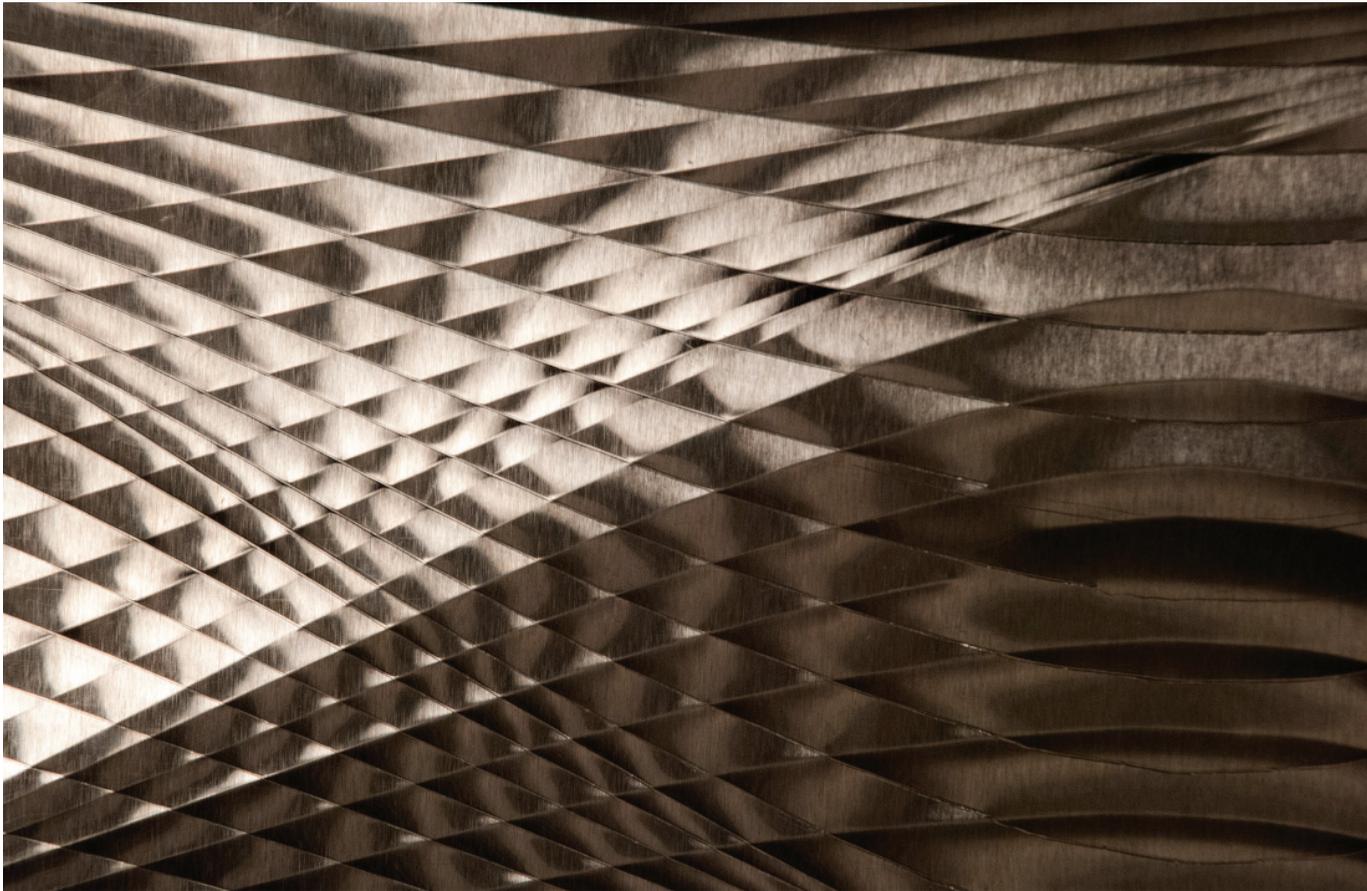


ROBOTIC BEAD ROLLING

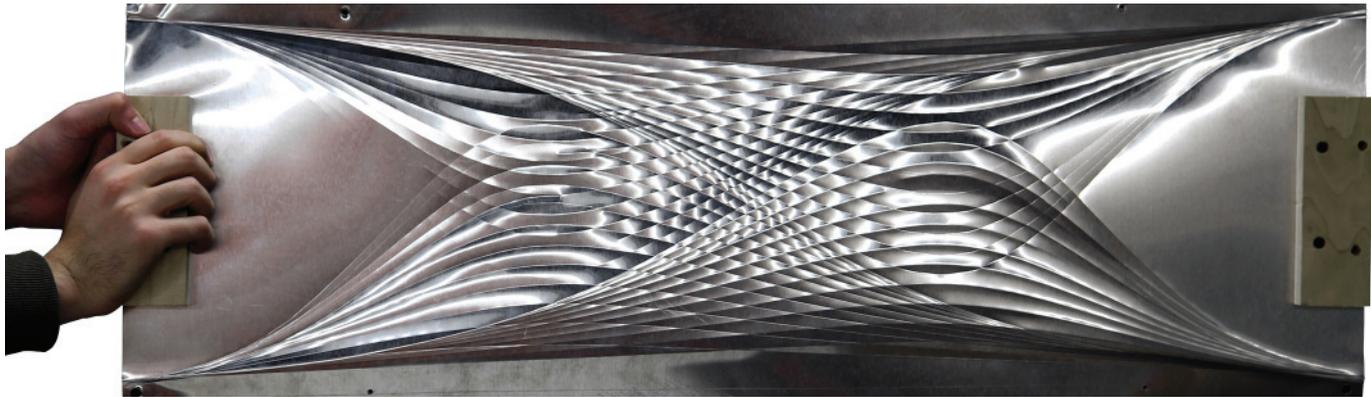
Jared Friedman Harvard Graduate School of Design
Ahmed Hosny Harvard Graduate School of Design
Amanda Lee Harvard Graduate School of Design



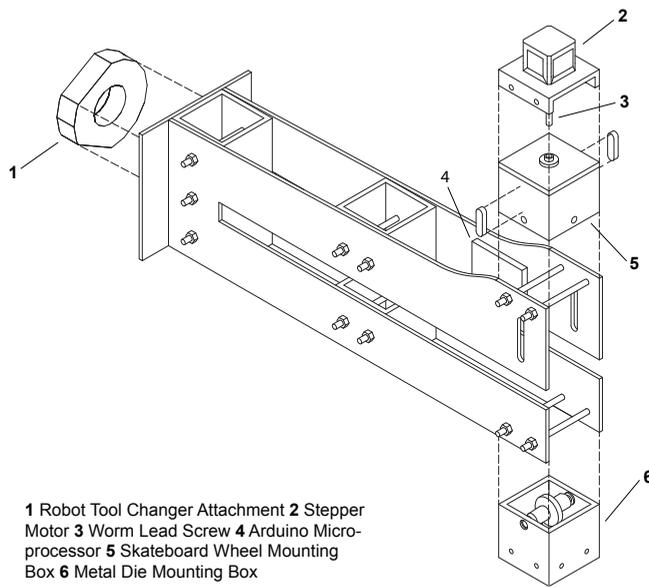
1 Detail

