Single Point Incremental Metal Forming

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Single Point Incremental Metal Forming (SPIMF) is a process that allows architectural panels to be incrementally formed from sheet metal into doubly-curved complex shapes using a robotic arm and a stylus-like end effector. SPIMF leverages industrial robots' precision and strength by gradually pushing the end effector into vertically supported sheet metal. This work was inspired by Anmar Kalo and Michael Jake Newsum's Incremental Sheet Metal Forming and CITA's Stressed Skins project. SPIMF examined how different materials, forming tools, and tool path generation methods impact the finished quality of completed pieces along with applications for the formed metal parts. Once an understanding of how SPIMF worked, focus was put on how to accurately program the robotic arm to produce repetitive geometries that correspond with a digital model. By creating a feedback loop that studies how the sheet metal deforms and how accurately the robot performs the forming task, new and more accurate geometry can be used to program the arm.

The process of creating routines for the robot up until this point was noncyclic, as the geometry would be created using a set of points and a plan drawing using the plugin Kangaroo. From there that geometry was fed into another Grasshopper script that would produce the robotic routine. Afterwards, a panel would be produced on the arm and that was the end of it.

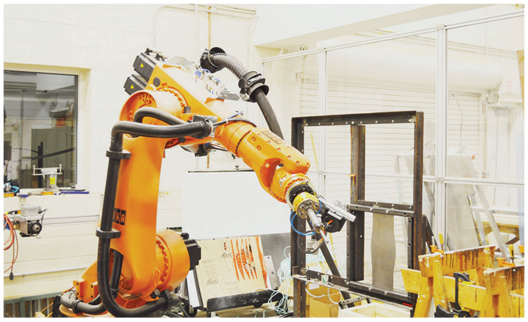
Now, a feedback loop is being utilized that has the ability to control the geometry being fed into the software. While this locks in the overall nature of the input geometry being formed it allows the software to gradually manipulate a geometry and test how well the formed panels match the digital model. Tests are conducted by robotically forming a new metal panel and then creating a 3D scan. Verification for how well the panel matches the input geometry is done using a Kinect to make a 3D point cloud by 3D scanning the object. The scan is then compared to the forming geometry. A comparison done in Grasshopper matches up points that have the same XY coordinate and compares their Z value. From there a heat map is also generated, so that users of the software can see where corrections to the forming geometry are needed. With that information the points used originally to create the form can be moved vertically to allow for a more accurate digital model to be fed to the Grasshopper script that generates the robot routine.

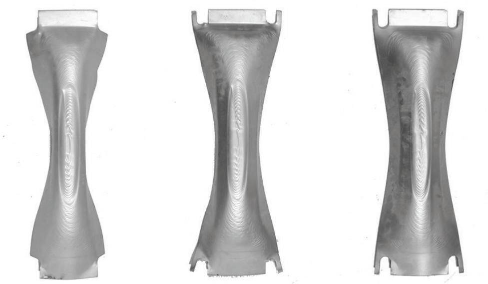
Ideally, by running enough panels through the system an adjustment factor can be created based off of how much the Z value must be modified. The adjustment factor would replace the need to verify the panels by 3D scanning them. This adjustment factor would allow a designer the ability to create a series of surfaces within the design environment and have those be correctly translated into a robot routine. The adjustment factor allows for the knowledge gained through the experiment phase of this project to be implemented into a design tool.

SPIMF

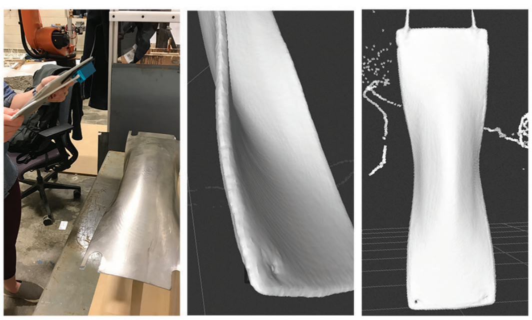
single point incremental metal forming

parametric accomodation of material properties
in complex sheet metal fabrication

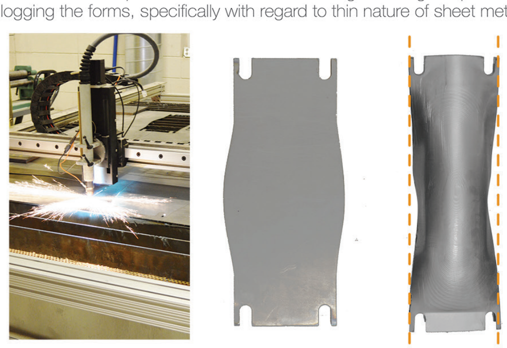




Numerous examples of various profile shapes were tested and logged to eliminate error in the data set and generate a more exact translation.



The 3d scanner provided a number of challenges during the process of logging the forms, specifically with regard to thin nature of sheet metal.



Using a CNC plasma cutter we were able to achieve an accurate blank geometry that deforms in a predictive manner when formed.

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Initial Material Blank 20 Gauge Cold-Rolled Sheet Metal

Relaxed Funicular Geometry from Kangaroo Physics Simulator

Contoured Surface at .3mm to generate high resolution tool path

Planes from divided contours to orient tool and set tool path based on digital geometry

The blank is pinned at the top and bottom in the frame to allow for greater material deflection. 6-axis Robotic Arm moves to material blank

Single Point Tool incrementally forms material in a spiral pattern, stepping .3 mm into material for each profile

Robot retracts from formed blank. The piece is then removed from frame and reaches a state of equilibrium. The panel is significantly stronger than the blank

Using a laser scanner with photogrammetric calibration a Mesh and Point Cloud are generated for the comparison of the formed geometry and the digital geometry

Digital Heat Map displaying variance between digital model and formed piece. The variance vectors are recorded to create a data-set for the material varriation based on its internal properties

A second geometry is Adjusted based on the material properties. This geometry is no longer funicular, but will result in a perfect geometry once formed

Adjusted Material Blank is then CNC plasma cut. The new blank, combined with the new tool path will result in a formed piece that factors in the internal material properties and stresses of forming