



Data Article

Data related to the effect of specimen geometry and orientation on tensile properties of Ti-6Al-4V manufactured by electron beam powder bed fusion



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ABSTRACT

Additive manufacturing quality assessment often relies on tensile testing as the preferred methodology to qualify builds and materials. The data included in this article provides additional supporting information on our manuscript [1] on the effect of specimen geometry and orientation on tensile properties of Ti-6Al-4V manufactured by electron beam powder bed fusion. As such, the data in brief provides in-depth details on the tensile specimen specifications, the tensile specimen build layout and replicate notations, and the tensile testing datasets. The information presented herein complements the manuscript.

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Specifications Table

Subject	Engineering, Materials Science
Specific subject area	Additive Manufacturing
Type of data	Tabulated data Microsoft Excel worksheet (XLSX) file Stereolithography (STL) file
How data were acquired	An Arcam A2X ¹ electron beam powder bed fusion additive manufacturing system was used to fabricate the tensile specimens using the build STL file and an Instron MTS Criterion tensile test instrument was used by an external certified lab to extract all tensile data that is provided in the XLSX file.
Data format	Raw Stereolithography file (STL) Microsoft excel worksheet (XLSX)
Parameters for data collection	As described in the manuscript (Shanbhag et al., 2021). Additional supporting data is included in this Data in Brief manuscript.
Description of data collection	Test specimens were fabricated in vertical and horizontal directions via the electron beam powder bed fusion (EB-PBF) technique. Tensile testing was performed at an external NADCAP certified lab and these tests were conducted following ASTM E8/E8M-16a (ASTM Standard E8 /E8M-16a, 2016) guidelines.
Data source location	Multi-Scale Additive Manufacturing Laboratory, University of Waterloo, Waterloo, ON, Canada
Data accessibility	With the article
Related research article	G. Shanbhag, E. Wheat, S. Moylan, M. Vlasea. Effect of specimen geometry and orientation on tensile properties of Ti-6Al-4V manufactured by electron beam powder bed fusion. <i>Addit. Manuf.</i> 48 (2021) 102366. https://doi.org/10.1016/j.addma.2021.102366 .

¹Certain commercial equipment, instruments, or materials are identified in this paper to foster understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology and the University of Waterloo, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

Value of the Data

- The tensile specimen dimensions (Table 1), location (Table 2), and STL build file provides the readers with the opportunity to replicate these experiments and compare the data they may generate with the data presented in the research article by (Shanbhag et al., 2021). The Raw tensile data XLSX file provides the readers the opportunity to plot stress-strain curves and examine the behaviour of the tensile specimens based on the executed experiments.
- The information presented and appended with this article is beneficial to be able to replicate the experiments, re-iterate on data analysis using other analytical tools, and compare results.
- The tensile specimen information, build file, and tensile test results from the present study on Ti-6Al-4V can be used for comparison purposes with other material systems that can be deployed in EB-PBF additive manufacturing.

1. Data Description

There are three tables and two supplementary data files that are described in this article.

(1) For this work, a single build consisting of a range of tensile specimen types provided by ASTM E8/E8M-16a were selected. These specimens with different geometries and orientations were manufactured using an Arcam A2X (GE Additive) electron beam powder bed fusion (EB-PBF) additive manufacturing system. Table 1 provides details of these specimens, along with

Table 1
ASTM E8/E8M tensile specimen types along with their dimensions [2].

	Specimen Type						
	Flat (Large)	Flat (Small)	E8-3	E8M-2	E8M-3	E8M-4	E8M-5
G (Gauge length in mm)	50.0 ± 0.1	25.0 ± 0.1	24.0 ± 0.1	45.0 ± 0.1	30.0 ± 0.1	20.0 ± 0.1	12.5 ± 0.1
W (Width in mm)	12.5 ± 0.2	6.0 ± 0.1	-	-	-	-	-
D (Diameter in mm)	-	-	6.0 ± 0.1	9.0 ± 0.1	6.0 ± 0.1	4.0 ± 0.1	2.5 ± 0.1
T _{max} (Maximum thickness)	19	6	-	-	-	-	-
T (Thickness used in the current work in mm)	3	3	-	-	-	-	-
R (Radius of fillet in mm)	12.5	6	6	8	6	4	2
L (Overall Length in mm)	200	100	88.57	115.98	94.57	79.71	73.12
A (Length of reduced parallel section, min in mm)	57	32	30	54	36	24	20
B (Length of grip section used in the current work in mm)	62.5	29.5	25	25	25	25	25
C (Width of grip section, approximate in min)	20	10	9.6	14.4	9.6	6.4	4

Table 2
Build orientation, location, and naming scheme for all specimen replicates as per ASTM 52921:2013 [3].

