2023

Automated Forming Outputs for Compound Curvature - Final Report

AGREEMENT #2019-483-06

SHIPCONSTRUCTOR SOFTWARE INC. (SSI)

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FINAL REPORT
AUTOMATED FORMING OUTPUTS FOR COMPOUND CURVATURE
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Executive Summary of Results

The Automated Forming Outputs for Compound Curvature Rapid Adoption Project was completed with the final demonstration at Austal USA on July 11, 2023. During the final demonstration, actual outputs from ShipConstructor were used to form production hull plates on a Nieland Press for an actual Navy program. The demonstration validated the workflow that was designed and developed to improve the flow of information from Engineering to Production.

During the course of the project, SSI was able to modify its Hull product to generate outputs to support the forming of complex curved plates on a Nieland Press. This output includes the ability to mark the plate with elongation values and a grid to indicate the location where pressure would need to be applied. The elongation values are converted into pressure using a Nieland generated pressure table. This approach allows the engineering team to use only one tool to generate forming outputs directly from ShipConstructor instead of the complicated process which required three different software tools and significant manual processes. Using the new process, forming data is generated directly from ShipConstructor reducing engineering time, cycle time, and opportunities for errors. Further, the availability of marking forming information directly on the plate improves operator understanding, making the forming process more efficient with fewer errors.

The approach required the creation and modification of two separate expansion algorithms: 1) expansion based on center elongation (i.e., bulbous bow section) 2) expansion for edge elongation (saddle shape). These expansion algorithms were provided to Austal USA to support generation of hull plate drawings and marking of a current Navy program to support immediate implementation. These capabilities are being further developed for inclusion in a future release of ShipConstructor's hull product which will benefit all SSI customers and multiple future programs. The project team reviewed its findings and approach in a meeting with Nieland after the final demonstration.

Category B: Data developed partially with funding from Project Participants that was not charged to a government contract and partially with Government funding.

Distribution Unlimited

We would like to thank all the participants for their contributions to this project.

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Project Returns

- Defined the process and information required by an operator to form curved plates using a Nieland forming press.
- Identified the information needed to translate hull geometry data contained in ShipConstructor into parameters that could be used by the operator to form the plates.
- Developed/modified two separate expansion algorithms to support the information requirements:

    - A center expansion algorithm for forming bulbous shapes.
    - An edge expansion algorithm to form saddle shapes.
- Modified the user interface within ShipConstructor's hull product to allow an engineer to generate the expansion data.
- Provided the ability to mark plates with expansion values and a grid to locate points where pressure should be applied.
- Multiple iterations testing various geometries against a 3rd party tool to validate accuracy of modified expansion algorithms.
- Final demonstration at Austal USA on actual production hull plates
- Deployment of revised hull product at Austal USA to support current Navy programs.
- Inclusion of new hull functionality in a future release of ShipConstructor (likely spring 2024) to allow all SSI customers to benefit from the results of this project.
- The Technology Readiness Level (TRL) of this functionality is TRL 9 at the conclusion of the project.

Project Overview:

The press operator, per information obtained, requires a location to position the plate on the press so the head is positioned properly to achieve the correct elongation and the appropriate pressure setting required for the proper elongation.

Prior to this project, Austal USA exported the data from the ShipConstructor 3D model to Rhino. The Rhino data is then exported to another CAD application where the file is further modified. The other software provides maps with elongation values. The elongation values are cross referenced to the Nieland Elongation – Pressure Table specific to the material type by material thickness. A person, the operator, uses the elongation values to determine the press pressure requirement. Additionally, the software's output shows work lines and other data points such as frames for the press operator to use as references. This workflow is a manual process while the duration to import the data from the ShipConstructor 3D model into another software can take up to a week.

This project had two (2) objectives:

1. This RAP developed a method to automate the press elongation pressure values using the ShipConstructor 3D model of a curved plate to determine the pressure setting value from the Nieland Elongation – Pressure Table. This eliminates the lengthy duration and complicated process of exporting the ShipConstructor 3D model for use in other software tools.
2. This RAP provided guidance for work lines to aide etching or marking on the plate through the ShipConstructor 3D model to assist the operator regarding where and how to position the plate for the most efficient press operation.

