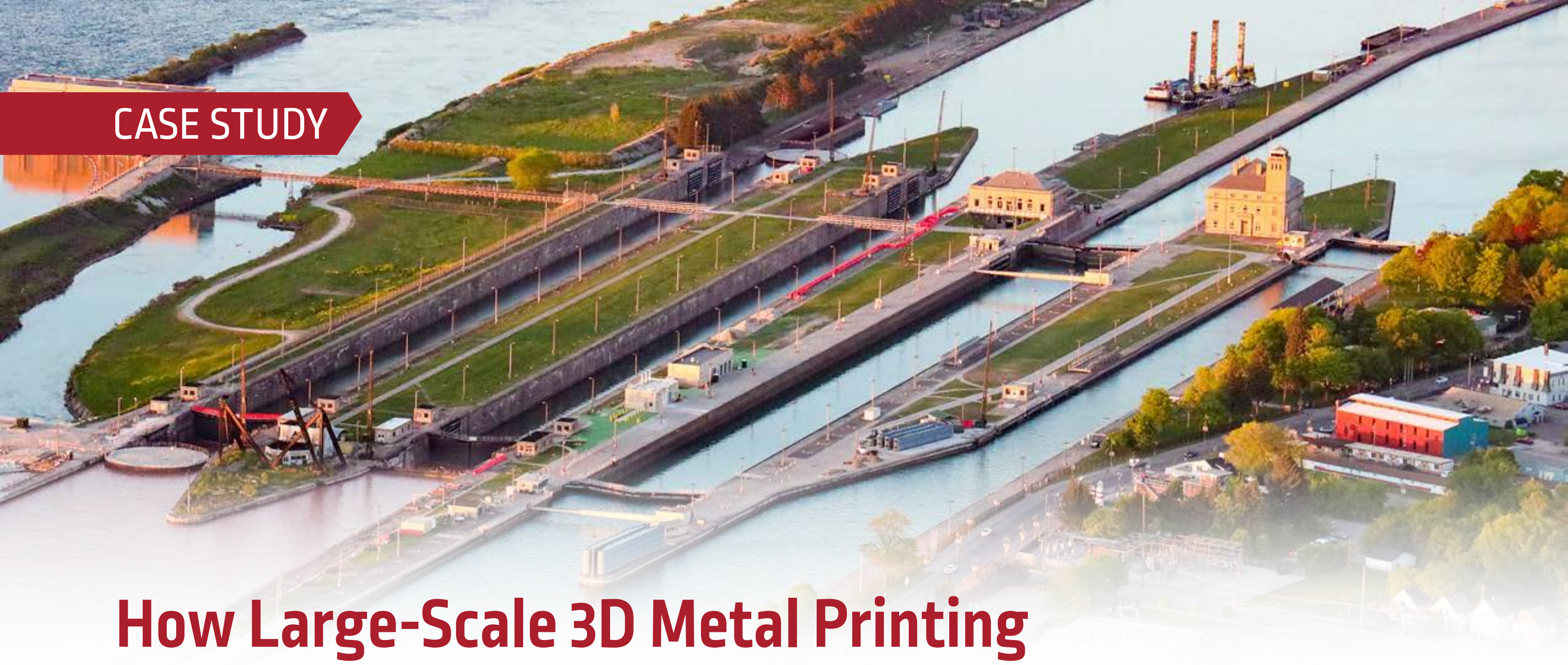


CASE STUDY

How Large-Scale 3D Metal Printing Technology Prevented a $1T Infrastructure Crisis

ADVANCED MANUFACTURING RESTORES CRITICAL INFRASTRUCTURE IN RECORD TIME

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) encountered a major issue when damage at the Soo Locks threatened to disrupt one of the country's most critical shipping channels. Cracks were discovered in the 60-year-old lever arm of the Poe Lock's ship arrestor system during its scheduled winter maintenance shutdown. USACE temporarily repaired the system but sought to install a permanent solution during the following year's maintenance window. Traditional manufacturing methods would have taken up to 18 months to produce a replacement, risking an additional six-month waterway closure that could cost the U.S. economy $1.1 trillion in GDP and threaten 11 million jobs.

To address this, USACE contracted Lincoln Electric Additive Solutions to produce a new lever arm using large-scale 3D metal printing, also known as additive manufacturing. The replacement—the largest U.S. civil works component produced via 3D printing—was delivered in just three months, in time for the scheduled maintenance window.

About the Soo Locks

The Soo Locks complete more than 7,000 vessel passages every year, moving up to 75 million tons of cargo. Vessels locking through vary in size from small private boats and workboats to 1,000-foot-long ships carrying up to 77,000 tons of freight in a single load. The primary cargoes carried through the Soo Locks are iron ore, coal, grain, and stone.

