ELEMENT X MANUAL V0.8

Elementiam Materials and Manufacturing

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User Manual for Element X version 0.8.

About This User Manual

This manual is intended for users who want to familiarize themselves with Element X software.

Element X provides both a graphical user interface (GUI) and an application programming interface (API).

Element X software is a computer assisted manufacturing software that provides tools for 3D scanning, 3D inspection and, hybrid toolpath generation based on real-world scanned data.

Element X is suitable for repair, maintenance, overlay, welding, surfacing and polishing operations.

This manual is based on the Element X. version 0.8. It is recommended to use the newest software version. Visit www.elementiam.ca for the most up-to-date information and documents.

Please read the Element X User Manual before using the software.

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Introduction

Element X software is a computer assisted manufacturing (CAM) software based on really world 3D scanned data. Element X is divided into three main modules tailored for automated inspection, repair, robotic overlay, and welding.

System Requirements

Please ensure that your computer meets the minimum recommended requirements to run Element X smoothly.

Processor: Intel Core i7 or higher, x64 architecture

Operating system: Only 64-bit platform

Windows 10/11

RAM: Recommended 16GB (minimum 8GB)

GPU: GeForce GTX 1060 3 GB or similar external graphics card with OpenGL v 3.0 support.

Installation

Windows

Download the installer provided by Elementiam Team.

Once downloaded, double click on the installer. A User account window will open, press *YES* to continue the installation. In some cases, a warning window might open, in this case, press *More info* and *run anyway.* After accepting the user conditions, the installation will start.

Once installed, open the license folder located at: *C:\Program Files (x86) \Elementiam\Element X.*

In the license folder, open the *README.txt* and replace the content of the file by the license key provided by Elementiam team. Then rename the *README.txt* into *license_key.key*.

Once the license key set up, double click on Element X.exe to open Element X.

Element X will automatically verify the license and Element X main menu should appear. In case the key license is invalid or not properly set up, an error message will be displayed.

User Interface

The first window to open when launching Element X is the main menu page. For the general version of Element X, three options are available:

- Dimensional
- Surfacing
- Cladding

The **dimensional** module is designed for inspection, repair, and manufacturing of dimensional components. This module requires to input at least a solid model. For inspection and repair, the scan of the damaged part is also required.

The **surfacing** module is designed for inspection and surfacing repair, meaning that only the scan of the damaged part is used as input. Surfacing is suitable for inspection and repair on flat and cylindrical surfaces such as pipes, shafts, wear plates, …

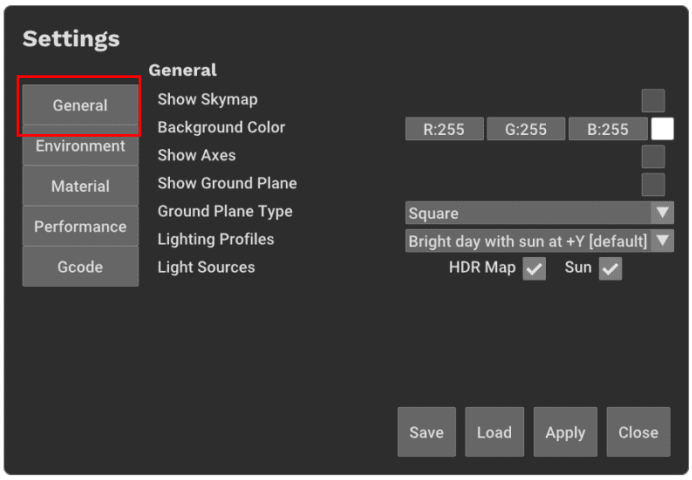
The **cladding** module is designed for robotic overlay, welding surfacing operations. Using, Cladding, the operator can select on the scan the area to weld or clad, and Element X automatically generate a 6 DOF path for robotic and CNC applications. The generated path can be exported to third party robot simulation software to create a robot-brand specific language.

The three modules share a same top ribbon with various options and filters useful for the different CAM operations.

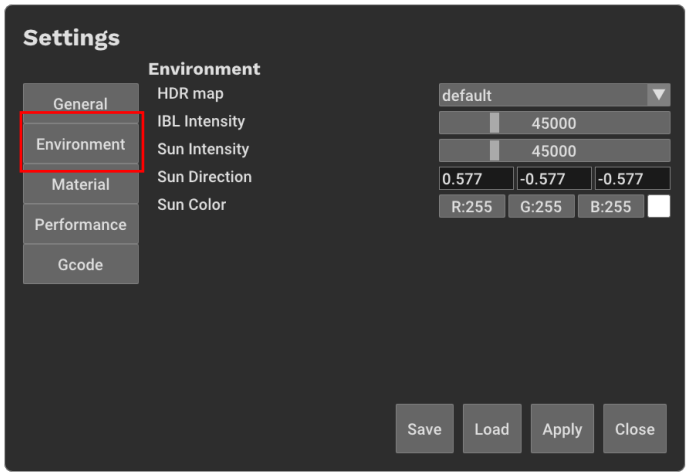
Top Ribbon

File

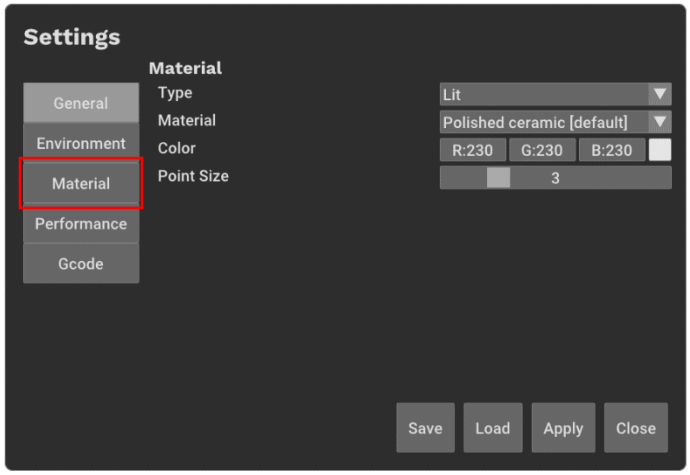
- *Add model*: add a model to Element X. (only. STl, .ply files accepted)
- *Export model*: click on the model to export (only. STl, .ply files available)
- *Add Lineset*: add an Element X format toolpath (.ply)
- *Import Gcode*: add a Gcode format file for visualization. (Works with Gcode created with Element X)
- *Change repair mode*: switch between modules.
- *Settings*:



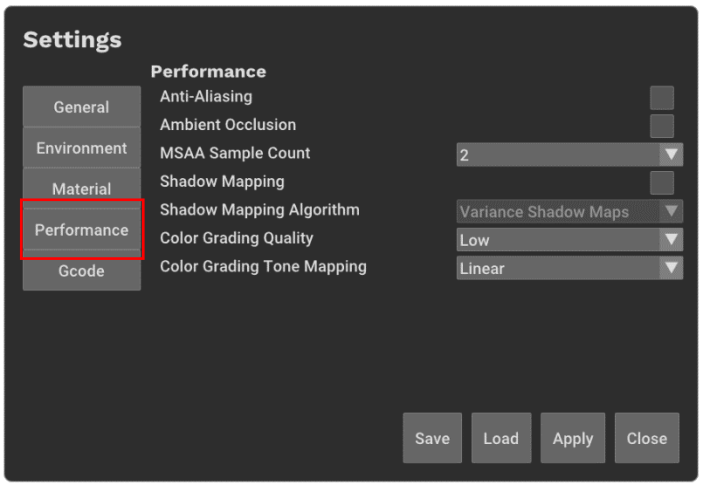
- *Show Skymap:* display background.
- *Background color:* change background color
- *Show axes:* display coordinate frame.
- *Show ground plane:* display a ground plane.
- *Ground plane type:* Square or Circle
- *Lighting Profiles:* lighting conditions and source
- *Light source:* High dynamic range and sun sources



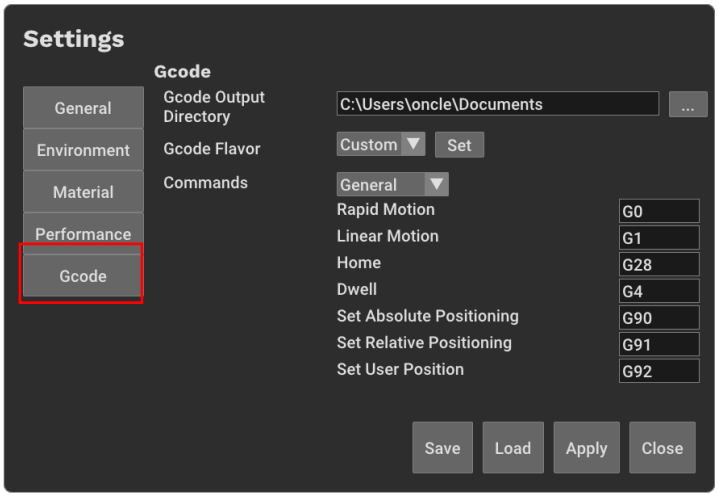
- *HDR map:* Change the background.
- *IBL Intensity:* change the image-based lighting associated with the HDR map.
- *Sun Intensity:* change the sun intensity referred to brightness.
- *Sun direction*: change direction of the light source
- *Sun color:* change light source color.



- *Type:* displayed surface information
  - *Normal vector field*
  - *Depth map*
  - *Transparent*
  - *Lit/ Unlit*
- *Material*: surface material
  - Polished ceramic
  - Clay
  - Glazed ceramic.
  - Plastic
  - Metal rougher
  - Metal smoother
- *Color:* change the color of the mesh
- *Point size*: change the size of the points within a point cloud.



