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Feasibility of Using Additive Manufacturing to Produce Automotive Tooling

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Energy and Transportation Science Division
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Feasibility of Using Additive Manufacturing to Produce Automotive Tooling

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This CRADA NFE-17-06828 was conducted as a Technical Collaboration project within the Oak Ridge National Laboratory (ORNL) Manufacturing Demonstration Facility (MDF) sponsored by the US Department of Energy Advanced Manufacturing Office (CPS Agreement Number 24761). Opportunities for MDF technical collaborations are listed in the announcement "Manufacturing Demonstration Facility Technology Collaborations for US Manufacturers in Advanced Manufacturing and Materials Technologies" posted at http://web.ornl.gov/sci/manufacturing/docs/FBO-ORNL-MDF-2013-2.pdf. The goal of technical collaborations is to engage industry partners to participate in short-term, collaborative projects within the Manufacturing Demonstration Facility (MDF) to assess applicability and of new energy efficient manufacturing technologies. Research sponsored by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office, under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

ABSTRACT

Oak Ridge National Laboratory's (ORNL) Manufacturing Demonstration Facility (MDF) worked with Diversified Tooling Group (DTG) in phase I of this technical collaboration to determine the feasibility of using additive manufacturing to produce automotive tooling using polymer Big Area Additive Manufacturing (BAAM) systems and will potentially work with DTG in phase II on metal BAAM systems. The following phase I goals in polymer BAAM were met: a polymer sheet metal check fixture and a polymer foundry casting pattern were completed and shipped to DTG.

1. THE FEASABILTY OF USING ADDITIVE MANUFACTURING TO PRODUCE AUTOMOTIVE TOOLING

Phase I of this technical collaboration project (MDF-TC-2017-124) began on July 26, 2017 and was completed in December 2017. DTG is a small automotive tooling company that provides a wide variety of tooling and end use parts for major original equipment manufacturers. During this project, two tools were manufactured by ORNL using the polymer BAAM system. A check fixture and a sand casting mold were fabricated using 3D printing, machined using a Thermwood CNC router, and shipped to DTG for testing. The check fixture meets 100% of the requirements as delivered, provides a useful tool now, and validates the concept for future use.

The foundry tool was delivered according to the original specifications provided by DTG; however, it was determined to be too heavy for their use. A second foundry tool was printed in a lightweight version and shipped to DTG; however, some machining errors occurred due to a fault in the Thermwood router that was not identified until scanning of the tool occurred at DTG. A repair path has been identified but has not been completed at this time. However, the concept has been validated as sound.

1.1 BACKGROUND

DTG is considered a small-medium enterprise (SME) and has a long history of providing a wide variety of tooling and end use parts for all of the major original equipment manufacturers (OEM) in the automotive industry. Current methods for manufacturing automotive tooling are very energy intensive and require long lead processes. Foundries provide billets that must be machined to the final net surface leading to significant waste. The goal of the project is to evaluate the impact, in terms of time and cost, that additive manufacturing can have in reducing DTG's manufacturing cost and lead times. The ability to manufacture tooling faster and cheaper will enable DTG to compete more globally. Furthermore, the results of the project will be demonstrated at tooling trade shows to help other U.S. tool and die manufacturers improve their global competitiveness. The overall goal is to help restore the U.S. automotive tool and die industry, and to help develop the next generation of tooling engineers knowledgeable about the impact of additive manufacturing.

1.2 TECHNICAL RESULTS

Two different types of tools were 3D printed on a polymer BAAM system during the first phase of this project. The first tool manufactured was a check fixture. Check fixtures are structures that hold sheet metal parts for inspection. Geometries of check fixtures can be complex, but the load requirements are usually very light. Fig. 1 shows the CAD model of the finished check fixture. The part was first printed on the BAAM system and then post-machined on the Thermwood 5-axis mill to bring it into the final required tolerances. The check fixture was printed using 20% by volume carbon fiber reinforced Acrylonitrile butadiene styrene (ABS) polymer. The check fixture weighed 51 lb., measured 18.5” x 6” x 18.8”, and took 1 hour and 35 minutes to print.

