GRAPE M1

Introduction

A high precision 3-dimensional modelling software windows® application that enables designers to construct an accurate model based on the construction and subsequent assembly of detailed model layers.

Based on our proprietary 3D modelling data format Graphical Rectangular Actual Positional Encoding GRAPE™ each model layer is constructed from a collection of solid rectangles. The modelling software provides a suite of "Structure Entity Enhanced Design" constructs (for example a circle formed by a collection of rectangles) that the designer can further manipulate. Each model rectangle can be individually selected/highlighted to delete or move; together with visual inspection of the rectangle's positional points XYZ.

Model layers and the overall structure model are saved to files in both GRAPE™ and STL data formats; to enable the model to be printed on Copner Biotech Bio Printers using GRAPE™ 3D printing method and by other vendor 3D printing devices that accept STL.

Utilizing Copner Biotech's bioprinters these models can be accurately printed RENDERABLE BIOFABRICATION™ with high batch to batch consistency essential for research activities.

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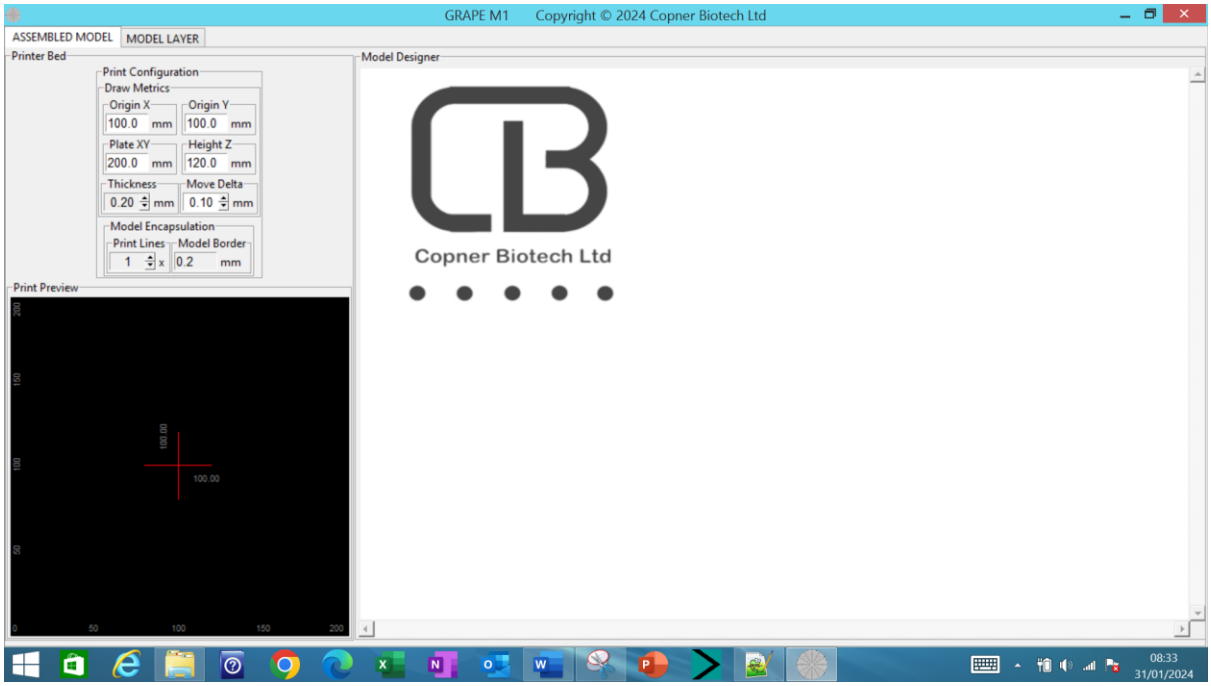

Figure 1 GRAPE M1 Splash Screen

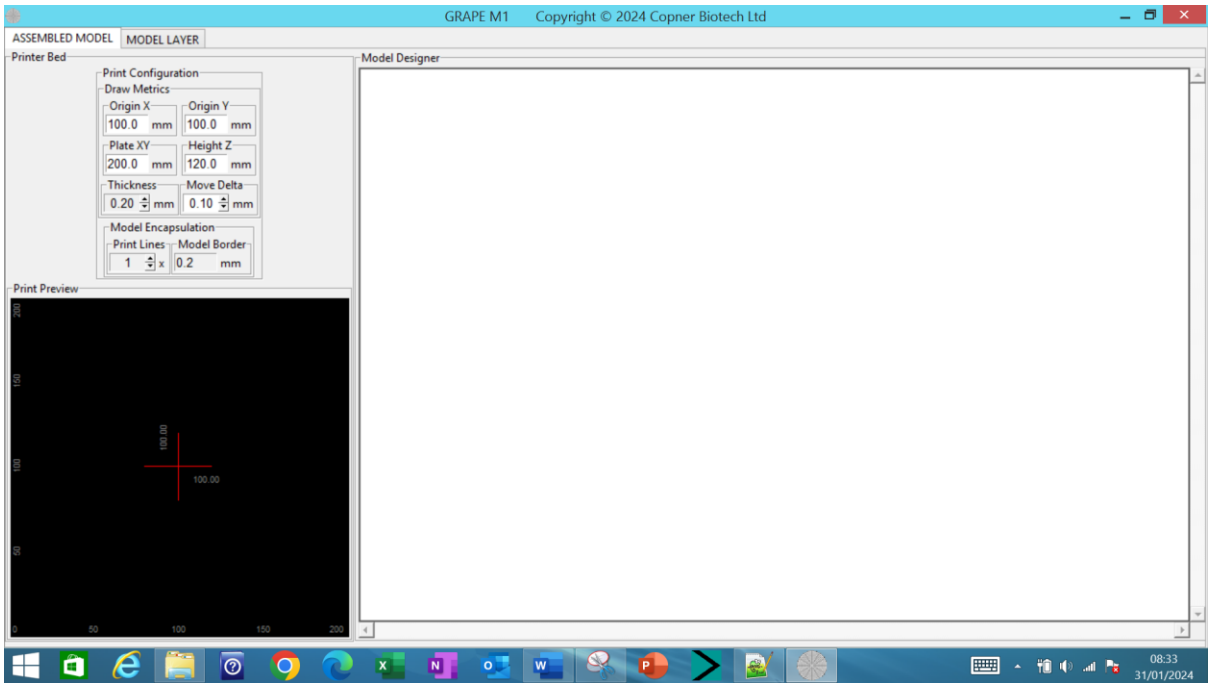

Figure 2 GRAPE M1 Scaffold and Layer Model Canvases – Print Preview pane and Bed parameters

Application can be minimised using its windows® control or pressing 'Esc' key

Printer Bed

This dialog presents 'Draw Metrics' which the designer can configure:

- dimensions of their printer bed printable volume.

- printer bed origin position X and Y which forms the centre point from which subsequent model constructs are drawn relative to this configurable origin.
- thickness of lines employed to create model constructs.
- delta movement of (selected for move) model constructs on action of the keyboard left/right/up/down arrow keys.

Print Preview

This panel shows the actual printer bed position(s) of model construct(s) drawn; together with current configured draw origin position and bed dimensions.

Model Layer

On selecting the 'Model Layer' notebook leaf the designer is presented with the 'Model Layer' canvas that enables a model layer to be constructed.

Right clicking the mouse displays a palette of "Structure Entity Enhanced Design" constructs that the designer can individually select, configure and draw; Figure 3 Layer Model Structure Entity Enhanced Design Draw Constructs - Select Origin

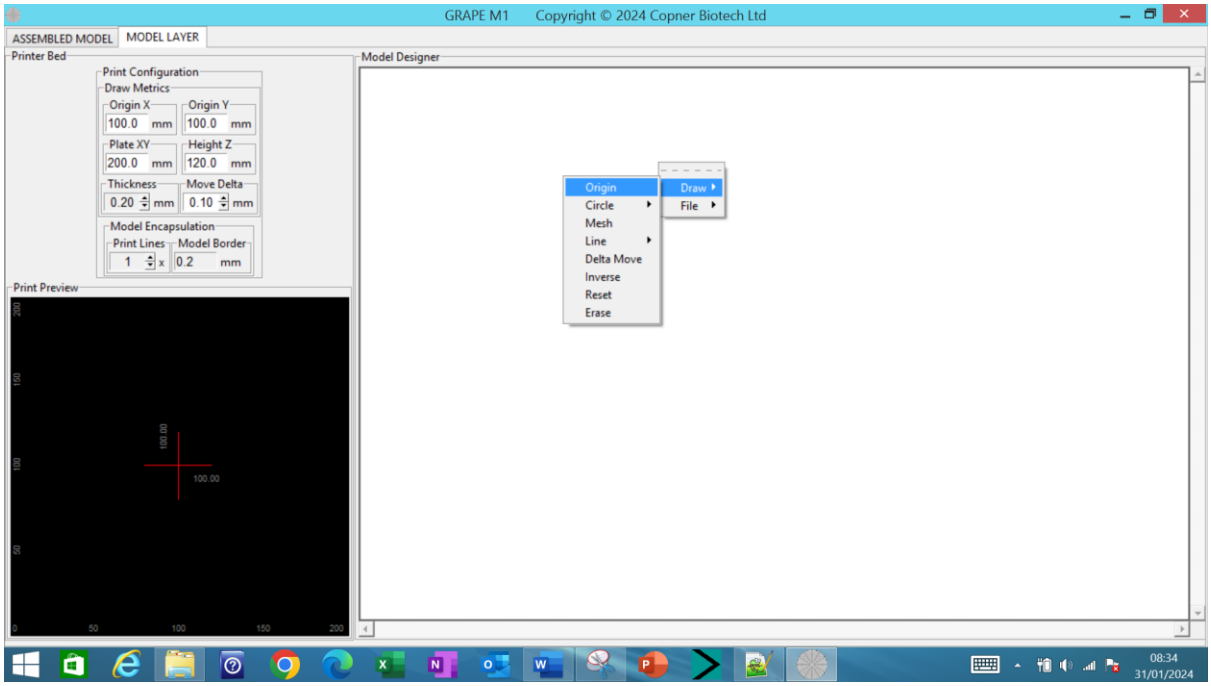

Figure 3 Layer Model Structure Entity Enhanced Design Draw Constructs - Select Origin

Layer Origin

Before constructing the model layer; the designer must select the model layer origin by right clicking the mouse on the layer canvas and selects to configure the draw origin using the pop-up menu Figure 3 Layer Model Structure Entity Enhanced Design Draw Constructs - Select Origin. The origin is the central position on the printer bed that the drawing aids use as a reference point; for example the centre point of a circle to be subsequently drawn around. Note GRAPE M1 outputs models in both STL (unit dimensionless) and GRAPE (units mm).

Copner Biotech bioprinter GRAPE measurements are in mm and this unit of measurement will be used throughout this document.

On selection of Draw->Origin the designer is presented with a dialog to enter subsequent draw origin X and Y coordinates Figure 4 Select Layer Origin Printer Bed Coordinates. Default values for X and Y origin coordinates are X 100.0 mm (allowable range 0.0 to PlateXY dimension value mm) and Y 100.0 mm (allowable range 0.0 PlateXY dimension value mm} the designer can either overwrite these values or adjust the values using the spin controls (allows adjustments in 0.01mm); before actioning 'Create' to apply these new values or selecting 'Cancel' to abort changes and keep the previous settings.

Draw origin X and Y can also be adjusted via the 'Draw Metrics' 'Origin X' and 'Origin Y' dialogs.

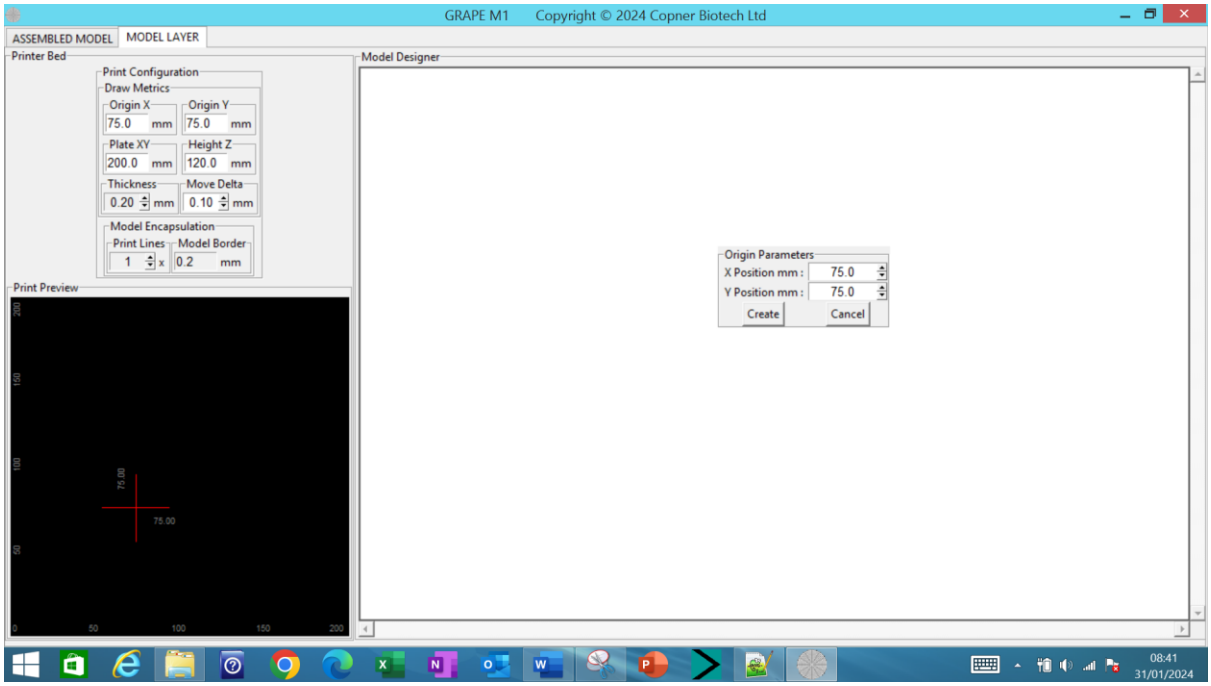

Figure 4 Select Layer Origin Printer Bed Coordinates

Circle Construct

A circle construct layer model can be constructed around the currently selected printer bed origin. The designer right clicks the mouse on the layer canvas and selects to draw a circle using the pop-up menu Figure 5 Layer Model Structure Entity Enhanced Design Draw Constructs - Draw Circle.

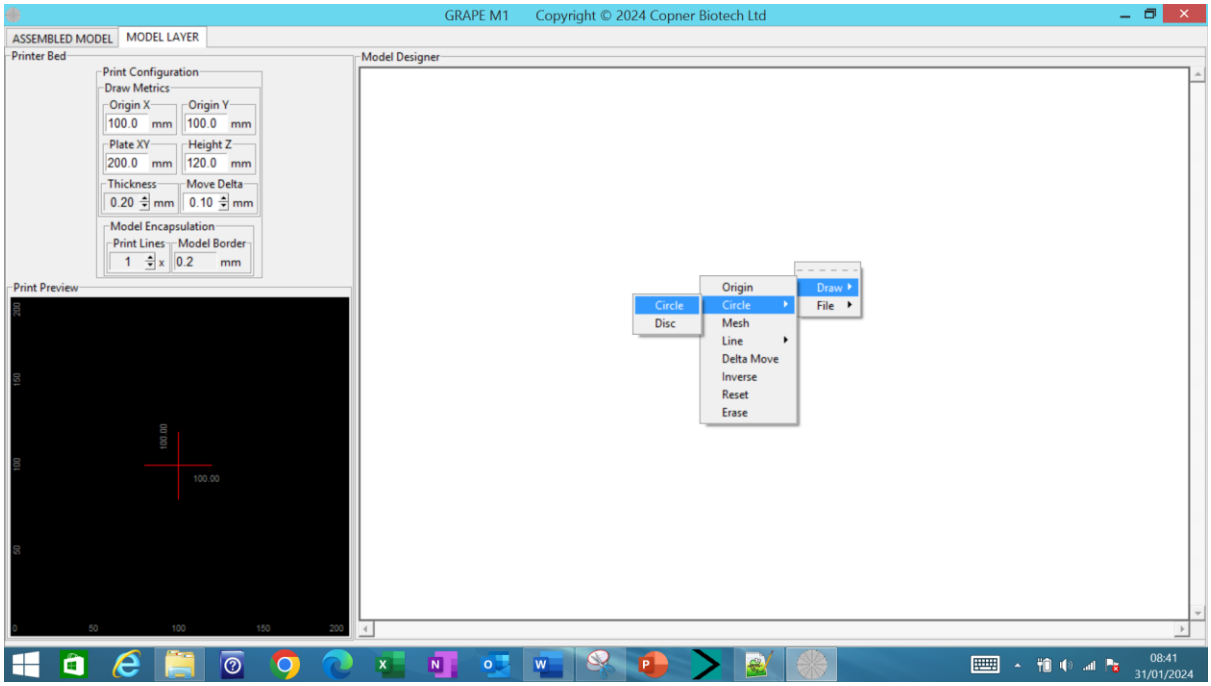

Figure 5 Layer Model Structure Entity Enhanced Design Draw Constructs - Draw Circle

On selection of Draw->Circle->Circle the designer is presented with a dialog to enter subsequent draw circle parameters Figure 6 Select Layer Circle Creation Parameters .

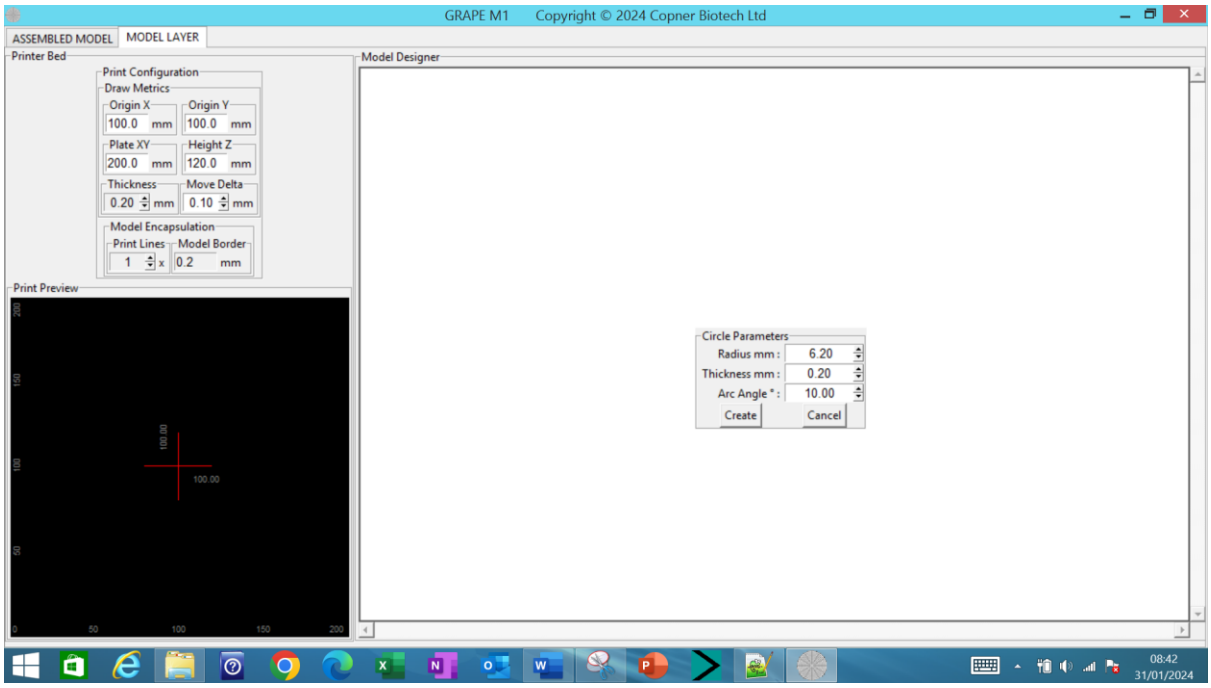

Figure 6 Select Layer Circle Creation Parameters

Utilising this dialog the designer can specify the circle radius (range 0.01 to 60.0) (with 0.01 mm adjustment resolution) and rectangle/line thickness (range 0.01 to 9.99) in mm (with 0.01 mm adjustment resolution) together with the arc angle (degrees with 0.25 resolution). All entry dialogs

can be overwritten or adjusted using the spin controls. The arc angle in degrees together with the radius dictates the length of the rectangle/line components employed to draw the polygon circle.

Selecting ‘Create’ realises the construction and subsequent drawing of the required circle Figure 7 Circle Construct with 6.2mm Radius 0.2mm thickness and Arc Angle 10 degrees - Top View

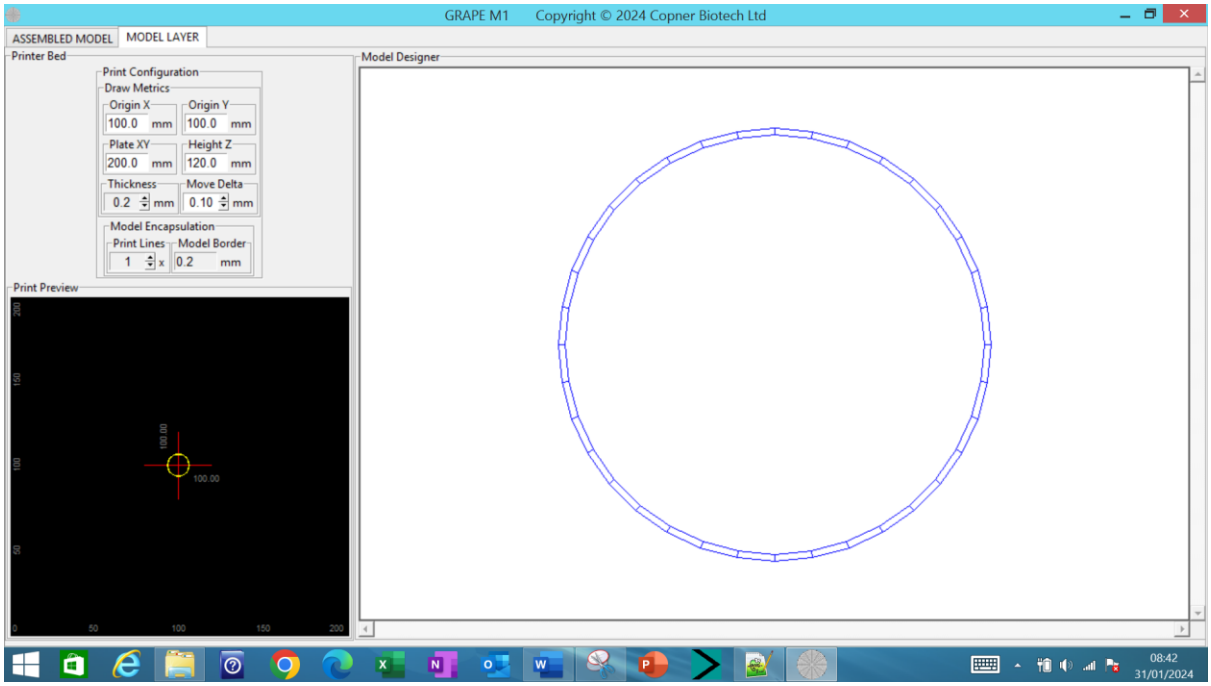

Figure 7 Circle Construct with 6.2mm Radius 0.2mm thickness and Arc Angle 10 degrees - Top View

The designer can rotate displayed constructs by clicking and holding down the left mouse on the layer canvas and dragging the mouse up/down/left/right Figure 8 Circle Construct with 6.2mm Radius 0.2mm thickness and Arc Angle 10 degrees - Rotated View

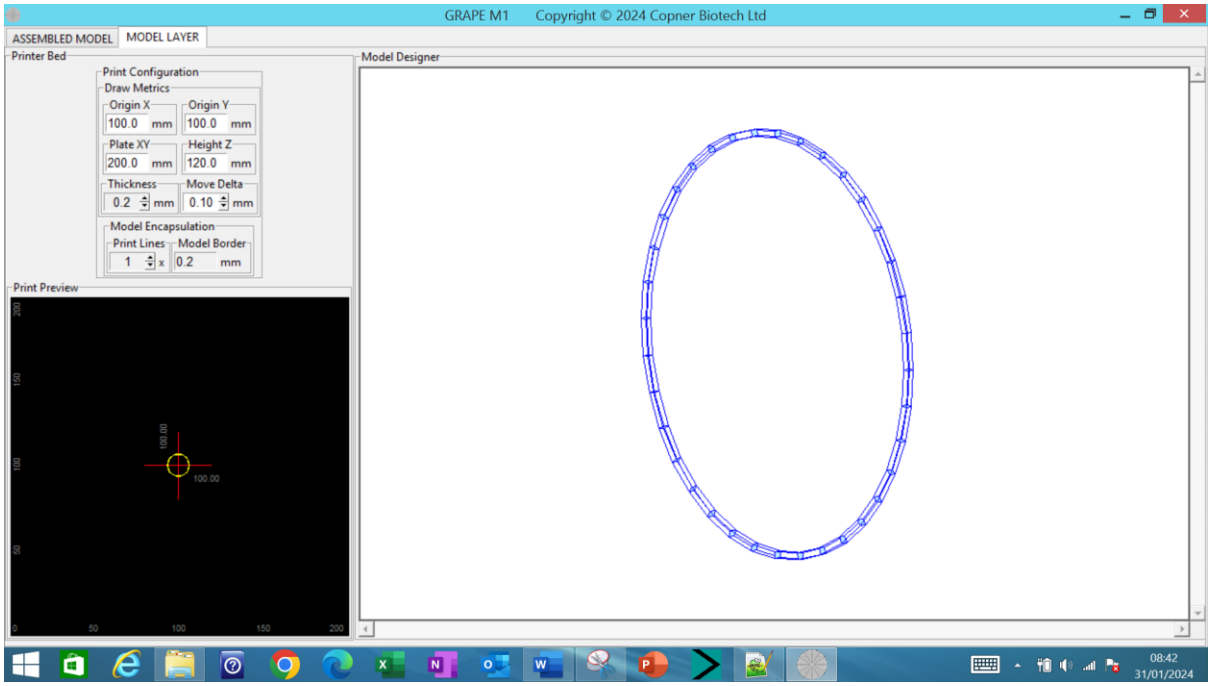

Figure 8 Circle Construct with 6.2mm Radius 0.2mm thickness and Arc Angle 10 degrees - Rotated View

The designer can zoom a displayed construct by operating the mouse wheel whilst on the layer model canvas; forward wheel rotation to zoom in and vice versa Figure 9 Circle Construct with 6.2mm Radius 0.2mm thickness and Arc Angle 10 degrees - Rotated and Zoomed View

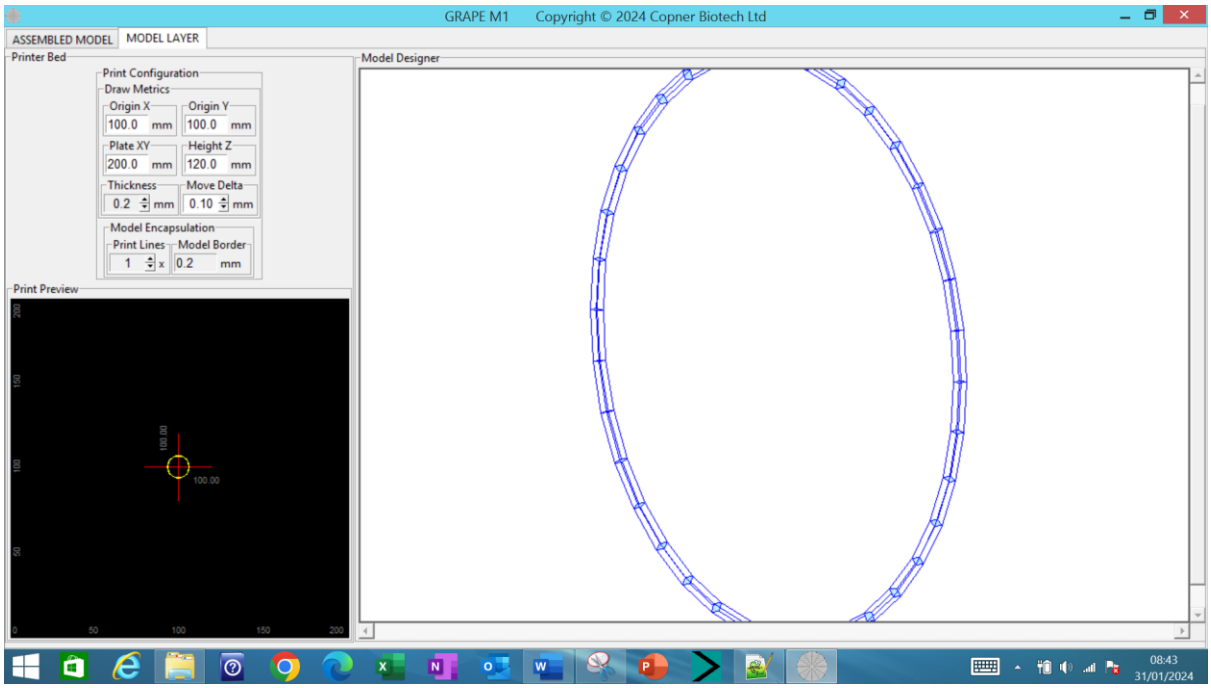

Figure 9 Circle Construct with 6.2mm Radius 0.2mm thickness and Arc Angle 10 degrees - Rotated and Zoomed View

Erase Canvas

Canvas can be erased of constructed/drawn model constructs by right clicking the mouse on the canvas and selecting ‘Erase’ from the pop-up menu Figure 10 Select to Erase Model Constructs

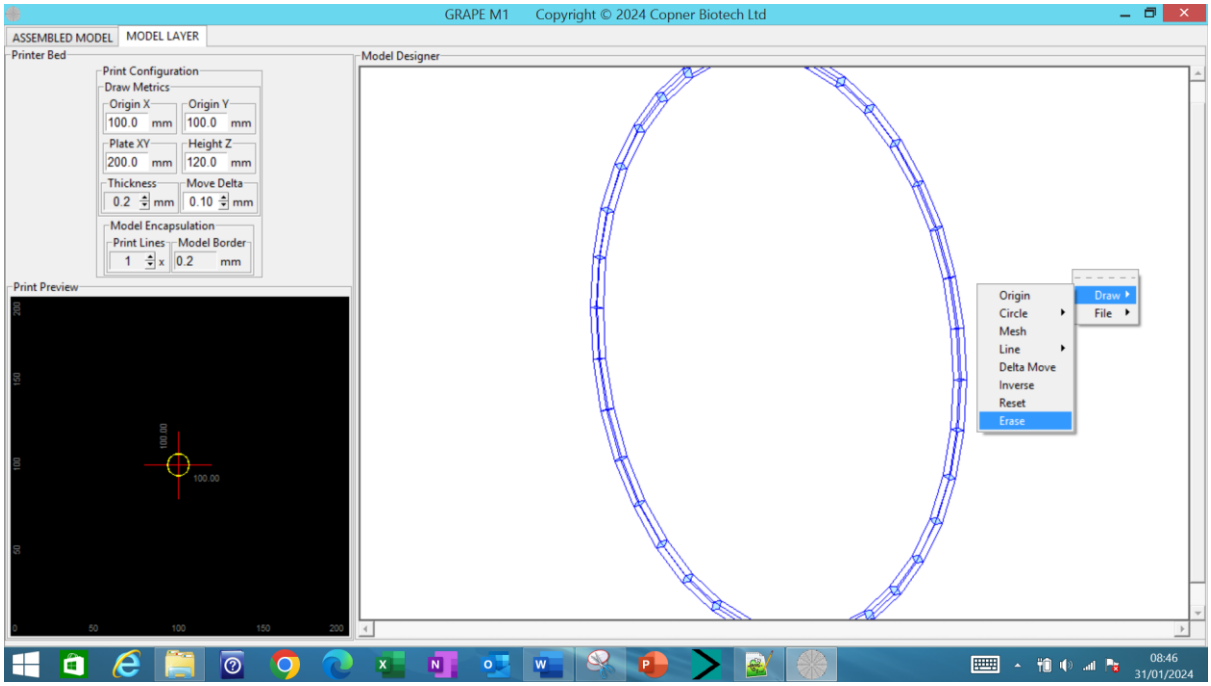

Figure 10 Select to Erase Model Constructs

Reset Canvas

Constructed and displayed models that have been rotated and/or zoomed can be conveniently reset to their non-zoomed top view by right clicking the mouse on the canvas and selecting ‘Reset’ Figure 11 Select to Reset Model Constructs. In this example to circle construct will be re-displayed as a top view.

