The robotic workflow proposed analyzes the bead rolling process, its potential digital interpretation, and improved fabrication aspects that accompany such a translation. The research focused on transferring the manual process of bead rolling to a robotic work environment to permit a higher level of control. Bead rolling, a metal forming process, consists of two rotating dies through which a sheet of metal is maneuvered to create corrugations, or beads. For this process to be automated, a robotic tool has been developed that integrates multiple variables observed from existing bead rolling machines, while simultaneously allowing further control. Material-informed decisions required a series of tests evaluating optimum tool and workflow design. While the process provokes a multitude of potentialities, it has been put towards a structural behavior testing scenario to demonstrate its validity. It attempts to bridge analysis methods with prototyping as means of direct performance testing and evaluation. Deeply rooted within a parametric modeling environment, the workflow creates a single digital interface that links several platforms that otherwise are not in direct communication.
TOOL DEVELOPMENT

Emulating the function of traditional bead rollers, an end effector was developed consisting of two spinning wheels affixed to the end of a steel body. The top wheel, a rubber skateboard wheel, enables intersecting corrugations without destroying the bead profile. Remotely controlled through the pairing of Bluetooth and Arduino, a stepper motor drives the lead screw into the wheel casing to allow the top wheel to enter and exit the sheet quickly and to impress varying corrugation depths in the sheet. This ability creates opportunities for improved structural performance of the sheet, as well as expands the lexicon of pattern possibilities.

DIGITAL WORKFLOW

Finite Element Analysis is performed on sheet metal samples given a set of user-defined load parameters and boundary conditions. The outcome is a series of stress vectors acting on the sample. These are hence identified as locations of weakness and where bead corrugations are introduced as means of enhancing the sample’s structural performance. Vector direction is translated into robotic toolpath while vector magnitude drives the corrugation depth through the tool-mounted microprocessor.
APPLICATIONS

Robotic beading tool development for stressed skin fabrication provokes a wide range of applications from decorative paneling to shelving. This is due to the structural integrity it provides sheet metal and increase in rigidity. By approaching material stock as an empty canvas and only treating areas that require additional strengthening, a smoother and simpler approach to structural optimization is achieved. This instigates new formal languages that arise out of pure functional and numerical investigations. By varying the input mode beyond the suggested FE results, any algorithmically generated pattern could be easily formalized in the form of a rapid visual prototype. Robotic bead rolling as an aesthetic impression and its associated play of light across corrugations has proven very provocative.
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IMAGE CREDITS

All image credits to Authors (2014).

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AMANDA LEE is a recent graduate from the Harvard Graduate School of Design (GSD) Master in Design Studies program and holds a Bachelor of Architecture degree from Virginia Tech. Having an interest in both digital and manual fabrication environments, her current research is on radiative cooling devices and the development of prototyping strategies that address both industrial and performance-based parameters required by the devices. As a Research Associate for the GSD Design Robotics Group, Amanda has been involved in a number of projects that explore the integration of digital fabrication technologies into custom material processes for architectural ceramic applications.