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Mechanical Anisotropy of Metal Alloys Fabricated by Laser Powder Bed Fusion: Effects of Build Orientation, Loading Conditions, and Post-Processing

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ABSTRACT

Laser powder bed fusion (LPBF) is an additive manufacturing technology that enables the production of metallic components with complex geometries. However, its layer-by-layer melting and rapid solidification processes can generate direction-dependent microstructures and mechanical properties. This review examines the mechanical anisotropy of four representative LPBF alloy systems: Ti-6Al-4V, 316L stainless steel, AlSi10Mg, and Inconel 718. The effects of build orientation, loading conditions, microstructural characteristics, and post-processing are discussed, with emphasis on tensile behavior, fatigue performance, fracture and crack propagation, and high-temperature mechanical response. The reviewed studies indicate that anisotropy results from the combined effects of crystallographic texture, grain morphology, solidification structures, process-induced defects, residual stress, and surface condition. Their relative contributions vary among alloy systems and depend on manufacturing and testing conditions. Furthermore, tensile anisotropy does not necessarily predict fatigue or fracture anisotropy because different loading modes interact differently with defects and microstructural interfaces. Post-processing methods, including heat treatment, hot isostatic pressing, recrystallization, and surface treatment, can modify mechanical properties and directional differences. However, improvements in average mechanical properties do not necessarily indicate the elimination of anisotropy. Finally, current limitations in orientation reporting, defect characterization, and multiscale modeling are identified. This review highlights the importance of integrated experimental and numerical approaches for the reliable design and qualification of LPBF-manufactured metal components.

KEYWORDS

Laser Powder Bed Fusion; Mechanical Anisotropy; Build Orientation; Loading Direction; Fatigue Behavior; Post-processing; Metal Alloys.

1. INTRODUCTION

Laser powder bed fusion (LPBF) is an additive manufacturing technology in which a focused laser selectively melts metallic powder according to a predefined digital model. Through repeated powder spreading, laser scanning, and layer deposition, LPBF can produce components with complex geometries and relatively high dimensional accuracy. It has therefore attracted considerable attention in aerospace, biomedical, automotive, and high-performance equipment applications. Titanium alloys, stainless steels, aluminium alloys, and nickel-based superalloys are among the most widely investigated LPBF materials.

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Despite these advantages, the mechanical properties of LPBF-manufactured metals are not always identical in different directions. Unlike conventional manufacturing processes, LPBF involves repeated localized melting and rapid solidification. The resulting thermal gradients, scanning strategies, and layer-by-layer deposition can generate direction-dependent microstructures and defect distributions. Consequently, the mechanical response of an LPBF component may depend on both its orientation during fabrication and the direction of subsequent loading. This phenomenon is generally referred to as mechanical anisotropy[1-3].

Mechanical anisotropy is important because it can affect component stiffness, deformation, fatigue life, and fracture resistance. Differences in elastic modulus and yield strength may influence structural stiffness and load redistribution, while variations in ductility and fatigue resistance can affect deformation localization and service life. Under cyclic loading, the orientation of pores, lack-of-fusion defects, melt-pool boundaries, and microstructural interfaces relative to the applied stress may influence crack initiation and propagation.

Previous studies have investigated the anisotropic properties of LPBF metals from different perspectives. Weaver and Rosenthal [1] reviewed the anisotropic tensile properties of selected LPBF metals. Kan et al. [2] examined the influence of process-induced porosity on the mechanical properties of LPBF alloys, while Huangfu et al.[3] discussed the broader mechanisms of anisotropy in additively manufactured metallic materials.

However, existing experimental results are distributed across different alloy systems, processing conditions, specimen geometries, and testing methods. Many studies focus on uniaxial tensile properties, whereas fatigue, fracture, torsion, and high-temperature behavior are often investigated separately. In addition, build orientation and loading direction are not always clearly distinguished.

This review examines the mechanical anisotropy of four representative LPBF alloy systems: Ti-6Al-4V, 316L stainless steel, AlSi10Mg, and Inconel 718. The discussion focuses on the relationships among build orientation, microstructure, loading conditions, and post-processing. The aim is to identify the major mechanisms governing anisotropic behavior and clarify the limitations of current research, providing a basis for material selection, process optimization, and structural design.

