

Haro Lineage Flatland Master 2017

Frame FEA - Steel and Titanium comparison

Overview

- Haro Lineage Flatland Master 2017 frame geometry from 3D scan and mfg drawing - https://evotechcae.com/bike_frame_rev_eng_sim/
- Idealised shell-meshed FEA model and linear static analysis, with ISO4210 physical test arrangement and unit loading
- Qualitative comparison between steel and titanium builds for different wall thickness configurations (weld details and stress convergence not considered)
- Significant benefits using titanium for strength and weight, although reduction in stiffness
- For strength/weight/stiffness-optimised titanium frame, consideration should be given to tube diameter as well as wall thickness

Frame FEA Output Summary

Frame	Load Case	Strength				Stiffness	
		Peak Stress	Yield Stress	Safety Factor	Steel Comparison	Peak Disp	Steel Comparison
		Mpa	Mpa	-	% change	mm	% change
Steel	LC01_Fork	343	435	1.27	n.a.	3.97	n.a.
Titanium		353	830	2.35	85.4	7.97	100.8
Titanium Conf 2		353	830	2.35	85.4	6.96	75.3
Steel	LC02_Seat	89.2	435	4.88	n.a.	0.233	n.a.
Titanium		106	830	7.83	60.6	0.625	168.2
Titanium Conf 2		103	830	8.06	65.2	0.502	115.5
Steel	LC03_BB_Side	249	435	1.75	n.a.	6.96	n.a.
Titanium		256	830	3.24	85.6	12.2	75.3
Titanium Conf 2		246	830	3.37	93.1	11.4	63.8
Steel	LC04_BB_Down	43.4	435	10.02	n.a.	0.274	n.a.
Titanium		55.1	830	15.06	50.3	0.578	110.9
Titanium Conf 2		50.9	830	16.31	62.7	0.461	68.2

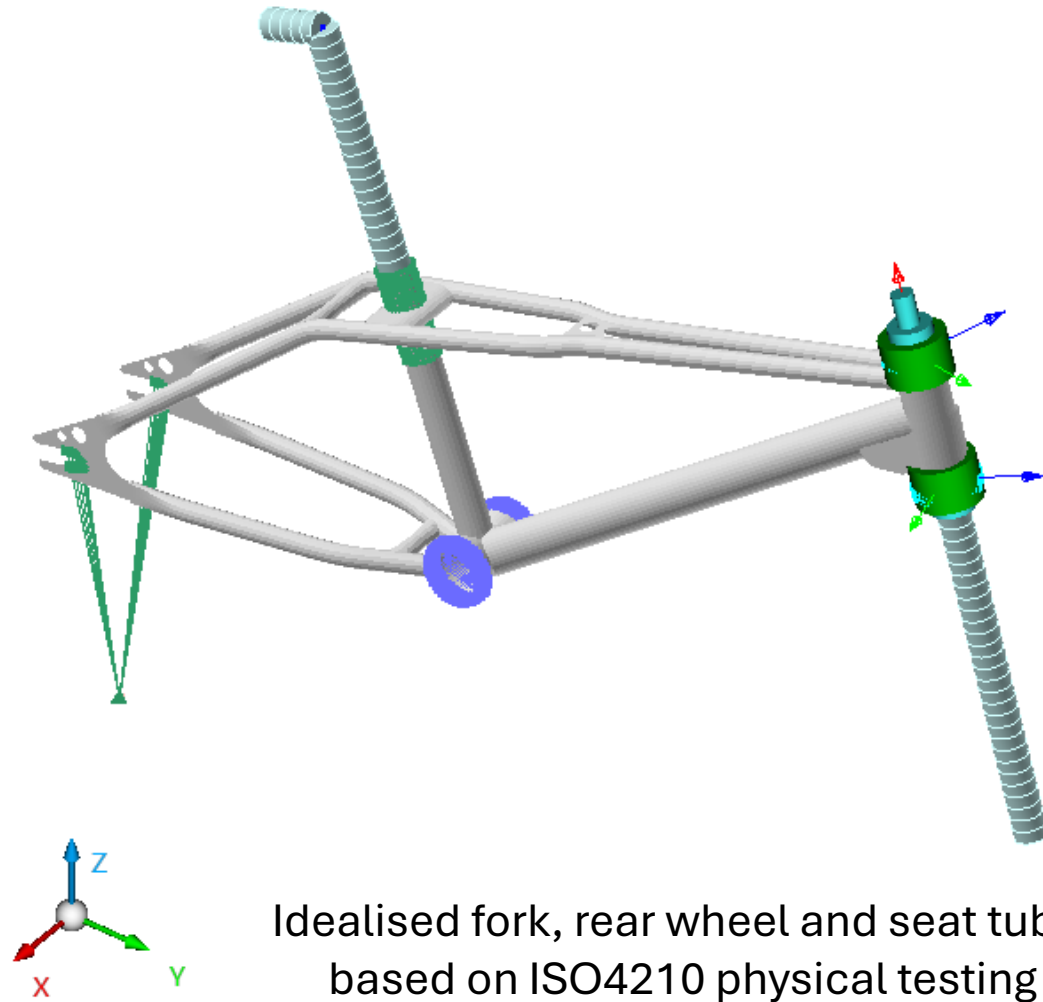
Frame	Weight	
	FEA Calc'd Mass	Steel Comparison
	Kg	% change
Steel	2.531	n.a.
Titanium	1.357	46.4
Titanium Conf 2	1.394	44.9

