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STUDY ON CORROSION BEHAVIOR OF ADDITIVELY MANUFACTURED STAINLESS STEEL

M. Mohamed Siddiq[1], S. Parimala Murugaveni[2], S. Periyasamy[3], N. Nandakumar[4]

PG scholar, Mechanical Engineering, Government College of Technology, Coimbatore, India[1]

Associate Professor, Mechanical Engineering, Government College of Technology, Coimbatore, India[2]

Associate Professor, Mechanical Engineering, Government College of Technology, Coimbatore, India[3]

Professor, Mechanical Engineering, Government College of Technology, Coimbatore, India4

Abstract: The utility of Additively Manufacturing (AM) Stainless Steel (SS) elements is swiftly rising in a extensive spectrum of industries. Laser Powder Bed Fusion (LPBF) and Direct Laser Deposition (DLD) are the primary AM techniques to manufacture a widespread variety of SSs like 316 L, AISI 420, 17-4 PH, 304 L, and AISI 4135. This article specializes in the corrosion overall performance of additively manufacturing steel made of LPBF and DLD. The passive movie formation mechanisms and the corrosion overall performance of LPBF/DLD AM SS elements are mentioned in assessment to their conventionally made counterparts. Microstructural functions like porosity, inclusions, residual stress, floor roughness, elemental segregation, phases, and grain length distribution are elaborated very well from the corrosion factor of view, intently connected with the AM processing parameters. Generally, process parameters play a critical function with inside the corrosion properties of AM elements via way of means of impacting the microstructural functions. Assuming a right set of parameters for the printing process, the general corrosion overall performance of AM SS is higher than its traditional counterparts. However, there are nonetheless controversies round a few critical aspects including passive film structure, the character of residual stress, put up warmth remedy processes, and grain length distribution and their effect on corrosion overall performance, which emphasizes the want for future research on this area.

Keywords: Corrosion; Additive manufacturing; Stainless steel; Laser powder bed fusion; Direct Laser deposit.

I. INTRODUCTION

Stainless steel (SS) alloys are used in many industrial applications such as aerospace. Austenitic medical devices, pipelines, automotive, mold and tool industries, Martensitic, ferrite or austenoferritic [1, 2]. These categories are chemical composition of the alloy manufacturing process [19]. Addition of elements such as chromium, nickel and carbon, Molybdenum, copper, nitrogen, aluminum, sulfur and selenium can change corrosion SS alloy resistance, strength, ductility, machinability and phase stability [1, 3, 4] Precipitation Hardened Stainless Steel [5], Tool Steel [6], Austenitic stainless steel [7] and maraging steel [8] are often used as additives. Manufacturing (AM). In addition to general applications, SS can also be used for high hardness Because of its relatively high strength, low density and excellent strength, the purpose of strength [9] Corrosion behavior. The main focus of this review is the corrosion resistance of SS. This is mainly due to the formation of a protective layer Cr2O3 passivation film on the surface. This is possible when the chromium content is about 11% by weight or more [9]

Many types of SS are additionally manufactured and their mechanical or corrosive the behavior was examined. The chemical composition of these alloys is as follows. The most studied SS alloy 316L is a widely used austenitic alloy. Industrial applications due to high corrosion resistance as well as acceptable mechanical properties [1, 10]. Form a thin protective layer on the surface, Molybdenum in its chemistry is known to be the reason for its better performance. Against both general and local corrosion attacks compared to other grades of austenitic SS. Like 304 and 304L [1, 10-11]. In addition, the low carbon content of this alloy Welding process by reducing the precipitation of carbides at grain boundaries [11]. Therefore, 316 L One of the few options for the marine, medical and food industries that offers excellent corrosion protection Property required [12]. AISI 420 is a martensitic stainless steel with its characteristics Heat treatment process [2, 13]. Its excellent tensile strength, high hardness, and with sufficient corrosion resistance, AISI 420 is widely used in the industry. Last the properties of this alloy are a function of the processing parameters. Anisotropic 3D structure Due to the repeated heating and solidification cycle, the AM AISI 420 component attracted attention. Melt-based AM process [14, 15]. Tensile strength occurs pre-cured and reinforced Designated strength of 700-930MPa [16]. Precipitation hardening (PH) SS, such as 174 PH, It has recently increased due to interest in AM applications in aerospace, nuclear, and oceans. A combination of two-phase microstructures of martensite and austenite [17,18]. Traction and impact

