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A Review of Preparation and Characterization of Additively Manufactured Stainless Steel

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Abstract

In today's world, ADDITIVE MANUFACTURING (AM) is a well-known method for creating true three-dimensional objects, either out of metals, ceramics, plastics, or a combination of these materials. ADDITIVE MANUFACTURING (AM) is connected with a series of rapid heating and cooling cycles, as well as substantial temperature gradients, which result in the development of complicated thermal histories, which have a direct impact on the resulting microstructures. Due to the nature of this dynamic and far-from-equilibrium process, different microstructural features emerge. For instance, these are likely to induce changes in the corrosion characteristics of ADDITIVE MANUFACTURING (AM) stainless steels, which have superior mechanical properties and corrosion resistance when manufactured using other production methods. Because such modifications are not fully understood at this time, inconsistencies and conflicts in the literature on the corrosion behaviour of ADDITIVE MANUFACTURING (AM) stainless steels are regularly seen. The preparation and characterization of additively made stainless steel is the subject of this work, which provides a critical assessment. In terms of producing huge metallic structures at high deposition rates and cheap costs, WIRE ARC ADDITIVE MANUFACTURING (WAAM) has emerged as a viable method. This article reviews some ADDITIVE MANUFACTURING (AM) methods used mostly with metallic materials focusing on the WIRE ARC ADDITIVE MANUFACTURING (WAAM) of stainless steel.

Keywords: ADDITIVE MANUFACTURING (AM) , additive manufacturing of Metals, WIRE ARC ADDITIVE MANUFACTURING (WAAM) of Stainless steel.

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1.Introduction

"The process of joining materials to make objects from 3D model data, usually layer upon layer," is how AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) International [1] defines ADDITIVE MANUFACTURING (AM) . ADDITIVE MANUFACTURING (AM) processes can be categorized in many ways, according to the research. Metals polymers and ceramics are all examples of base materials that can be bonded together, as well as other materials such as liquids, molten, powders and solid layers [2–5]. Bonding methods include indirect and direct processes. Some methods and applications of metal additive manufacturing are discussed in this study.

2.Additive Manufacturing Processes

Based on the adhesion and bonding methods used, AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) International [1] categorizes additive manufacturing technologies into seven major groups. There are a few different types of photopolymerization in a vat, including vat photopolymerization, binder jetting, material extrusion, material jetting, and sheet lamination. Among the many options for liquid additive manufacturing, vat polymerization and material jetting are two options, while filament processes can make use of material extrusion as an alternative. When it comes to the process of binding powder particles together, powder fusion, binder jetting, or direct energy deposition are all viable options. As depicted in Figure. 1, the bonding procedures are categorized based on the raw material's "feedstock." With Charles W. Hull's invention of additive manufacturing in 1986, [6] it is still a young manufacturing process. Since then, several new procedures have been put into practice. Figure. 2 depicts a classification of several additive manufacturing processes based on the state of the raw material. In this study, we go into deeper detail about these ADDITIVE MANUFACTURING (AM) mechanisms.

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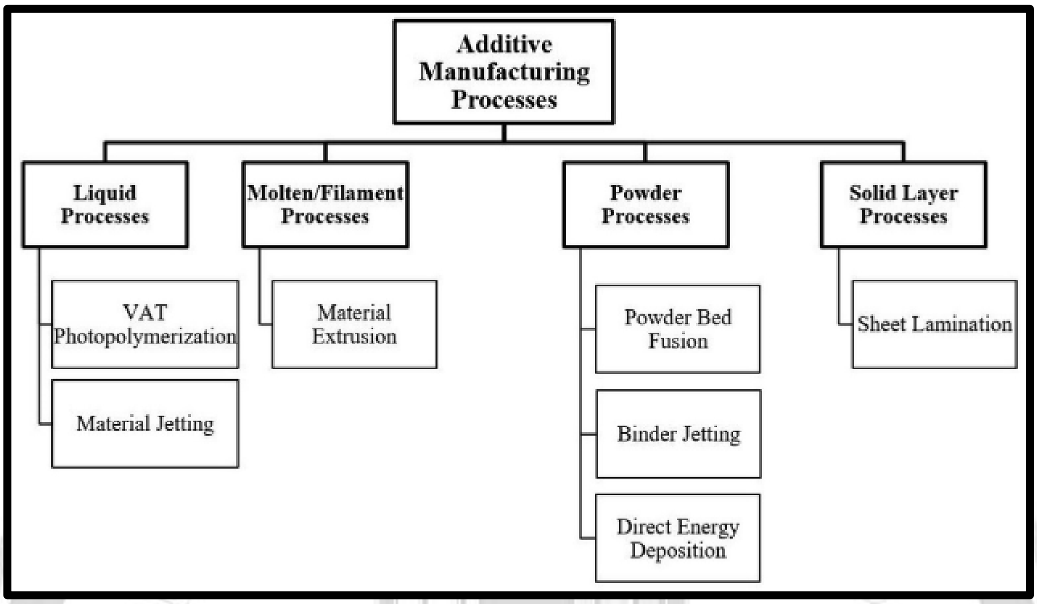

Figure (1): Classification of ADDITIVE MANUFACTURING (AM) processes depending on adhesion and bonding techniques [1]