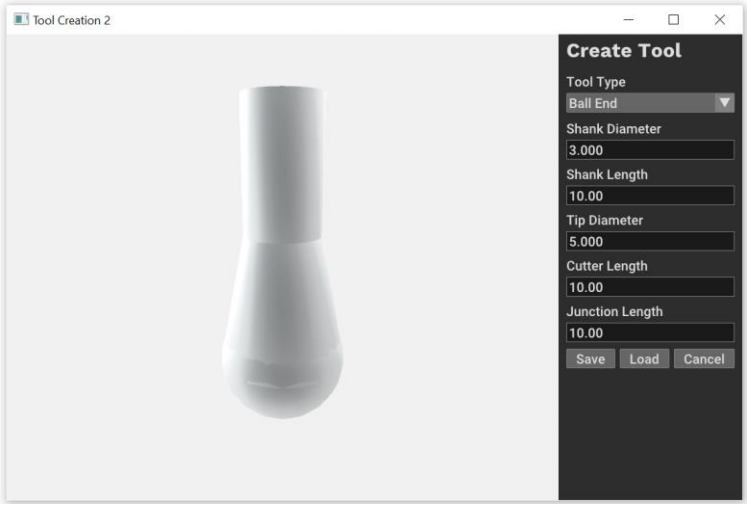
- *Anti-Aliasing:* ON/OFF
- *Ambient Occlusion:* ON/OFF
- *MSAA Sample Count:* 0-8
- *Shadow Mapping:* ON/OFF
- *Shadow Mapping Algorithm:* available if shadow mapping ON
- *Color Grading Quality:* Low to Ultra
- *Color grading tone Mapping:* encoding functions.



- *Gcode Output directory:* change the folder in which the Gcode files are saved.
- *Gcode Flavor:* pre-defined Gcode languages
- *Commands:* modify the Gcode action and motion commands
  - 

Tool

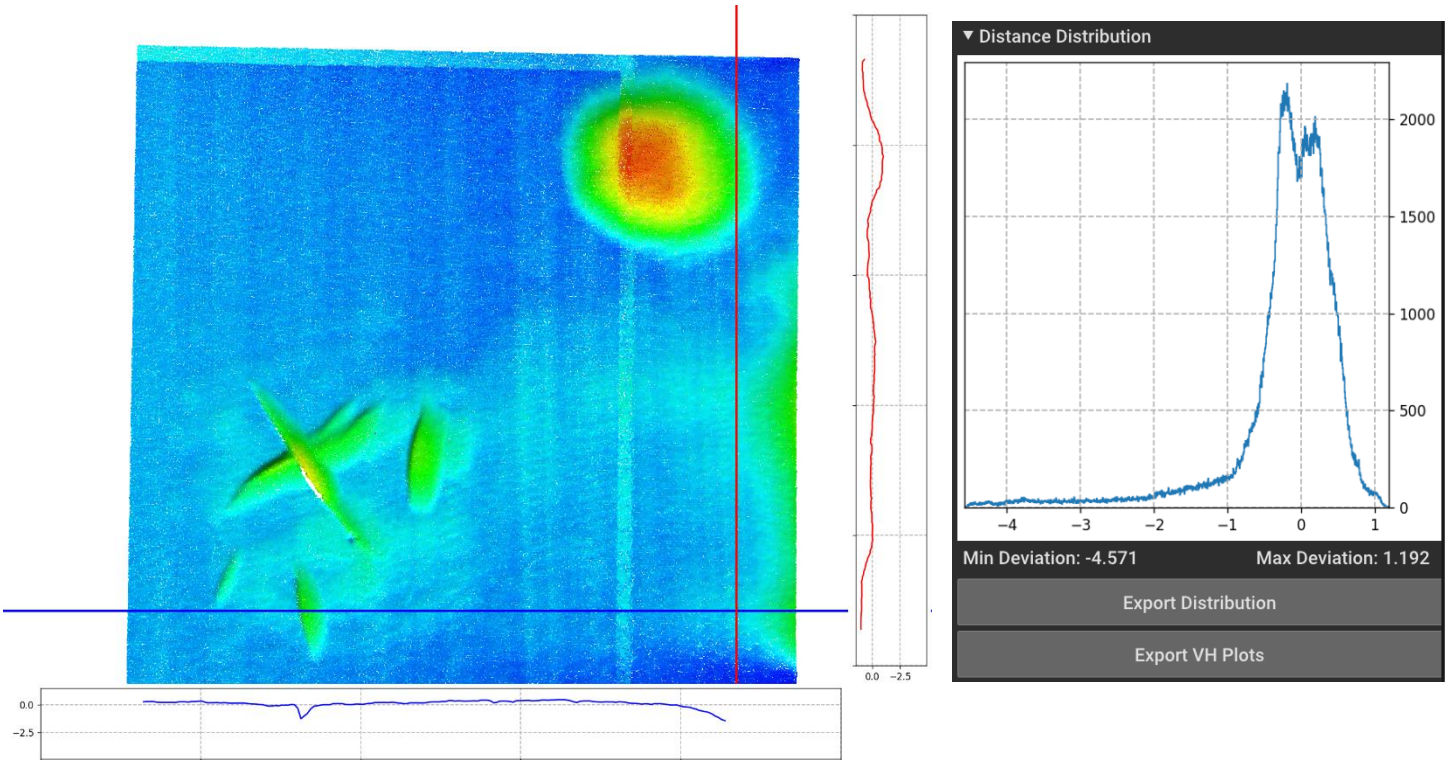
Create tool.



- *Create a tool for additive and subtractive CAM computation:*
  - Drill bit
  - Additive nozzle

Mesh Operations

- **Align to XY plane**: orient the mean normal of the mesh to the Z-axis.
- **Boolean Operations**: Union, difference, and Intersection
- **Compute normal**: compute the normal vector field associated with the mesh/point cloud.
- **Convert mesh type:** convert a mesh to a point cloud and a point cloud to a mesh.
- **Create mesh:** create a primitive geometry.
- **Create plane:** create a plane parallel to XY, YZ or ZX planes, or passing by 3 points.
- **Distance to mesh:** create a color map based on the distance to a mesh from a reference mesh.
  - Two graphs should appear on the side of the screen and present a deviation profile based on the cursor position.
  - A distance distribution is also displayed on the bottom right of the screen.



- **Modify color:** modify color of the selected mesh.
- **Remove outliers:** noise filter for outlier removal (high probability → less points removed)
- **Simplify:** decrease point cloud density of the selected point cloud
- **Transform:** translate and rotate the selected mesh

Right ribbon

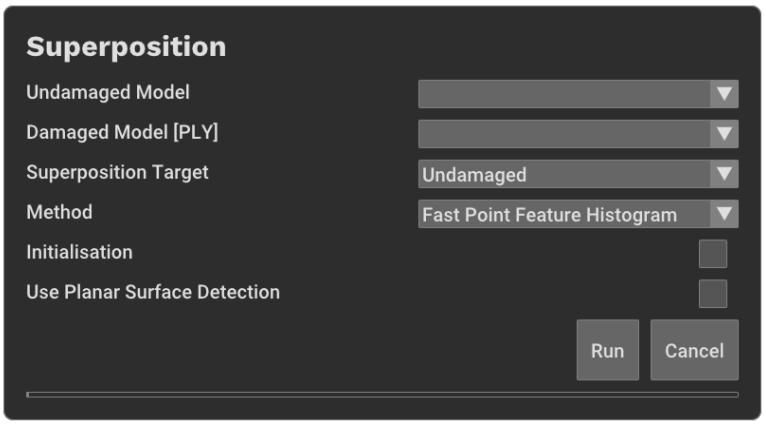
3D models window

- *3D Models* – display the loaded and computed meshes, point clouds and toolpaths.
  - Point cloud → Blue.
  - Mesh → Pink
  - Toolpath → Green
- B → Display the bounding box
- W→ Display the wireframe.
- N→ Display the normal vectors.
- T→ Render the model with transparency
- V→ Turn the visibility of the model ON/OFF
- I→ Isolate the model.
- C→ Center the camera on the model
- X→ Delete the model.

Dimensional module

Superposition

The superposition function computes the transformation matrix to register a mesh (Source) and a Point cloud (Target). For repair purposes, the coordinates of the scan are maintained. The transformation is applied on the reference/ideal mesh.



The undamaged model is the source model, and the damaged model is the target. The damaged model input requires a PLY (Point cloud) format.

The superposition target is used to change which model corresponds to the source or the target in the registration algorithm. In case the superposition target is the undamaged/Ideal model, the inverse transformation will be applied to the undamaged model.

Three methods are available to register the two models, the fast registration point, the accurate registration and the coherent point drift. It is advised to choose the accurate registration only if the fast registration does not converge. In case of divergence, the registration algorithm can be executed several times with the newly undamaged transformed mesh as input.

The Initialisation improve the convergence likelihood of the registration method but can sometimes introduce bias.

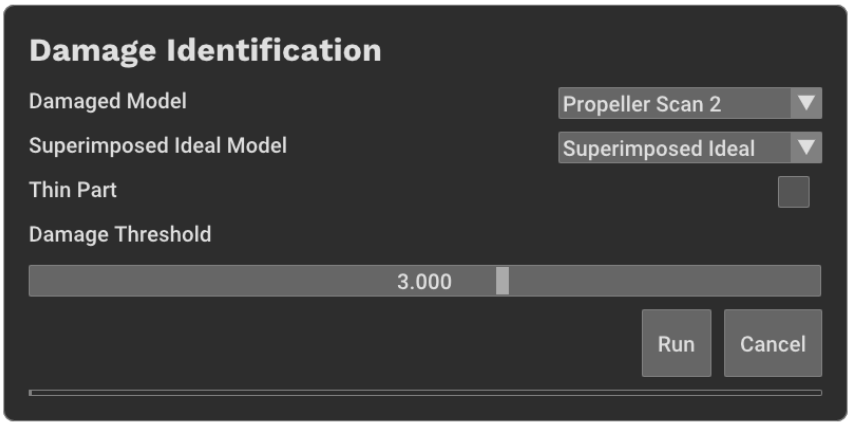
The Planar detection method improve the convergence likelihood of the registration algorithm in the case where the models have planar surfaces.

At the end of the registration process, two new models, a mesh, and a point cloud of the transformed ideal model ae created

Figure 1. Undamaged and scan models of a propeller and results of the registration process.

NOTE BENE: depending on the computational power of the computer and the size of the models, the registration can take several minutes to complete.

Damage Identification



The damage identification process automatically identifies the damaged or morphological singularities of the scan point cloud compared to the ideal model created during the registration process.

The damage threshold is the minimum distance between a point of the Ideal model and a point on the damaged point cloud for the point on the damaged point cloud to be considered as within a damaged area. For instance, a threshold of 1mm means that the damage areas identified will be bigger than 1mm of deviation.

Thin part filter is used in case the damaged area is only points coming from the ideal model and not the damaged one.