2. ORIGIN OF MECHANICAL ANISOTROPY IN LPBF

2.1. Thermal History and Build Orientation

LPBF produces components through repeated powder deposition and selective laser melting. During each scanning cycle, the laser generates a localized molten pool that rapidly solidifies. Subsequent layers may partially remelt or reheat previously deposited material, resulting in steep temperature gradients, rapid cooling, and repeated thermal cycling.

Heat transfer occurs through the consolidated material, surrounding powder, and build platform. The resulting directional heat flow can influence grain growth and crystallographic orientation. In many LPBF alloys, epitaxial solidification promotes elongated grains that extend across multiple deposited layers. These features may produce a preferred crystallographic texture and direction-dependent mechanical response.

Build orientation describes the orientation of a specimen or component relative to the build direction during manufacturing. Specimens may be fabricated with their longitudinal axes parallel, perpendicular, or inclined to the build direction. The terms vertical, horizontal, and inclined are frequently used, but the exact angle convention should be checked for each study.

Loading direction, in contrast, describes the direction of the applied force or stress during mechanical testing. Build orientation and loading direction are related but not interchangeable. Changing build orientation may alter the microstructure and defect distribution, whereas changing loading direction

changes how the applied stress interacts with the existing microstructural features. Both should therefore be reported when evaluating mechanical anisotropy.

2.2. Process-induced Defects

Process-induced defects are another important source of mechanical anisotropy. Common defects in LPBF materials include lack-of-fusion (LoF) defects, gas pores, keyhole pores, cracks, and surface-connected imperfections. Their formation depends on laser energy input, powder characteristics, scanning strategy, and melt-pool stability.

LoF defects are often irregular and may be elongated along layer interfaces or scan tracks. Their orientation relative to the applied load can influence local stress concentration and crack initiation. Gas pores are generally more rounded, but their effects still depend on size, location, and distribution.

Porosity should therefore not be evaluated only by its total volume fraction. Defect size, shape, orientation, and proximity to the component surface are also important. Even when the influence of a small defect population on monotonic tensile strength is limited, surface-connected defects may significantly affect fatigue performance. Kan et al. [2] emphasized the importance of process-induced porosity in determining the mechanical properties of LPBF alloys.

2.3. Microstructural Features and Residual Stress

The repeated formation and partial remelting of melt pools produce characteristic boundaries and interfaces. These features may be associated with changes in microstructure, local composition, and defect distribution, potentially influencing deformation localization and crack propagation.

Residual stresses develop because different regions experience non-uniform heating, cooling, and mechanical constraint during manufacturing. Their magnitude and distribution depend on process parameters, component geometry, build-plate constraint, and subsequent heat treatment. Residual stresses may interact with external loading and influence local yielding or crack initiation.

Surface condition is particularly important in fatigue applications. As-built surfaces may contain partially fused particles, surface-connected pores, and pronounced roughness. These features can act as stress concentrators and affect fatigue crack initiation. Consequently, fatigue results obtained from as-built specimens should not be directly compared with those from machined or polished specimens without considering surface condition.

Overall, mechanical anisotropy in LPBF metals originates from the combined effects of crystallographic texture, grain morphology, solidification structures, defects, residual stresses, and surface condition. Their relative importance varies with alloy composition, processing conditions, and loading mode.

3. MICROSTRUCTURAL MECHANISMS IN DIFFERENT ALLOY SYSTEMS

3.1. Crystallographic Texture and Grain Morphology

Crystallographic texture refers to the non-random distribution of crystal orientations in a polycrystalline material. Directional heat flow and epitaxial solidification during LPBF can promote preferred crystallographic orientations. When the texture is sufficiently strong, the measured elastic and plastic responses may depend on the direction of loading.

For alloys with crystallographically anisotropic slip behavior, texture can influence slip-system activation, resolved shear stress, and the onset of plastic deformation. This may lead to differences in elastic modulus, yield strength, and strain hardening between specimens tested in different directions.

Grain morphology also contributes to anisotropy. Columnar grains extending along the build direction may produce different deformation constraints from those associated with equiaxed grains. The combined effects of texture and grain morphology should therefore be considered when interpreting directional mechanical properties [3, 4].

3.2. Ti-6Al-4V

LPBF Ti-6Al-4V commonly exhibits prior-β grains and fine α' martensitic structures in the as-built condition. The morphology and orientation of prior-β grains, together with the distribution of α' laths, can influence deformation behavior.