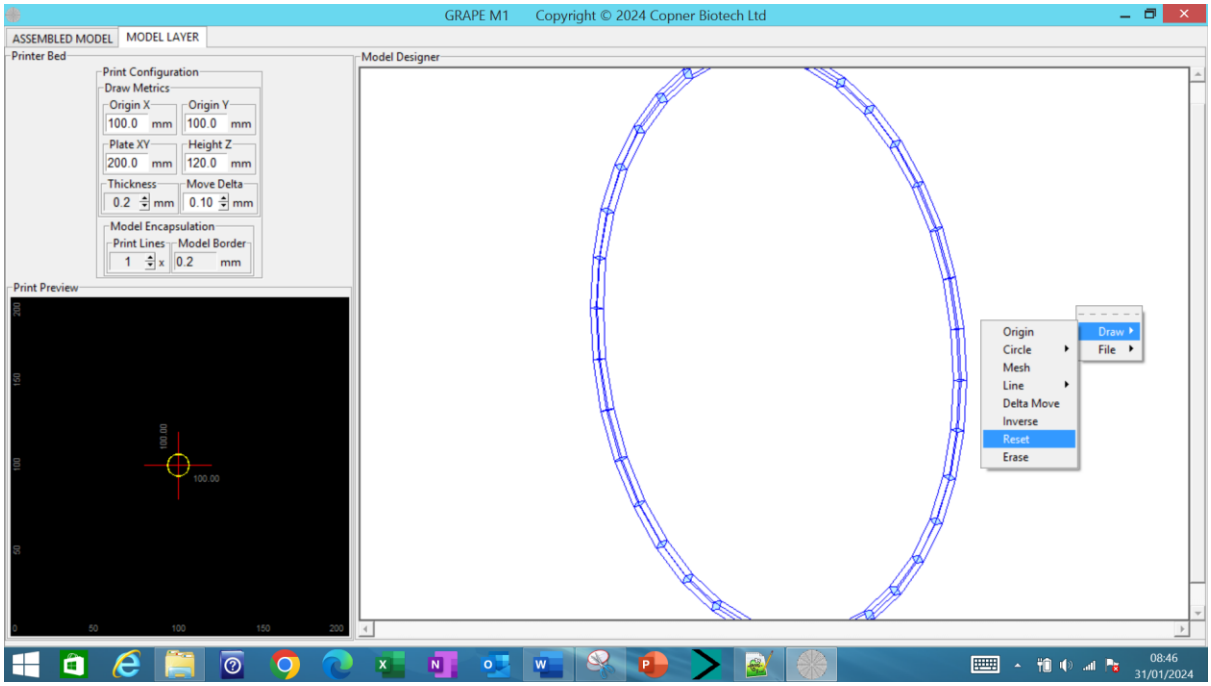

Figure 11 Select to Reset Model Constructs

Disc Construct

A disc construct layer model can be constructed around the currently selected printer bed origin. The designer right clicks the mouse on the layer canvas and selects to draw a disc using the pop-up menu Figure 12 Layer Model Structure Entity Enhanced Design Draw Constructs - Draw Disc

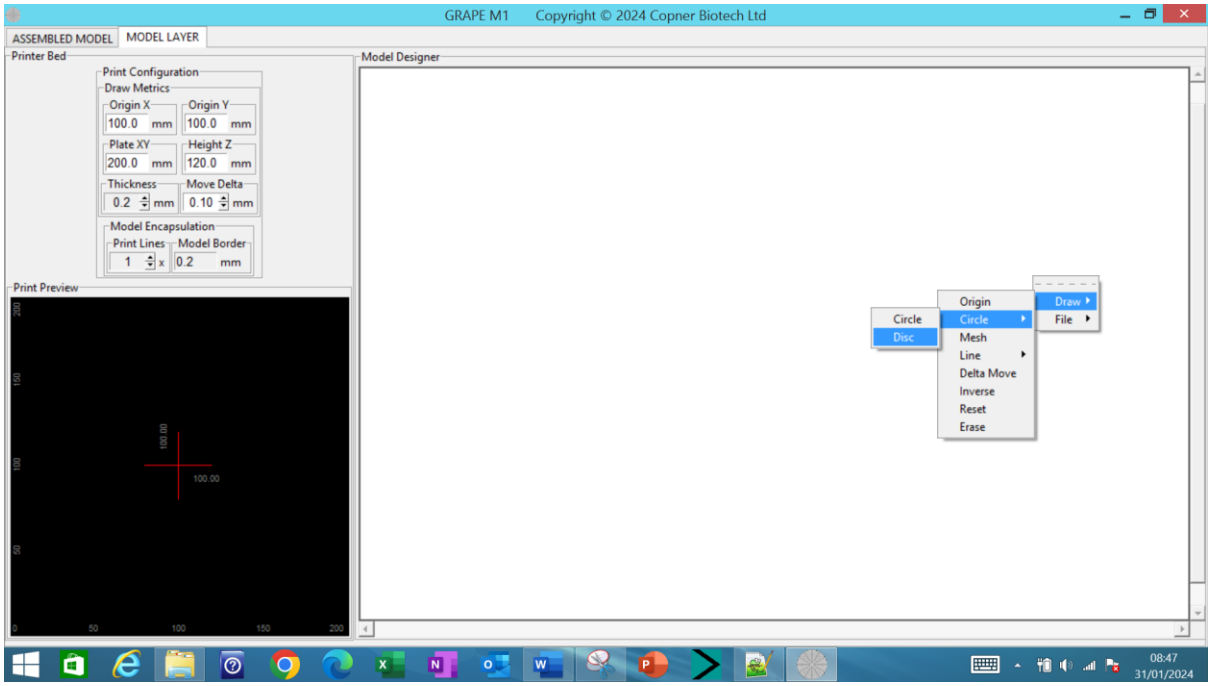

Figure 12 Layer Model Structure Entity Enhanced Design Draw Constructs - Draw Disc

On selection of Draw->Circle->Disc the designer is presented with a dialog to enter subsequent draw circle parameters Figure 13 Select Layer Disc Creation Parameters.

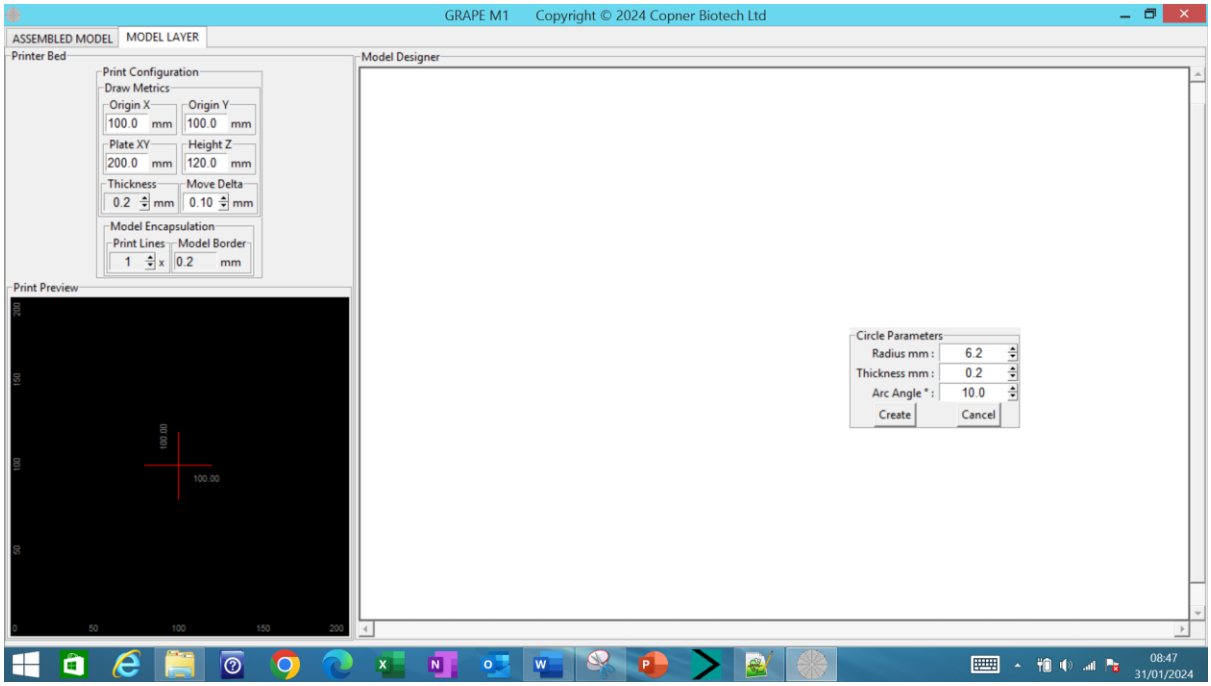

Figure 13 Select Layer Disc Creation Parameters

Utilising this dialog the designer can specify the circle/disc radius (range 0.01 to 60.0) and rectangle/line thickness (range 0.01 to 9.99) in mm (with 0.01 mm adjustment resolution) together with the arc angle (degrees with 0.25 resolution). All entry dialogs can be overwritten or adjusted using the spin controls. The arc angle in degrees together with the radius dictates the length of the rectangle/line components employed to draw the polygon circle.

Selecting ‘Create’ realises the construction and subsequent drawing of the required disc Figure 14 Disc Construct with 6.2mm Radius 0.2mm thickness and Arc Angle 10 degrees - Top View

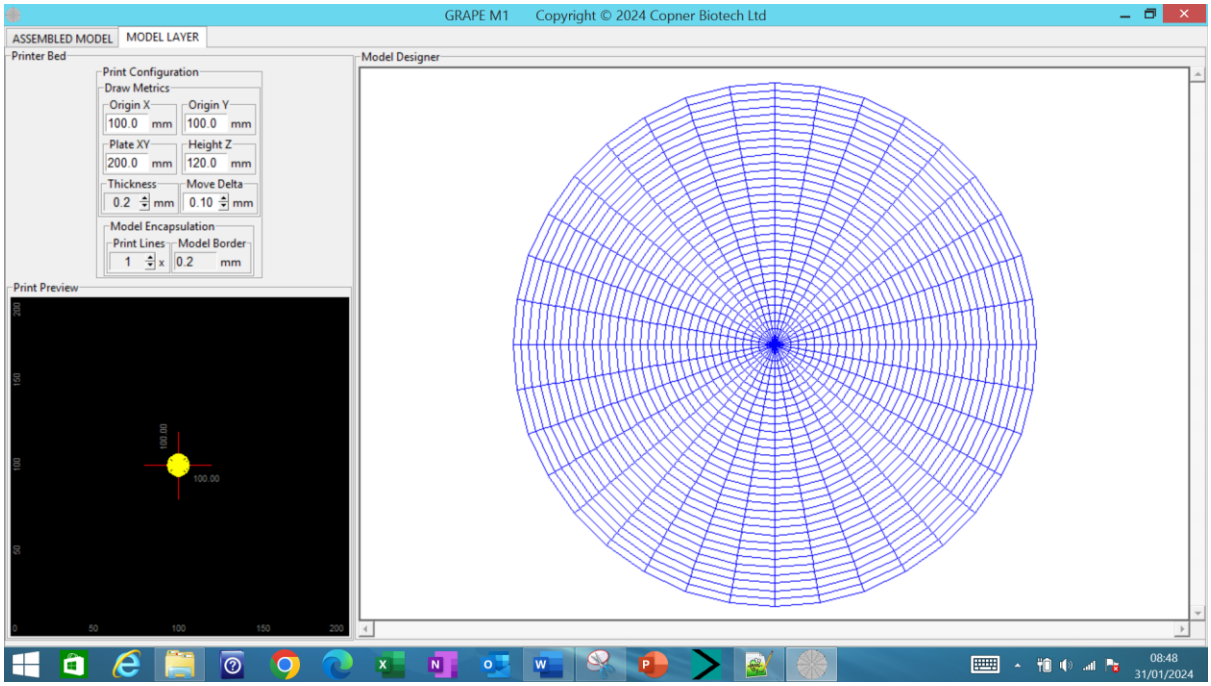

Figure 14 Disc Construct with 6.2mm Radius 0.2mm thickness and Arc Angle 10 degrees - Top View

Inverse Model Construct

The designer can also select to create rectangular constructs that will serve to encapsulate the constructs of a model layer.

This feature is useful for creating a model layer mould for subsequent filling of the mould voids with low viscosity BioInks.

This inverse border feature is also useful for protecting the model whilst in transit or storage prior to its removal and model use. For example low viscosity BioInks can be encased in gelatine to allow post print crosslinking and then the gelatine melted away prior to deploying the model. For example inverse of disc model layer; Figure 15 Model Layer with disc model and Inverse model selection

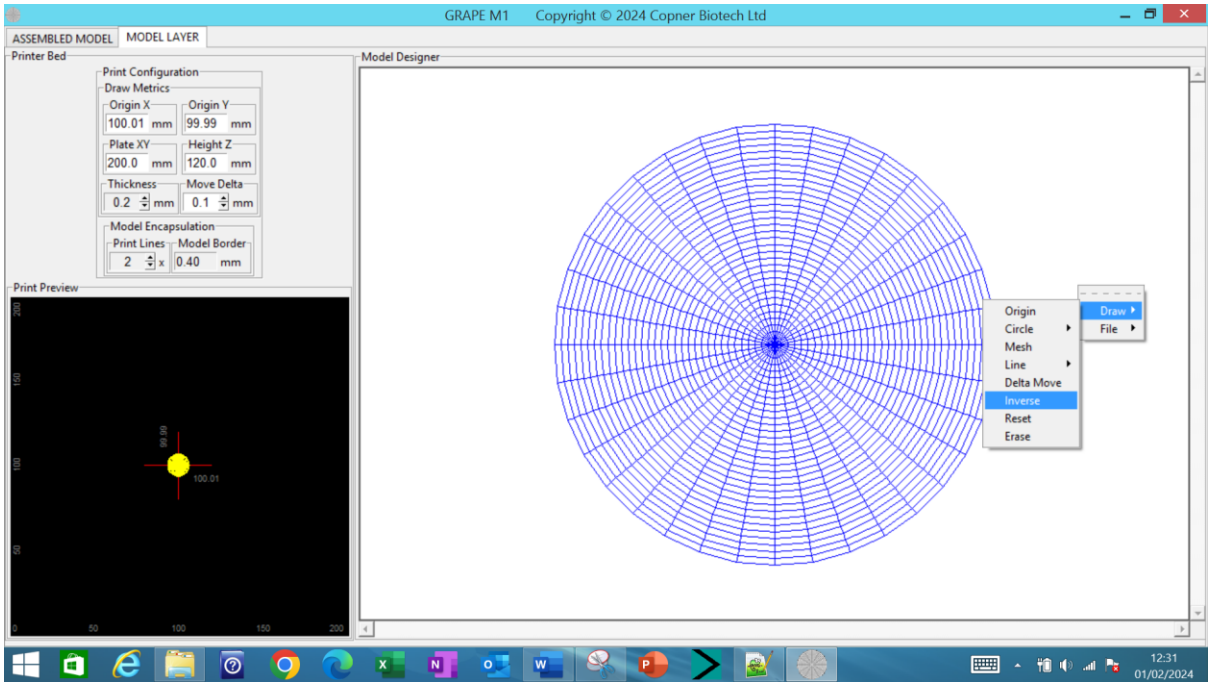

Figure 15 Model Layer with disc model and Inverse model selection

On selection of the inverse model option the software will encapsulate the disc model layer currently displayed on the 'Model Designer' canvas. Using the 'Model Encapsulation' parameters defined in the 'Printer Bed' settings; the software uses the 'Print Lines' parameter together with the 'Draw Metrics' 'Thickness' selection to calculate the 'Model Border' setting. 'Model Border' is determined by multiplying the 'Print Lines' with 'Thickness' parameter values; and the software uses this to create a square around the model to be encapsulated. Figure 16 Inverse disc model layer with 0.4mm border

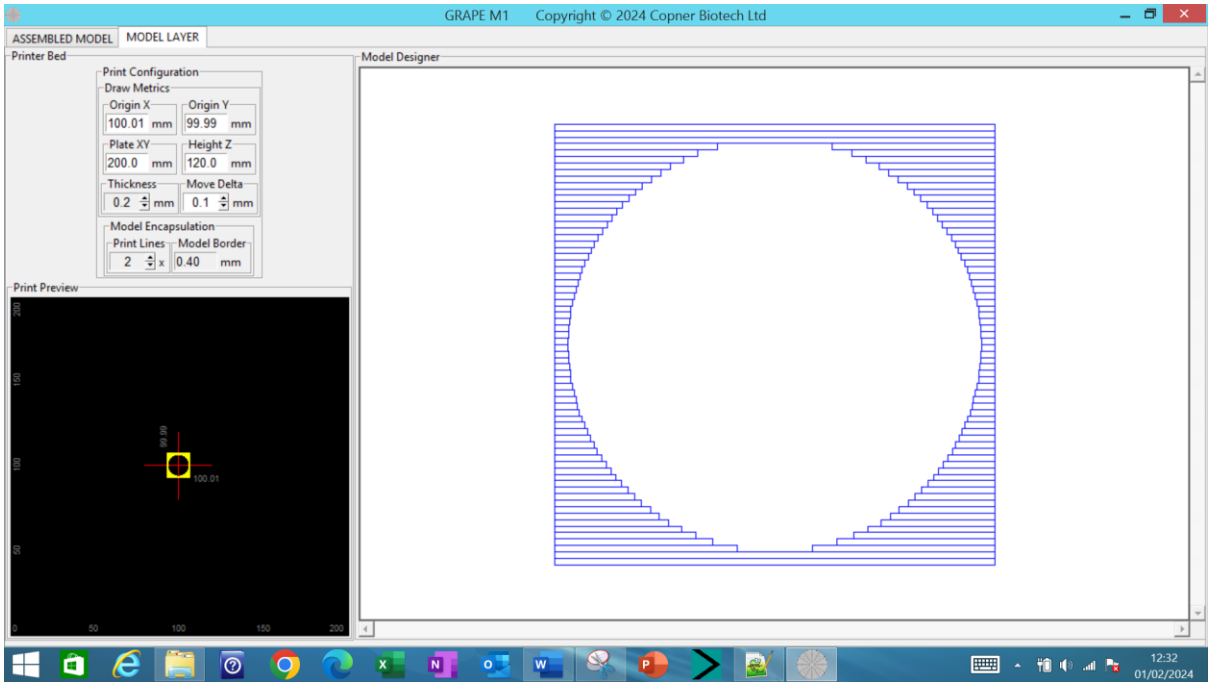

Figure 16 Inverse disc model layer with 0.4mm border

Similarly the designer can create the inverse of any created model layer; for example a mesh Figure 17 Mesh Model Layer Figure 18 Select to create inverse mesh model Figure 19 Inverse mesh model with 0.4mm border Figure 20 Inverse mesh model layer rotated and zoomed

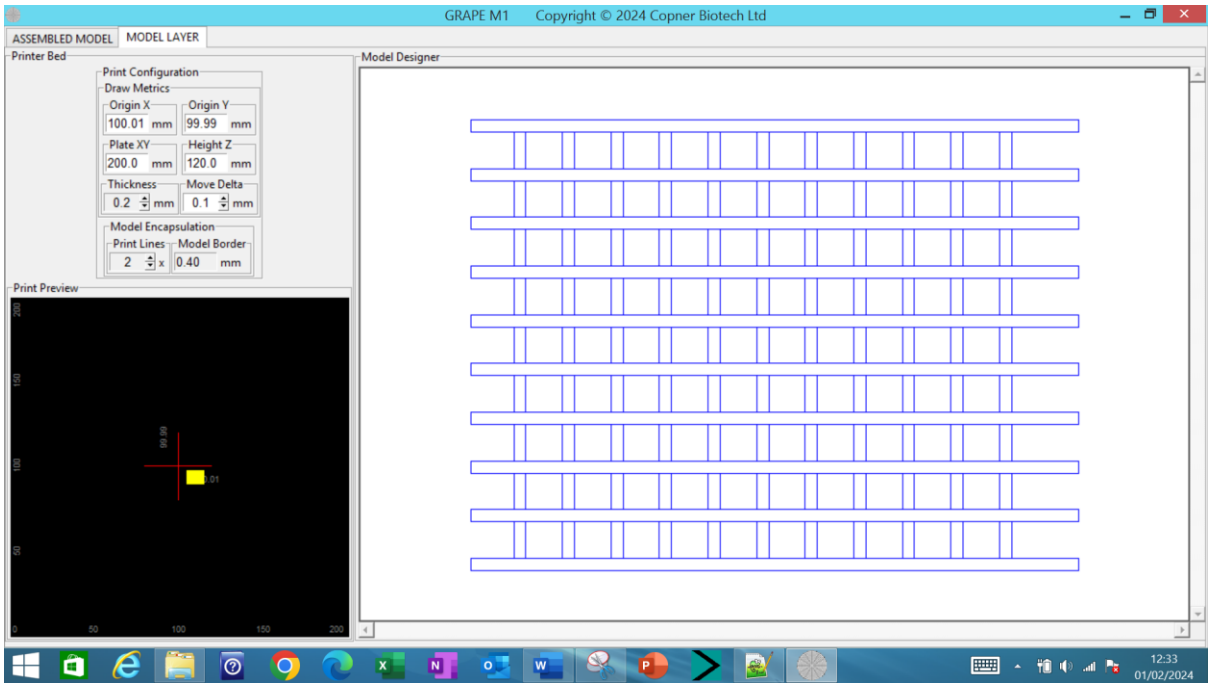

Figure 17 Mesh Model Layer

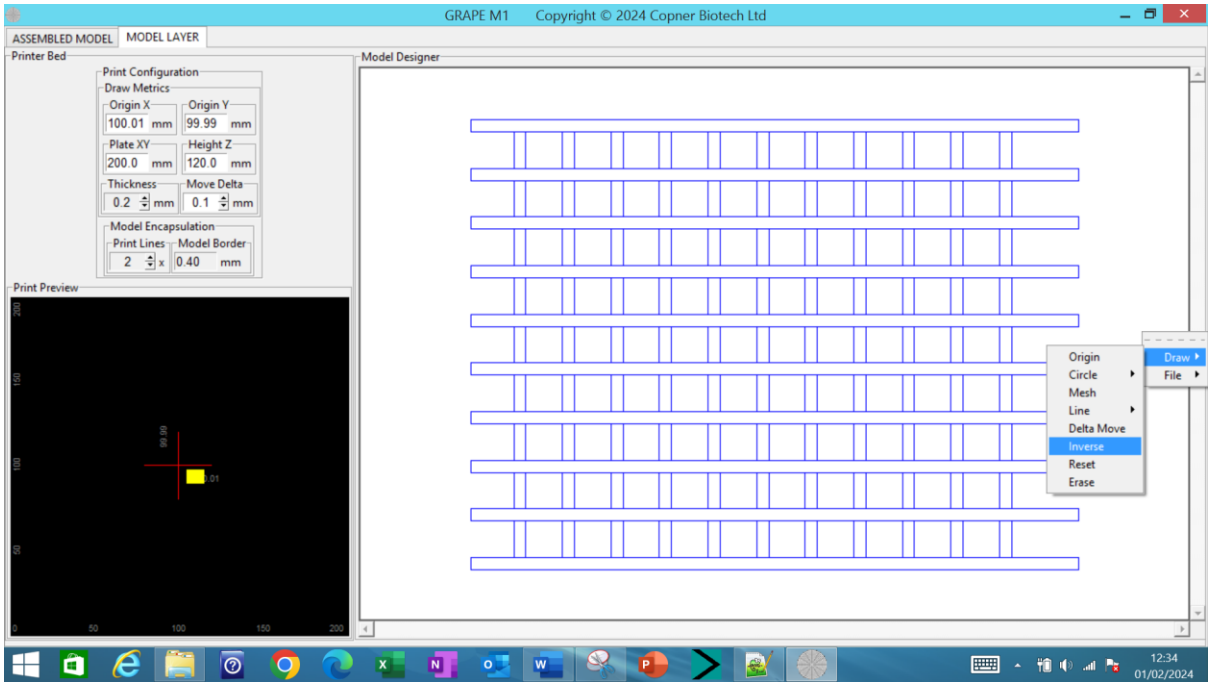

Figure 18 Select to create inverse mesh model

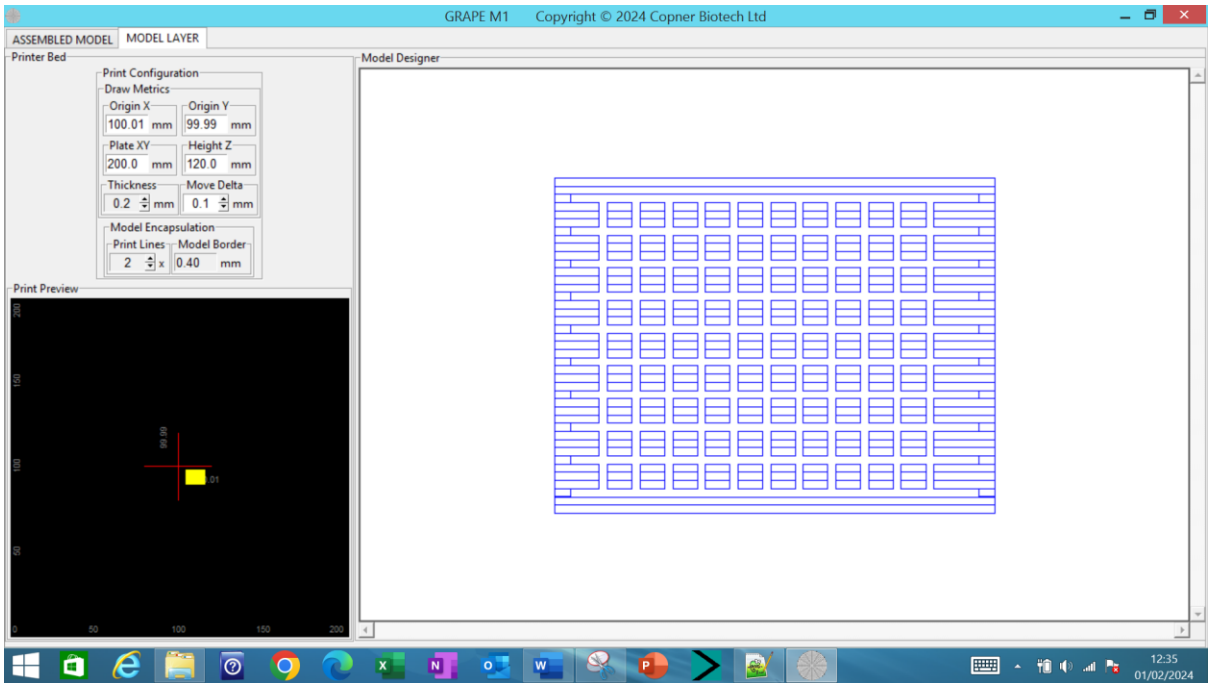

Figure 19 Inverse mesh model with 0.4mm border

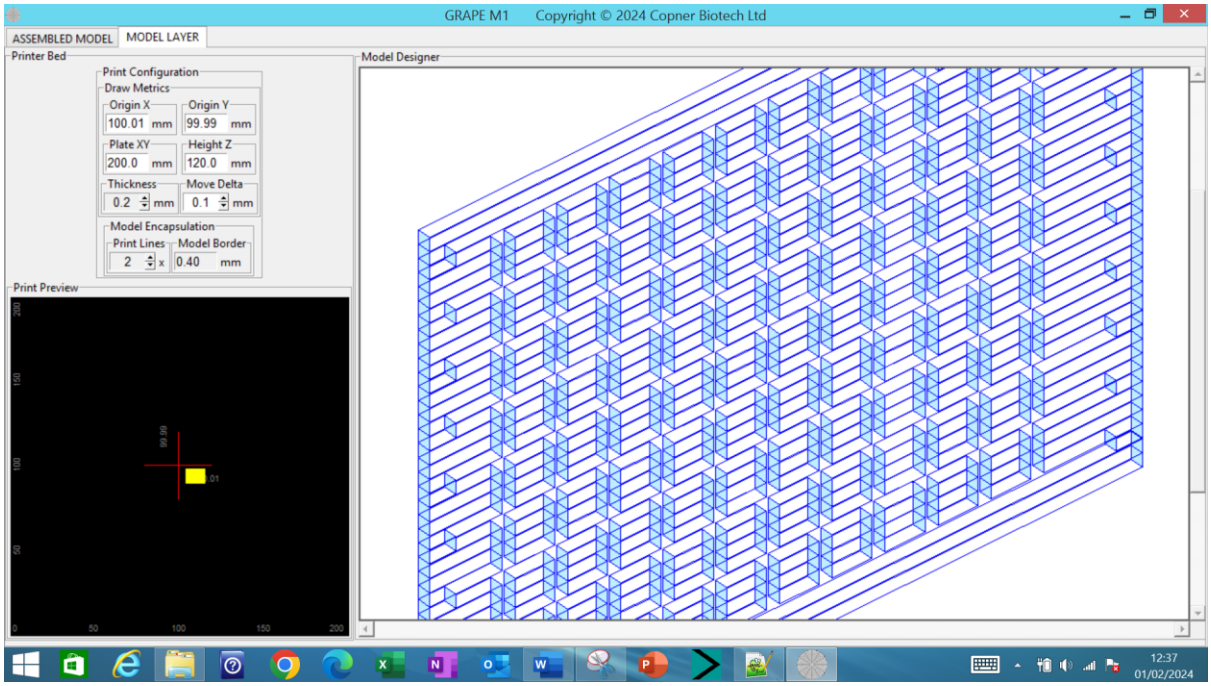

Figure 20 Inverse mesh model layer rotated and zoomed

Draw Mesh

A mesh construct layer model can be constructed around the currently selected printer bed origin. The designer right clicks the mouse on the layer canvas and selects to draw a mesh using the pop-up menu Figure 21 Layer Model Structure Entity Enhanced Design Draw Constructs - Draw Mesh

