ADDITIVE MANUFACTURING: OVERVIEW ABOUT STANDARDS APPLIED TO OIL AND GAS INDUSTRY

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Abstract: Additive Manufacturing (AM) is a group of manufacturing methods capable of producing complex parts from digital models without investment in tooling. The applicability of AM in different industries has become increasingly common and this is no different for the oil and gas industry. In this way, seeking to ensure predictability in the supply chain, reduce lead time and cost, and assure safety and quality of parts obtained by AM throughout the oil and gas industry, standards are being developed and published to meet this market. This work aimed to evaluate if there is established standardized tools and methodologies for AM part designs for oil and gas fields.

Keywords: Additive Manufacturing; Design for Additive Manufacturing; Standards; Oil and Gas Industry.

MANUFATURA ADITIVA: UMA VISÃO GERAL SOBRE NORMAS APLICADAS À INDUSTRIA DO PETRÓLEO E GÁS

Resumo: A manufatura aditiva (AM, do inglês *Additive Manufacturing*) é um conjunto de métodos de fabricação capazes de produzir peças complexas a partir de modelos digitais sem investimento em ferramental. A aplicabilidade da AM em diferentes indústrias tem se tornado cada vez mais comum e isso não é diferente para a indústria de óleo e gás. Dessa forma, buscando garantir previsibilidade na cadeia de suprimentos, reduzir lead time e custo, e garantir a segurança e qualidade das peças obtidas pela AM em toda a indústria de óleo e gás, normas estão sendo desenvolvidas e publicadas para atender este mercado. Este trabalho teve como objetivo avaliar se existem ferramentas e metodologias padronizadas para projetos de peças obtidas por AM e destinadas aos campos de petróleo e gás.

Palavras-chave: Manufatura Aditiva; Projeto para Manufatura Aditiva; Normas; Indústria de Petróleo e Gás.

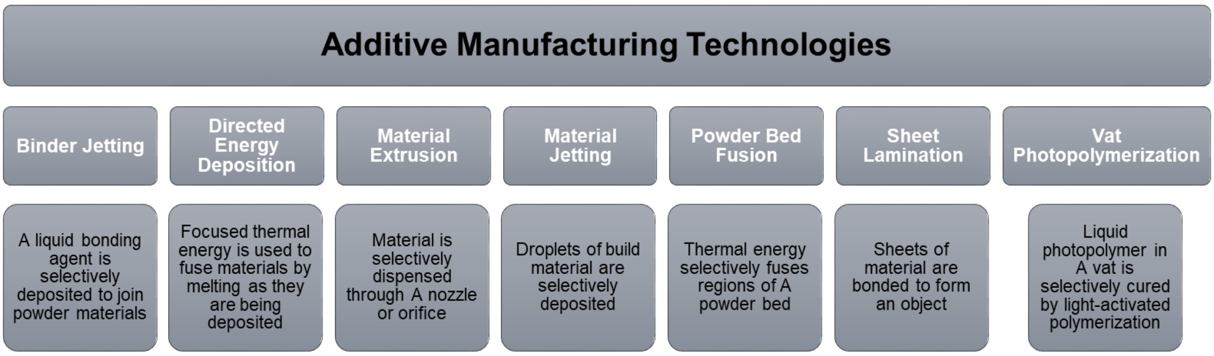
1. INTRODUCTION

1.1. Additive Manufacturing

Additive manufacturing (AM), also referred to as 3D printing, is classified as a process of joining materials to manufacture components from 3D model data, adding material in a layer-by-layer manner, as opposed to subtractive manufacturing methods [3, 7]. Additionally, 3D printing is defined as the manufacturing products through the deposition of a material using a print head, nozzle, or other printer. In a few cases, AM can be treated as a supplement to conventional manufacturing technologies. At other times, is the merely means through which complex products can be fabricated [3].