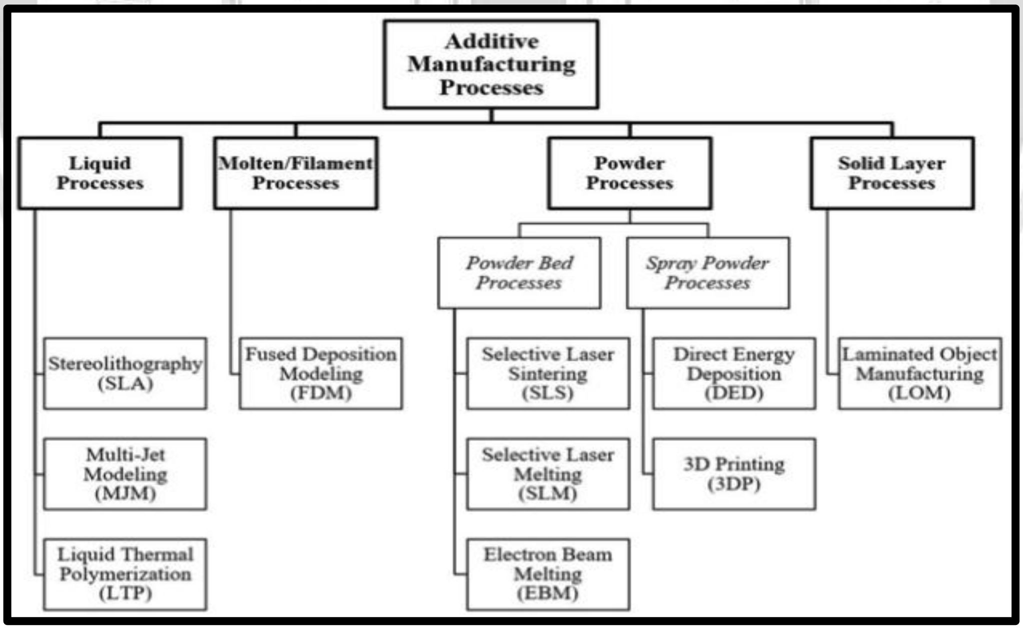

Figure (2) Processes for additive manufacturing [7].

2.1 Powder Bed Processes

2.1.1 Selective Laser Sintering.

SELECTIVE LASER SINTERING (SLS) is a layer-by-by-layer additive manufacturing technology that uses fine powder to produce a product. An even layer of powder is applied using a coater arm to create a level, Figure 3a depicts a construction site with a smooth, uniform surface. A laser beam is focused towards the powder layer to do a cross-sectional scan of the part. It is necessary

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to repeat the printing process until all of the layers have been produced [11, 12]. Particle binding processes include solid-state sintering, chemically induced binding, liquid-phase sintering, and partial melting. During solid-state sintering, the warmed powder melts between the melting point and half of the melting point. Binder components are absent from chemically induced binding, while metal atoms combine with oxygen to form a binding substance that helps to fuse the powder. It's possible to use the same material as both the structural material and the binder in liquid-phase sintering or partial melting [14]. SELECTIVE LASER SINTERING (SLS) can treat a wide variety of materials, allowing it to be used in a wide range of industries.

2.1.2 Selective Laser Melting.

It is the goal of full melting of powders to generate dense, mechanically similar objects. To achieve the same purpose, SELECTIVE LASER MELTING (SLM) technology was developed. All metals have the potential to be candidates, however, processing alters the behavior of certain. Differences in laser absorption reactions, surface tensions, and viscosities are examples of these kinds of variations. SELECTIVE LASER MELTING (SLM) metals are restricted by these issues [13]. Single-material powders and alloyed powders are the two basic types of SELECTIVE LASER MELTING (SLM) powders. Powders made from only one type of material, such as titanium, are known as single-material powders. Even though tests show a near-total density of 100%, excessive thermal loads can lead to fissures. Ti-6Al-4V and steel powders are two common alloyed materials used in alloyed powder formative processes. Due to their lack of ductility, these materials' mechanical characteristics are nearly identical to bulk materials [15]. Non-ferrous metals, such as titanium, aluminum, and copper, can be processed using SELECTIVE LASER MELTING (SLM) as shown Figure 3b. Due to increased energy consumption, melt pool instability and part shrinkage are becoming issues [16].