THE CHALLENGE

- **Aging Component:** The failure of a decades-old component underscored the challenges of sourcing rare, custom-fabricated components quickly.
- **Long Lead Times:** Casting would have required an 18-month turnaround, jeopardizing scheduled maintenance.
- **Critical Role:** The ship arrestor system is essential for preventing damage to the Poe Lock, which handles 88% of domestically produced high-strength steel shipments.
- **Extreme Performance Requirements:** The component required exceptional material and mechanical properties, including high strength, durability, and resistance to extreme operational stresses.
- **Large-Scale Manufacturing:** The component measured nearly 14 feet long and weighed over 6,000 pounds, requiring large-scale equipment and techniques.

LINCOLN® ELECTRIC

WHY LINCOLN ELECTRIC

To meet these extraordinary challenges, Lincoln Electric's proprietary large-scale 3D metal printing technology—wire-arc additive manufacturing (WAAM)—was selected, which allowed for rapid production of the complex, high-strength component. Lincoln Electric's end-to-end production processes ensured efficiency and reliability, and the company was well-positioned to handle stringent requirements and unexpected manufacturing challenges. The ability to produce the lever arm in just three months instead of the 18 months required by casting suppliers enabled installation within the planned maintenance window, avoiding costly disruptions. The printed high-strength, low-alloy (HSLA) steel exceeded performance requirements, ensuring long-term durability and reliability.

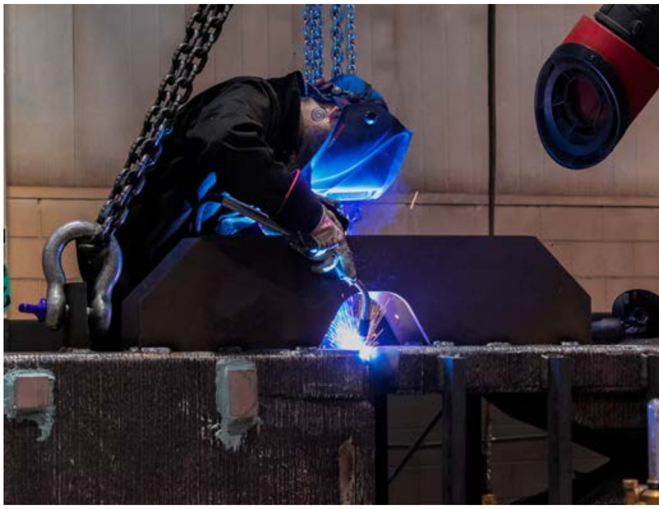
HOW LINCOLN ELECTRIC RESPONDED

Lincoln Electric worked closely with USACE and the U.S. Army Engineer Research and Development Center (ERDC) throughout the production of the lever arm, a critical component that helps stabilize and guide the motion of the ship arrestor system's rolling segment, which moves as the boom is raised or lowered.

The teams worked hand-in-hand to refine the design, optimize printing strategies, and execute precision fabrication and secondary processing. The process involved:

Additive Manufacturing

The lever arm was printed in two sections rather than as a single piece due to manufacturing constraints. One section of the arm weighed approximately 4,000 pounds and the other 2,000 pounds. The WAAM process ensured the ability to rapidly produce such a large part with the required structural integrity and reduced material waste compared to conventional methods.

