Additive manufacturing - a view through the prism of standardization

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This paper explores the significance of standardization in the field of additive manufacturing (AM). The rapid growth of AM in modern industries has highlighted the need for standardization to ensure compatibility, quality control, and market opportunities for AM products. The paper emphasizes the flexibility of AM technologies in meeting industrial and ecological requirements, revolutionizing business models, and satisfying customer needs. It provides an overview of the International Organization for Standardization (ISO) and ASTM International (American Society for Testing and Materials), two major organizations involved in developing and publishing international standards for AM. The paper discusses the technical committees, working groups, and collaborations established by ISO and ASTM to address various aspects of AM standardization. Additionally, it highlights the ongoing efforts in Serbian national standardization and proposes future research on analyzing the scopes and contents of AM standards for improved usability. Overall, the paper emphasizes the crucial role of standardization in supporting the continued advancement of additive manufacturing.

Keywords: additive manufacturing, additive technologies, standardization, standards, ISO, ASTM International

1. INTRODUCTION

The application of additive manufacturing (AM) is imperative in modern, digital industries and is rapidly growing day by day. The reason for this is the complete flexibility of technologies and procedures of AM to present concepts of industrial development, but also to the rigorous ecological, energy and environmental requirements of modern society development. AM is changing the way companies work and the way they communicate with consumers, opening up new horizons for increased profits and more sustainable business models. AM also has a powerful role in fulfilling the complicated and unique needs of customers by applying different technologies and materials. The contribution of the development of AM to competitiveness and profitability through the optimization of production processes, as well as wide opportunities for the implementation of innovative solutions that vary from the reduction of waste and the consumption of material resources and energy, to shorter supply chains and to a longer product life [1], is also significant. In recent years, new additive technologies and materials have been intensively developed. Products obtained by applying AM are increasingly used in almost all areas of modern consumer society. These products must meet many specific requirements, such as mechanical, physical, chemical, ergonomic, aesthetic, ecological and other properties, as well as safety and security properties, economy, energy efficiency and many other conditions of modern society. That's why there is a need for organization and regulation of the entire system of AM in present-day and future industries and product exploitation, and this can only be achieved through standards and standardization!

2. ADDITIVE MANUFACTURING

Additive manufacturing is a common term for technologies, which are based on the principle of making objects by adding materials [2]. The material is added in the places where it is needed and in the quantities that are needed. In doing so, material is added layer by layer, without using tools to shape or remove material. The process is based on the direct translation of a three-dimensional digital CAD model into a real physical object. Thanks to additive technologies, it is possible to make parts with reduced mass, with bionic design, make assemblies contained in one component, adjustment of the object's geometry and function to the user, integration of two or more functions in one component, make moulding tools with cooling channels, make of medical aids completely topologically adapted to the user etc [2]. Over the years, the need for standards in the field of AM has been widely recognized as a necessity in academia, research organizations, and industry. Priorities in the development and publication of standards include materials, production processes and test methods, as well as increasing market opportunities for the placement of products obtained by AM [3].

3. STANDARDS AND STANDARDIZATION

A standard is an official document that provides characteristics, specifications, guidelines or requirements used to ensure that materials, processes, products and services are fit for purpose [4]. International standards establish the desirable or mandatory performance of products and services, as well as the level, methods and means of their quality control. In this way, optimal conditions and procedures are ensured, to achieve compatibility of products and services in space and time. Engineering standards prescribe rules and provide recommendations for the construction and equipment, the performance of structures, durability, service life, quality, safety, codes of practice, test methods, analysis, evaluation, verification, measurement, production, design, drawing, use, the machines safety and production conditions, symbols and terminology, abbreviations, symbols, units, etc.

ISO is the International Organization for Standardization. It is founded to develop and publish international standards, as it said in [4]: to answer the

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question "What is the best way to do this?". This organization was founded in 1946 when 67 Technical Committees were constituted. At the time of writing this paper, ISO has 816 committees and subcommittees dealing with standards development, and the number is increasing every year. The organization has members from national standardization organizations of 168 countries around the world. So far, 24780 standards have been published, covering practically all features of production, technology and management [4].