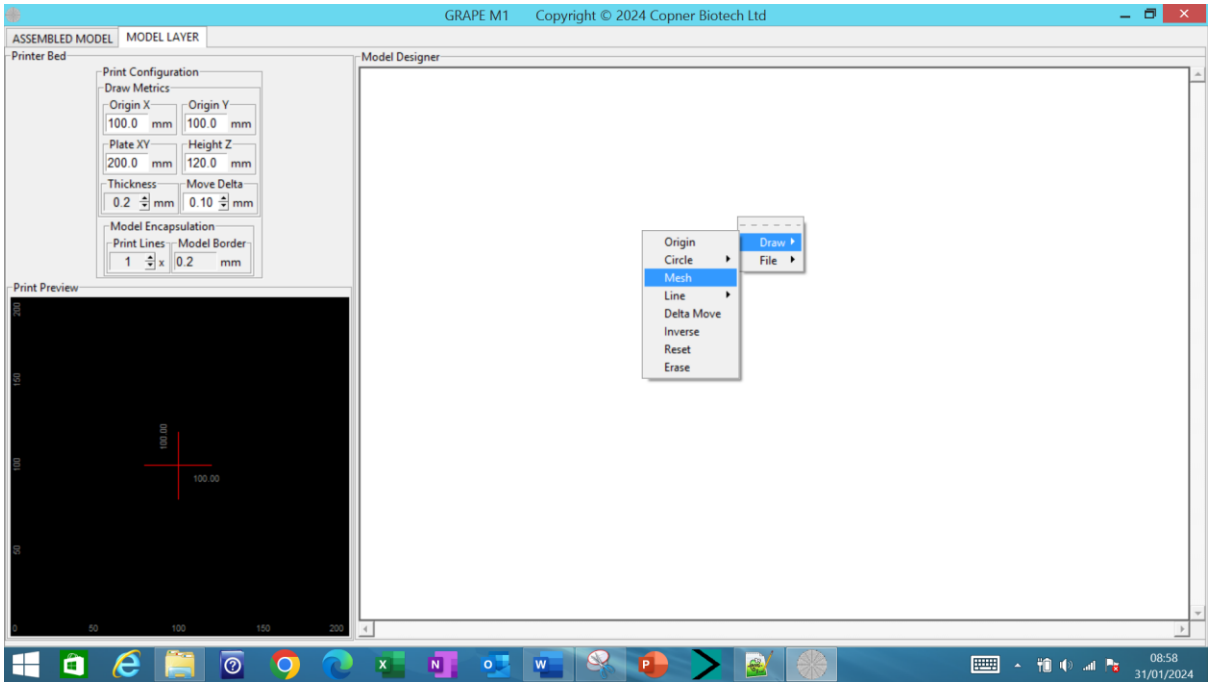

Figure 21 Layer Model Structure Entity Enhanced Design Draw Constructs - Draw Mesh

On selection of Draw->Mesh the designer is presented with a dialog to enter subsequent mesh construct parameters Figure 22 Select Layer Mesh Creation Parameters

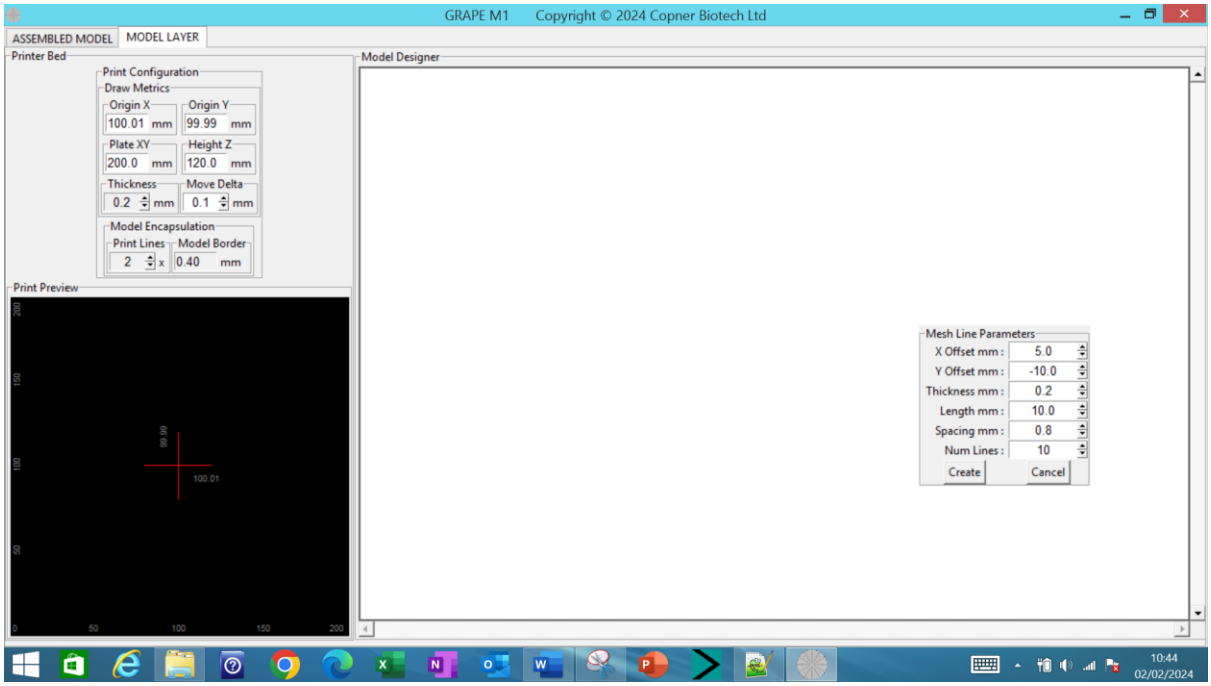

Figure 22 Select Layer Mesh Creation Parameters

Utilising this dialog the designer can specify:

- mesh offset point X & Y coordinates from the current configured origin (range -60.0 to +60.0) in mm (with 0.01 mm adjustment resolution)
- rectangle/line thickness (range 0.01 to 9.99) in mm (with 0.01 mm adjustment resolution)
- mesh line length (range 0.01 to 60.0) in mm (with 0.01 mm adjustment resolution)
- mesh line spacing (range 0.01 to 9.95) in mm (with 0.01 mm adjustment resolution)
- number of mesh lines (range 2 to 6000 with 1 adjustment resolution)

All entry dialogs can be overwritten or adjusted using the spin controls

Selecting ‘Create’ realises the construction and subsequent drawing of the required mesh Figure 23 Mesh Construct X 5.0 mm Y -10mm thickness 0.2 mm length 10 mm spacing 0.8 mm and number lines 10 – Rotated and Zoom View

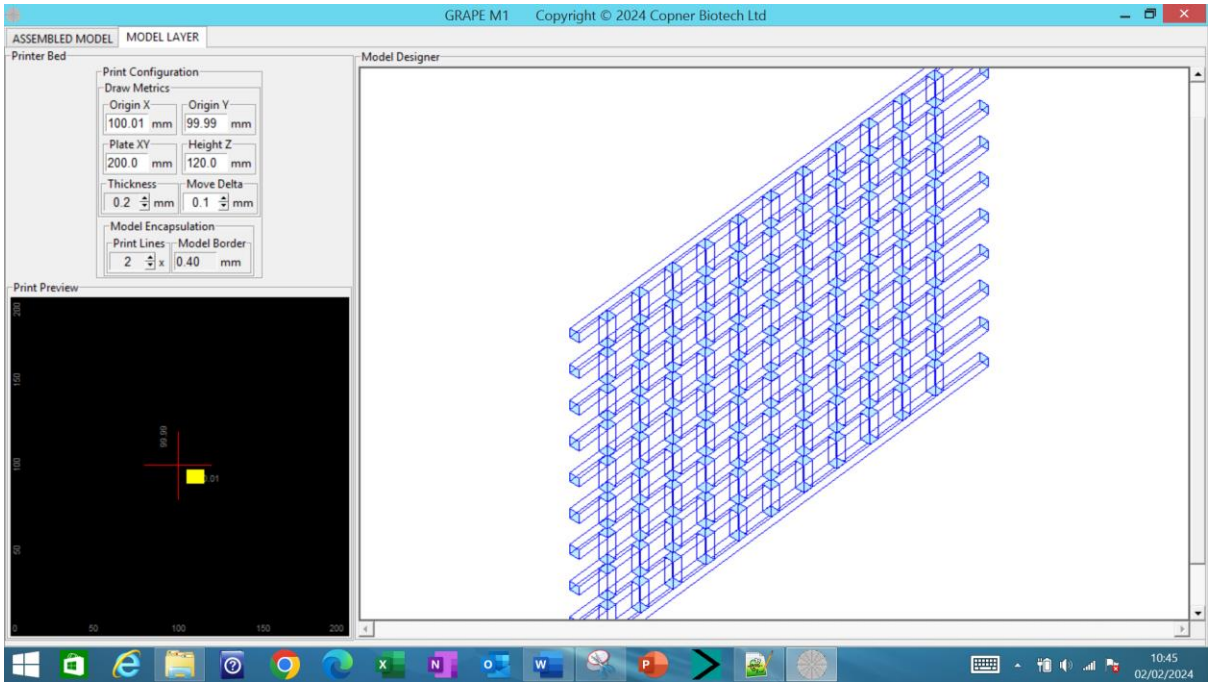

Figure 23 Mesh Construct X 5.0 mm Y -10mm thickness 0.2 mm length 10 mm spacing 0.8 mm and number lines 10 – Rotated and Zoom View

Draw Line Offset

A line can be constructed and drawn at an offset point location from the currently defined printer bed origin.

The designer right clicks the mouse on the layer canvas and selects to draw an offset line using the pop-up menu Figure 24 Layer Model Structure Entity Enhanced Design Draw Constructs - Draw Line Offset

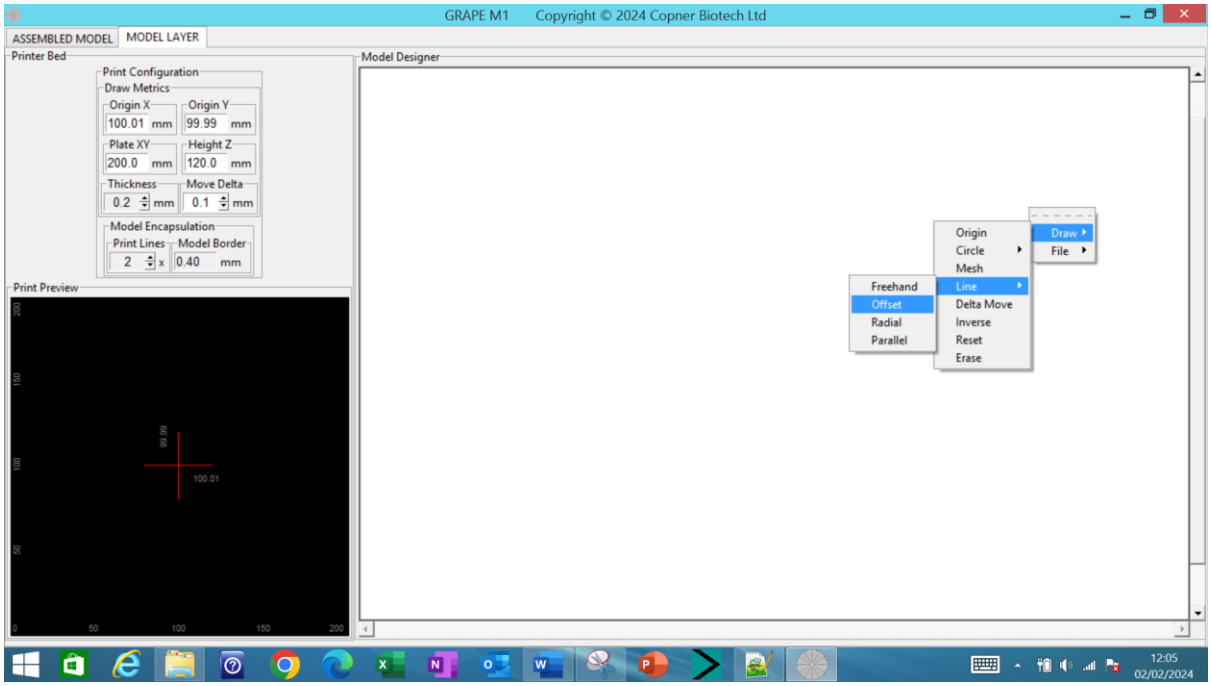

Figure 24 Layer Model Structure Entity Enhanced Design Draw Constructs - Draw Line Offset

On selection of Draw->Line->Offset the designer is presented with a dialog to enter subsequent line construct parameters Figure 25 Select Layer Line Offset Creation Parameters

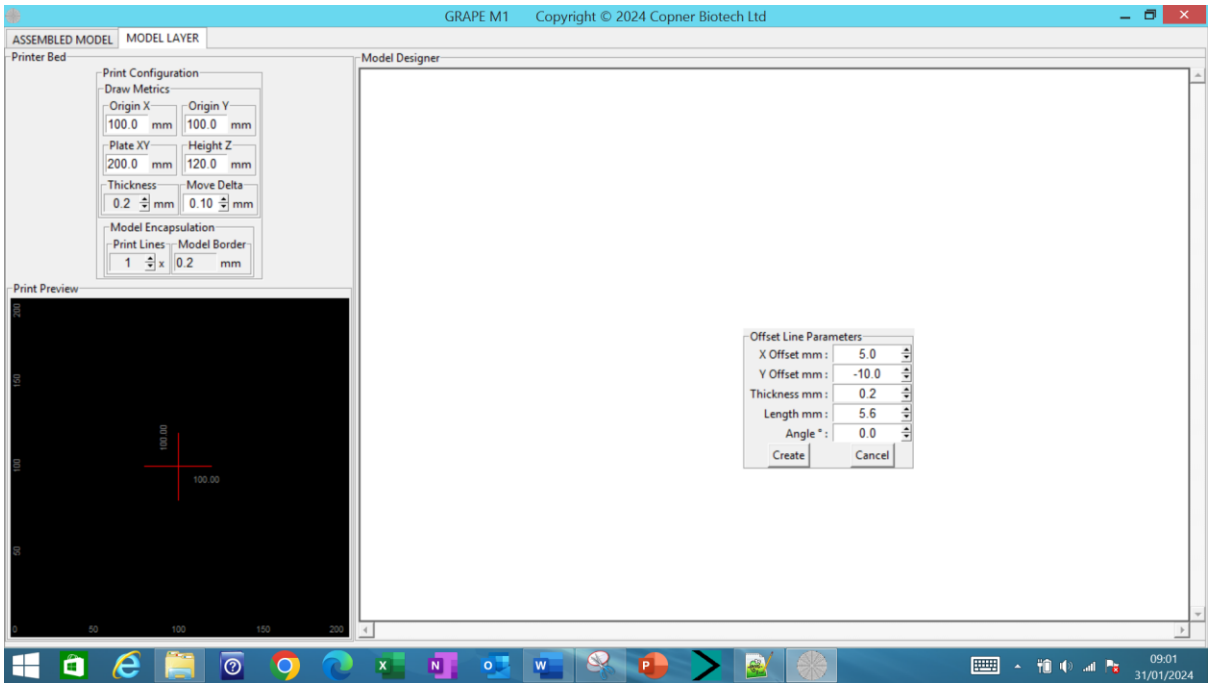

Figure 25 Select Layer Line Offset Creation Parameters

Utilising this dialog the designer can specify:

- line offset point X & Y coordinates from the current configured origin (range -60 to +60.0) in mm (with 0.01 mm adjustment resolution)

- rectangle/line thickness (range 0.01 to 9.99) in mm (with 0.01 mm adjustment resolution)
- line length (range 0.01 to 60.0) in mm (with 0.01 mm adjustment resolution)
- line slope angle (range -180 to +180) degrees (with 0.1 degree adjustment resolution)

All entry dialogs can be overwritten or adjusted using the spin controls

Selecting ‘Create’ realises the construction and subsequent drawing of the required line Figure 26 Offset Line Construct X offset 5mm Y offset -10 mm thickness 0.2 mm length 10 mm slope angle 0 degrees - Top View

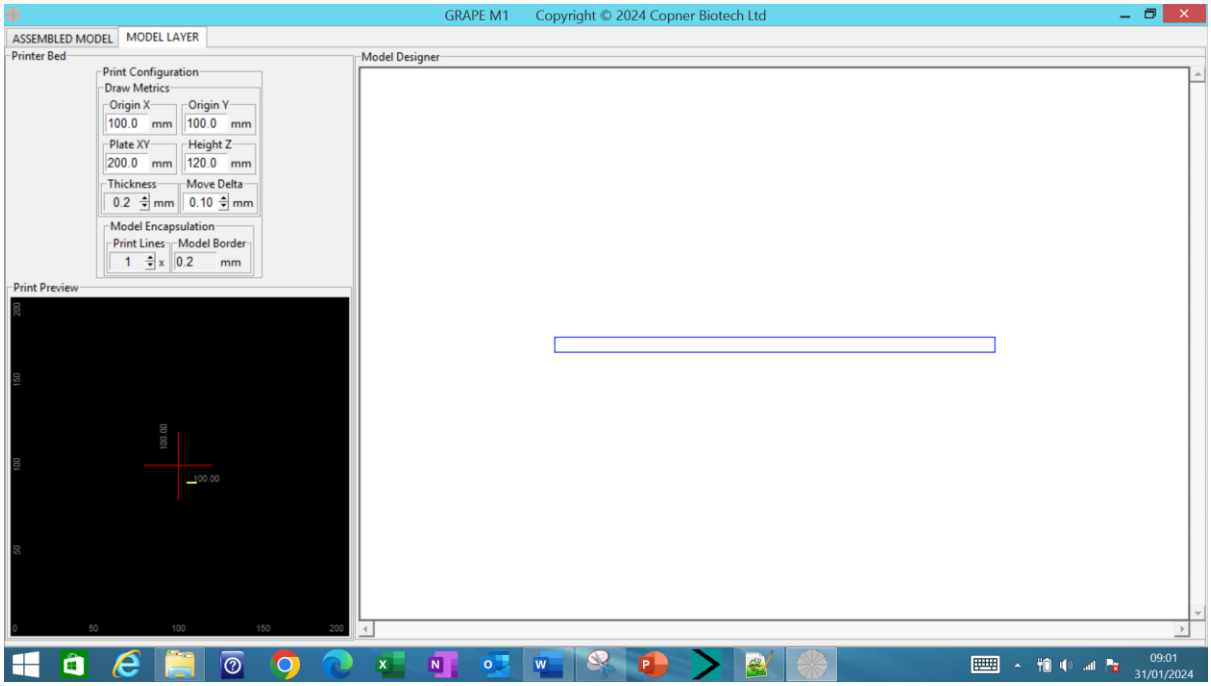

Figure 26 Offset Line Construct X offset 5mm Y offset -10 mm thickness 0.2 mm length 10 mm slope angle 0 degrees - Top View

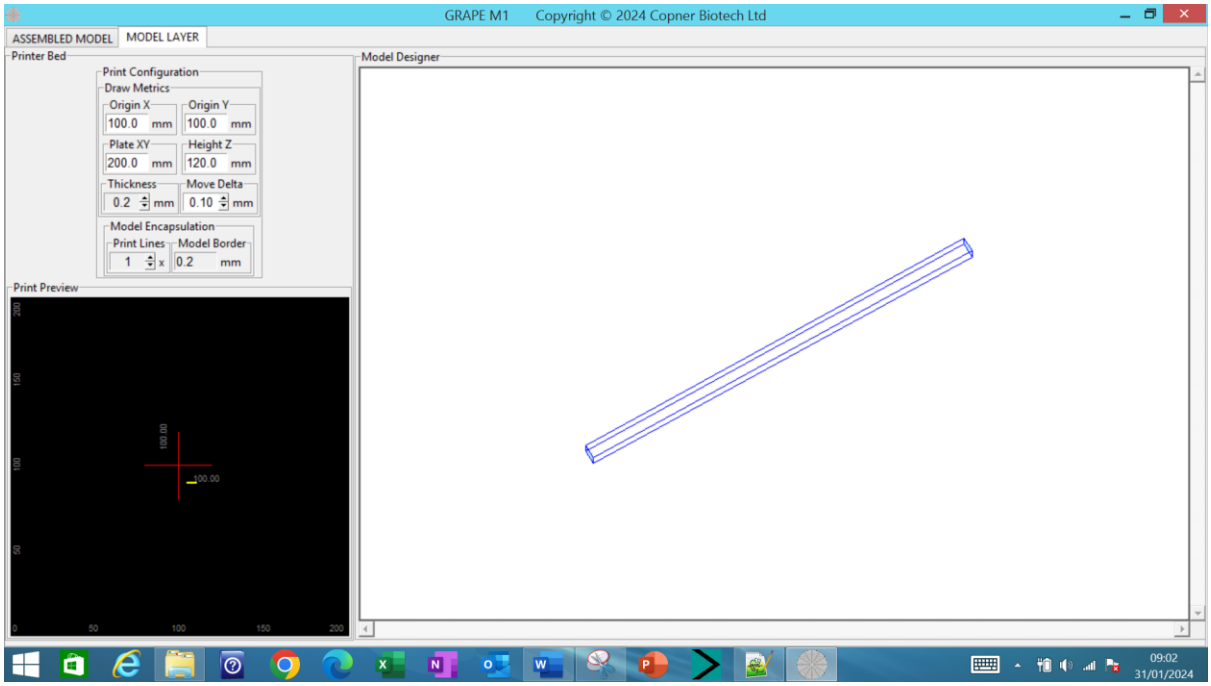

Figure 27 Offset Line Construct X offset 5mm Y offset -10 mm thickness 0.2 mm length 10 mm slope angle 45 degrees - Top View

Draw Radial Line

A line can be constructed and drawn from the circumference of a circle (internal data representation of a circle of the specified radius centred around the printer bed origin) towards the currently defined printer bed origin.

The designer right clicks the mouse on the layer canvas and selects to draw a radial line using the pop-up menu Figure 28 Layer Model Structure Entity Enhanced Design Draw Constructs - Draw Line Radial

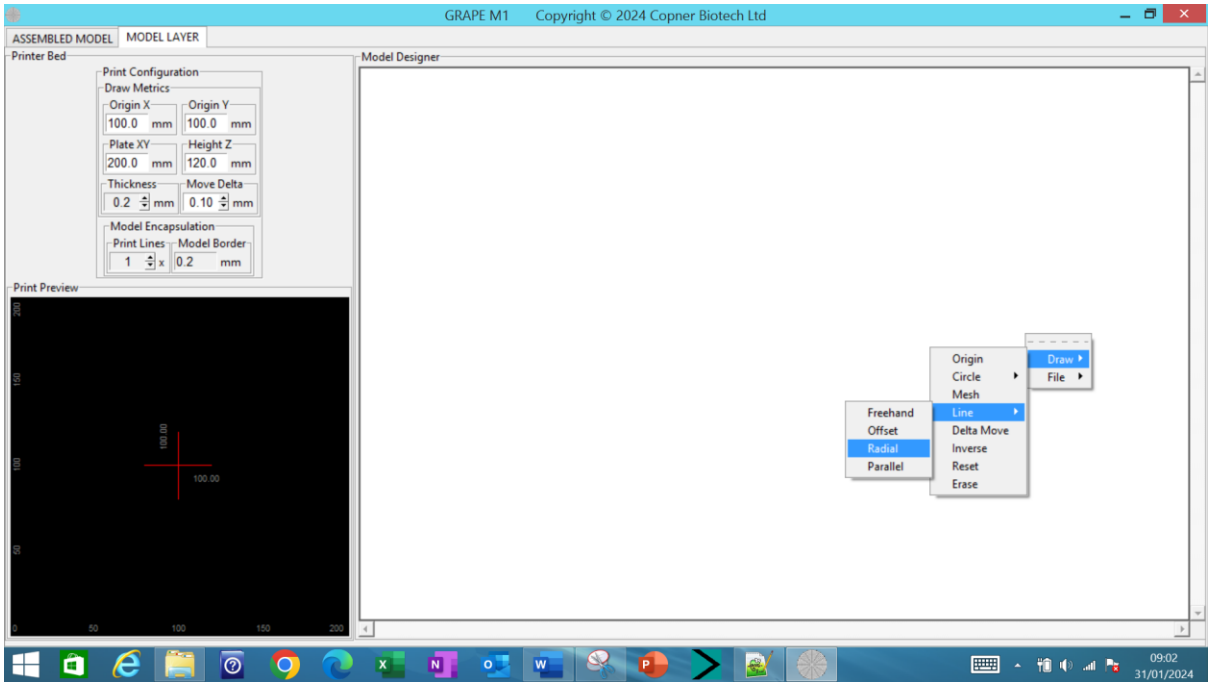

Figure 28 Layer Model Structure Entity Enhanced Design Draw Constructs - Draw Line Radial

On selection of Draw->Line->Radial the designer is presented with a dialog to enter subsequent line construct parameters Figure 29 Select Layer Line Radial Creation Parameters

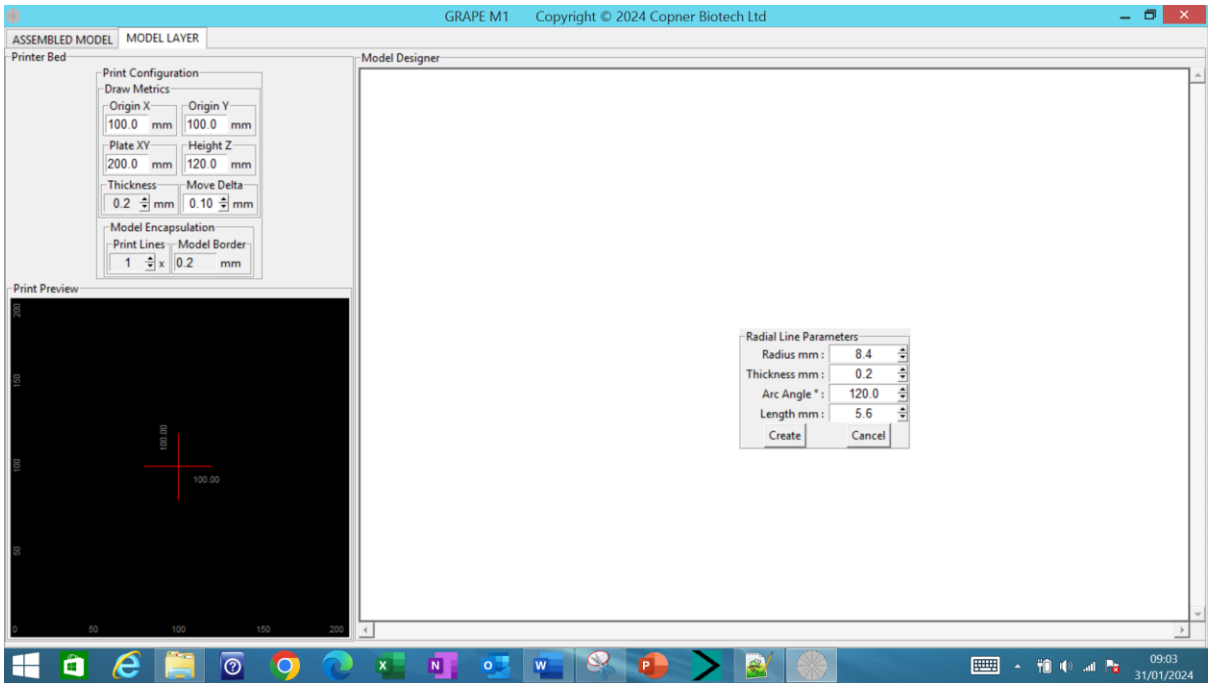

Figure 29 Select Layer Line Radial Creation Parameters

Utilising this dialog the designer can specify:

- radius of calculated circle circumference from the current configured origin (range 0.01 to 60.0) in mm (with 0.01 mm adjustment resolution)
- rectangle/line thickness (range 0.01 to 9.99) in mm (with 0.01 mm adjustment resolution)
- line length (range 0.01 to 60.0) in mm (with 0.01 mm adjustment resolution)

- line arc angle (range 0 to 360) degrees (with 0.1 degree adjustment resolution)

All entry dialogs can be overwritten or adjusted using the spin controls

Selecting ‘Create’ realises the construction and subsequent drawing of the required line.

An example of 3 radial lines drawn at arbitrary arc angles 60/120/270 degrees using calculated circle circumference of 8.4 mm; line thickness 0.2 mm and length 5.6 mm are depicted in Figure 30 Radial Line Constructs Circle Radius 8.4 mm thickness 0.2 mm length 5.6 mm arc angles 60/120/270 degrees - Top View

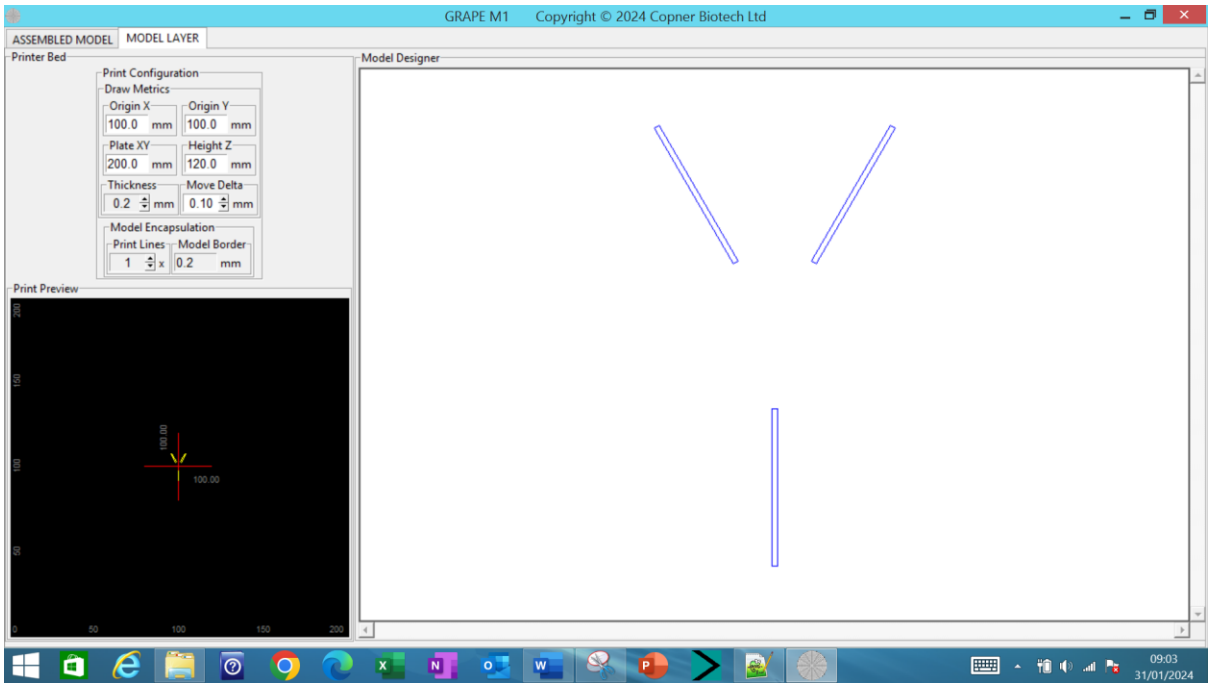

Figure 30 Radial Line Constructs Circle Radius 8.4 mm thickness 0.2 mm length 5.6 mm arc angles 60/120/270 degrees - Top View

Draw Parallel Lines

Parallel lines can be constructed and drawn at an offset point location from the currently defined printer bed origin.

