Part Accuracy Prediction

3DSIM Tech Brief

What is it?

exaSIM™ is a predictive simulation tool that enables Additive Manufacturing (AM) users to rapidly understand how their parts will distort during the build process without the need to perform multiple trial and error iterations of a physical build. In short, exaSIM will save users time and money to make accurate parts.

What is the hurdle?

When producing parts using metal powder bed AM processes such as metal laser sintering, significant thermal gradients are created in a part during material solidification and cooling. Unlike some thermal-based manufacturing processes, AM components are relatively free to distort except for locations where they are anchored with a support structure. Due to the geometric complexity designed into AM parts and the interactions of different thermomechanical effects during the layer-by-layer process, it is difficult for designers and machine operators to estimate where, how much, and in what direction parts will distort.

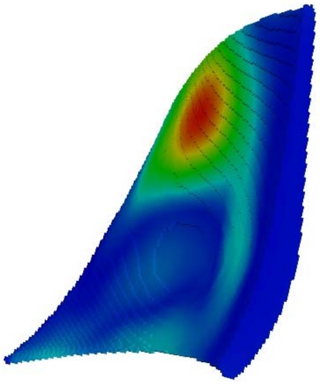

Figure 1: Generic airfoil geometry indicating the type of geometry represented in this document

In the metal AM industry, the negative effects of distortion can be one of the most costly "failures" for a build. For a part to be found non-comforming from a part accuracy/tolerance perspective, this determination is typically made after post-processing, which may include heat treatment, support removal via CNC milling, and automated inspection. Many AM users find that less than 50% of parts are conforming on the first iteration, and oftentimes parts will take 3 or 4 iterations to build appropriately. In an America Makes 'Success Story' from a project led by GE it was reported that it can take up to 15 iterations for a geometrically accurate part to be made that conforms to the CAD model. This can end up costing from tens to hundreds of thousands of dollars in wasted builds. (https://www.americamakes.us/images/publicdocs/Approved_Success_Stories/4026_SuccessStory.pdf)

This Tech Brief describes the comparison of simulated and measured results for a proprietary airfoil-shaped part (the full part details are confidential) that was produced using metal laser sintering. The part is a full-scale aerospace component with bounding box dimensions in the range of 230mm X 180mm X 50mm.

Is exaSIM accurate enough to clear the hurdle?

In order to achieve a suitable return on investment (ROI) from predictive simulation, the results must be accurate enough to drive the practitioner to the correct solutions. Otherwise the prediction does not save time or money compared to trial and error physical prototyping. The following results illustrate how exaSIM predictions provide sufficient accuracy to drive design decisions.

This geometry was provided to 3DSIM™ and a simulation was carried out utilizing the exaSIM Uniform Assumed Strain mode of simulation. For even higher fidelity simulations, a Scan Pattern Based Strain or Thermal Strain simulation can be performed if the scan vectors used to build the part are available. In this case, the full process parameters details were not available to 3DSIM and thus Assumed Uniform Strain was used.

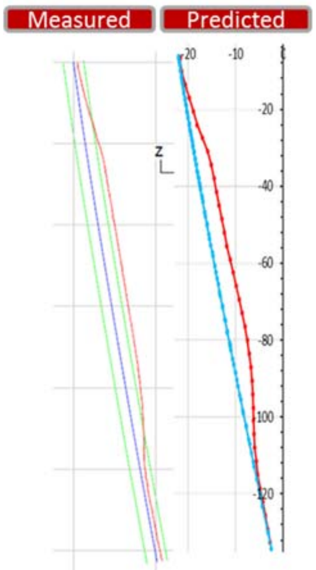

Figure 2: Trailing edge contour comparison of measured vs. predicted results.