The American Society for Testing and Materials - ASTM was formed in 1898. In 2001, they changed the name to ASTM International. This organization deals with the development and publication of international standards. Today, over 12,000 ASTM standards are used worldwide to improve product quality, improve health and safety, strengthen market access and trade, and build consumer confidence [5]. ASTM International employs more than 30,000 professionals from 140 countries, who create classifications, specifications, test methods, guides and practices that support industries and governments around the world. Within ASTM there are more than 140 committees for writing technical standards from a wide range of industries [6]: metals, construction, petroleum, consumer products, and many others. When emerging industries – such as additive manufacturing, nanotechnology, industrial biotechnology etc. want to advance the growth of technologies through standardization, they come to ASTM International [5].

3.1. ISO

Technical Committee TC 261 - Additive manufacturing [7,8], created in 2011, operates within the ISO organization. This committee's working groups (36 in total so far) deal with standardization in the area of AM: terms and definitions, hardware and software for the Technical Committee TC 261 - Additive manufacturing [7,8], created in 2011, and operates within the ISO organization. The working groups (36 in total so far) of this committee deal with standardization in the field of AM: terms and definitions, hardware and software for the accomplishment of different AM technologies, testing, quality of facilities and processes, procurement contracts, etc. Two working groups are ad hoc ones and the third one is the Chair's Advisory Group. The primary ISO/TC 261 working groups are WG1 – Terminology, WG 2 – Processes, systems and materials, WG 3 – Test methods and quality specifications, WG 4 – Data and Design and WG 6 – Environment, Health and Safety. Two joint working groups were formed within the cooperation of TC 261 and other committees: with committee ISO/TC 44 (Welding and allied processes) working group JWG 10 - Additive manufacturing in aerospace applications and with committee ISO/TC 61 (Plastics) working group JWG 11 - Additive manufacturing for plastics. Other working groups are joint groups - JG, formed within the ISO cooperation with ASTM International.

Active members of the ISO/TC 261 committee are representatives of national standardization organizations from 27 countries: Australia - SA, Austria - ASI, Belgium - NBN, Brazil - ABNT, Canada - SCC, China - SAC, Denmark - DS, Finland - SFS, France – AFNOR, Germany – DIN, Ireland – NSAI, Israel – SII, Italy – UNI, Japan – JISC, Republic of Korea – KATS, Netherlands – NEN, Norway – SN, Philippines – BPS, Poland – PKN, Portugal – IPQ, Russian Federation - GOST R, Singapore - SSC, Spain - UNE, Sweden - SIS, Switzerland - SNV, United Kingdom - BSI, United States - ANSI. Observer members are from 8 countries: Czech Republic - UNMZ, Iran - INSO, Jordan - JSMO, Luxembourg - ILNAS, New Zealand - NZSO, Romania - ASRO, Rwanda - RSB, South Africa - SABS and Türkiye - TSE. He is currently the secretary of this committee under the authority of the German Organization for Standardization (Deutsches Institut für Normung e.V. - DIN).

The titles of the standards issued by TC 261, which have only ISO in the designation, are given in Table 1. It is a group of three standards that refer to general principles in the field of AM: part positioning, coordinates, orientation, process categories, feedstock, main characteristics and corresponding test methods.

In addition to the standards listed in Table 1, another ISO standard is under preparation and is currently in the draft category - ISO/DIS 27548: Additive manufacturing of plastics — Environment, health, and safety — "Test method for determination of particle and chemical emission rates from desktop material extrusion 3D printer".

Table 1: Published ISO standards

ISO 17295: 2023	Additive manufacturing — General principles — Part positioning, coordinates and orientation
ISO 17296-2: 2015	Additive manufacturing — General principles — Part 2: Overview of process categories and feedstock
ISO 17296-3: 2014	Additive manufacturing — General principles — Part 3: Main characteristics and corresponding test methods

3.2. ASTM International

ASTM Technical Committee F42 on Additive Manufacturing Technologies was formed in 2009. Currently, this committee has more than 725 members, working on the development of AM standards [9]. Within the F42 committee, there are technical subcommittees that deal with specific segments within the general subject area - additive manufacturing [10].

An overview of the subcommittees of Committee F42 is given in Table 2. A list of the 28 standards published by Committee F42 that carry only the ASTM “F” designation is given in Table 3.