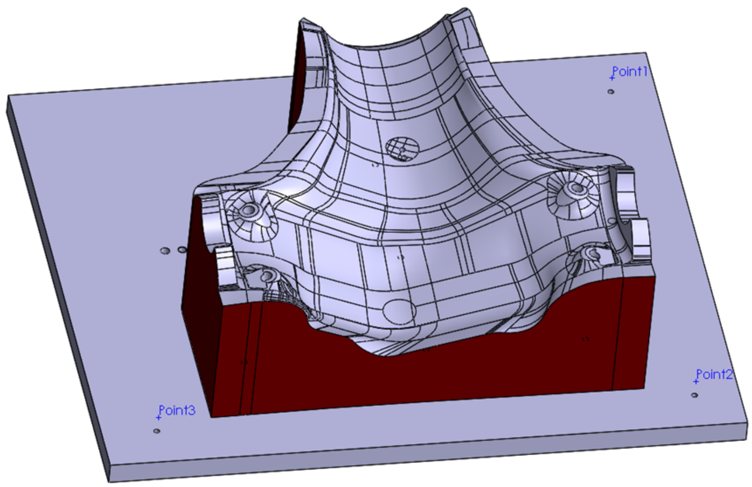


Fig. 1. CAD model of the check fixture.

After DTG received the MDF manufactured check fixture, they tested it in actual application, and it met all functional requirements and tolerances. This component is usable as is in real world service for the intended application. Therefore, this is a valid use of polymer BAAM technologies.

The second tool manufactured was a foundry sand casting pattern. The automotive industry generally produces many parts via casting. The patterns are shapes that go into the sand casting to create an imprint of the part to be casted. Creating the patterns can be a costly and time-consuming process. The MDF designed CAD model of the pattern is shown in Fig. 2. It was designed to be printed in two parts that were then to be epoxied together to accommodate post-machining requirements. The sand casting pattern was printed using 20% by volume carbon fiber reinforced ABS polymer. The bottom, or larger, section of the sand casting pattern weighed 440 lb., measured 12” x 55” x 17.6”, and took 6 hours and 1 minute to print. The top, or smaller, section of the mold weighed 230 lb., measured 12” x 55” x 8”, and took 3 hours and 12 minutes to print. The post-machining process is shown in Figs. 3-4.

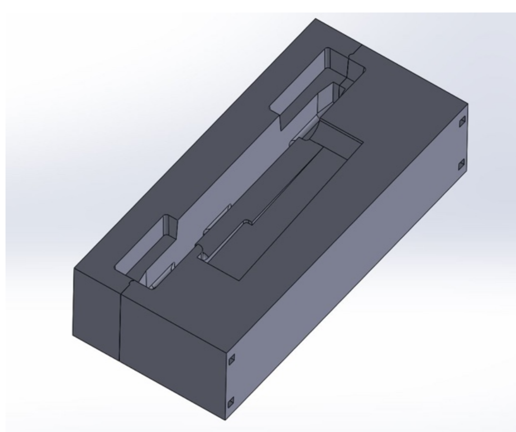


Fig. 2. CAD model of the casting pattern. Both the top and bottom sections of the pattern are shown together.

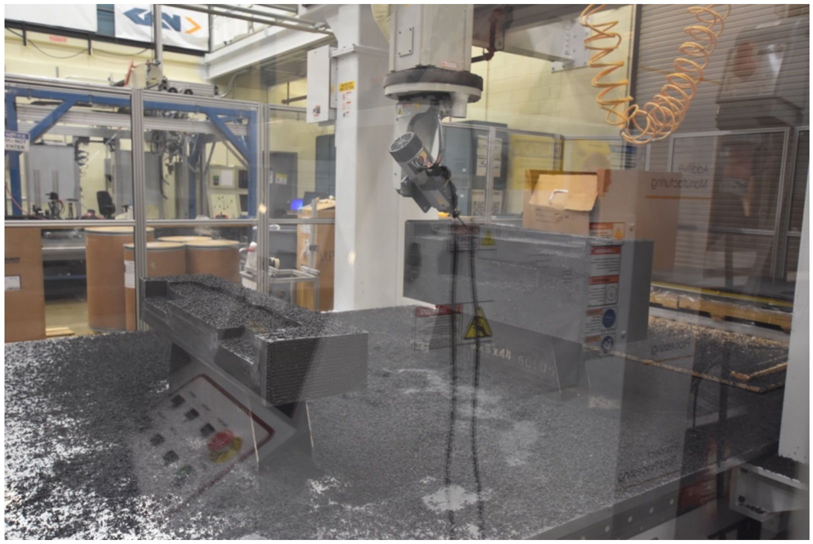


Fig. 3. The top (front) and bottom (back) sections of the casting pattern during the machining process.