Upon completion of the simulation, 3DSIM evaluated specific contour measurement locations provided by the partner to enable comparisons of measured vs. predicted data. In each of the images the blue lines are the nominal (e.g. CAD file) geometry, and red lines show the actual geometry. For 'Measured' figures, the red line shows the CMM results for the as-built component versus the nominal blue line. For "Predicted" figures the red line shows the simulation results versus the nominal blue line. The green lines are the tolerance zone for each contour profile. The measured part was non-conforming since the red lines are often outside the green line tolerance zone.

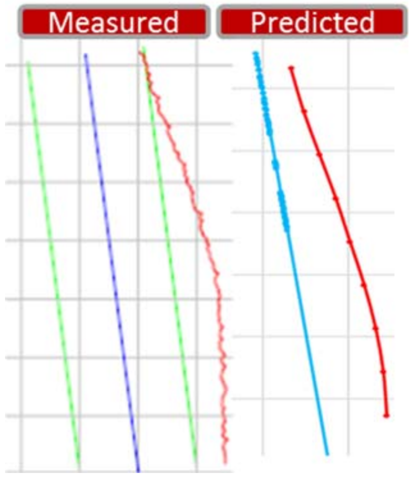

Figure 3: Trailing edge connection rib contour comparison of measured vs. predicted results.

The results in Figure 2 are from a contour taken along the trailing edge of the airfoil in a direction transverse to airflow. The exaSIM prediction accurately captured the deformation shape and magnitude when compared to the physical component.

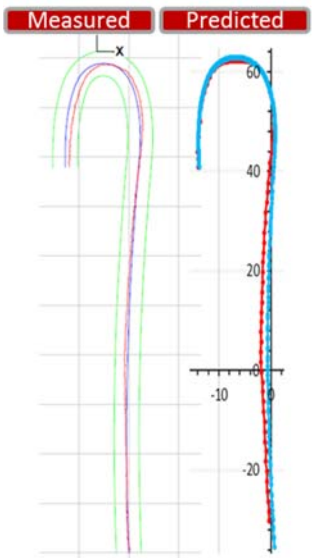

Figure 4: Airfoil surface near base contour comparison of measured vs. predicted results.

Figure 3 shows a contour of a rib along the trailing edge that is also transverse to the airflow direction. It can be seen in this image that the simulation effectively predicted the trends leading to non-compliant distortions.

A contour taken around the leading edge near the bottom of the build is shown in Figure 4. For this contour, the trends were predicted very well with the distortion converting from inside distortion to outside distortion at the top right of the figure, then crossing back to inside distortion about 20mm lower, gradually diverging, and then converging back at the bottom of the profile. In this location, however, there are some variations in displacement magnitude between measured and predicted results which may have been predicted more accurately using either Scan Pattern Based or Thermal Strain modes.

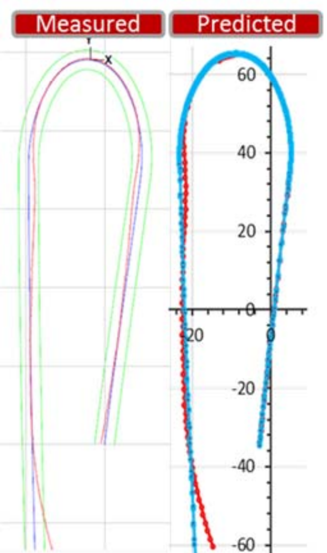

Figure 5: Airfoil surface near top contour comparison of measured vs. predicted results.

The last evaluated contour was around the airfoil surface near the top of the build. Results are shown in Figure 5. In this location, the predicted trend and magnitude are quite precise. It is interesting to note how effectively the simulation predicts the very large displacement at the bottom left hand side of Figure 5, which corresponds to the trailing edge. This is where an intersection between a rib and a transverse wall was located.

Conclusion?

A full-scale aerospace component was simulated using the exaSIM Assumed Uniform Strain method. The simulation results provide accurate trend and magnitude predictions. These predictions enable users to avoid building non-conforming parts, thus saving exaSIM users significant time and effort.