Project Results

The project began with the assumption that the project team could use existing geometry data within ShipConstructor and create a third-party translator application to generate the information needed to support forming curved plates. It was determined after an initial analysis and design effort that using the SSI already available Pin Jig data would not work with Austal USA using the press to form cones and cylinders.

The project team decided to move development to within the ShipConstuctor Hull product to reduce further complexity for the user and the necessity to purchase any additional software. The project team compared ShipConstructor's Hull product's current offering to what is required for Nieland pressure tables. A new expansion algorithm had to be developed to support edge elongation cases. Further, since this effort is more art than science, providing the operator with the work lines and elongation value at each intersection is a vast efficiency improvement. Regarding the pressure, the table increments for each tenth of a millimeter of elongation is 2 metric tons; therefore, the pressure from the table is approximated to allow the operator a ballpark to start from.

For SSI to assess table modifications, Austal USA developed a shaped plate. This shape was processed for forming by the Nieland Press using the other software workflow. Below is SSI's first run with the table assessment. Even though the color output does not reflect the other software's map output color, the data is not too far apart.

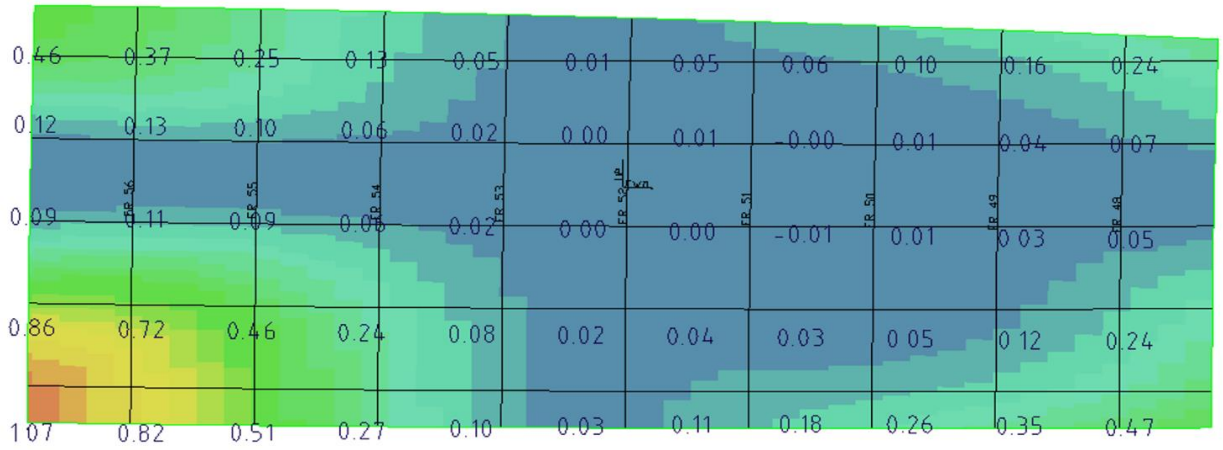

Figure 1: Initial Elongation Map

For ShipContructor's numerical elongation methods to get close to the provided values, the pressure application must be in specific locations. ShipContructor developed methods to laser etch grid lines on the plate to assist the operator in applying the Neiland press in the specific spot. Plate etching is a feature that can be turned off if this operation leads to a bottle next to the cutting tables. The locations will need to be marked by some other means.

Two computational methods have been developed to generate the information required for the Nieland press. For elongation on the edge of the plate one method is used and for elongation in the center of the plate another method is used. The edge of the plate elongation method is used on saddle shaped panels. The center elongation method is used on plates with center plate deformation, like bulbous bow panels.

