PARAMETRIC INFLUENCES ON MECHANICAL TRAITS IN SELECTIVE LASER MELTING OF AlSi10Mg

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Abstract- The objective of this review is to present a thorough evaluation of the existing knowledge concerning the processing of AlSi10Mg Aluminum alloy by using Selective Laser Melting (SLM). The manufacturing of complex and intricate components has been significantly influenced by additive manufacturing in a wide range of industries, with SLM becoming increasingly popular owing to its numerous advantages. This review explores key characteristics of AlSi10Mg alloy components made by SLM. In this review, the impacts of various process parameters, post-processing treatments, and heat treatments on the mechanical characteristics of AlSi10Mg alloy components are comprehensively elaborated.

Keywords: AlSi10Mg, Parameter, optimization, properties, parametric influences.

1. INTRODUCTION

Selective Laser Melting (SLM) is a popular metal AM technique that is well-known for its adaptability in processing a wide range of materials, including metals, ceramics, and composites. Of the wide range of materials that can be used for SLM, the AlSi10Mg alloy has attracted a lot of attention because of its unique set of properties, which includes high strength-to-weight ratio, resistance to corrosion, and excellent thermal conductivity.

SLM of metal alloys involves the setting up of various Process parameters such as laser scanning velocity, laser power, hatch style, hatch spacing, layer thickness, powder particle size among others. The meticulous selection and control of these process parameters hold a pivotal role in shaping the properties of the produced parts. The resultant microstructure and mechanical characteristics are significantly influenced by these process parameters. Some influential parameters during the SLM process are depicted in Figure 1.1.

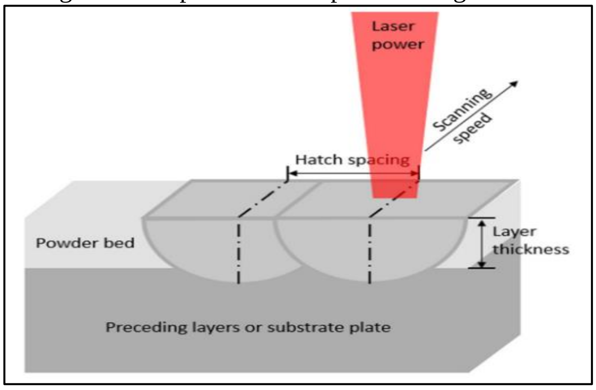

Fig. 1.1 Schematic diagram of SLM process [1]

2. PARAMETRIC INFLUENCE ON PART PROPERTIES IN SLM

In this section, the common properties of AlSi10Mg Alloy parts produced with SLM will be discussed. This section includes the studies of variation of part properties with respect to the changing processing parameters. This section tries to summarize the recent research related to the SLM fabricated AlSi10Mg in order make the optimization of process parameters easier and more accessible.

2.1 Relative Density

The relative density of a fabricated part is defined as the ratio of its density to the absolute density of the material from which it is made. In the context of AlSi10Mg components made by SLM, the term "relative density" refers to the ratio of the density of the fabricated part to the absolute density of the AlSi10Mg material which is known to be approximately 2.67 g/cm3 as per the material datasheet from SLM Solutions [2].

Liu et al. [3] examined the effect of laser power on the relative density, microstructure of AlSi10Mg parts produced by SLM. In this experiment, the maximum relative density was observed at 300 watts laser power. Aboulkhair et al. [4] studied the effect of various process parameters such as scan speed, hatch space on relative density and other part properties and defects. Hyer et al. [5] also studied the SLM process on AlSi10Mg. In this research, various processing parameters such as laser power, scan speed, hatch spacing and layer thickness were considered, and their effect on relative density was studied. In another study, Mfusi et al. [6] observed the effects of various build orientations on relative density and other mechanical properties. Build orientations were found to be less influential on relative density as compared to other processing parameters. Similar study was conducted by Awd et al. [7] to establish the relation between processing parameters and part properties. One of the findings of this research was the effect of build orientations on the relative density of the part. In this research, the maximum relative density was found to be 99.94% at 45° build orientation.

