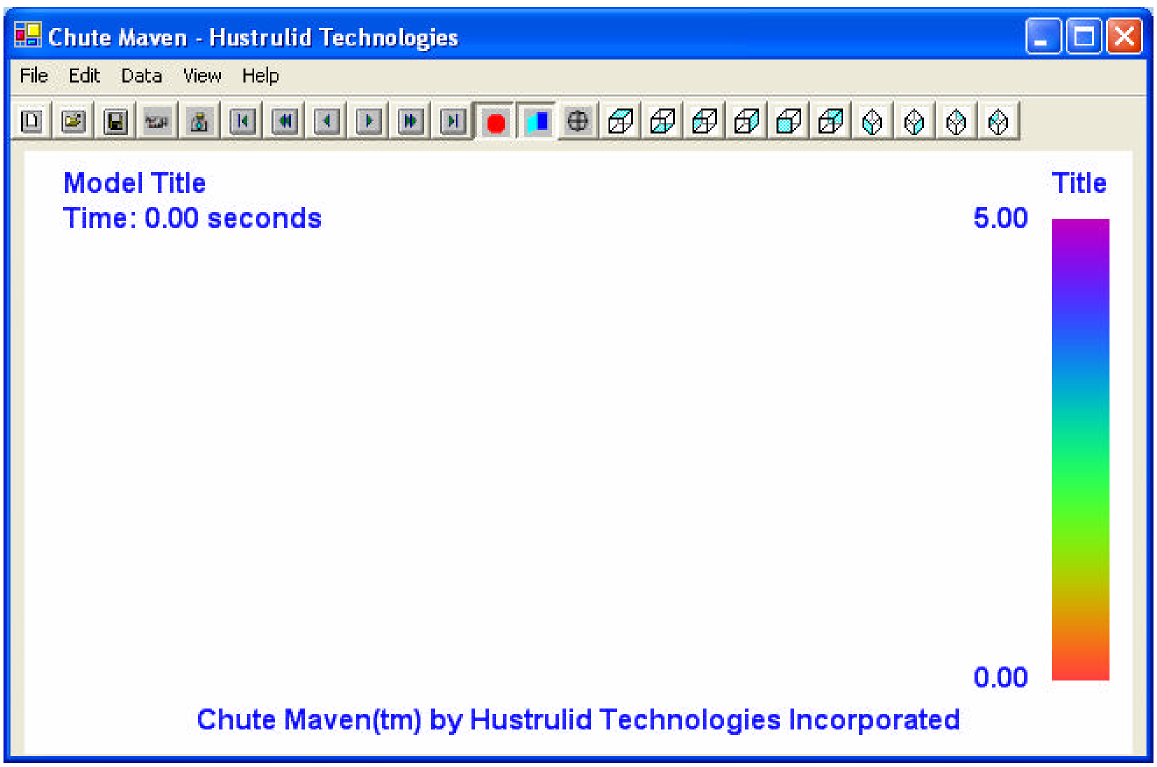


Figure 7 Chute Maven^{TM} Startup Screen

Importing a DXF File

The next step is to import the AutoCAD dxf file. Under the File Menu, select Import DXF. This will bring up a file selection dialog box. Select the dxf file and press ok. Several dialog windows will be displayed showing any errors in the imported file and a summary of the number and type of items imported. The imported model will look something like Figure 8.

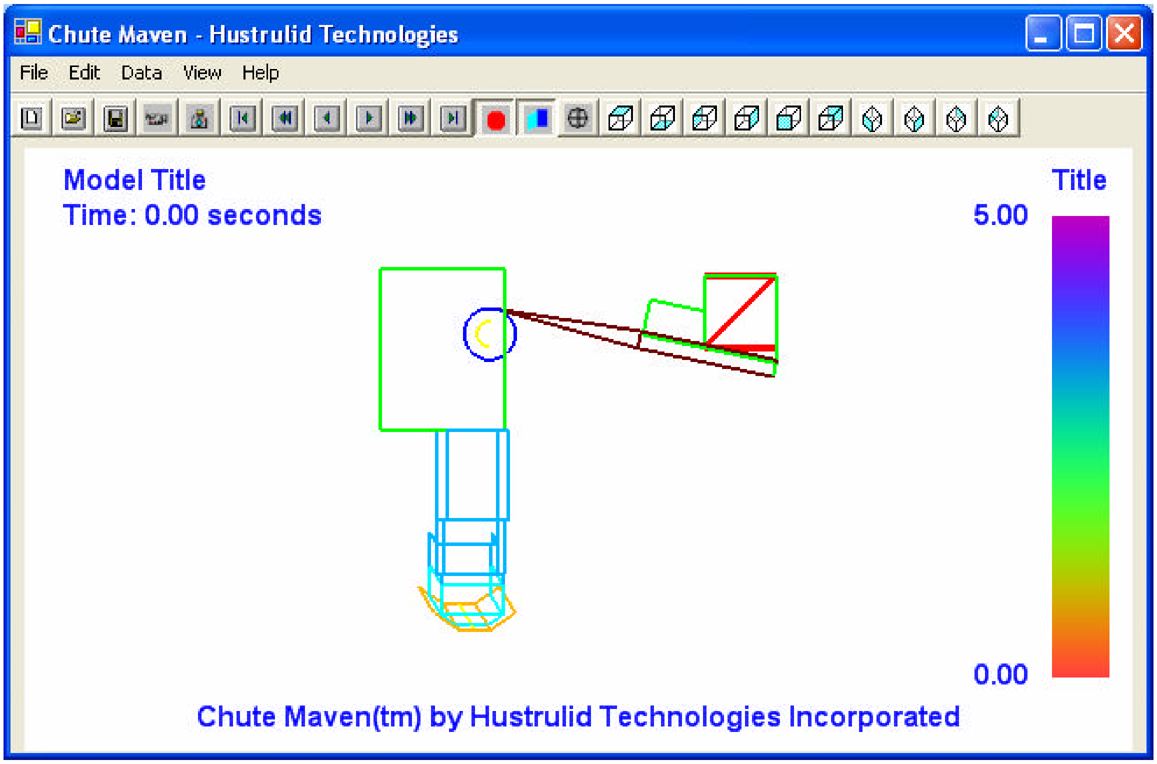


Figure 8 Initial Model View

The circle with cross hairs button on the toolbar will return the display to this view.

As the DXF file is written, Chute Maven[tm] makes a determination if the units of the drawing are in inches or millimeters and sets the appropriate mode. This can be changed later if incorrect.

Zoom, Pan and Rotate using the Mouse

The mouse is used to zoom, pan and rotate the model.

Pressing and holding the center mouse button (or the left and right button simultaneously) and moving the mouse up or down will zoom the model in or out, respectively.

Pressing and holding the left mouse button and moving the mouse will rotate the model.

Pressing and holding the right mouse button and moving the mouse will pan the model up, down, left and right.

Using a combination of zoom, pan, and rotate you should be able to position the model in any desired viewing position.