Summary

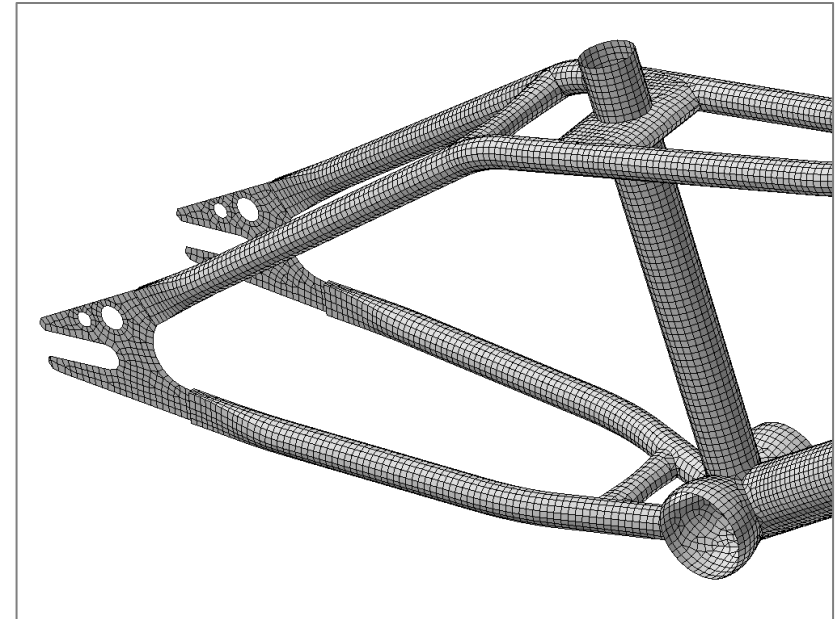
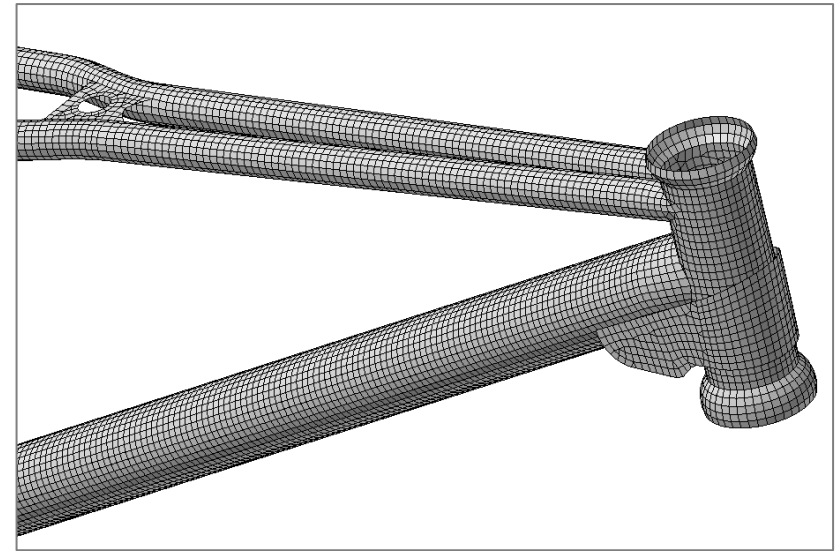
- **Strength** – Titanium gives a considerable strength increase over steel (between 50% and 93%, depending on load case and configuration)
- **Weight** – Titanium gives a considerable weight reduction over steel (~45% reduction for both Ti configurations)
- **Stiffness** – Titanium gives a considerable stiffness reduction over steel (between 64% and 168%, depending on load case and configuration)

FEA Build

FEA Model Build



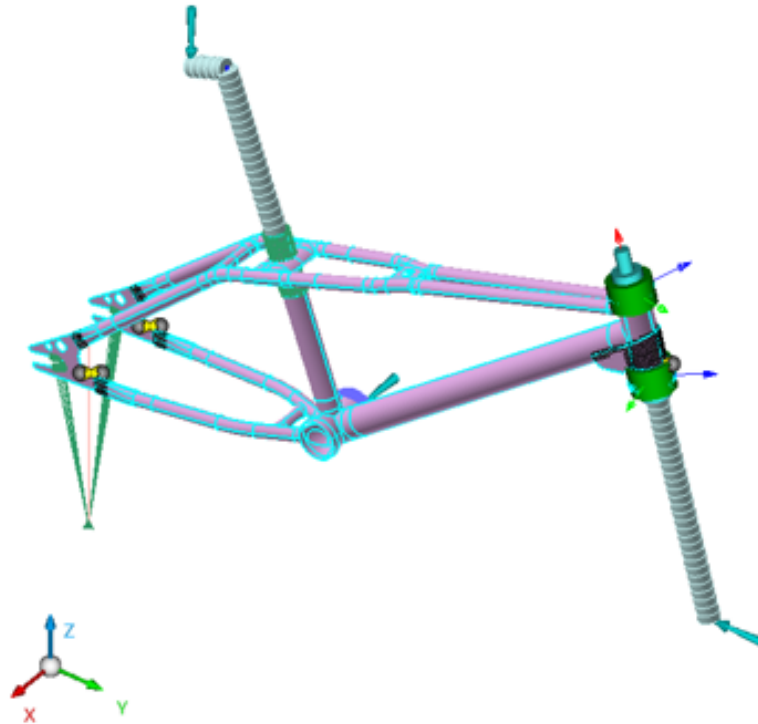
Idealised fork, rear wheel and seat tube,
based on ISO4210 physical testing



FEA Model Load Cases

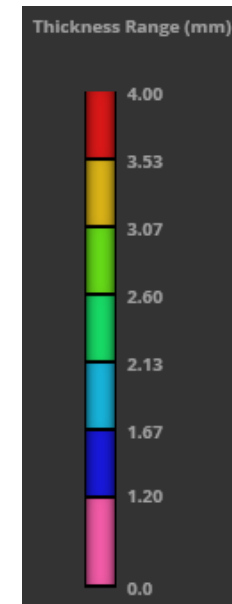
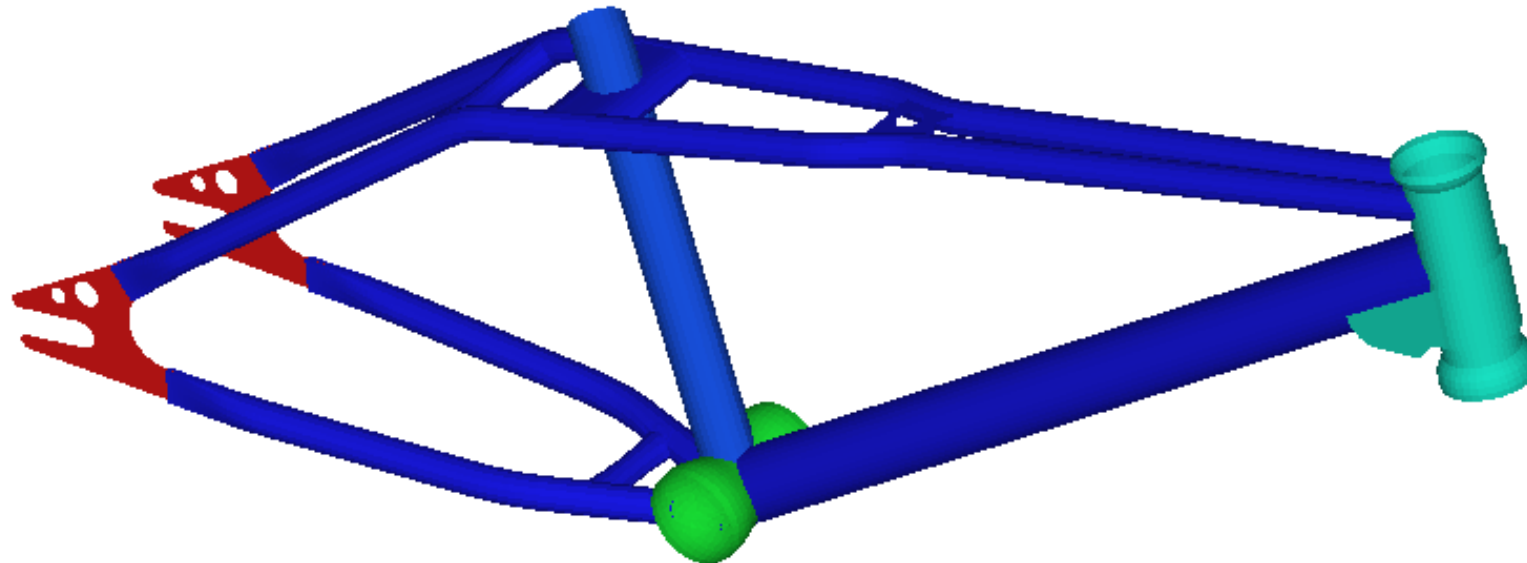
Description	Load Case	DOF Constraints		Load (N)		
		Fork	Wheel	Region	Direction	Magnitude
Horizontal load through fork	LC01_Fork	1x3x56	123x56	Fork	Y	-1000
Vertical through seat	LC02_Seat	1x3x56	123x56	Seat	Z	-1000
Sideways load through BB	LC03_BB_Side	123456	123xxx	BB	X	-1000
Vertical load through BB	LC04_BB_Down	123x56	123xxx	BB	Z	-1000