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Strength, fracture toughness and corrosion resistance of hardened martensite precipitates SS has been studied at high operating temperatures up to 300 ° C [5, 19, 20]. Another group of AM rated steels are high-strength low-alloy steels (HSLA) such as AISI 4135. Often not classified as SS, but still has a wide range of uses despite the relatively poor corrosion behavior [21, 22]. But it is shown Adjustment of nickel content as an austenite-forming element in AM raw material powder This process can improve corrosion resistance by affecting the ultrastructure of the alloy [23]

II. ADDITIVE MANUFACTURING PROCESS

Ability to manufacture near-net shapes and complex parts, including additive manufacturing Known as 3D printing, it is in high demand in various industries and research. Topic [23,24]. Minimize the waste of raw materials and quickly produce unique parts. Small quantities are a major advantage of AM [24, 25]. Traditional in terms of corrosive behavior the method can cause intergranular corrosion in SS [34], which is another reason for its rapidity. Development of advanced technologies such as AM. Metal AM can be divided into two main groups. The first group, known as Powder Bed Fusion, itself contains two processes, laser powder. Bed fusion (LPBF) and electron beam melting (EBM). Direct Laser Deposition (DLD) The second group of common metal AM processes [27, 28]. Among these methods are LPBF and DLD. It is widely used in SS AM and will be explained in detail.

LPBF, also known as Selective Laser Melting (SLM), is the most widely used process. Manufacture of SS via AM due to relatively wide availability of raw material powder and very high flexibility not only design, but also cost and time savings [28]. Completed parts are created layer by layer Computer-aided design (CAD) -based control [29, 30]. Focused laser beam (usually selectively melt and melt successive elements using a rare earth element-doped fiber laser) Layers to complete the creation of near-net shape objects, as outlined in the figure 2 Left [31, 32]. Extreme local heating (maximum) compared to traditional manufacturing processes 2500 ° C), higher cooling rate (105-107 K / s), and remelting of the previous layer creates novelty. Microstructure of LPBF components containing a wide range of non-equilibrium phases Composition, inclusions and residual stress [33,34]. This condition also triggers what is not melted Powder, porosity, dislocation cell formation, microcracks and rough surfaces [35,37]. These metallurgical defects, along with the boundaries of the weld pool, will eventually It has significantly reduced plasticity and serves as a priority site for local corrosion [38,39]. For this reason, LPBF component quality is the number one challenge for using AM components in a variety of industries. That is Recognized process parameters such as laser power, hatch spacing and scan speed. Layer thickness and construction orientation determine the final microstructure and operational performance. Manufactured parts [34,40]. In addition, a post-heat treatment process can be applied to reduce the defects mentioned improve the usability of the part [39].

DLD is another laminated molding technology used in the manufacture of SS parts. Simultaneous supply of raw materials and energy to the construction area (Fig. 2, right) [41,42]. This Also known by many other names such as Laser Engineered Net Shaping (LENS) and Direct Laser. Manufacturing (DLF), Direct Metal Deposition (DMD), Direct Light Manufacturing (DLF), Laser Metal Metal Deposition (LMD), Laser Metal Deposition (LDW), Powder Fusion Welding (PFW), Laser Powder Deposition (LPD), Direct Energy Deposition (DED), Laser Direct Metal Deposition (DLMD), or in some cases the general term "laser metal deposition" [2, 25, 34, 41, 43, 44]. With this Raw metal in the form of powder or wire is supplied to the device and melted by a laser source It is the base material and creates near-net-shaped parts for each layer based on the CAD design [36,41]. This method precisely controls the powder supply, laser power, and other parameters. Therefore, DLD can use a wide range of raw materials. Some research papers It shows that the tensile strength and fatigue strength of DLDSS are significantly improved compared to DLDSS. Parts made by conventional methods [45,46]. DLD can also be applied to surfaces Technical and additional repairs based on adjustment of surface properties and / or composition About those applications [47,48]. Cooling rate is a function of processing parameters Experimental measurements are estimated to be in the range 103-10 DLD process K / s, the result is a coarser microstructure compared to LPBF. More residual ferrite and higher porosity of the finished part. These are important Factors in functional properties, especially the corrosive behavior of components [27, 50, 52]. Compared to LPBF, DLD uses a relatively high energy density. For this reason, for larger weld pools, using DLD will significantly reduce the cooling rate, but DLD The solidification rate is much faster than the traditional casting process [52-53].

