SNAME MARITIME 2022 CONVENTION

26-29 September | Houston, TX

Quality Assurance for Additively Manufactured Parts Produced for Maritime Applications

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Overview

- Introduction
- Potential and Obstacles for the Adoption of AM
- Three Main Concerns
- A Specific Approach Based on Class Systematics
- Why Does It Matter
- Conclusion

Introduction

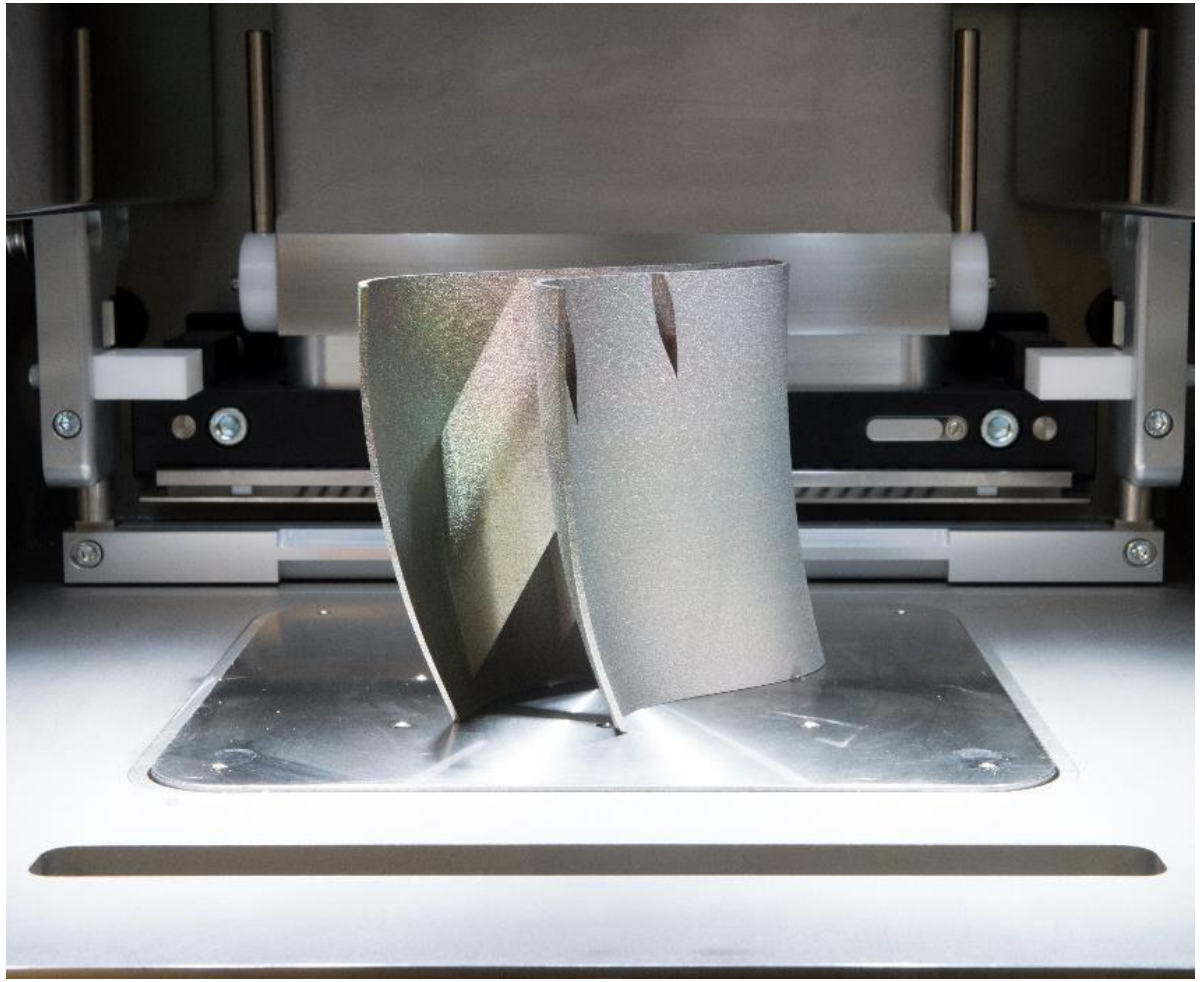
- Additive Manufacturing (AM) is a relatively new technology
- Potentially the most impactful technology for the future of manufacturing[2]
- Key component of Industry 4.0[2]
- AM is the process of generating parts by adding material layer by layer, bonding each layer to the existing layers.
- Processes include fusing material in a bed or pool, such as powder bed fusion (PBF) or by adding material through the AM tool, such as directed energy deposition (DED).