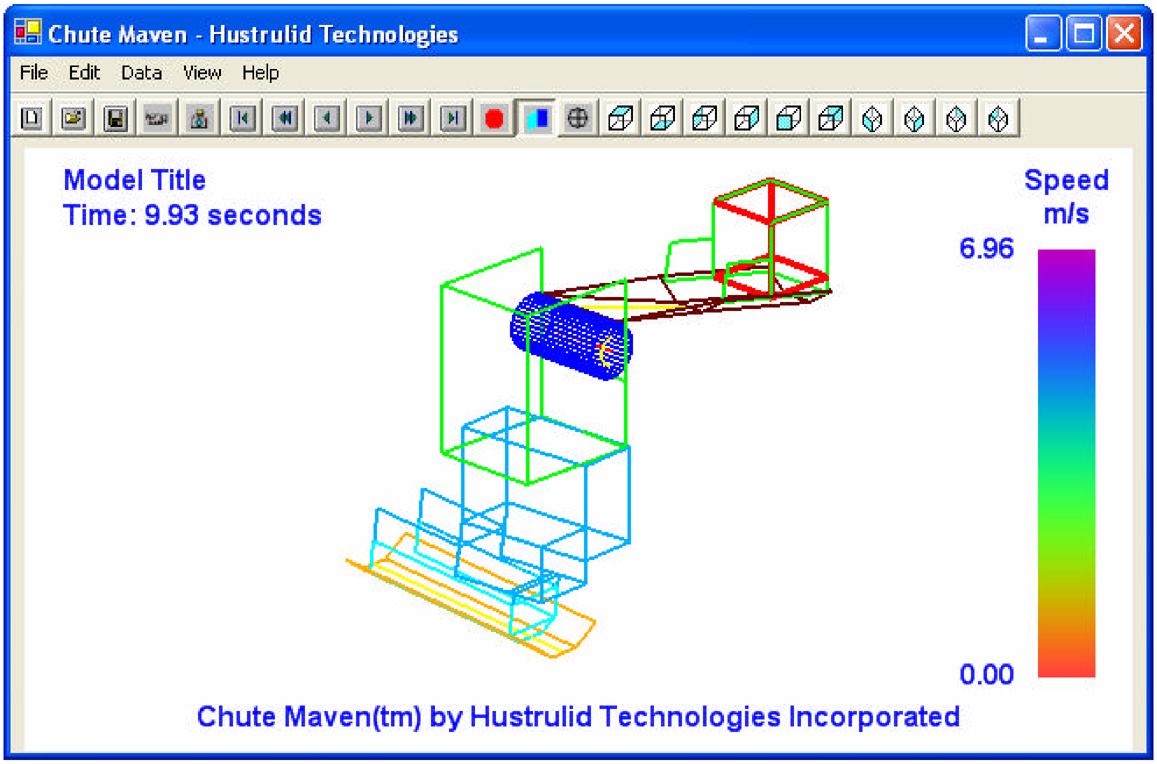


Figure 9 Chute Maven™ Screen Capture

Displaying Off Layers

The display of 3D Faces that are located on Off layers in the AutoCAD drawing can be toggled by pressing the toolbar button with the drawing of 2 blue boundaries on it. This feature allows the designer to see other features of the drawing that are not modeled in the discrete element simulation.

Editing the Model Parameters

All of the model parameters are set with dialog boxes under the Edit menu. The general model parameters are changed in the Model Parameters dialog box and the model specific information in the _______dialog box.

The Model Parameters dialog box allows the user to edit the main properties of the DEM simulation. All of these properties have default values and most may never need to be adjusted. The dialog box is show in Figure 10.

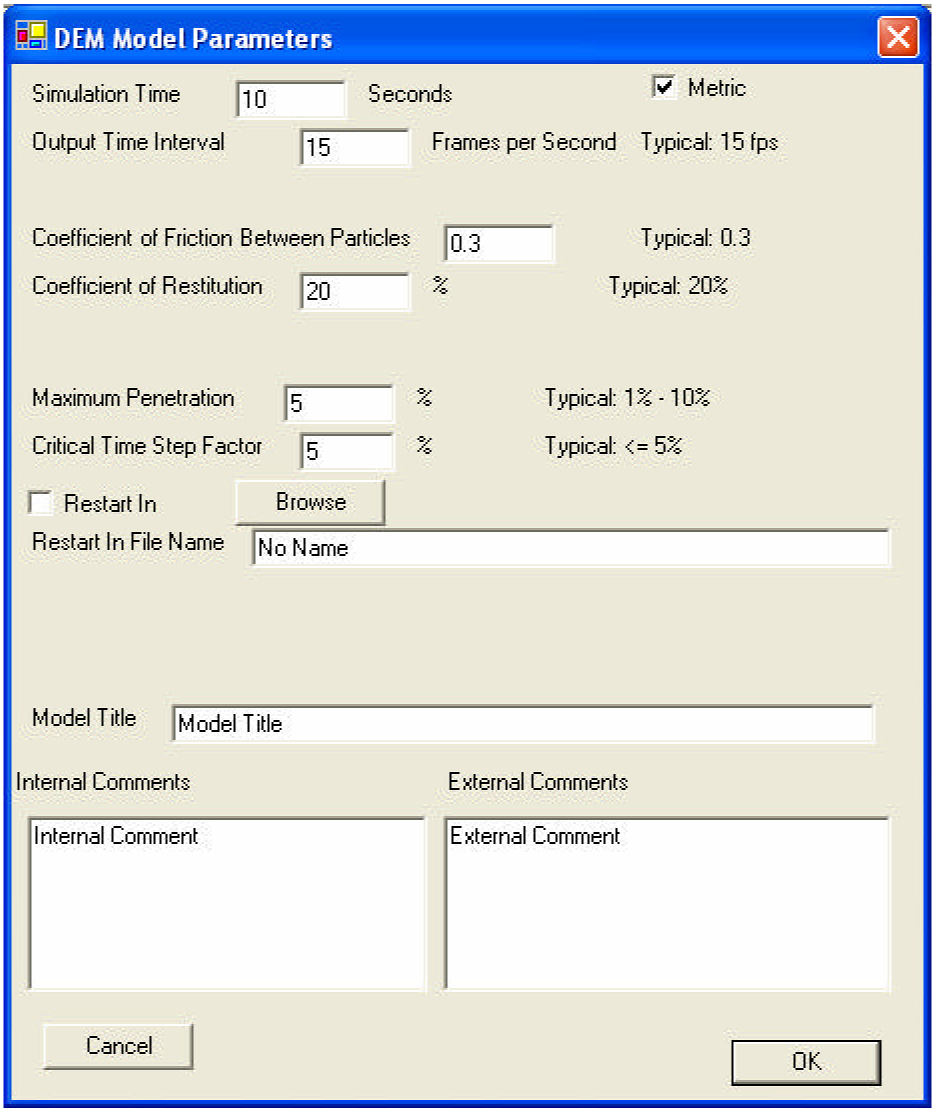


Figure 10 General Model Parameters

Simulation Time – The discrete element simulation will start at 0 seconds and continue for the duration of the simulation time. The simulation time should be taken into consideration when defining the time that boundaries and injection points turn on and off. The total amount of simulation time will depend on the size and configuration of the transfer chute you are modeling. Experience has shown that 10 to 20 seconds is usually adequate to reach a steady state for most chutes. The simulation time is defined in seconds.

