

Advanced Near Net Shape Technology

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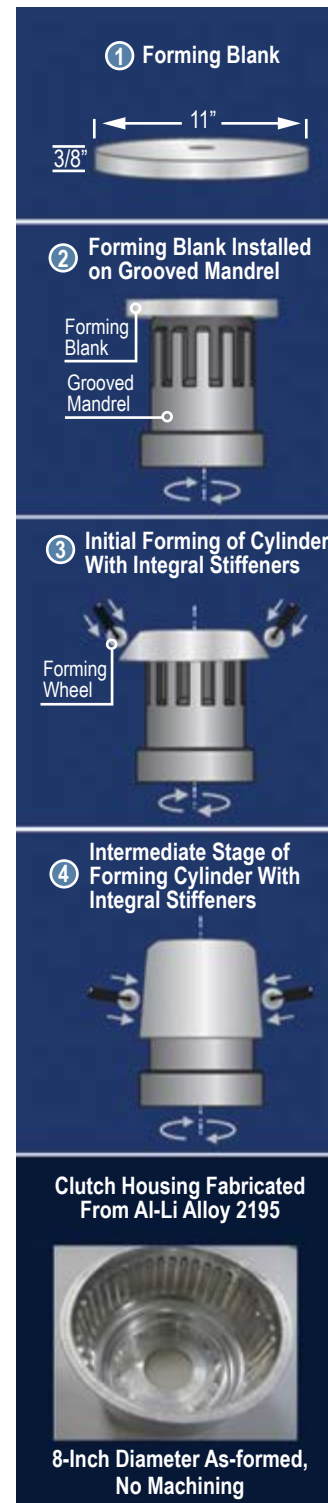
Sponsoring Program(s)

Space Technology Mission Directorate
Game Changing Development

Project Description

The objective of the Advanced Near Net Shape Technology (ANNST) project is to radically improve near net shape manufacturing methods from the current Technology/Manufacturing Readiness Levels (TRL/MRL 3-4) to the point where they are viable candidates (TRL/MRL-6) for shortening the time and cost for insertion of new aluminum alloys and revolutionary manufacturing methods into the development/improvement of space structures. Conventional cyrotank manufacturing processes require fabrication of multiple pieces welded together to form a complete tank. A variety of near net shape manufacturing processes has demonstrated excellent potential for enabling single-piece construction of components such as domes, barrels, and ring frames. Utilization of such processes can dramatically reduce the extent of welding and joining needed to construct cryogenic tanks and other aerospace structures. The specific focus of this project is to successfully mature the integrally stiffened cylinder (ISC) process in which a single-piece cylinder with integral stiffeners is formed in one spin/flow forming process.

Structural launch vehicle components, like cryogenic fuel tanks (e.g., space shuttle external tank), are currently fabricated via multipiece assembly of parts produced through subtractive manufacturing techniques. Stiffened structural panels are heavily machined from thick plate, which results in excessive scrap rates. Multipiece construction requires welds to assemble the structure, which increases the risk for defects and catastrophic failures.



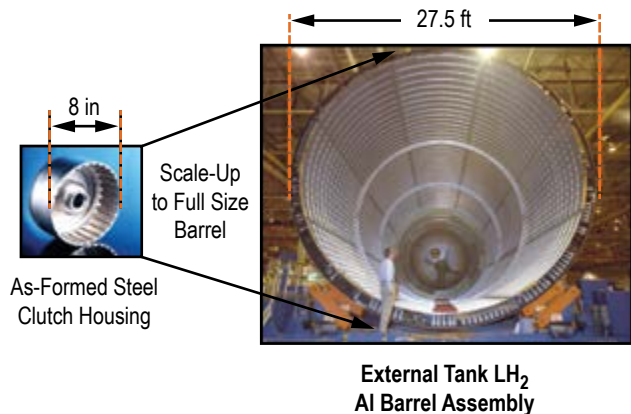
Integrally stiffened cylinder fabrication process.

Weld regions require increased material thickness to offset reduced material properties in the weld metal and require costly nondestructive evaluation inspections. For example, the previous space shuttle external tank (27.5 feet in diameter × 154 feet tall) had a material scrap rate of nearly 90%, resulting in ~\$8 million per tank in wasted material and had roughly half a mile of welds. Multipiece machined and welded construction is 30⁺-year-old technology that works but is material inefficient, expensive, and risky. There is significant room for improvement with adoption of advanced manufacturing technology, which can be applied across multiple platforms.

This project seeks to develop and adapt manufacturing technology currently used in production of small steel automotive parts to enable fabrication of single-piece stiffened metallic launch vehicle structures using aerospace grade aluminum-lithium (Al-Li) alloys. The novel ISC process will improve manufacturing efficiency and structural performance by producing single-piece stiffened barrels in one manufacturing process through combined spin- and flow-forming operations. Such a technique has never before been applied to launch vehicle structures. If successful, this will revolutionize the way integrally stiffened, metallic structures are fabricated with projected weight savings of up to 30%, cost savings of 40%, and the elimination of all longitudinal welds compared to the current state-of-the-art practice. Additional performance benefits will be realized through selective reinforcement with metal matrix composite materials incorporated into a hybrid launch vehicle structure.

Anticipated Benefits

NASA missions will benefit from the ISC process through manufacture of launch vehicle structure sub-elements at lower cost and with improved reliability and performance. The ISC process will greatly expand cryogenic tank barrel design space enabling greater structural performance benefits and significant mass savings.



Potential Applications

Potential applications for the ISC manufacturing technology include launch vehicle structures such as cryogenic tank barrels, dry bay structures, and payload shrouds for vehicles from sounding rockets and small satellite launchers to potentially Space Launch System scale vehicles.

Notable Accomplishments

The ANNST project has demonstrated transition of the ISC process from forming with automotive steel to an aerospace Al-Li alloy through successful fabrication of a typical automotive component. Further process optimization has shown successful increase in stiffener height from gear teeth to cryogenic tank barrel scale stiffeners.

Laboratory experiments have demonstrated the potential to selectively reinforce the stiffener's top using metal matrix composite materials. Initial testing of small-scale reinforced stiffeners showed a 30% increase in bending stiffness with only a 1% increase in mass.