ENABLING COMPLETE PROCESS CONTROL

Open Additive's Open Machine Control™ (OMC) is a complete control software solution, derived from a robust commercial software used across the laser processing industry. Users can load part files in multiple formats, arrange on build plate, select processing parameters, add supports, perform slicing, and compile and execute the build process. The software is designed for openness, allowing full control of all standard and advanced process parameters, ability to integrate additional hardware, "if/then" coding capability for feedback approaches, and potential for additional customization/expansion through the use of plug-ins. The software includes preset "recipes" and allows users to create and store their own, enabling the ability to save and access configuration and processing strategies for later use.

INPUT FILE FORMATS

The software accepts STEP, STL, and IGS solid model formats. In general, STEP files are recommended for optimal part quality, to avoid subtle facets on curved surfaces which are inherent to the STL format. A plug-in integration is also in testing to input CLI files generated from other software (e.g., Materialise Magics). Other software integrations may be developed in future for general or specific use cases.

LASER SCANNING OVERVIEW

Laser powder bed fusion (LPBF) is governed by a set of programmable process parameters that directly influence build process and final part performance. The schematic in Figure 1 provides an introduction to some of the many parameters associated with the laser scanning of interior regions and contours. All of these parameters can be fully controlled through the OMC user interface.

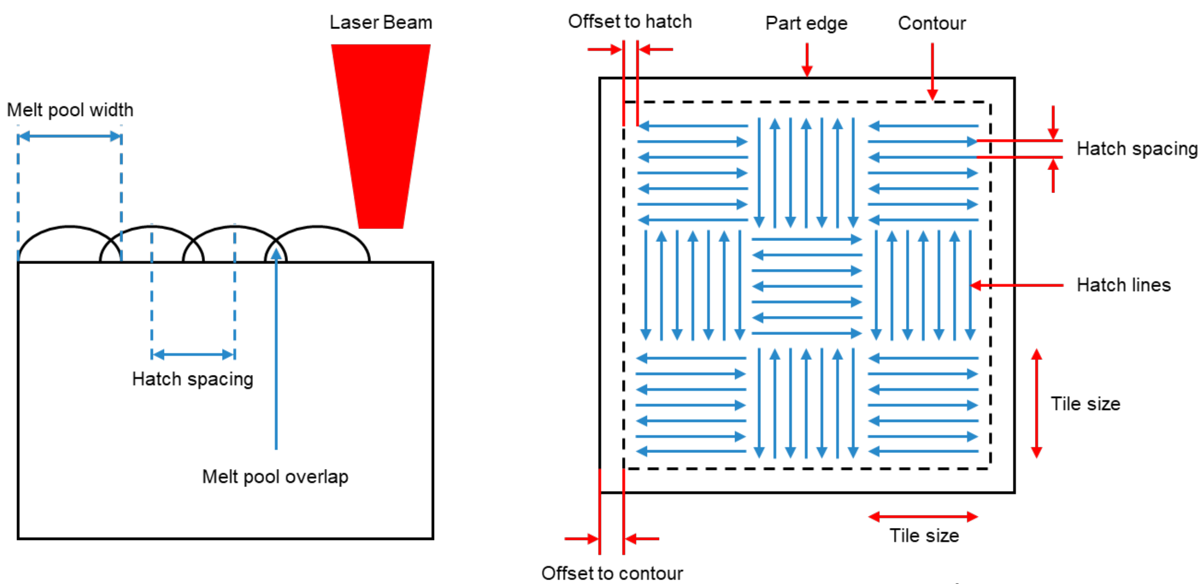

Figure 1

OMC provides the capability to independently set the laser scan parameters for different regions of the build (hatching zones), as shown in Figure 2, with a wide selection of pre-built patterns for both interior sections and surface contours available through pull-down menus. Users can set different scan patterns and parameters for each hatching zone. The parameters can also be set to change by region on a layer-by-layer basis, as desired. Ability to alter the laser marking parameters for upskin/downskin contours is also possible. We can also work with users to integrate additional scan strategies, as needed.