ROBOTICS AND AUTONOMOUS DESIGN SYSTEMS

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.



2 Bottom: Pattern Panel

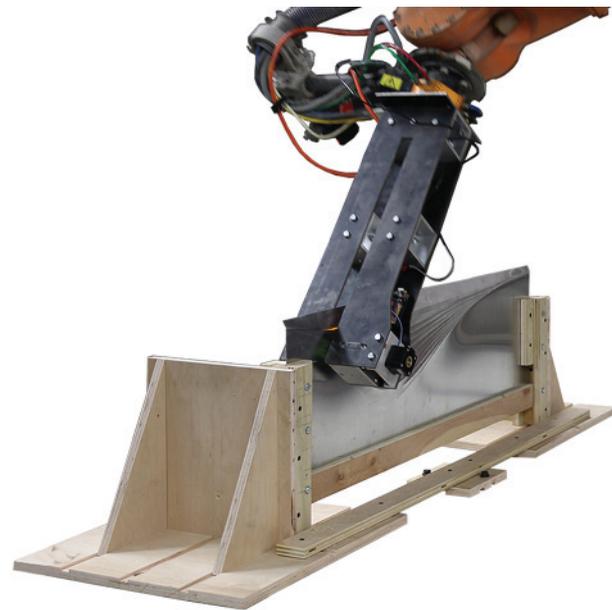


1 Robot Tool Changer Attachment 2 Stepper Motor 3 Worm Lead Screw 4 Arduino Micro-processor 5 Skateboard Wheel Mounting Box 6 Metal Die Mounting Box

