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Study of the Printability, Microstructures, and Mechanical Performances of Laser Powder Bed Fusion Built Haynes 230

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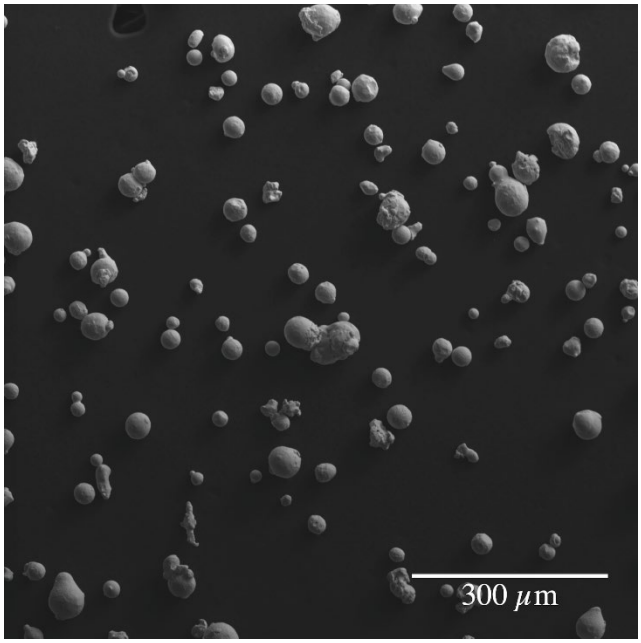

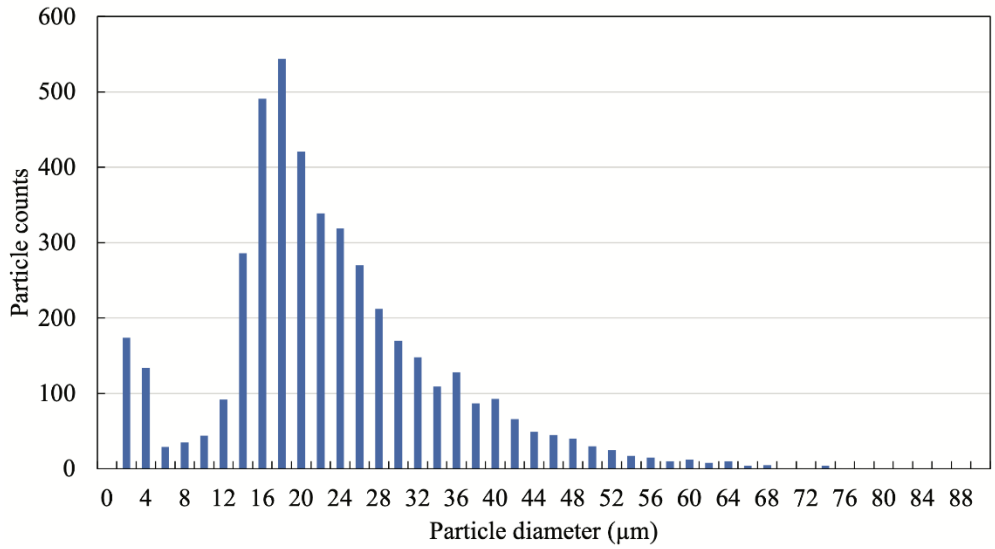

Figure S1. A SEM image and the corresponding size distribution of the H230 powder feedstock.