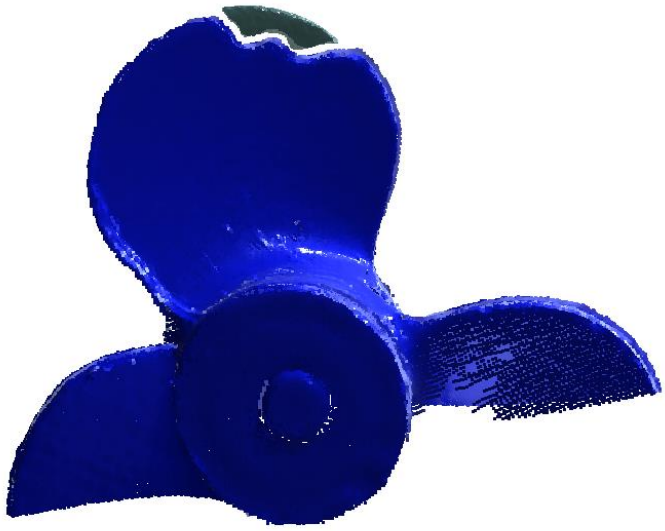
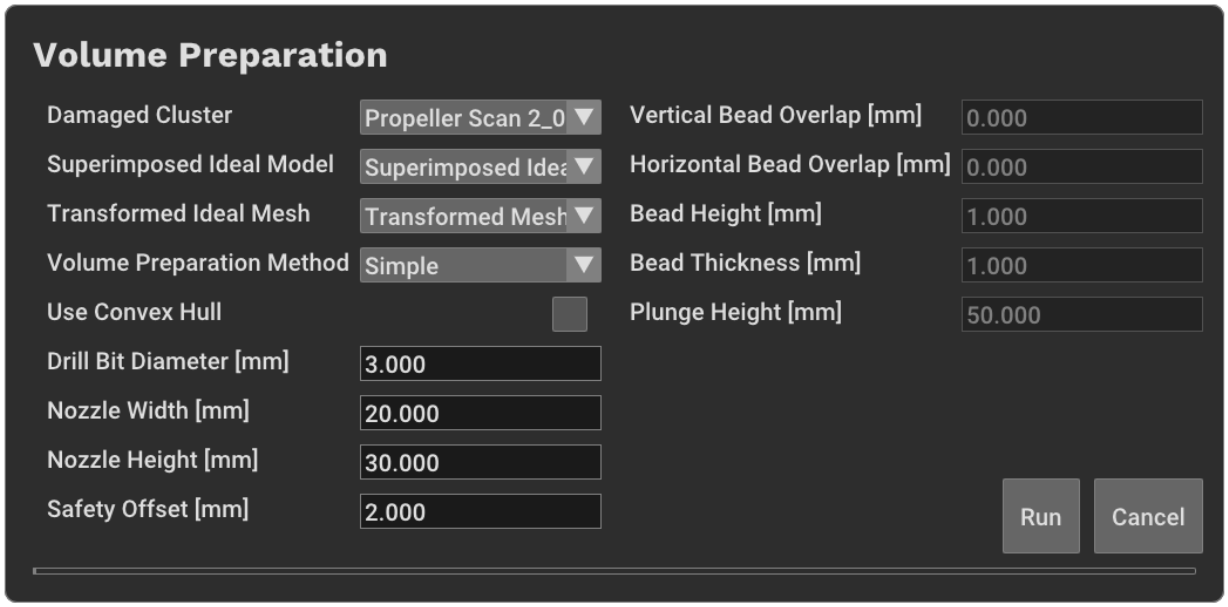


Figure 2. Damage identification with thin part option ON

NOTE BENE: depending on the computational power of the computer and the size of the models, the damage identification can take several minutes to complete.

Volume Preparation



The volume preparation computes a repair strategy using a hybrid additive manufacturing process. Based on the dimensions and geometry of the tools used for repair including machining bits and AM nozzle, the volume preparation computes the minimum amount of material to be removed from the damaged part to guarantee a correct collision free repair process. To do so, volume preparation requires:

- The damaged cluster that can be chosen from the drop-down menu. In case, there are several clusters, these clusters can be identified using the 3D model's window.

- The Ideal model, computed from the registration process.
- The transformed mesh also computed from the registration process.
- The preparation method, it is advised to use the simple one for this beta version of Element X
- Use convex hull: compute the repair strategy based on the convex hull of the damaged cluster instead of the damaged cluster itself.
- The drill Bit Diameter used for the pre-machining/ material removal step. It is advised to keep it low to maintain a good resolution.
- The Nozzle/ torch Width and Height used to deposit material.
- The safety offset which is a vertical offset. It is advised to take it equal to the damaged threshold value used in the damaged identification step.

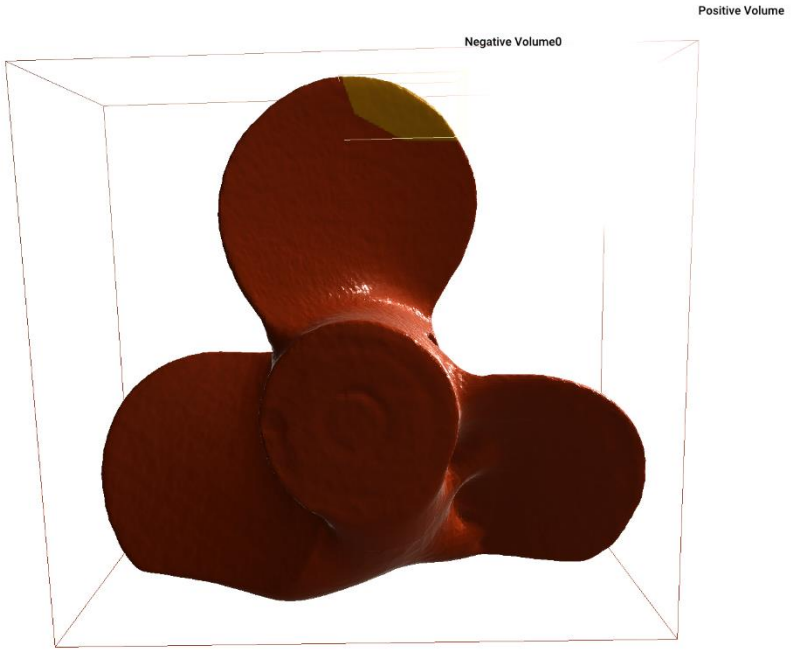


Figure 3. Negative and Positive volumes created from the volume preparation step.

The volume preparation process creates two volumes used to compute the toolpaths for repair. The negative toolpath can be sliced for pre-machining, material deposition and surfacing toolpath computation.

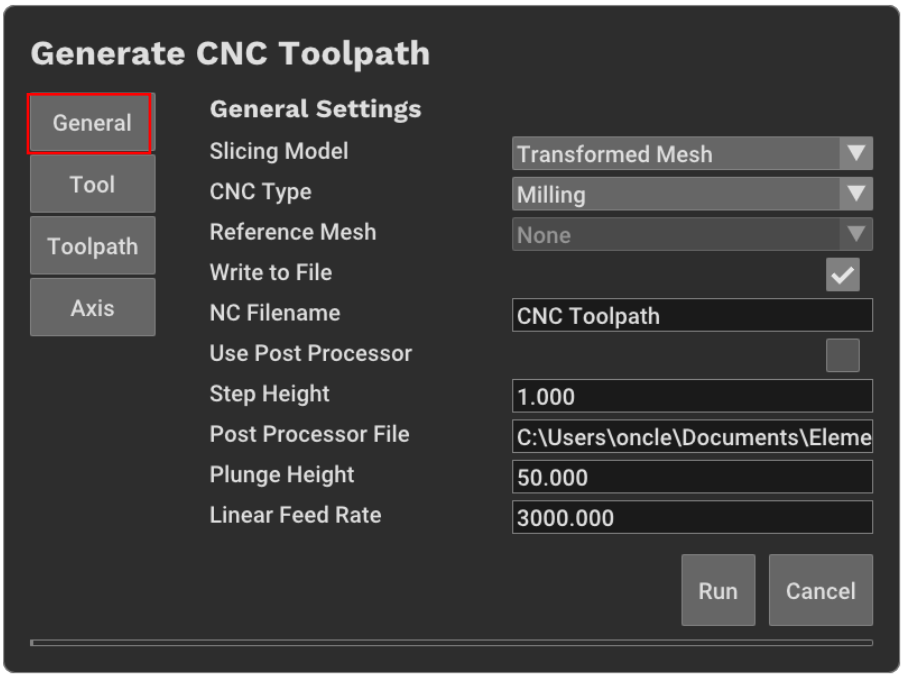
NOTE BENE: depending on the computational power of the computer and the size of the models, the volume preparation process can take several minutes to complete.

CAM solution

The Element X CAM solution offers up to 6 degrees of freedom path computation for additive and subtractive operations.

Generate subtractive toolpath.

The subtractive or CNC toolpath is designed for milling and surfacing operations.



The **slicing model** is the input model from which the toolpath will be created.

- For **milling** operation, this is the only model input required.
- For **surfacing** operation, a reference mesh can be used as model to determine the limit of the surfacing toolpath.

The **write to file** option allow the user to chose between creating a program for each run or simply creating an Element X toolpath for visualisation purposes.

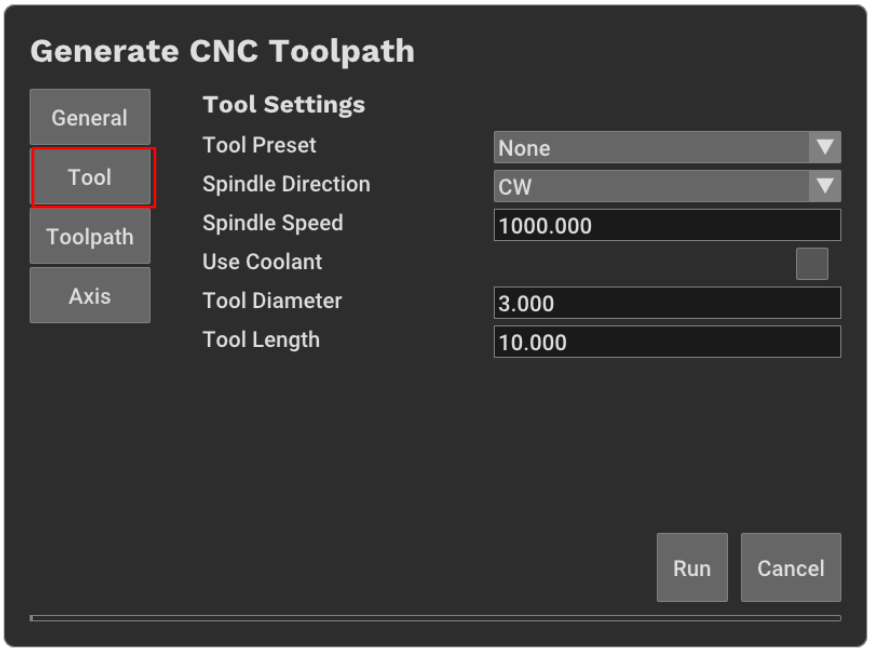
The **Use Post processor** option is an advanced parameter that allows Element X to communicate with the machine used for the manufacturing operation.