3 Diagram

TOOL DEVELOPMENT

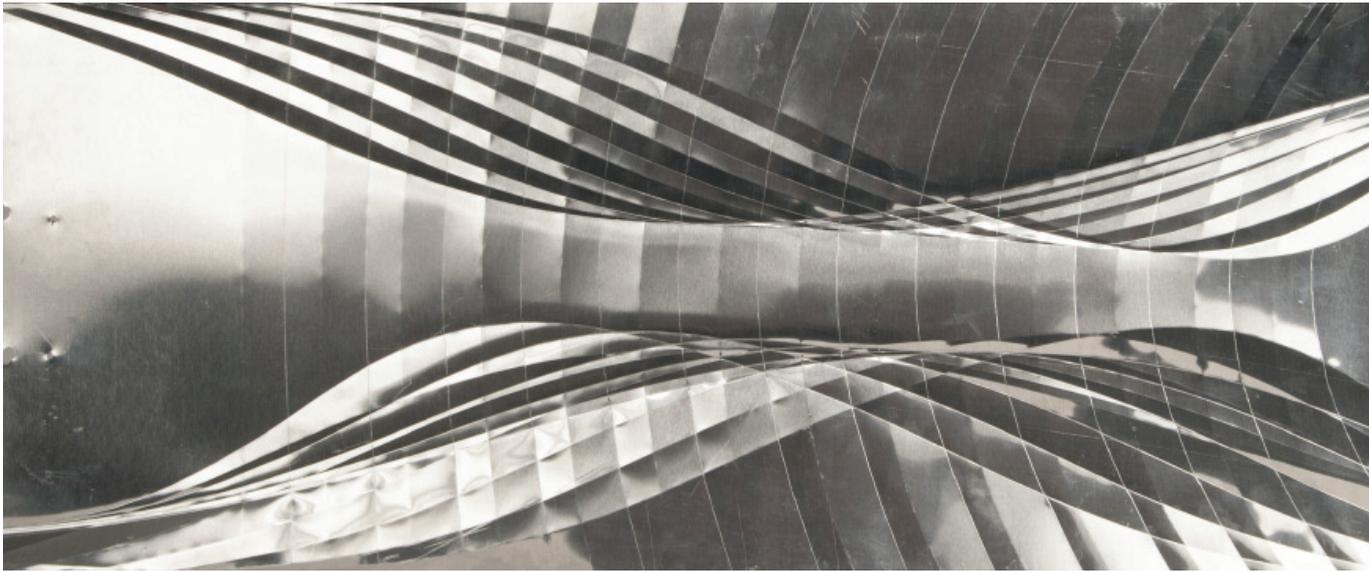
Emulating the function of traditional bead rollers, an end effector was developed consisting of two spinning wheels affixed to the end of a steel body. The top wheel, a rubber skateboard wheel, enables intersecting corrugations without destroying the bead profile. Remotely controlled through the pairing 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.



4 Robot

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.