AM techniques are applied to provide rapid prototyping, rapid manufacturing and rapid tools, producing, on those ways, prototypes models, parts of end-use, and tools for long-term mass production of parts, respectively. The AM operations can be categorized into four main categories in agreement with the operation principle: addition, subtraction, hybrid, and forming operations [1]. AM technologies are divided into seven categories, as illustrated in Figure 1. AM technologies and definitions[7].

Figure 1. AM technologies and definitions [7]



The principal AM markets which include automotive, aerospace, medical, consumer products, and general industries announce similar accomplishment stories [9]. For the maritime and oil and gas economic sectors, the interest is increasing substantially. However, the challenge for these industries has been that there are no established methods of guaranteeing the quality of an additive manufacturing process and an additively manufactured component [4].

1.2. Design For Additive Manufacturing

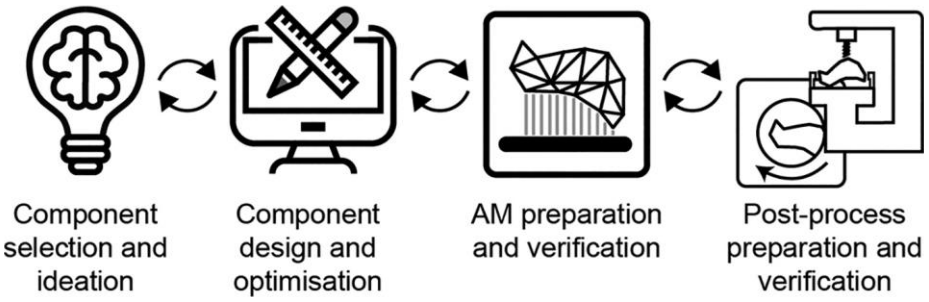
As a process that enables many more degrees of freedom than other manufacturing processes [7], new design alternatives for additive manufacturing can be adopted, for instance, to merge an assembly of parts into one part and hence, to minimize the needed assembly work and costs. This assembly combination permit to an integration of functions from different parts, which could result in superior performance and to reduce maintenance [3]. Consequently, adaptations in current design-to-manufacturing practices have been required, giving rise to the recent Design for Additive Manufacturing concept (DfAM) [8].

DfAM is a category of methods and knowledge that assists the design process of parts by thoroughly using the advantages of AM [9]. Other concepts about DfAM subject to the capabilities of AM technologies can be defined, as maximize product performance through the synthesis of shapes, sizes, hierarchical structures and material compositions; or a design method by which functional performance and/or other important lifecycle considerations of the product, such as manufacturability, reliability, and cost, can be optimized, consistent with the capabilities of AM technologies [9].

From a design engineer's perspective, DfAM can be divided into four categories (component selection and ideation, design and optimization, AM preparation and postprocess preparation), as shown in

[9]. The crucial point of the first phase is the component selection and assembly design. In the second category, the focus is on the design support, where the computer-aided design (CAD) softwares and optimization methods and tools dominate. The third category focuses on to prepare and verify the success of the manufacturing through rules, software and simulation methods. Within the fourth step, the component is adapted and prepared for postprocessing, as well as removal from the build plate, elimination of support structures, heat treatment and achievable surface improvement methods [9].

Figure 2. Four steps in the design for additive manufacturing process [9]



1.3. Design for Additive Manufacturing: Sustainability Considerations

The DfAM sustainability guidelines include fabricating durable products, applying recycled materials, adjusting high efficiency manufacturing processes, removing/minimizing the usage of hazardous materials, and building a profound association within the product and the consumer. All approaches of the sustainability of AM methods based on three main dimensions, such that economic, environmental, and social dimensions [1].