Fig. 4. The top and bottom sections of the casting pattern with epoxy applied to them to fill voids that occur during the printing process and are revealed during the machining process.

After DTG received the foundry pattern tool, it was determined that it met all specifications as designed. However, the weight was too high for their use, and DTG decided that they wanted further modifications before use in a real-world application including the use of an alternate fill pattern to light weight the part for easier handling. A second version of the tool was printed, machined, and shipped to DTG. After DTG received the second pattern, it was laser scanned for geometric accuracy as seen in Appendix A. The laser scan data revealed that an error had occurred during Thermwood routing machining that put the part out of tolerance on one surface. A repair procedure was sent to DTG for their consideration but has not been completed at this time, and will not be part of this project.

1.2.1 Recommendations for Additional Work

If approved, the second phase of this project will focus on the development of a low volume draw die and a hot stamping die using the metal BAAM technology. The low volume draw die will be a conventional three-piece die to assess friction, wear-ability of forming surface, and overall structural integrity for 1,000 tons of repeated compression in a stamping press. The hot stamping die will be used to form and heat treat hot sheet metal stamping (900 C) and will rapidly cool to harden a panel. The primary challenge will be the integration of cooling lines into the hot stamping die to rapidly quench the material.

1.3 IMPACTS

The tool and die industry for the automotive industry has been in steady decline in America. Approximately 80% of the tooling for the automotive industry has been off-shored to Asia. The goal of this project is to evaluate the feasibility of using large-scale additive manufacturing for automotive tooling. The project opens the potential to significantly reduce tooling costs and lead times enabling the reshoring of tooling to the U.S.

The phase I work has determined that the use of polymer BAAM technology for both the check fixture and the foundry core mold/pattern tool is practical and cost effective for real world use. The path forward is determined by commercial access to polymer BAAM printing.

1.3.1 SUBJECT INVENTIONS

No subject inventions resulted from the technical collaboration.