The **step height** is the size of the step down the drill will go for each layer.

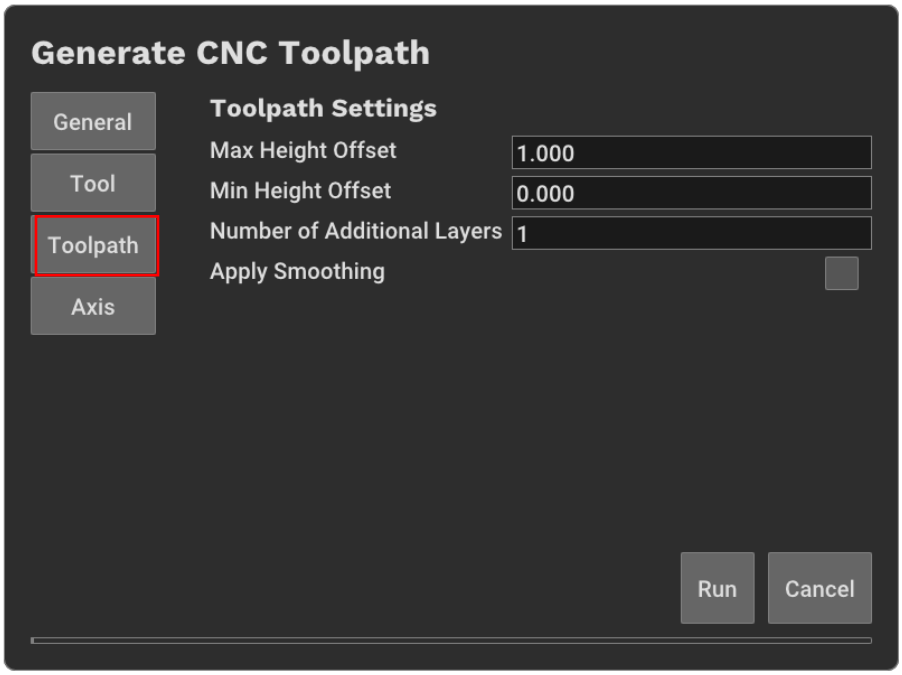
The **Post processor file** is a Python file designed to communicate with the machine used for the manufacturing operation. See the advanced parameters and Element X API for more information.

The **Plunge height** is the distance from the object, the drill will retract between each layer.

The **Linear Feed** rate is the applied speed of the machine when milling.

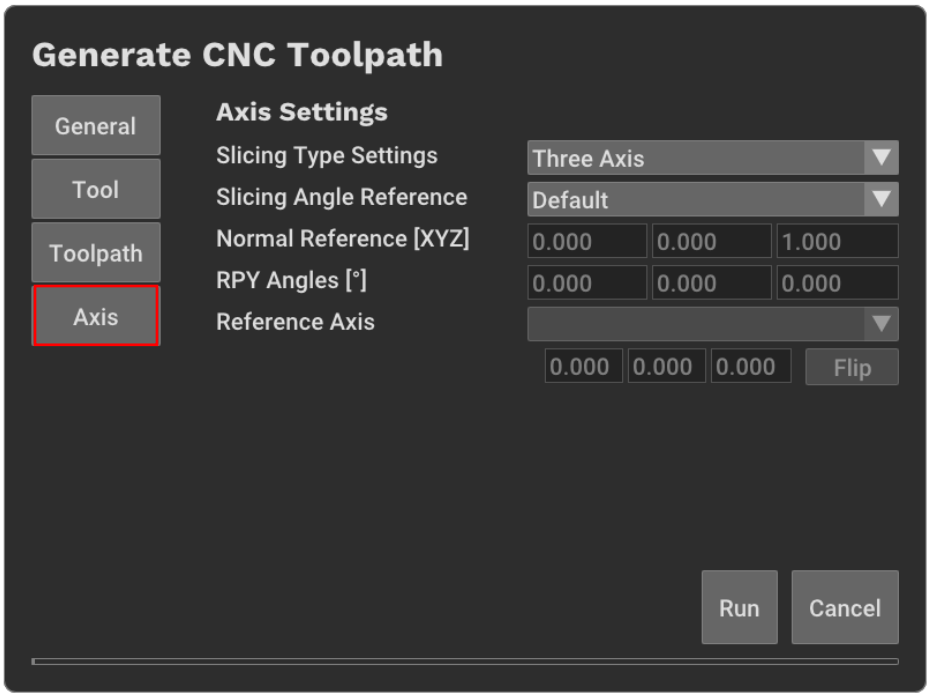


The **tool Settings** window allows to chose to execute the milling operation. The tool can be designed in the tool window. If None, a quick milling toolpath can be computed using the available parameters.



The **toolpath settings** window is a pre-defined window in the beta version of Element but can be optimized and tailored based on the operator requirements.

The **Apply smoothing** filter should only be used when working nominal meshes computed from 3D scanned.



The axis settings allow the operator to choose a reference axis to slice the model. The operator can also choose the complexity of the slicing program either 3-axis for cartesian slicing or 5-axis for conformal slicing.

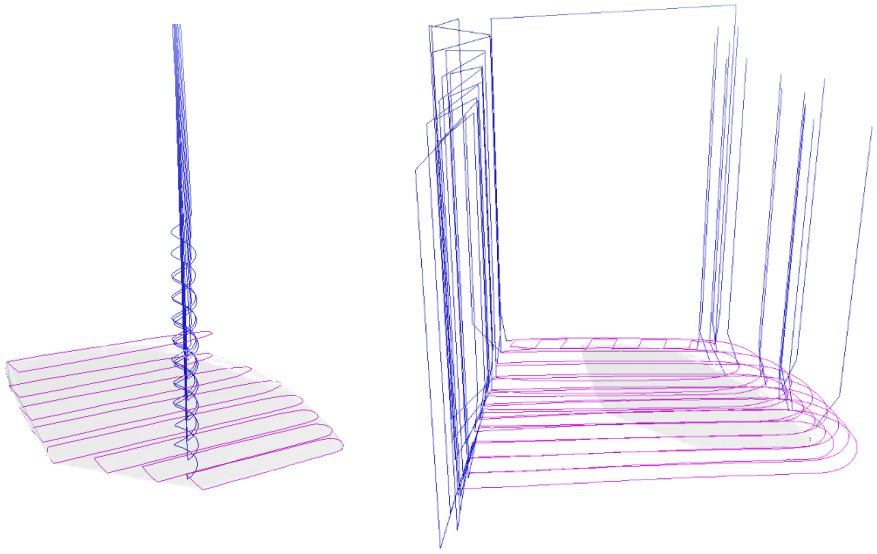
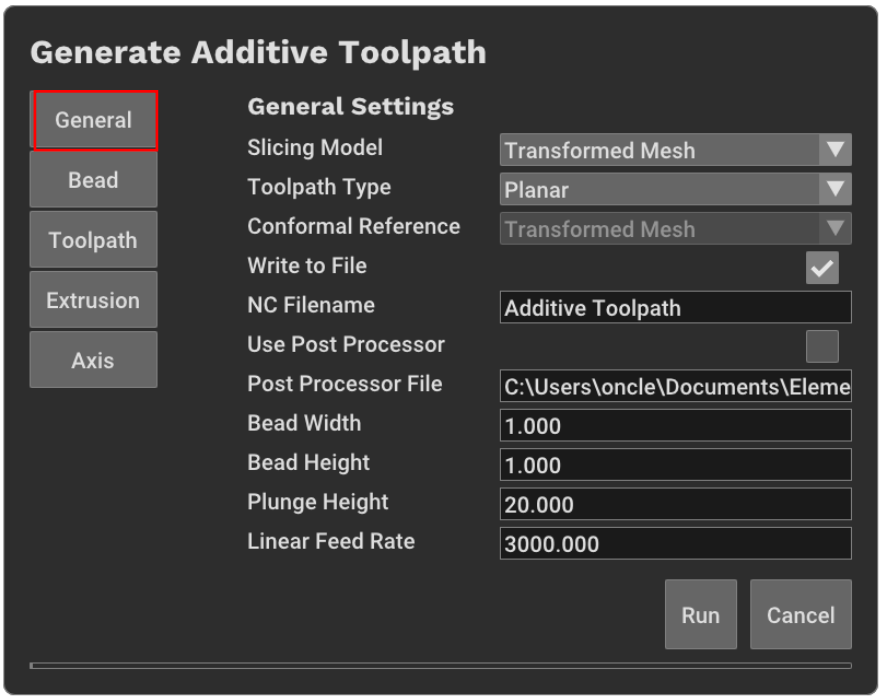


Figure 4. Milling and Surfacing toolpath computed from the negative volume obtained earlier.

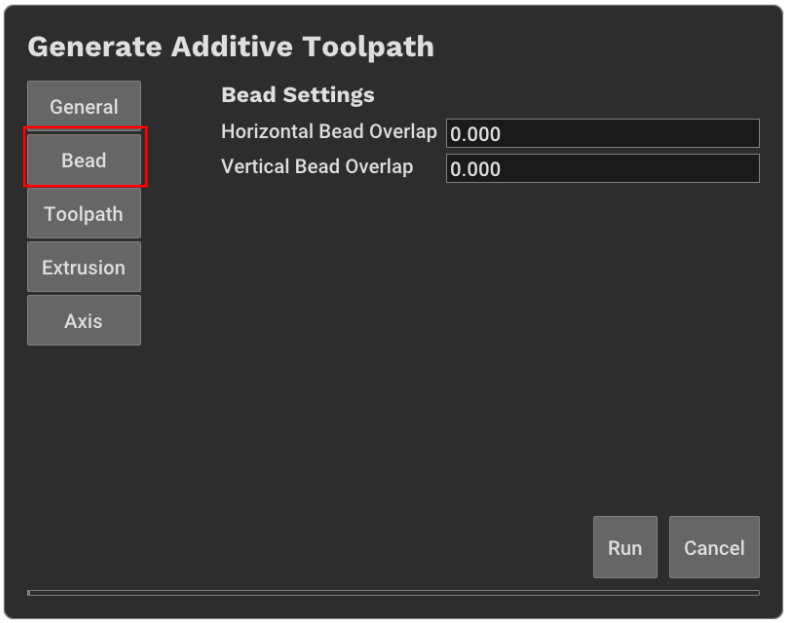
Generate additive toolpath.