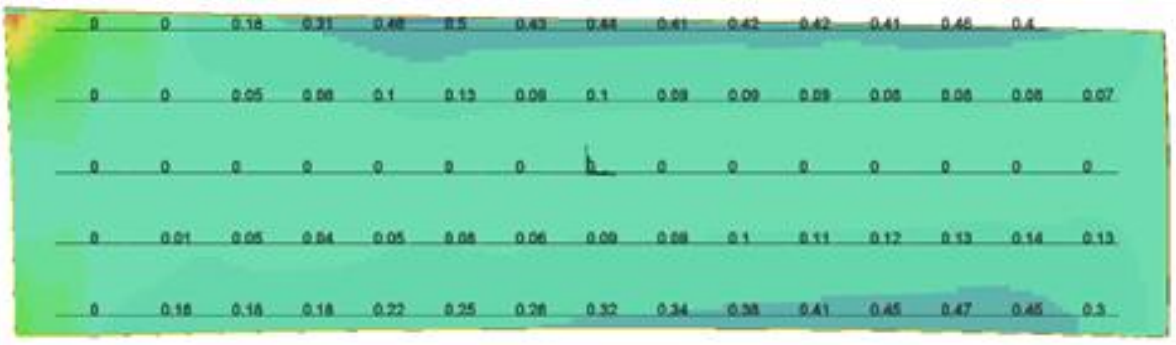

Figure 2 Edge Elongation

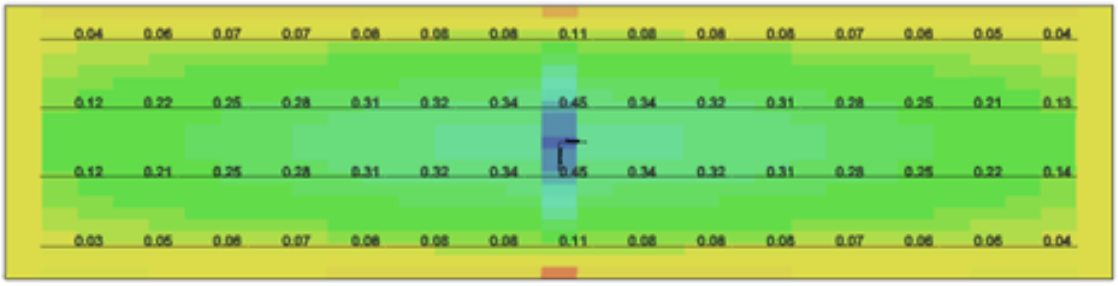

Figure 3 Center Elongation

Since the expansion algorithms are being developed from scratch, the test and evaluation process included multiple iterations of developing expanded plates and comparing them to the manual process. Austal USA provided multiple hull drawings from a current project. This project was not export controlled to allow SSI Corporate easy access to it without requiring a Technology Assistance Agreement. The hull plates included two different types of geometry representing both types of expansion: center elongation and edge elongation.

Center elongation expansion tended to match closely with the manual process. The expansion algorithm consistently produced expansion profiles that only needed to be adjusted to accommodate the 900 mm spacing required by the Nieland press pressure table. The goal is to produce a result that can be marked on the plate to aid the operator in production without having to constantly refer to a drawing.

The project team discussed the output requirements needed to create a separate visual aid in addition to the plate marking. SSI recommended the creation of an assembly drawing with the expanded plate, another view showing a 3D image of the formed plate, and a final view of the formed plate with the template's locations included. The project team reviewed this proposed output with Austal, and they agreed that the output would be adequate to support the forming operation in addition to the plate markings, including frame lines and longitudinal construction lines. Creation of assembly drawing is also a core function of ShipConstructor. The drawing below represents a sample output supporting the plate forming operation.