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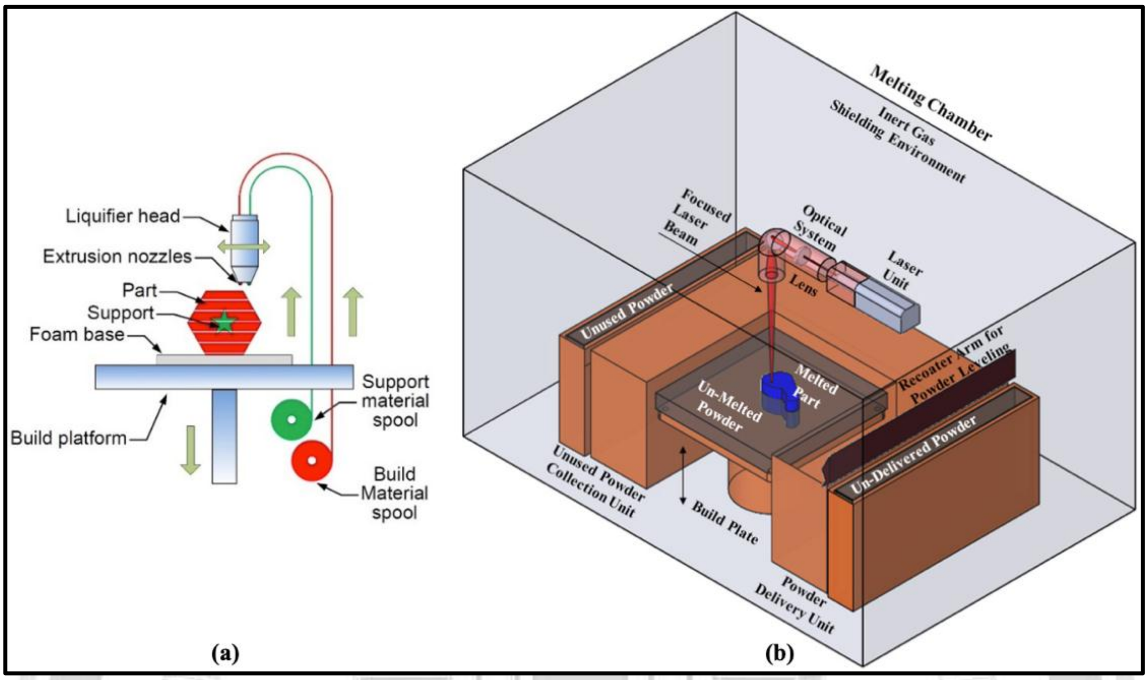

Figure. 3: (a) Fused deposition modelling [9, 10], and (b) selective laser sintering [11, 12] processes.

2.1.3 Electron Beam Melting

Because an electron gun melts warmed powder instead of a laser source for melting powder, ELECTRON BEAM MELTING (EBM) has more power because its build rate is faster than that of SELECTIVE LASER MELTING (SLM). In the case of metallic applications, powder bed techniques are a popular choice. In metal fabrication, ELECTRON BEAM MELTING (EBM) is now preferred, however, it is constrained by the material's electrical conductivity and the need to operate in a vacuum. SELECTIVE LASER MELTING (SLM), on the other hand, is more adaptable due to these drawbacks [17].

2.2 Spray Powder Processes

2.2.1 Direct Energy Deposition.

3D Cladding and Welding are two methods of DIRECT ENERGY DEPOSITION (DED) , which is an ADDITIVE MANUFACTURING (AM) process. When a laser or plasma beam melts the metal powder, it forms layers in the 3D Cladding process (see Figure. 4 [18]). Laser Metal Deposition, Laser Engineered Net Shaping, and Laser Consolidation are all laser-based processes. A nozzle feeds metal powder to the substrate, which is then laser melted to create Laser Metal Deposition (LMD) or LC. An extremely versatile technology, it can restore metal pieces that cannot be mended using other methods. These materials, which include nickel-based superalloys, cobalt alloys, titanium alloys, and steel [19], have the potential to be used to coat, manufacture, and rebuild complicated components. An inert gas atmosphere of argon or helium or nitrogen is used to keep the oxidation of the powder to a minimum during the plasma-based process known as Plasma Deposition Manufacturing (PDM). Plasma beams can't remove all oxygen from commercially available gas; hence, some oxidized particles can still form while the powder melts and solidifies. For low-volume metals, Plasma Deposition Manufacturing (PDM) is a viable 3D part generation method [20]. It is a wire-based method called Shaped Metal Deposition (SMD) [21] that uses small-diameter wire to melt and bond to the preceding layers. When compared to laser deposition or electron beam welding, Shaped Metal Deposition (SMD) has the advantage of being able to use a greater variety of metals. Wire has a smaller surface area than powder, therefore oxidized particles have fewer chances to develop. Despite its promise, there are numerous issues identified in the literature, mostly linked to the regulation of the weld pool and its impact on dimensional and geometrical accuracies. In addition, this technology is capable of producing extremely dense and massive pieces with mechanical qualities comparable to cast metal [21].

2.3 Inkjet 3D Printing.

There are two primary types of inkjet 3D printing: binder jetting and material jetting. Using an inkjet head to selectively spray and print a binder liquid onto a powder bed, the binder jetting three-dimensional printing (3DP) binds the powder particles one layer at a time. Post-processing is necessary to ensure that the produced parts have suitable mechanical strength. A more common method of layering a model is through the inkjet head with droplets of the building material in a liquid state. After the droplets are sprayed, an Ultraviolet laser (UV) laser is passed through each layer to cure them [22]. Binder selection can have a considerable impact on a part's mechanical strength and characteristics, making it a difficult component of three-dimensional printing (3DP). A variety of biomedical applications use the three-dimensional printing (3DP) method because of its ability to create unique biocompatible devices. This includes clinical investigations as well as surgical trainers, custom reconstructive and orthopaedic implants, tissue engineering, and dental repairs. The quality of the finished surface is another issue that arises in three-dimensional printing (3DP) techniques. As a result, one of the primary research concerns for this technique is increasing the surface finish through intelligent powder distribution or the use of small particle sizes [23].