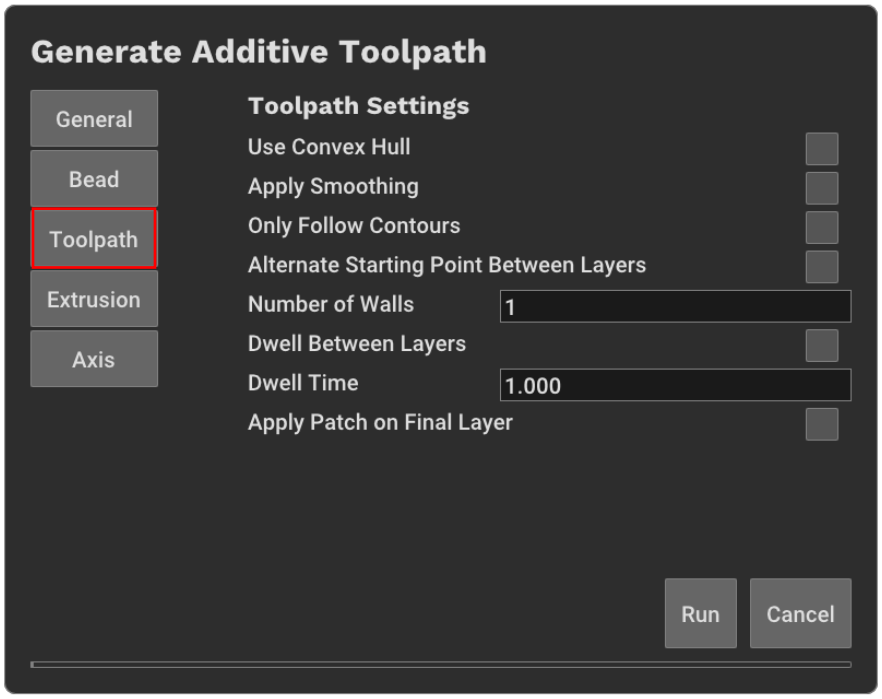
The **Toolpath type** offers two choices:

- **Planar** for 3-axis slicing.
- **Conformal** for 6 DOF slicing, in case of conformal slicing, a conformal reference mesh is required. See the cylindrical shape repair for more information.

The **bead width and bead height** determine the geometry of the material bead being deposited during the additive process.

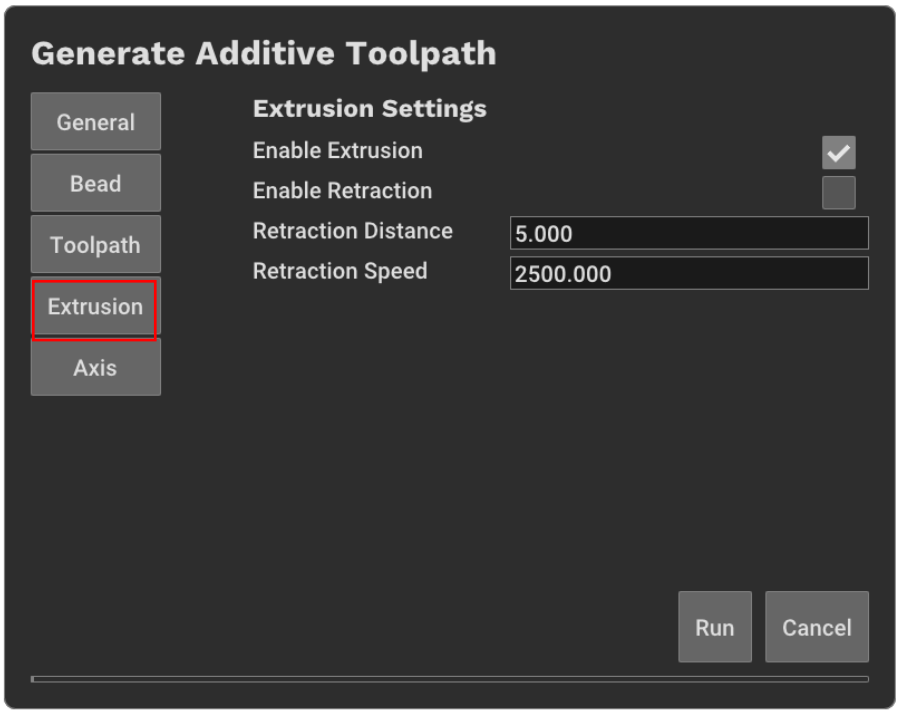


The **bead settings** offer default parameters available in the beta version of Element X. Other parameters such as overfill and underfill percentages can be added according to the operator's requirements.



The **toolpath settings** provide geometrical and practical parameters:

- Use convex hull: to generate the additive toolpath.
- Only follow contours: generate a path without infill.
- Alternate Starting Point Between Layers: alternate the zigzag infill between x and y direction.
- Number of walls: number of boundary layers
- Apply Patch on final layer: only use for surfacing repair.



The **extrusion settings** are used for extrusion rate control in case of controlled feeder applications.

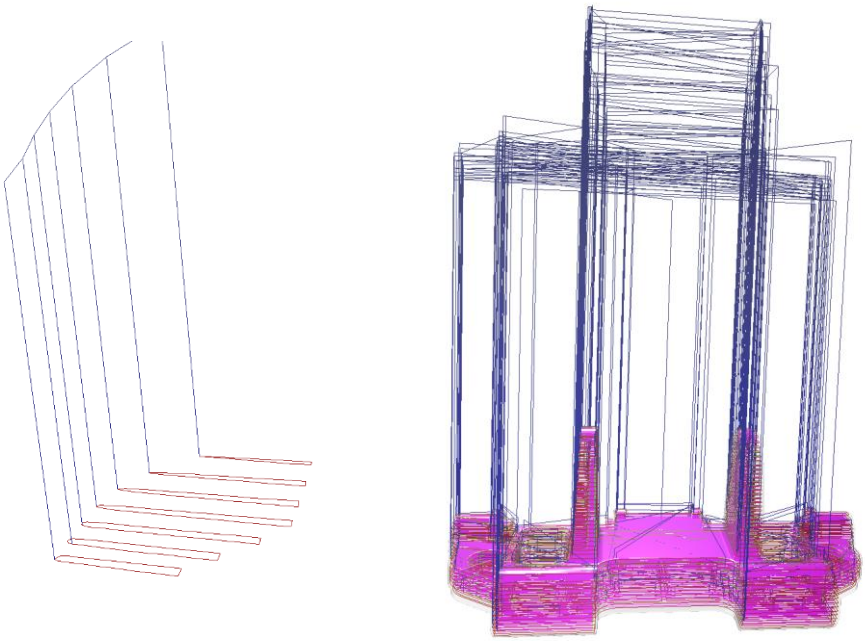
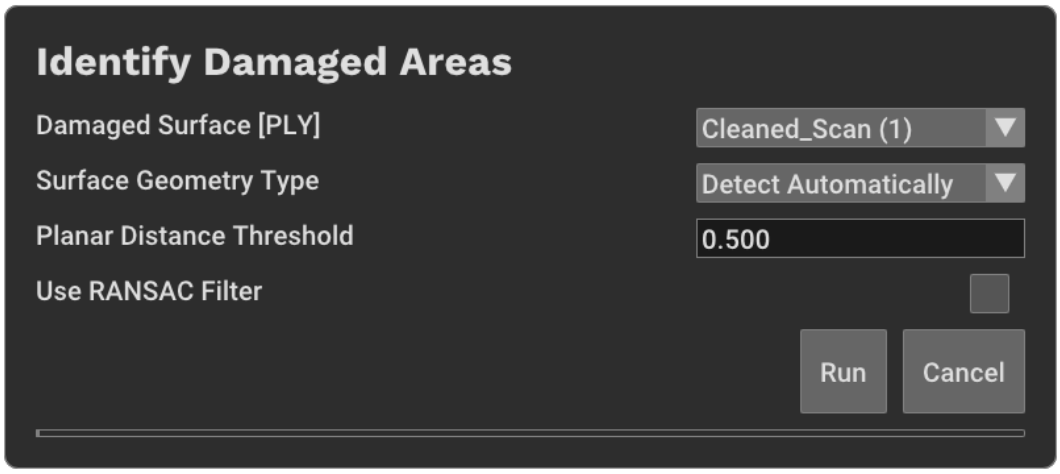


Figure 5. Additive toolpath computed for the negative volume obtained previously and AM toolpath for a complex track link.

Surface module

The surface module is designed to repair damaged planar and cylindrical surfaces without the need of having a nominal reference model.

Identify damaged areas.



Damaged Surface requires a point cloud input (PLY format)

Surface Geometry is the type of geometry loaded for damage identification either planar or cylindrical.

Planar Distance Threshold is used to determine the accuracy of the damage identification, the distance is in mm.