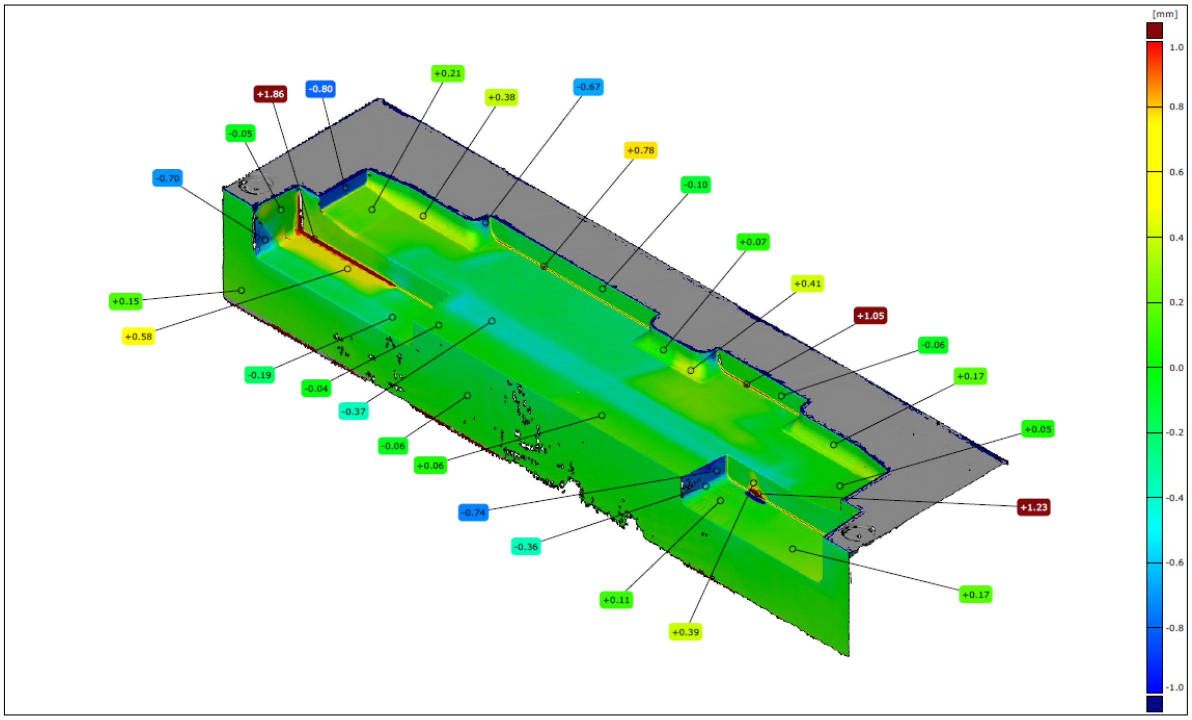
1.4 CONCLUSIONS

The polymer BAAM activities of phase I have been completed. The use of polymer BAAM with post-machining for high accuracy to quickly create check fixtures for stamped sheet metal quality control is a good fit of the technology. The use of polymer BAAM to produced foundry cores for casting shows serious promise that should be explored.

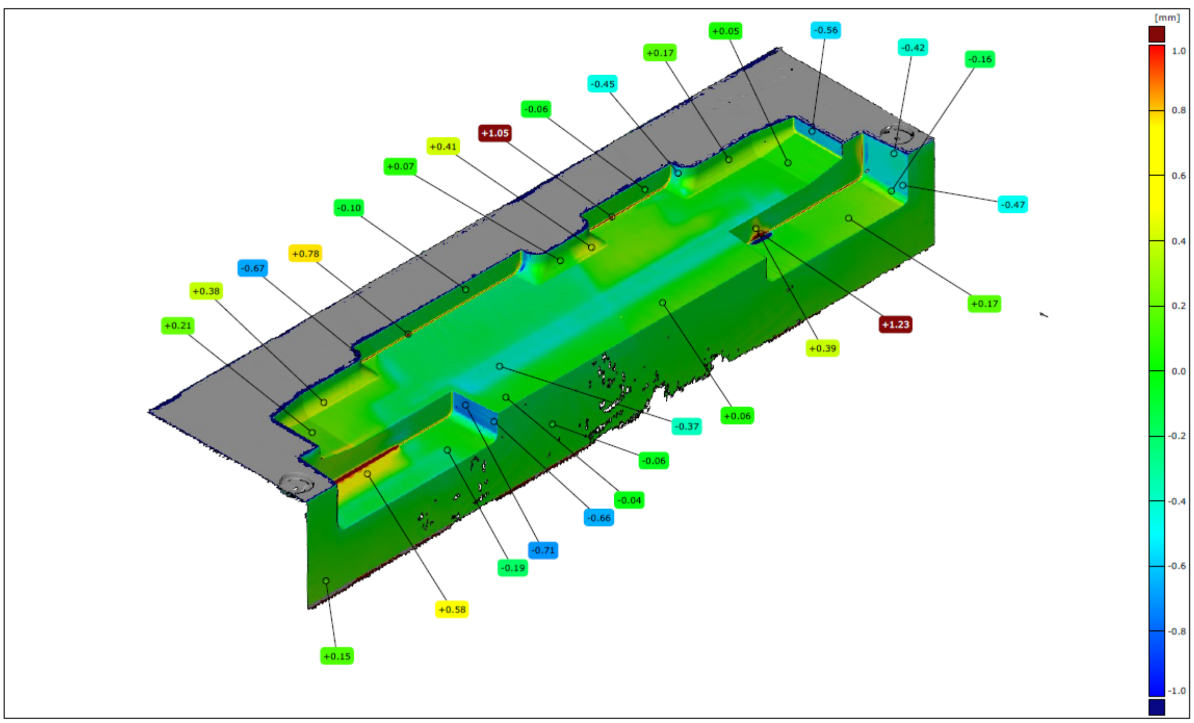
2. DIVERSIFIED TOOLING GROUP BACKGROUND

With DTG's four affiliated companies and 505,000 square feet of engineering and manufacturing floor space, DTG delivers single source solutions to the automotive, heavy truck, defense, oil & gas, power generation, infrastructure, rail, and foundry industries. As its name implies, Diversified Tooling Group's diversified capabilities enable DTG to be a full-service manufacturer of prototype and production stamping dies and low-volume stamped parts as well as the fabrication, machining, and assembly of some of the largest and most highly engineered components made today.