2.2 Tensile Properties

Tensile properties are mechanical traits of a component that indicates how it behaves under tension. AlSi10Mg has a high tensile strength, making it ideal for applications that require structural integrity and load-bearing capabilities. Tensile characteristics are heavily influenced by the process parameters used during the SLM process. Laser power, scanning speed, layer thickness, and energy density are crucial variables in determining the tensile properties of manufactured parts.

Higher laser power generally leads to increased material melting, impacting the tensile strength. Numerous studies have been undertaken to analyze the effects of processing parameters on the tensile properties of the manufactured components. Concise outcomes from these investigations are summarized in Table 2.1. For instance, Patakham et al. [8] conducted an investigation examining the influence of build direction and heat treatment on the tensile characteristics of the component. This study showed a reduction in tensile strength as a result of heat treatment. The findings from this study are visually represented in Figure 2.1.

Table-2.1 Parametric Influences on Tensile Strength

Process Parameter	Parameter Value	UTS (Mpa)	References
Scanning Strategy (°)	67	469.4	[9]
	90	435.8	
Laser Power (W)	480	274	[10]
	620	319	
	910	255	
Scan Speed (mm/s)	800	282	[11]
	1000	287	
	1200	292	
Energy Density (J/mm3)	89	370	[12]
	131	388	
	200	355	
Preheat Temperature (°C)	80	303.3	[13]
	120	310.2	
	160	303.1	
Construction Angle (°)	0	449.67	[14]
	30	433.62	
	60	463.54	
	90	410.83	
Built Orientation (°)	0	379	[15]
	45	382.5	
	90	398.00	

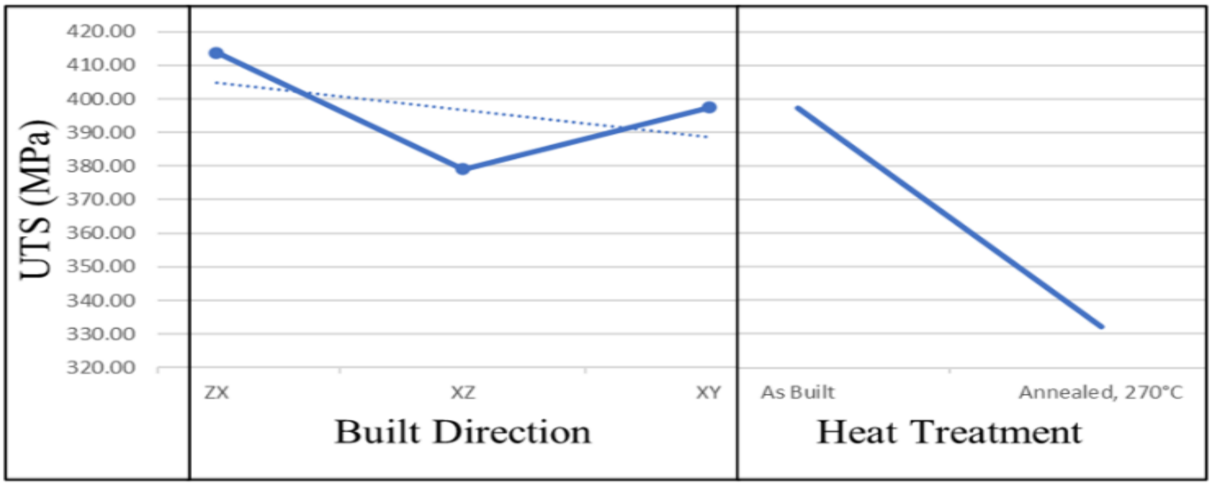

Fig. 2.1 Effect of built direction and heat treatment on UTS [8]

3. COMPRESSIVE PROPERTIES

The compressive properties of a part refer to its ability to withstand forces that attempt to shorten or compress it. The compressive properties of SLM parts are impacted by various process parameters and powder characteristics. Presently, there is a limited body of research that comprehensively explores the impacts of influential process parameters on the compressive properties of fabricated components.