Use Ransac Filter is used to reduce the noise on the surface. (Not Available for the beta version)

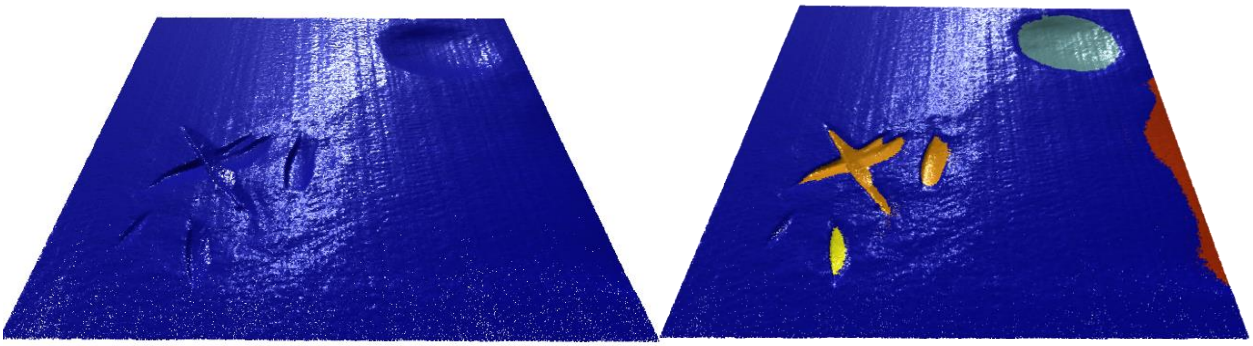
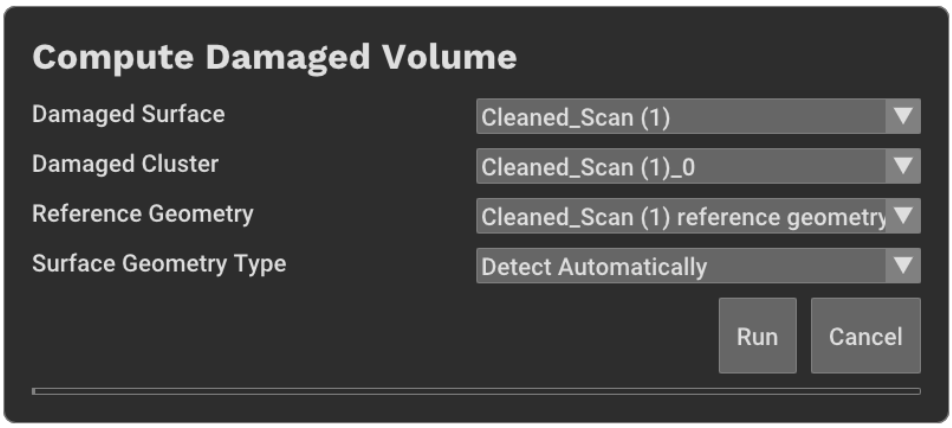


Figure 6. Result of the damage identification on planar surfaces

At the end of the damage identification process, a reference geometry and axis are created. These new objects will be used for the additive toolpath creation later.

Compute Damaged Volume

The compute damaged volume window allows to compute the negative mesh associated with the damaged cluster.



The damaged surface, a damage cluster, the reference geometry, and the surface geometry type are required to compute the damaged volume.

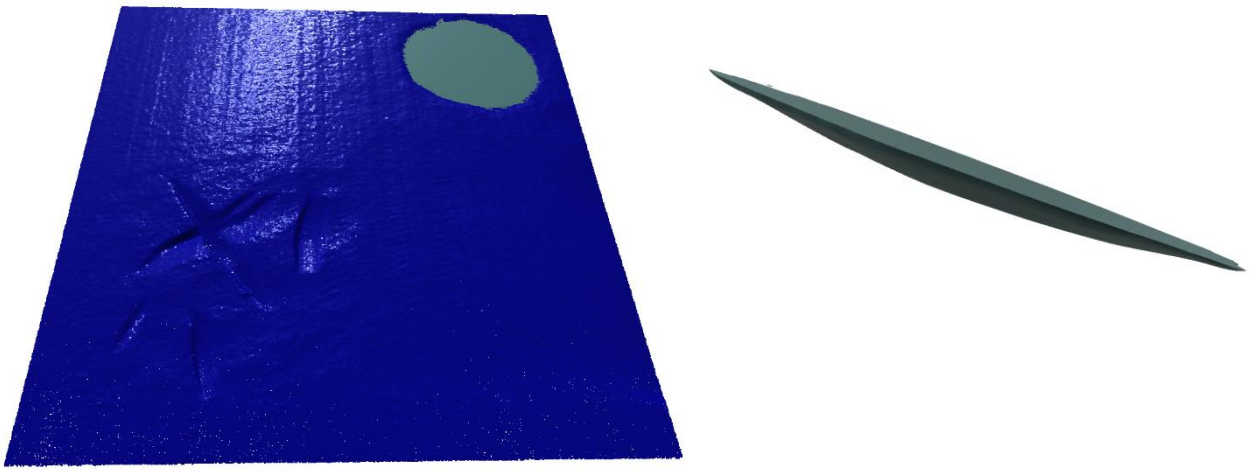
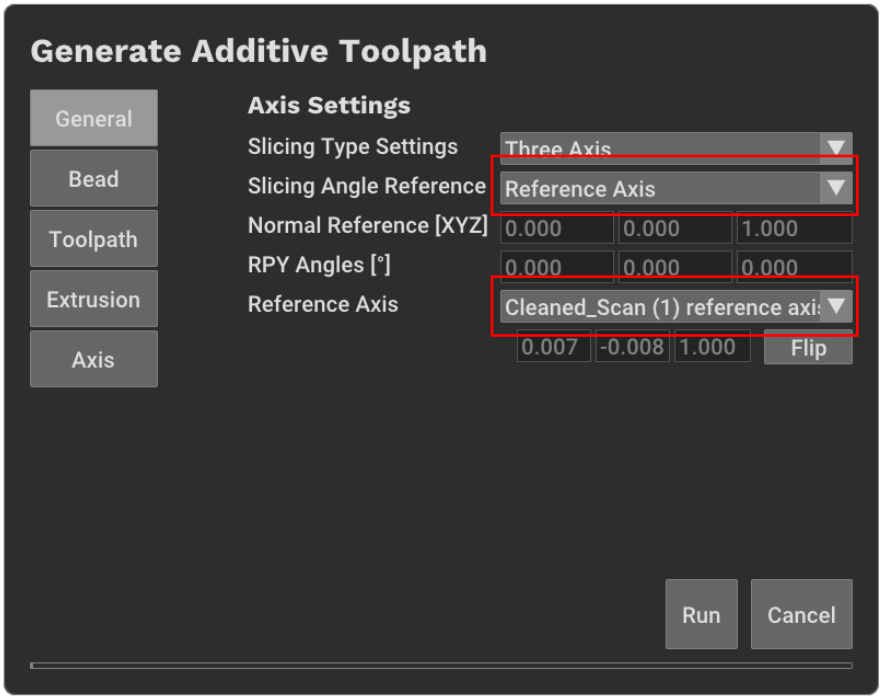


Figure 7. Damage volume reconstruction based on planar surface identification.

Generate additive toolpath.

To generate the additive toolpath, the axis settings must be modified to adapt to the orientation of the plane. To do so, the slicing angle reference must be changed to reference axis. The reference axis input should then change to the normal vector associated with the plane computer earlier.



The smoothing, alternate x, y direction and final patch options can also be used in this configuration.

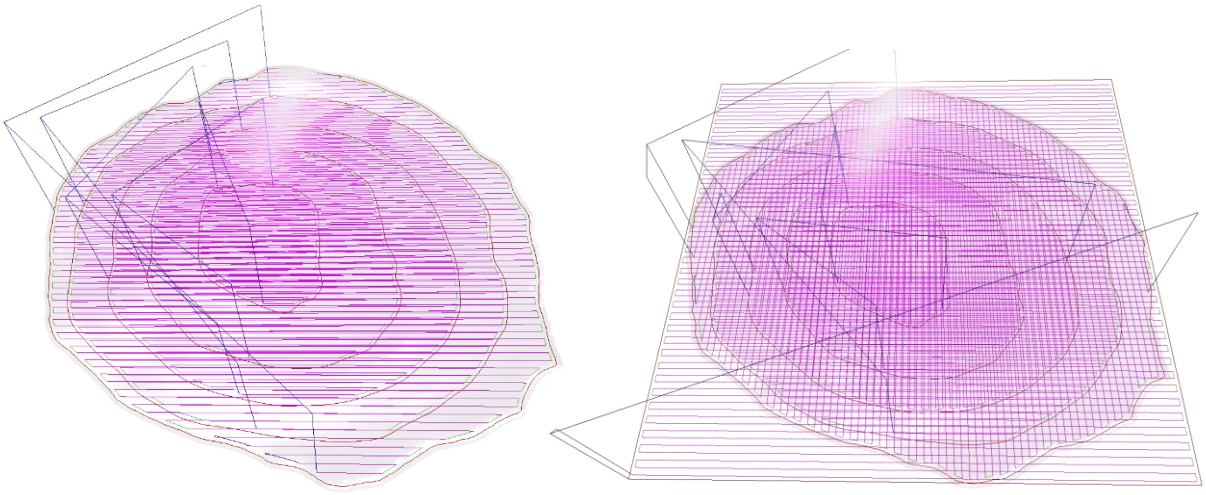
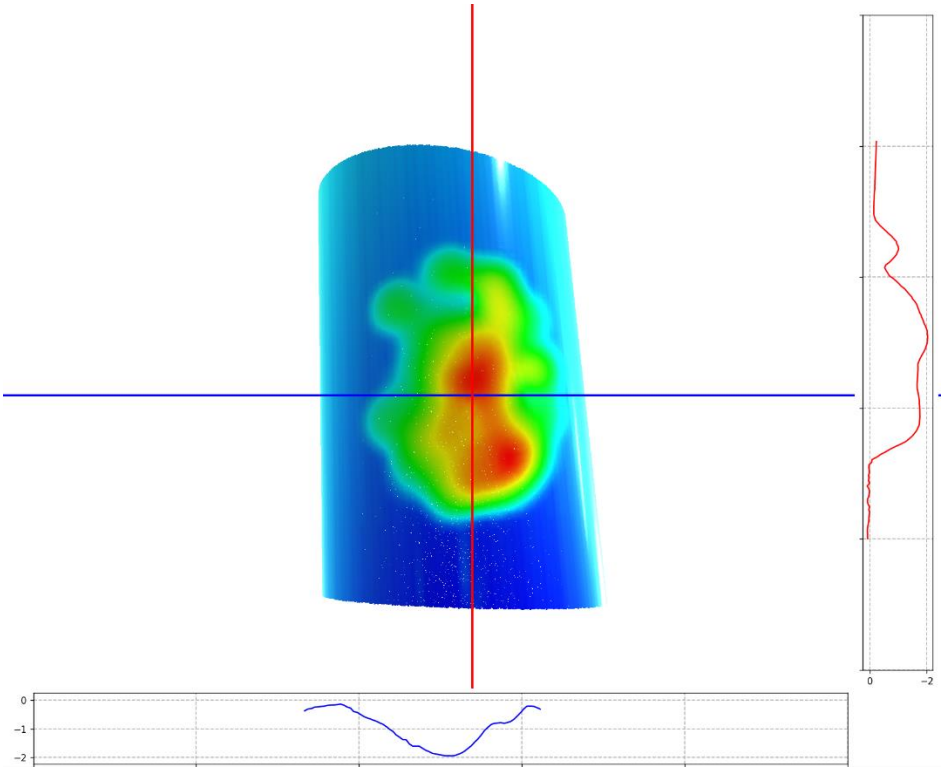


Figure 8. Additive toolpath for the rebuilt damaged volume without and with smoothing, alternate starting point, and final patch options.