Output Time Interval – This parameter defines how often snap shots of the particle positions and properties are output to the position file (.pos) during the simulation. This output also defines how many frames per second (fps) that the animations you create will contain. Experience has shown that 15 fps provides a reasonable trade off between the file size and smooth flow in the video. A maximum frame rate should be considered 30 fps. The output time interval is defined in frames per second.

Coefficient of Friction Between Particles - A common coefficient of friction is used between all of the particles in the simulation. It is defined here. A rough approximation of an appropriate value can be taken from the tan of the surcharge angle. For example a surcharge angle of 20 degrees returns a value of 0.36. Other parameters that affect the flow of particles in the model are the size distribution and the percentage of particles free to rotate. The value you ultimately select should be determined based on what you are trying to avoid or see – for example the chute plugging up or conversely material flowing though so quickly it slides off the side of the belt. In these examples higher and lower friction coefficients of friction, respectively, should be used. The default value is 0.3.

Coefficient of Restitution – Like the friction between particles the coefficient of restitution is defined for all particles in the simulation. Additionally it defines the restitution between particles and boundaries. The coefficient of restitution defines the amount of energy that remains following a collision between two items. The default value is 20%.

Maximum Penetration – This is a fundamental variable in the program. The contact between particles or between a particle and a boundary is fundamentally made up by a spring. As the items physically overlap, a spring between the items compresses. This creates a force repelling the items from one another and causes them to tend to move apart. The maximum penetration allowed is one factor in determining the stiffness of that spring.

First imagine the fastest we might expect a particle to be moving in the simulation. We can start to estimate this value by looking at the velocity of the belt boundaries. In addition, imagine that a particle traveling at the belt speed free falls from the top of the simulation space to the bottom of the simulation space. Here it will pick up more energy. Finally consider that this is the largest, heaviest particle in the simulation and it collides with the smallest diameter particle in the simulation. Given that all these things happen, the maximum penetration defines the maximum amount we would allow the large heavy particle to penetrate into the small particle. The default value in the program is set to 5%. In the actual simulation we would not expect to every see this amount of penetration.

As you will see, the value selected here will have a direct impact on how long the simulation takes to run. The relationship is nearly linear. For material that is flowing, for example, through a transfer chute, 5% to 10%, penetration is acceptable. For more static situations lower values should be considered. A recommendation is to perform the initial runs at a higher allowed penetration value and the final "fine tuning" runs at a lower allowed penetration value to evaluate the effect in your particular situation.

Critical Time Step Factor – This value is also critical to the discrete element simulation and it is one that should not need adjustment. A numerical iteration scheme is used to model the material flow through time. The time step used in the numerical algorithm is critical. If the time step is too large the system will become unstable and you will get inaccurate and occasionally completely unrealistic and unstable results. If the time step is too small you will end up wasting a significant amount of computation time. The value of 5% has been shown by experience to be reasonable for simulations in conveyor belt transfer chutes using spherical particles.

Restart In File – The Restart In check box, filename, and browse button give access to a very important feature of the program. A restart file allows you to define a starting point in a simulation from which the model will start.

Restart files are created in two ways. First they are output automatically during, and at the end of, each simulation. Second you can output a restart file from any point in time while you are reviewing the results of a simulation. Both of these procedures are discussed later.

By selecting the Restart In button the simulation will read the restart file. The restart file is found by pressing the browse button and navigating to the desired file.

Model Title – The model title is displayed at the top of the model viewing window, in animations, and image captures.

Internal and External Comments – These comments are stored when the model is saved in a .dem file format. Currently nothing else is done with the comments.

Simulation Data

The simulation data dialog box allows the user to input information regarding the conveyor belts, injection locations and individual layers. The units for the data depend on the mode of the program, metric or US units, which depends on the base units of the AutoCAD drawing that has been read.

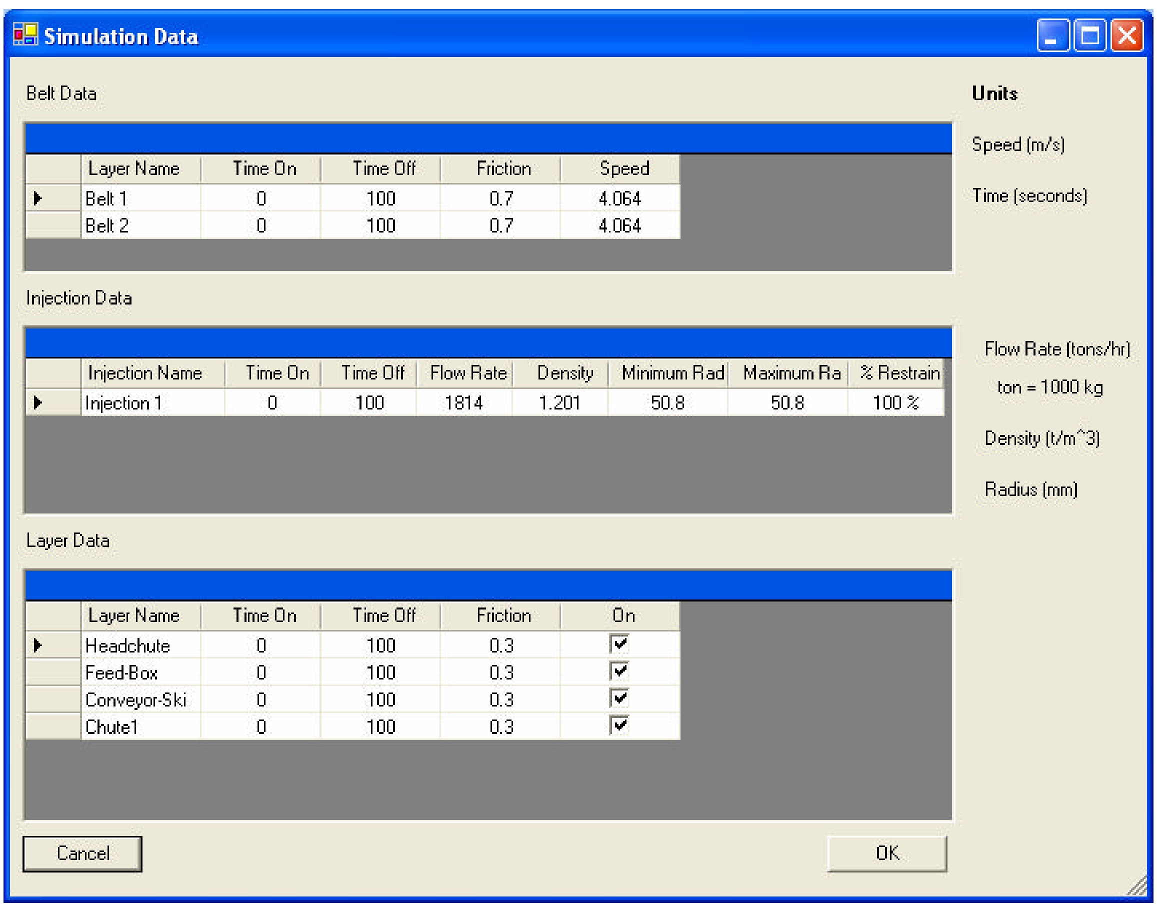


Figure 11 Simulation Data Dialog Box

Belt Data

The layer names listed in the Belt Data dialog box are taken directly from the imported AutoCAD dxf file. Do not edit these names. The remaining values impact the belt and a pulley if one is associated with the belt.