The designer right clicks the mouse on the layer canvas and selects to draw parallel lines using the pop-up menu Figure 31 Layer Model Structure Entity Enhanced Design Draw Constructs – Draw Line Parallel

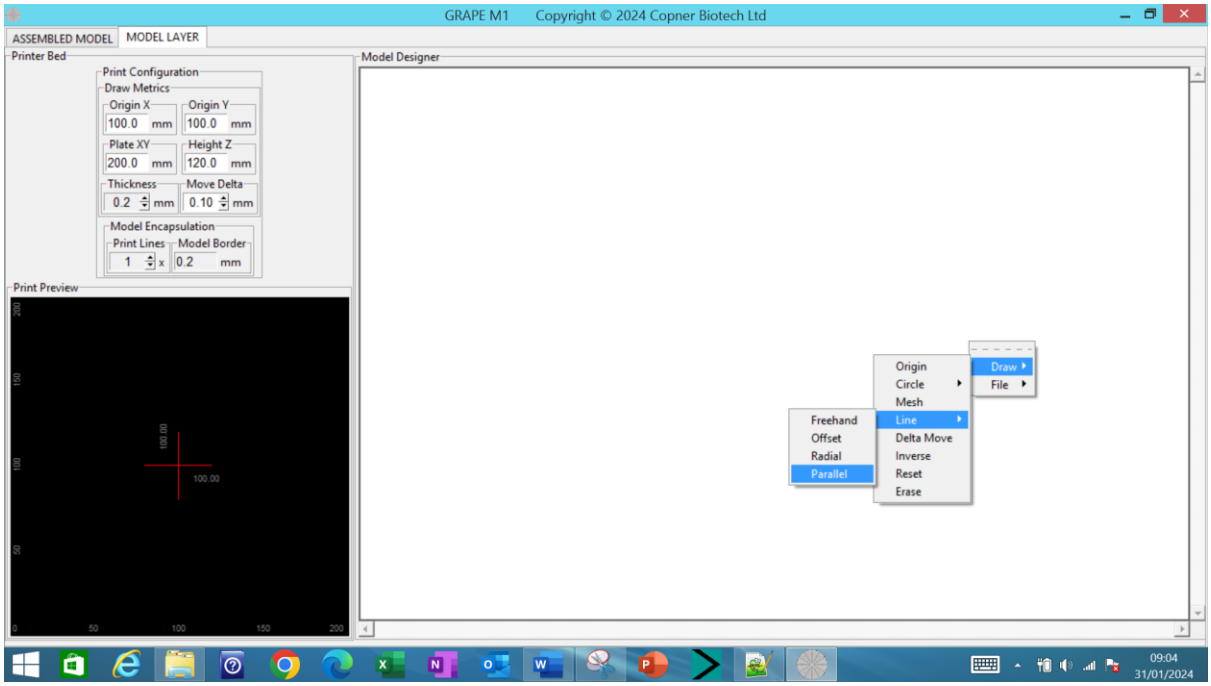

Figure 31 Layer Model Structure Entity Enhanced Design Draw Constructs – Draw Line Parallel

On selection of Draw->Line->Parallel the designer is presented with a dialog to enter subsequent line construct parameters Figure 32 Select Layer Line Parallel Lines Creation Parameters

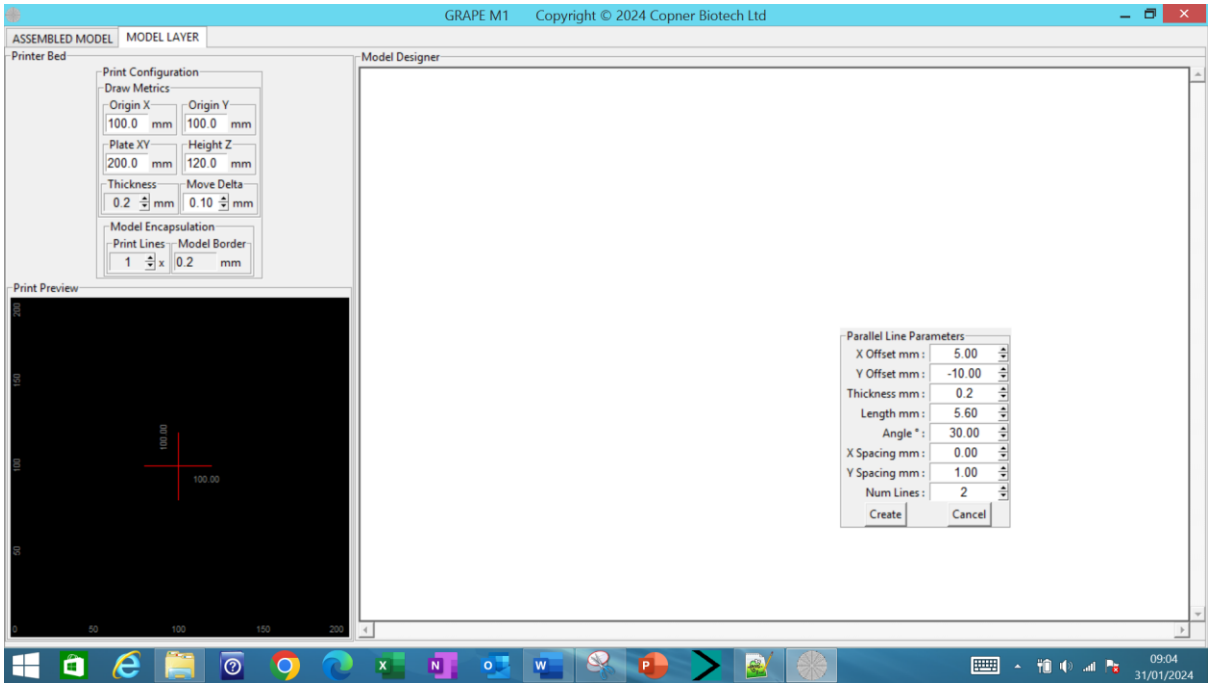

Figure 32 Select Layer Line Parallel Lines Creation Parameters

Utilising this dialog the designer can specify:

- line offset point X & Y coordinates from the current configured origin (range -60 to +60.0) in mm (with 0.01 mm adjustment resolution)
- rectangle/line thickness (range 0.01 to 9.99) in mm (with 0.01 mm adjustment resolution)
- line length (range 0.01 to 60.0) in mm (with 0.01 mm adjustment resolution)

- line slope angle (range -90 to +90) degrees (with 0.1 degree adjustment resolution)
- Line Spacing X and Y Components (range 0.0 to 5.0) in mm (with 0.01 mm adjustment resolution
- Number of parallel lines (range 2 to 6000)

All entry dialogs can be overwritten or adjusted using the spin controls

Selecting ‘Create’ realises the construction and subsequent drawing of the required parallel lines Figure 33 Parallel Lines Construct X offset 5.0mm Y offset -10.0mm Thickness 0.2mm Length 5.6mm Slope Angle 30 degrees X Spacing 0.0mm Y Spacing 1.0mm Number Lines 2

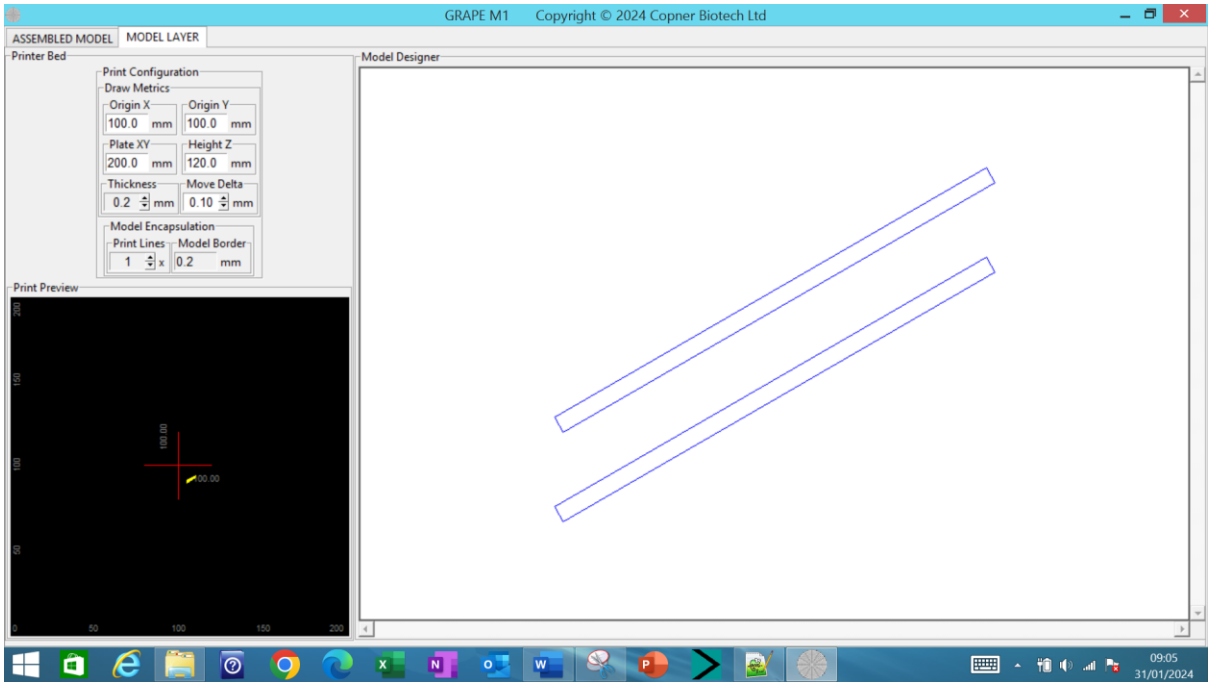

Figure 33 Parallel Lines Construct X offset 5.0mm Y offset -10.0mm Thickness 0.2mm Length 5.6mm Slope Angle 30 degrees X Spacing 0.0mm Y Spacing 1.0mm Number Lines 2

Freehand Drawing

Lines can be drawn by the designer using the ‘Drawing Print Preview Panel‘ launched by pressing the ‘Insert’ key whilst the Model Layer->Model Designer panel has focus. The Model Layer->Model Designer panel can obtain focus when the designer clicks the left mouse key whilst the mouse is positioned inside the ‘Model Designer’ panel.

The ‘Drawing Print Preview Panel’ can also be accessed on selection of Draw->Line->Freehand; Figure 34 Layer Model Structure Entity Enhanced Design Draw Constructs – Draw Line Freehand where the designer is presented with a dialog to enter subsequent line construct thickness Figure 35 Select Draw Line Thickness Parameter. On subsequent selection of select the ‘Drawing Print Preview Panel’ is displayed Figure 36 Drawing Print Preview Panel.

The displayed ‘Drawing Print Preview Panel’ can be removed by pressing the ‘Insert’ key whilst the mouse position is within the ’Drawing Print Preview Panel’.

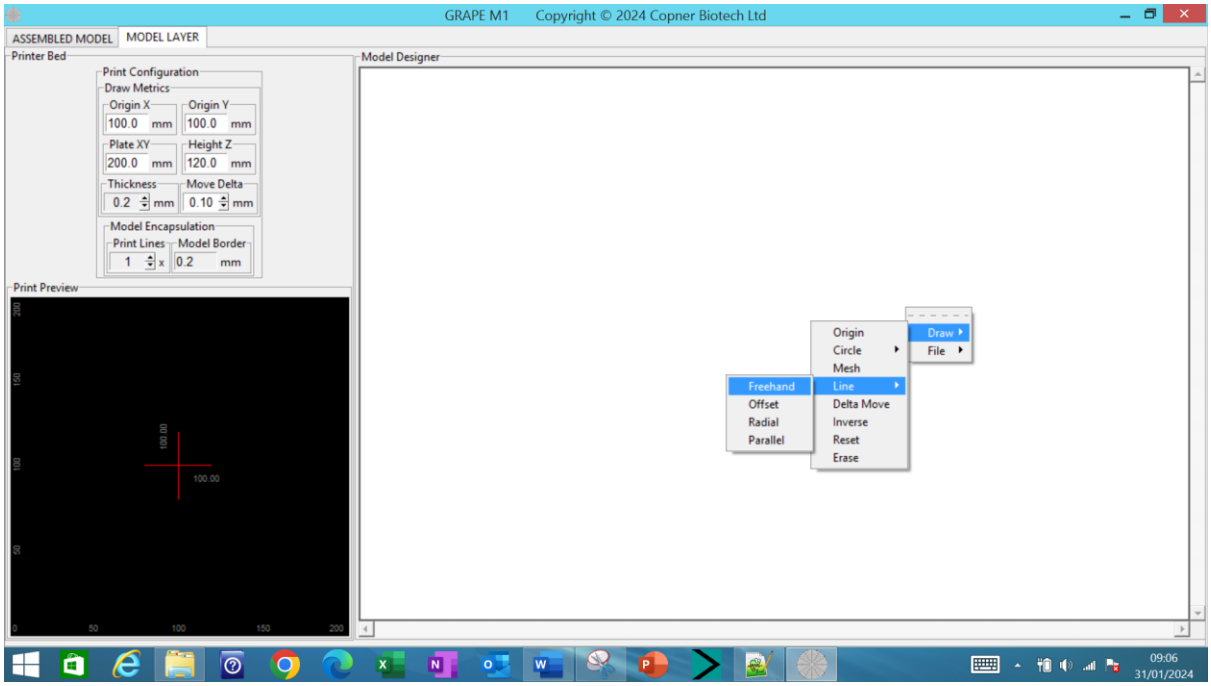

Figure 34 Layer Model Structure Entity Enhanced Design Draw Constructs – Draw Line Freehand

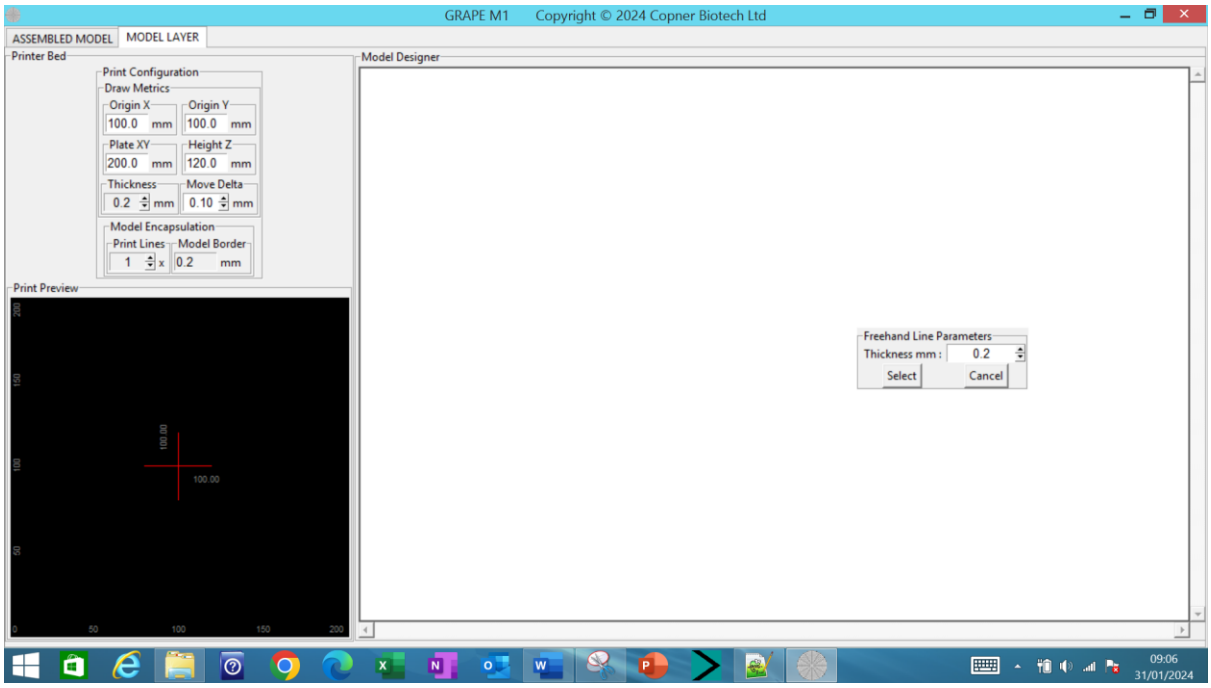

Figure 35 Select Draw Line Thickness Parameter

Utilising this dialog the designer can specify:

- line draw thickness (range 0.01 to 9.99) in mm (with 0.01 mm adjustment resolution)

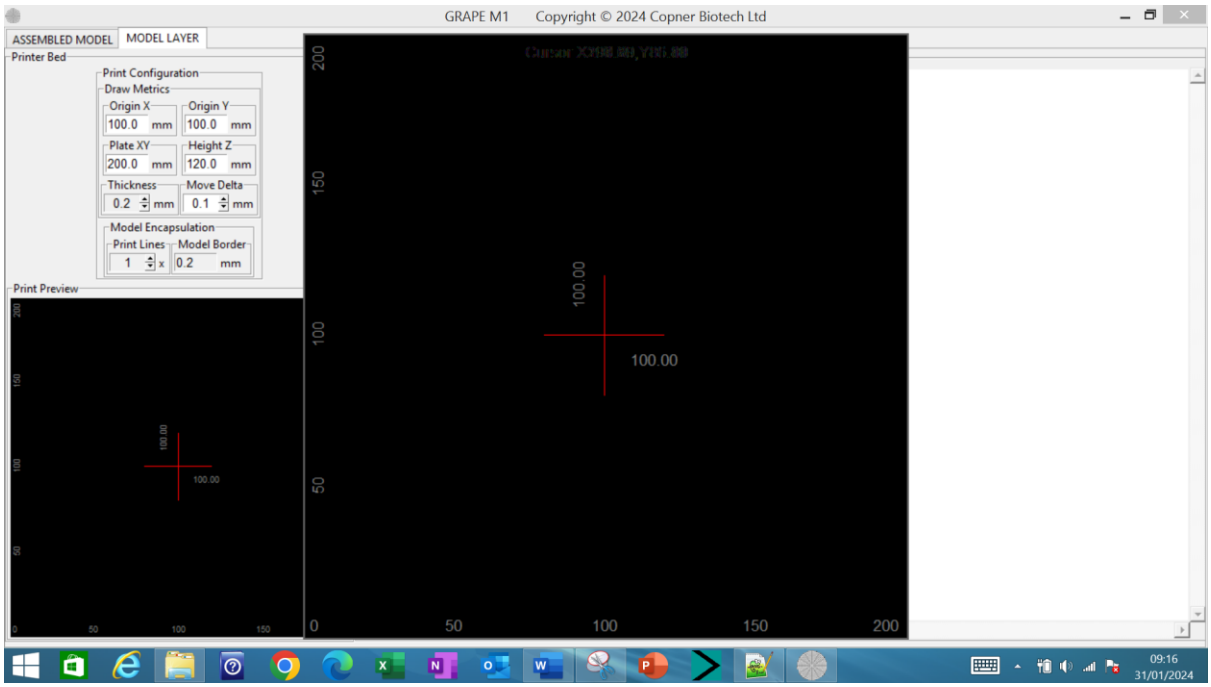

Figure 36 Drawing Print Preview Panel

Movement of the mouse with in the 'Drawing Print Preview Panel' is tracked to show its actual print bed positional coordinates displayed as Cursor X & Y Figure 37 Drawing Print Preview Panel - Cursor Position

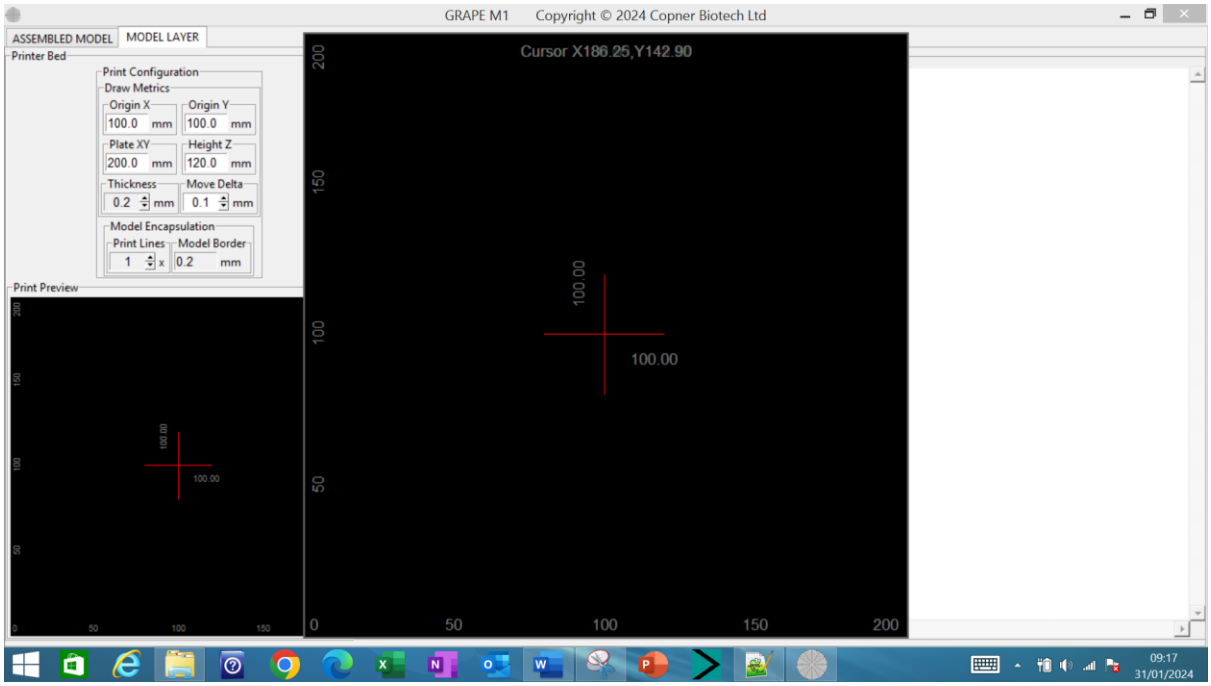

Figure 37 Drawing Print Preview Panel - Cursor Position

Drawing can be realised by clicking and holding the mouse Left button whilst moving the mouse Figure 38 Drawing Print Preview Panel - Constructs Drawn.

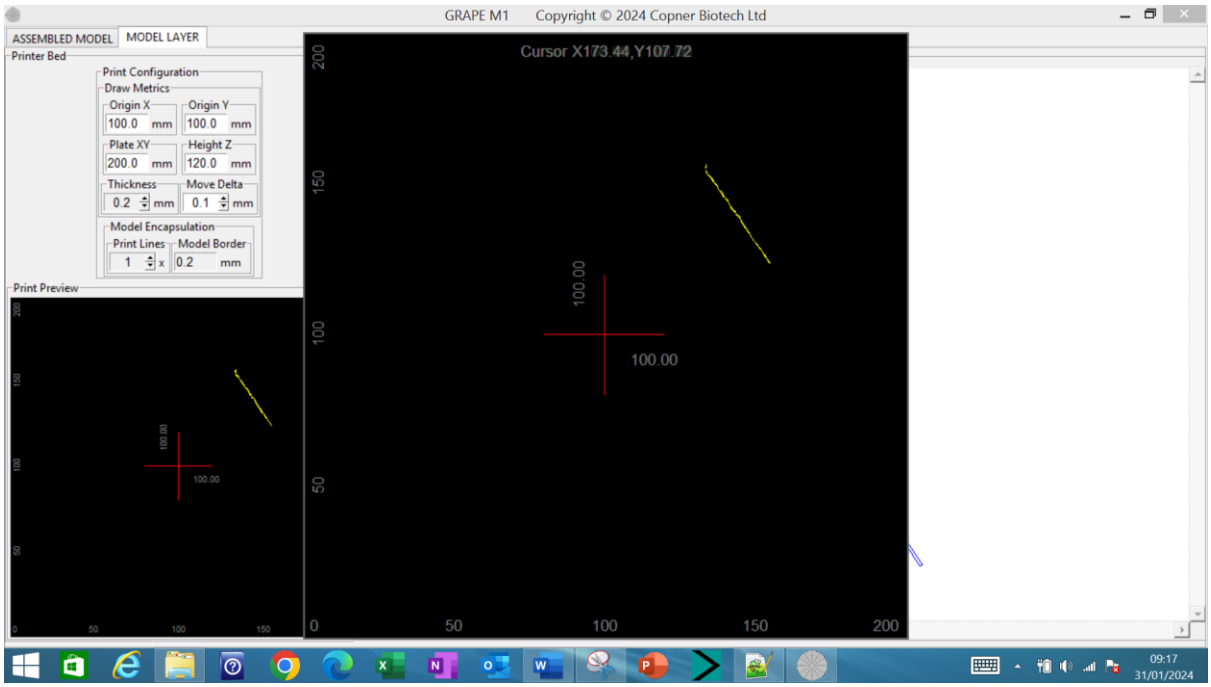

Figure 38 Drawing Print Preview Panel - Constructs Drawn

On selection of the 'Insert' key whilst 'Drawing Print Preview Panel' is in focus; the 'Drawing Print Preview Panel' closes down to show the drawn constructs on the 'Model Designer' panel Figure 39 Model Designer - Constructs Drawn to allow further editing/manipulation – see section Modification of Layer Constructs.

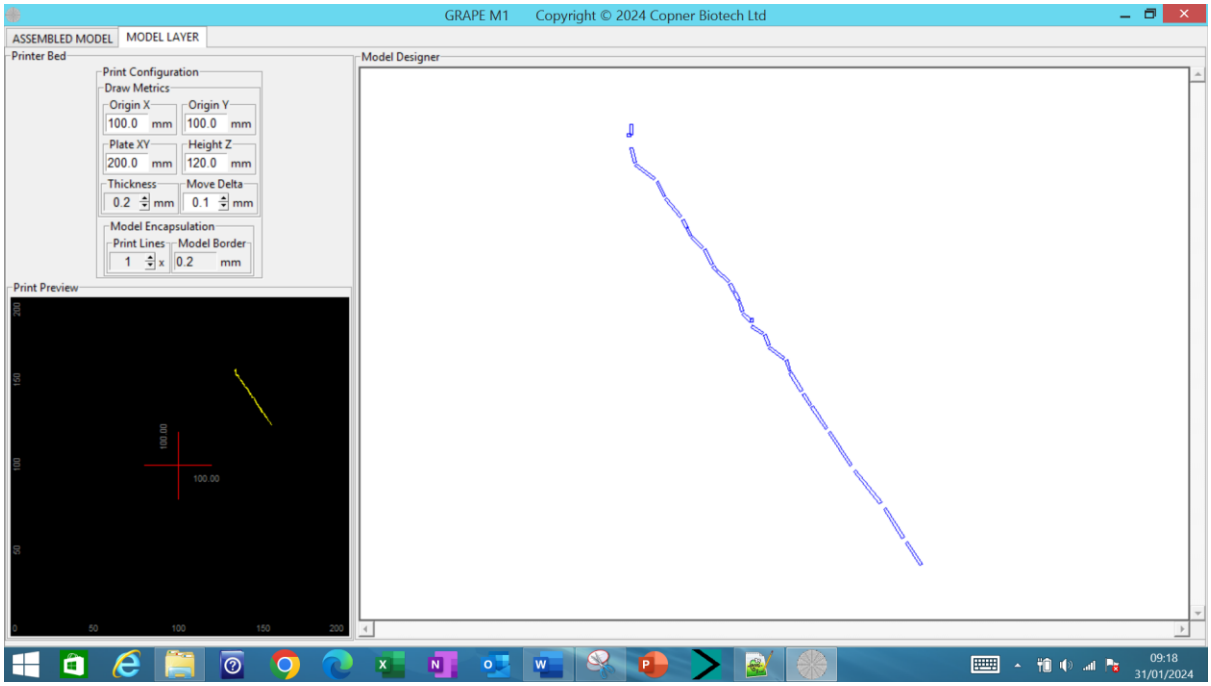

Figure 39 Model Designer - Constructs Drawn

Modification of Layer Constructs

Draw Layer constructs can be further inspected and edited such that the designer can:

- Verify a construct's position and dimensions
- Move a construct's position
- Delete a construct
- Adjust a construct's dimensions thickness and length together with the construct's X and Y offsets and slope angle

Verification of a Construct's position and dimensions

The designer can highlight using the mouse; the model layer rectangular construct of interest and verify is position and dimensions from the pop-up dialogs; Figure 40 Rectangular Construct Positional Point Information;

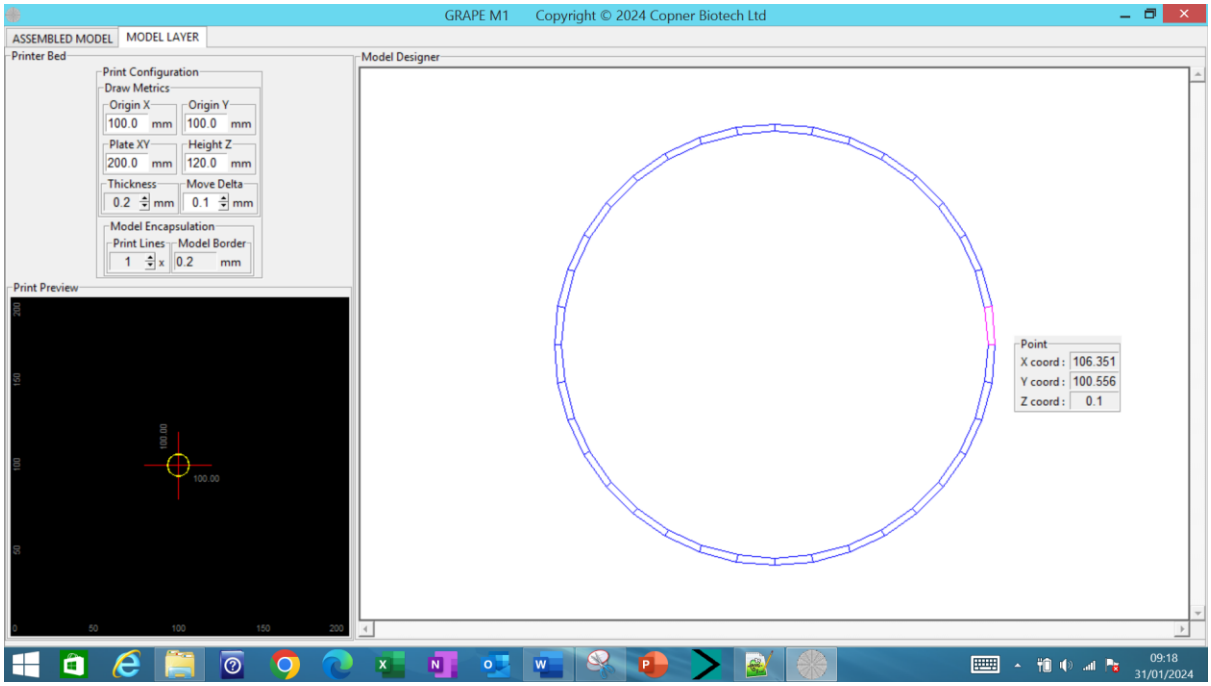

Figure 40 Rectangular Construct Positional Point Information

The designer can move a highlighted rectangular construct by using the keyboard arrow keys; Figure 41 Adjust Placement of Layer Constructs using the Left/Right/Up/Down keys

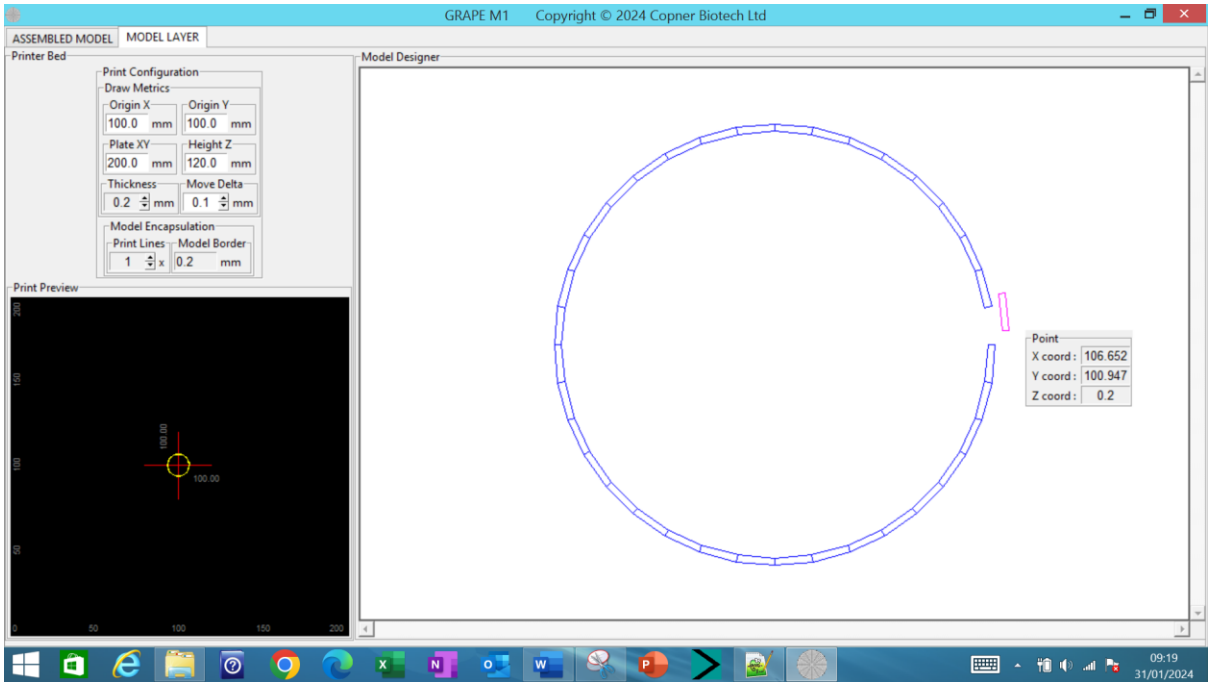

Figure 41 Adjust Placement of Layer Constructs using the Left/Right/Up/Down keys

The designer can delete a highlighted rectangular construct; Figure 42 Deletion of Layer Constructs