Specimen Type	Orientation	Specimen Replicate					
		Replicate 1		Replicate 2		Replicate 3	
		Specimen designation	Location (X, Y, Z) mm	Specimen designation	Location (X, Y, Z) mm	Specimen designation	Location (X, Y, Z) mm
Flat (Large)	YZX	E	0.0, -61.4, 15.0	J	0.0, -9.9, 15.0	R	0.0, 62.6, 15.0
Flat (Small)	YZX	C	-46.1, -70.3, 10.0	T	44.8, 70.2, 10.0	Q	47.9, 54.7, 10.0
E8-3	Y	G	47.9, -47.9, 9.8	N	-52.3, 36.6, 9.8	I	48.9, -19.5, 9.8
E8M-2	Y	A	-37.3, -87.3, 12.2	M	0.4, 15.0, 12.2	U	38.7, 88.0, 12.2
E8M-3	Y	H	-46.7, -19.1, 9.8	O	48.5, 31.9, 9.8	F	-50.9, -39.9, 9.8
E8M-4	Y	K	-45.7, -0.1, 8.2	P	-55.5, 54.1, 8.2	S	-55.5, 71.4, 8.2
E8M-5	Y	B	60.8, -90.9, 7.0	D	59.0, -69.7, 7.0	L	54.3, 0.2, 7.0
Flat (Large)	ZYX	1B	29.9, -34.0, 100.0	2B	-63.8, -29.4, 100.0	3B	-26.7, 27.3, 100.0
Flat (Small)	ZYX	4	11.3, 45.0, 149.9	10	-73.9, 24.4, 149.9	11	-32.5, -29.3, 149.9
E8-3	Z	7	-36.3, 84.4, 154.9	8	4.5, 0.6, 154.9	9	52.7, -80.5, 154.9
E8M-2	Z	1	-71.9, 87.3, 141.9	5	-86.7, 15.2, 141.9	6	50.3, 44.1, 141.9
E8M-3	Z	13	36.3, 84.4, 47.2	14	4.5, 0.6, 47.2	15	52.7, -80.5, 47.2
E8M-4	Z	17	75.3, 15.1, 160.0	20	67.9, -35.4, 59.1	22	-50.4, -77.9, 59.1
E8M-5	Z	28	49.6, 78.9, 163.3	27	-10.4, -53.4, 163.3	29	73.4, -83.5, 163.3

Table 3

Anomalous stress-strain curves.

Type	Orientation	Designation	Notes
E8M-5	Horizontal	B	Failed outside gauge length as per testing laboratory
Flat (Large)	Horizontal	R	Failed outside gauge length as per testing laboratory
Flat (Small)	Horizontal	Q	Failed outside gauge length as per testing laboratory
E8-3	Vertical	7	Odd shape, suspected early failure
E8M-3	Horizontal	O	Odd shape, suspected early failure
E8M-5	Horizontal	L	Odd shape, Suspected sample slippage in the grips
Flat (Large)	Horizontal	E	Odd shape, suspected early failure
Flat (Large)	Horizontal	J	Odd shape, suspected early failure
Flat (Small)	Horizontal	C	Odd shape, suspected early failure

their nominal design dimensions and nomenclature as per ASTM E8/E8M- 16a [2]. Supplementary STL data file named “Ti6Al4V Tensile Build.stl” is provided as an attachment along with this article.

(2) A total of 48 specimens were fabricated and the placement of these specimens was randomized. Six replicates of every specimen type were manufactured, with three in each orientation. Table 2 provides information on the naming scheme, orientation, and location of the specimens as per ASTM 52921:2013 [3].