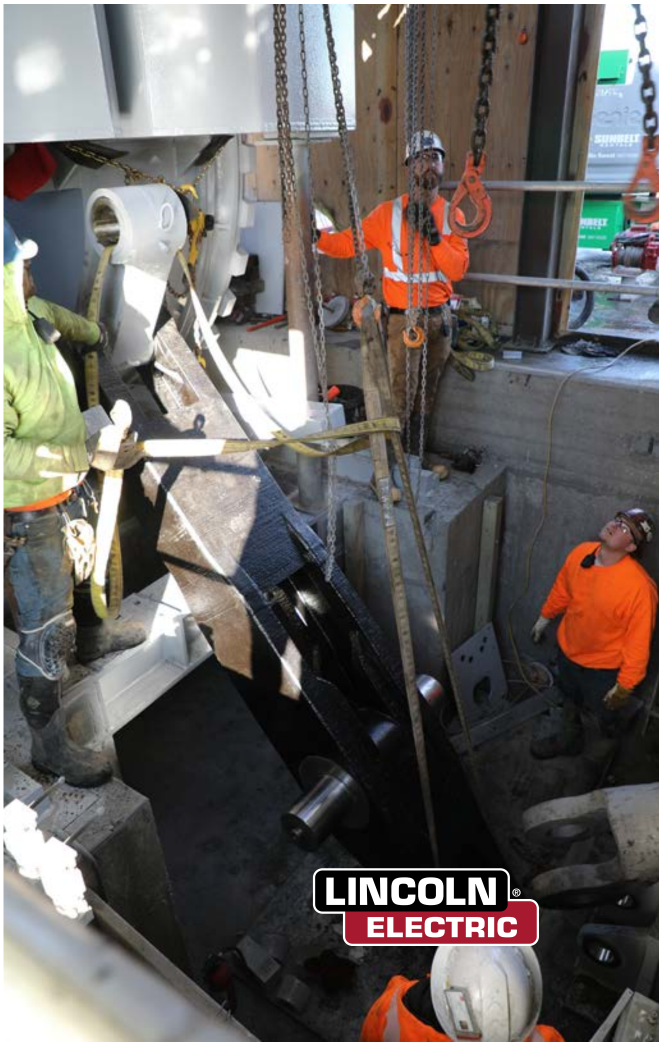


Stock Model Creation

The sections were 3D scanned after printing to create stock models, making post-processing as efficient as possible. Due to the layer resolution of WAAM, the post-print surface has a rough texture that differs from the smooth, precise dimensions of a 3D model. Stock models allow programmers and fabricators to prepare for machining and fabrication using an accurate representation of the actual printed part rather than an idealized CAD design.

CNC Machining

Before welding the halves together, Baker Industries, a Lincoln Electric company, performed pre-weld machining on the surfaces that would form the weld joints. This step ensured a precise fit and optimal weld quality, reducing potential defects and improving overall structural integrity.



Fabrication

After machining, the lever arm sections were setup for welding using a laser tracker. Strongback-style bracing was temporarily attached to the sections to ensure precise alignment and reinforcement, which minimized distortion and maintained dimensional accuracy during the joining process. The sections were then welded together, with the bracing providing rigidity and preventing movement. This was done using a Welding Procedure Specification (WPS) developed by Baker Industries specifically for this project and based on the AWS D1.5 Bridge Welding Code. A Complete Joint Penetration (CJP) V-Groove weld was applied all around.

Final Steps

Before being packaged and shipped to a third party contracted by ERDC for the finish machining, the lever arm underwent thermal stress relief, rigorous dimensional inspection, and radiographic testing to ensure structural integrity and conformance with the customer's specifications and tolerances. Once the contractor completed the finish machining, protective coatings, and final inspection, the lever arm was off to the Poe Lock. It was installed by USACE's general contractor in March 2024, allowing the Lock to reopen for the season on time on March 22.

THE RESULTS

The use of WAAM enabled the successful replacement of the Poe Lock ship arrestor lever arm while maintaining operational efficiency. This project achieved a remarkable reduction in lead time, bringing the timeline down from an initial projection of 18 months for castings to just three months with large-scale 3D metal printing. By executing the replacement so swiftly, the team preserved economic stability, greatly mitigating the risk of a prolonged shutdown that could have had dire consequences for the U.S. economy.

In addition to time and economic benefits, the project also enhanced component strength, with the new 3D-printed lever arm proving to be stronger than its traditionally manufactured counterpart. The lever arm is now the largest U.S. civil works component produced by 3D printing. It demonstrates the future viability of large-scale 3D metal printing for infrastructure projects and set a precedent for the application of the technology in civil works.

> "The Poe Lock arrestor arm really shows what can be done with the technology in terms of complex designs, and it signals a paradigm shift in how large parts can be manufactured.
>
> **Dr. Zack McClelland**
> Research Mechanical Engineer
> U.S. Army ERDC Geotechnical and Structures Laboratory

84%
FASTER LEAD TIME

20-30%
STRONGER PART

GRAPPLING WITH LONG LEAD TIMES OR MANUFACTURABILITY CHALLENGES?

Lincoln Electric is your go-to partner for cutting-edge manufacturing solutions to tackle today's supply chain challenges head-on. Contact us today to learn more about how we can help you take your critical projects to new heights.

About Lincoln Electric

Lincoln Electric is a high-performance industrial machinery and technology leader who helps customers manufacture and maintain vital equipment and infrastructure. Lincoln Electric's innovative solutions enable higher quality and productivity across a variety of processes including welding, cutting, brazing, machining, process automation, and field repair. The Company leverages proprietary technologies and expertise in materials science, power electronics, automation, and intelligent software to help customers build better and achieve resilience in their operations. Headquartered in Cleveland, Ohio, Lincoln Electric is the essential 'Linc' that keeps the economy running. The Company operates 71 manufacturing and automation facilities across 20 countries and serves customers in over 160 countries. For more information about Lincoln Electric and its products and services, visit the Company's website at www.lincolnelectric.com.

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