User Manual: Additively Manufactured Titanium – 6 Aluminum – 4 Vanadium Material Models

Tool Reference

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1. General Information

This RST is a dataset of seven material models for AM Ti-6Al-4V for use in engineering applications such as finite element analysis (FEA). The dataset spans a percentile range for tensile data of AM Ti-6Al-4V that has been hot isostatically pressed (HIPed) per ASTM F3001. The seven material models are provided in tabular form as pairs of True-Stress and Plastic-Strain data along with other key material properties.

These tabular data sets can be used to create multilinear isotropic models in the user's finite element analysis software. Device designers may use the material models to simulate a range of mechanical responses of AM Ti-6Al-4V medical devices, drawing on data from multiple AM contract manufacturers.

Feedback can be provided via email to RST_CDRH@fda.hhs.gov.

2. Information for Users

Citing this RST in Submission

If you use this RST in your submission to FDA, please reference the use of this tool using U.S.

- Food and Drug Administration. (2026). *Additively Manufactured Titanium – 6 Aluminum – 4 Vanadium Material Models* (RST26OP10.01). https://cdrh-rst.fda.gov/additively-manufactured-titanium-6-aluminum-4-vanadium-material-models

Content under this RST

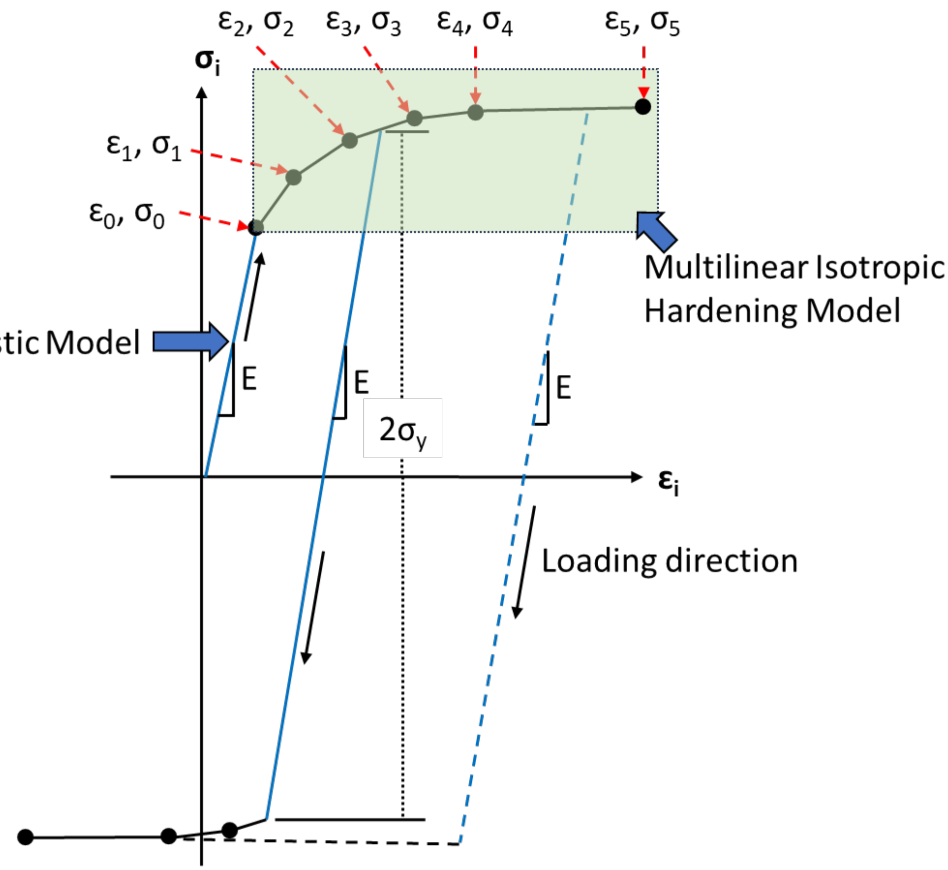
This RST includes a dataset of seven material models in two tables:

- A table of material parameters
- A table of true stress and plastic strain for the plastic deformation

3. Material Models:

All material models were derived using a Poisson's ratio of 0.36. Multilinear Isotropic Hardening profiles were generated for each chosen percentile model.

A multilinear isotropic hardening model has multiple linear piecewise definitions for stress versus plastic strain as shown below. It may describe the yield function of the material as a function of plastic strain, i.e. $\sigma_y(\varepsilon_p)$.



Stress versus total strain for a multilinear isotropic hardening process. Blue lines are linear elastic portions while the green area defines the non-linear points (stress versus plastic strain).

List of Terms for Table Below:

E: Elastic Modulus
N_ε_{true}: Necking True Strain
N_$\varepsilon_{plastic}$: Necking Plastic Strain
N_σ_{true}: Necking True Stress
n: Tuning parameter
$\varepsilon_{true,\ fracture}$: True Fracture Strain
Note: Based on experimental cross-sectional area reduction
ε_{true}: True Strain
ε_p: Plastic Strain
σ_t: True Stress

Information needed to use the models is provided in the table below. Poisson's ratio of 0.36 was used for all models.