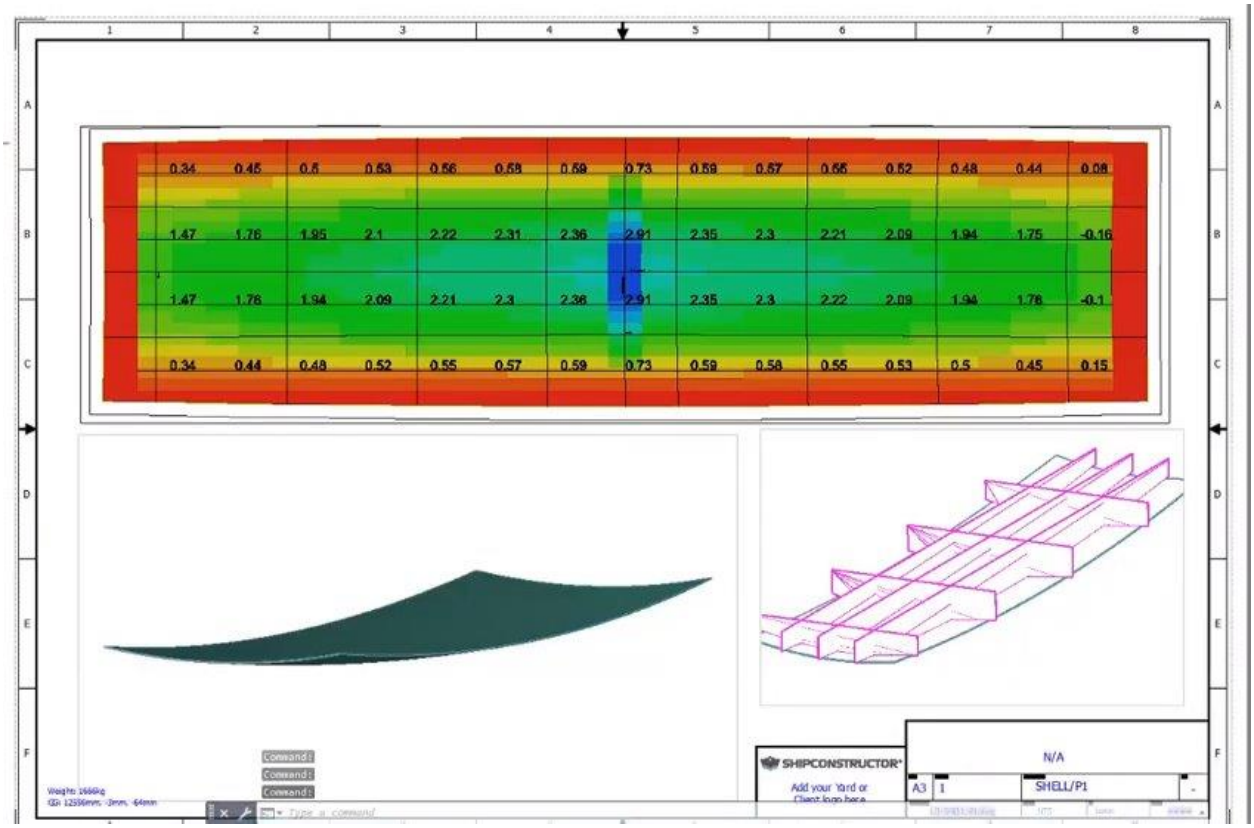

Figure 4: Sample Output

The edge elongation algorithm did take some additional iterations of testing to generate a consistent result that achieved similar values to the manual process. Austal provided multiple samples and the SSI team used the new edge expansion algorithm to generate the elongation values. These values had to be scaled similar to the center elongation values to support the 900 mm spacing to match the Nieland press pressure table. After several iterations this algorithm was accepted by Austal engineering and preparations were made to support the final demonstration which would be held onsite at Austal.

Technology Transfer and Implementation

The demonstration was scheduled to take place at Austal USA on July 10, 2023, where Austal production would form a production plate from each type of formed plate: center stretch and edge stretch. The demonstration was performed in Austal's new steel production facility on the Nieland press. The demonstration included the press operator, two representatives from Austal Engineering, and the

Austal ECB representative. Only one participant was in attendance from SSI as another SSI participant had an issue with the visitor badge and could not get access to the facility.