Table 2: Subcommittees of F42 Technical Committee

F42.01	Test Methods
F42.04	Design
F42.05	Materials and Processes (Metals, Polymers, Ceramics)
F42.06	Environment, Health, and Safety
F42.07	Applications (Aviation, Spaceflight, Medical/Biological, Transportation/Heavy, Machinery, Maritime, Electronics, Construction, Oil/Gas, Consumer, Energy)
F42.08	Data
F42.90	Executive (Terminology, US Technical Advisory Group to ISO TC 261)

Table 3: Published ASTM standards

F42.01 – Test Methods	
F2971-13 (2021)	Standard Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing
F3122-14 (2022)	Standard Guide for Evaluating Mechanical Properties of Metal Materials Made via Additive Manufacturing Processes
F3522-22	Standard Guide for Additive Manufacturing of Metals — Feedstock Materials — Assessment of Powder Spreadability
F3571-22	Standard Guide for Additive Manufacturing – Feedstock – Particle Shape Image Analysis by Optical Photography to Identify and Quantify the Agglomerates/Satellites in Metal Powder Feedstock
F3606-22	Standard Guide for Additive Manufacturing — Feedstock Materials — Testing Moisture Content in Powder Feedstock
F3624-23	Standard Guide for Additive Manufacturing of Metals – Powder Bed Fusion – Measurement and Characterization of Surface Texture
F3626-23	Standard Guide for Additive Manufacturing — Test Artifacts — Accelerated Build Quality Assurance for Laser Beam Powder Bed Fusion (PBF-LB)
F42.04 – Design	
F3413-19e1	Guide for Additive Manufacturing — Design — Directed Energy Deposition
F3529-21	Guide for Additive Manufacturing — Design — Material Extrusion of Polymers
F3530-22	Standard Guide for Additive Manufacturing — Design — Post-Processing for Metal PBF-LB
F42.05 – Materials and Processes	
F2924-14 (2021)	Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion
F3001-14 (2021)	Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium ELI (Extra Low Interstitial) with Powder Bed Fusion
F3049-14 (2021)	Standard Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes
F3055-14a(2021)	Standard Specification for Additive Manufacturing Nickel Alloy (UNS N07718) with Powder Bed Fusion
F3056-14 (2021)	Standard Specification for Additive Manufacturing Nickel Alloy (UNS N06625) with Powder Bed Fusion
F3091/F3091M-14(2021)	Standard Specification for Powder Bed Fusion of Plastic Materials
F3184-16	Standard Specification for Additive Manufacturing Stainless Steel Alloy (UNS S31603) with Powder Bed Fusion
F3187-16	Standard Guide for Directed Energy Deposition of Metals
F3213-17	Standard for Additive Manufacturing – Finished Part Properties – Standard Specification for Cobalt-28 Chromium-6 Molybdenum via Powder Bed Fusion
F3301-18a	Standard for Additive Manufacturing – Post Processing Methods – Standard Specification for Thermal Post-Processing Metal Parts Made Via Powder Bed Fusion
F3302-18	Standard for Additive Manufacturing – Finished Part Properties – Standard Specification for Titanium Alloys via Powder Bed Fusion
F3318-18	Standard for Additive Manufacturing – Finished Part Properties – Specification for AlSi10Mg with Powder Bed Fusion – Laser Beam
F42.07 – Applications	
F3456-22	Standard Guide for Powder Reuse Schema in Powder Bed Fusion Processes for Medical Applications for Additive Manufacturing Feedstock Materials
F3554-22	Standard Specification for Additive Manufacturing – Finished Part Properties – Grade 4340 (UNS G43400) via Laser Beam Powder Bed Fusion for Transportation Applications
F3572-22	Standard Practice for Additive Manufacturing – General Principles – Part Classifications for Additive Manufactured Parts Used in Aviation
F42.08 – Data	
F3490-21	Standard Practice for Additive Manufacturing — General Principles — Overview of Data Pedigree
F3560-22	Standard Specification for Additive Manufacturing – Data – Common Exchange Format for Particle Size Analysis by Light Scattering
F3605-23	Standard Guide for Additive Manufacturing of Metals — Data — File Structure for In-Process Monitoring of Powder Bed Fusion (PBF)

The percentage distribution of published standards by subcommittees (specific areas of AM to which they refer) is shown in Figure 1.