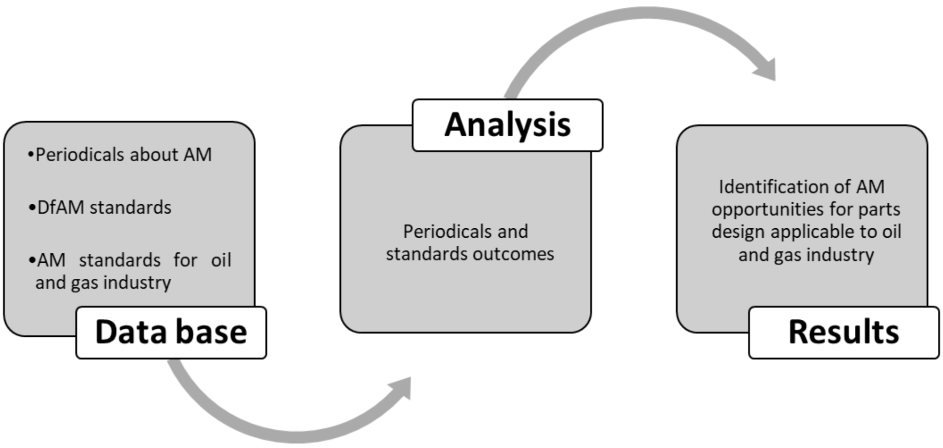
There are some future challenges involving the AM suitability that must be more investigated, such as techniques for early cost estimation; the late life cycle steps of postprocessing, inspection and certification, once these steps are inadequately represented in present DfAM approaches; the majority of product designers and engineers are still educated “to think subtractive”, then more education on (design for) Additive Manufacturing is necessary [9].

Therefore, this paper aims to provide AM analysis considering a literature overview in terms of definitions, classifications, technologies and sustainability. Moreover, the standards internationally applicable to oil and gas industries are examined to understand the AM opportunities once the AM standards applied on oil and gas sector are fresh and there is no internationally accepted framework for AM part design for oil and gas application.

2. METHODOLOGY

Figure 3 summarizes the activities that were carried out for the search about AM standards with a focus on guidelines for AM part design for oil and gas application.

Figure 3. Methodology used on the search about AM standards applied for oil and gas industry



The scientific databases of this work were: API, COBEF (Congresso Brasileiro de Engenharia de Fabricação), ISO, MPDI, ScienceDirect, and Scholar google in general. Then, nine papers [1,2,3,4,5,6,7,8,9] were chosen based in their application for this initial study.

The guiding questions are a significant phase about the proposed overview because the search becomes more systematized.

Question 1: Are there standards applied to design for additive manufacturing?

Question 2: Are there standards applied to additive manufacturing of parts designed for the oil and gas industry?

Question 3: Are there guidelines applied to parts obtained by additive manufacturing and applied specifically to the oil and gas industry?

3. RESULTS AND DISCUSSION

To internationally prepare, develop and publish standards concerning to AM, the two main international institutions, ISO (International Standardization Organization) and ASTM (American Society for Testing and Materials), has been structured a joint standards development plan. The Table 1 shows the guidelines standards for DfAM developed by both organizations [6].

Table 1. Design standards for additive manufacturing [6]

Standard	Title	Status
ISO/ASTM 52910:2018	Additive manufacturing — Design — Requirements, guidelines and recommendations	Published
ISO/ASTM DIS 52910	Additive manufacturing — Design — Requirements, guidelines and recommendations	Under development
ISO/ASTM 52911-1:2019	Additive manufacturing — Design — Part 1: Laser-based powder bed fusion of metals	Published
ISO/ASTM 52911-2:2019	Additive manufacturing — Design — Part 2: Laser-based powder bed fusion of polymers	Published
ISO/ASTM DIS 52911-3	Additive Manufacturing — Design — Part 3: Electron beam powder bed fusion of metals	Under development
ISO/ASTM TR 52912:2020	Additive manufacturing — Design — Functionally graded additive manufacturing	Published

It is essential that products from AM technology are reliable, safe and legally approved to apply them in the oil and gas field. Consequently, the AM process needs to be standardized [5]. Furthermore, the premature nature of AM technologies induces uncertainties and strengthened risk exposure for involved stakeholders [3]. Along with, as health safety and environment (HSE) is a fundamental element of the oil and gas sector, the risk should always be mitigated [5]. Therefore, specific standards for products employed in petroleum and gas fields were recently published, such as API 20S: Additively Manufactured Metallic Components for Use in the Petroleum and Natural Gas Industries, and DNV-ST-B203: Additive manufacturing of metallic parts.

