Additive Manufacturing for Nautical Design:
An Automated Approach to Marine Manufacturing

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Abstract: How can additive manufacturing (AM) technology be applied to automate the production of small marine vessels? For the past 50 years small (below 40 meters) marine vessel manufacturing has been dominated by moulded fiber-reinforced plastics (FRP). There are several shortcomings to this manufacturing method that affect both the formal outcome and the manufacturing process of boats built in FRP: 1) manufacturing requires the use of expensive moulds, 2) formal geometric freedom is limited by moulds which reduce the potential for customization, and 3) special assemblies and structural reinforcements must be moulded separately and joined using a time-consuming hand lay-up process. The use of AM may reduce cost of production by eliminating need for moulds, allow greater ease of customization, and improve worker safety by limiting exposure to harmful materials and chemicals.

The purpose of this research project is to evaluate existing AM technology and assess its potential for application to small marine vessel manufacturing. The project aims to investigate new methods for generating novel AM tool paths and demonstrate through proof of concept that it may be possible to produce the complex topological surfaces and assemblies that are common in marine vessels using multi-bias additive manufacturing (MBAM). However, AM is a broad term that describes a variety of different ways to manufacture objects. As such, AM can be applied to marine manufacturing in a variety of different ways, in different phases of the manufacturing process, and to different extents. At the same time, building boats is a complex process that presents specific problems that must be addressed in any automation solution. Several marine vessel construction projects have already been completed using AM which can serve as case studies for understanding the opportunities and challenges for applying AM to the marine sector. A review of the current state of the technology and qualitative analysis (QA) of case studies provides a set of guidelines for designing a manufacturing method that may prove effective for producing small marine vessels using AM.

The project relied on design-based research (DBR) to develop a series of experimental extruder prototypes for novel toolpath testing on excerpts from a small reference vessel. The combination of QA and DBR experimentation point to a manufacturing solution using articulated robotic manipulators and a continuous fiber thermoset plastic extruder using a modified version of the fused filament fabrication process. This kinematic solution can be extended with external linear or rotational axes and/or by mounting robotic manipulators within a large gantry. This will allow the extruder to approach the work using a wide range of orientations that will be optimal for both the geometry of marine vessels

and the requirements of MBAM extrusion. Meanwhile, toolpath generation using the software Rhino 7.0 with Grasshopper and KukaPRC plugins demonstrated a proof of concept for creating MBAM toolpaths optimized for small marine vessels. While the method proved feasible for smaller excerpts there remain significant challenges to successful deployment of this manufacturing method that can only be addressed with additional research.

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