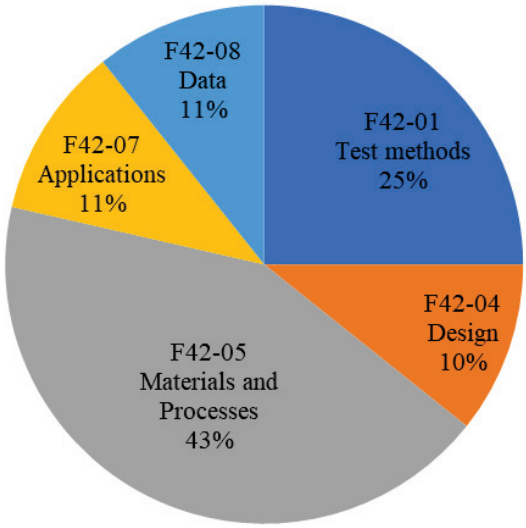

Figure 1: Distribution of published ASTM standards by subcommittees

Currently, most ASTM standards on AM are published in the field of Materials and Processes (43%), followed by Test Methods (25%). In the areas of Design, Application and Data there is an almost equal number of standards (about 11%). In the domain of Materials and Processes, one standard refers to Plastics, and all others to metals and alloys, as well as related processes. In the area of Design, there are three standards, one of which refers to metals, the second one to polymers, and the third one to directed energy deposition. Dedicated standards have been developed for medical applications, transport applications and for use in aviation.

In addition to the standards listed in Table 3, there is also a large group of standards that have been developed and published jointly by ISO and ASTM International.

3.3. ISO/ASTM

ISO and ASTM signed a cooperation agreement in 2011, with the aim of joint development and adoption of international standards that serve the global market in the field of AM. The purpose of this agreement is to eliminate duplication of effort while optimally allocating resources in the AM industry.

The working groups formed for cooperation between ISO and ASTM International on the development and publication of joint standards in the area of AM are listed in Table 4. A large number of working groups tells us about the great and growing importance of AM in all spheres of human activity.

Table 4: Joint ISO/TC 261-ASTM F 42 working groups

JG	Working group name
51	Terminology
52	Standard test artifacts
54	Fundamentals of Design
56	Standard Practice for Metal Powder Bed Fusion to Meet Rigid Quality Requirements
57	Process-specific design guidelines and standards
58	Qualification, quality assurance and post processing of powder bed fusion metallic parts
59	NDT for AM parts
61	Mechanical properties characterization of additively manufactured metallic materials
62	Guide for conducting round robin studies for additive manufacturing
63	Test methods for characterization of powder flow properties for AM applications
64	Additive Manufacturing File Format (AMF)
68	EH&S for 3D printers
69	EH&S for use of metallic and polymer materials
71	Powder quality assurance
72	Machine - Production process qualification
73	Digital product definition and data management
74	Personnel qualifications
75	Industrial conformity assessment at additive manufacturing centres
76	Revision of ISO 17296-3 & ASTM F3122-14
77	Test method of sand mold for metalcasting
78	Safety regarding AM-machines (relating to harmonized European Standards, Type C-Standard)
79	Qualification for AM processes in automotive applications
80	Quality requirements for additive manufacturing in building & construction (structural and infrastructure elements)
81	Metallic materials for additive manufacturing
82	Characterization of ceramic feedstock materials

The common ISO/ASTM standards are listed in Table 5. These are the standards, whose description and offer to users are available on the websites of both organizations. Those standards were either created or were last updated in the period from 2020-2023. Some standards have the common designation ISO/ASTM but are available on the website of only one of these two organizations. The titles of these standards are given in Tables 6 and 7.

Table 5: Published ISO/ASTM standards available on both ISO and ASTM websites [4-10]

ISO/ASTM 52900:2021	Additive manufacturing — General principles — Fundamentals and vocabulary
ISO/ASTM 52903-1: 2020	Additive manufacturing — Material extrusion-based additive manufacturing of plastic materials — Part 1: Feedstock materials
ISO/ASTM 52903-2: 2020	Additive manufacturing — Material extrusion-based additive manufacturing of plastic materials — Part 2: Process equipment
ISO/ASTM 52909: 2022	Additive manufacturing of metals — Finished part properties — Orientation and location dependence of mechanical properties for metal powder bed fusion
ISO/ASTM 52911-1: 2019	Additive manufacturing — Design — Part 1: Laser-based powder bed fusion of metals
ISO/ASTM 52911-2: 2019	Additive manufacturing — Design — Part 2: Laser-based powder bed fusion of polymers
ISO/ASTM 52911-3: 2023	Additive manufacturing — Design — Part 3: PBF-EB of metallic materials
ISO/ASTM 52915: 2020	Specification for additive manufacturing file format (AMF) Version 1.2
ISO/ASTM 52925: 2022	Additive manufacturing of polymers — Feedstock materials — Qualification of materials for laser-based powder bed fusion of parts
ISO/ASTM TS 52930: 2021	Additive manufacturing — Qualification principles — Installation, operation and performance (IQ/OQ/PQ) of PBF-LB equipment
ISO/ASTM 52931: 2023	Additive manufacturing of metals — Environment, health and safety — General principles for use of metallic materials
ISO/ASTM 52936-1: 2023	Additive manufacturing of polymers — Qualification principles — Part 1: General principles and preparation of test specimens for PBF-LB
ISO/ASTM 52942: 2020	Additive manufacturing — Qualification principles — Qualifying machine operators of laser metal powder bed fusion machines and equipment used in aerospace applications
ISO/ASTM 52950: 2021	Additive manufacturing — General principles — Overview of data processing