Sun et al. [5] investigated the influence of specimen build orientation on the tensile deformation and properties of LPBF Ti-6Al-4V. Their results showed orientation-dependent tensile behavior and differences in fracture strain. The reported fracture strains were 9.34±0.67% for the Z orientation, 5.33±0.74% for the Z45 orientation, and 7.89±0.56% for the X orientation. These values represent total strain at fracture in that study and should not be interpreted as universal properties of LPBF Ti-6Al-4V.

The anisotropic tensile response of Ti-6Al-4V is also related to its crystallographic and microstructural characteristics. Somlo et al. [4] used crystal plasticity modeling to investigate the anisotropic tensile behavior of additively manufactured Ti-6Al-4V. Their work demonstrates the value of considering crystallographic orientation when predicting deformation.

Fatigue behavior provides additional evidence of orientation dependence. Qian et al. [6] investigated the very-high-cycle fatigue behavior of selective laser melted Ti-6Al-4V. At 10^9 cycles, the reported median fatigue strengths were 217 MPa, 201 MPa, and 155 MPa for the 0°, 45°, and 90° build orientations, respectively. These results show that build orientation can influence very-high-cycle fatigue performance under the investigated conditions.

3.3. 316L Stainless Steel

LPBF 316L stainless steel generally develops an austenitic matrix containing cellular or subcellular solidification structures. These structures may be associated with solute segregation and high dislocation densities. The cellular network, crystallographic texture, and grain morphology can influence local deformation and strain distribution.

O' Neill et al. [7] investigated the tensile anisotropy of LPBF 316L specimens fabricated at different build angles. Their study reported changes in tensile properties with build orientation. However, such trends should be interpreted within the specific processing and testing conditions of that investigation rather than generalized to all LPBF 316L materials.

Fatigue behavior also depends on the loading mode. Liang et al. [8] compared the effects of building direction and loading mode on the high-cycle fatigue strength of LPBF 316L. Their results indicated that bending fatigue was more sensitive to build direction than torsional fatigue. This finding suggests that the influence of orientation cannot be evaluated independently of the stress state.

3.4. AlSi10Mg

LPBF AlSi10Mg typically contains an α-Al matrix and a fine Si-rich eutectic network formed during rapid solidification. The distribution and morphology of the Si-rich phase can influence dislocation motion and local deformation. Melt-pool boundaries and process-induced defects may also contribute to directional differences.

Wang et al. [9] investigated the effects of build orientation and heat treatment on the anisotropic tensile properties of LPBF AlSi10Mg. Their work demonstrates that the relationship between orientation and tensile behavior is influenced by the material's microstructural condition.

Fatigue and crack propagation provide further evidence of orientation-dependent behavior. Di Giovanni et al. [10] studied fatigue crack growth in selective laser melted AlSi10Mg and reported that crack propagation behavior was affected by crack orientation and material condition. Lupi et al. [11] also investigated fracture toughness and reported orientation-related differences associated with the interaction between cracks and microstructural features.

Fini et al. [12] examined the effects of build orientation, heat treatment, and surface treatment on the fatigue response of LPBF AlSi10Mg. Their results showed that heat treatment and surface condition could substantially influence fatigue performance. Importantly, the study did not establish a universal fatigue limit for AlSi10Mg. Its reported fatigue strength values were obtained from specific rotating-bending tests and S-N data under defined experimental conditions.

3.5. Inconel 718

LPBF Inconel 718 can develop columnar grains, dendritic or cellular segregation patterns, and crystallographic texture. Its mechanical properties are also influenced by the precipitation state of strengthening phases and the thermal history during manufacturing.

Watring et al. [13] investigated the effects of laser energy density and build orientation on the microstructure, pore structure, and tensile properties of as-built LPBF Inconel 718. Their findings showed that laser energy density and build orientation could jointly affect the resulting structure-property relationships. In particular, specimens manufactured at a low energy density of 38 J/mm³ contained substantial lack-of-fusion porosity, reported as 6.91 vol%. This defect population significantly affected the mechanical response. Therefore, the observed property differences cannot be attributed to build orientation alone.

Table 1. Summary of microstructural characteristics and major factors influencing mechanical anisotropy in different LPBF alloys.

Alloy	Typical microstructural features	Major factors influencing anisotropy	References
Ti-6Al-4V	Prior-β grains and α' martensitic structures	Crystallographic texture, grain morphology, build orientation, and defects	[4-6]
316L stainless steel	Austenitic matrix with cellular or subcellular structures	Build orientation, solidification structures, defects, and loading mode	[7, 8]
AlSi10Mg	α-Al matrix and Si-rich eutectic network	Build orientation, heat treatment, surface condition, and defects	[9-12]
Inconel 718	Columnar grains and dendritic or cellular segregation structures	Laser energy density, build orientation, texture, and post-processing	[13-15]

De Luca et al. [14] investigated the influence of build orientation on high-temperature fatigue crack growth in LPBF Inconel 718. Their study provides evidence that orientation-related effects may remain relevant under elevated-temperature fatigue crack-growth conditions.