100Kg at 1g, rigid surroundings, impact forces would be lower for Ti frame, due to lower stiffness



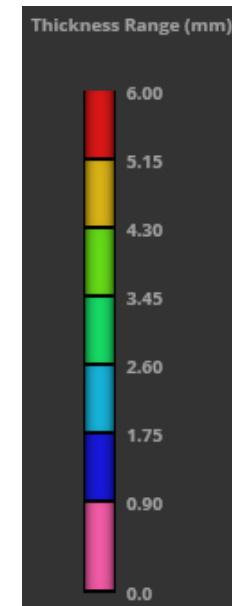
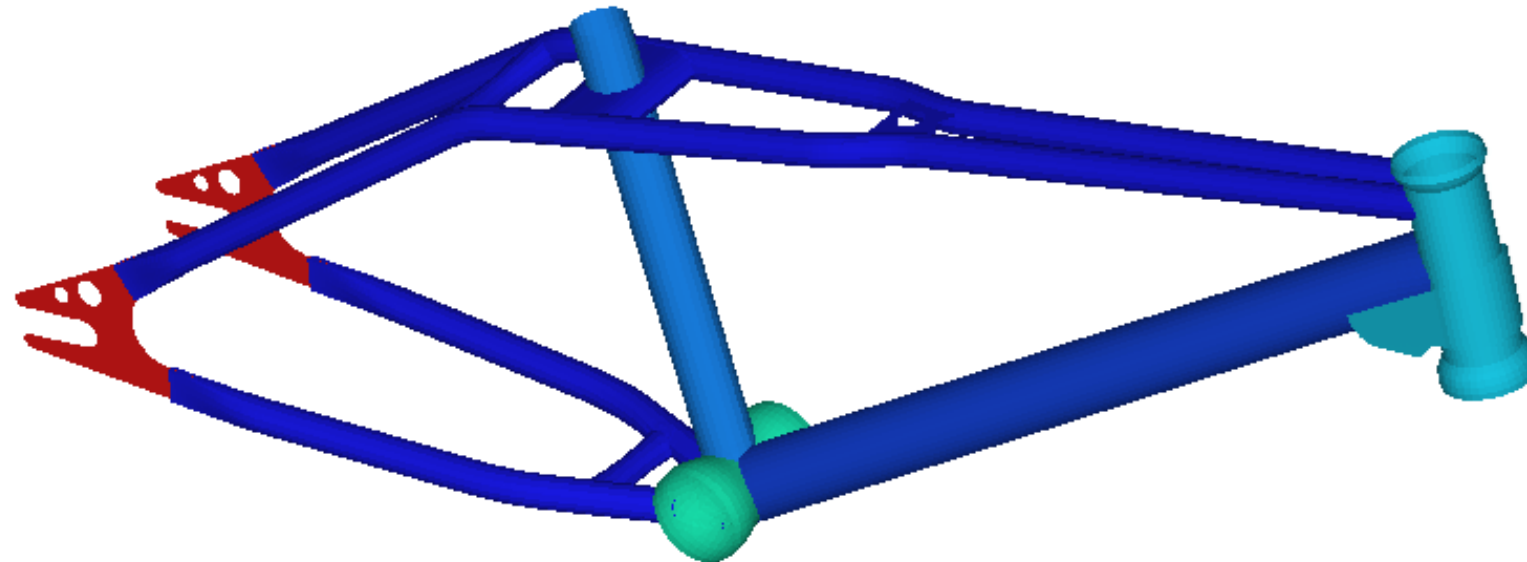
FEA Model Properties - Steel

Region	Steel								
	Dia	Thickness	Offset	Material	Modulus	PR	Density	Yield Strength	FEA Calcd'd Mass
	mm	mm	mm	n.a.	GPa	n.a.	g/cm3	MPa	Kg
01_Head_Tube	n.a.	2.0	1.0	Cro-Mo 4130	205.0	0.29	7.85	435.0	2.531
02_Down_Tube	34.9	1.2	0.6						
03_Top_Tube	16.0	1.2	0.6						
04_Seat_Tube	28.6	1.4	0.7						
05_Chain_Stay	16.0	1.2	0.6						
06_BB	46.0	2.5	1.0						
07_Drop-Outs	n.a.	4.0	0.0						
08_Misc_Bridges	n.a.	1.2	0.6						
09_Misc_Plates	n.a.	1.2	0.6						
10_Misc_Gusset	n.a.	2.0	1.0						