Austal had prepared the production plate to support the edge elongation demonstration. The plate had been cut and marked with the elongation values, longitudinal construction lines, and frame lines (see Fig 5 below). The elongation values were located at the intersection of the longitudinal lines and frame lines. Before the operator started the forming process, he had to change out the press die for the English wheel configuration. The English wheel applies pressure to the plate while the plate moves between the wheels to provide constant pressure across the width of the plate. The pressure is adjusted while the plate moves to generate the correct elongation to form the required curvature. The other die that is used for forming plate is a punch and die similar to a break press. The operator uses a combination of the two tools to form the plate.

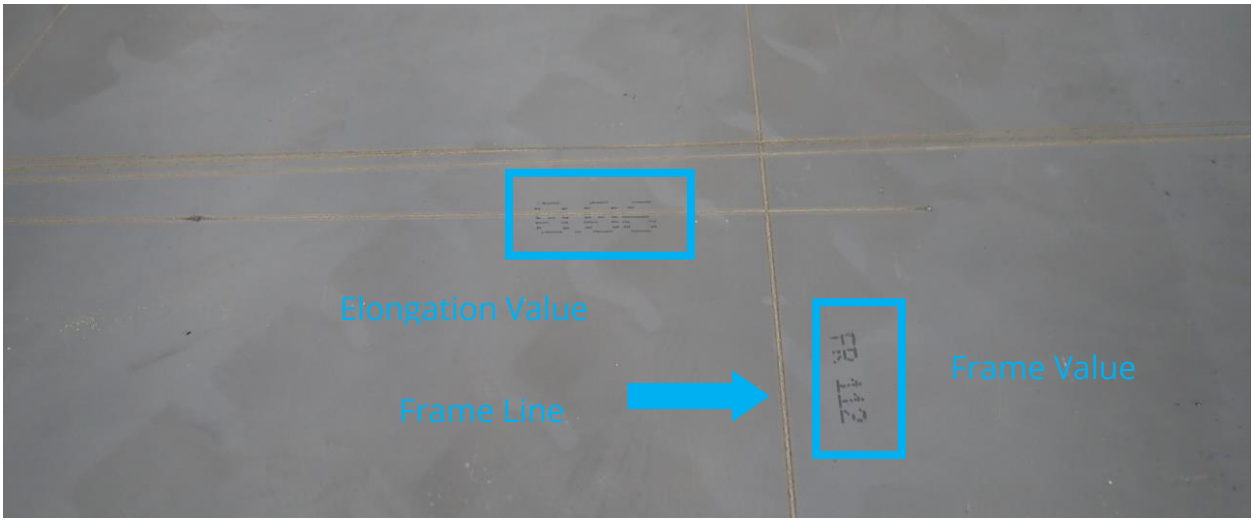

Figure 5: Picture of Marked Plate

The operator analyzed the plate markings and determined how the plate will need to be formed. He proceeds to form the plate using the English wheel and the pressure values that were derived from the elongation numbers. The operator still requires a template which has been pre-cut to validate the final geometry. This template is also generated by ShipConstructor's Hull product. After the plate is stretched using he English wheel, the die is changed to a punch to complete forming the plate. The template is used heavily throughout this process to validate the geometry. The overall process takes approximately one 8-hour shift to form a

single large complex curved plate. Pictures from the demonstration are included below.