Hitzler et al. [16], examined the influence of process parameters on the mechanical traits of SLM fabricated specimens. This study shows the variations in compressive properties with respect to the various part configurations. The results of this study show that compressive strength is optimum when both the Azimuth and Polar angles are 45° inclined. In another study, Sert et al. [17] investigated the compressive characteristics of AlSi10Mg specimens with various orientations. This study found that the yield compressive strength is highest at 90° built orientation, whereas the Young's modulus is highest at 75° built orientation. In another investigation, Schuch et al. [18] investigated the compressive behavior of T5 and T6 treated specimens. Aboulkhair et al. [19] conducted another comparable investigation, specifically investigating the effect of heat treatment on compressive attributes. This study compared the compressive properties of Solution Heat Treated (SHT) specimens to those of as-built specimens and found that Solution Heat Treated specimens have lower compressive strength, whereas as-built specimens have much higher compressive strength.

4. MICROHARDNESS

Microhardness refers to the measurement of hardness at a microscopic scale, providing insights into the localized mechanical properties of materials. It is also measured in terms of HV. This method of hardness testing is very beneficial for evaluating small or thin specimens or focusing on specific sections of a material. Several parameters influence the hardness of AlSi10Mg components, including laser power, layer thickness, scan speed, hatch spacing, and built orientation. Table 4.1 describes how various process factors affect microhardness. Galetto et al. [20] investigated the influence of several process parameters on the microhardness of manufactured components. The graphical representation of the findings from this study is illustrated in Figure 4.1.

Table-4.1 Parametric Influences on Microhardness

Process Parameter	Parameter Value	Microhardness (HV)	References
Layer Thickness (mm)	0.015	117	[21]
	0.02	89.1	
Scan Strategy	Meander	117.5	[22]
	Remelting	121.6	
Preheat Temperature (°C)	100	130	[23]
	150	140	
	200	118	
Construction Angles (°)	0	141.59	[14]
	45	154.44	
	90	145.51	
Built Orientation	XY	127	[6]
	45°	128	
	Z	126	
Heat Treatment	HPDC	100	[24]
	HPDC+T6	131.5	
	As Built	136	
	T6, 520°C	100	[19]
	As Built	125	

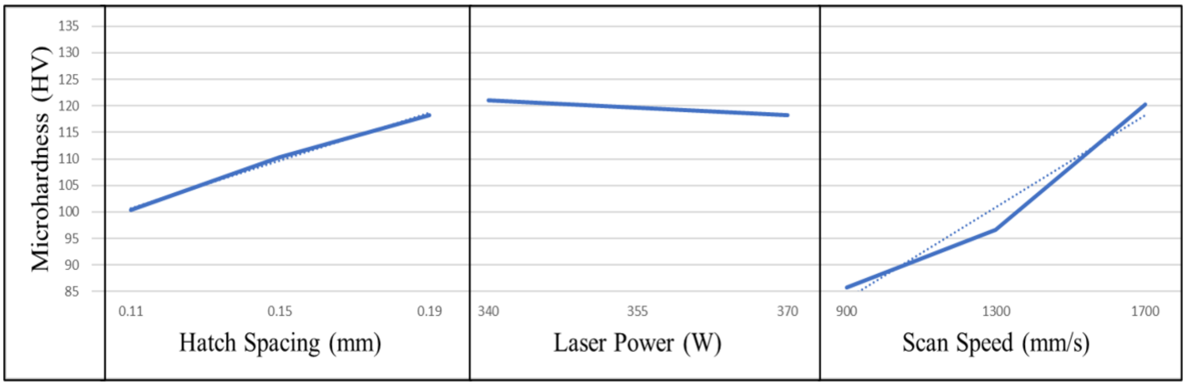

Fig. 4.1 Parametric influences on Vicrohardness [20]

5. SURFACE ROUGHNESS

Surface roughness refers to the irregularities and deviations in the texture of a material's surface. It quantifies the closely spaced, repeating deviations from the desired surface caused by different manufacturing procedures and gradual wear over time. The most commonly used parameter for expressing surface roughness is average roughness (Ra).