The layer names listed in the Belt Data dialog box are taken directly from the imported AutoCAD dxf file. Do not edit these names. The remaining values impact the belt and a pulley if one is associated with the belt.

The time on and time off values determine when the belt will be present in the model. They do not control when the belt will be moving or not moving!

The friction coefficient defines the friction between all of the particles and the belt and pulley. This is an important value. On the incoming belts you are trying to get the material up to the full speed of the belt. In reviewing the simulation results you want to make sure that the material is actually up to the belt speed. This is particularly important with particles that are allowed to rotate, at low tonnage, on a steeply inclined incoming belt. On the incoming belt it is probably best to keep this value on the high side.

On the receiving belt you should vary this value depending what you are trying to look at. If in the simulation you are worried about material build up in the chute and possible blockage, then run a simulation with a lower coefficient of friction. This will allow you to look at the sensitivity of the simulation to various friction factors.

The speed of the belt is defined in ft/min. This speed, in combination with the line defined on the belt layer in the AutoCAD dxf file defines the direction the belt is traveling. The speed is also used to calculate the rotational speed of the associated pulley.

Injection Details

The details for the injection area are selected in the Injection Details dialog box.

The injection names are taken directly from the AutoCAD dxf file. Do not modify these values. The time on and time off define the period when the injection will start and stop generating particles during the simulation. The flow rate is the tons per hour that the simulation will try to generate in the injection area. If the injection area becomes blocked a warning will be generated during the simulation. The density of the material is defined in lb/ft^3. This is the in situ density not the bulk density.

The minimum and maximum particle radii are used to define the range of particle sizes that will be created in the injection area. A uniform size distribution between the maximum and minimum radius will be created. Please be aware that the larger the difference between the largest and smallest particle the slower the simulation will run. It is recommended to run the initial simulations with larger particles that are of the same size. Then, as the geometry is refined, move to smaller particles. Finally, move to particles of different sizes. To save simulation time, it is also recommended to run the initial simulations at lower tonnages in order to position rock boxes and other items.

Typically it is best to run the simulation with the particles completely restrained. This should provide the most conservative results regarding potential chute build up and plugging. You will find that allowing all of the particles to rotate freely will result in a very loose and free flowing material. The final value in the Injection Details dialog box defines the percentage of particles created in the injection area that are restrained from rotating. This allows the user to vary the material properties between full and no rotation. The percentage entered is the percentage of particles restrained from rotating. For example to restrain 8 out of every 10 particles from rotation you will need to enter 0.8 to set the percentage at 80%.

Layer Properties

The Layers Properties dialog box is used to set the values for the flat boundaries in the simulation grouped by AutoCAD layers.

The layer names are brought in directly from the AutoCAD DXF file. The names should not be changed. The time On and time Off are when the boundary will appear or leave the simulation.

In general there are no problems in turning Off a layer, such as when opening a gate on a hopper, however care must be taken in turning boundaries on in the middle of a simulation. If the turned on boundary intersects particles that may be present, the forces on the particles are extreme and they will likely shoot out of the simulation!

One use of the time On and time Off is to position flop gates. You could set the time On and time Off to 0 for the flop gate not to appear in a certain position. While this will work it is more efficient to use the layer On/Off feature. Using time On and time Off set to zero will still simulate the boundary in the model. However, it will require some checking, which will slow the simulation down slightly. Setting the layer to Off, as discussed below, will not simulate the boundary at all.

The Layer On/Off toggle button is brought in from the properties of the layer in AutoCAD. If the layer is Off it is not modeled in the DEM simulation. The toolbar button on the main screen with the two blue boundaries toggles whether the Off boundaries are displayed or not in the viewer.

Saving the Model Files

To save the geometry and the information defining the model, select File ⟶ Save DEM File. This will output a file with the .dem extension that can be read back in with the File ⟶ Open DEM menu item.

The File ⟶ Save DIN file saves the file required to run the DEM simulation. DIN files cannot be read back into the DEM Maven™ program and modified.

Running the Simulation

After you have imported the model geometry from the AutoCAD dxf file, set the model parameters with the dialog boxes, and created the model file with the File ⟶ Save DIN menu item, it is time to run the simulation.

Depending on the size of the simulation and the speed of your computer this may take a few minutes or several hours.

The simulation is run by executing a separate executable file. Fortunately this is done automatically from the DEM Maven[TM] program. From the file menu select Run DIN Model. A file dialog box is brought up. Select the .din file you saved for the model and click OK. A separate DOS window will be brought up and the simulation started. The window should look similar to Figure 12.