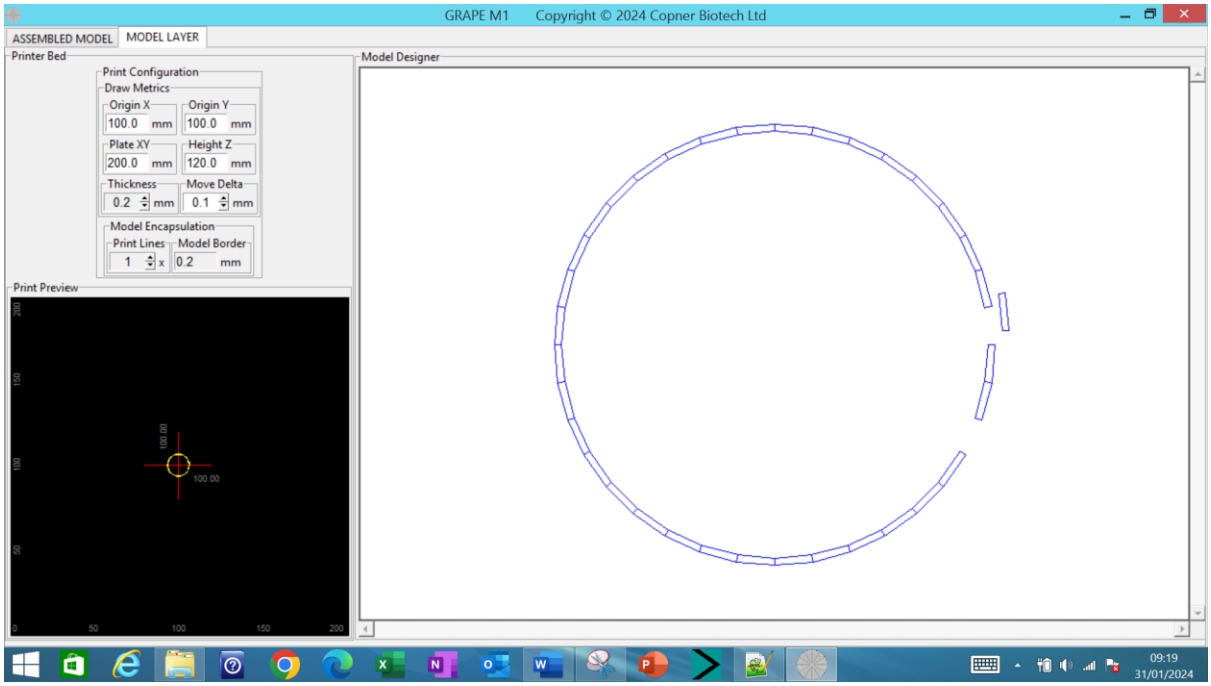

Figure 42 Deletion of Layer Constructs

The designer can modify a construct's dimensions and slop angle post initial drawing by right clicking the mouse whilst the construct is highlighted; Figure 43 Construct modification Dialog which initially presents the Construct's current properties

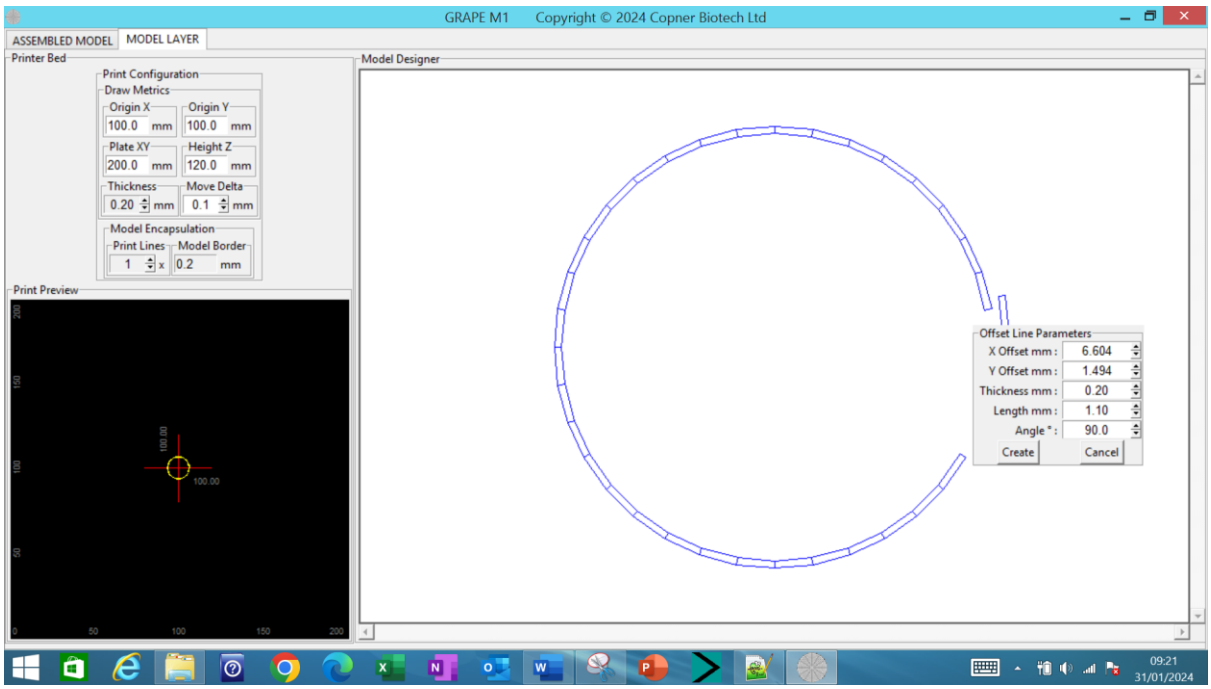

Figure 43 Construct modification Dialog which initially presents the Construct's current properties

Utilising this dialog the designer can specify:

- line offset point X & Y coordinates from the current configured origin (range -60 to +60.0) in mm (with 0.01 mm adjustment resolution)
- rectangle/line thickness (range 0.01 to 9.99) in mm (with 0.01 mm adjustment resolution)
- line length (range 0.01 to 60.0) in mm (with 0.01 mm adjustment resolution)
- line slope angle (range -180 to +180) degrees (with 0.1 degree adjustment resolution)

All entry dialogs can be overwritten or adjusted using the spin controls; Figure 44 Construct Modification Dialog now showing the required adjustment settings

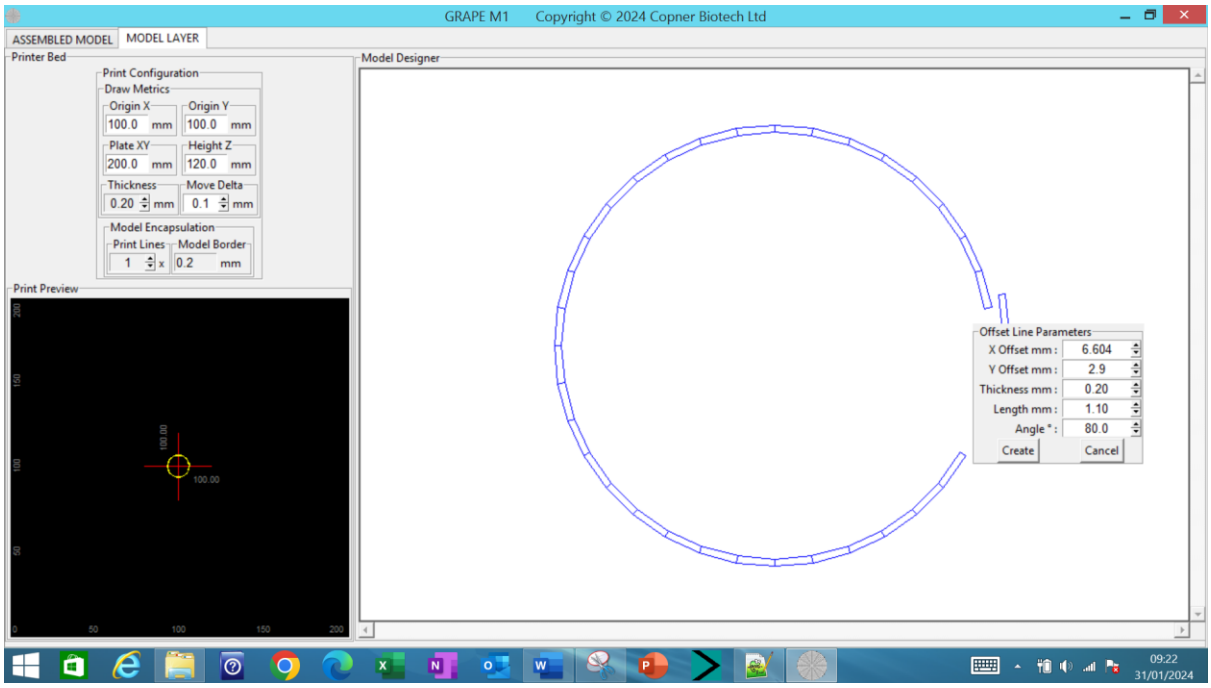

Figure 44 Construct Modification Dialog now showing the required adjustment settings

Selecting ‘Create’ realises the construction and subsequent redrawing of the required line; Figure 45 Construct Modification now completed by redrawing the construct with the new settings

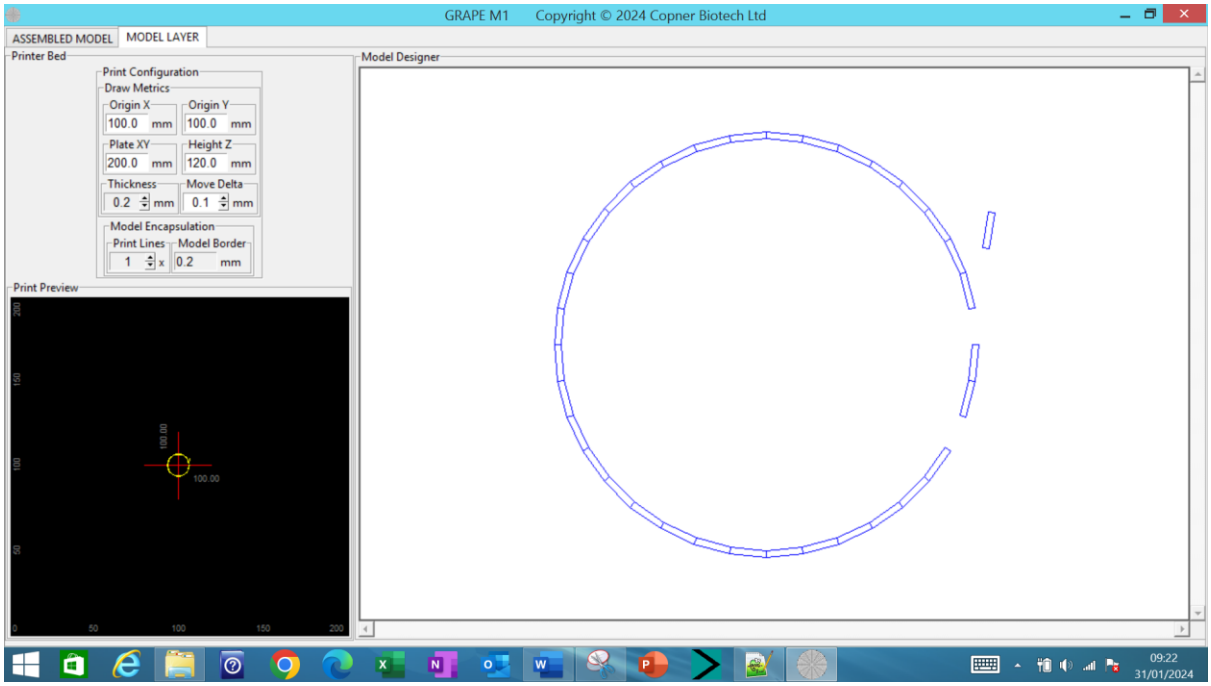

Figure 45 Construct Modification now completed by redrawing the construct with the new settings

Saving a Model Layer

On completion of a Model Layer construction the designer can save this to a file using the pop-up menu; Figure 46 Save Model Layer

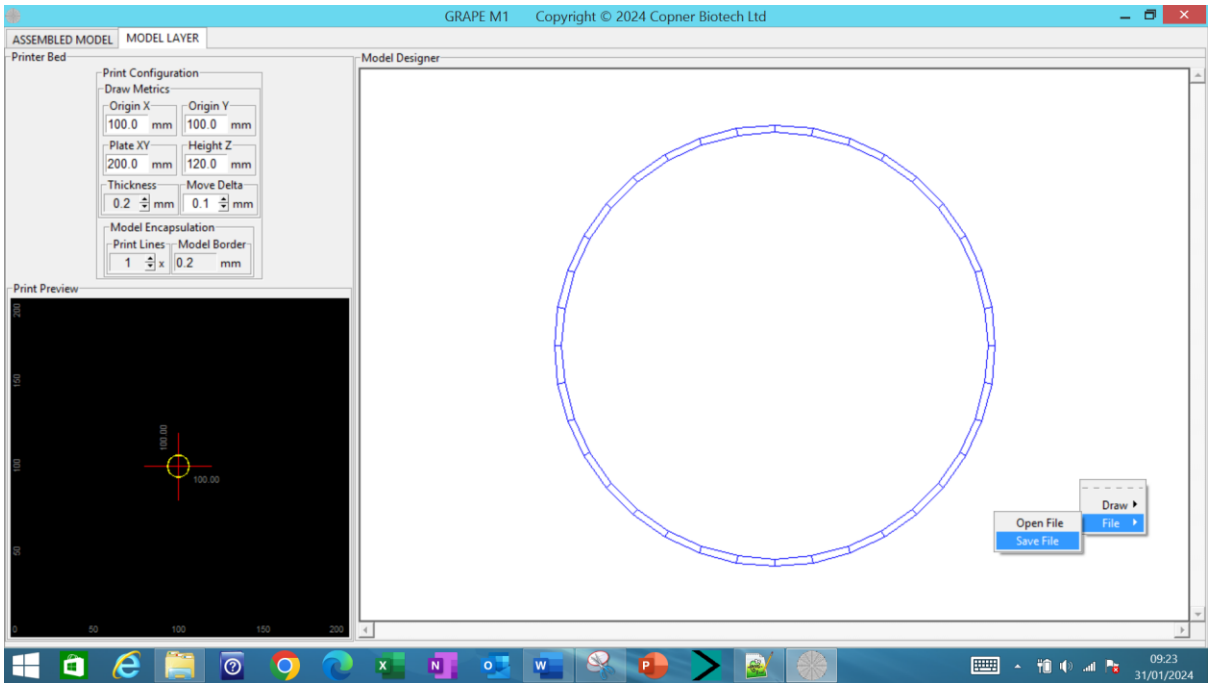

Figure 46 Save Model Layer

On action of the ‘Save File’ the designer is presented with a dialog to select filename and location to save; Figure 47 Save File Selection Dialog

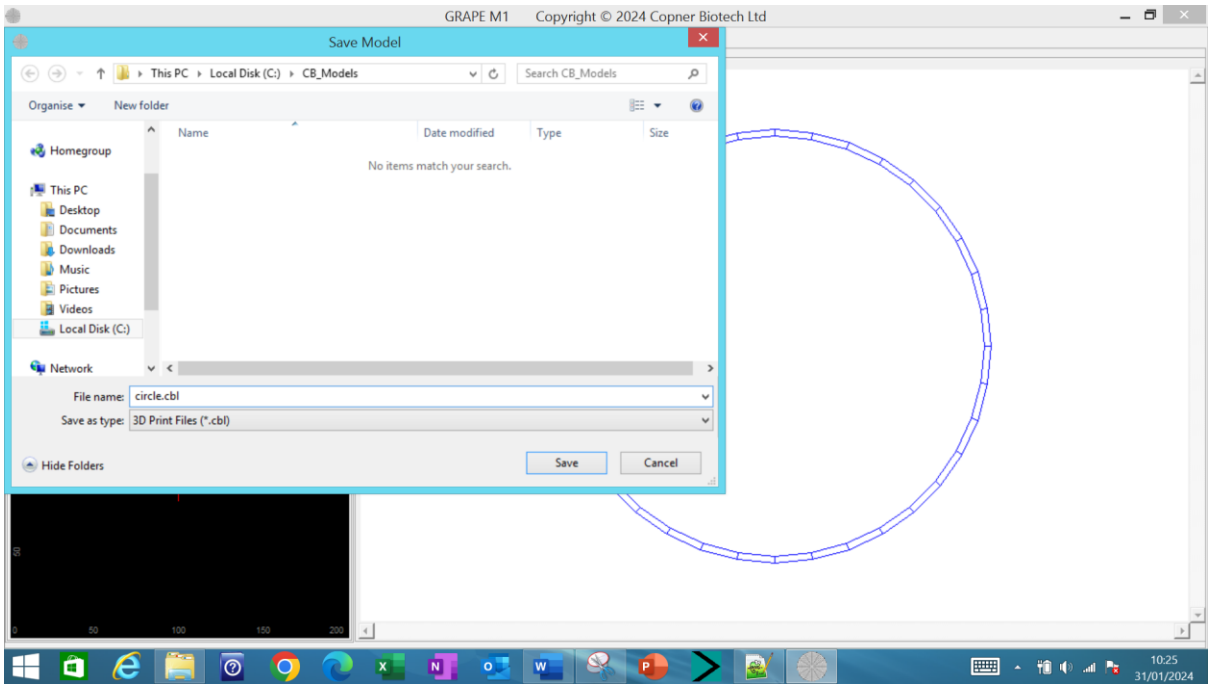

Figure 47 Save File Selection Dialog

On actioning ‘Save’ the model layer is saved; Figure 48 Model Layer saved in both GRAPE and STL data formats.

GRAPE data format for use with Copner Biotech’s GRAPE family of 3D bio printers; e.g. GRAPE S1

STL data format for conventional 3D printers; useful for visualising your 3D bio construct in plastic.

Note: Ensure the selected file folder name has no spaces

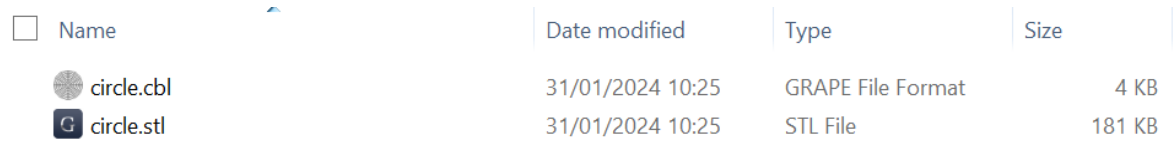

Figure 48 Model Layer saved in both GRAPE and STL data formats

Open a Model Layer

The designer can select previously saved model layers; Figure 49 Open previously saved Model Layer

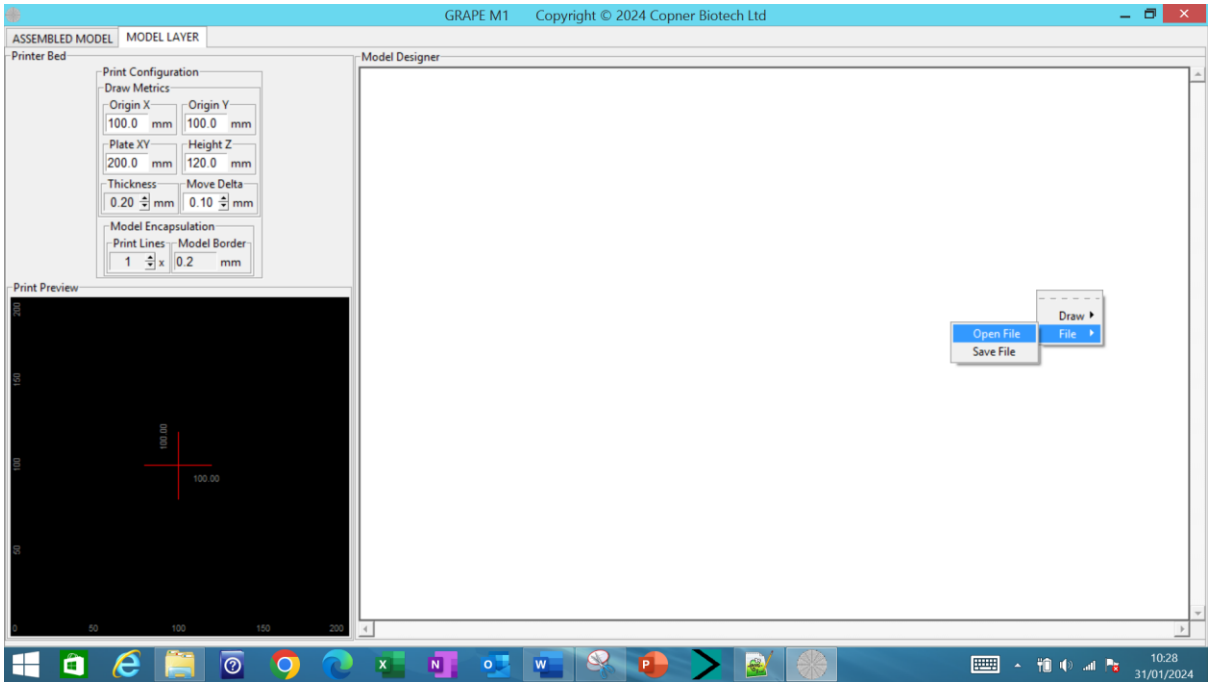

Figure 49 Open previously saved Model Layer

Designer is presented with a dialog; Figure 50 Select Model Layer GRAPE file to load

NOTE: GRAPE M1 will only read in GRAPE .cbl files; but will save model layers is both GRAPE and STL formats

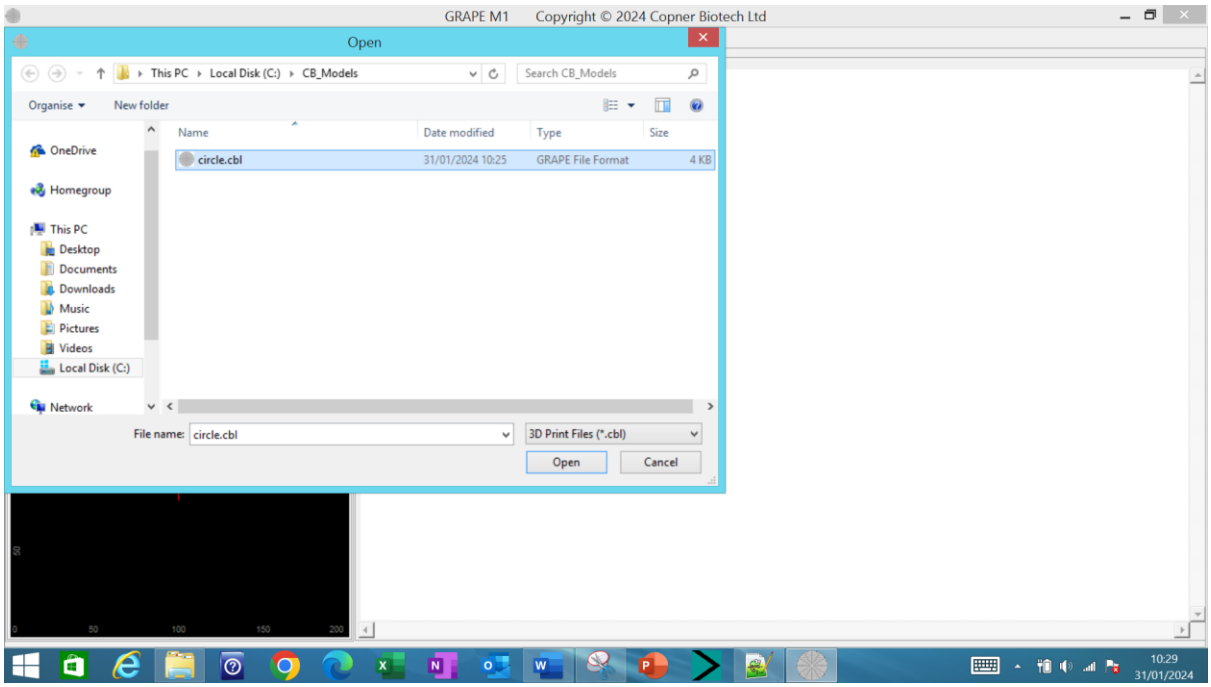

Figure 50 Select Model Layer GRAPE file to load

On selection of ‘Open’ the previously saved GRAPE file is loaded and displayed; Figure 51 Model Layer loaded and displayed.

Note: Ensure the selected file folder name has no spaces

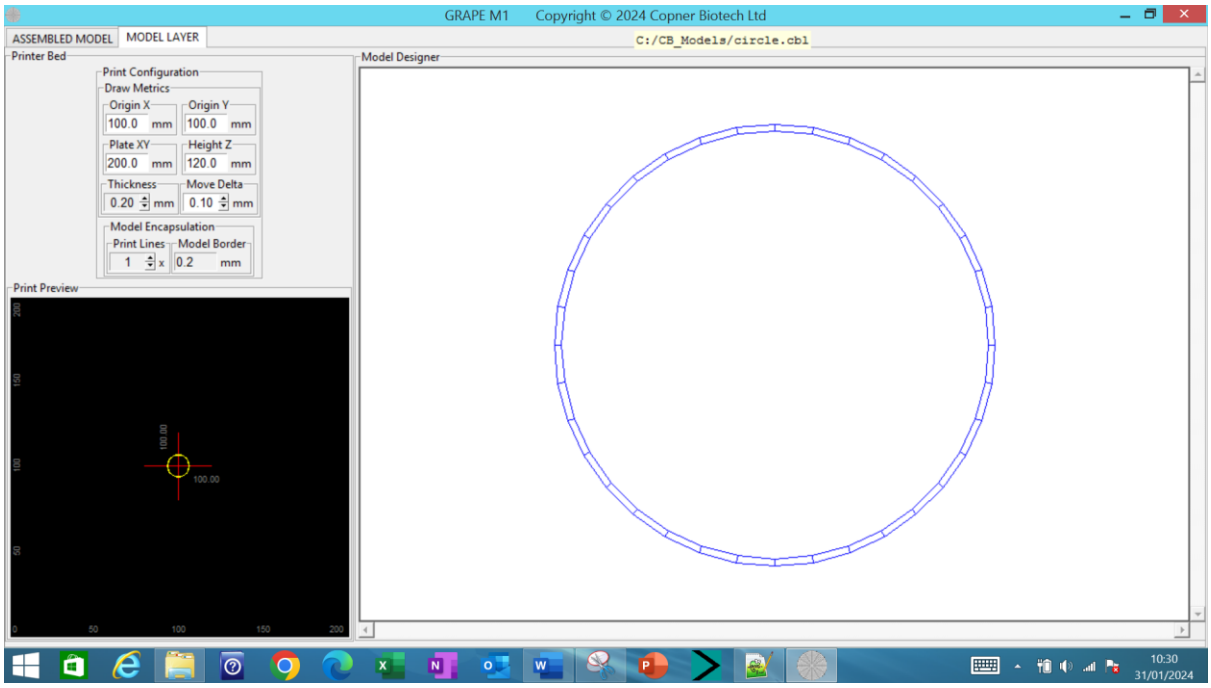

Figure 51 Model Layer loaded and displayed

Model Layer Construct Manipulation

Designer can also select specific rectangles of a model construct to be manipulated;

Using the ‘Drawing Print Preview Panel’ a designer can move/copy/delete construct(s) to fine tune the model layer under construction; Figure 52 Model Layer Drawing Print Review Panel

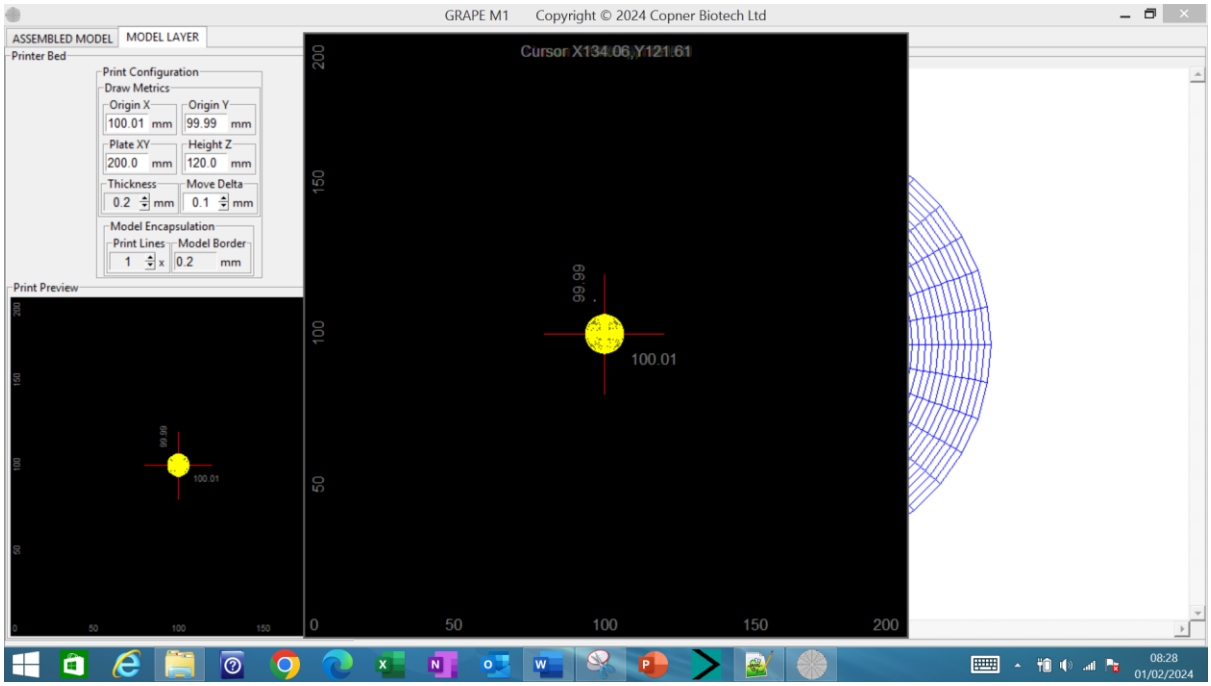

Figure 52 Model Layer Drawing Print Review Panel

All the model manipulation features that are documented below for assembled models are available for the Model Layer; Delta Move/Copy & Paste/Delete. Figure 53 Model Layer select rectangular constructs

Construct(s) can be selected by pressing and holding the middle mouse button and drawing a box around the construct to be selected to be moved/copied/deleted. Selected constructs are highlighted in blue.

