Opening Remarks

- ABS Advisory – Published in 2017
- ABS Guidance Notes – Published in 2018
- ABS Approved Crane Hook - Installed in 2019
- ABS Guide – Published in April 2021
Outline

• Introduction
• Standardization
• Approval for AM Facility
• Approval for AM Part
• AM Activities in ABS
• Summary
Introduction

• AM History
  - Prototype to end-use
  - Non-metallic to metallic
  - Desktop to computer numerical control (CNC) machine or robotic arm

• Feasible to implement AM technology for Marine and Offshore

- Rapid Prototype, 1980
- Molds and Tooling, 1990
- Digital Manufacturing, 2000
- Customized Fabrication, 2010
AM Value

- Market Forecast in Oil and Gas

![Graph showing AM Revenues in Oil and Gas (USD) 2019-2029]

Source: Grandview Research

- Supply Chain
- More Flexibility in Design
- Small Batch Production
- Hybrid Metal AM Process
# AM vs. Traditional Manufacturing

<table>
<thead>
<tr>
<th>Traditional Manufacturing</th>
<th>Additive Manufacturing (AM)</th>
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<tbody>
<tr>
<td><strong>Materials Manufacturing</strong></td>
<td>• Integrated process of materials manufacturing, machining and welding</td>
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<tr>
<td>- Rolling, Casting, Forging, Heat Treatment etc.</td>
<td>• Fused/Joined materials to make parts from sliced 3D solid model data</td>
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<td>- To meet mechanical property requirements</td>
<td>• Built layer by layer</td>
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<tr>
<td><strong>Machining</strong></td>
<td>• Digital controlled by machine software and hardware</td>
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<tr>
<td>- Cutting, Turning, Milling, Grinding, Drilling etc.</td>
<td></td>
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<tr>
<td>- To meet dimension and special features</td>
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<tr>
<td><strong>Connecting</strong></td>
<td></td>
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<tr>
<td>- Welding, Brazing, Soldering, Fastening</td>
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<tr>
<td>- To join or connect multi-pieces</td>
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AM Processes

Additive Manufacturing

Powder Bed Fusion (PBF)
- Powder
  - Laser
  - E-Beam

Direct Energy Deposition (DED)
- Powder
  - Laser
  - Plasma

Binder Jetting
- Wire
  - Laser
  - E-Beam
  - Plasma
  - Gas Tungsten (GT)
  - Gas Metal (GM)
  - Arc

Materials Extrusion
Standardization

• Specifications with revision
• Documentation
• Production
Part Design Package (PDP)

- Functional and Technical Specifications
- System or Equipment to be Installed

Engineering Design

- Part Solid Model and/or Drawing
- Specific Digital Design for AM
- Engineering Calculation or Simulation, if required
- Requirements for Mechanical Properties
- Requirements for Other Properties such as Fatigue, Corrosion, Wear/Erosion, etc.
- Non-Destructive Testing

Materials Specification

- Functional and Technical Specifications
- System or Equipment to be Installed

Engineering Calculation or Simulation, if required

Requirements for Mechanical Properties

Requirements for Other Properties such as Fatigue, Corrosion, Wear/Erosion, etc.

Non-Destructive Testing
Feedstock

- **General**
  - Handling, Storage and Re-use, if applicable

- **Powder**
  - Specification
  - Material Grade, Atomization Process, Post Atomization Classification, Composition, Powder Size, Distribution and Morphology, Flowability etc, refer to ASTM standards

- **Wire**
  - Specification
  - Material Grade, Composition, Wire Size, refer to ASTM or AWS welding consumable standards

- **Documentation**
AM Manufacturing Process

- Machine (Hardware and Software)
- Procedure
- Operator

- Part and Support Removal
- Stress Relief
- Hot Isotropic Pressure (HIP)
- Other Heat Treatment
- Surface or Feature Finish

- Heat Input: Beam/Arc Power and Size
- Heat History: Scan Pattern, Travel Speed, Hatch Overlap and Distance, Layer Thickness, Edge and Surface Control
- Build Environment
- Part Location and Orientation
- Test Coupon Location and Orientation
- Machining allowances
- Others such as support, infill, contour, transition etc.
- Digital Build Model, STL, 3MF etc.

Pre-Build
- General

Post-Build
- AM Build
- Digital Build Model, STL, 3MF etc.
Inspection and Testing

- ABS Rules for Materials and Welding and the applicable sections enclosed in other ABS Rules for application.
- ASTM A751 for Chemical Analysis
- ASTM A370 for Mechanical Testing
- ASTM E8 for Tensile Testing
- ASTM E23 for Notched Bar Impact Testing
- ASTM E10 for Hardness
- ABS Guide for Non-Destructive Inspection or ASTM WK68731
- Other recognized industry standards in accordance with ISO/ASTM

Testing Report, in accordance with Rule/Guide, Industry standard or Designer's Specifications

- VT for Dimension, Features, Surface
- MPT/LP for Surface Defects
- RT/UT/CT for Volumetric Defects
- Tensile and Charpy
- Chemistry and Microstructure
- Part Function Testing
- Special Properties, if required
ABS Approval and Certification Process

Design Review

AM Facility Approval

Part Specific Testing during Qualification for Approval

Manufacturing Process and Procedures

Deliverables of Engineering Review

Part Certification during Production
Approval for AM Facility

- Quality Management System
- AM Capability
- Machine, Procedure, Operator Qualification
- Approval Tests
- Submittals
- Approval for AM Facility
- Range of Approval
Approval for AM Part

• ISO Standards
• ASTM Standards for AM Process
• Approval Tests
• Submittals
• Approval for AM Part
• Range of Approval
• Fabrication Plan
ABS Review and Survey

- Adoption and Expansion by Collaboration
- Input by Ship Builder or Original Equipment Manufacturer
- Pre-building, Building, Post-building, Inspection and Testing by Additive Manufacturing Facility
- Design Review, Manufacturer Survey and Approval by ABS
- On-Board Performance and Close-Loop Feedback for Continuous Improvement
AM Activities in ABS

- Small Crane Hook with Design Load of 80 Metric Tons
- 4 Prong Crane Hook with Design Load of 250 Metric Tons
- Pump Impeller
- Pump Flexible Coupling
- Pump Gear Sets
- Generator Air Ejector Nozzle
Summary

- AM process is standardized using Specification. The applied parameters are controlled, monitored and documented.

- AM facility can be qualified and approved based upon the desired materials properties support by the history data in manufactured materials or parts.

- AM part can be qualified and approved based upon the desired requirements for part engineering design and functionality.

- Class parts can be certified based upon satisfactory completion of required approval of AM facility and AM part, as well as agreed fabrication plan and witness. Certification is optional for non-class parts.

- Qualification and Certification follow ABS Rules/Guides for class parts and industry standards or designer’s specifications for non-class parts.
Closing Remarks

- Update ABS Guide for Polymer and Polymer Composite
- Expand Adoption of AM Technology in Spare Parts
- Improve Capabilities and Efficiency of DED Process for Large Structure
- Explore Non-Critical Marine and Offshore Applications of Low-Cost AM Processes such as Binder Jetting or Materials Extrusion Processes
Thank You

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