The DNV GL (Det Norske Veritas Holding AS) published the DNV-ST-B203: Additive manufacturing of metallic parts, which is the first standard to afford an internationally acknowledged framework for producing and using high quality additively manufactured metal parts for the oil and gas, maritime and related industries [3]. Additionally, the API (American Petroleum Institute) published the first edition of API 20S, Additively Manufactured Metallic Components for Use in the Petroleum and Natural Gas Industries, the standard that furnishes requirements for qualification of the manufacturing process, production, marking and documentation of metallic parts [2]. It is relevant to notice that both standards are in accordance with and complements relevant international AM standards published by ISO and ASTM.

Aiming to consider the natural gas and oil industry's emphasis on new technologies and innovations to satisfy the growing global requirement for energy while protecting the environment Earth's [10] and to optimize part design to decrease lead time and force efficiency and improvement throughout the entire sections of that industry [2], the API published API Standard 20S. The three principal characteristics of Standard 20S contain [10]:

- Specifications for eligibility in the fabrication, production, marking and documentation of metallic components manufactured using Additive Manufacturing;

- Establishment of three AM specification levels that determine technical, quality and qualification requirements promoting metallic additively manufactured components made are appropriate for design goals;

- Conditions for training, inspection, monitoring and measuring machinery, including materials testing, acceptance and quality control of final products.

Seeking to guarantee predictability in the supply chain, reducing lead time and cost, as well as safety and quality of AM feedstock [4], equipment, components and parts, the DNV, through a joint industry project (JIP) that includes academic institutions, industry operators and companies across the oil and gas supply chain, published DNV-ST-B203 standard which specifies requirements and guidance for acquisition, quality mainframe for manufacturers and qualification of AM metal products manufactured for the oil and gas, maritime and related industries utilizing different types of technologies. A resume across the API 20S and DNV-ST-B203 are shown in Table 2.

Table 2. Published standards about additive manufacturing standards for oil and gas industries [2, 4]

Standard	Title	Scope	Applicability
API 20S	Additively Manufactured Metallic Components for Use in the Petroleum and Natural Gas Industries	Requirements for qualification of the manufacturing process, production, marking, and documentation of additively manufactured metallic components used in the petroleum and natural gas industries when referenced by an applicable API equipment standard or otherwise specified as a requirement for conformance.	Additively manufactured metallic components produced by powder bed fusion (PBF), directed energy deposition (DED), and binder jetting (BJT) processes.
DNV-ST-B203	Additive manufacturing of metallic parts	Requirements and guidance for: the qualification of parts made by AM for the oil and gas and related industries; the purchasing of AM parts; quality management for manufacturers of AM parts; the manufacturing of AM parts.	Additively manufactured metallic components in general, with additional requirements for the following specific AM technologies: wire arc additive manufacturing (WAAM); laser beam powder bed fusion (PBF-LB).

4. CONCLUSION

API Standard 20S and DNV-ST-B203 are standards published with the intend to provide an internationally accepted framework for producing, marking and documentation for high quality additively manufactured metal parts applicable to oil and gas sector and other industries corelated [2, 3]. However, there is no specific guidelines for AM part design for oil and gas application, demonstrating, therefore, the need for standardized tools and methodologies applied to this market, although there is an effort by international standardization institutions, such as ASTM and ISO, to establish a general guideline for AM designs. Because of that, most researchers have identified specific niches to develop and apply project methods and tools [8].

Furthermore, both two international standards, API Standard 20S and DNV-ST-B203, presents requirements only for additively manufactured metal products, putting aside products manufactured with different types of materials. A feasible conclusion is that oil and gas fields are extremely severe, which demands acceptable toughness materials to resist the high pressure, temperature and corrosive agents [5]. This scenario can be seen as an opportunity to develop frameworks to design and manufacture parts made by unusual materials utilizing AM technologies.

5. REFERENCES

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