Deletion of selected model rectangle constructs can be achieved using this workflow example;

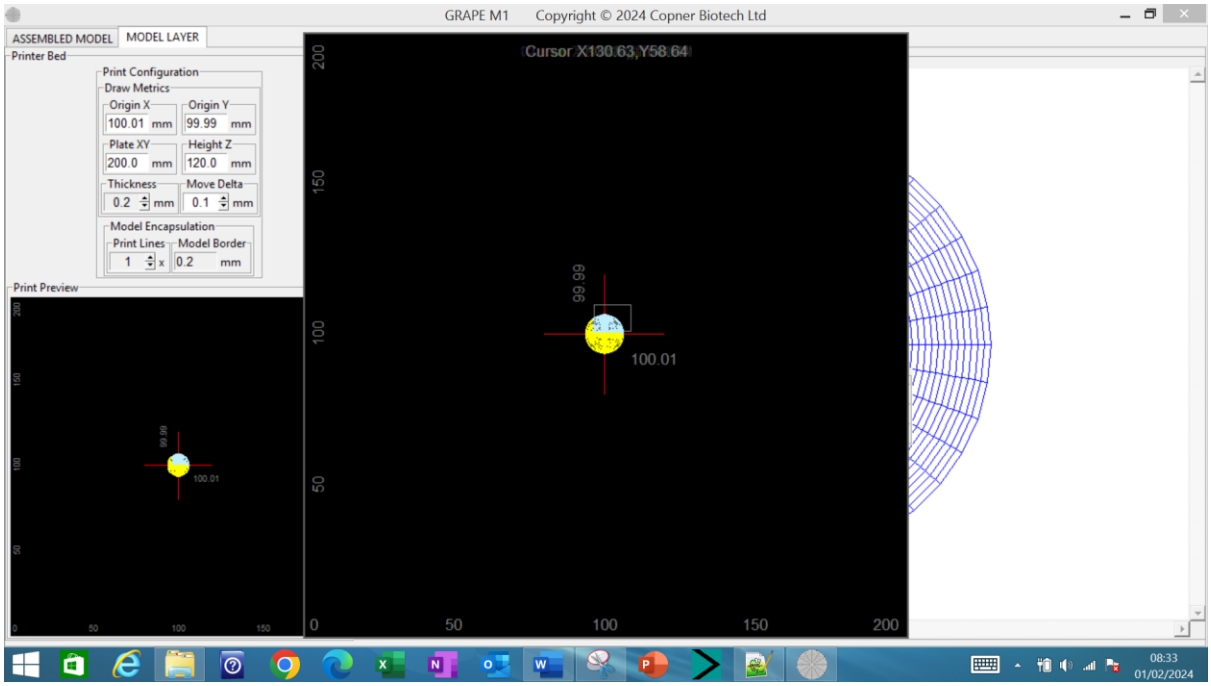

Figure 53 Model Layer select rectangular constructs

Selected model layer can be deleted using the popup menu Figure 54 Model Layer Select to delete constructs

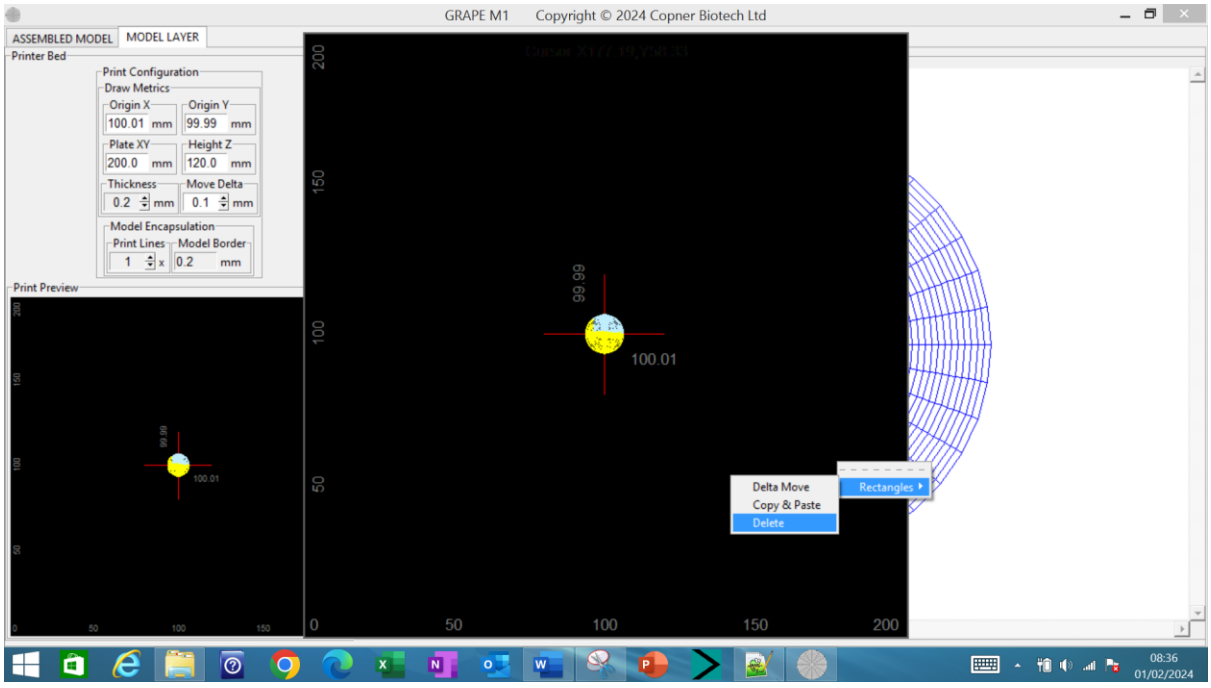

Figure 54 Model Layer Select to delete constructs

On action of ‘Delete’ the selected constructs are deleted Figure 55 Model Layer demonstrating deleted constructs and Figure 56 Model layer disc model with deleted constructs

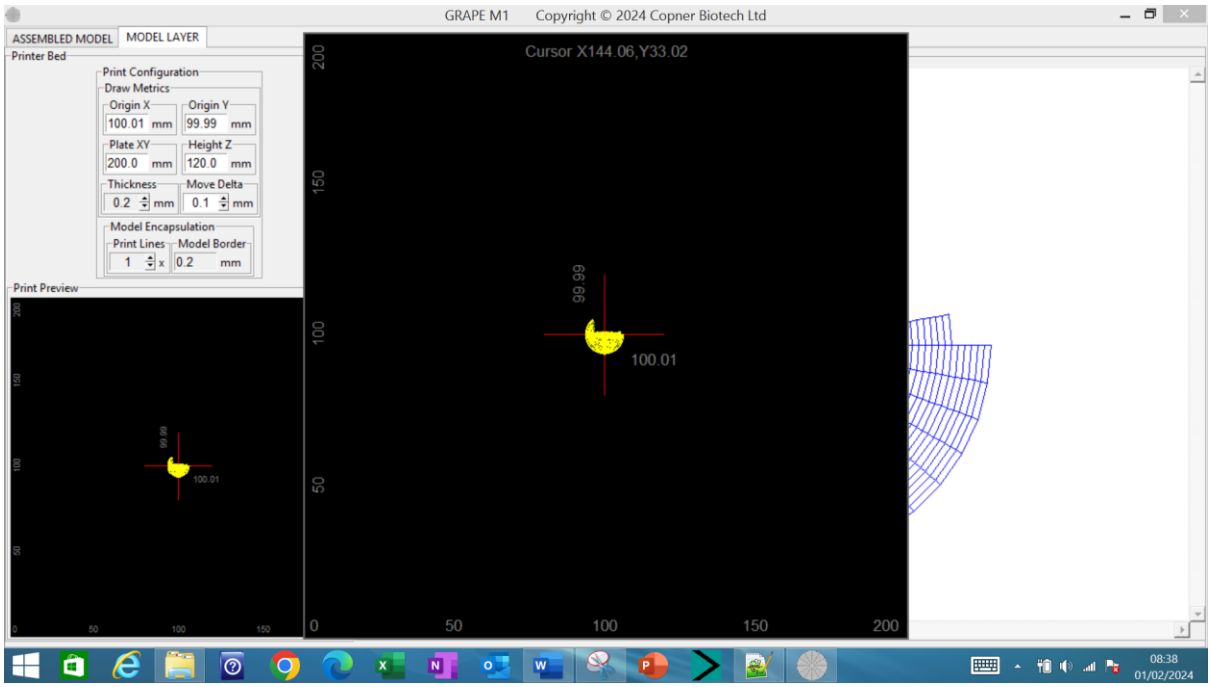

Figure 55 Model Layer demonstrating deleted constructs

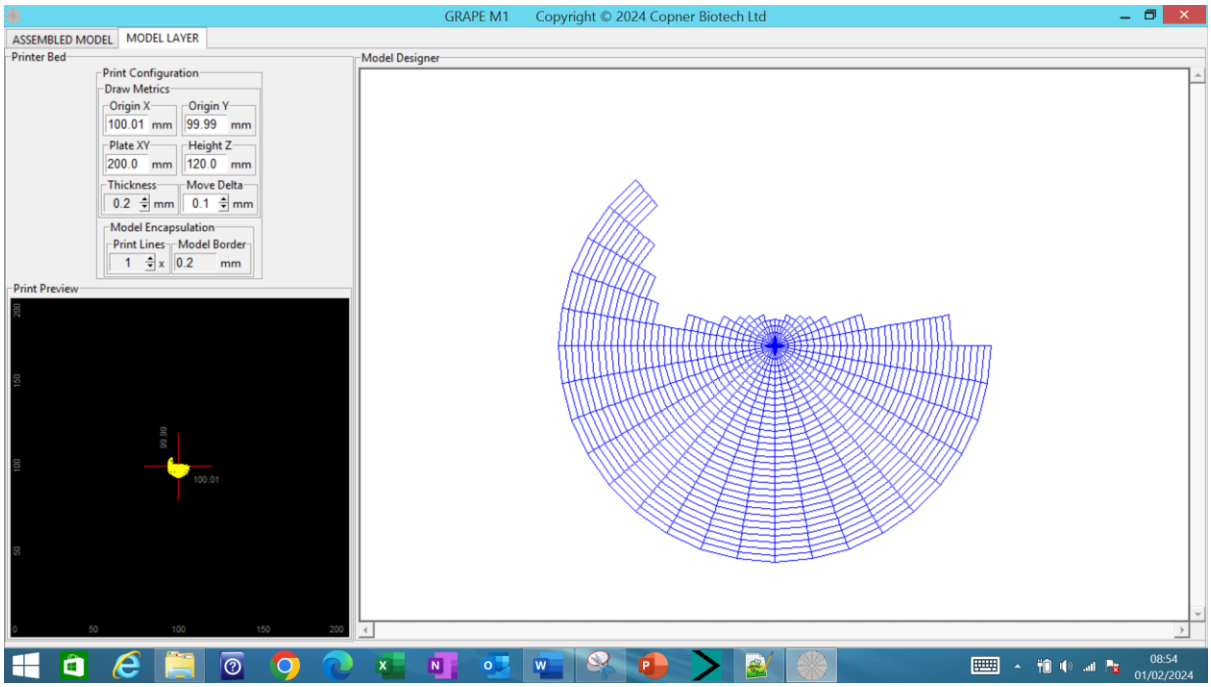

Figure 56 Model layer disc model with deleted constructs

‘Copy & Paste’ of selected model rectangle constructs can be achieved using this workflow example;

Begin by selecting the rectangle constructs to be copied; Figure 57 Selection of constructs to be copied

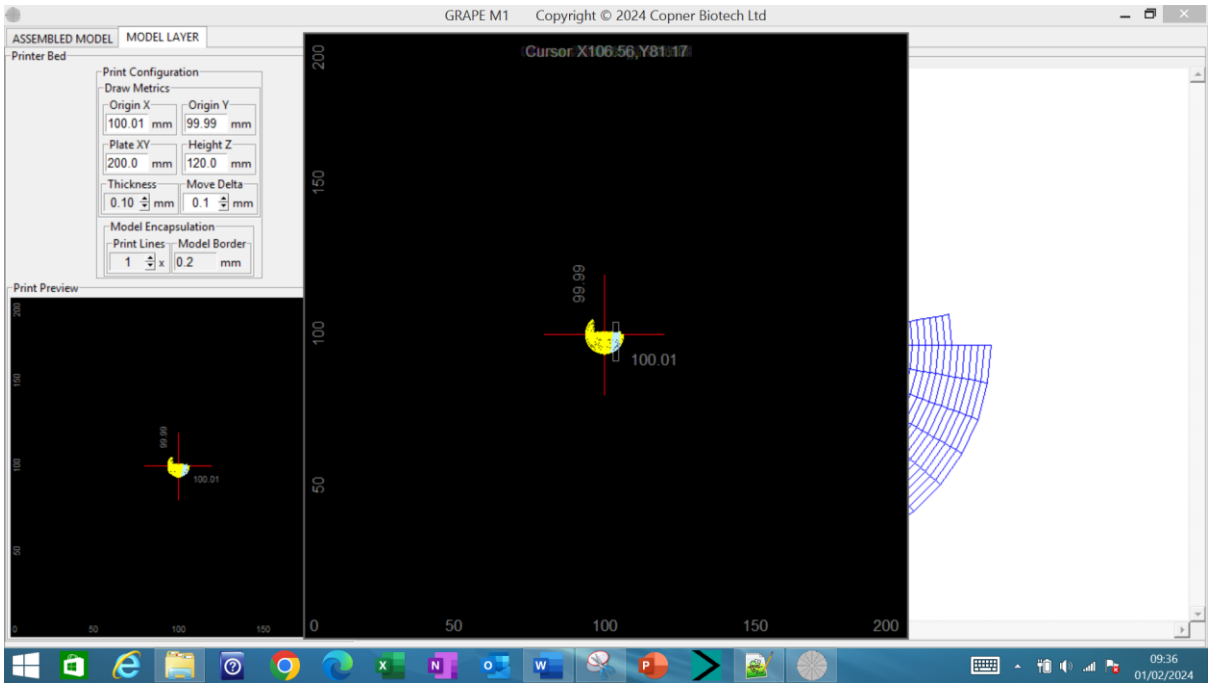

Figure 57 Selection of constructs to be copied

On moving the mouse pointer inside the 'Drawing Print Preview Panel' the printer bed 'Cursor' X and Y coordinates corresponding to the mouse position are displayed to the designer. Once at the desired 'Cursor' position the designer can mouse right click to display the popup menu to select 'Rectangles->Copy & Paste' to effect the copying of selected constructs to be centred on this 'Cursor' position; Figure 58 Copy selected constructs to be centred on cursor position Figure 59 Drawing Print Preview Panel showing copied model constructs. Figure 60 Model Designer showing result of copied constructs.

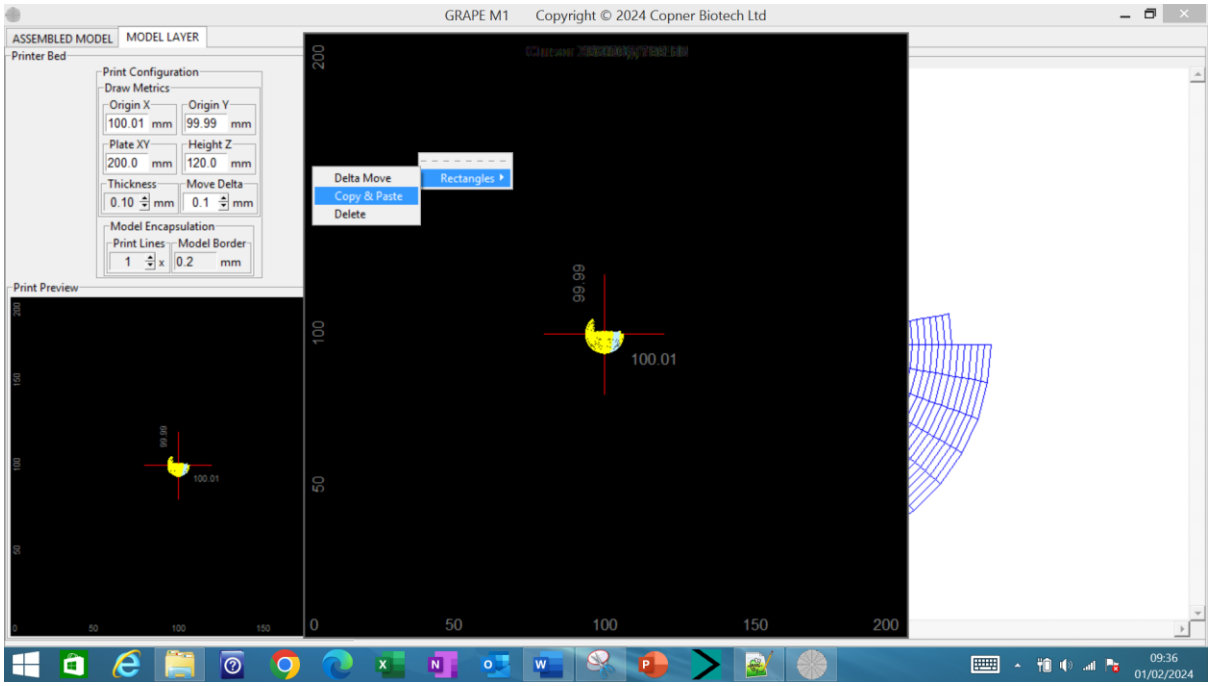

Figure 58 Copy selected constructs to be centred on cursor position.

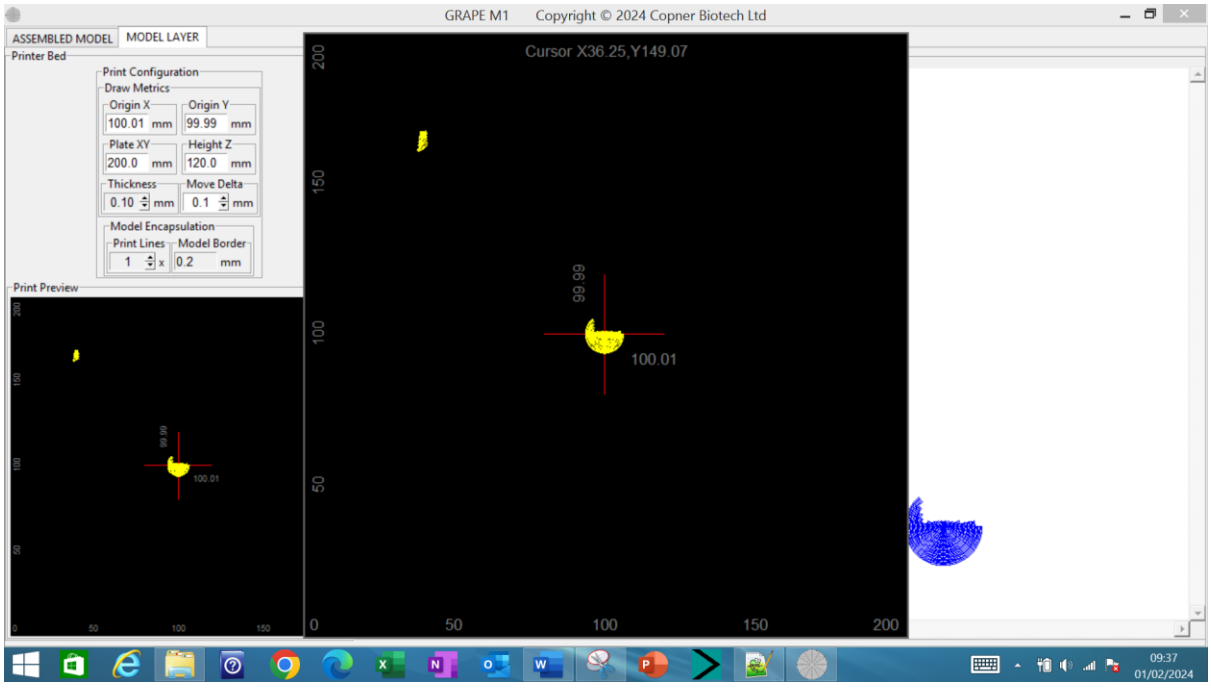

Figure 59 Drawing Print Preview Panel showing copied model constructs.

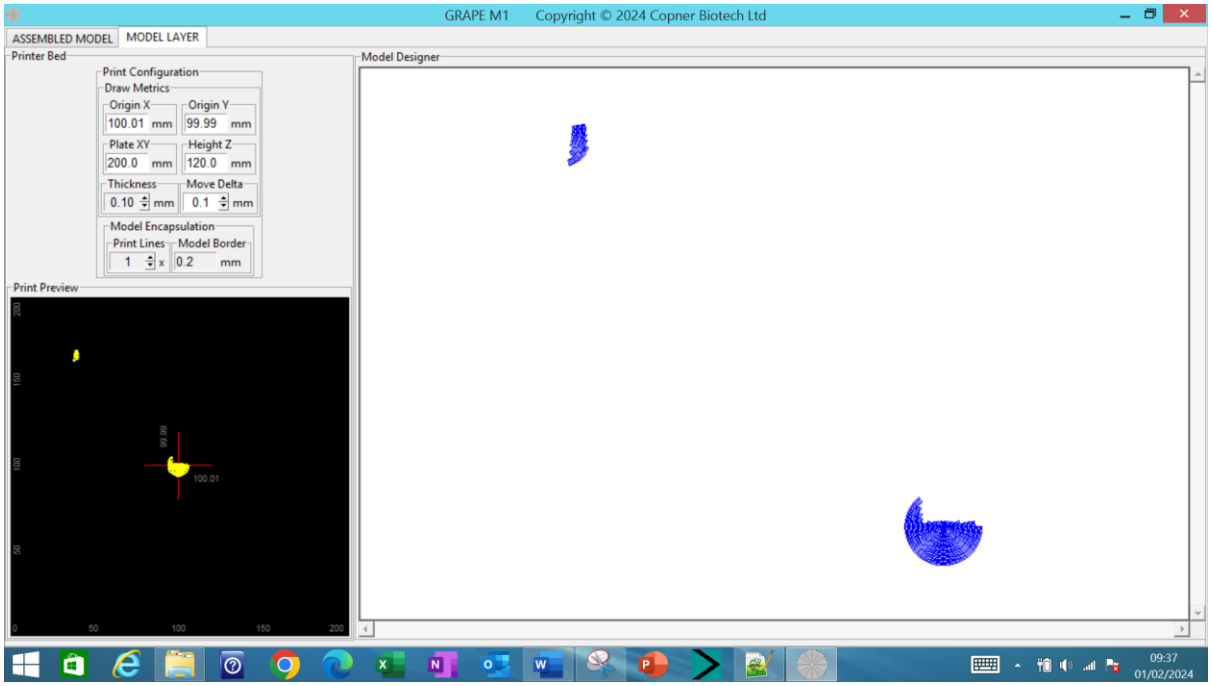

Figure 60 Model Designer showing result of copied constructs.

'Delta Move' of selected model rectangle constructs can be achieved using this workflow example;

Begin by selecting the rectangle constructs to be copied Figure 61 Selection of model constructs to move*;* Figure 62 Move selected constructs centred on Cursor position Figure 63 Drawing Print Preview Panel showing moved model constructs. Figure 64 Model Designer showing result of moved constructs.

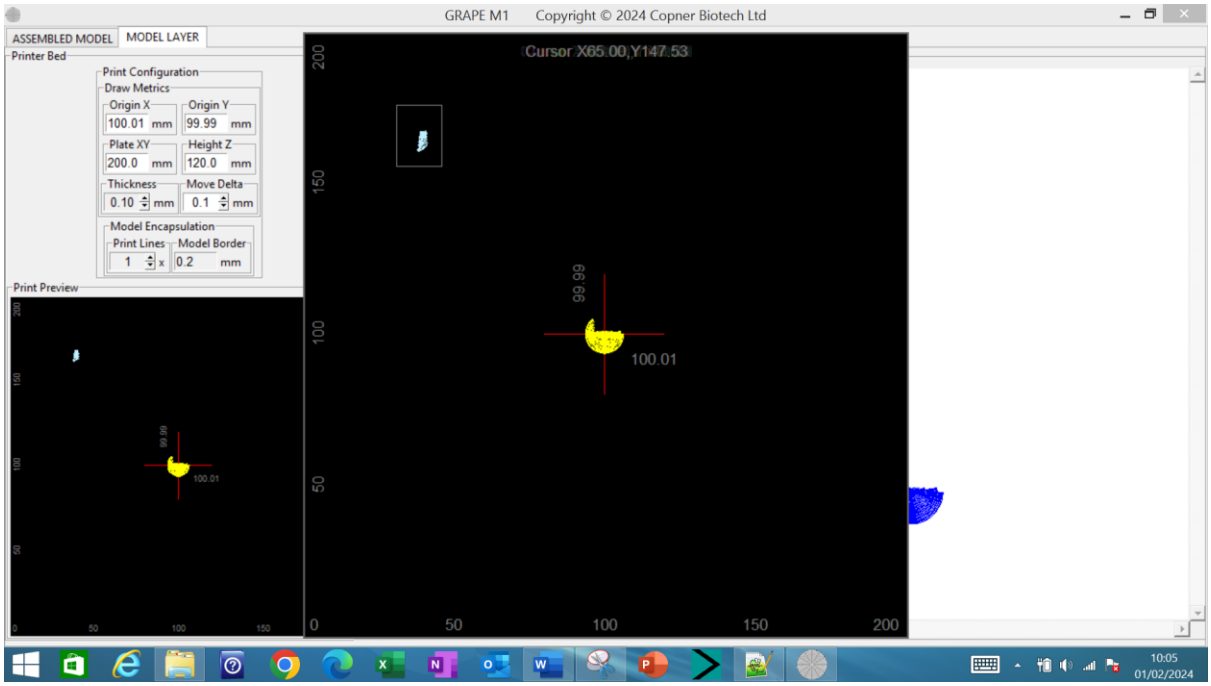

Figure 61 Selection of model constructs to move

On moving the mouse pointer inside the 'Drawing Print Preview Panel' the printer bed 'Cursor' X and Y coordinates corresponding to the mouse position are displayed to the designer. Once at the desired 'Cursor' position the designer can mouse right click to display the popup menu to select 'Rectangles->Delta Move' to effect the moving of selected constructs to be centred on this 'Cursor' position;

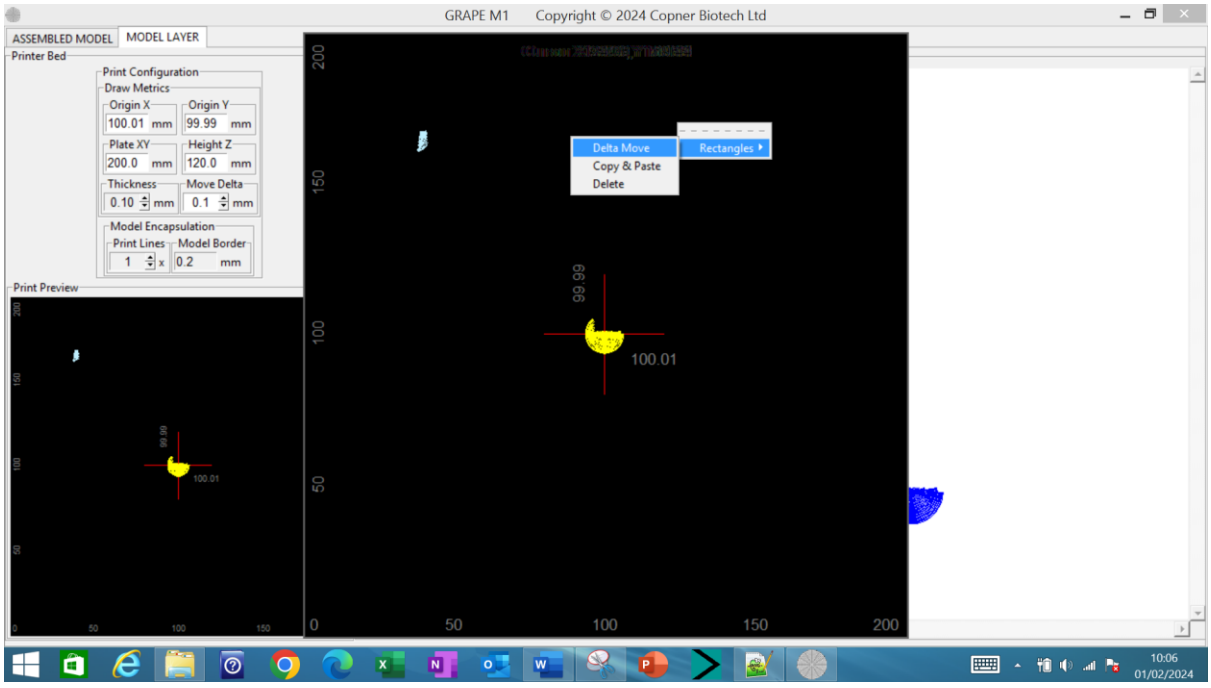

Figure 62 Move selected constructs centred on Cursor position

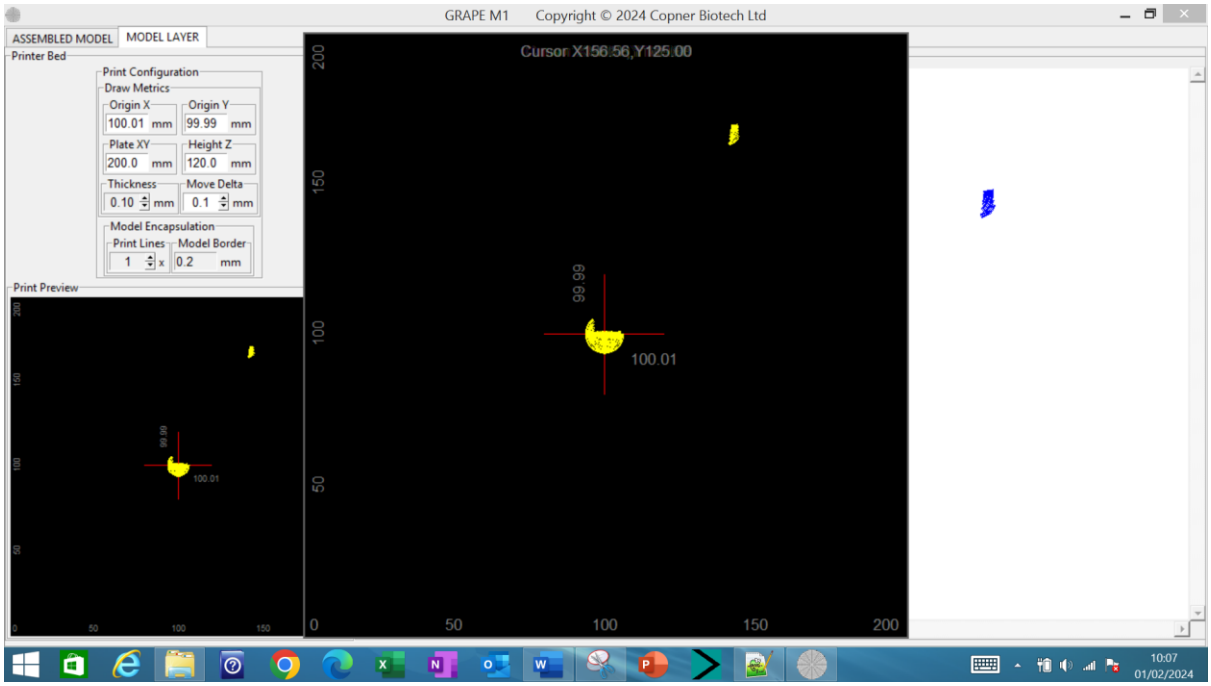

Figure 63 Drawing Print Preview Panel showing moved model constructs.