III. SPECIAL APPLICATIONS OF AM SS

Common applications for AM SS components are growing rapidly in industries such as Aerospace. Automotive and marine based on the discussed benefits of this manufacturing process. To for example, many parts of a jet engine can be created by am in a few weeks, not just a few. The traditional method takes several months [51,52]. AMASS parts were being used gradually special environments described in more detail in this section with a focus on corrosion performance. In these applications, the solution used for corrosion testing is different. Common applications where mixtures of nacl and water of different concentrations are used simulates the working environment of a part ([69-72] to name a few). In all of these application am is becoming more popular every day.

IV. METALLURGICAL PARAMETERS AFFECTING CORROSION PERFORMANCE

In general, some metallurgical parameters such as phase distribution, microstructure, porosity, etc. Residual stress, surface roughness, etc. affect not only mechanical behavior but also corrosion behavior. Behavior of metal parts [34, 54, 55]. In the AM process, these factors are printing process parameters such as laser power, scan speed, hatch spacing, layers, etc. Thickness and powder size [56, 57]. On the other hand, local heating and high speed Metal reinforcement in AM causes non-traditional behavior manufactured counterparts, emphasizing the need for complete research on all aspects AM certifies these parts for industrial purposes [10, 58]. SS is very sensitive Process parameters [5, 9]. For example, there is evidence that metal formation is reduced. Droplets interfere with the preferential uniform distribution of the molten powder during laser melting LPBF AM [39], using non-optimized AM processing parameters (known as ball phenomenon) [53, 59,60]. It is also known that the number of dislocations in AMSS is large. Higher than forged stainless steel due to reduced yield strength due to quenching in the AM process AM sample [61]. In other literature, samples made by the LPBF method are not included. Taller than Energy density as a Process function Parameters Usually often displayed Performance compared to samples made with lower energy densities to predict importance Parameter optimization [62]. In other words, it can be eliminated by optimizing the parameters some of AM's weaknesses, I. H. Ultrastructure changes, increased density [62, 63]

A. POROSITY

In general, pores are a major location for corrosion attacks, especially pitting corrosion. AM as a powder base The manufacturing process involves the presence of unavoidable pores in the product Parts that can affect mechanical properties and corrosion behavior [25,65,66]. Voids are usually caused by gas trapped around or inside unmelted powder particles. Powder or melting bath during initial treatment, gas spray or laser melting Void process or elemental mapping reveals the presence of oxide powder As a confirmation of these sources, unfused silicon in the pores of AM components [53]. The pores of AM components can be divided into two classes: regular (spherical) and irregular (non-spherical). Pore [66, 67]. Spherical pores are formed by the gas trapped during grinding In manufacturing and / or melt bath. This type of pore is relatively smaller than the irregular pore. Regardless of the regular shape of the pores and the unique presence of the part Pressure treatment parameters make it less important as a focus for corrosion research AMSS parts [4]. Non-spherical pores, on the other hand, are formed by unmelted powder Particles that are the direct result of incorrect processing parameters [65]. As reported by According to many researchers, this class of pores, also called lack of fusion (LOF) pores, can be important. Plays an important role in reducing density and facilitating both initiations (reaching the surface) Pit propagation (shape and irregular shape) and aggressive ion accumulation Their corners [50, 65,] due to their irregular shape. In related studies, Possibility of failure (this) Passive film was usually used as a passive indicator Film properties against local corrosion attacks in the presence of pores. Lower this Showed greater sensitivity to pitting corrosion associated with the presence of LOF pores Compared to dense parts and samples made by traditional manufacturing processes. the overall qualitative results are about the same in any environment containing sulfuric acid or sulfuric acid. Phosphoric acid, iron chloride and NaCl contain aqueous solutions [68].