Introduction

Several types of AM are in use for maritime, however the focus tends towards:

- **Powder bed fusion**
- **Directed energy deposition**

These tend to be preferred for maritime use, as the parts can be made more precisely and more ruggedly due to the characteristics of the materials[2]



Potential of Additive Manufacturing

- Greater degree of freedom in design over conventional subtractive manufacturing
- Not limited by tool access concerns
- Can use multiple materials (i.e. incorporating corrosion resistant alloys into the printing of a part)
- Reduced waste and requirements for storage of stock[4]
- On demand manufacturing, even on-board a vessel
- Can reduce carbon emissions by printing closer to the destination and reducing transit time

Expected to grow from a 12B USD industry in 2020 to 51B USD in 2030[1]

Obstacles to the Growth of AM

Some resistance is due to the movement of the technology

- **Rapid changes**
- **Manufacturers need to protect IP, including proprietary methods and techniques**

There is a lack of trust among end users due to a lack of accepted standards specific to the generation of maritime equipment for

- **AM manufacturers**
- **AM materials and suppliers**
- **AM generated products**

A similar issue has been noted within the aerospace industry as it works to qualify parts for aircraft[3]

Obstacles to the Growth of AM

- With a scarcity of internationally recognized standards, most manufacturers conduct their own testing – end users must trust that the testing and proprietary standards are adequate and adhered to and that the testing applies to Maritime applications
- There is a lack of experience-based data for FMECA analysis, and what does exist is often proprietary
- Material standards currently in force control chemistry, material and physical properties as applied to solid shapes, forgings, castings, etc. These don't translate to powder, for example
- Technical challenges also exist, but are outside this scope

Three Trust Related Concerns

Three trust related concerns need to be addressed to raise the confidence in AM for increased adoption in maritime:

- **Manufacturer Qualifications**
  - **Can this manufacturer produce to the stringent requirements of Maritime applications?**
- **Product Qualifications**
  - **Is this product going to stand up to the harsh environments encountered at sea?**
- **Supplier Qualifications**
  - **Are the materials supplied proper for maritime applications?**

Needing a Different Approach

A quality management certification specific to maritime applications is key

ISO 9001 is a generic approach, focused on the QMS

- **Ensures consistency in a process**
- **Takes a process approach**
- **“Plan-Do-Check-Act”**
- **Non-technical, non-specific**

- **A process that is specific to AM and bridges the gap between proprietary standards and industry recognized standards is needed**

Applying Class Systematics

DNV applies class systematics to address the three main concerns

- ***Class Programme for Approval of Manufacturers in Additive Manufacturing***
  -Addresses the qualification of the AM manufacturers
- ***Class Guideline for Additive Manufacturing - Qualification and Certification Process for Materials and Components***
  -Addresses the qualification of new products and materials produced by AM relative to the needs of maritime applications
- ***Class Programme for Type Approval of Additive Manufacturing Feedstock***
  -Specific program for the long term certification of feedstock material to be used in additive manufacturing

Qualifying the Manufacturer

Class Programme for Approval of Manufacturer – Additive Manufacturing **(DNV-CP-0267) has been generated to qualify the capability of the manufacturer for production of maritime equipment via AM**