The same identification and repair process can be used for cylindrical areas. The resulted additive toolpath will be a 6 DOF toolpath that can export into external robotic simulation software. To be converted into brand-specific joint positions.

Case study: Cylindrical damage

Inspection using distance to mesh feature:



Damaged area identification and damaged surface reconstruction:

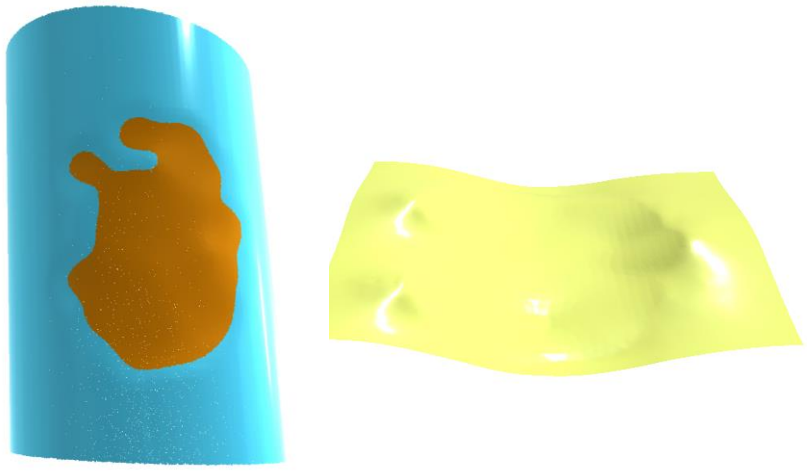
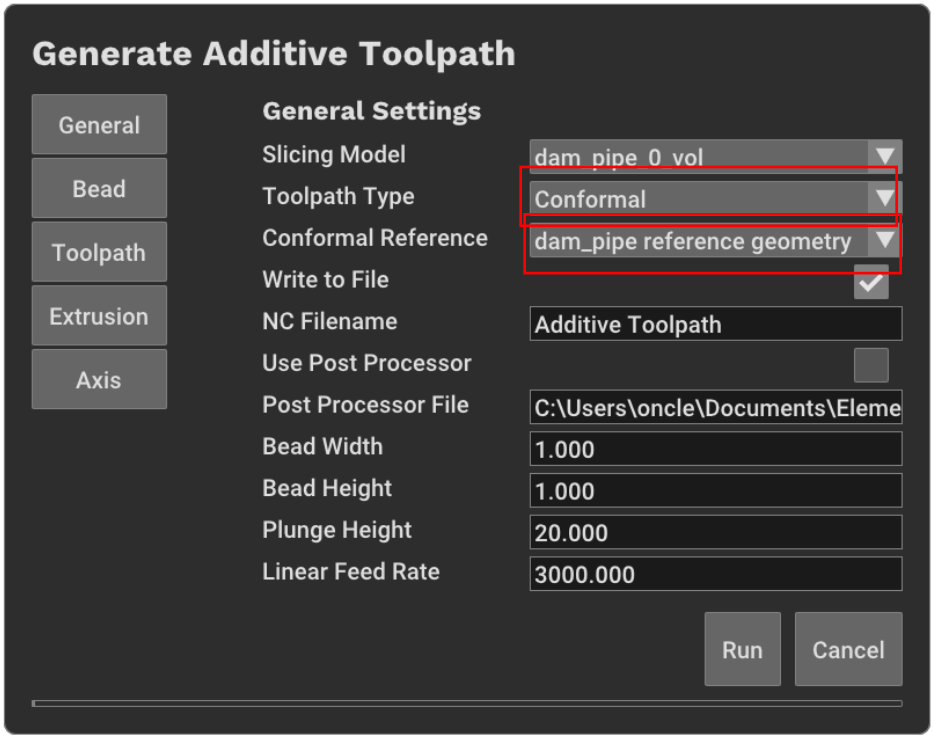


Figure 9. Damaged areas identification and surface reconstruction

Generation of the additive toolpath:

The toolpath generated in case of cylindrical shapes is a 6 DOF conformal path. The toolpath settings must be change in consequence.



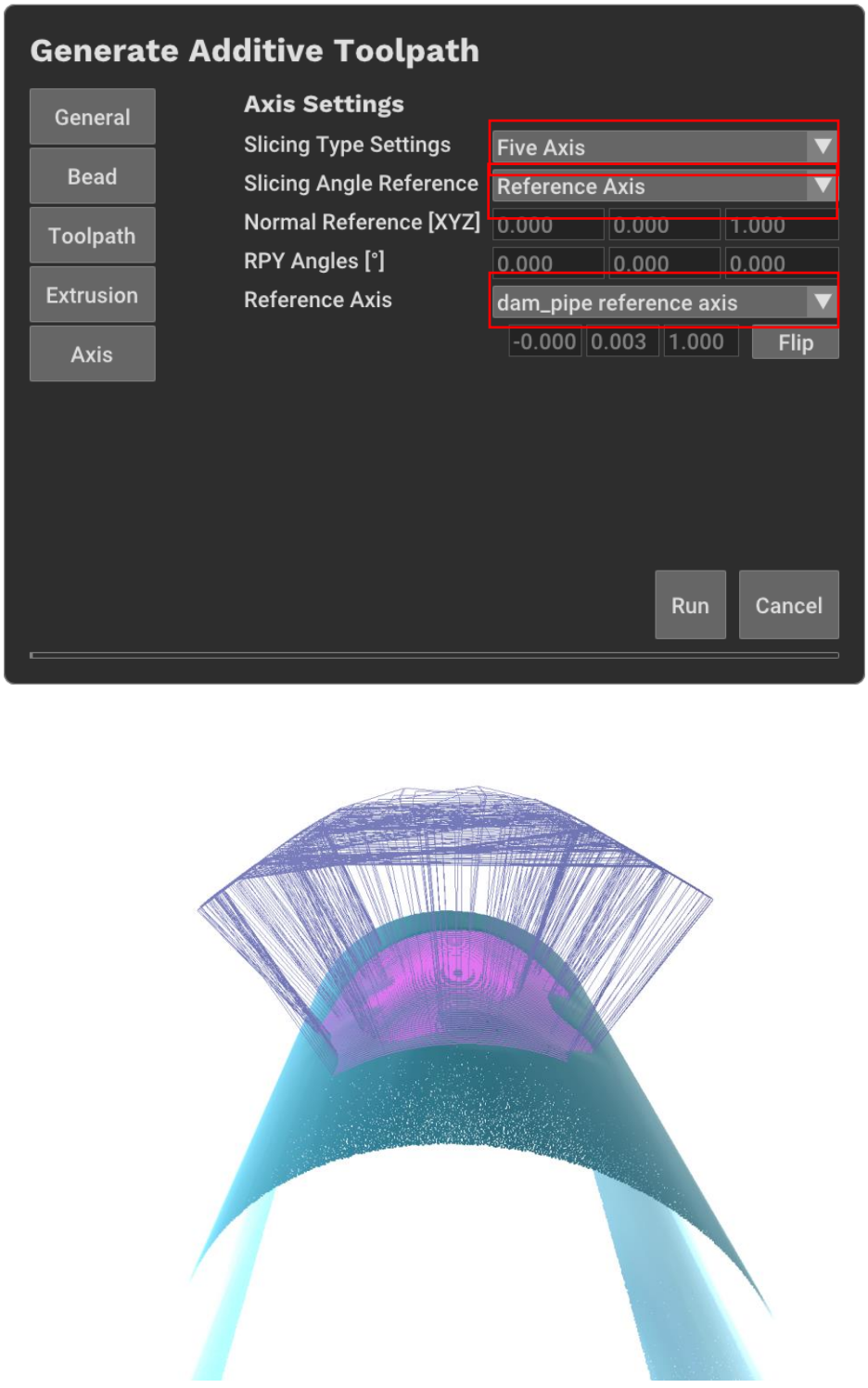


Figure 10. Conformal Additive Toolpath for automated repair of cylindrical areas

Cladding module

The cladding module is designed for robotic overlay and welding operations based on 3D scanned data.

Path selection

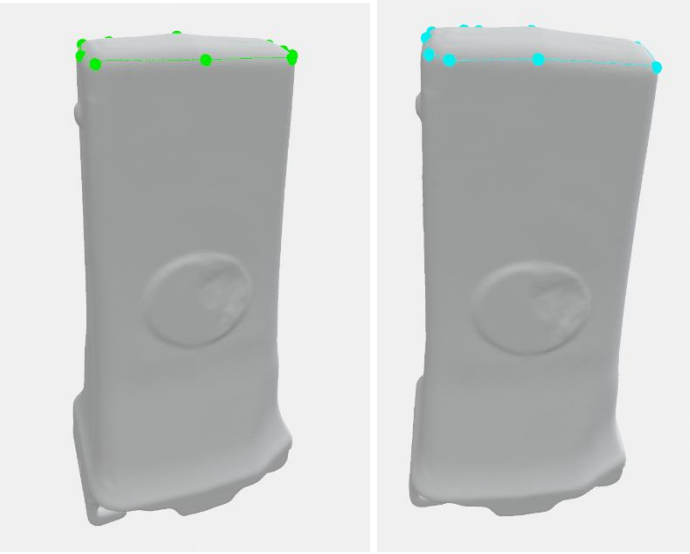
The path selection allows the operator to choose a welding path or delimitate an area to be overlayed, polished or cladded. When pressed it will open a new window.