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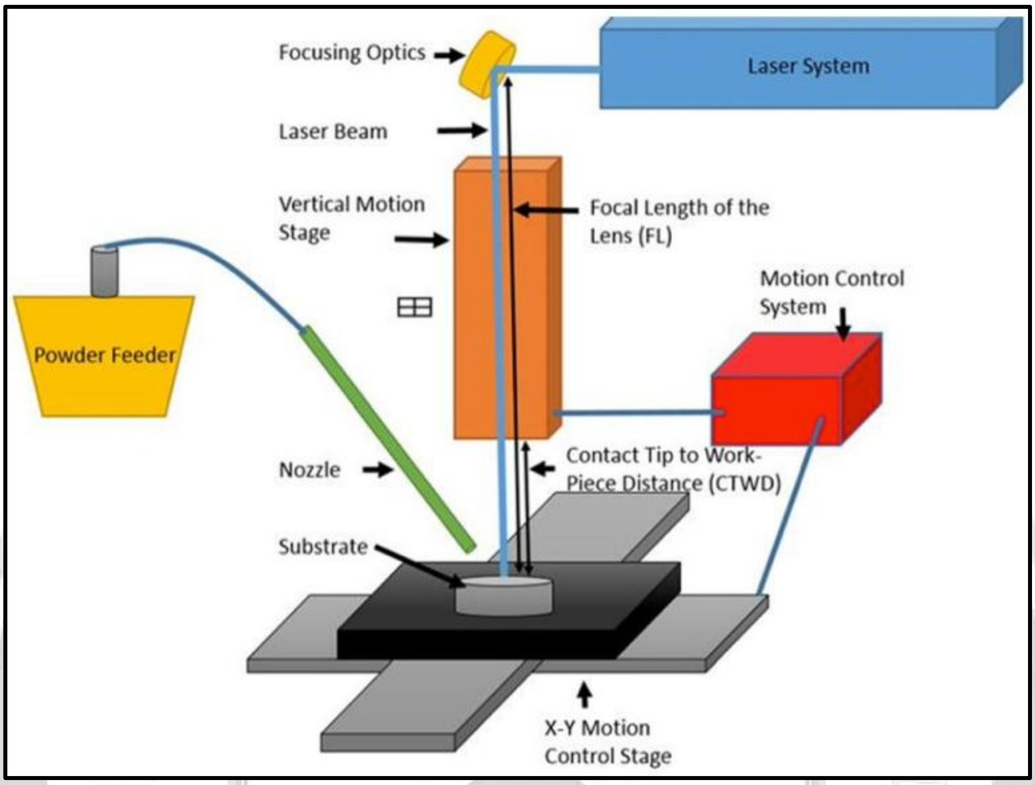

Figure 4: Laser cladding process [23].

2.4 Molten Filament Processes

In the Fused Deposition Modeling (FDM) method, two distinct nozzles, one for the model material and one for the support material, are used to build a 3D model developed using a computer-aided design (CAD) system. When using a conventional Fused Deposition Modeling (FDM) system, a layer of the part is built up layer-by-layer, as shown in Figure 3a, by melting and depositing the build material. It is necessary to remove the support material at the end of construction, but it is added to each layer as a means of supporting the created layer. The poor surface smoothness and dimensional errors of the manufactured items are two drawbacks of the Fused Deposition Modeling (FDM) technique. In the Fused Deposition Modeling (FDM) research field, predicting dimensional accuracy as a function of process parameters is a major focus [8]. As with most ADDITIVE MANUFACTURING (AM) metal techniques, mechanical and thermal qualities provide a significant difficulty. The mechanical and thermal properties of ADDITIVE MANUFACTURING (AM) metal parts are therefore of particular interest to many scientists [10].

2.5 Solid Layer Processes

Helisys Inc. pioneered the solid-state ADDITIVE MANUFACTURING (AM) process of Laminated Object Manufacturing (LOM) in 1991 [24]. To cut and laminate the construction material layers, the Laminated Object Manufacturing (LOM) system uses a laser to cut the layers into desired

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shapes and a bonding tool to heat and press together the solid layers. A high-speed ADDITIVE MANUFACTURING (AM) technique as shown Table 1, Laminated Object Manufacturing (LOM) is five to ten times quicker than conventional processes, although it has significant difficulties in obtaining geometric accuracy, surface smoothness, and desirable material qualities. [25].

Additive Manufacturing (AM) Processes							
Process	Laser Based AM Processes: Laser Melting	Laser Based AM Processes: Laser Melting	Laser Based AM Processes: Laser Polymerization	Extrusion Thermal	Material Jetting	Material Adhesion	Electron Beam
Process Schematic	Laser source; Powder bed	Laser source; Powder supply	Laser source; Liquid resin	Material melt in nozzle	Material jetting	Laser cutting; Compactor	Electron beam; Powder bed
Name / Material	SLS	DMD	SLA	FDM	3DP	LOM	EBM
	SLM	LENS	SGC	Robocasting	IJP	SFP	
	DMLS	SLC	LTP		MJM		
		LPD	BIS		BPM		
			HIS		Thermojet		
Bulk Material Type	Powder		Liquid	Solid			

Table 1 Additive Manufacturing Processes technologies [26].