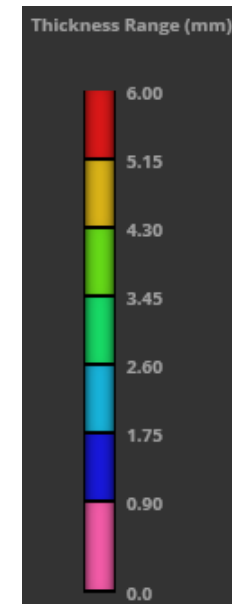
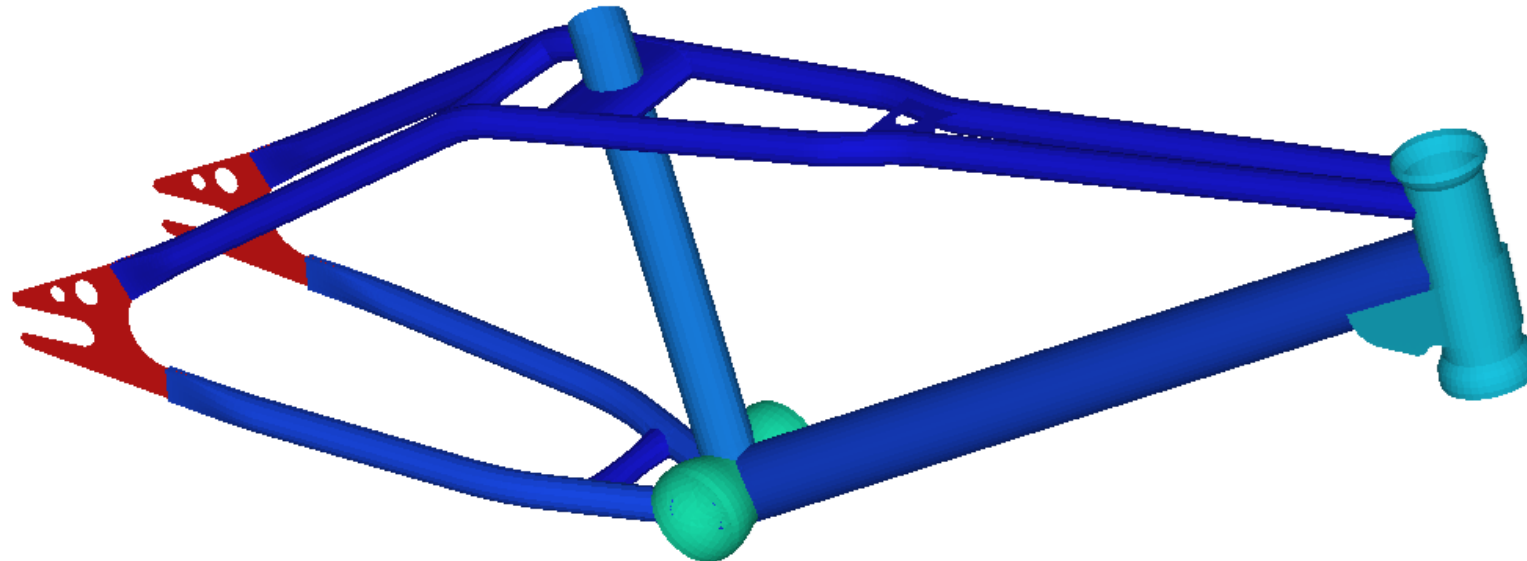
FEA Model Properties - Titanium

Region	Titanium								
	Dia	Thickness	Offset	Material*	Modulus	PR	Density	Yield Strength	FEA Calcd'd Mass
	mm	mm	mm	n.a.	GPa	n.a.	g/cm3	MPa	Kg
01_Head_Tube	n.a.	2.000	1.000	Ti Grade 5	114	0.33	4.43	1100	1.357
02_Down_Tube	34.9	1.200	0.600	Ti Grade 9	100	0.3	4.48	830	
03_Top_Tube	16.0	0.900	0.450	Ti Grade 9	100	0.3	4.48	830	
04_Seat_Tube	28.6	1.550	0.775	Ti Grade 9	100	0.3	4.48	830	
05_Chain_Stay	16.0	0.900	0.450	Ti Grade 9	100	0.3	4.48	830	
06_BB	46.0	2.500	1.250	Ti Grade 5	114	0.33	4.43	1100	
07_Drop_Outs	n.a.	6.000	0.000	Ti Grade 5	114	0.33	4.43	1100	
08_Misc_Bridges	n.a.	0.900	0.450	Ti Grade 9	100	0.3	4.48	830	
09_Misc_Plates	n.a.	0.900	0.450	Ti Grade 9	100	0.3	4.48	830	
10_Misc_Gusset	n.a.	2.000	1.000	Ti Grade 9	100	0.3	4.48	830	



FEA Model Properties – Titanium Conf 2 (19mm CS)