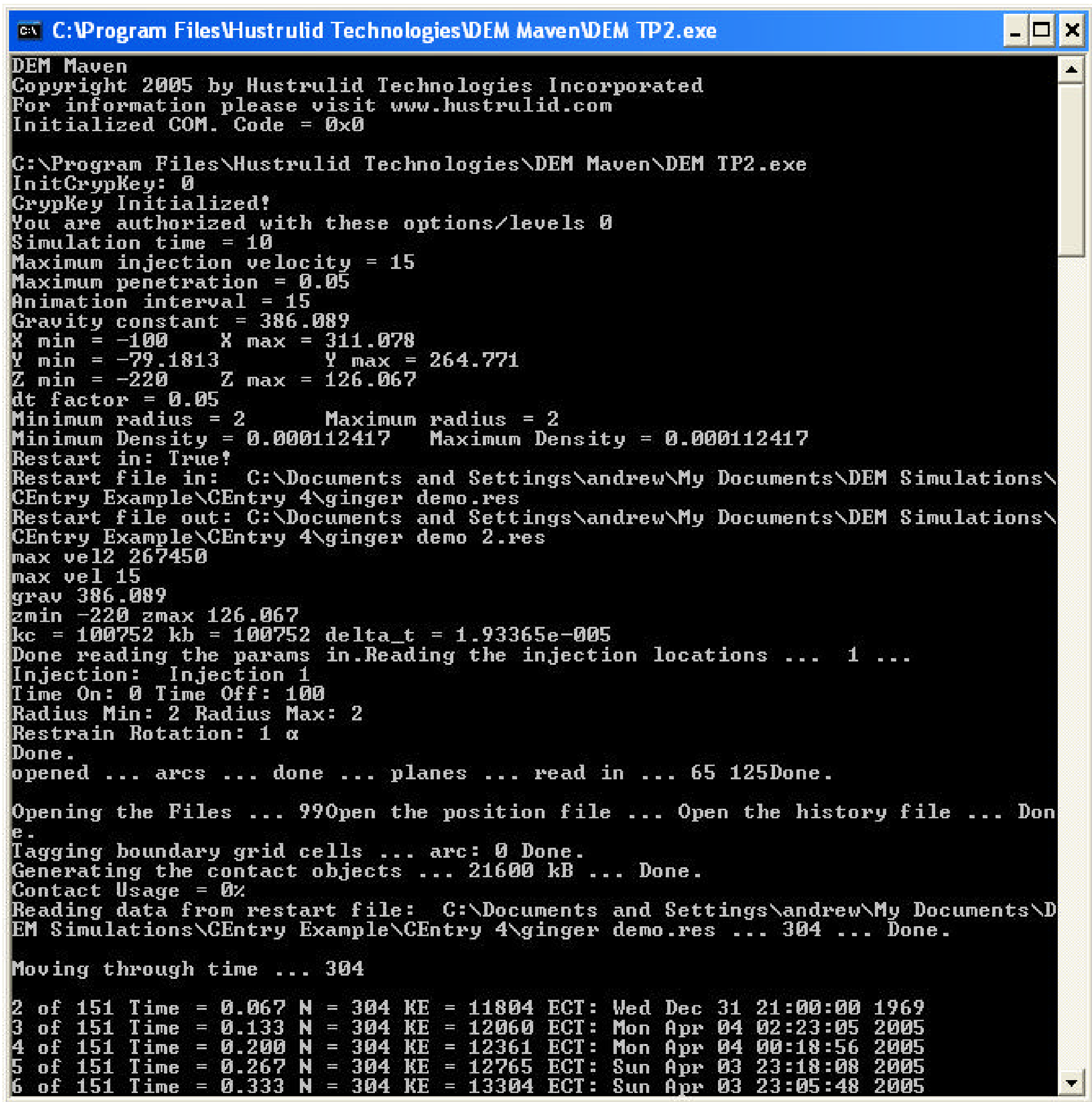


Figure 12 Output From Running Simulation

The simulation starts by echoing much of the model import information and then begins the actual simulation by showing the time, number of particles, kinetic energy, and an estimated completion time (ECT). The ECT becomes more accurate as the model progresses. However, if there are significant change in the number of particles during the simulation, such as injection boundaries being turned On or Off the ECT will be less accurate.

The number of particles and the kinetic energy can be used as an indication as to whether the model has reached a steady state with particles flowing into and out of the chute.

For every second of simulated time a restart file is written to the directory where the model was created. This is done so that you can check the progress of the model without interrupting the simulation. It is a good idea to initially check large simulations just after they have been started to make sure they are progressing as expected. To see the model progress from the DEM Maven™ software, select File ⟶ Load Output File from the main menu. Then in the open file dialog box "Select Files of Type ⟶ Restart File" at the bottom of the dialog. Select the restart file and the particles will be displayed in the main window.

If an injection area becomes plugged during the simulation a warning is displayed notifying you that the injection region in plugged. However, the simulation will continue.

After the simulation is completed you will be prompted to press the enter key which will close the DOS window.

Viewing the Results

After the simulation is complete a modelname.pos file will be created. This is a binary file that has all the information for every particle and each output moment in time. The frequency of the data, selected in the Model Parameters dialog box, defaults to 15 frames per second.

From the File Menu Select ⟶ Load Output File and the available position files will be displayed. Select the position file for the model being reviewed. You will be returned to the main window.

On the tool bar there are buttons for moving to the start of the simulation, moving to the end of the simulation, stepping forward or backward one second at a time, or stepping one frame at a time. You will find it useful to step trough the model one second at a time to quickly get to the time frame of interest.

Also on the toolbar is a button with a red circle on it. This button toggles the display of particles on or off. If there are a lot of particles in the simulation it is useful to turn off the display of particles prior to rotating, panning and zooming. Then the display of particles is turned back on.

The colors of the particles default to their speed. The scale on the right side of the main window displays the speed represented by the different colors. The menu items under View set what the colors represent and the scale. The color range can be set for the step being viewed or for the entire model. The colors can either represent either the speed of the particles or the pressure acting on the particle.

View Data Output From the Simulation

From the Data ⟶ Particle Data menu you can retrieve specific information about each time step and the particles at that time step. Initially the window shown in Figure 13 will be brought up.

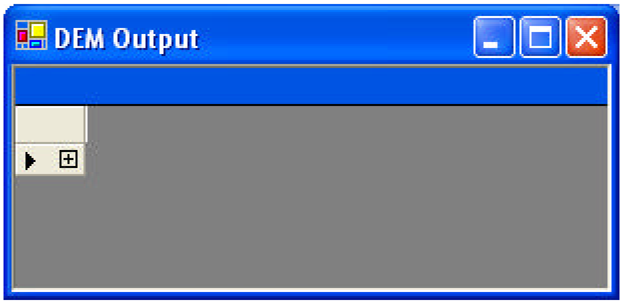
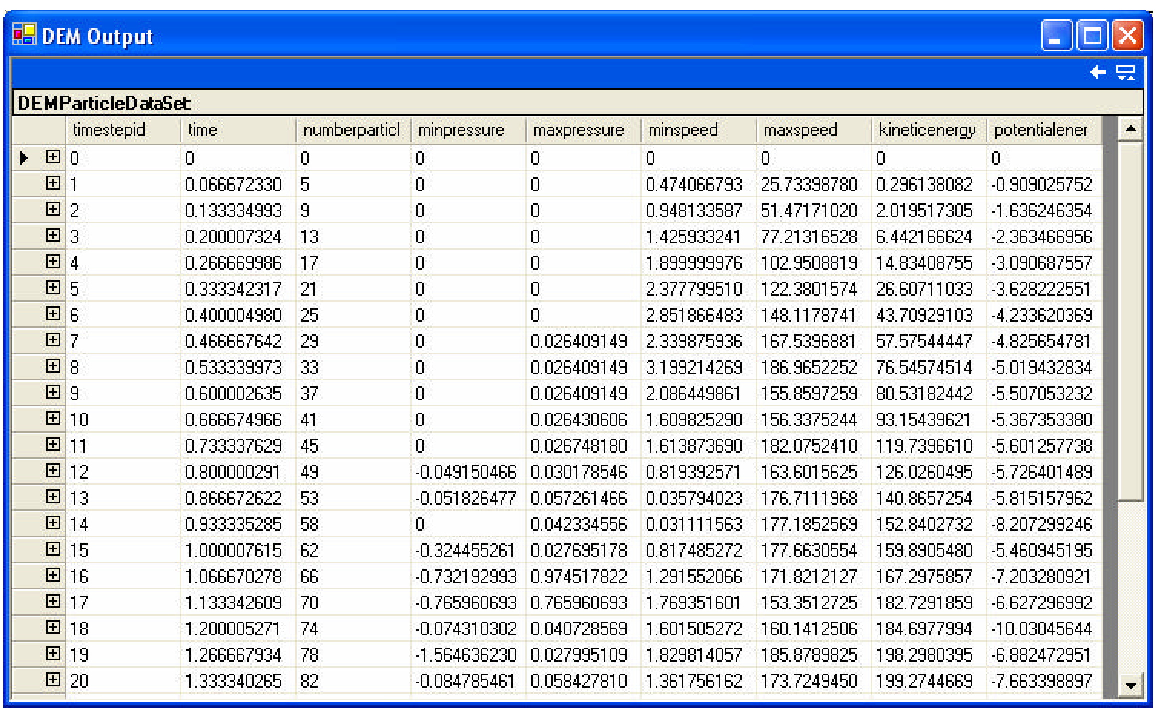


Figure 13 DEM Output Window

Pressing the '+' box will expand the tree exposing two tables as shown in Figure 14.