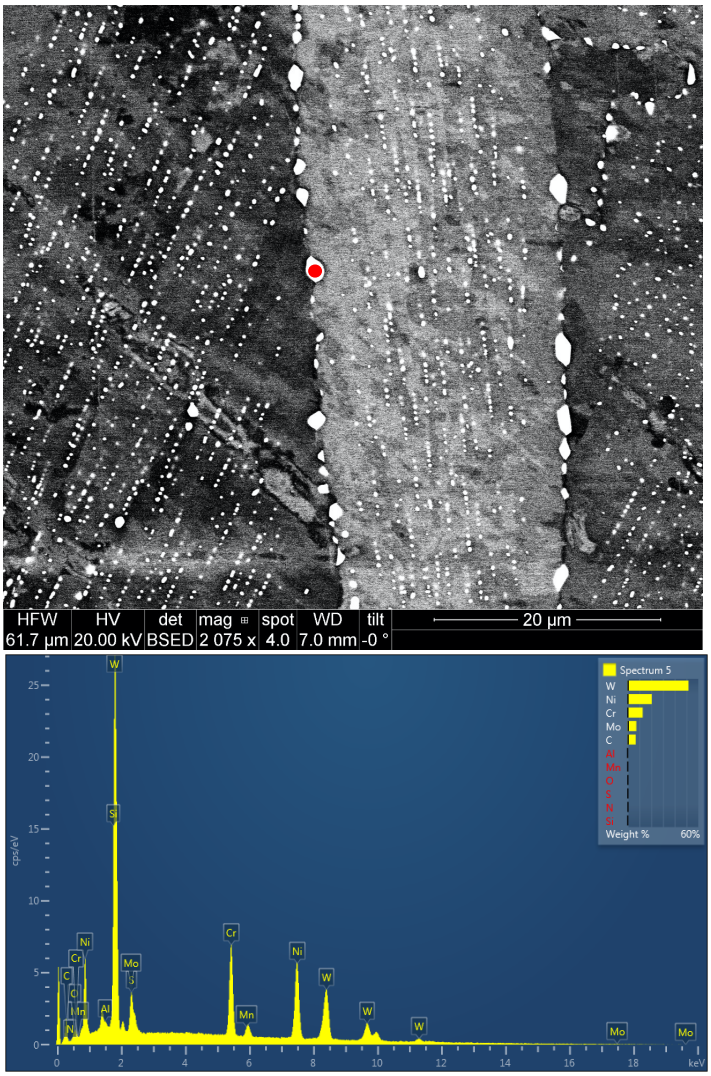

Figure S2. A SEM image and the corresponding EDS spectrum of a grain boundary carbide in a L-PBF-built H230 specimen annealed at 1200°C for 2 hours followed by water quench. The red dot highlights the location where the EDS spectrum was acquired.

Table S1. H230 material properties [2] used in the finite element stress simulations.

Thermal Expansion Coefficient (K^{-1})	0.0000118
Elastic Modulus (GPa)	209
Poisson Ratio	0.31
Material Yield Strength (MPa)	383
Hardening Factor	0.0041
Support Yield Strength Ratio	0.4375
Strain Scaling Factor	1
Anisotropic Strain Coefficient (Longitudinal)	1.5
Anisotropic Strain Coefficient (Transverse)	0.5
Anisotropic Strain Coefficient (Depth)	1
Purging Gas Convection Coefficient	12.5
Powder Packing Density Ratio	0.6

Table S2. The raster process parameters of the testing coupons and the corresponding porosity contents. Note that all specimens share the same contour parameters. The marker 'x' indicates a failed part due to excessive energy input and extreme scanning velocity. The parameters for the mechanical coupons are highlighted in **bold**.

Sample #	Pre-heat	Power (W)	Velocity (mm/s)	Hatch (mm)	Energy Density (J/mm^3)	Porosity (%)
L1/H1	80°C/200°C	285	700	0.11	92.53	0.55/0.17
L2/H2	80°C/**200°C**	**330**	**700**	**0.11**	107.14	0.18/0.10
L3/H3	80°C/200°C	370	700	0.11	120.13	0.23/0.17
L4/H4	80°C/200°C	285	960	0.11	67.47	0.62/0.06
L5/H5	80°C/200°C	330	960	0.11	78.13	0.34/0.07
L6/H6	80°C/200°C	370	960	0.11	87.59	0.29/0.10
H7	200°C	285	400	0.11	161.93	1.85
H8	200°C	330	400	0.11	187.50	2.04
H9	200°C	170	700	0.05	121.43	0.10
H10	200°C	220	700	0.05	157.14	0.17
H11	200°C	170	960	0.05	88.54	0.04
H12	200°C	220	960	0.05	114.58	0.03
H13	200°C	220	1300	0.05	84.62	0.04
H14	200°C	285	1300	0.05	109.62	0.30
H15	200°C	330	1300	0.05	126.92	x
H16	200°C	370	1300	0.05	142.31	x
H17	200°C	285	1600	0.05	89.06	0.05
H18	200°C	330	1600	0.05	103.13	x
H19	200°C	370	1600	0.05	115.63	x
H20	200°C	330	1900	0.05	86.84	0.08
H21	200°C	370	1900	0.05	97.37	x
L7	80°C	285	550	0.11	117.77	0.42
L8	80°C	330	550	0.11	136.36	0.68
L9	80°C	370	550	0.11	152.89	0.77
L10	80°C	70	250	0.11	63.64	1.55
L11	80°C	100	350	0.11	64.94	3.02
L12	80°C	130	450	0.11	65.66	0.44