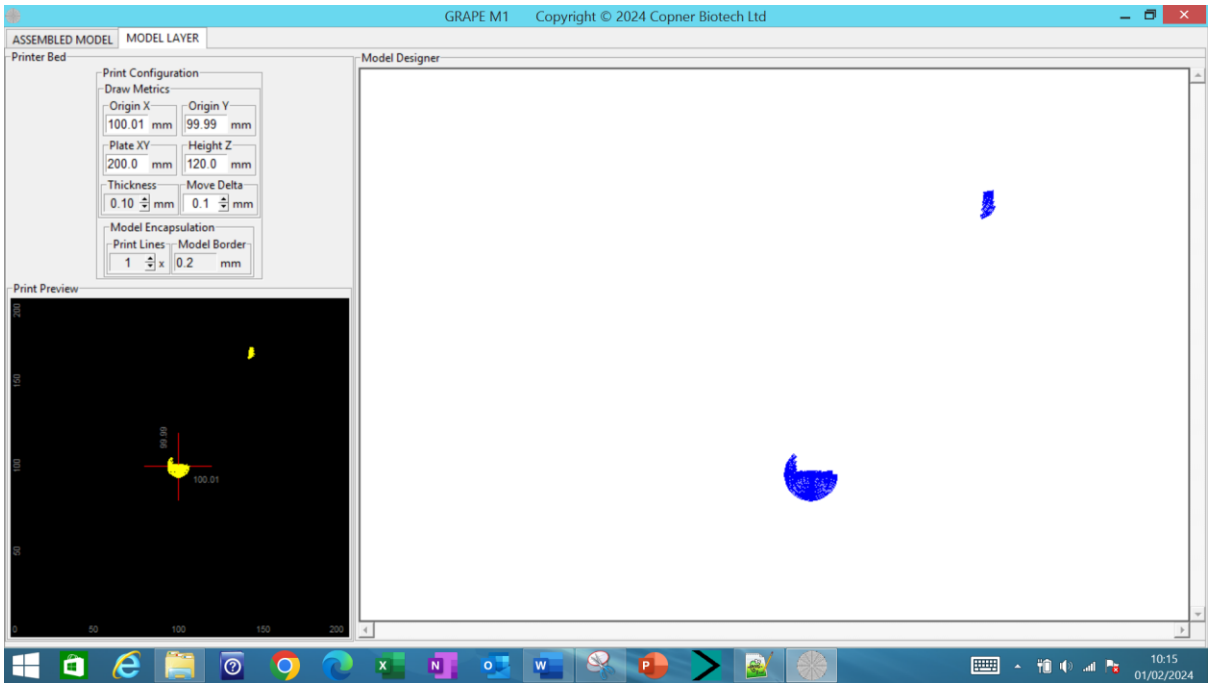

Figure 64 Model Designer showing result of moved constructs.

Assemble Model

On selecting the 'Assembled Model' notebook leaf the designer is presented with the 'Model Designer' canvas that enables a complex 3D model to be constructed from individual 3D model layers Figure 65 Model Layer Assembler.

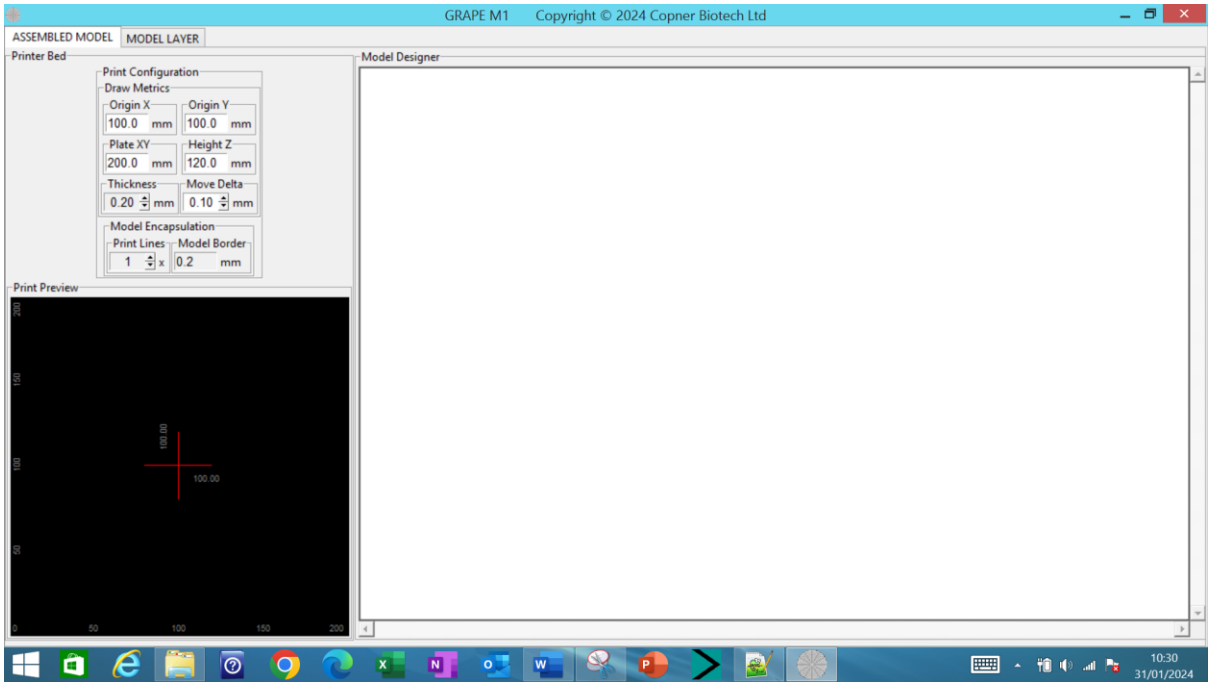

Figure 65 Model Layer Assembler

Assemble Model Layer

Model layers can be individually assembled either into the same assembled model layer and/or assembled to form a stack of layers.

Right clicking the mouse displays; Figure 66 Assemble Model Layer which provides options to assemble a model layer at “This Layer” OR “Next Layer”

Next Layer

Right clicking the mouse displays; Figure 66 Assemble Model Layer which provides options to assemble a model layer at ““Next Layer”

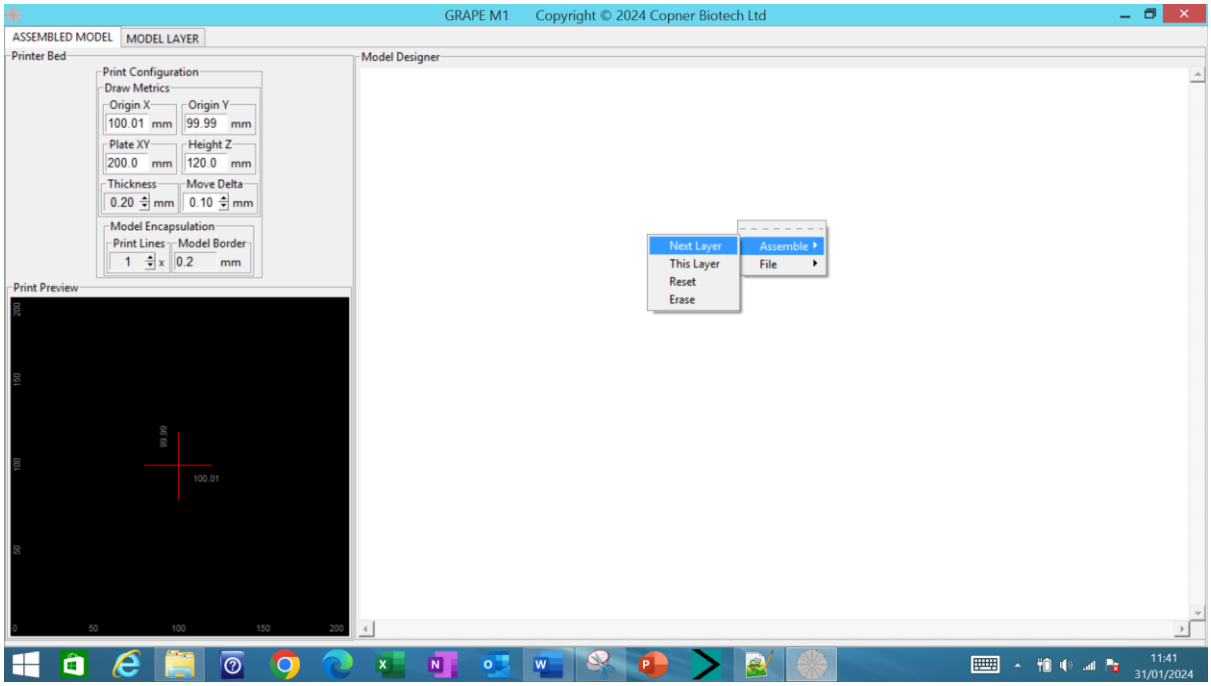

Figure 66 Assemble Model Layer

The designer can choose to assemble a layer model to be placed on top of the current model assembled layers height (maximum layers Z position) by selecting 'Next Layer' thereby creating a new model layer on top of the current assembled layers.

On selecting 'Assemble – Next Layer' the designer is presented; Figure 67 Open Model Next Layer to Assemble

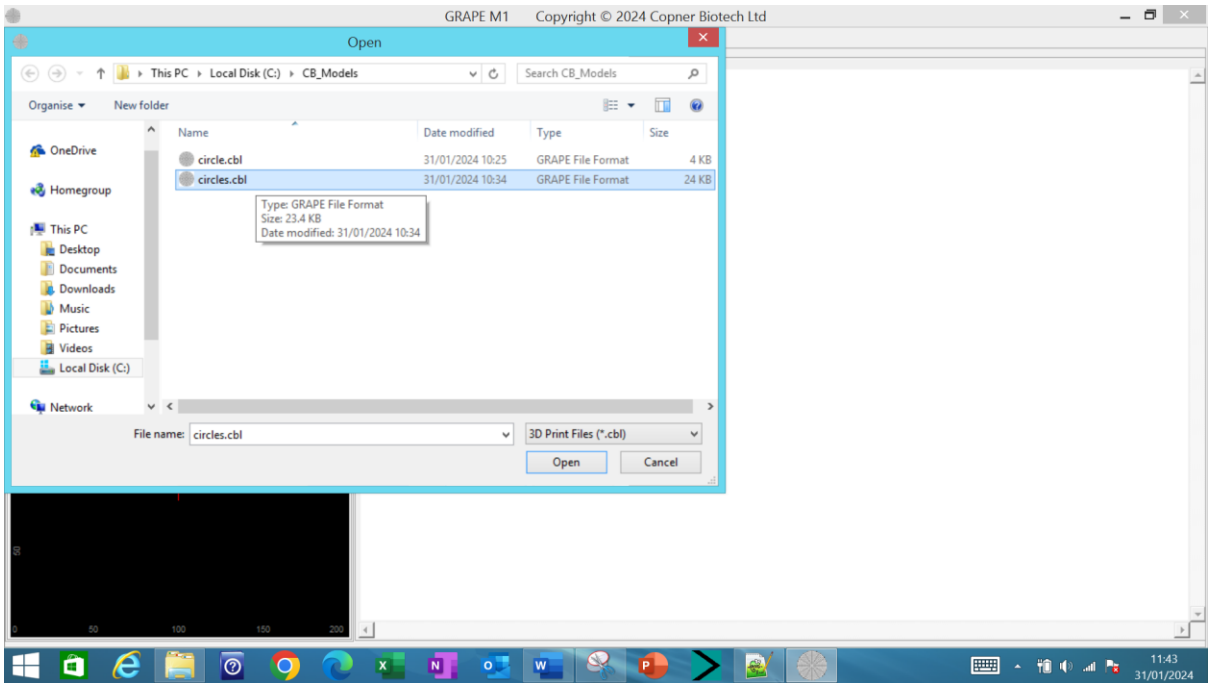

Figure 67 Open Model Next Layer to Assemble

On selecting ‘Open’ the designer can see the selected model layer assembled into the structure under construction; Figure 68 Assembled first Model Structure Next Layer

Initially ‘Assembled Layer’ displays layer constructs at a rotation of 45 degrees unless the designer has applied any rotational and zoom adjustments. The designer can revert to the 45 degrees rotation with no zoom by selecting the ‘Reset’ option from the pop-up menu.

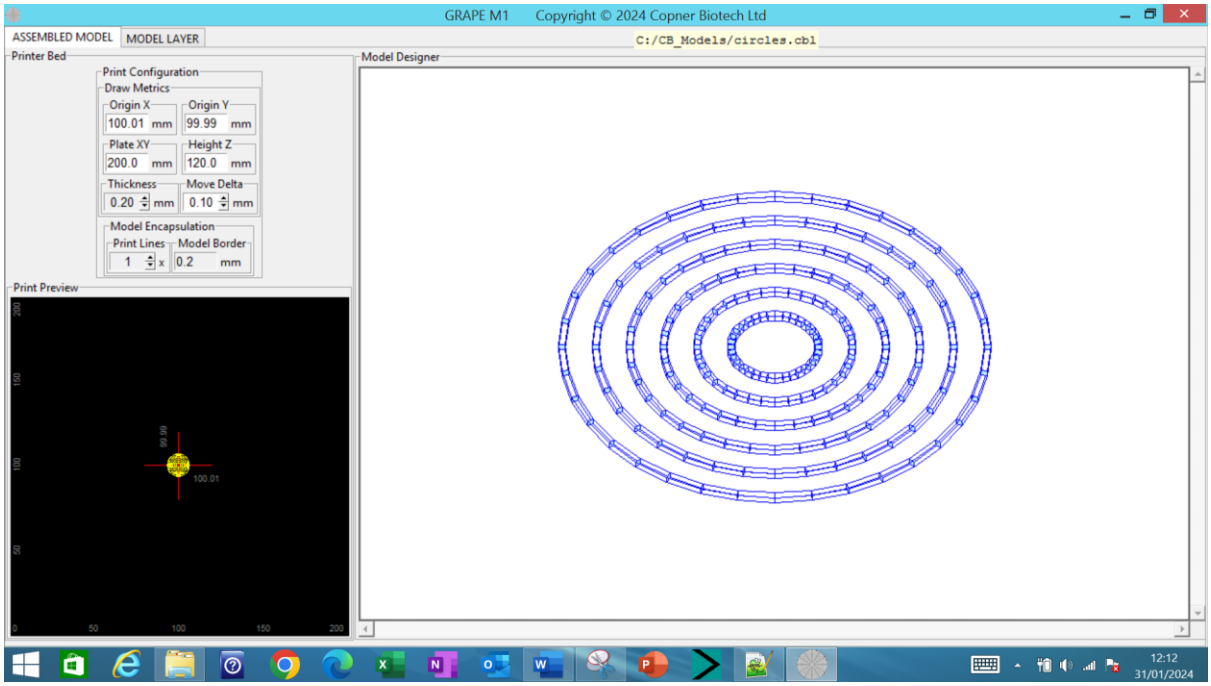

Figure 68 Assembled first Model Structure Next Layer

The process can be repeated to assemble another layer with the same Model Layer or an alternate Model Layer; Figure 69 Assembled Model Scaffold with First Next Layer and Second Next Layer with Circles

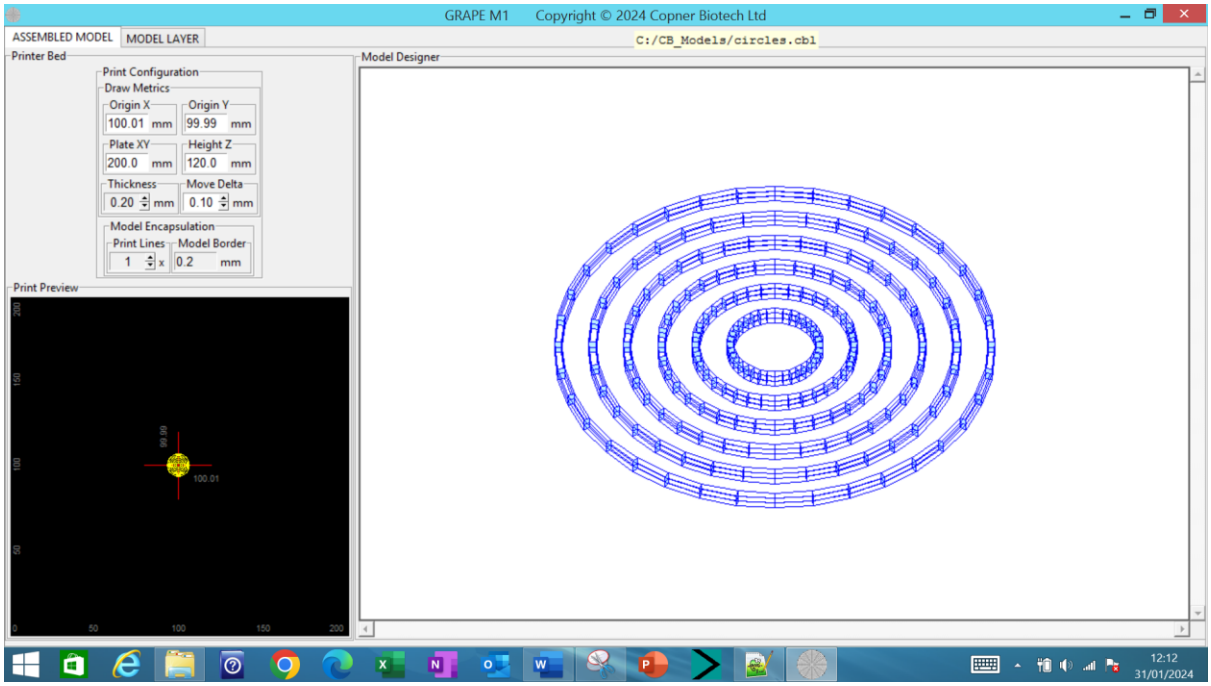

Figure 69 Assembled Model Scaffold with First Next Layer and Second Next Layer with Circles

This Layer

Right clicking the mouse displays; Figure 70 Assemble Model Layer which provides options to assemble a model layer at “This Layer”

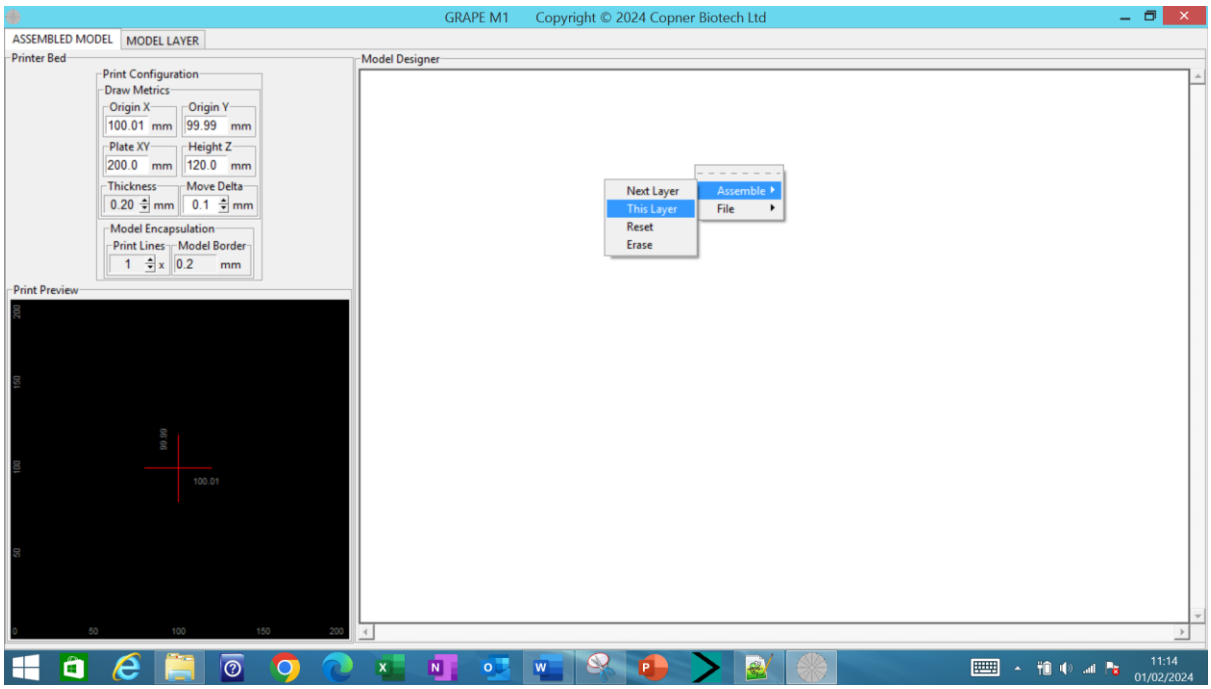

Figure 70 Assemble Model Layer which provides options to assemble a model layer at “This Layer”

The designer can choose to assemble a layer model at the current model assembled layers height (maximum layers Z position) by selecting ‘This layer’

On selecting ‘Assemble – This Layer’ the designer is presented; Figure 71 Open Model This Layer to Assemble

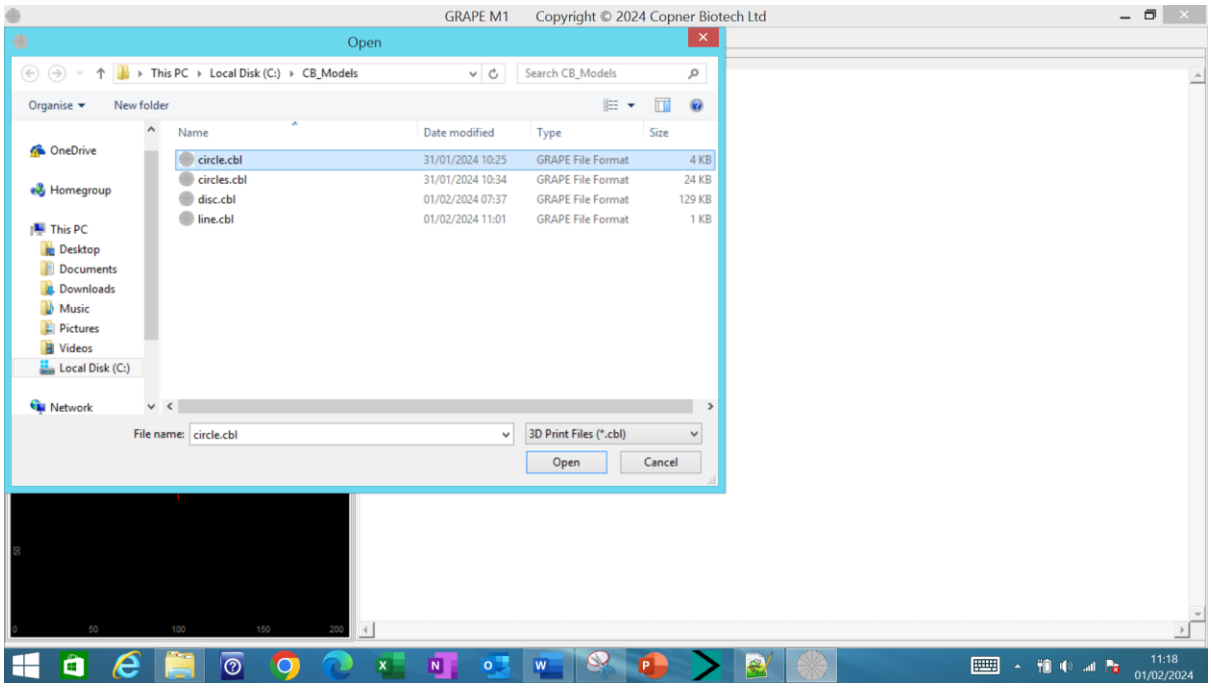

Figure 71 Open Model This Layer to Assemble

On selecting ‘Open’ the designer can see the selected model layer assembled into the structure under construction; Figure 72 Assembled first Model Structure This Layer

Initially ‘Assembled Layer’ displays layer constructs at a rotation of 45 degrees unless the designer has applied any rotational and zoom adjustments. The designer can revert to the 45 degrees rotation with no zoom by selecting the ‘Reset’ option from the pop-up menu.

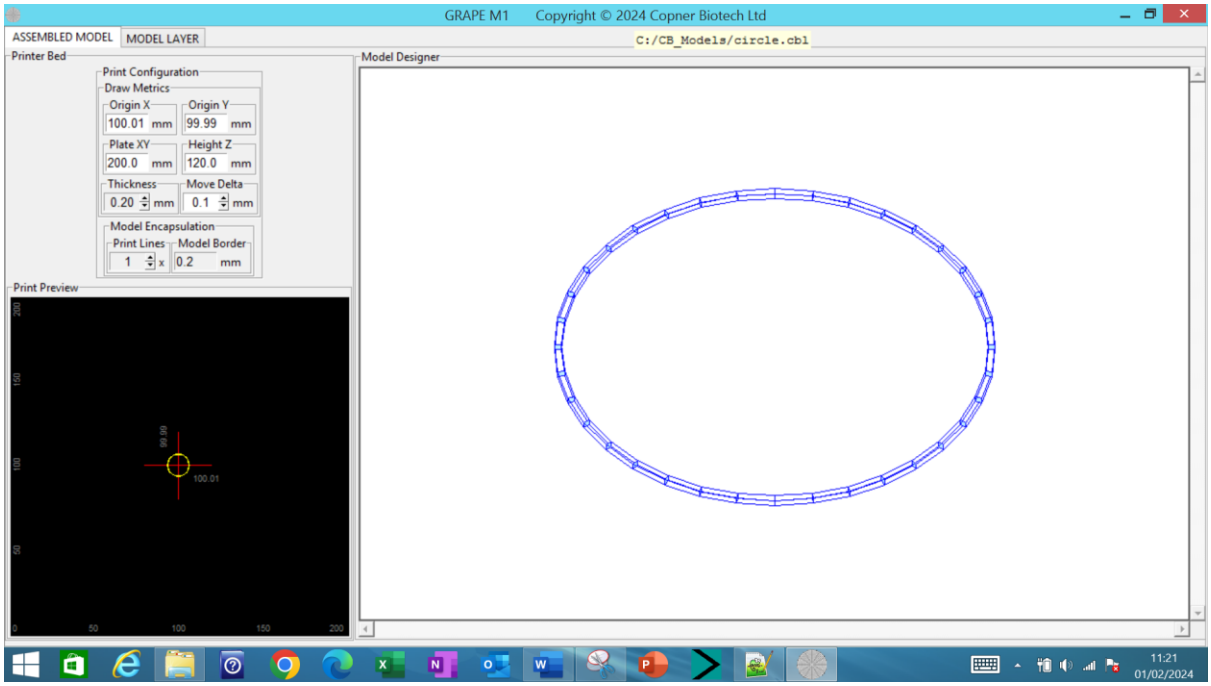

Figure 72 Assembled first Model Structure This Layer

The process can be repeated to assemble another layer with the same Model Layer or an alternate Model Layer; Figure 73 Assembled Model Scaffold with First This Layer with circle and Second This Layer with Line

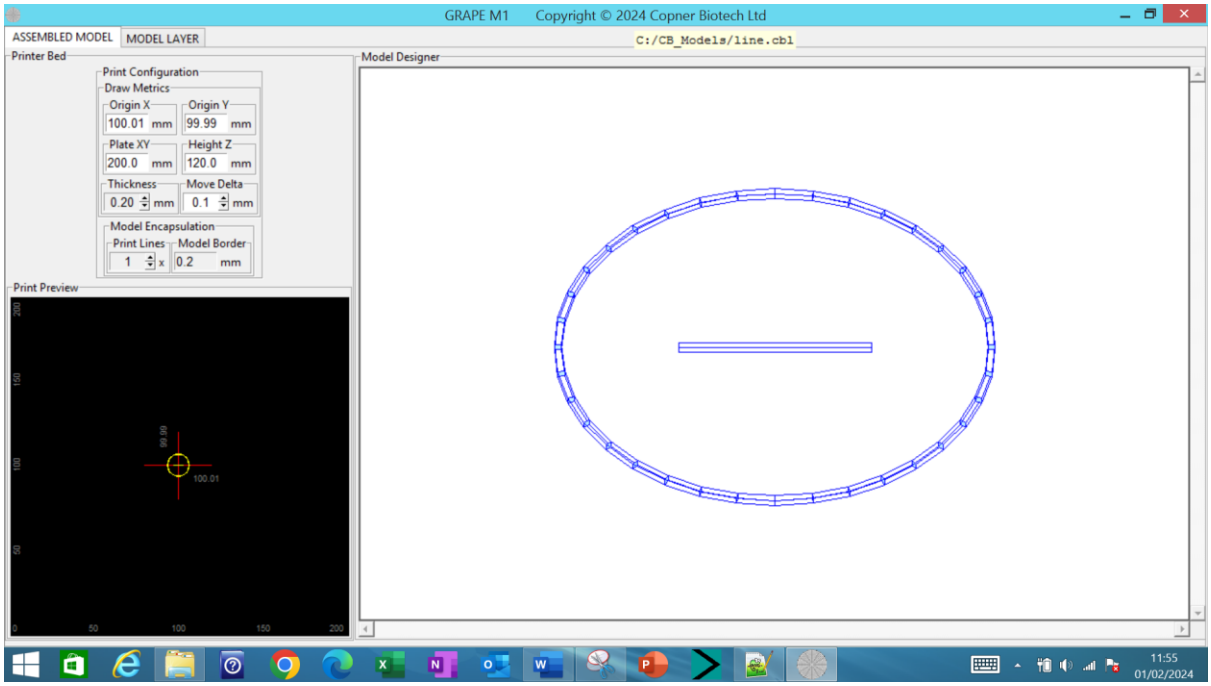

Figure 73 Assembled Model Scaffold with First This Layer with circle and Second This Layer with Line

Assembled Layer Construct Manipulation

Using the 'Drawing Print Preview Panel' an designer can move/copy/delete construct(s); Figure 74 Assembled Layer Constructs – to reposition them on the print bed prior to printing; Figure 75 Drawing Print Preview Panel - Assembled Layer Constructs.