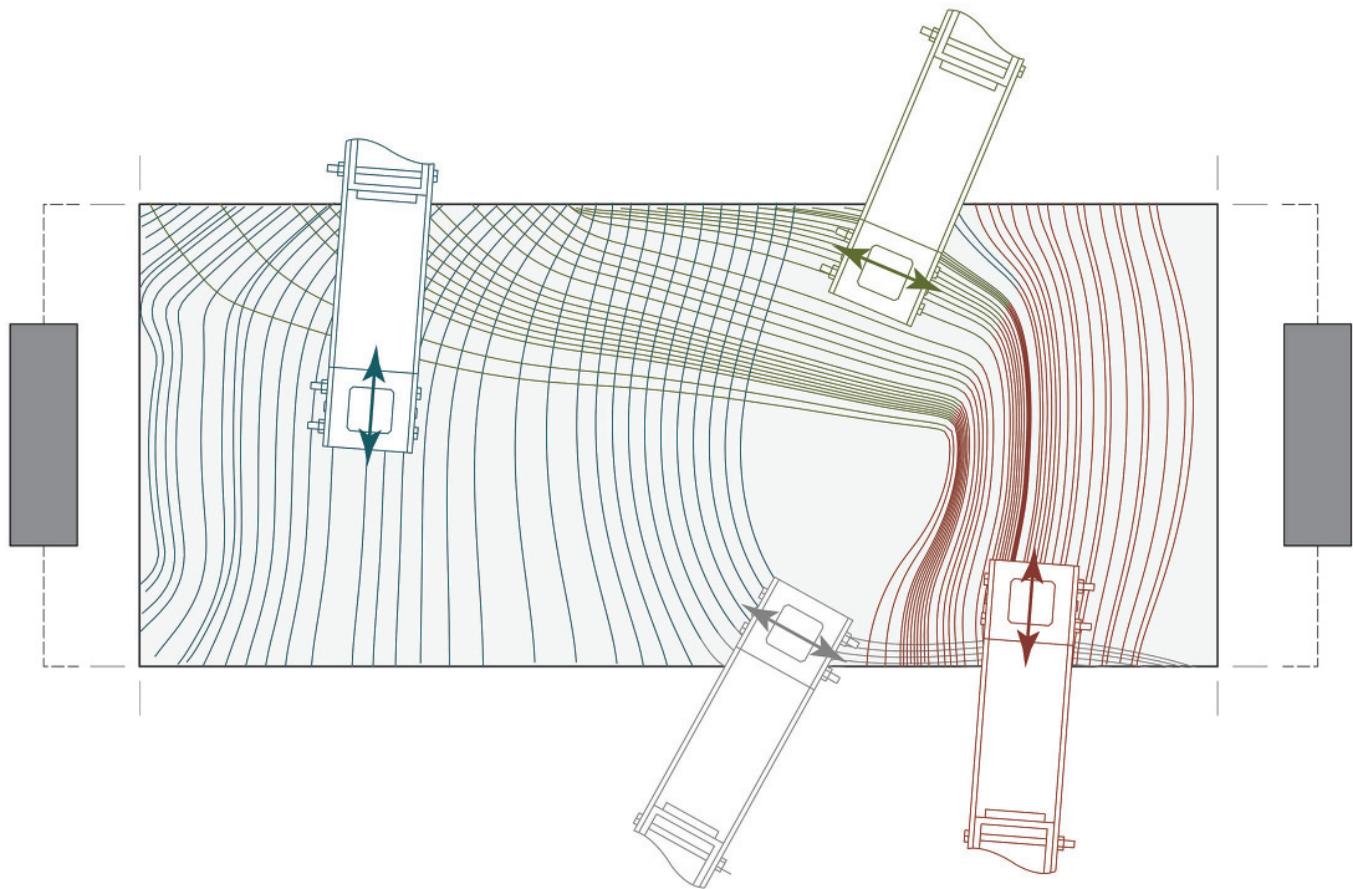


5 Bead Rolling

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.



6 Tool Approach

ACKNOWLEDGEMENTS

This research was conducted under the guidance of instructor Andrew Witt and fabrication specialist Burton LeGeyt during the course: Expanded Mechanism/Empirical Materialisms at the Harvard University Graduate School of Design; Cambridge MA; Fall 2013.

IMAGE CREDITS

All image credits to Authors (2014).

JARED FRIEDMAN is currently a student at the Harvard Graduate School of Design where he is pursuing a Masters in Design Studies within the Technology concentration. Coming from a background in architecture and construction, Jared is interested in exploring how emerging technologies and fabrication processes can influence traditional methods of construction and material use. Jared's professional experiences have led to his interests in innovative digital workflows and building delivery methods in the Architecture, Engineering, and Construction industry. He believes there is an opportunity to advance the reciprocal relationships between design ideas, material use, fabrication, and assembly methods.

AHMED HOSNY is currently pursuing a Master's degree in Design Technology at the Harvard University Graduate School of Design. His work bridges design computation with material behavior. Using data aggregated from material performance, feedback loops are generated informing design decisions. Prior to his graduate career, Ahmed was involved with Foster + Partners in Beijing responsible for the cladding and steel structure packages on the Datong Art Museum. He also managed a small team for Playze in Shanghai recycling shipping containers into habitable spaces. Ahmed received a NAAB-accredited Bachelor of Architecture from the American University of Sharjah 2009.

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.