In SLM, the surface finish is considerably affected by the layer-wise deposition of material. Several factors contribute to surface roughness in SLM, including the layer thickness, scanning strategy, and laser parameters. Post-processing procedures, such as machining or polishing, can be used to improve surface quality and reduce roughness. Majeed et al. [25] conducted a thorough investigation on the effect of various process parameters on the surface roughness of produced components. Table 5.1 shows how different process parameters affect surface roughness.

Table-5.1 Parametric Influences on Surface Roughness

Process Parameter	Parameter Value	Surface Roughness (µm)	References
Hatch Spacing (µm)	70.9	4.28	[26]
	76.3	4.48	
	102.4	6.86	
Scan Strategy	Stripes 67°	7.32	
	Meander	13.34	[22]
	Remelting	9.94	
Scan Speed (mm/s)	800	3.75	[27]
	1050	4.59	
	1300	7.25	
Powder Particle Size (µm)	40	4.59	
	9	5.17	
Built direction	XY	3.57	[28]
	YZ	9.25	
	XZ	9.36	

6. FATIGUE BEHAVIOR

The fatigue behavior of a material describes its ability to tolerate repeated cyclic stress while resisting the initiation and propagation of cracks or fractures over time. When a material experience fluctuating or cyclic stress, such as repetitive bending or cyclic loads, small, microscopic cracks can form and propagate. These Microscopic cracks can cause the part to fail. Fatigue strength is evaluated through fatigue testing, which involves subjecting specimens to cyclic loading until failure, and the results are used to characterize the material's fatigue performance under various stress levels and loading conditions. The fatigue strength of SLM components is influenced by a variety of process parameters such as layer thickness, laser power, scan speed, part orientation, post-processing, and heat treatments. Table 6.1 illustrates how different process parameters affect fracture strength.

Table-6.1 Parametric Influences on Fatigue Behavior

Process Parameter	Parameter Value	Fatigue Strength (Mpa)	References
Part Placement	Horizontal	114	[29]
	Vertical	45	
Build Chamber Gas	Argon	144	[30]
	Nitrogen	127	
Built Orientation (°)	0	122	[15]
	45	97	
	90	134	
Post Processing	Vibro-Finished	95	[31]
	Sand Blasted	152.5	
	As Built	56	
	Shot Peened	185	[32]
	HT + Sand Blasted	175	
	HT + Shot Peened	102	
Heat Treatment	Annealed, 320°C	60	[33]
	Annealed, 244°C	80	
	Stress Relief, 300°C	90	[34]
	SHT, 530°C	90	
	T6 Treated, 170°C	90	

7. CURRENT STATE OF KNOWLEDGE AND FUTURE WORK

In the realm of research and development, AlSi10Mg alloy has gained much popularity and numerous research are underway to understand the SLM process on this alloy better. But there is still some lack of research in this field. For instance, only a few studies are available that examines the effects of process parameters on compressive properties and fracture resistance properties of the fabricated components. Moreover, flexural strength have not been studied by the researchers yet. Studies can be easily conducted to analyze the flexural strength of the specimen under different processing conditions. Additionally, material properties like Thermal and Electrical conductivity have also not been studied by the researchers yet. So, research scope in this field is very high.

CONCLUSION

SLM of AlSi10Mg represents a versatile AM process with significant potential across diverse industries. This review has explored various aspects of SLM, beginning with a basic introduction, it delves into the fundamentals of SLM process parameters and their impacts on the properties of the produced components. Extensive research efforts are highlighted, particularly in comprehending the mechanical properties of AlSi10Mg parts fabricated through SLM. Various research studies about SLM fabricated AlSi10Mg are reviewed.

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