Table 6: Published ISO/ASTM standards available only on ISO website [4,7,8]

ISO/ASTM 52901:2017	Additive manufacturing — General principles — Requirements for purchased AM parts
ISO/ASTM 52904:2019	Additive manufacturing — Process characteristics and performance — Practice for metal powder bed fusion process to meet critical applications
ISO/ASTM TR 52906:2022	Additive manufacturing — Non-destructive testing — Intentionally seeding flaws in metallic parts

ISO/ASTM 52907:2019	Additive manufacturing — Feedstock materials — Methods to characterize metal powders
ISO/ASTM TR 52912:2020	Additive manufacturing — Design — Functionally graded additive manufacturing
ISO/ASTM TR 52916:2022	Additive manufacturing for medical — Data — Optimized medical image data
ISO/ASTM TR 52917:2022	Additive manufacturing — Round robin testing — General guidelines

Table 7: Published ISO/ASTM standards available only on ASTM website [5,9,10]

ISO/ASTM52921-13(2019)	Standard Terminology for Additive Manufacturing—Coordinate Systems and Test Methodologies
ISO/ASTM52901-16	Standard Guide for Additive Manufacturing – General Principles – Requirements for Purchased AM Parts

3.4. Standards under development

AM standards currently under development in co-production between ISO and ASTM International are listed in Table 8.

Table 8: ISO/ASTM standards under development [5,9,10]

ISO/ASTM FDIS 52902	Additive manufacturing — Test artifacts — Geometric capability assessment of additive manufacturing systems
ISO/ASTM TR 52905	Additive manufacturing of metals — Non-destructive testing and evaluation — Defect detection in parts
ISO/ASTM DIS 52908	Additive manufacturing of metals — Finished Part properties — Post-processing, inspection and testing of parts produced by powder bed fusion
ISO/ASTM DIS 52910	Additive manufacturing — Design — Requirements, guidelines and recommendations
ISO/ASTM DTR 52913-1	Additive manufacturing — Feedstock materials — Part 1: Parameters for characterization of powder flow properties
ISO/ASTM CD TR 52918	Additive manufacturing — Data formats — File format support, ecosystem and evolutions
ISO/ASTM CD 52919	Additive manufacturing — Qualification principles — Test method of sand moulds for metal casting
ISO/ASTM FDIS 52920	Additive manufacturing — Qualification principles — Requirements for industrial additive manufacturing processes and production sites
ISO/ASTM FDIS 52924	Additive manufacturing of polymers — Qualification principles — Classification of part properties
ISO/ASTM DIS 52926-1	Additive Manufacturing of metals — Qualification principles — Part 1: General qualification of operators
ISO/ASTM DIS 52926-2	Additive Manufacturing of metals — Qualification principles — Part 2: Qualification of operators for PBF-LB
ISO/ASTM DIS 52926-3	Additive Manufacturing of metals — Qualification principles — Part 3: Qualification of operators for PBF-EB
ISO/ASTM DIS 52926-4	Additive Manufacturing of metals — Qualification principles — Part 4: Qualification of operators for DED-LB
ISO/ASTM DIS 52926-5	Additive Manufacturing of metals — Qualification principles — Part 5: Qualification of operators for DED-Arc
ISO/ASTM DIS 52927	Additive manufacturing — General principles — Main characteristics and corresponding test methods
ISO/ASTM DIS 52928	Additive manufacturing of metals— Feedstock materials — Powder life cycle management
ISO/ASTM CD 52929	Additive manufacturing of metals — Powder bed fusion — Presentation of material properties in material data sheets
ISO/ASTM DIS 52933	Additive manufacturing — Environment, health and safety — Test method for the hazardous substances emitted from material extrusion type 3D printers in the non-industrial places
ISO/ASTM DIS 52935	Additive manufacturing of metals – Qualification principles – Qualification of AM coordination personnel
ISO/ASTM DIS 52938-1	Additive manufacturing of metals — Environment, health and safety — Part 1: Safety requirements for PBF-LB machines
ISO/ASTM DIS 52939	Additive Manufacturing for construction — Qualification principles — Structural and infrastructure elements
ISO/ASTM CD 52940	Additive manufacturing of ceramics — Feedstock materials — Characterization of ceramic slurry in vat photopolymerization
ISO/ASTM CD 52941	Additive manufacturing — System performance and reliability — Acceptance tests for laser metal powder-bed fusion machines for metallic materials for aerospace application
ISO/ASTM DIS 52943-2	Additive manufacturing for aerospace — Process characteristics and performance — Part 2: Directed energy deposition using wire and arc
ISO/ASTM DIS 52945	Additive manufacturing for automotive — Qualification principles — Generic machine evaluation and specification of key performance indicators for PBF-LB/M processes
ISO/ASTM AWI 52948	Additive manufacturing for metals — Non-destructive testing and evaluation — Imperfections classification in PBF parts
ISO/ASTM DTR 52952	Additive manufacturing of metals — Feedstock materials — Correlating of rotating drum measurement with powder spreadability in PBF-LB machines
ISO/ASTM DIS 52953	Additive manufacturing for metals — General principles — Registration of geometric data acquired from process-monitoring and for quality control
ISO/ASTM CD 52957	Additive Manufacturing — Design — Parts using ceramic materials
ISO/ASTM CD 52958	Additive Manufacturing of Metals — Powder Bed Fusion (PBF) — Best Practice for In-Situ Flaw Detection and Analysis for Laser-based PBF
ISO/ASTM CD 52959	Additive Manufacturing — Test Artifacts — Compression Validation Coupons for Lattice Designs