Table S3. Summary of the tensile properties of the L-PBF H230 at the annealing condition (1200°C for 2 hours followed by water quench) and the wrought H230 reported Haynes International, Inc [2].

Sample	Temp.	UTS (MPa)	0.2% YS (MPa)	Elongation (%)	RA (%)	Modulus (GPa)
T-1	Room	868.1	443.3	43	52	188.9
T-2	Room	872.9	447.5	46	52	184.1
T-3	Room	857.0	442.0	39	42	184.8
T-4	Room	825.6	422.0	45	51	168.9
Average	Room	858.4 ± 16.6	438.7 ± 11.4	43.3 ± 3.1	49.3 ± 4.9	181.7
Wrought Haynes 230 [2]	Room	852	383	46	-	-

Table S4. Summary of the tensile properties of the L-PBF H230 at the stress relieved condition (1165°C for 3 hours followed by furnace cool) and the wrought H230 reported Haynes International, Inc [2].

Sample	Temp.	UTS (MPa)	0.2% YS (MPa)	Elongation (%)	RA (%)	Modulus (GPa)
Sample1	Room	911.5	728.8	33	29	133
Sample2	Room	903.2	479.9	35	31	146
Sample3	Room	899.1	477.8	33	36	112
Sample4	Room	902.5	484.0	31	29	211*

Average	Room	904.1 ± 4.6	480.6 ± 2.6	33 ± 1.4	31.3	130.3**
Wrought Haynes 230 [2]	Room	852	383	46	-	-

* The extensometer slipped during the experiment. ** The average was calculated without sample 4.

Table S5. Summary of the creep properties of the L-PBF H230 at the annealing condition (1200°C for 2 hours followed by water quench) and the wrought H230 reported Haynes International, Inc [2] tested at 760°C and 100 MPa.

Sample #	Stress (MPa)	Tempera-ture (K)	0.5% Creep Time (hrs)	1% Creep Time (hrs)	Rupture Time (hrs)	Total Creep (%)	Elongation (%)	RA (%)
C-L1	100	1033	52.37	209.29	-	3.504	-	-
C-L2	100	1033	317.19	> 500	-	0.7287	-	-
C-L3	100	1033	157.83	448.3	-	1.115	-	-
C-L4	100	1033	244.64	> 500	-	0.831	-	-
Wrought [2]	100	1033	10–100	> 100	10^3–10^4	-	-	-

Table S6. Summary of the creep properties of the L-PBF H230 at the annealing condition (1200°C for 2 hours followed by water quench) and the wrought H230 reported Haynes International, Inc [2] tested at 816°C and 121 MPa.

Sample #	Stress (MPa)	Tempera-ture (K)	0.5% Creep Time (hrs)	1% Creep Time (hrs)	Rupture Time (hrs)	Total Creep (%)	Elongation (%)	RA (%)
C-H1	121	1089	2.76	5.88	40.7	29.9709	28.9	33.7
C-H2	121	1089	2.84	5.92	40.8	38.9416	42.5	37.4
C-H3	121	1089	2.97	5.51	35.8	32.7338	36.8	36.5
C-H4	121	1089	1.34	2.59	19.9	36.0745	50	38.5
Wrought [2]	121	1089	< 10	< 10	> 100	-	-	-

References

1 Haynes International. HAYNES ® 230 ® alloy, 2021. https://haynesintl.com/docs/default-source/pdfs/new-alloy-brochures/high-temperature-alloys/brochures/230-brochure.pdf?sfvrsn=ae7229d4_86 (accessed on 3 July 2022)