2.6 Wire Arc Additive Manufacturing

Because of the great manufacturing efficiency and low forming costs of the wire arc additive manufacturing method (WIRE ARC ADDITIVE MANUFACTURING (WAAM)), it is capable of producing completely dense and large-dimensional items with lower manufacturing costs than powder-based ADDITIVE MANUFACTURING (AM) processes [29]. Compared to metal powder, the primary cost of metal wire is around 10% higher [28]. With the addition of WIRE ARC ADDITIVE MANUFACTURING (WAAM) machines, arc welding robots may be quickly converted into WIRE ARC ADDITIVE MANUFACTURING (WAAM) machines, which are often less expensive than L-PBF and laser-DIRECT ENERGY DEPOSITION (DED) machines, respectively. Wires are heated to melting temperature before being melted and transported to the melt pool, where they solidify layer by layer, as depicted in Figure 5 [30]. WIRE ARC ADDITIVE MANUFACTURING (WAAM) is a direct energy deposition (DIRECT ENERGY DEPOSITION (DED)) welding technique adapted from classic arc welding technology [27]. WIRE ARC ADDITIVE MANUFACTURING (WAAM) sometimes referred to as shape welding in Europe and structural weld build-up in the United States, has been around for a while [31]. [32] As early as 1926, Baker [23] was granted his patent for using electric arcs as heat sources to create large things by spraying liquid metal into previously formed layers. Shape welding was used by Kussmaul in 1983 to produce 79 tons of high-strength 20MnMoNi5 steel in considerable quantities [31]. Late in the

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twentieth century, the Germans employed WIRE ARC ADDITIVE MANUFACTURING (WAAM) (shape welding) to make main nuclear components [31].

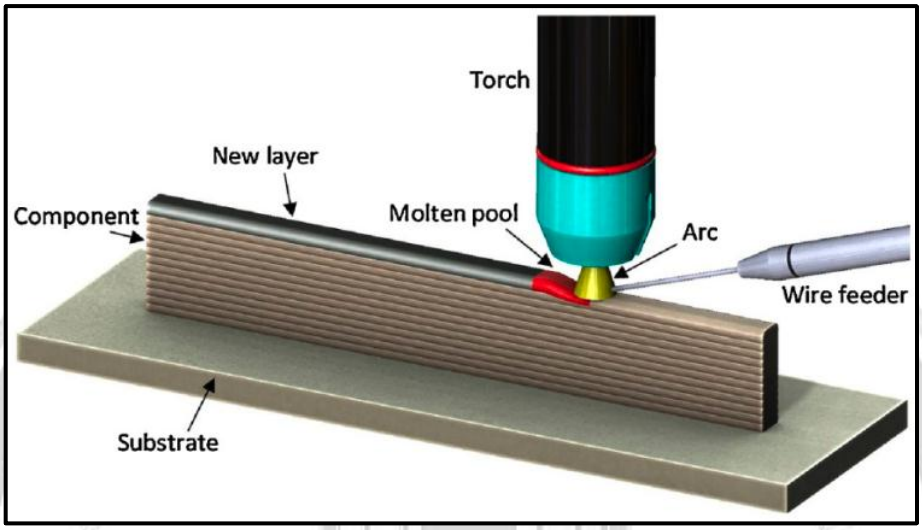

Figure 5. Diagrammatic sketch of the WIRE ARC ADDITIVE MANUFACTURING (WAAM) process [30].

3. Review of WIRE ARC ADDITIVE MANUFACTURING (WAAM) of Stainless-Steel

Feng et al, [34] use of plasma arc additive manufacturing to create Cr-Ni stainless steel components have been proposed in this research as a new and highly efficient approach to DOUBLE-WIRE FEED AND PLASMA ARC ADDITIVE MANUFACTURING (DWF-PAM)). DOUBLE-WIRE FEED AND PLASMA ARC ADDITIVE MANUFACTURING (DWF-PAM) processing's better bead appearance, microstructure, and mechanical properties were examined in the test components as a whole. In comparison to the single-wire feed and plasma additive manufacturing SINGLE-WIRE FEED AND PLASMA ADDITIVE MANUFACTURING (SWF-PAM) technique, the results demonstrate that the deposition rate in the DOUBLE-WIRE FEED AND PLASMA ARC ADDITIVE MANUFACTURING (DWF-PAM) process rose by an average of 1.06 times at the same procedure settings. The DOUBLE-WIRE FEED AND PLASMA ARC ADDITIVE MANUFACTURING (DWF-PAM)-processed sample had a considerable number of completely grown equiaxed ferrite (CGEF) grains near the following layer's interface, while the SINGLE-WIRE FEED AND PLASMA ADDITIVE MANUFACTURING (SWF-PAM)-processed sample had an equal amount of incompletely grown equiaxed ferrite grains in the same location. The DOUBLE-WIRE FEED AND PLASMA ARC ADDITIVE MANUFACTURING (DWF-PAM)-processed materials' ultimate tensile strengths and elongation rates were significantly enhanced by the CGEF grains. The maximum increase in elongation rate was 176 per cent, and the average increase in final

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tensile strength was 10.2%. A fine-grained microstructure and higher mechanical characteristics may be achieved by using the DWF process instead of the SWF process to manufacture components. In addition, with the DOUBLE-WIRE FEED AND PLASMA ARC ADDITIVE MANUFACTURING (DWF-PAM) technique, a greater deposition rate is possible shown in table 2.

