MEDIA RELEASE

New standards initiatives to support I4.0 technology adoption in manufacturing sector

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1. In line with Singapore's push to accelerate the adoption of Industry 4.0 (I4.0) technologies to enhance manufacturing capabilities among enterprises, the Singapore Standards Council (SSC) and Enterprise Singapore (ESG) have launched a series of standards initiatives to guide enterprises in the understanding and application of advanced and additive manufacturing. These efforts were announced at the Industrial Transformation Asia Pacific (ITAP 2021) today.

Two new standards to ensure quality and safety of additive manufacturing products

2. The SSC, the Ministry of Defence (MINDEF) and the National Additive Manufacturing Innovation Cluster (NAMIC), together with industry stakeholders[1], have developed two new standards on additive manufacturing (AM)[2].

   a. **Singapore Standard 666 (SS 666)** provides users with a framework that covers the qualification of 3D printed metal parts. The standard also provides guidelines for each stage of the AM process to ensure that all aspects which can affect the quality of the product – the material quality of the metal powders being used, operator training, machine maintenance, and how the final AM printed parts can fulfil the criteria for acceptance – are considered and controlled. Enterprises implementing the metal AM techniques can leverage the best practices in the standard to guide their production processes and provide

[1] The standards were developed with key stakeholders including the Singapore Armed Forces (SAF), Singapore University of Technology and Design, the additive manufacturing industry, and the Singapore Manufacturing Federation – Standards Development Organisation.

[2] Together with the TR 70 published in 2019, SS 666 and TR 92 complete the full suite of AM standards developed by the Military AM Working Group, convened by the Technical Committee for Additive Manufacturing, involving several public and private AM experts from government agencies, companies, SAF (HQ-MES), and Singapore University of Technology and Design.

assurance to customers that the manufactured metal products are consistent in quality. This also enables enterprises to meet the safety and reliability requirements, by implementing more stringent controls in the manufacturing process. Please refer to **Annex A** for more details.

b. **Technical Reference 92 (TR 92)** covers design guidelines for complex additive manufactured parts to ensure safety and mitigate any potential risks during the design stage. TR 92 addresses critical process specific considerations during the manufacturing of these complex parts. This aims to reduce the lead time and cost incurred for design amendments as well as prevent design errors which may result in serious injuries caused by part failure. Please refer to **Annex B** for more details.

New standard programme to boost cyber readiness among manufacturers

3. The first Workshop Agreement (WA), "Cybersecurity self-evaluation checklist and guidelines for digitalisation in manufacturing", was launched today. Led by Cyber Security Agency of Singapore (CSA) and the Agency for Science, Technology and Research's (A*STAR) Singapore Institute of Manufacturing Technology (SIMTech), and supported by TÜV SÜD Asia Pacific, the WA sets out cybersecurity standards requirements to help manufacturing companies determine cybersecurity gaps and readiness which are critical as they build up their digital value chain and connected production assets as part of their I4.0 journey. A new type of standard, WAs seek to address urgent industry needs, especially in emerging fields, with a shortened development timeline. More details on the WA can be found in **Annex C**.

New partnership to incorporate standards in training programmes on I4.0

4. ESG has also partnered the Advanced Manufacturing Training Academy (AMTA) to enhance I4.0-related courses with standards content. This will help manufacturing enterprises better understand how they can leverage standards when implementing I4.0 technologies. ESG and AMTA will work with Institutes of Higher Learning (IHLs) to incorporate standards in key I4.0 areas such as connectivity, cybersecurity and robotics in their training courses.

5. The first course to be developed under the partnership is on industrial connectivity which references the SS IEC 62541 Open Platform Communication Unified Architecture (OPC UA) series of connectivity standards that enable the exchange

of data across machines and systems. Supported by OPC Hub ASEAN, the course will be offered by Singapore Polytechnic to the advanced manufacturing workforce in early 2022.

6. **Ms Choy Sauw Kook, Director-General (Quality & Excellence), Enterprise Singapore**, said, “To help manufacturers step up on their I4.0 efforts, ESG has worked with industry stakeholders to develop new standards and training courses. With these new standards, it will allow companies of all sizes to kickstart their implementation of I4.0 technologies and additive manufacturing techniques. The training courses will ensure the effective use of standards and prepare manufacturing companies to move into new areas without the need for trial and errors, while shortening their learning curve in standards adoption. I thank our partners for their contributions in these new standards initiatives.”