Figure 14 DEM Output Window After Being Expanded

The TimeStep and Particles selections are two tables that can be viewed. The TimeStep table has summary information including the number of particles, minimum and maximum speed, minimum and maximum pressure, kinetic energy, potential energy, and tonnage for each frame in the simulation. A typical output is shown in Figure 15.



timestepid	time	numberparticl	minpressure	maxpressure	minspeed	maxspeed	kineticenergy	potentialener
0	0	0	0	0	0	0	0	0
1	0.066672330	5	0	0	0.474066793	25.73398780	0.296138082	-0.909025752
2	0.133334993	9	0	0	0.948133587	51.47171020	2.019517305	-1.636246354
3	0.200007324	13	0	0	1.425933241	77.21316528	6.442166624	-2.363466956
4	0.266669986	17	0	0	1.899999976	102.9508819	14.83408755	-3.090687557
5	0.333342317	21	0	0	2.377799510	122.3801574	26.60711033	-3.628222551
6	0.400004980	25	0	0	2.851866483	148.1178741	43.70929103	-4.233620369
7	0.466667642	29	0	0.026409149	2.339875936	167.5396881	57.57544447	-4.825654781
8	0.533339973	33	0	0.026409149	3.199214269	186.9652252	76.54574514	-5.019432834
9	0.600002635	37	0	0.026409149	2.086449861	155.8597259	80.53182442	-5.507053232
10	0.666674966	41	0	0.026430606	1.609825290	156.3375244	93.15439621	-5.367353380
11	0.733337629	45	0	0.026748180	1.613873690	182.0752410	119.7396610	-5.601257738
12	0.800000291	49	-0.049150466	0.030178546	0.819392571	163.6015625	126.0260495	-5.726401489
13	0.866672622	53	-0.051826477	0.057261466	0.035794023	176.7111968	140.8657254	-5.815157962
14	0.933335285	58	0	0.042334556	0.031111563	177.1852569	152.8402732	-8.207299246
15	1.000007615	62	-0.324455261	0.027695178	0.817485272	177.6630554	159.8905480	-5.460945195
16	1.066670278	66	-0.732192993	0.974517822	1.291552066	171.8212127	167.2975857	-7.203280921
17	1.133342609	70	-0.765960693	0.765960693	1.769351601	153.3512725	182.7291859	-6.627296992
18	1.200005271	74	-0.074310302	0.040728569	1.601505272	160.1412506	184.6977994	-10.03045644
19	1.266667934	78	-1.564636230	0.027995109	1.829814057	185.8789825	198.2980395	-6.882472951
20	1.333340265	82	-0.084785461	0.058427810	1.361756162	173.7249450	199.2744669	-7.663398897

Figure 15 Information about All Frames

The units of the values in the table depend on the mode of the program. They are as follows:

Measure	*US*	*International*
Time	Seconds	Seconds
Pressure	Lb/in2	N/mm2
Speed	In/sec	mm/sec
Kinetic Energy	in-lb	N-mm
Potential Energy	In-lb	N-mm
Tonnage	lb	Kg

The pressure measurement will most likely be removed in future versions as it is very sensitive to the exact time step and therefore of little real value in it's current form.

Pressing the left arrow in the upper right corner of the window will allow you to navigate back to the parent window.

Selecting the Particles table brings up all the internal data for the particles displayed in the current frame including the position, properties, forces and speeds. A typical output is show in Figure 16.

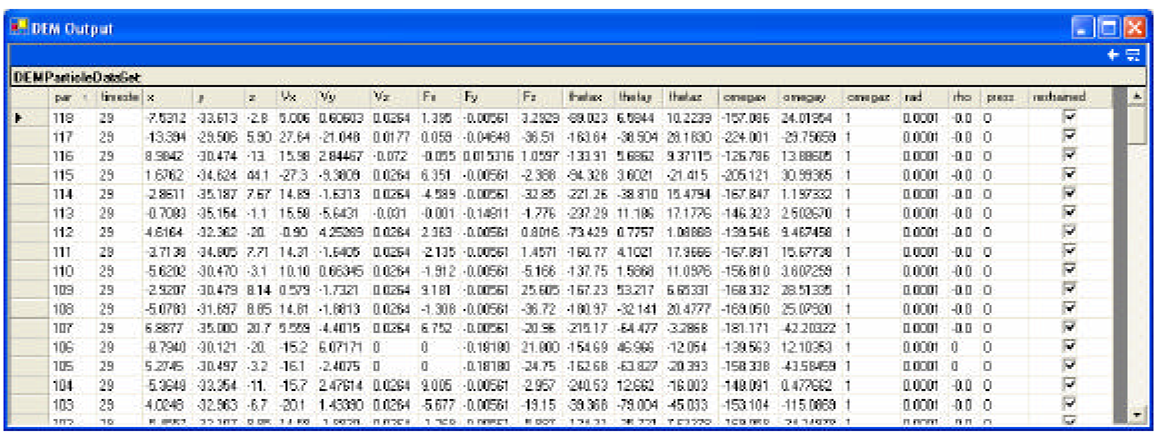


Figure 16 Particle Information for the Current Time Step

A useful tool at this point is to select all of the data in the table by pressing Ctrl-A, copy it to the clipboard with Ctrl-C, and then paste into a new Microsoft Excel worksheet. You can then easily create graphs of speed versus position to analyze and review the simulation results.

Creating AVI Videos

After the model has run and you have opened the .3d file you can create an AVI. Orient the model for the perspective you wish to see. And select File ⟶ Create AVI from the menu bar. The dialog box shown in Figure 17 will appear.

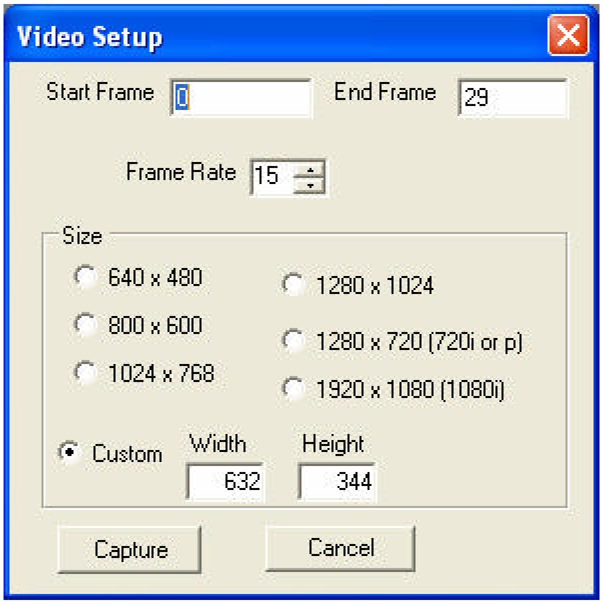


Figure 17 Video Setup Dialog Box

The starting and ending frames are automatically populated from the information in the .pos file. The frame rate also corresponds to the speed at which frames are saved to the .pos file. Changing this value will either slow down or accelerate the speed of the movie relative to actual time.

