ACCSCIENCE PUBLISHING

Materials Science in Additive Manufacturing

ORIGINAL RESEARCH ARTICLE

Enhanced strength of A131 steel via heterostructures induced by laser-directed energy deposition

Supplementary File

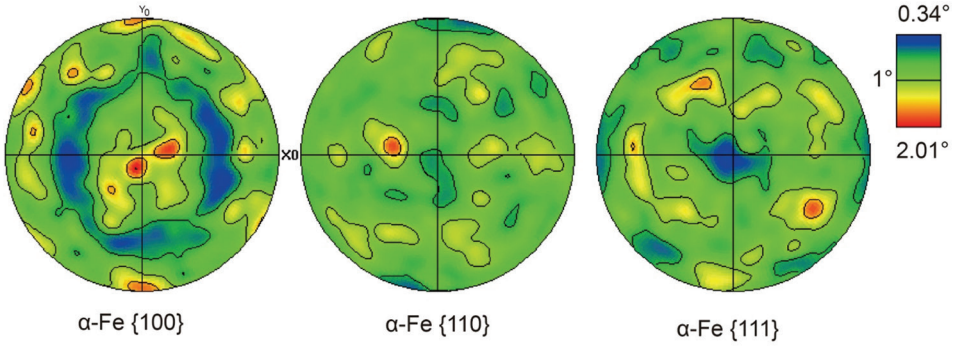

Figure S1. Pole figures of as-built (AB) A131 steel. The pole figures exhibit a strong misorientation in different crystal planes with a max orientation intensity of 2.01°

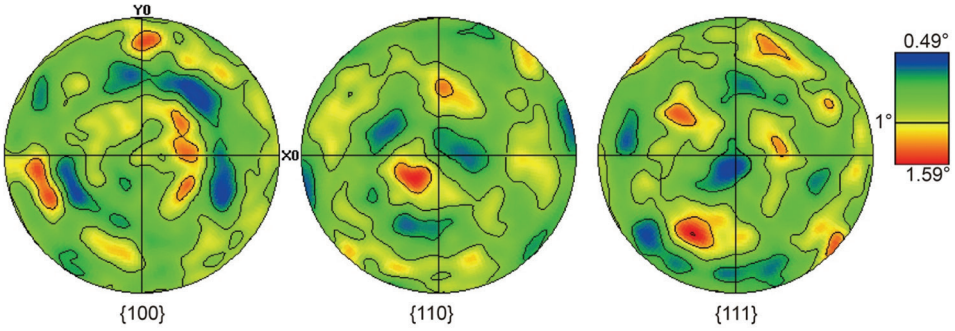

Figure S2. Pole figures of hot-treated (HT) A131 steel. After hot-treated, compared to Figure S1, the intensity of the maximum value significantly decreased to 1.59°, illustrating that a significant decrease in the misorientation of crystal planes

Figure S3. Optical microscope (OM) image of the entire cross-sectional profile for a single-pass deposition. Scale bar 200 μm. The height of the single-pass deposition is around 2.4 mm with a welding joint shape on the top. Three different sections (marked by dark line) with distinct various grain size and profiles formed due to the temperature fields during consolidation of the melt pool

Table S1. Chemical composition of the ASTM A131 steel powder

Element	C	Cr	Mn	Si	Mo	Ni	V	P	S	Cu	Fe
Weight (%)	0.09	0.05	1.18	0.22	0.01	0.02	0.09	0.005	0.005	0.01	Bal.

Table S2. Measured density and relative density of ASTM A131 steel

Parameter	AB	HT	HR
Measured density (g/cm^3)	7.75±0.01	7.76±0.01	7.72±0.01
Relative density (%)	98.72±0.09	98.84±0.08	98.39±0.15

Abbreviations: AB: As-built; HR: Hot rolling; HT: Hot treatment.

Table S3. Tensile properties of A131 steel along different directions

Sample	σ_{YS} (MPa)	σ_{UTS} (MPa)	Elongation (%)
AB-ND	929.5±11.2	970.4±10.8	24.6±0.6
AB-TD	804.5±17.3	799.0±6.1	17.8±0.1
HT-ND	589.1±6.4	676.1±8.5	39.5±0.6
HT-TD	441.2±9.3	520.1±10.5	29.1±1.5
HR-TD	346.5±4.5	545.0±7.3	50.1±3.7

Abbreviations: AB: As-built; HR: Hot rolling; HT: Hot treatment; ND: Nominal direction; TD: Transverse direction.

Table S4. Hardness of A131 steel along different directions

Loading direction	Sample	Vicker hardness (HV)
ND	AB A131 steel	244.1±8.9
	HT A131 steel	146.7±5.7
	HR A131 steel	139.1±7.5
TD	AB A131 steel	223.5±11.6
	HT A131 steel	152.9±3.7
	HR A131 steel	153.7±9.9

Abbreviations: AB: As-built; HR: Hot rolling; HT: Hot treatment; ND: Nominal direction; TD: Transverse direction.