(3) All tensile data (elongation at fracture, ultimate tensile strength, yield strength, elastic modulus) was obtained from the engineering stress-strain curves for each specimen. The post-yield strain was calculated from the actuator displacement and the length of the reduced parallel section. The raw tensile data file named “Ti6Al4V Tensile Data.xlsx” is provided as an attachment along with this article. Table 3 summarizes the engineering stress-strain curves that showed anomalous behaviour.

2. Experimental Design, Materials and Methods

A range of tensile specimen types provided for ASTM E8/E8M-16a [2] were selected. Table 1 provides the gauge length, width, thickness, and diameter information for these specimens as per ASTM E8/E8M- 16a [2]. SolidWorks (Dassault Systèmes, France) was used to create the specimen stereolithography (STL) file. A total of 48 specimens were fabricated and the placement of these specimens was randomized. In order to see if there is any influence of the orientation of the stacked layers on densification behavior and the tensile properties, specimens were fabricated in two orientations: (i) in the first orientation class, the long axis of the specimens was oriented perpendicular to the powder-stacked layers (Z direction), these are the vertically-built (V) specimens, and (ii) in the second orientation class, the long axis of the specimens was oriented parallel to the powder stacked layers (X direction), these are known as the horizontally-built (H) specimens. Six replicates of every specimen type were manufactured, with three in each orientation. For specimen types E8M-4 and E8M-5, an extra specimen was built on top of the previous specimen in the Z (vertical) direction to maintain uniform part distribution such that the beam scans the entire build platform until the very last layer. Supplementary Stereolithography (STL) data file named “Ti6Al4V Tensile Build.stl” is provided as an attachment to be able to replicate the build. File preparation for manufacturing was then performed using Materialise Magics version 25.0 (Materialise, Belgium). The software was used for scaling, positioning of specimens on the start/build platform, and support structure creation, where required. To account for thermal shrinkage after melting, the specimens were scaled, as recommended by the machine manufacturer, by 1.0092 for X and Y directions and 1.1032 for Z direction. Slicing the files was then executed by the Arcam Build Processor version 3.2 (Arcam plug-in for Materialise Magics), which converts the information into an Arcam build file (.abf) that is imported to the machine. All specimens were manufactured using Arcam Theme 5.2.52 on an Arcam A2X machine.

All tensile tests were conducted according to the ASTM E8/E8M-16a Control Method C [2] using an Instron MTS Criterion test instrument. The crosshead speed for all specimens was 0.005 mm/mm/min up to yield. The elongation at fracture (% EL), 0.2 % offset yield strength (YS), ultimate tensile strength (UTS), and elastic modulus (E) were obtained from the engineering stress-strain curves for each specimen. Specimens E8M-5 B, Flat (Large) R, and Flat (Small) Q were reported to have failed outside the gauge and therefore their tensile properties have not been included in the results. The raw stress-strain data is provided as an attachment.

Ethics Statement

The authors declare that this submission follows the ethical requirements for publication in Data in Brief.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

CRediT Author Statement

Gitanjali Shanbhag: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization; **Evan Wheat:** Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing, Visualization; **Shawn Moylan:** Methodology, Writing – review & editing, Funding acquisition, Supervision; **Mihaela Vlasea:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Funding acquisition.

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Supplementary Materials

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.dib.2021.107613](https://doi.org/10.1016/j.dib.2021.107613).

References

- [1] G. Shanbhag, E. Wheat, S. Moylan, M. Vlasea, Effect of specimen geometry and orientation on tensile properties of Ti-6Al-4V manufactured by electron beam powder bed fusion, *Addit. Manuf.* 48 (2021) 102366, doi:[10.1016/j.addma.2021.102366](https://doi.org/10.1016/j.addma.2021.102366).
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- [3] ISO /ASTM Standard 52921-13 (2019) Standard Terminology for Additive Manufacturing-Coordinate Systems and Test Methodologies, ASTM International, West Conshohocken, PA, 2019, doi:[10.1520/ISOASTM52921-13](https://doi.org/10.1520/ISOASTM52921-13).