Percentile	**1**		**15.9**		**25**		**50**		**75**		**84.1**		**99**	
E (MPa)	117885		124514		127547		131436		134657		137061		137683	
	ε_p (m/m)	σ_t (MPa)	ε_p (m/m)	σ_t (MPa)	ε_p (m/m)	σ_t (MPa)	ε_p (m/m)	σ_t (MPa)	ε_p (m/m)	σ_t (MPa)	ε_p (m/m)	σ_t (MPa)	ε_p (m/m)	σ_t (MPa)
	0.0000	816.7	0.0000	879.9	0.0000	922.8	0.0000	977.6	0.0000	1001.6	0.0000	1012.2	0.0000	1054.2
	0.0038	858.6	0.0060	930.4	0.0061	964.2	0.0079	1021.6	0.0081	1047.8	0.0075	1054.6	0.0079	1122.1
	0.0061	887.0	0.0103	956.7	0.0104	988.4	0.0141	1041.3	0.0143	1069.9	0.0132	1076.8	0.0142	1146.7
	0.0086	903.5	0.0146	977.6	0.0148	1003.0	0.0202	1056.1	0.0206	1084.6	0.0189	1090.6	0.0205	1162.0
	0.0111	912.4	0.0190	996.7	0.0192	1016.9	0.0264	1070.2	0.0269	1096.5	0.0246	1106.1	0.0268	1174.1
	0.0136	920.0	0.0233	1010.0	0.0236	1027.8	0.0326	1083.9	0.0333	1107.8	0.0303	1120.4	0.0331	1183.6
	0.0208	932.1	0.0306	1022.7	0.0329	1045.9	0.0392	1094.7	0.0447	1124.2	0.0492	1147.9	0.0604	1223.1
	0.1208	1024.7	0.1306	1118.0	0.1329	1141.9	0.1392	1192.0	0.1447	1229.5	0.1492	1253.7	0.1604	1340.3
	0.2208	1074.8	0.2306	1171.1	0.2329	1195.6	0.2392	1247.2	0.2447	1294.6	0.2492	1319.6	0.2604	1422.9
	0.3208	1110.0	0.3306	1208.6	0.3329	1233.8	0.3392	1286.6	0.3447	1342.7	0.3492	1368.2	0.3604	1487.6
	0.4208	1137.3	0.4306	1237.9	0.4329	1263.6	0.4392	1317.4	0.4447	1381.0	0.4492	1407.2	0.4604	1541.3
	0.5208	1159.7	0.5306	1262.0	0.5329	1288.1	0.5392	1342.9	0.5447	1413.1	0.5492	1439.7	0.5604	1587.3
	0.6208	1178.8	0.6306	1282.6	0.6329	1309.1	0.6392	1364.6	0.6447	1440.8	0.6492	1467.9	0.6604	1627.8
	0.7208	1195.5	0.7306	1300.6	0.7329	1327.4	0.7392	1383.6	0.7447	1465.2	0.7492	1492.6	0.7604	1664.1
	0.9208	1223.6	0.9306	1331.0	0.9329	1358.4	0.9392	1415.7	0.9447	1506.8	0.9492	1535.0	0.9604	1727.1

Additional information for the models is provided in the table below.

Percentile	**1**	**15.9**	**25**	**50**	**75**	**84.1**	**99**
N_ε_{true} (m/m)	0.0292	0.0387	0.0411	0.0474	0.0528	0.0574	0.0680
N_$\varepsilon_{plastic}$ (m/m)	0.0208	0.0306	0.0329	0.0392	0.0447	0.0492	0.0604
N_σ_{true} (MPa)	932.1	1022.7	1045.9	1094.7	1124.2	1147.9	1223.1
n, tuned	0.100	0.100	0.100	0.100	0.125	0.125	0.175
$\varepsilon_{true,\ fracture}$ (m/m)	0.3935	0.4728	0.4917	0.5394	0.6071	0.6332	0.7894
$\varepsilon_{true,\ avg,\ FEA}$ (m/m)*	0.5081	0.4281	0.4568	0.4754	0.4726	0.5785	0.6484
Lowest ε_{true} (m/m) limit	0.3935	0.4281	0.4568	0.4754	0.4726	0.5785	0.7894

*Based on FEA values when tensile models were loaded to 9.6, 9.3, 9.6, 10, 10.5, 11.5, and 13%

engineering strain for the 1, 15.96, 25, 50, 75, 84.1, and 99 percentile model, respectively.

4. Instructions to use the material models

Read your FEA software's instruction manual and apply the material models per its instruction.

5. Troubleshooting

These material models should be FEA software agnostic, but there may be nuances to how a software handles material models that could require users to ensure the models are in the correct format. For general FEA troubleshooting, the user may consult the manual for their FEA software.