7. **Brigadier-General David Neo, Deputy Secretary (Technology), MINDEF,** said, “Additive Manufacturing (AM) is an important capability for MINDEF/SAF to strengthen our supply chain, and allows us to enhance innovation and operational outcomes through efforts such as rapid prototyping. The new technical and safety standards will enable the SAF, our partners, and local industries to harness the transformative potential of AM."

8. **Dr Ho Chaw Sing, Co-chair of the Technical Committee on Additive Manufacturing and Managing Director NAMIC** said, “I am pleased to see the completion of one of the most important areas under the strategic partnership laid down in the Memorandum of Understanding between NAMIC and MINDEF/SAF in 2017. We expect these new standards and technical references, together with the TR 70 published in 2019, to not just benefit the Defence sector, but also in heavy industry sectors such as aerospace and marine, with additional considerations based on the field operating conditions of AM parts, providing clear design and tiered-qualification requirements for mission-critical applications.”

9. The SS 666, TR 92 and Cybersecurity Checklist Workshop Agreement Document can be purchased from the Singapore Standards eShop at www.singaporestandardseshop.sg.

ANNEX A: Factsheet on the SS 666: 2020 Qualification of parts printed by metal additive manufacturing

ANNEX B: Factsheet on the TR 92: 2021 Design guidelines for additive manufacturing parts

ANNEX C: Factsheet on the Workshop Agreement "Cybersecurity self-evaluation checklist and guidelines for digitalisation in manufacturing"

ANNEX D: Other standards that support Singapore's advanced manufacturing sector

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About Enterprise Singapore

Enterprise Singapore is the government agency championing enterprise development. We work with committed companies to build capabilities, innovate and internationalise.

We also support the growth of Singapore as a hub for global trading and startups, and build trust in Singapore's products and services through quality and standards.

Visit www.enterprisesg.gov.sg for more information.

About Singapore Standards Council

The Singapore Standards Council (SSC) facilitates the development, promotion and review of Singapore Standards, Technical References and Workshop Agreements in Singapore. This work is done through partnerships with the industry, academia and government organisations, under the national standardisation programme overseen by Enterprise Singapore.

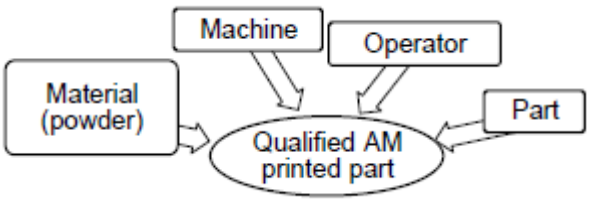
ANNEX A: Factsheet on the new SS 666: 2020 Qualification of parts printed by metal additive manufacturing

The SS 666 aims to provide guidance on the production of consistent, safe and reliable metal AM parts, and is applicable to the manufacturing processes of powder bed fusion (PBF) and laser-based powder bed fusion of metals (PBF-LB/M). It sets out industry best practices in all aspects of the AM parts' manufacturing process such as material feedstock, AM machine maintenance, manufacturing facility characteristics, operator training and AM process details. In addition, SS 666 provides tiered qualification options based on part criticality to help balance cost and application needs. The usage of the SS will help to ensure consistent quality of additive manufactured parts.

Part classification

The SS classifies AM parts using risk analysis methodologies into three classes – critical, major and minor, based on the part's safety and reliability requirements. Parts classified as critical will require more stringent controls in the manufacturing process.

Qualification of AM parts



Unlike conventional manufacturing, the manufacture of an AM printed metal part requires emphasis on a good qualification process. Key areas of focus identified in the SS are on materials (powder), machine, operator, and the printed part itself. These areas of focus are outlined during each stage of the AM process, from data preparation, to pre-process, in-process and post-process.

a) Data preparation

Data preparation ensures a high level of repeatability and quality for AM parts during the reproduction phase. During the data preparation stage, information on the part design is tested and documented (e.g. part coordinate information in the build platform, build process parameters, build orientation and spacing, and the use of support structure).

b) Pre-process

In the pre-process stage, the following key requirements are considered:

- Material (powder) – Powder feedstock control, proper storage requirements and powder requirements for different part classes
- Machine Operator – Certified AM machine operators with knowledge and practical skills in accordance with standards such as ISO/ASTM 52942 for PBF-LB/M process and ISO/ASTM 52926 for both PBF and dedicated energy deposition (DED) processes.
- Preliminary checks on AM machine – Machines are qualified and have completed preventive maintenance.

c) In-process

During the in-process stage, a manufacturing plan should be developed so that the details of in-process qualification, design requirements and application needs for the part can be recorded properly. This manufacturing plan will then serve as a reference for future quality checks and inspections. The quality assurance requirement during the part production should also be defined.

d) Post-process

After fabricating AM parts, there may be a need to carry out various post-processes (e.g. heat treatment, hot isostatic pressing (HIP)) to remove any residual stress or porosity and possible defects, or perform removal of temporary supports used during the fabrication stage. SS 666 provides guidelines on these post-processes that could have an impact on the quality of the AM printed part. The part then undergoes final part inspection which focuses on measuring the dimensional accuracy and inspecting for internal and external defects due to uncertainty and variability of AM processes.