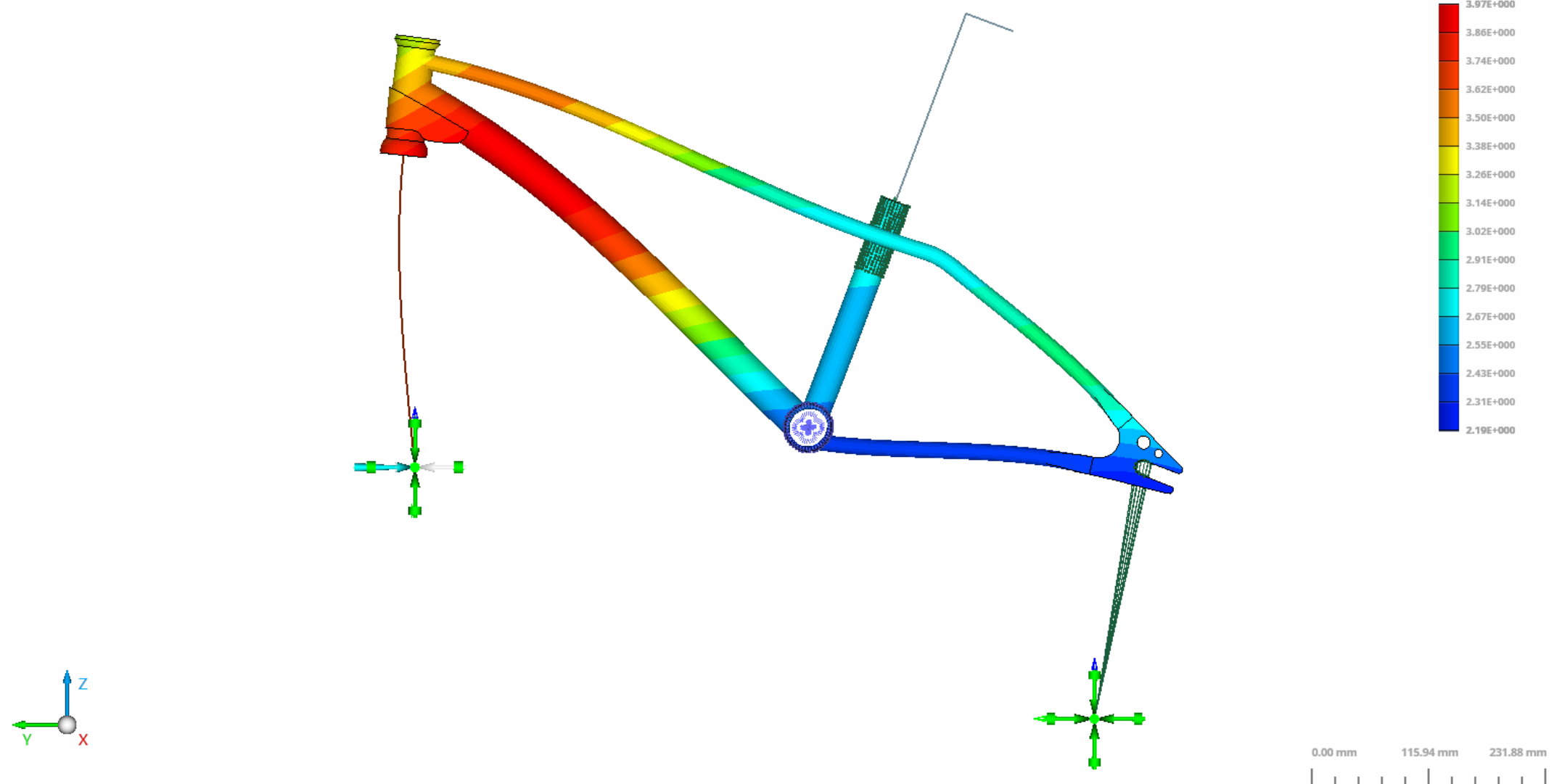
Region	Titanium Conf 2 (Updated Chainstays)								
	Dia	Thickness	Offset	Material	Modulus	PR	Density	Yield Strength	FEA Calcd'd Mass
	mm	mm	mm	n.a.	GPa	n.a.	g/cm3	MPa	Kg
01_Head_Tube	n.a.	2.000	1.000	Ti Grade 5	114	0.33	4.43	1100	1.394
02_Down_Tube	34.9	1.200	0.600	Ti Grade 9	100	0.3	4.48	830	
03_Top_Tube	16.0	0.900	0.450	Ti Grade 9	100	0.3	4.48	830	
04_Seat_Tube	28.6	1.550	0.775	Ti Grade 9	100	0.3	4.48	830	
05_Chain_Stay	19.050	1.200	-0.900	Ti Grade 9	100	0.3	4.48	830	
06_BB	46.0	2.500	1.250	Ti Grade 5	114	0.33	4.43	1100	
07_Drop_Outs	n.a.	6.000	0.000	Ti Grade 5	114	0.33	4.43	1100	
08_Misc_Bridges	n.a.	0.900	0.450	Ti Grade 9	100	0.3	4.48	830	
09_Misc_Plates	n.a.	0.900	0.450	Ti Grade 9	100	0.3	4.48	830	
10_Misc_Gusset	n.a.	2.000	1.000	Ti Grade 9	100	0.3	4.48	830	