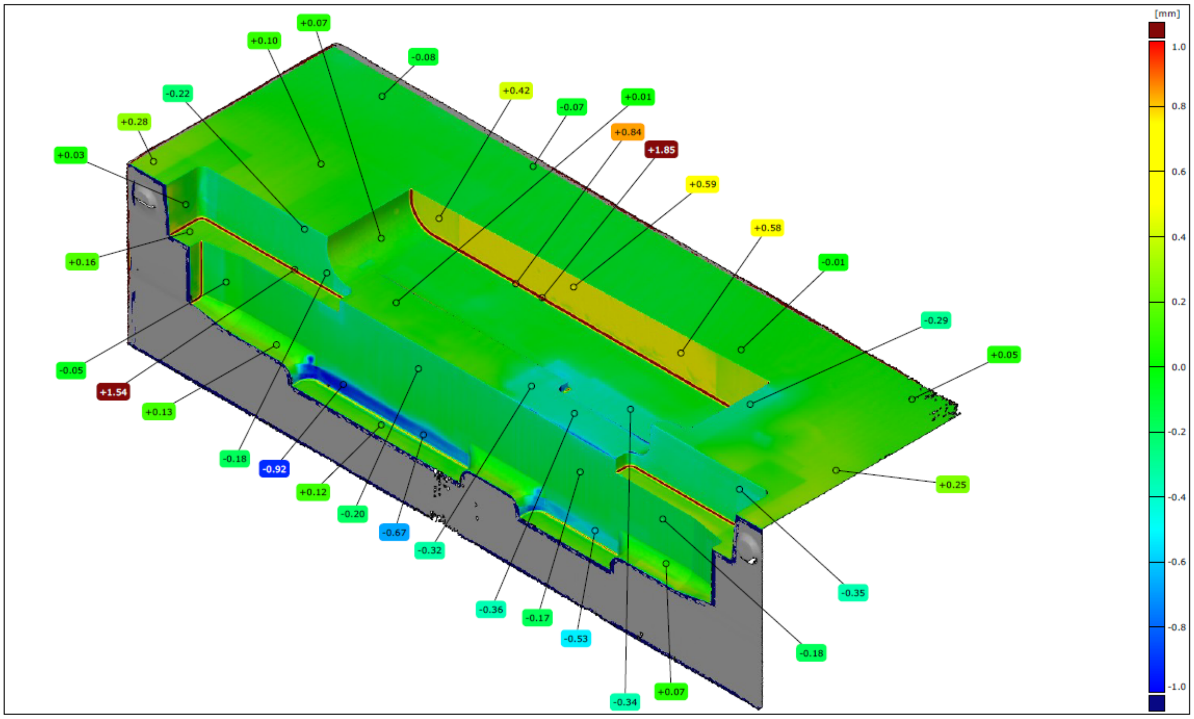
APPENDIX A



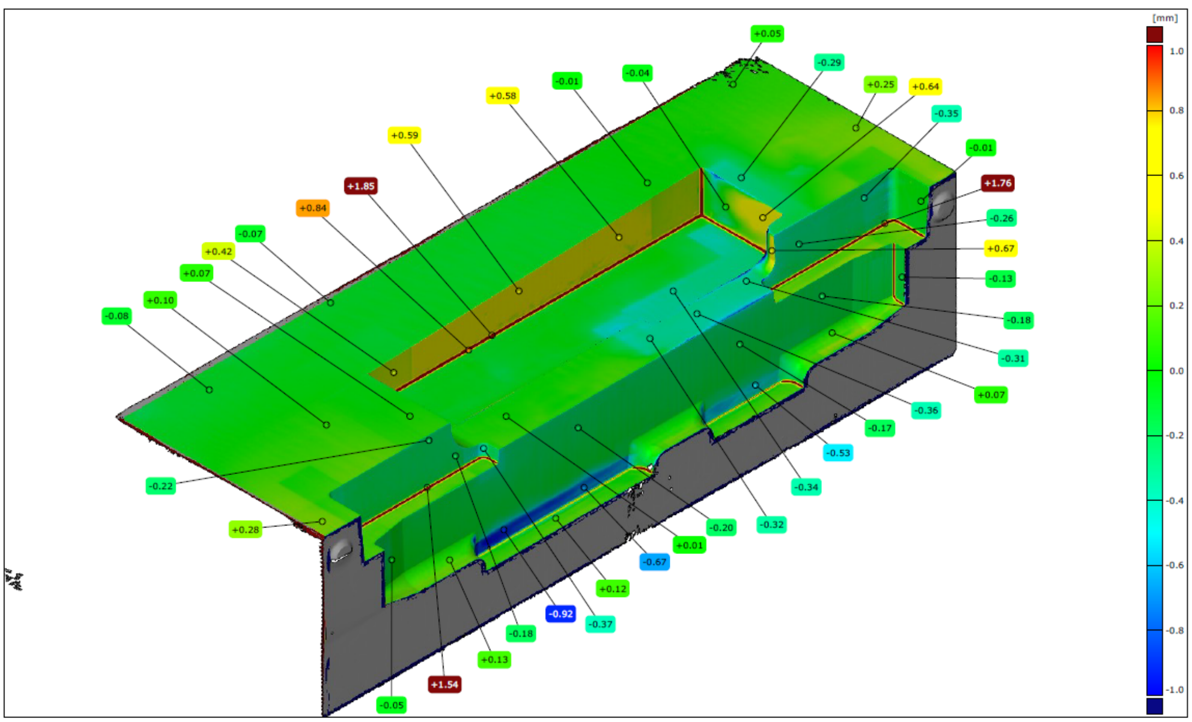
Top section of the casting pattern.