Finally you can select the desired frame size of the video. The larger the size the more storage space is required for the video. Several sizes of available PC and HDTV are preprogrammed for convenience.

After pressing the Capture button you are presented with a file selection dialog box to enter the file name for the animation and then a dialog box to select the video codec format in which to save the movie in. This dialog box is shown in Figure 18.

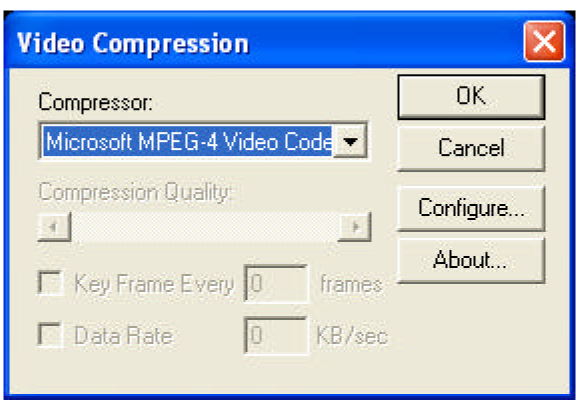


Figure 18 Video Codec Selection

The list of available video codecs is dependent on what is installed on your system. Our recent experience is that the Microsoft MPEG-4 Video Codec V2 works the best for the DEM animations with regard to both size and quality.

After selecting the codec the animation is created. A progress dialog box will be displayed showing the status. After completion you can view the animation through Windows Media Player.

When you are creating an animation you must choose a video compression format to use. Different compression algorithms work better on different types of animations or movies. The video compressors available on your system will be dependent on which software you have installed on the computer. The best way to determine which compressor is best for the application is to try them and compare the results.

We created a simple animation, 10 seconds long, 640x480 pixels in size, using the video compressors available on our system. The various files sizes are listed in Table 1.

Video Compressor	**Size**	**Error**
Full Frames (Uncompressed)	134,106 kB	
Cinepak Codec by Radius	5,604 kB	
Intel IYUV Codec		1
Intel 4:2:0 Video V2.50		2
Intel Indeo ® Video R3.2	2,409 kB	
Intel Indeo ® Video 4.5	4,522 kB	
Indeo ® Video 5.0	3,971 kB	
Microsoft RLE		2
Microsoft H.261 Video Codec		2
Microsoft H.263 Video Codec		2
Microsoft Video 1	8,128 kB	
Microsoft MPEG-4 Video Codec V1	305 kB	
Microsfot MPEG-4 Video Codec V2	284 kB	

Table 1 Video Compression Results

Error 1: Object Reference Not Set to an Instance of an Object
Error 2: Error in VideoStreamSetFormat -2147205018

Chute Maven™ will generate one of two errors with some of the older video codecs. Please select another codec on your system if an error is generated while trying to create an animation.

Microsoft MPEG-4 Codecs provides a good selection for the Chute Maven™ Videos with regards to both size and quality

Capturing Still Shots

Capturing still shots is very easy. Position the model for the desired view and frame you wish to capture. From the File menu select File ⟶ Capture Image. You will be presented with the dialog box shown in Figure 19.

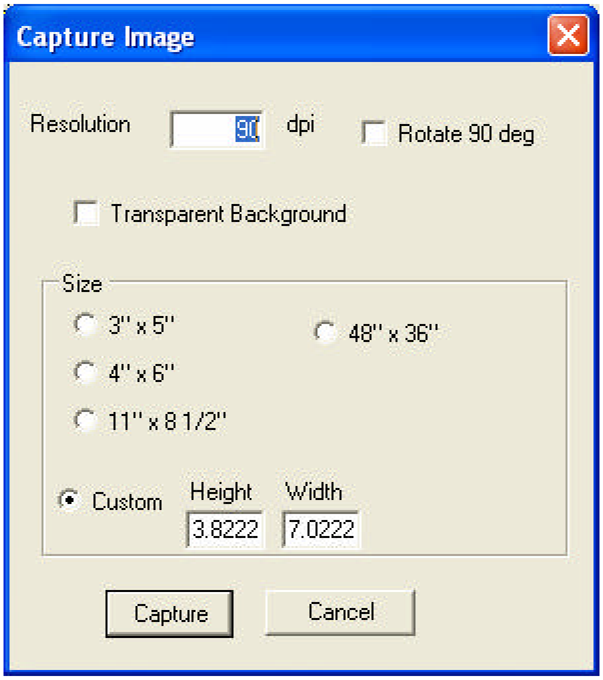


Figure 19 Capture Image Dialog Box

Here the resolution can be selected, the image can be rotated 90 degrees, a transparent background can be specified (which is helpful for overlays), and finally the physical size for the image is set.

For general guidance, a computer screen displays about 72dpi. In color about 200dpi is acceptable for reproduction quality.

After you select the capture button a file selection dialog box will appear. You can save the image in PNG, JPEG, Bitmap, GIF, or TIFF file formats.

Installation Instructions

Selecting setup.exe from the installation directory will automatically install the application. The program must be installed in the

C:\Program Files\Hustrulid Technologies\Chute Maven\

directory to function correctly.

The installation will add a shortcut to the program in the Start menu.

During the installation you are asked to review and accept the license agreement for the software.

To install the program you will need to register one of the .dll files.

Change the directory to the Chute Maven™ directory.

Type: “regsvr32 CrypKeyCOM.dll”

Registering the Program

After the initial installation you will be able to start the program and have some basic functionality. However, you will not be able to run your own simulation until the software is properly registered. Once the program is registered with an indefinite license it is your responsibility to maintain the license at your site.

To register a new program go to the Help ⟶ Registration menu item. The window shown in Figure 20 will be brought up.

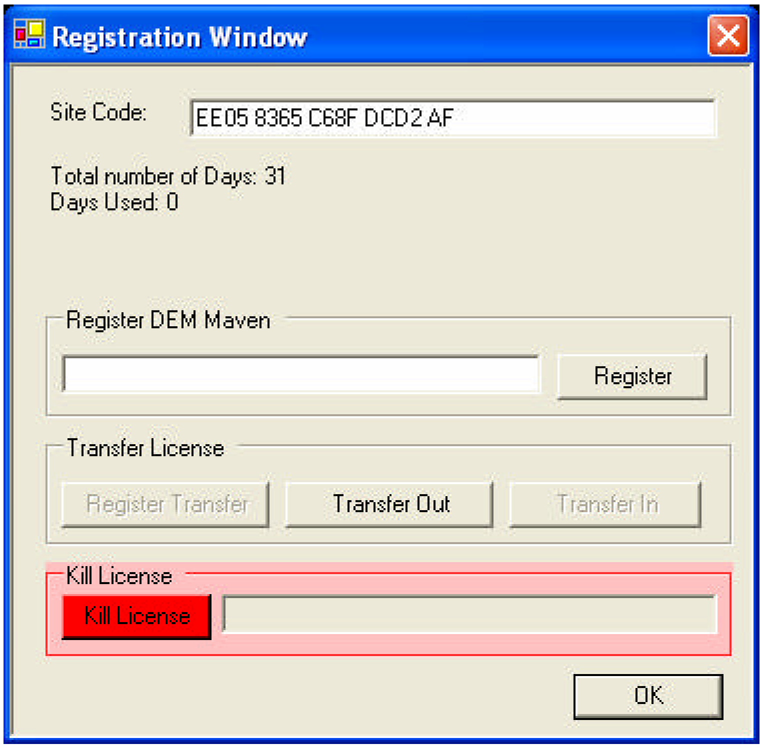


Figure 20 Registration Window

Here you can (1) see the status of the registration, (2) update the registration, and (3) transfer the registration.