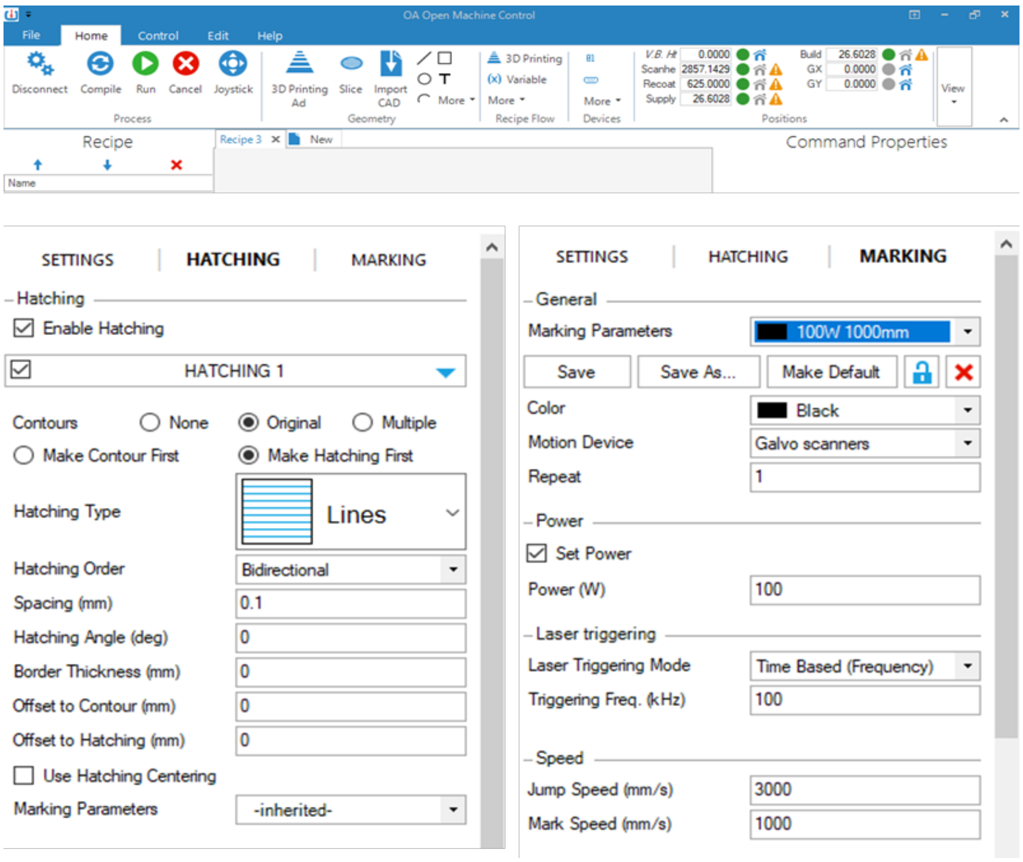

Figure 2

The software also provides a rich environment for research in process control. For example, an external signal (e.g., a voltage input based on a sensor reading or dial setting) could be used to dynamically change the laser power for a scan region. Control of order of operations is an important consideration, and allows for development and use of such advanced processing strategies. Customization for more advanced scan strategies not already included is also possible, either working through Open Additive to develop a custom plug-in or coding and integrating a user-developed plug-in directly.

Of course, not all users will require such extreme versatility, and most "print to build" applications will rely on various tried-and-true scan patterns that have been used to produce high quality parts. Open Additive's **Open Materials Library™** provides scan parameters for commonly used LPBF materials, which can be directly accessed/input for each build, making printing quite straightforward. Users can also save their parameters as part of their own proprietary set of processing recipes.

The sections to follow provide an introduction to the various parameters which can be controlled in the OMC environment. It is not intended as an exhaustive list of all such parameters.

LAYER THICKNESS

The layer thickness is a key build parameter, representing the height of each powder layer deposited across the build area by a spreader. Varying the layer thickness has a significant effect on the build:

- **Build time** – Increasing the layer thickness results in faster builds.
- **Surface quality** – Layer thickness impacts the quality of curved/angled surfaces more noticeably than surfaces which are straight upward. Thin layers result in smoother curved/angled surfaces.
- **Mechanical performance** – Varying layer thickness may influence mechanical performance of fabricated components for a variety of reasons, as it affects melting and solidification dynamics, porosity, condensate generation, and formation of other processing artifacts (defects).

LASER SPOT SIZE

Laser spot size refers to the diameter of the laser beam that interacts with the powder bed material, and it is another key build parameter. Control of laser spot size is made possible in the standard PANDA configuration through the use of a Z-stage, to which the scan head is mounted. The control software then allows the scan head to be raised or lowered to focus/defocus the laser spot on the build plane.