ANNEX B: Factsheet on the new TR 92: 2021 Design guidelines for additive manufactured parts

TR 92 aims to provide users with the pros and cons of various AM process while setting out additional details such as operating conditions and general design considerations to ensure safety and reliability. The TR helps to minimise the risk of manufacturing failure and details the characteristics and design guidelines for PBF-LB/M, DED and fused deposition modelling processes.

a) General design considerations
   Designers need to recognise the importance of their role and understand that the best time to mitigate or eliminate design safety and reliability risk is during the initial stage of part design. This can help to reduce the cost of research and design for any new or reverse engineered parts as it reduces the number of iterations, injuries caused by part failure and damage to other parts during the design stage.

b) Designing for parts' operating conditions
   Designers should factor the parts' operating conditions when designing parts. Unconventional operating environments, where conditions are harsh and unpredictable, such as in military and offshore marine operations, could affect the durability and performance of parts.

c) Design verification
   Designers need to take into consideration post-processing operations (e.g. heat treatment and HIP) to alleviate residual stress can affect the mechanical properties of parts printed using AM.

d) Design changes
   Changes to the design, may be required, to meet design requirements, and ensure quality and manufacturability of the part. Design changes may also be done to optimise the part (e.g. for better inspectability, to optimise build orientation and to enhance the availability of post-processing like support removal).

The TR also details the unique capabilities of AM and the use of Design for Additive Manufacturing (DFAM) methods to manufacture parts that could replace those made through conventional manufacturing. AM parts can be designed to be more lightweight, customised to meet needs. It also details how existing multiple non-AM parts can be replaced with a single AM designed equivalent that performs the function of the original parts.

Annex C: Factsheet on the new Workshop Agreement "Cybersecurity self-evaluation checklist and guidelines for digitalisation in manufacturing"

The "Cybersecurity self-evaluation checklist and guidelines for digitalisation in manufacturing" Workshop Agreement aims to help manufacturing companies identify cybersecurity gaps as they digitalise; and mitigate risks such as unauthorised access, intellectual property theft and operational disruptions. Led by Cyber Security Agency of Singapore (CSA) and the Agency for Science, Technology and Research's (A*STAR) Singapore Institute of Manufacturing Technology (SIMTech), and supported by TÜV SÜD Asia Pacific, a total of 58 stakeholders were involved in the development of the WA.

The WA is developed based on international standards and industry practices and references ISO / IEC 27000 on Information security management systems, and IEC 62443 Industrial communication networks - IT security for networks and systems.

What are Workshop Agreements?

Workshop Agreements (WA) are a new type of national standard product that is designed to fast track the standards development process to meet urgent market requirements. WAs are developed within an average of 5 to 6 months and is suitable where the speed of delivery is of importance. Consensus is built in a workshop setting, with a wide participation of experts and key stakeholders from industry associations, academia, research centres, professional bodies, government agencies, non-governmental organisations, voluntary welfare associations and consumer associations.

ANNEX D: Other standards that support Singapore's advanced manufacturing sector

Enterprise Singapore (ESG) and the Singapore Standards Council (SSC) have published and promoted more than 70 standards to support advanced manufacturing and engineering in areas such as additive manufacturing or 3D-printing, robotics, autonomous vehicles, drones, smart manufacturing and cybersecurity.

These standards play an important role in addressing key issues of interoperability, cybersecurity, safety, reliability and sustainability in the adoption of advanced manufacturing technologies. They also help in efforts to translate R&D knowledge in both the public and private sectors into innovative processes, products and services for use by industry.

To help enterprises use these manufacturing standards, ESG and SSC worked with TÜV SÜD Asia Pacific and Singapore Manufacturing Federation (SMF) to launch an online standards toolkit (www.standardsi40.sg) in October 2019. Referencing the 14 key performance indicators listed in the Smart Industry Readiness Index (SIRI) Prioritisation Matrix (https://www.siri.gov.sg), the standards toolkit offers guidance on key standards, use cases and training courses that can help enterprises adopt I4.0 solutions in their business.