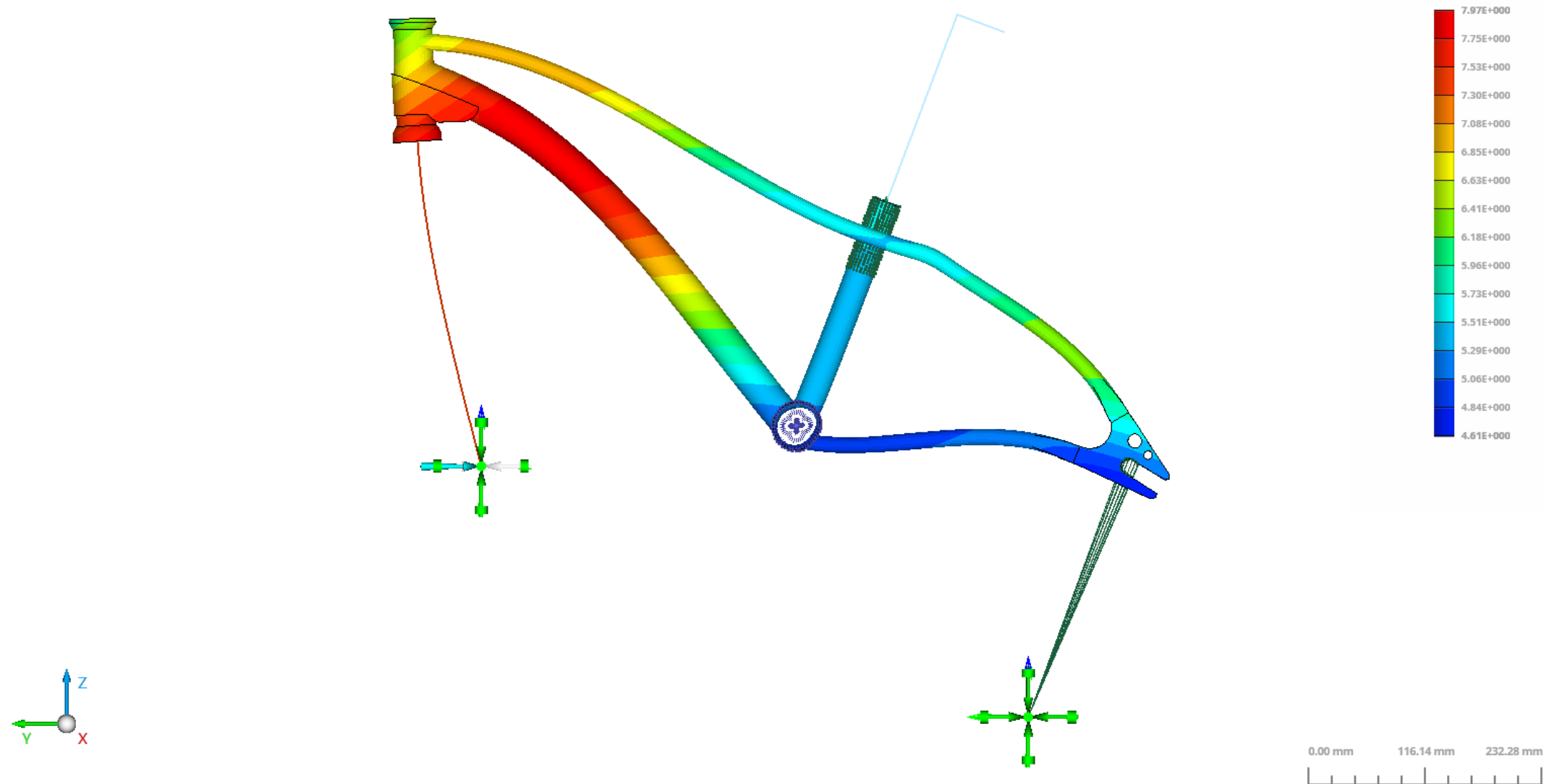
Frame FEA Output

LC01_Fork

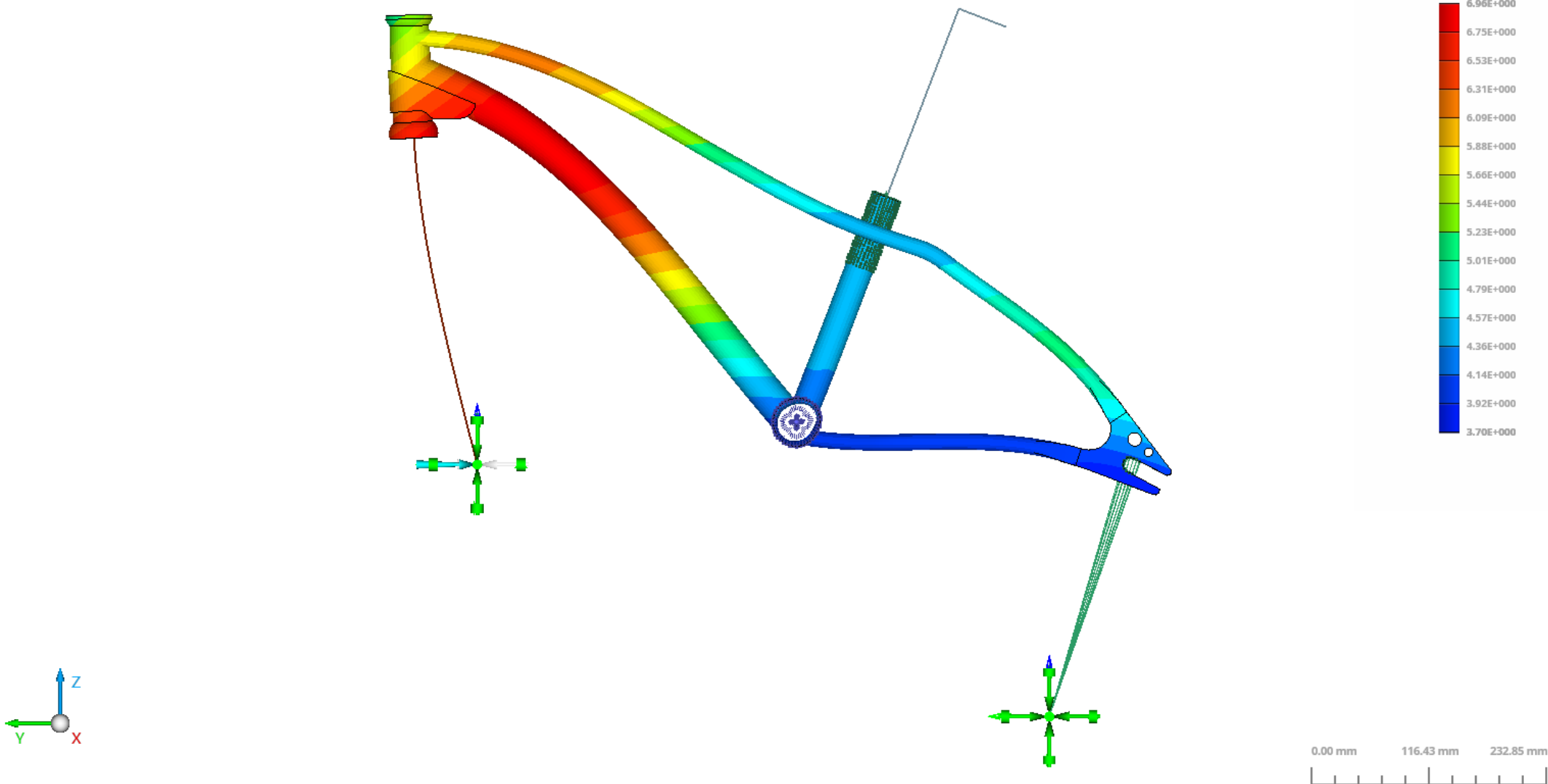
Steel Frame – Resultant Disps (True Scale x 20)



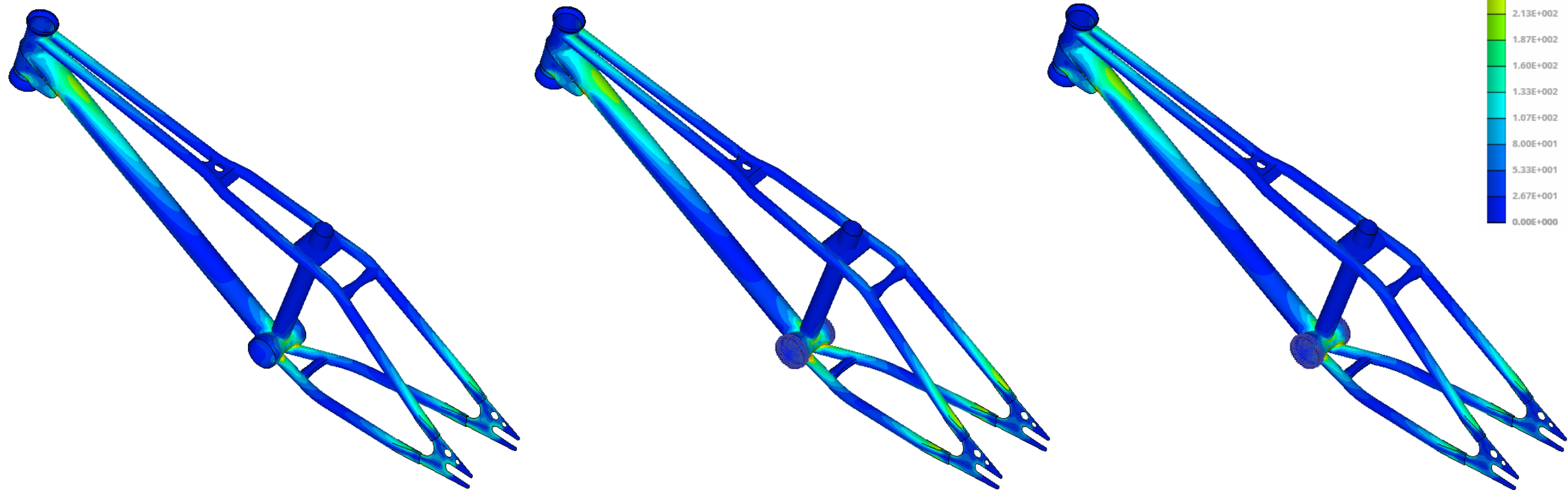
Ti Frame (16mm CS) – Resultant Disps (True Scale x 20)