Kouraytem et al. [15] studied recrystallization heat treatment and deformation anisotropy in additively manufactured Inconel 718. Their results showed that recrystallization could reduce deformation anisotropy under compression by modifying grain morphology and crystallographic texture. This finding should not be interpreted as direct evidence that the same treatment eliminates tensile or fatigue anisotropy. The main microstructural characteristics and factors influencing mechanical anisotropy in different LPBF alloys are summarized in Table 1.

4. EFFECTS OF LOADING CONDITIONS ON MECHANICAL ANISOTROPY

4.1. Tensile and Elastic Properties

Tensile testing is widely used to evaluate the mechanical anisotropy of LPBF materials. Commonly measured parameters include Young's modulus, yield strength, ultimate tensile strength, and elongation. These parameters describe different aspects of mechanical behavior and may not exhibit identical directional trends.

Young's modulus is related to elastic deformation and can be influenced by crystallographic texture. Yield strength is affected by texture, grain morphology, dislocation structures, and defects. Ultimate tensile strength and elongation are additionally influenced by strain hardening, deformation localization, and damage evolution.

The reviewed studies demonstrate that the magnitude and direction of tensile anisotropy depend on the alloy and processing conditions [5,7,9]. For this reason, a single tensile parameter is insufficient to describe the complete anisotropic response of an LPBF material.

4.2. Fatigue Behavior

Fatigue behavior is governed by repeated crack initiation and propagation. In LPBF materials, defects, surface roughness, residual stress, and microstructural interfaces can strongly influence fatigue performance.

Qian et al. [6] demonstrated orientation-dependent very-high-cycle fatigue strength in LPBF Ti-6Al-4V. Liang et al. [8] showed that the influence of building direction on LPBF 316L fatigue strength differed between bending and torsional loading. Fini et al. [12] further demonstrated that build orientation, heat treatment, and surface treatment should be considered together when evaluating the fatigue response of AlSi10Mg.

These findings indicate that fatigue anisotropy cannot be reliably predicted from tensile properties alone. Fatigue-specific experiments are necessary, particularly for components subjected to cyclic or multiaxial loading.

4.3. Fracture and Crack Propagation

Fracture toughness and fatigue crack growth provide additional information about the resistance of LPBF materials to crack propagation. Crack paths may interact with grain boundaries, melt-pool interfaces, defects, and other microstructural features.

In AlSi10Mg, Di Giovanni et al. [10] and Lupi et al. [11] investigated fatigue crack growth and fracture toughness, respectively. Their studies indicate that crack orientation and heat-treatment condition can influence fracture-related behavior.

For Inconel 718, de Luca et al. [14] examined orientation-dependent high-temperature fatigue crack-growth mechanisms. These findings demonstrate that the effects of build orientation may remain important under elevated-temperature conditions.

Therefore, a comprehensive assessment of mechanical anisotropy should consider both crack initiation and crack propagation, rather than relying exclusively on tensile strength or elongation.

Representative quantitative results related to mechanical performance and defect formation in LPBF alloys are presented in Table 2.

Table 2. Representative quantitative results related to mechanical performance and defect formation in LPBF alloys.

Material	Research focus	Experimental results	References
Ti-6Al-4V	Tensile fracture strain	Z: 9.34±0.67%; Z45°: 5.33±0.74%; X: 7.89±0.56%	[5]
Ti-6Al-4V	Very-high-cycle fatigue	Median fatigue strength at 10^9 cycles: 217 MPa (0°), 201 MPa (45°), and 155 MPa (90°)	[6]
Inconel 718	Lack-of-fusion porosity	6.91 vol% porosity at a laser energy density of 38 J/mm³	[13]
AlSi10Mg	Rotating-bending fatigue	62.8 MPa at 10^6 cycles for the specific slanted, T6-treated, and shot-peened specimen group	[12]

5. POST-PROCESSING AND ITS INFLUENCE ON ANISOTROPY

5.1. Heat Treatment

Heat treatment is widely used to modify the microstructure, residual stress, and mechanical properties of LPBF alloys. Its effects depend on alloy composition, initial microstructure, and treatment temperature and duration.