Nevertheless, the level of porosity and density of parts can be optimized to some extent Apply correct pressure parameters such as scan speed and laser power supply. Improve heating and cooling speed of melting basin [65]. For example, too high a Scandreh number (> 1400 mm / s) or too low laser output can be accelerated dramatically Formation of LOF pores on SS remaining in undesirable powder. To high laser On the other hand, performance facilitates capture of the printing section gas [65, 69]. Several quantitative studies are available as evidence of this result. The test indicates that the pore size of up to 50 µM and the porosity level greater than 2% are reasonable reasons. Performance of SS 316 L and 174 pH samples [12]. Similarly, the level of porosity is 1.7% In AMS SS, the corrosion resistance is deteriorated as compared to traditionally manufactured samples In Shrimp. Both groups of groups are the same area [53]. Report in other studies Samples with a density of 99.1% or more are the highest Shrimp. Compared with the lower value Density levels and their values are substantially the same as traditionally manufactured samples Lily influence on sliding ability [65, 70,71]. Or lower levels of level As 99.1%, one corrosion performance is insufficient Shrimp. The following 200mV value Traditionally 316 L SS [65]. Check the influence of porosity on AM corrosion performance SSS, comparison was performed to confirm the higher pitting potential of the non-porous region. More than 200mV compared to the porous area of AMS SS 304L. This is confirmed Role of pores in pit start process [65]. Research on the characteristics of metastable holes The LPBF 316 L shows it by posting the porosity in the range of 0.04% 0.5 from SS 316 L. %, Pit start can be delayed compared to traditionally prepared samples [4]. this This behavior is claimed to be the result of dissolution of MNS inclusions in velocity Function in AM process known to be the main cause of pit start in SSS [72]. During the polarization test of men and conventional SS 316L flow Spikes were detected with high anode potential for AM samples that are signs Metabereey pit formation In other words, existing passive layers exist on the side wall of Pore, but this protective layer is not stable enough and collapses with higher anode potential Makes fluctuations in the anode branch of the polarization curve. These variations are more Sample of higher porosity levels of levels [73] Manufacturing process, etc. The quality of the starting material can also affect the porosity of AM components [74]. Use Powders with larger particles, irregular shapes, and higher contamination have all been reported. Increases the porosity of AM-SS parts [74]. In addition, the study compares final densities Manufacture of LPBF parts using gas or water sprayed 316LSS powder and water the sprayed powder has a high oxygen content and low packing, resulting in a low density. Density [75]. All of these parameters should be considered for quality purposes.

A more systematic optimization method for AM machining parameters to achieve the highest density Possible AMSS parts are done via Laser Energy Density (LED), also known as Volume Energy. Density (VED) calculated by dividing the laser energy by the product of the sample rate and the hatch distance. And layer thickness [28, 30, 76]. Low LED levels produce non-spherical voids, while high LED levels produce voids. The amount of this parameter leads to the formation of spherical pores during the AM process [77, 78]. Reportedly the densest SS316L sample with a porosity level of about 0.3 & lt ;. Can be achieved by AM with a laser energy density of approximately 105 J / mm [79]. But Despite this low level, porosity is not evenly distributed across the parts. For example, for 316 stainless steel The average porosity produced by the LPBF process was about 0.82%, but the local pores Concentrations of up to 1.68% have been reported in some areas, resulting in Anisotropic behavior of the AM part [80]. Overall, AM SS Optimized processing parameters can show equivalent or even better corrosion Performance compared to traditionally manufactured SS by keeping the porosity level as low as possible [10, 25, 81]

B. **INCLUSIONS**

Austenitic stainless steels such as 316L and 304L are usually Presence of unwanted inclusions as the second phase of the austenite matrix. Manganese sulfide (MnS) is the most prominent and plays an important role in the corrosive performance of SS Depending on their density, composition and size. The removal or size control of MnS is as follows: It is said to be a method for suppressing corrosion of SS [82, 84]. Steel production in progress during the process, Mn is added to form MnS, neutralizing the adverse effects of FeS formation. Others MnS is thermodynamically stable and has a higher melting point than FeS. And its formation eliminates the presence of low melting point FeS along the grain boundaries of the steel. Structures that are the main cause of crack problems in hot rolling [85]. Whatever it is It is theorized that the chromium content of the alloy decreases in the region around MnS. The inclusions and this Cr-poor region have a low Cr content along with the inclusions themselves. As a critical value for passivation layer formation leading to local susceptibility to corrosion S2,[30,83]. During the pit initiation process, elemental sulfur and ionic sulfur (S, HS 2) S2O3 Formed as a result of MnS oxidation, providing an unsuitable environment The reimmobilization process and pits propagate as a result [86,87]