To register the program for the first time, email the Site Code to support@ChuteMaven.com or call 1-305 433-4891. You will be given a registration key to enter in the Register Chute Maven™ area of the dialog box. Typing spaces in the registration key are optional but help to insure the correct code is entered. Press the Register button to complete the registration. You will be returned to the Registration Window and the status will be updated.

Transferring the Registration

The license allows you to run the software on only one computer at a time. To transfer the license between computers you must follow the procedure to transfer the registration.

1. On the target computer you will first need to install the Chute Maven™ software.
2. After the installation is complete go to the Help ⟶ Registration window and select the “Register Transfer” button. You will be asked to create a directory on a

disk or directory that can be accessed by the computer where the software is currently licensed. Create the directory.

3. On the computer that is currently licensed, start the Chute Maven™ software, go to the Help ⟶ Registration window, and press the "Transfer Out" button. Here you will be asked to select the directory created in step 2. The license has not been transferred off the original machine and is now in the transfer directory.
4. On the target computer, go to the Help ⟶ Registration window, and press the "Transfer In" button. Select the directory created in step 2 and used in step 3. The license will now be transferred from the transfer directory to the target machine.

Speed Ideas

Discrete Element simulations are computationally very intensive and can take anywhere from a few minutes to hours and even days to run. Much of the time is impacted by the size of the simulation you are trying to run, how you setup the model, and the speed of your computer. Considerable effort has been taken to make the Chute Maven™ software as efficient as possible. Some steps you can take in designing and running your model include:

- Shorten the incoming and exiting belts as much as possible.
- Increase the friction of the incoming belt to help get the material up to speed as quickly as possible.
- Fill rock boxes first by running an injection boundary over the rock box for a short period of time at the start of the simulation.
- Fill dead spaces in rock boxes with enclosed boundaries.
- Use larger particles to do initial simulation runs.
- Use the same size particles.
- Kill extra processes on the computer.

Obviously you will receive better performance running on a faster computer. This release of Chute Maven™ does not take advantage of multiple processors so the program will not run noticeable faster on a dual processor machine over a single processor machine. What you will observe is that the computer behaves less lethargic when you are trying to run other applications while the simulation is running. Using chipsets with Hyper Threading (HT) technology will have a similar impact.

In addition to a fast processor it is beneficial to have a good graphics card, preferably one that supports OpenGL acceleration.

File Structure

The file structure for Chute Maven is shown in Figure 21.

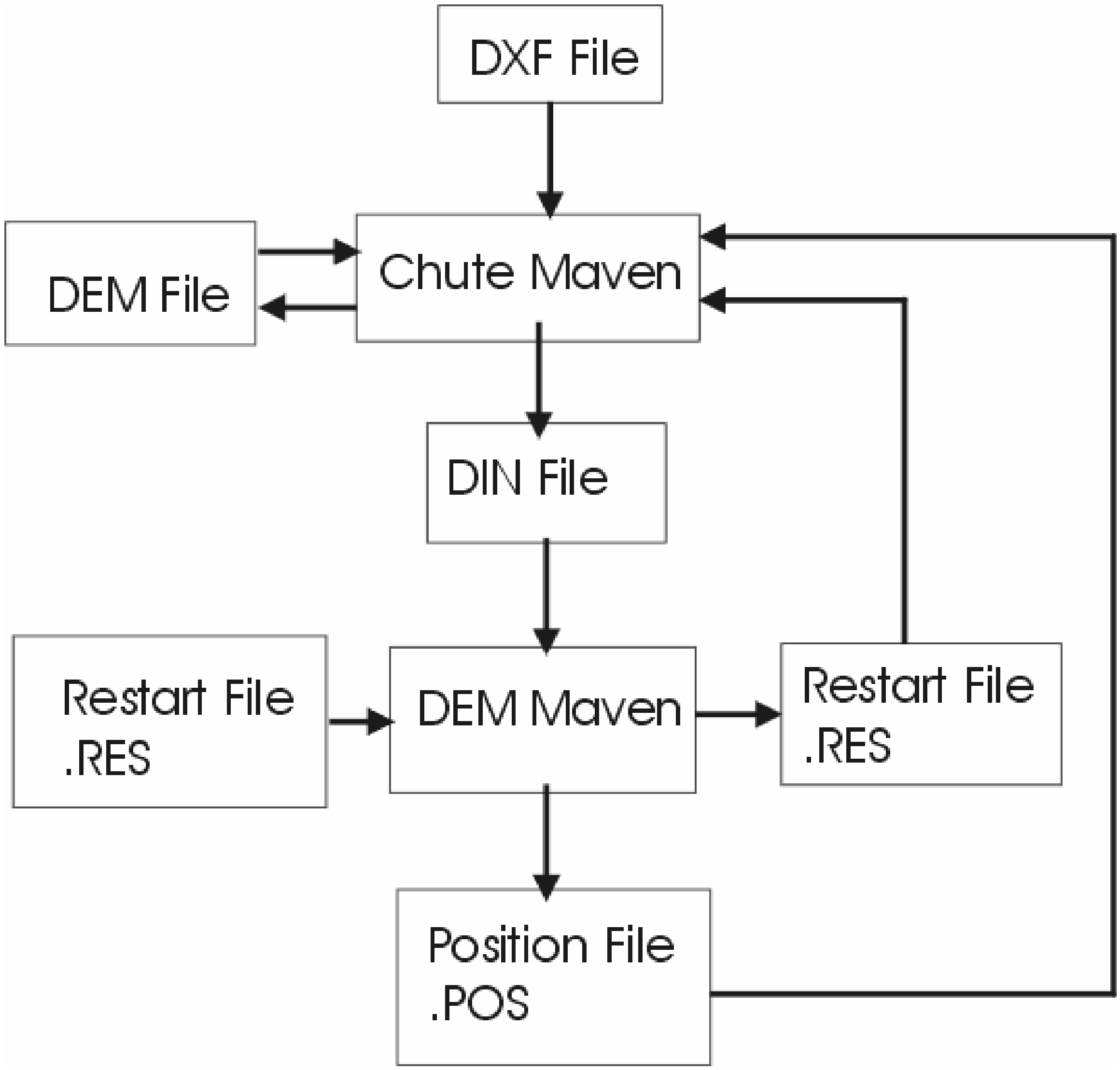


Figure 21 Chute Maven File Structure

References

A. I. Hustrulid, G.G.W. Mustoe, "Engineering Analysis of Transfer Points Using Discrete Element Analysis", Presented at 1996 SME Annual Meeting, Phoenix, AZ, February 1996.

A. I. Hustrulid, "Transfer Station Analysis", Presented at 1998 SME Annual Meeting, Orlando, FL, February 1998.

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