- **Builds on the Approval of Manufacturer (AOM) processes applied by class societies to manufacturers (previously including such activities as welding, material handling, testing, personnel qualifications, etc.)**
- **Relies on auditing the facility, personnel, and processes and reviewing documentation**
- **Can be applied to sub-suppliers and vendors as well**

Qualifying the Manufacturer

- This program addresses concerns specific to manufacturing maritime products via AM, rather than a general approach
- The Approval of Manufacturer (AOM) review includes concepts specific to AM, including:
  - how the design is adapted for AM
  - a given feedstock
  - pre-processing and software control
  - monitoring of the process
  - post-processing and post- manufacturing techniques (hot isostatic processing, heat treatment)
  - Testing

Qualifying the Manufacturer

Auditing includes:

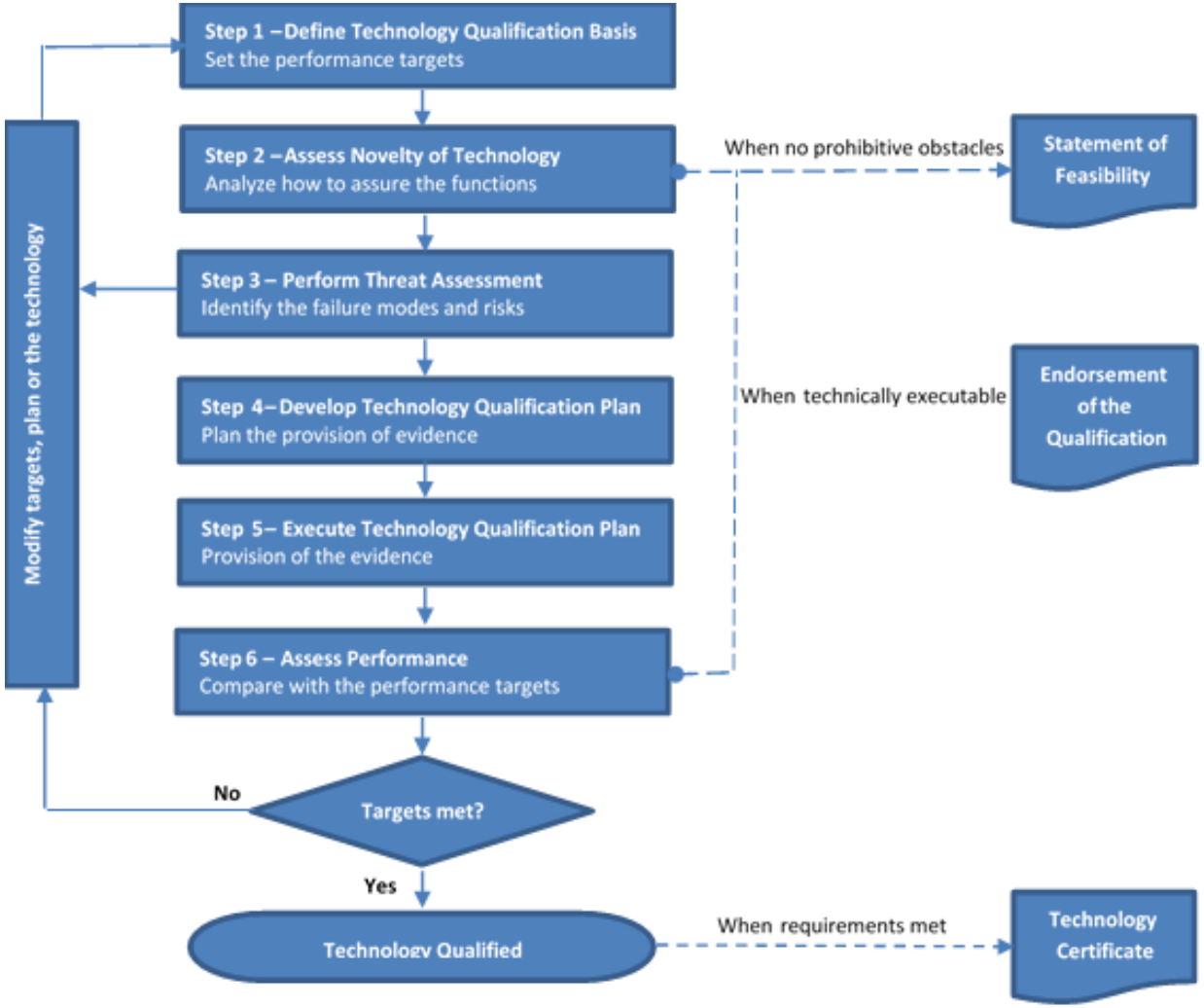
a. Processes related to the manufacture by AM of parts
b. Personnel processes
c. Testing done to date including obtained results and NDT
d. Quality management (often overlaps with ISO 9001 type audit)
e. Design management
f. Digital modeling (3D modeling, FEA, etc.)
g. Feedstock (specification, acquisition, and management)
h. AM equipment
i. Preparation, parameters, procedures
i. Facility parameters
j. Post building operations and equipment
k. Inspection and NDT
l. Material testing
m. Functional testing