Table S5. Anisotropy ratios of strength and elongation between ND and TD

Sample	Ratio of σ_{YS} (%)	Ratio of σ_{UTS} (%)	Ratio of elongation (%)
AB A131 (this study)	115.55±1.38	121.45±0.43	138.21±2.97
HT A131 (this study)	133.55±1.82	130.03±1.51	135.89±7.92
AB A131[1]			
I	-	101.09	1
II		101.41	34.29
III		98.24	85.71
IV		100.73	94.29
AB A131[2]	94.44	90.96	92.86

Note: AB A131 [1]refers to wire arc additive manufacturing. AB A131 [2]refers to selective laser melting. I: HR; II: HR+Air cooling; III: AB+Air cooling. Abbreviations: ND: Normal direction; TD: Transverse direction; HR: Hot rolling.

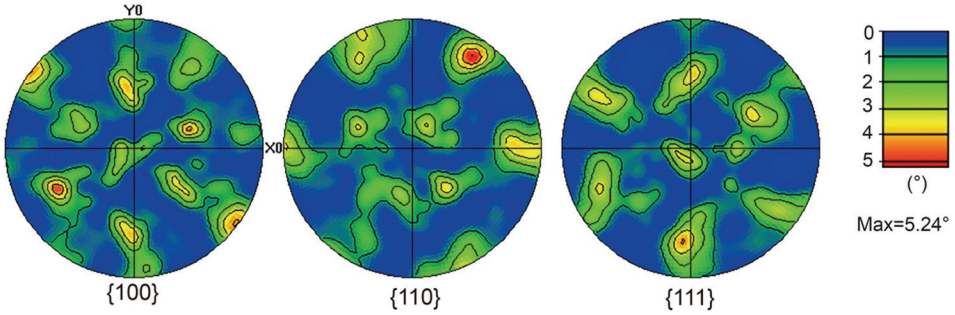

Figure S4. Pole figures of the single-pass track at the top section. The pole figures exhibited a strong intensity reaching 5.24°, illustrating a weak texture in {110} plane

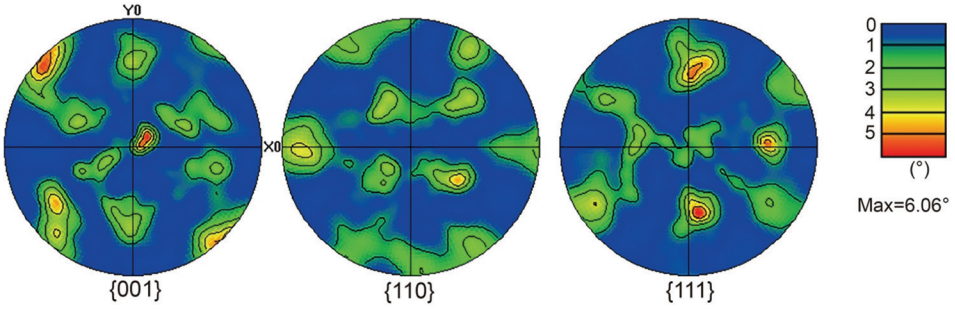

Figure S5. Pole figures of the single-pass track at the middle section. The maximum misorientation increased slightly compared to that in Figure S4, while the patterns were similar, indicating the same weak texture in the middle of the single-pass track

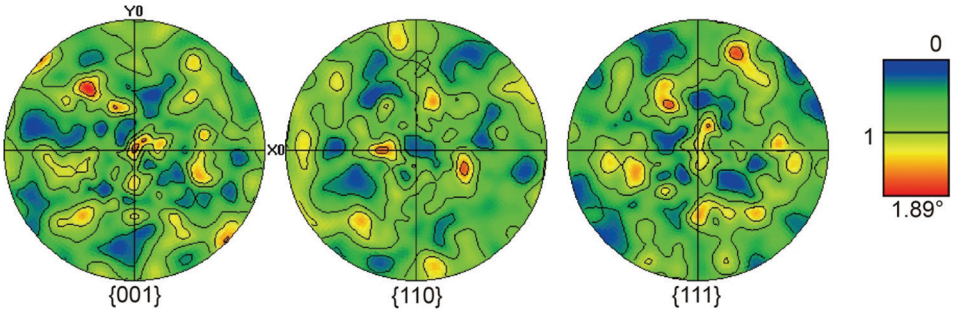

Figure S6. Pole figures of the single-pass track at the bottom section. Compared to the pole figures at the top and middle section, the maximum misorientation decreased slightly compared to that in Figure S4-5, while the patterns change significantly, indicating the small disorientation texture in the middle of the single-pass track

References

1. Vahedi Nemani A, Ghaffari M, Nasiri A. Comparison of microstructural characteristics and mechanical properties of shipbuilding steel plates fabricated by conventional rolling versus wire arc additive manufacturing. *Add Manuf*. 2020;32:101086.

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2. Wang J, Chew YX, Wu WJ, *et al*. Microstructure and mechanical properties of ASTM A131 EH36 steel fabricated by laser aided additive manufacturing. *Mater Charact*. 2021;174:110949.

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