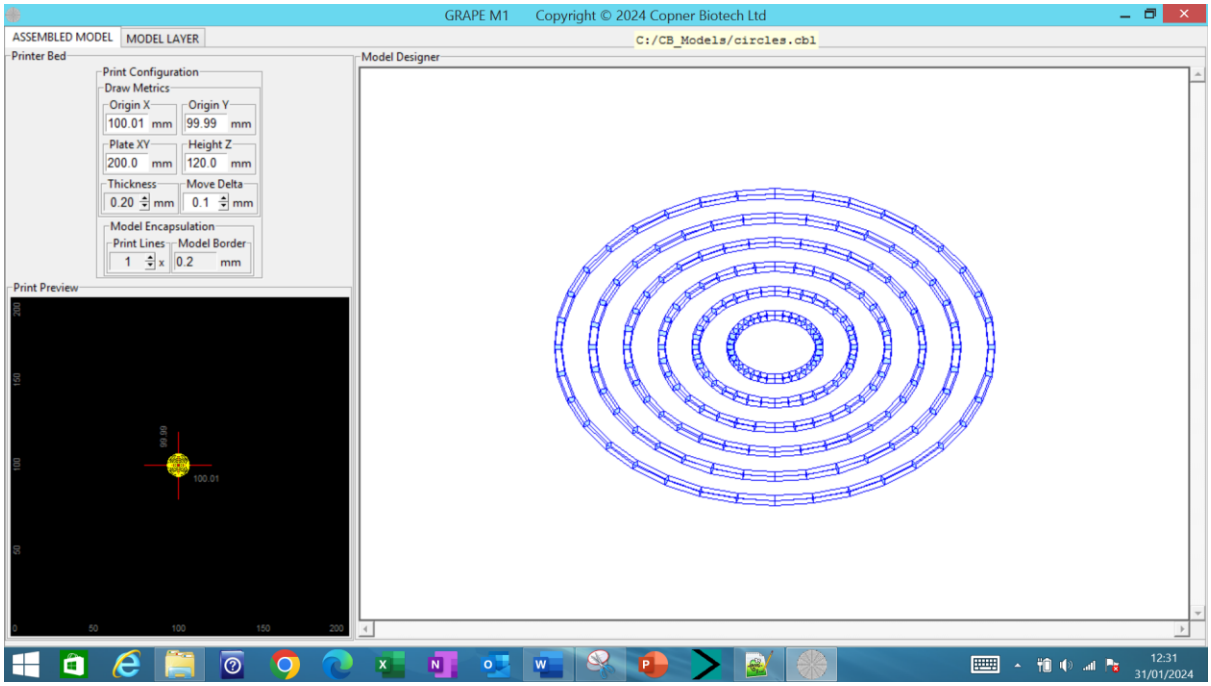

Figure 74 Assembled Layer Constructs – Manipulation Selection

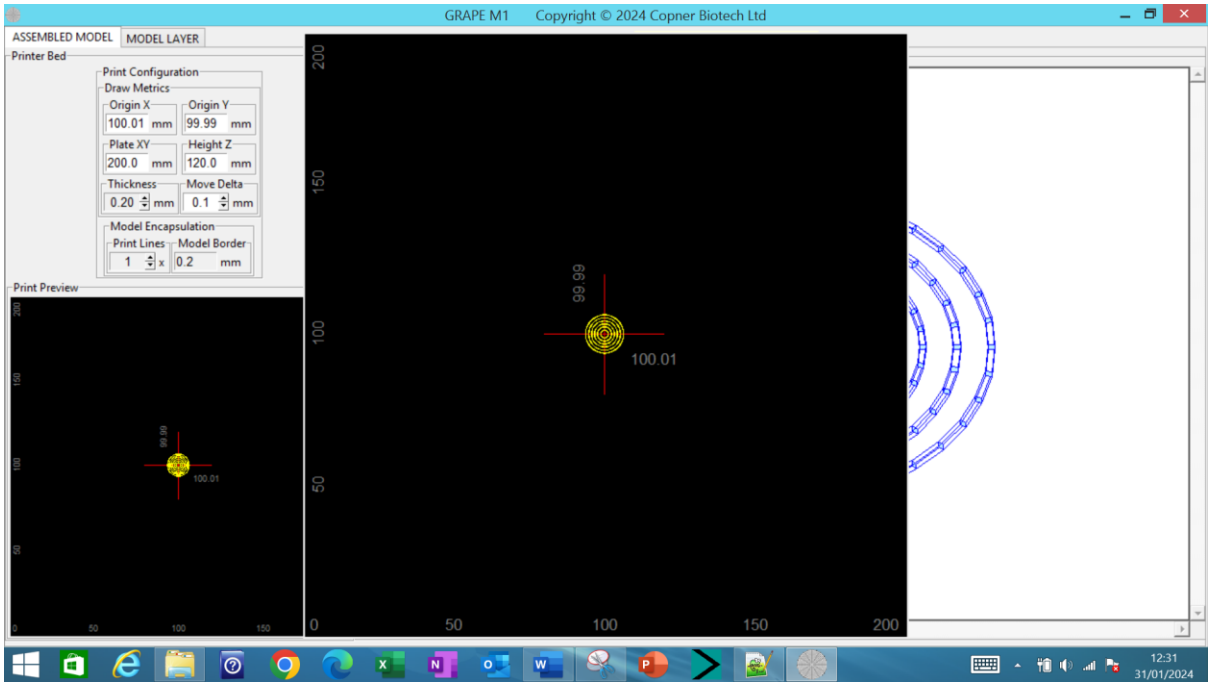

Figure 75 Drawing Print Preview Panel - Assembled Layer Constructs

Construct(s) can be selected by pressing and holding the middle mouse button and drawing a box around the construct to be selected to be moved/copied. Selected constructs are highlighted in blue Figure 76 Assembled Layer - Construct Select.

Selected construct(s) can be deselected by either pressing the ‘Esc’ key or selecting alternative construct(s)

Selected construct(s) can also be moved using the ‘Left’, ‘Right’, ‘Up’ or ‘Down’ arrow keys; which on each key press will move the contruct(s) in the required direction by the distance configured in the ‘Delta Move’ dialog.

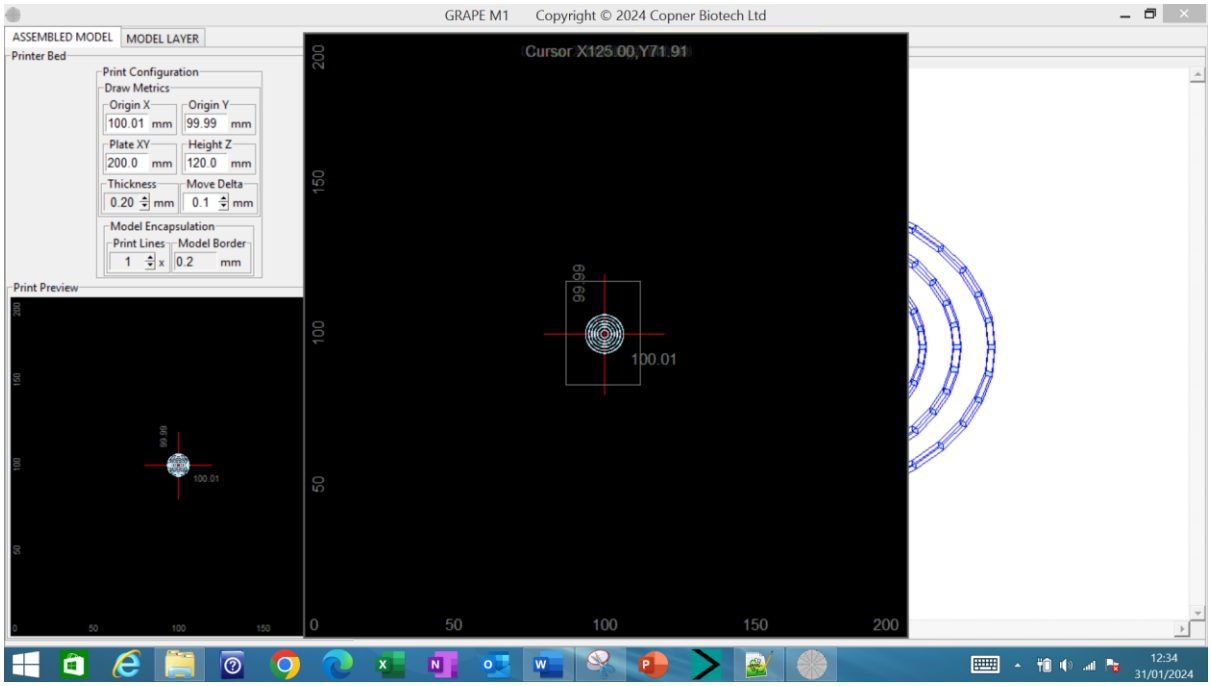

Figure 76 Assembled Layer - Construct Select

On moving the mouse pointer inside the 'Drawing Print Preview Panel' the printer bed 'Cursor' X and Y coordinates corresponding to the mouse position are displayed to the designer.

A selected construct can be moved to the mouse print bed cursor position by right clicking the mouse button and selecting Rectangles->Delta Move from the pop-up menu Figure 77 Assembled Layer Selected Construct - Delta Move. On selection of 'Delta Move' the construct is moved to the required cursor position Figure 78 Assembled layer Selected Construct Moved .

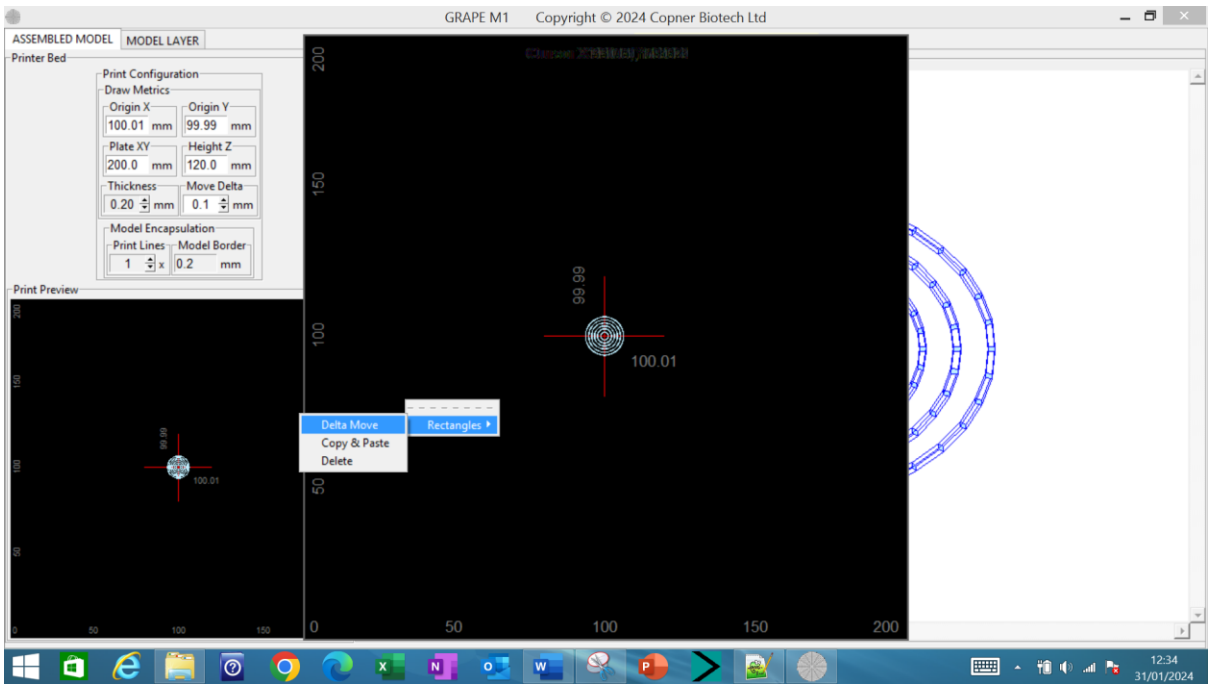

Figure 77 Assembled Layer Selected Construct - Delta Move

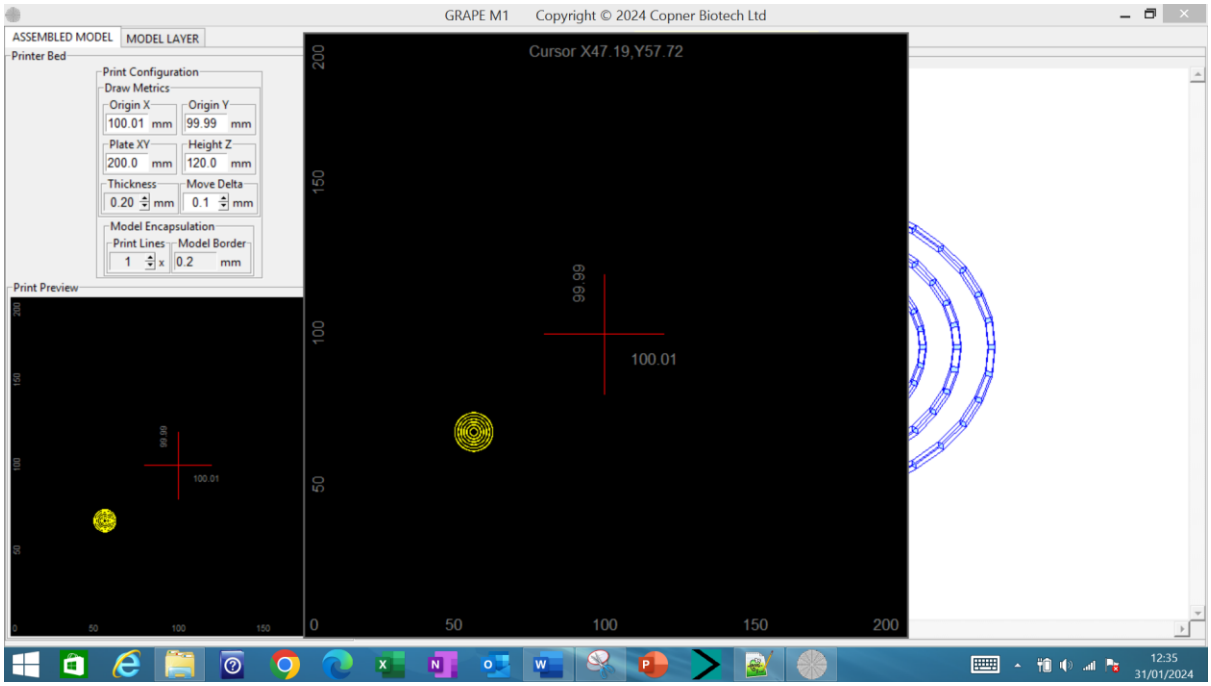

Figure 78 Assembled layer Selected Construct Moved

A selected construct can be copied Figure 79 Assembled Layer Selected Construct to Copy; by right clicking the mouse and selecting the option Rectangles->Copy & Paste Figure 80 Assembled Layer Selected Construct Copy & Paste.

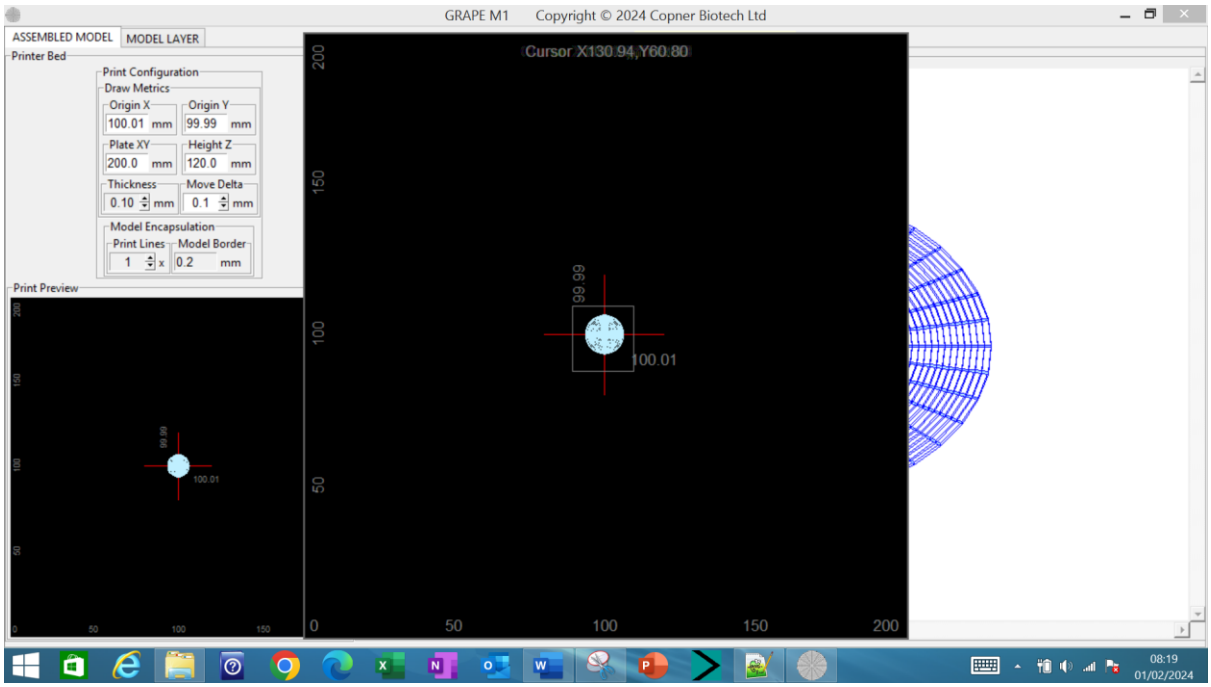

Figure 79 Assembled Layer Selected Construct to Copy

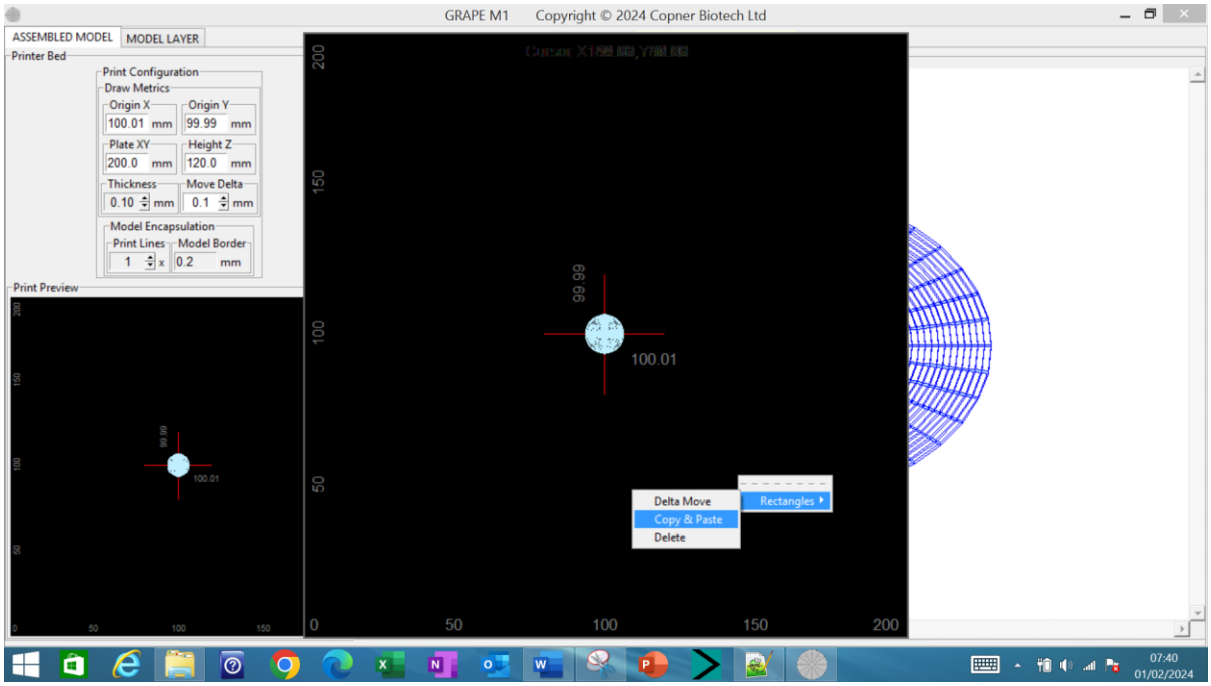

Figure 80 Assembled Layer Selected Construct Copy & Paste

Selection of Rectangles->Copy & Paste results in the selected construct being copied and pasted to the required printer bed cursor position Figure 81 Assembled Layer Selected Construct Copied.

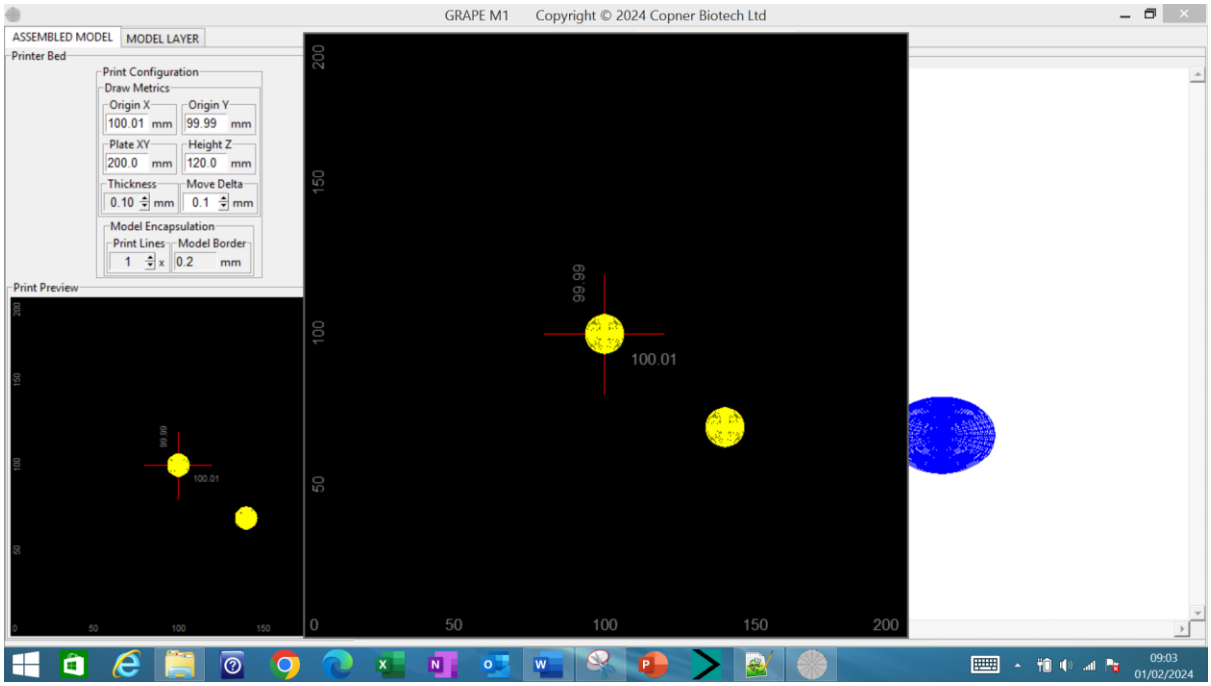

Figure 81 Assembled Layer Selected Construct Copied

A selected construct can be deleted Figure 82 Assembled Layer Construct Selected for Deletion; by right clicking the mouse and selecting the option Rectangles->Delete Figure 83 Assembled Layer Selected Construct Delete.

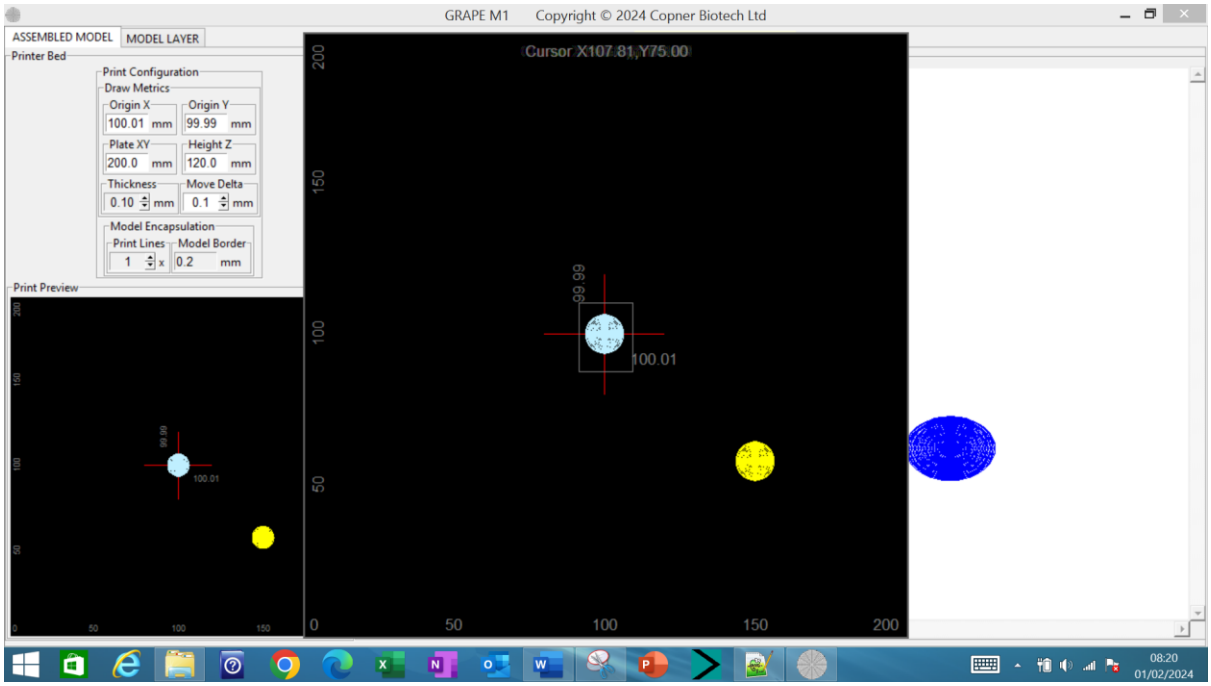

Figure 82 Assembled Layer Construct Selected for Deletion

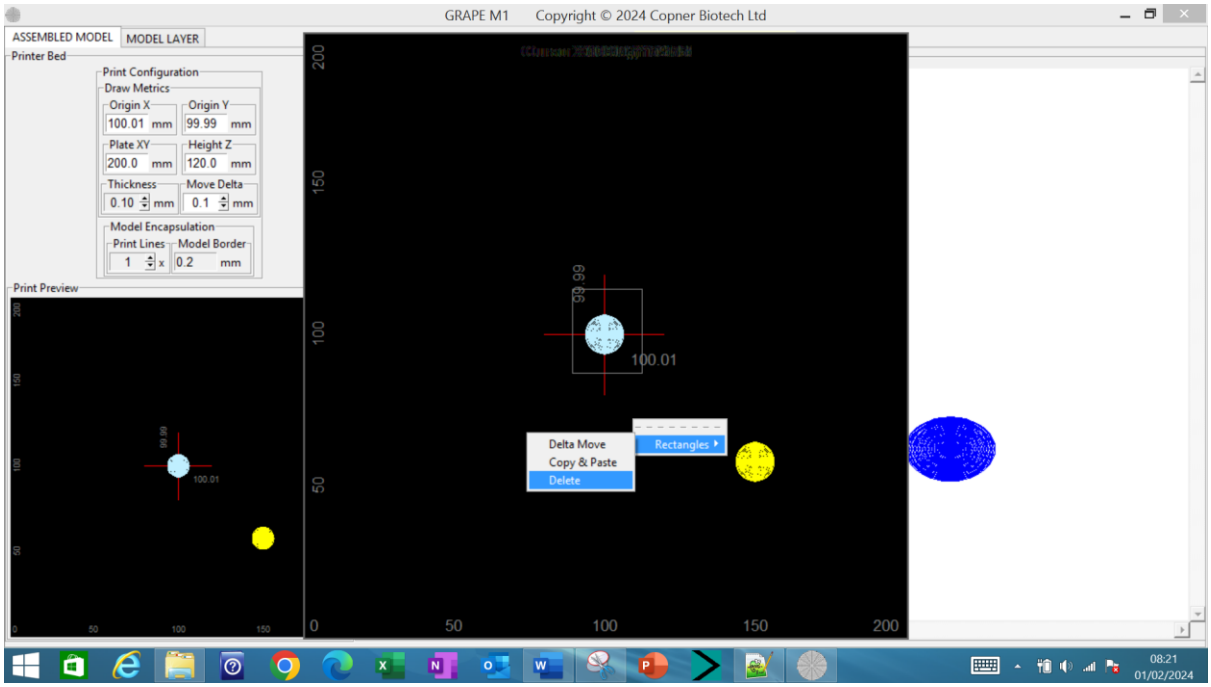

Figure 83 Assembled Layer Selected Construct Delete

Selection of Rectangles->Delete results in the selected construct being deleted Figure 84 Assembled Layer Construct Deleted

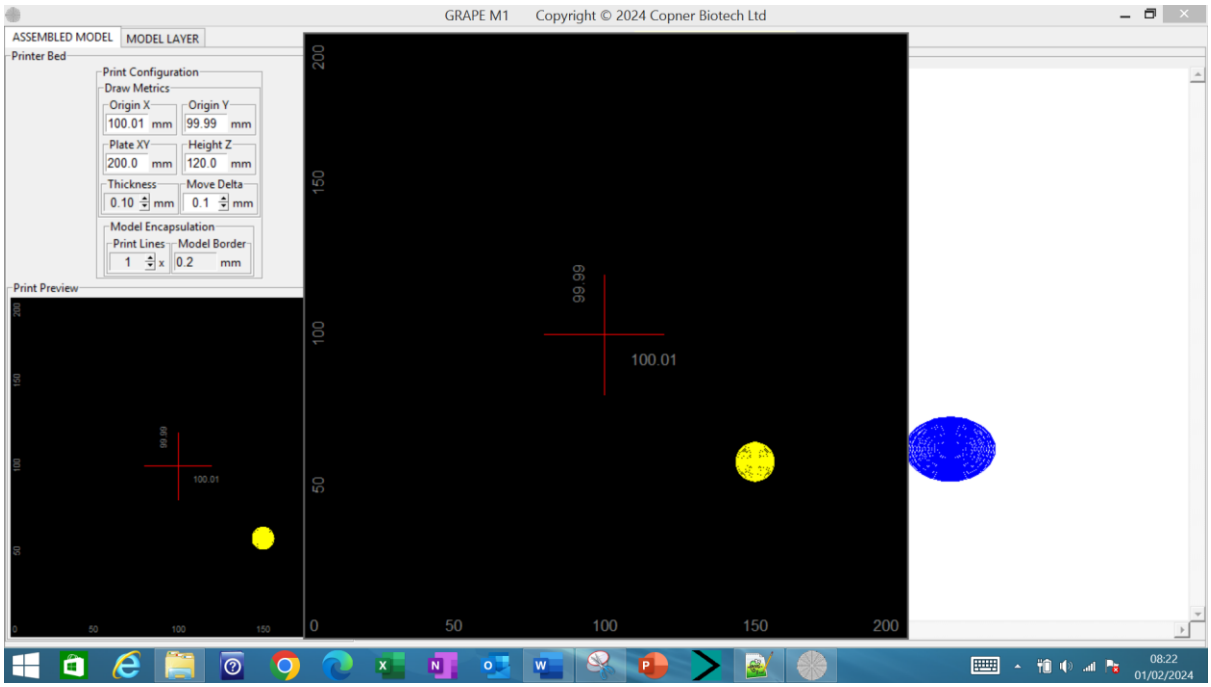

Figure 84 Assembled Layer Construct Deleted

Trouble Shooting

Model Designer Panel not updating

Due to precision software calculations employed to create and render the model constructs; there can be an increased response time experienced when using the software for complex architectures

Be patient the software will always complete the model construction.

Cannot load GRAPE files

Due to cross platform development that enables the GRAPE M1 modelling software to be used both on Personal Computers running Windows; and also on the GRAPE S1/S2 bioprinters; there is a restriction on how file folder names can be defined. If a file folder contains a space or spaces then selected GRAPE model files will not load from these folders.

Note: File folder names must not contain spaces otherwise the software will fail to read the files from these folders.

Drawing Print Preview Panel Still Visible

The 'Drawing Print Preview Panel' is a top level window and can remain visible when the GRAPE M1 application is minimised for example; this panel can be closed by just mouse clicking anywhere on the desktop or performing another windows action such as interacting with another application.

Cannot load STL files

GRAPE M1 cannot load STL files only GRAPE files. However, GRAPE M1 does output GRAPE models in STL and GRAPE formats.

STL Model has missing lines when sliced into G-code

GRAPE M1 can produce very fine model construction lines and some G-code slicing software can have issues with line thicknesses of less than 0.2mm. If this occurs try reconfiguring your G-code slicer or/and redraw the model in GRAPE M1 with say a line thickness 0f 0.21mm.

Trademarks and Patents

Recognised trademarks and protections.

Patents

Bio Scaffold patent GB2605009 and PCT/GB2022/000023 – UK Grant

Additive Manufacturing using Low Viscosity Materials patent applications GB2206780.5 and PCT/GB2022/000051 – UK Grant

GRAPE Data Format and method of 3D Printing patent application GB2206781.3 and PCT/GB2023/050890

Trademarks

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