Qualifying the Product

Class Guideline for Additive Manufacturing - Qualification and Certification Process for Materials and Components **(DNV-CG-0197) is used to apply a systemic qualification approach to approval and certification of materials, products, and components generated by AM**

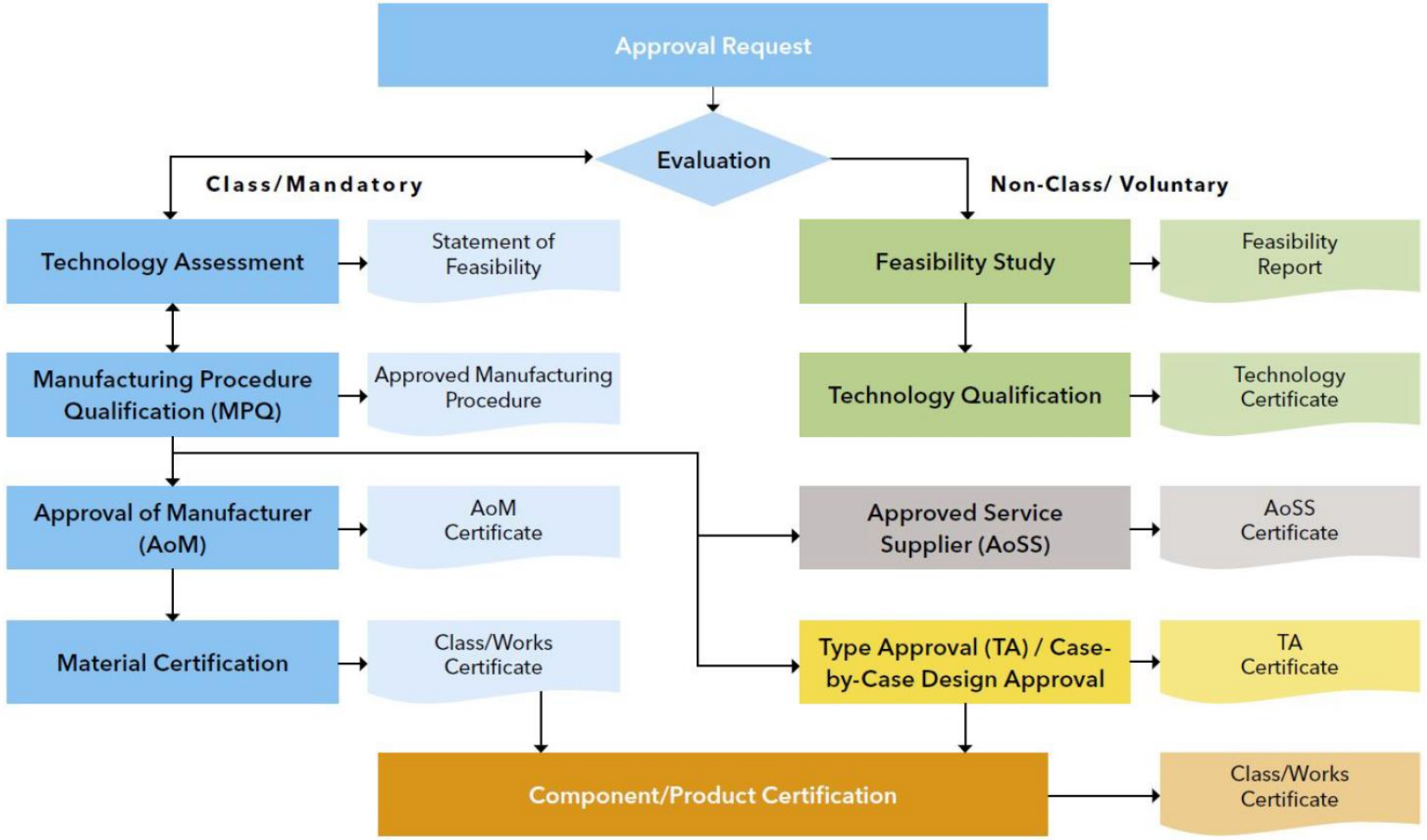
- **Expands upon the technology qualification (TQ) process to address AM as a new or limited experience technology**
- **TQ approach is useful when existing standards are not available by addressing fitness for purpose**
- **Allows manufacturers to maintain confidentiality of documentation and processes during certification**