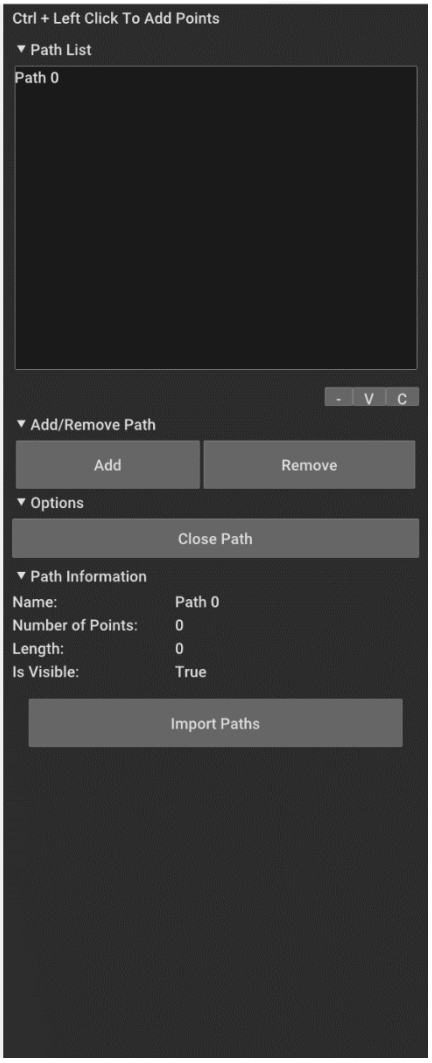
Press **Ctrl + Left Click** on the surface of the mesh to add points to create a path.

The path will directly be projected on the surface of the mesh.

The ADD and REMOVE buttons allow to create and delete additional paths.

The close path function automatically creates a closed loop based on the path already created. The path is closed when it goes from green to blue.



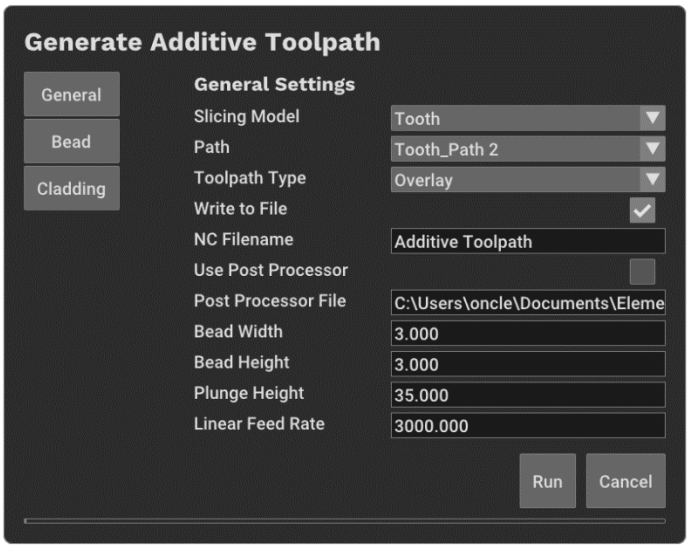


The press **Impost Paths** to load the path in the main window.

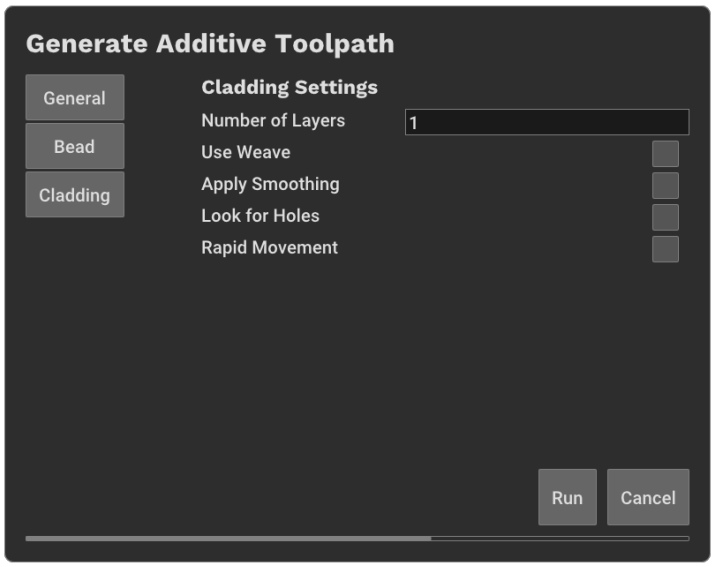
The path should be displayed in Pink in the main window.

Toolpath Generation

Based on the previously imported path, two options are available for welding and overlay applications.



The Overlay creates a 6 DOF zigzag toolpath on the surface of the mesh and within the previously imported path. The **Bead Height** gives the distance between each bead on the surface of the mesh.



The **cladding Settings** offers different parameters such as the apply smoothing and rapid movement. In the Element X beta version, the **look for holes** and **number of Layers** are not available.

Figure 11. Overlay on the tip of G.E.T

For welding applications, a single line path can be created and imported onto the main window.

From a scan, a mesh can be rebuilt using the convert mesh type and smooth surface reconstruction function.

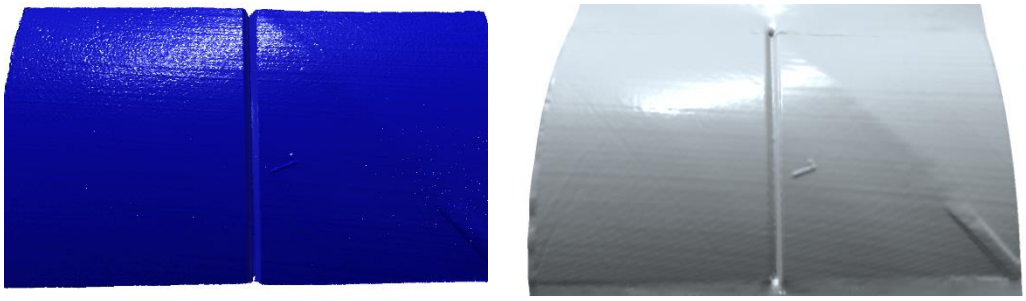


Figure 12. Scan and mesh of a weld joint

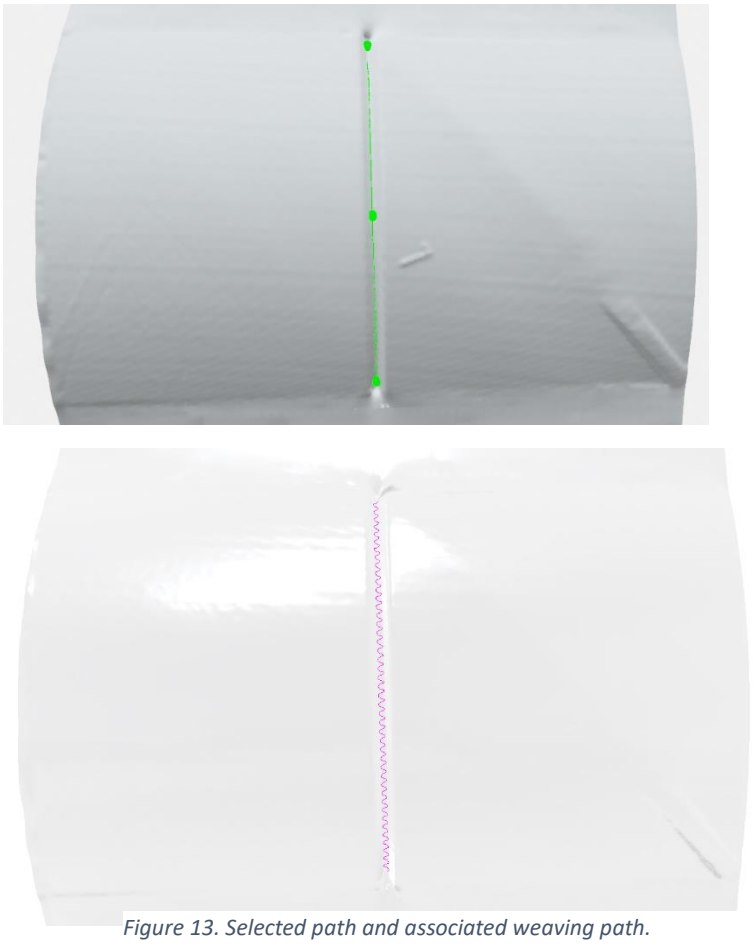
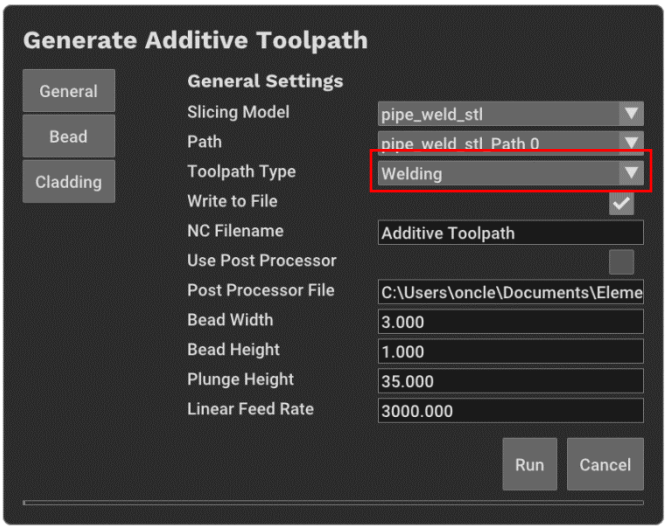


Figure 13. Selected path and associated weaving path.

Based on the path created in **the path selection** window, one can create a linear or weaving path for welding applications using the welding option in the **toolpath generation** window. The path is a 6 DOF welding path with collision avoidance optimization parameters.



Advanced Parameters

Element X offers a method to integrate the CAM solution with existing equipment. Using the post-processor python program available at:

C:\Program Files (x86) \Elementiam\Element X\post_processor

This processor uses a CSV file created directly from Element X. In the beta version, the CSV file is given as follow:

Motion Type	X	Y	Z	Feed Rate	Extrusion	Layer	A	B	C

PS: the beta version only includes the parameters shown above. For tailored applications, Elementiam team adds additional parameters such as potential dwell time, layer number, tool approach strategy, coolant rate, spindle rotation type, tool number, …

The post processor file, when selected overwrite the Gcode parameters chosen in Element X. To use the parameters set up on the GUI, do not use the post processor option.

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