Considering the rapid coagulation associated with the AM process, much research has been done on this basis. No reported MnS content and Cr depletion zone, or at least much smaller Matrix shape, about the pitting potential of AM-SS 300 mV in various corrosive media [37, 72, 88]. But traditional in the manufacturing process, the cooling rate is relatively slow, so Mn and S have enough time. Formed by diffusing harmful MnS-containing substances. Improves pitting corrosion resistance AM parts are also due to changes in the chemistry, size, and shape of inclusions after AM. Process. Some studies have included Mn, Si, Al, Cr, N, O do not have a negative effect and do not even improve corrosion. Performance [72]. The size of inclusions after the AM process Range of 5200 nm as opposed to traditional counterparts with inclusions in the size range at 2-4 µm, this is 13 orders of magnitude larger [72]. Nano-containing substances in this range they have been reported to exist in both LPBF and DLD methods of AM and are too small to start. Pitting corrosion of AM samples [7, 88, and 89]. Also, the shape of the later inclusions AM processes have been reported to exhibit spherical and irregular shapes in parts manufactured by traditional methods. [72].

Because post-heat treatment is an unavoidable process in many industrial applications of AM components it is important to understand the effect of heat treatment on preformed inclusions during AM process. After the post-heat treatment process, inclusions become smaller and smaller Low melting point elements such as Al from the viewpoint of chemical composition It diffuses into the matrix and changes the composition of nan inclusions [39]. Afterglow what is contained in heat-treated AM parts can be classified into the following three classes. (1) Manganese silicate Production sample inclusions still present after the heat treatment process Temperature range of 900 1000 ° C with a duration of 1560 minutes; heat treatment in (2) Temperatures of 1100 1200 ° C lead to the formation of irregular manganese chromate Inclusions from manganese silicate inclusions; (3) Harmful MnS-containing inclusions (pitching) Initiator) that should be formed under the same heat treatment conditions as type (2). Recognized as the main reason for the dramatic reduction in heat corrosiveness Processing process for AM-SS components at temperatures above 1000 ° C. At this high temperature in the non-equilibrium state of the manufactured structure, Equilibrium due to the formation of saturated Mn in the matrix and MnS from S.

C. SURFACE ROUGHNESS

Surface roughness as a unique feature of AM parts is Determining corrosion behavior because rough surfaces are electrochemically accelerated Reactions between the surface and the environment leading to both general and local corrosion [90, 91]. The surface roughness of AM parts is significantly higher than others traditionally the manufacturing process is highly dependent on the laser energy density (Figure 9). For example, Studies have shown that AM-LPBF parts have a roughness of 1030 µm, while parts manufactured on milling machines have a roughness of approximately 1 µm [91]. Given four main reasons as a source of rough Surface of finished parts [37, 92, 93]

1) Evaporation: Unstable and irregular welding pool during AM process due to this Produces gas during the melting of the powder, along with the destabilizing flatulence force Increases both melt flow and surface roughness and porosity [94]. Less gas expansion given for a thinner powder layer. However, you need to choose a thinner powder layer thickness Extend the production time considered [94].

2) Ball phenomenon: If the laser output is low, it will not be able to supply enough energy to melt the powder. Completely particles. As a result, the adhesion of solid particles to the surface increases. Surface roughness [59, 96]. You can increase the heat input by using a higher laser output it was adopted as a solution to this problem. In addition, higher heat input It melts due to the key Hall effect and improves interlayer bonding by flattening the molten pool. This phenomenon also relieves the surface tension of the melt and reduces the number of balls. Phenomena and the resulting surface roughness [60 97]. However, it is optimized Too much heat input can affect the surface roughness, so heat input should be applied. Stirring of the molten pool and increasing recoil pressure. Another reason for the ball phenomenon Is the size of the starting powder. This is difficult because the laser spot diameter is typically 50100 µm. Powder particles over 100 µm in diameter melt, which is Surface roughness. In another study, the heat accumulated during AM Thin-walled objects increase the adhesion of molten particles to the surface, it worsens the final surface finish [92]

3) Stairs effect: Additional manufactured parts are created by stacking multiple 2D layers. On top of each other to form 3D objects. However, geometric differences between them are expected Theoretical (CAD design) and actual printed parts [98]. This difference is due to the layer Use The accumulation of layers in AM is called a staircase or staircase step effect. Pronounced on a sloping surface [98]. The use of smaller diameter starting powder Proposed to reduce the layer thickness as well as the staircase effect [36, 98].

4) Opposite: Some research literature expresses surface differences Roughness of the upper and lower surfaces with different tilt angles. Result indicates that the surface roughness of the upward surface is small. This is probably due to filling Gap through the particles in the formation of an upward surface [99,100]

V. KNOWLEDGE GAPS AND PROSPECTS

Much research has been done on the corrosive behavior of AM-SS, but there are still some. Partially missing meaningful information indicating the need for future work this area. Below are some of the key gaps that are currently being addressed or not addressed. There is controversy over their results.