3.5. Serbian national standardization in the field of AM

The Institute for Standardization of Serbia (ISS) is the national standardization body of the Republic of Serbia [11]. Work on the adoption of Serbian standards takes place in national technical committees. Technical committees are formed according to corresponding complementary international technical committees. Committee M010 "Technical drawings, tolerances, gears, bearings and threaded fasteners", with 1189 available standards and 94 new projects works within this organization. Among others, this committee collaborates with the ISO/TC 261 - Additive manufacturing committee (since September 2017). However, due to the permanently growing number of standards, there was a need to form a new national standardization technical committee within the ISS that will deal exclusively with standards on AM. The constitutive session of this committee, which will have the designation KS M261 (as well as the corresponding ISO committee), was held in March 2023. All relevant information about the ISS KS M261 committee will be available on the ISS website [8] soon. The authors of this paper are members of this committee.

4. CONCLUSION

Based on the carried out analysis, it can be concluded:

- standardization in the field of AM is lasting almost 15 years;
- standardization for AM is developing very quickly and the number of standards is increasing from year to year, following the increase in AM popularity in the industry and customers' everyday life;
- ISO and ASTM International have published 76 standards in the area of AM, and currently, 33 standards are under development;
- in the future, there will be a need for new standards, according to the further progressively growing development of additive manufacturing and products obtained using additive technologies.

Future work could be a detailed analysis of the scopes and contents of the standards mentioned in this paper and their classification into certain categories to make using the standards easier.

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REFERENCES

[1] B. Elhazmiri, N. Naveed, M. Naveed Anwar and M. I. Ul Haq, “The role of additive manufacturing in industry 4.0: An exploration of different business models”, Sustainable Operations and Computers, Vol. 3, pp. 317-329, (2022)

[2] S. Ćirić-Kostić and N. Bogojević, “Principles and application of additive manufacturing” (in Serbian), University in Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Kraljevo (Serbia), (2020)

[3] R. Kawalkar, H. K. Dubey and S. P. Lokhande, “A review for advancements in standardization for additive manufacturing”, Materials Today: Proceedings, Vol. 50, pp. 1983-1990, (2022)

[4] www.iso.org

[5] www.astm.org

[6] https://www.astm.org/get-involved/technical-committees/committee-all

[7] https://www.iso.org/committee/629086.html

[8] https://committee.iso.org/home/tc261

[9] https://www.astm.org/get-involved/technical-committees/committee-f42

[10] https://www.astm.org/get-involved/technical-committees/committee-f42/subcommittee-f42

[11] www.iss.rs