Ahsan et al, [37] used BAMSs (bimetallic additively produced structures) to reduce post-processing-induced regional mechanical degradation by replacing traditionally constructed functionally graded components. These structures are constructed using fusion welding methods. Using a wire + arc additive manufacturing (WIRE ARC ADDITIVE MANUFACTURING (WAAM)) approach based on gas metal arc welding(GMAW). This work fabricates a BAMS by layering austenitic stainless steel and Inconel 625. They found that it was there was no recognition of the interface between the layers of the two materials. This results in a seamless compositional transition. An electron backscattered diffraction (EBSD) examination of the interface shows that both materials are austenite with an FCC crystallographic structure, with long-elongated grains in the 001> direction exhibiting a smooth and cross-interface crystallographic growth. At the interface, neither material differed significantly in hardness from the other, with values ranging from 220 to 240 HV for each. Stainless steel failed at a tensile strength and elongation of 600 MPa and 40%, respectively. According to the findings of this study, WIRE ARC ADDITIVE MANUFACTURING (WAAM) can make BAMS that have higher properties shown in table 2.

Wu et al, [33] used 316L stainless steel welding wire to create 30-layered thin-walled samples with a 2 mm thickness and up to 65mm height by using speed cold welding. It is found that the stability of the deposition process, macro morphology, structure, and mechanical qualities are affected by three process parameters (bottom current mode, scanning speed, and cooling time). Compared to other samples, sample #GRBC-30 cm/min-10 s had narrower third- and tenth-layer probability density curves, indicating a more stable process. While the three process parameters have some bearing on performance, their primary impact is on the morphology of the layer deposition. The deposition direction has a major impact on the hardness and tensile strength of the finished product. The bottom moulding and performance, as well as the deposition efficiency and process stability, are improved and stabilized through gradual, layer-by-layer current decrease. End formation is destabilized by increasing the scanning speed or reducing the cooling time, which lowers the effective deposition rate. All samples deposited are anisotropic, yet meet the requirements of the industry. All in all, the deposition in speed cold welding mode, with a cooling time of just 10 seconds, a scanning speed of 30 cm/min, and a rapidly decreasing bottom current demonstrates excellent stability shown in table 2.

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Hosseini et al [35], wire-arc additive manufacture of duplex stainless steel blocks to study how microstructures change during heat cycles. High and low heat input–high interlayer temperatures (LHLT and HHLT) arc energies were used to create samples. For high heat input–high interlayer temperature (HHLT), interlayer temperatures of 150°C and 250°C were employed (HHHT). Various thermocouples were employed for recording heat cycles on the substrate and constructed layers. An in-depth examination of the microstructure was performed using O&SEM. LHLT and HHHT were able to create equivalent geometries with 14 and 15 layers of beads in each layer, respectively. At higher temperatures (over 600 °C), LHLT had more warming cycles than HHHT, although each layer was warmed for less time. The austenite content was 8 per cent higher in as-deposited LHLT beads that were cooled at a faster pace between 1200 and 800 °C. There were equal austenite fractions in both LHLT and HHHT samples throughout a wide range of additively created samples that had been heated several times. The HHHT sample had a larger percentage of secondary phases as a result of the prolonged reheating at a high temperature. There was an adequate austenite fraction (35–60 per cent) with just a modest number of secondary phases in the majority of wire-arc additively manufactured duplex stainless steel samples (800–1200 degrees Celsius) shown in table 2.

Rumman and Ali [36] used the wire with arc additive manufacturing (WIRE ARC ADDITIVE MANUFACTURING (WAAM)) method based on gas metal arc welding (GMAW) to create metal products in nearly net shape products. WIRE ARC ADDITIVE MANUFACTURING (WAAM) is flexible enough to create a single component from multiple materials sequentially or simultaneously. A key concern is design. This work generated components by sequentially fusing low-carbon steel and AISI 316L stainless steel (SS). To do this a new M2WIRE ARC ADDITIVE MANUFACTURING (WAAM) system was built utilizing commercial resources. The system's use for WIRE ARC ADDITIVE MANUFACTURING (WAAM) and M2WIRE ARC ADDITIVE MANUFACTURING (WAAM) has been proved using two metals – LOW-CARBON STEEL (LCS) and stainless steel (SS)– and two designs. The mechanical, microstructural, and composition of the various specimens were compared to a single LOW-CARBON STEEL (LCS) and stainless steel (SS)material specimen. No welding defects were found at the joint between the two components. However, the interface hardness increased considerably. The EDS analysis attributes the increase in hardness to chromium diffusion from the stainless steel (SS)side into the LOW-CARBON STEEL (LCS) side. Despite the interface's varying hardness, the failure occurred on the LOW-CARBON STEEL (LCS) side, away from the contact. The UTS and elongation of the multi-material specimen are essentially identical. LOW-CARBON STEEL (LCS), being the weaker of the two materials used, failed. The WIRE ARC ADDITIVE MANUFACTURING (WAAM) technique can properly combine LOW-CARBON STEEL (LCS) and SS, according to this study's findings. Although WIRE ARC ADDITIVE MANUFACTURING (WAAM) has welding strength equivalent to steel, it is

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found to be less ductile. Heat treatment of Wire arc additive manufacturing (WAAM) ed parts may improve yield strength and ductility, however, this has not been evaluated as shown in table 2.