Figure 6: Initial Layout Prior to Forming

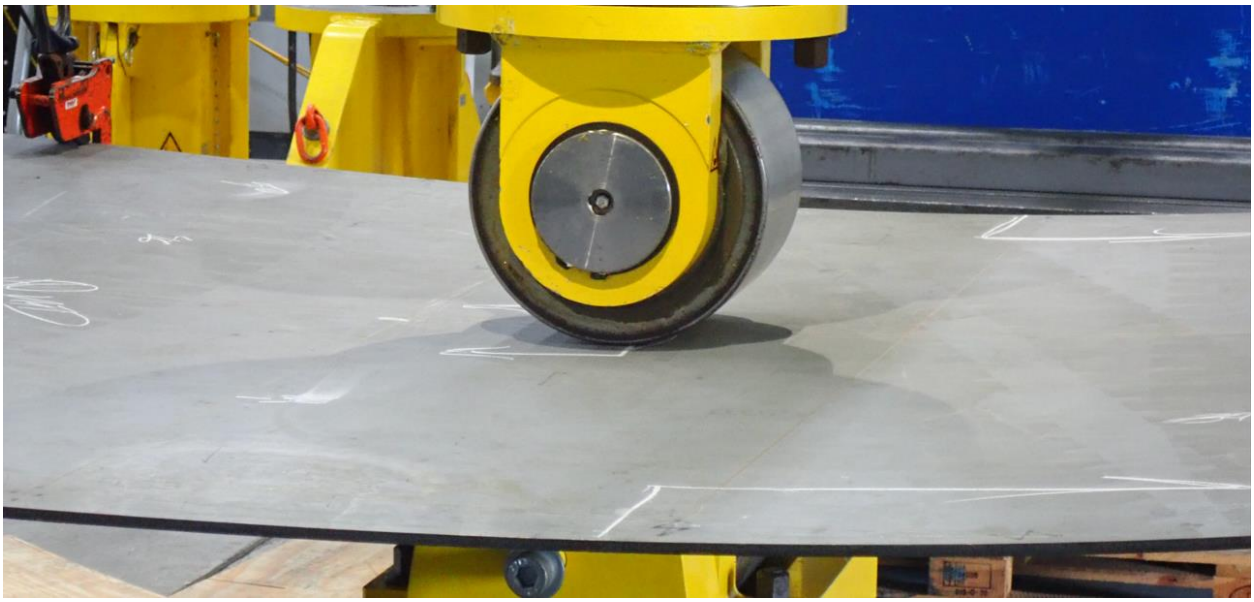

Figure 7: Plate Stretching Using English Wheel

Figure 8: Forming Complex Curvature Using Punch Die

Figure 9: Final Shape of Plate with Edge Elongation

At the conclusion of the final demonstration, Austal USA asked when they would be able to get a version of ShipConstructor to allow them to create their own forming outputs in the ShipConstructor hull module. SSI committed to provide the updated version of their current version of ShipConstructor (2022 R2.2.1) to support generation of automated forming outputs for Nieland operations directly from the Hull product. Further, SSI has included this functionality in its current development

roadmap. The basic functionality demonstrated during this NSRP RAP project will be enhanced to provide a more robust user experience and will be included in the future release of ShipConstructor's hull product. The exact version of ShipConstructor is still to be determined but once this capability is available, it will allow all of SSI's client base to exploit the features to enable more robust forming outputs for complex curved plates.

The results from this project were presented at the Planning Production Processes and Facilities Panel meeting in Oak Ridge, TN in July 2023. This project was also submitted as an abstract for the SNAME production symposium, however, SSI decided not to complete the paper due to delays in the overall project which would have prevented documenting the final results. This project would be a candidate for presenting at future panel meetings or industry events. The current technology readiness level of this functionality is TRL 9.

Conclusion and Recommendations

This Rapid Adoption Project developed a capability to generate outputs directly from ShipConstructor that can be used to form complex shapes on a Nieland press. Prior to this project, the process for generating these outputs required multiple software applications and could take almost one week to generate the parameters for one plate. This new functionality also provides the capability to mark the plate with relevant information to assist in the plate forming process. The demonstration of this functionality was successful, and the new functionality will be used immediately to help with the plate forming process on current Navy contracts and Austal USA resulting in this functionality being TRL 9. The SSI development team plans to enhance this initial functionality further and eventually release it as part of it is Hull product so that all SSI customers who use Nieland presses for forming hull plates can benefit from this new process. Several recommendations were made during the final demonstration and are being incorporated into the development plan.

SSI has had additional discussions both internally and with other shipyards about additional concepts to further enhance the forming process. Additional technologies such as augmented reality or 3D scanning technologies have been proposed as potential enhancements to provide feedback to the overall forming process. SSI is considering additional research projects to address these needs.