The Technology Qualification Approach



From the DNV Class Guideline, DNV-CG-0197 Additive manufacturing - qualification and certification process for materials and components, https://rules.dnv.com/docs/pdf/DNV/CG/2021-10/DNV-CG-0197.pdf, pg. 41

The Technology Qualification Approach



From the DNV Class Guideline, DNV-CG-0197 Additive manufacturing - qualification and certification process for materials and components, https://rules.dnv.com/docs/pdf/DNV/CG/2021-10/DNV-CG-0197.pdf, pg. 28

Qualifying the Material

Class Programme for Type Approval of Additive Manufacturing Feedstock **(DNV-CP-0291) exists for the type approval certification of the feedstock suppliers**

- **Specifically applies to powder and wire metal feedstocks**
- **Supplements existing material specifications to ensure material is consistent and of sufficient quality for maritime applications**
- **Procedures for material manufacturing are reviewed and witnessed**
- **Testing considers the method of AM**
  - **-For example, in addition to tensile, impact, and bend testing, powder material is evaluated for corrosion resistance and hydrogen resistance, key factors in maritime applications**

Why Does Using Third Parties Matter?

- Truthful third parties, such as Classification Societies, lack a financial incentive to qualify or certify a manufacturer or product that is not worthy, but a reputation-based incentive to ensure that only high-quality manufacturers, products, and suppliers are certified
- Such organizations are neutrally oriented, so stringent adherence to the class programmes and guidelines are applied evenly to all manufacturers
- By applying a third-party qualification, owners and operators can know that the parts have met a level of quality that will be sufficient for maritime applications

Concept in Action

- Joint Industry Projects (JIPs) have been conducted with DNV involvement to show this process in effect for the production of a crane hook through AM
  -Crane Hooks are difficult to cast and are subject to particular loadings and environmental stresses in offshore applications that may not be addressed by non-maritime qualifying approaches
- Components generated by AM and qualified by DNV range from scupper plugs to propellers
  - Scupper plugs are often custom sized to a particular vessel and need to be designed for immersion in saltwater while still holding against pressure.

Outlook

- **Collaboration between reliable third parties and manufacturers will be necessary to cover the gap in trust until standards can catch up to the technology.**

- **This trust will increase adoption of AM for parts used in maritime applications**

- **Even as the technology matures, these systematics will provide the ability to maintain trust in the latest technology**

References

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Thank you for your attention. This concludes the presentation

Questions?