For Ti-6Al-4V, heat treatment can modify the as-built martensitic structure and influence strength and ductility. For 316L, thermal treatment can affect residual stress and dislocation structures. In AlSi10Mg, heat treatment modifies the Si-rich eutectic network and the aluminium matrix. For Inconel 718, solution and aging treatments influence the precipitation state and strengthening mechanisms.

However, an improvement in average mechanical properties does not necessarily mean that anisotropy has been eliminated. Directional properties should be measured before and after treatment under comparable conditions.

5.2. Hot Isostatic Pressing

Hot isostatic pressing (HIP) applies high temperature and isostatic pressure to reduce internal porosity. It can be beneficial when the mechanical performance of an LPBF component is strongly influenced by internal defects.

Nevertheless, HIP does not necessarily remove all sources of anisotropy. Crystallographic texture, grain morphology, and other microstructural features may remain after treatment. The effects of HIP should therefore be evaluated separately from those of subsequent heat treatment, because combined treatment schedules may produce additional microstructural changes.

5.3. Recrystallization and Surface Treatment

Recrystallization can modify grain morphology and crystallographic texture. Kouraytem et al. [15] demonstrated that recrystallization heat treatment could reduce deformation anisotropy in LPBF Inconel 718 under compression. Further work is required to establish how this effect translates to other loading modes.

Surface treatment is particularly important for fatigue-critical components. Machining, polishing, and shot peening can modify surface roughness, remove surface-connected defects, or change near-surface residual stresses. Fini et al. [12] demonstrated that heat treatment and surface treatment both influenced the fatigue response of LPBF AlSi10Mg.

In summary, no single post-processing method can be considered universally effective for eliminating mechanical anisotropy. The appropriate treatment depends on the dominant anisotropy mechanism and the intended service conditions.

The effects of loading conditions and post-processing treatments on mechanical anisotropy in LPBF alloys are summarized in Table 3.

Table 3. Effects of loading conditions and post-processing on the mechanical anisotropy of LPBF alloys.

Factor	Material	Main findings	References
Tensile loading	Ti-6Al-4V	Build orientation affects tensile deformation and fracture strain.	[5]
Fatigue loading	Ti-6Al-4V	Build orientation affects very-high-cycle fatigue strength.	[6]
Bending and torsion	316L stainless steel	Bending fatigue is more sensitive to build direction than torsional fatigue under the investigated conditions.	[8]
Heat treatment	AlSi10Mg	Heat treatment influences fatigue response and orientation-related differences.	[12]
Surface treatment	AlSi10Mg	Surface treatment affects fatigue performance.	[12]
Recrystallization	Inconel 718	Recrystallization reduces deformation anisotropy under compression in the investigated study.	[15]

6. CROSS-ALLOY COMPARISON AND ENGINEERING IMPLICATIONS

The four alloy systems considered in this review demonstrate that mechanical anisotropy in LPBF materials is governed by multiple interacting mechanisms.

For Ti-6Al-4V, prior-β grain morphology, α’ martensitic structures, crystallographic texture, and defects contribute to directional tensile and fatigue behavior [4-6]. For 316L stainless steel, cellular solidification structures, texture, defects, and loading mode influence the mechanical response [7-8]. For AlSi10Mg, the Si-rich eutectic network, defects, surface condition, and heat treatment are important factors in tensile, fatigue, and fracture behavior [9-11]. For Inconel 718, columnar grains, texture, solidification structures, laser energy density, and post-processing influence its mechanical properties [13-15].

A comparison of different loading conditions also shows that tensile anisotropy cannot be regarded as a direct indicator of fatigue or fracture anisotropy. Under monotonic tensile loading, the measured response is influenced by elastic and plastic deformation mechanisms. Under cyclic loading, defects and surface condition may become more important because they provide potential crack-initiation sites. During crack propagation, the interaction between the crack path and microstructural interfaces can further influence fracture behavior.

These findings have several engineering implications.

First, build orientation should be selected according to the dominant service loading condition rather than manufacturing convenience alone. For tensile-loaded components, directional yield strength and ductility should be considered. For fatigue-critical components, the distribution of internal and surface defects requires particular attention.

Second, process optimization should aim to control defect formation and microstructural heterogeneity. Insufficient energy input may promote lack-of-fusion defects, while inappropriate process conditions can produce undesirable residual stresses and microstructural variations [2, 13].