Ti Frame (19mm CS) – Resultant Disps (True Scale x 20)



VM Stress, Max Top/Bottom, Averaged



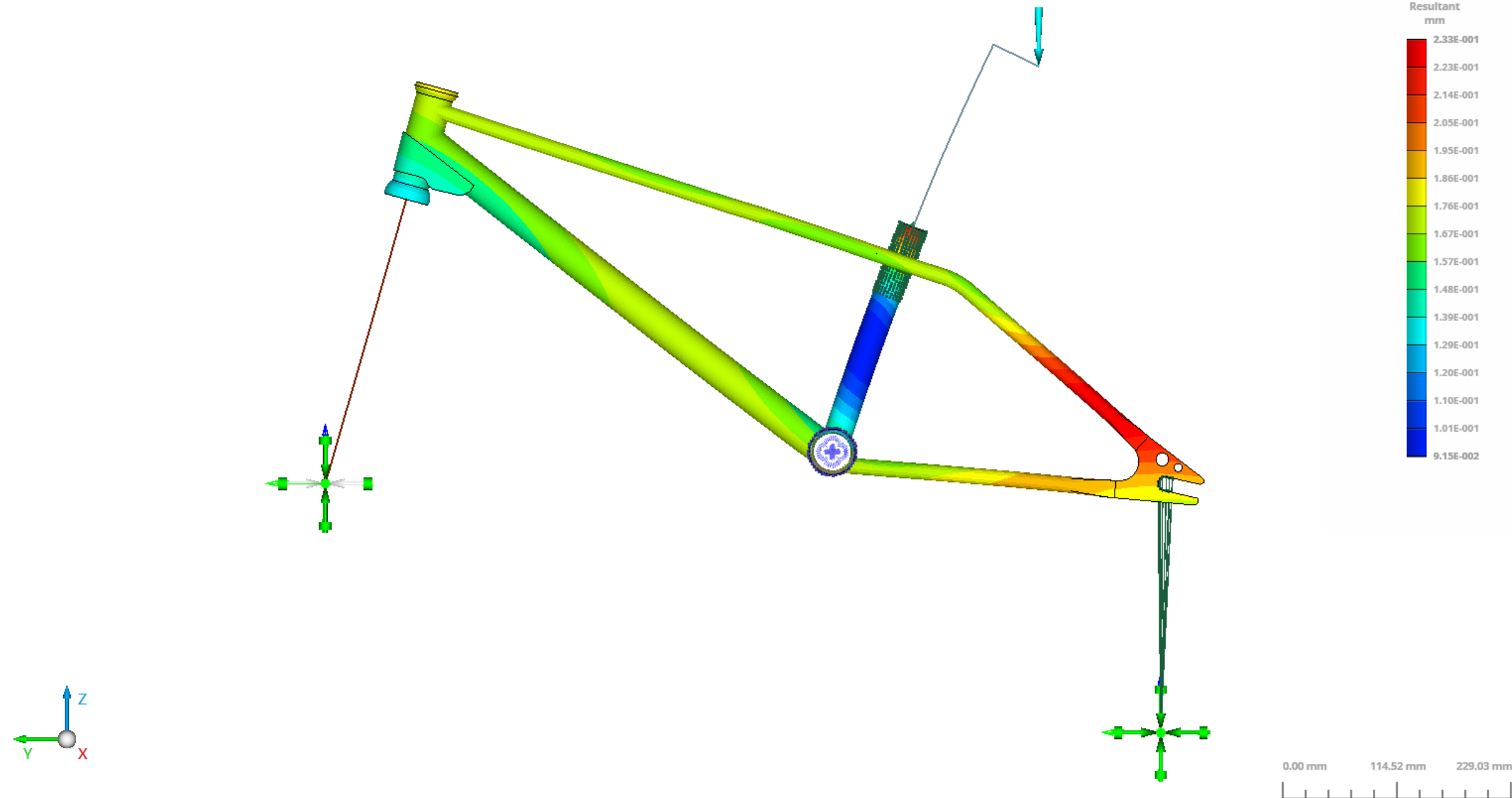
Steel Frame

Ti Frame (16mm CS)