- The study focused on AM processes that include multiple variables such as processes Parameters, alloy composition, test method, electrolyte, pH and temperature, it will be difficult to investigate and compare with general cross-paper. Standard test method the corrosive behavior of AM alloys may be provided by the associated tissue. Facilitates the use of AM components in the industry.
- The main cause of the various metallurgical properties of AM parts is the printing process. The set of parameters has a great effect on corrosion Appearance in various media. But lacks systematic analysis Introduce the optimal set for each alloy in a particular environment.
- There is no general consensus on the causes and effects of residual stress Corrosion behavior. There is the same controversy over passive film formation Mechanism of AM SS parts and role of microstructure, crystal grain size and structure Passive layer.
- Clarity about the optimal use of heat treatment is also needed, as both can be present. Positive (densification, grain refinement) and negative (decrease in dislocation density, Removal of sub grain boundaries, precipitation of inclusions) Impact on corrosion performance.
- Currently, all research on AMSS is limited to available alloys. Commercial market. The new SS design has been customized to take into account various conditions during the AM process, such as high energy, fast cooling rates and micro-segregation. This is a particularly interesting topic for AM.
- Lack of information on long-term exposure to AM-SS in the industry application

VI. CONCLUSION

- This summary paper summarizes the evaluation of additive manufactured stainless steel parts. Focusing on corrosion behaviour in a wide range of applications, including biomedicine, Nuclear and fuel cell industries that require a higher level of consideration corrosion. Advantages and Disadvantages of LPBF and DLD as the Leading AM Method for Manufacturing SS Parts It was discussed and compared to traditionally manufactured counterparts. Most important difference between the two methods is the relatively fast cooling rate during LPBF. Fewer inclusions and unnecessary phases. In addition, the characteristics of passive films and their mechanism of formation has been elucidated in detail by influence of its process parameters' quality. The central part of the work is a systematic overview of AM microstructure and its features. SS parts such as porosity, precipitation of inclusions, residual stress, surface roughness, etc. Chemical composition and element separation, particle size and phase. In each section Explain the source of each function and the effect of AM processing parameters, Corrosion performance was evaluated.

o You can optimize the degree of porosity and density of parts by applying texts such as rights Print parameters. The SS component with a porosity level less than 1% showed almost identical ones. Or some cases, better corrosion characteristics compared to traditionally made samples. Polarized curve anode-branched power tips check the metering pits Education because there is a hole in structure. .

o For high speed coagulation between AMS MNS inclusions and CR delivery zones It is much smaller than traditionally produced patterns (nan scale pair Micro scale) Independently Process parameters improve the pitting corrosion resistance of AM-SS components. Reheat process at temperatures above 1000 ° C, with diffusion Formation of more inclusions, reduced corrosion resistance.

o Residual stress in AM-SS is a function of build direction, yield strength, and process. Part parameters and shape. The effects of residual stress on corrosion behaviour are as follows: It's very complicated. Residual compressive stress makes the passivation film slightly denser Concentration of sync point defects. However, it remains with the distortion of the parts. Stress causes micro galvanic bonds between regions under tensile and compressive stress, which is the main pitching site of the part

o The surface roughness of AM parts is significantly higher than other traditional manufacturing processes. Evaporation, ball phenomenon, aliasing, and disguise direction methods all of these can be optimized by controlling the processing parameters. Reduction Surface roughness reduces the electrochemical reaction with the surface It provides both environmental, general and local corrosion mitigation. Among the alloying elements, Cr and Ni have a positive effect on corrosion behaviour. It is due to the formation of a passivation layer or the stabilization of the austenite matrix. O is known to be low AMSS pitching potential. C forms carbides and forms their precipitates at the grain boundaries Causes intergranular corrosion. The presence of Mo in the alloy composition Formation of passivation film and improvement of pitting corrosion resistance. High energy It causes a spatially non-uniform configuration of the SS in relation to the AM process. It affects the corrosion behaviour based on the role of each element.

o Effect of crystal grain size and substructure formation on the corrosion behaviour of AM SS is controversial in the literature. The dominant hypothesis is Manufactured SS sub grain boundaries serve as the preferred passive film site.

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