Varying laser spot size will most noticeably affect:

- **Build time** – A larger spot size will generate a wider meltpool, which will fuse more material at a given time.
- **Mechanical performance** – A smaller spot size will, on average, input more heat and penetrate deeper into the powder bed material, which can have a noticeable effect on microstructure formation and development of processing artifacts (defects).

HATCHING PARAMETERS

As shown in Figure 1, there are a significant number of parameters associated with the hatching control. This section provides a summary of the key hatching parameters available for control in OMC.

- **Hatch pattern** – This is the laser scanning pattern used for each cross-sectional hatching region of the build layer. OMC includes 11 preset hatching patterns, from straight lines, cross pattern, dots, concentric contours, various stripes and chessboard patterns, etc. Open Additive can also work with customers to integrate any special hatching strategies as needed (or users can attempt to code their own plug-in, if desired).
- **Hatch spacing** – The space between consecutive laser passes in the hatching region.
- **Tile size (hatch width)** – The distance the laser travels in one pass before moving to the next.
- **Tile overlap** – The overlap distance that the laser will shoot into the adjacent tile.
- **Offset to hatch and contour** – The distance from the part edge that the laser will shoot.

- **Layer rotation and shift** – The change in direction and linear starting point of the laser from layer to layer. Rotation and shift are used to mitigate formation of bands or defects.
- **Contours configuration** – Specifies whether separate marking parameters should be used for contours (part surfaces) versus interior regions; and if so, the order of operations.
- **Marking parameters** – The specific laser scan parameters for each interior/surface section.

MARKING PARAMETERS

OMC provides a wealth of options for controlling the laser scan characteristics, which play a critical role in controlling the materials properties and surface finish. Marking parameters include:

- **Laser power** – The energy input of the laser (measured in watts).
- **Laser triggering mode** – Sets a mode for laser triggering, with various time and position based triggering modes supported.
- **Jump speed** – The speed at which the laser moves between segments (laser is not firing).
- **Mark speed** – The speed at which the laser travels while firing.
- **Skywriting** – Parameters associated with skywriting feature (see next section).

ADVANCED FEATURES

- **Skywriting** – This is the capability of the scanner to move the mirrors in arcs outside the hatching lines with the laser not firing to account for mirror inertia and ensure that the laser fires at a constant linear speed for more consistent weld beads. As the name implies, the laser acts similarly to an airplane which writes across the sky by turning its trailing smoke on and off. Without skywriting, there is potential for the additional laser energy imparted in corners to create “zipper” sections with unintended microstructure and degraded material properties. In general, all Open Additive recommended parameters employ the use of laser skywriting.

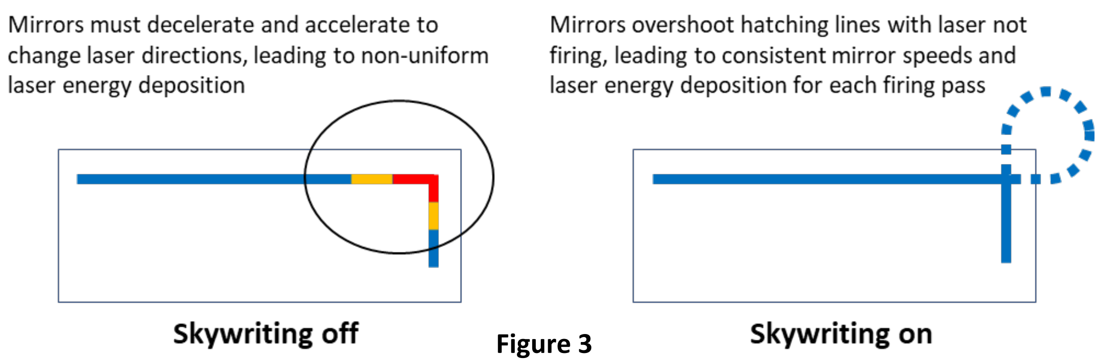

Figure 3

- **Wobbling** – Laser wobbling is often used in the laser welding industry to more effectively weld difficult materials. As the name implies, the laser “wobbles” in a subtle pattern during each pass rather than passing in straight lines. OMC allows the option to use wobbling and specify the parameters. In some preliminary tests on particular materials, wobble can reduce the formation of spatter. In general, it provides another tool in the process development toolkit.