Third, post-processing should be selected according to the dominant failure mechanism. Heat treatment can modify phase morphology and residual stress, HIP can reduce internal porosity, and surface treatment can improve the near-surface condition. However, improvements in average properties should not automatically be interpreted as the elimination of anisotropy.

Finally, mechanical qualification should report build orientation, loading direction, specimen geometry, processing conditions, heat-treatment history, surface condition, and defect characteristics. Such information is necessary for meaningful comparisons between studies and for reliable structural design.

7. RESEARCH GAPS AND FUTURE PERSPECTIVES

Despite considerable progress, several issues remain unresolved in the study of LPBF mechanical anisotropy.

First, the reporting of build orientation and loading direction is not always consistent. Different studies may use different coordinate systems and angle conventions, making direct comparison difficult. Future investigations should clearly define the build direction, specimen axis, loading direction, and specimen geometry.

Second, research on tensile anisotropy is more extensive than systematic comparisons involving fatigue, fracture, torsion, and high-temperature loading. However, directional differences observed under tensile loading cannot necessarily predict performance under cyclic or crack-propagation conditions. Future studies should combine multiple mechanical tests using specimens manufactured under comparable processing conditions.

Third, the individual contributions of microstructure and defects are difficult to separate because they often coexist. Three-dimensional defect characterization, electron backscatter diffraction, microscopy, and residual-stress measurements should be integrated with mechanical testing. Such an approach would help quantify the relative contributions of texture, grain morphology, and defects to anisotropic behavior.

Fourth, the effects of post-processing require further investigation. Heat treatment, HIP, recrystallization, and surface treatment may improve specific mechanical properties, but their influence on directional differences varies with alloy and loading mode. Future work should distinguish improvements in average mechanical performance from actual reductions in anisotropy.

Finally, improved multiscale modeling is needed. Crystal plasticity models can describe the influence of crystallographic orientation on deformation, while finite element methods can evaluate structural responses under complex loading conditions [4]. However, reliable prediction requires accurate descriptions of microstructure, defects, and material behavior. Models calibrated only with limited tensile data may not adequately predict fatigue or fracture performance.

Future research should integrate experimental characterization, crystal plasticity, finite element analysis, and defect-sensitive fatigue and fracture models. Data-driven methods may also help identify relationships among process parameters, microstructural features, and mechanical properties, provided that sufficiently large and consistently reported experimental datasets are available.

8. SUMMARY AND CONCLUSION

This review examined the mechanical anisotropy of four representative alloy systems manufactured by laser powder bed fusion: Ti-6Al-4V, 316L stainless steel, AlSi10Mg, and Inconel 718. The effects of build orientation, loading conditions, microstructural characteristics, and post-processing were considered. The main conclusions are as follows.

(1) Mechanical anisotropy in LPBF alloys originates from the combined effects of crystallographic texture, grain morphology, solidification structures, process-induced defects, residual stress, and surface condition. The relative contributions of these factors vary among alloy systems and depend on processing and testing conditions.

(2) The relationship between build orientation and mechanical properties is property-dependent. Young's modulus, yield strength, ultimate tensile strength, and ductility do not necessarily exhibit identical directional trends. Therefore, anisotropy should be evaluated using multiple mechanical parameters rather than a single tensile property.

(3) Anisotropy under different loading conditions cannot be directly inferred from tensile test results. Fatigue, fracture, crack propagation, and high-temperature mechanical behavior involve different deformation and failure mechanisms. Defects, surface condition, and crack-path orientation can strongly influence fatigue and fracture responses.

(4) Post-processing can substantially modify the microstructure and mechanical performance of LPBF alloys. Heat treatment, hot isostatic pressing, recrystallization, and surface treatment may improve specific properties or reduce directional differences. However, improvements in average mechanical performance do not necessarily indicate the elimination of anisotropy.

(5) Reliable evaluation of LPBF mechanical anisotropy requires consistent reporting of build orientation and loading direction, together with specimen geometry, processing conditions, heat-treatment history, surface condition, and defect characteristics. Integrated experimental characterization and multiscale modeling are needed to establish more accurate structure-property relationships.

Overall, mechanical anisotropy should be treated as an important design consideration in LPBF manufacturing. A comprehensive understanding of its dependence on alloy composition, processing history, loading conditions, and post-processing is essential for the reliable design and qualification of LPBF-manufactured metallic components.

CONFLICTS OF INTEREST

The author declares that there is no conflict of interest.

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