Table 2 Process parameters affecting the macro morphology of WIRE ARC ADDITIVE MANUFACTURING (WAAM) stainless steel parts

WIRE ARC ADDITIVE MANUFACTURING (WAAM) Techniques	Material	Process Parameters	Macroscopic Characteristics	References
MIG	316L (austenitic) stainless steel	Welding current mode Increasing scanning speed Gradual reduction of bottom current	Improves bottom formation The unevenness of both ends	[34]
PAM PAM: SINGLE-WIRE FEED AND PLASMA ADDITIVE MANUFACTURING (SWF-PAM), THE DOUBLE-WIRE FEED AND PLASMA ARC ADDITIVE MANUFACTURING (DWF-PAM)	H00Cr21Ni10 (austenitic) stainless steel	SINGLE-WIRE FEED AND PLASMA ADDITIVE MANUFACTURING (SWF-PAM): single-wire feed and plasma additive manufacturing THE DOUBLE-WIRE FEED AND PLASMA ARC ADDITIVE	Slightly better surface quality than that of Double-wire feed and plasma additive manufacturing ////	[35]

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		MANUFACTURING (DWF-PAM): double-wire feed and plasma additive manufacturing Increasing scanning speed	Better surface quality	
GMAW	Type-2209 (duplex) stainless steel	Deposition path Alternating direction deposition path One-direction deposition path	Uniform layer height Uneven sides: the start side was higher than the end side.	[36]
GMAW	H08Mn2Si low-carbon steel	Decreasing interlay temperature Increasing scanning speed Increasing wire feeding speed	Surface roughness decreases Surface roughness increases Surface	[37]

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			roughness increases	

4. Discussion and Conclusion

Complex components can be produced with reduced material and energy loss, as well as with a quicker processing cycle, thanks to new technologies [8,9]. Up to this point, ADDITIVE MANUFACTURING (AM) has been used to successfully treat a wide variety of metal components. A laser beam, an electron beam, or an arc is used as the heat source in metal additive manufacturing processes, and the feedstock material is powder, wire, or sheet [1, 7]. Powder bed fusion (PBF) [8], directed energy deposition (DIRECT ENERGY DEPOSITION (DED)), and sheet lamination (SL) are the most frequent additive manufacturing (ADDITIVE MANUFACTURING (AM)) processes for metals [8, 9]. PBF-L (powder bed fusion with a laser as the heat source) [9], DIRECT ENERGY DEPOSITION (DED) -GMA (directed energy deposition with gas metal arc), and DIRECT ENERGY DEPOSITION (DED) -L (directed energy deposition with a laser beam as the heat source) are three metal ADDITIVE MANUFACTURING (AM) technologies that are widely utilized [10]. Powder-based and wire-based metal additive manufacturing systems are two types of metal additive manufacturing processes that can be classified based on the material feedstock used. Given the high reactivity of the melt pool and the potential dangers associated with fine powders. Additive manufacturing processes based on metal powders, which primarily use an electron beam or laser as their heat source, are typically contained within sealed chambers, severely restricting the size of parts that can be manufactured. Moreover, because fine powder is substantially more expensive than wires and develops at a slower rate, it is only suited for small to medium-sized high-value components that require a greater level of resolution [11]. In addition, the wire arc additive manufacturing (WIRE ARC ADDITIVE MANUFACTURING (WAAM)) approach, which uses an electric arc as the heat source and has a building capacity of tens of meters, can create fully dense and large dimensional items with relatively low forming costs and high manufacturing efficiency [12, 13]. Compared to metal powder [11], metal wire has a major cost that is around 10% of the comparable weight of metal powder. It is also possible to create WIRE ARC ADDITIVE MANUFACTURING (WAAM) machines with little effort by modifying arc welding robots, which are often less expensive than L-PBF or laser-DIRECT ENERGY DEPOSITION (DED) machines. WIRE ARC ADDITIVE MANUFACTURING (WAAM) involves heating the wire until it melts and transferring it to a melt pool, where it solidifies at the melt pool's edge and creates the desired parts layer by layer [11]. The

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wire is melted and transported to the melt pool during the WIRE ARC ADDITIVE MANUFACTURING (WAAM) process. Indirect energy deposition (DIRECT ENERGY DEPOSITION (DED)) is a method that was developed from traditional arc welding technology [7].