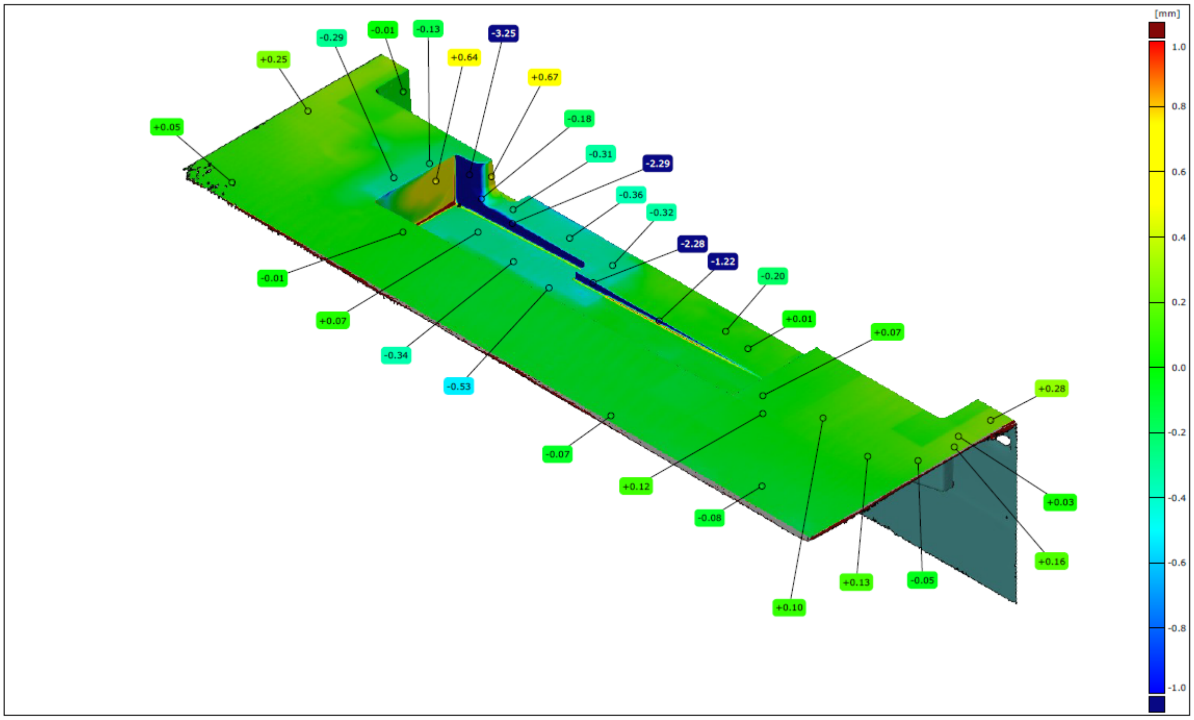
Top section of the casting pattern.



Bottom section of the casting pattern.



Bottom section of the casting pattern.



Bottom section of the casting pattern.