WIRE ARC ADDITIVE MANUFACTURING (WAAM) , also known as shape welding in Europe and structural weld build-up in America, has been around for quite some time [20]. Baker [20] received a patent in early 1926 for "the use of an electric arc as a heat source to manufacture bulk objects by spraying molten metal into the formed layers," which described "the use of an electric arc as a heat source to manufacture bulk objects by spraying molten metal into the formed layers" A 79-ton piece of high-strength 20MnMoNi5 steel was produced by Kussmaul in 1983 [20] using shape welding on an industrial scale. Germany used WIRE ARC ADDITIVE MANUFACTURING (WAAM) (shape welding) to construct the bulk of its nuclear weapons in the late twentieth century [12]. In the aerospace industry (stretched panels, wing ribs), nuclear energy, maritime (ship propeller), and architectural (steel bridge) [14], WIRE ARC ADDITIVE MANUFACTURING (WAAM) has already been successfully implemented.

5. Concluding Remarks

ADDITIVE MANUFACTURING (AM) stainless steels frequently have a multidimensional and non-homogeneous microstructure, as well as high residual stress, which complicates corrosion behaviour and processes. While there is considerable diversity in the corrosion parameters of ADDITIVE MANUFACTURING (AM) stainless steels documented in the literature, based on the current state of the art, some basic conclusions can be formed.

Porosity affects the corrosion parameters of ADDITIVE MANUFACTURING (AM) stainless steel such as passivity, pitting, and erosion-corrosion in a negative way. Due to the presence of porosity, low-density ADDITIVE MANUFACTURING (AM) stainless steels have lower pitting corrosion resistance. Because the necessary conditions for pit stability may be easily produced in the presence of LOF pores, such pores, in particular LOF pores, were identified as more sensitive sites to pitting corrosion. The role of pores in pit initiation in ADDITIVE MANUFACTURING (AM) stainless steels, on the other hand, is still being researched and debated.

Due to the absence of detrimental inclusions/precipitates, such as MnS inclusions, the pitting corrosion resistance of high-density ADDITIVE MANUFACTURING (AM) stainless steels is generally higher than that of their conventionally manufactured counterparts. However, using post-ADDITIVE MANUFACTURING (AM) heat treatment to release residual stress in ADDITIVE MANUFACTURING (AM) stainless steels, especially over 1000°C, may result in the formation of detrimental inclusions/precipitates, resulting in lower pitting corrosion resistance.

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ADDITIVE MANUFACTURING (AM) stainless steels have unique microstructural characteristics that cause a variety of surprising localized corrosion behaviours. ADDITIVE MANUFACTURING (AM) stainless steels have a lower capacity to passivate, which leads to a worse erosion-corrosion resistance. ADDITIVE MANUFACTURING (AM) austenitic stainless steels show significantly better resistance to IGC when subjected to long-term sensitisation heat treatment, which has been attributed to a high density of twins and low-angle grain boundaries in ADDITIVE MANUFACTURING (AM) materials.

Corrosion research on ADDITIVE MANUFACTURING (AM) stainless steels is still in its early phases, and additional work is needed to quantify the resistance of ADDITIVE MANUFACTURING (AM) stainless steels to key kinds of localised corrosion such as crevice corrosion and galvanic corrosion under various and practical corrosion environments.

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مراجعة أدبية لتحضير وتوصيف الفولاذ المقاوم للصدأ المصنوع مضافًا

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الخلاصة

في عالم اليوم، يعد التصنيع بالإضافة طريقة معروفة لإنشاء نماذج ثلاثية الأبعاد، إما من المعادن أو السيراميك أو البلاستيك أو مزيج من هذه المواد. يرتبط التصنيع بالإضافة بسلسلة من دورات التسخين والتبريد السريعة، فضلاً عن التدرجات الكبيرة في درجات الحرارة، مما يؤدي إلى تطوير تواريخ حرارية معقدة، والتي لها تأثير مباشر على الهياكل الدقيقة للمواد الناتجة. نظرًا لطبيعة هذه العملية الديناميكية والبعيدة عن التوازن، تظهر ميزات هيكلية مجهرية مختلفة. على سبيل المثال، من المحتمل أن تحدث تغييرات في خصائص التآكل للفولاذ المقاوم للصدأ المصنوع بتقنية الاضافة، والتي تتمتع بخصائص ميكانيكية فائقة ومقاومة للتآكل عند تصنيعها باستخدام طرق إنتاج أخرى. نظرًا لأن مثل هذه التعديلات غير مفهومة تمامًا في هذا الوقت، فإن التناقضات والاختلافات في الأدبيات المتعلقة بسلوك التآكل للفولاذ المقاوم للصدأ المصنوع مضافا تظهر بانتظام. يعد تحضير وتوصيف الفولاذ المقاوم للصدأ المصنوع مضافاً موضوع هذا العمل، والذي يوفر تقييمًا نقديًا. فيما يتعلق بإنتاج الهياكل المعدنية الضخمة بمعدلات ترسيب عالية وبتكلفة رخيصة، فقد برز التصنيع بالإضافة السلكي كطريقة قابلة للتطبيق. تستعرض هذه المقالة بعض طرق التصنيع بالإضافة المستخدمة في الغالب مع المواد المعدنية مع التركيز على التصنيع بالإضافة السلكي من الفولاذ المقاوم للصدأ.

الكلمات الدالة: التصنيع الإضافي (AM)، التصنيع الإضافي للمعادن، التصنيع الإضافي للقوس السلكي (WAAM) من الفولاذ المقاوم للصدأ.