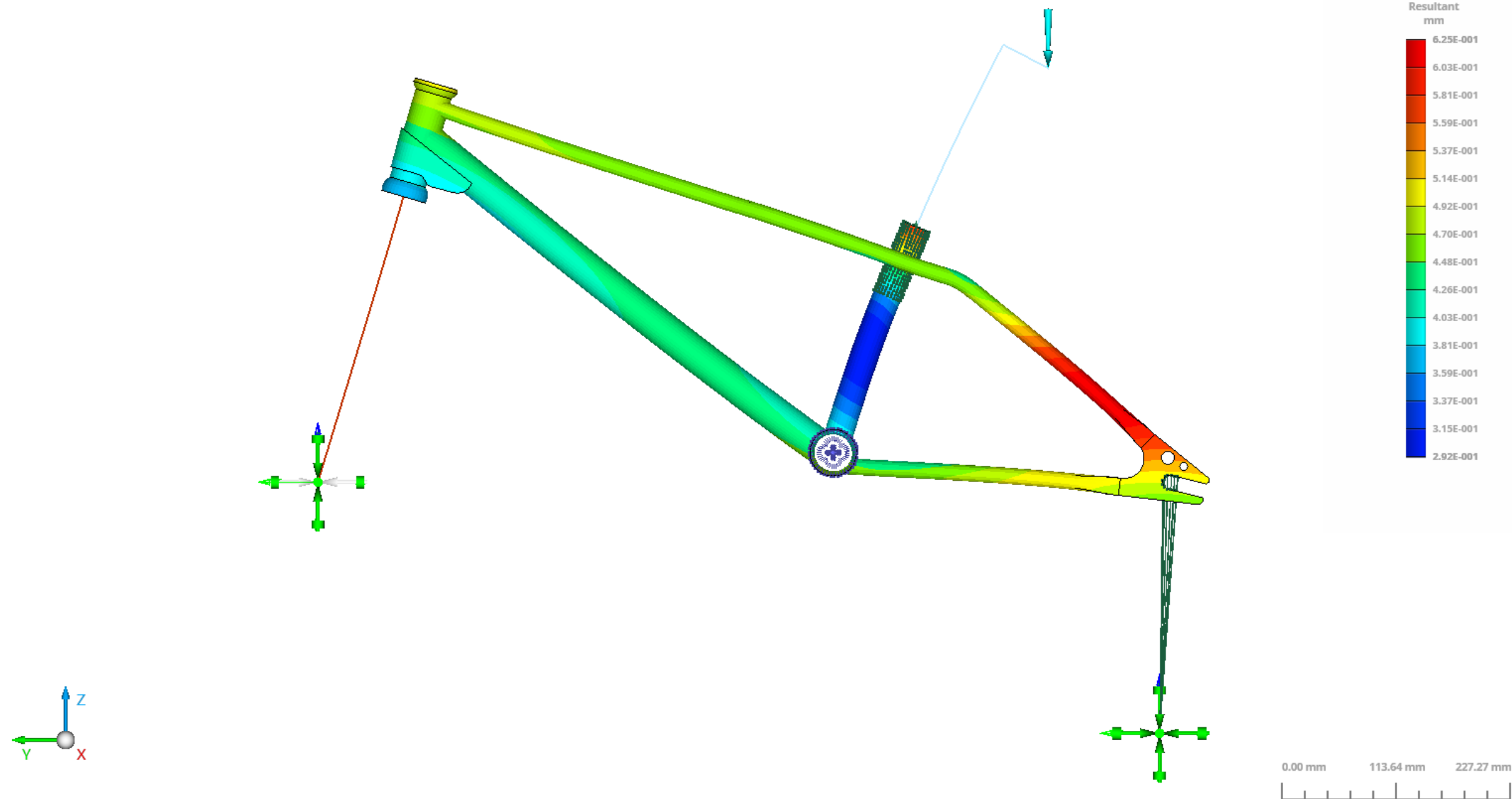
Ti Frame (19mm CS)

LC02_Seat

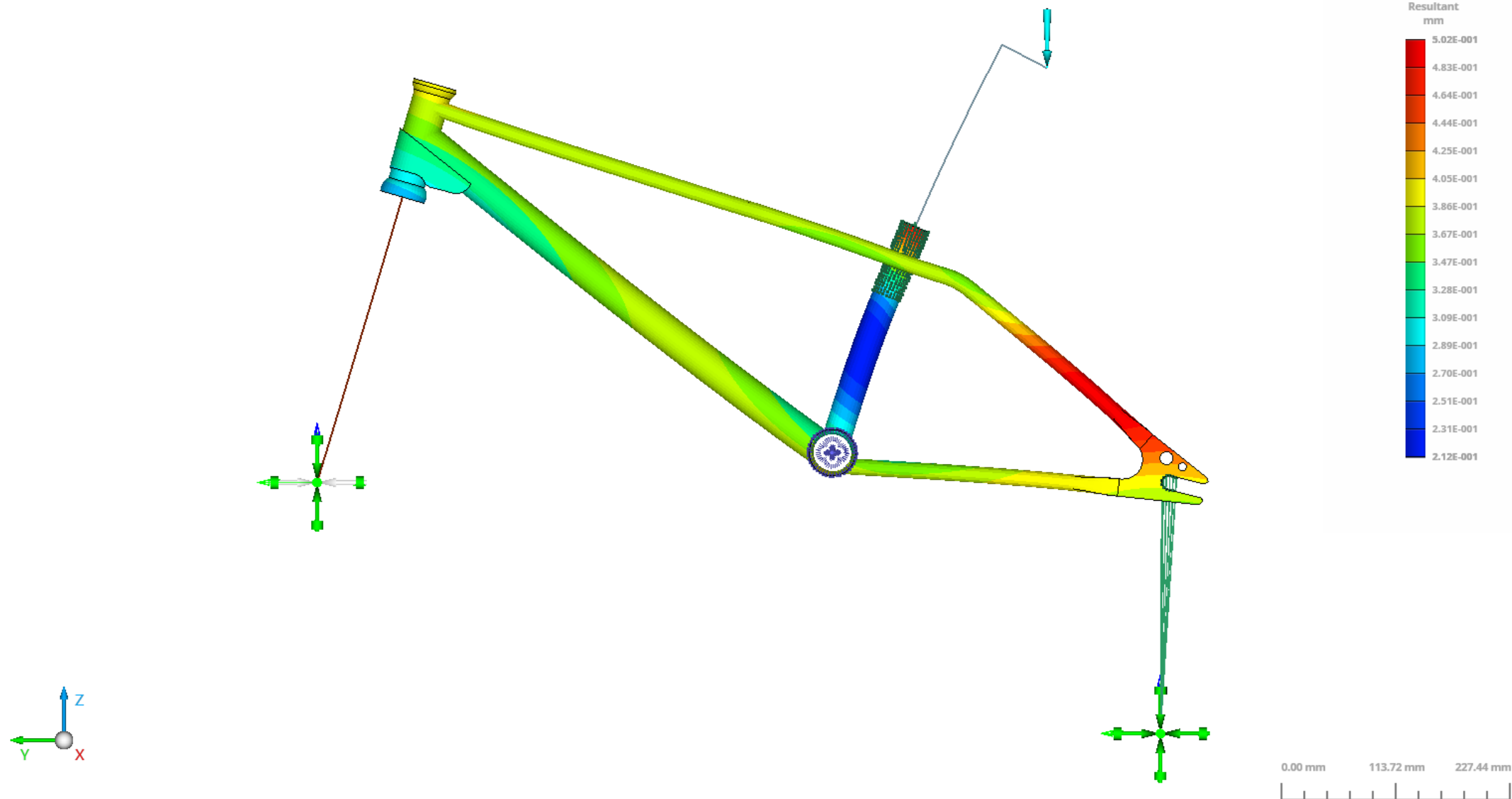
Steel Frame – Resultant Disps (True Scale x 20)



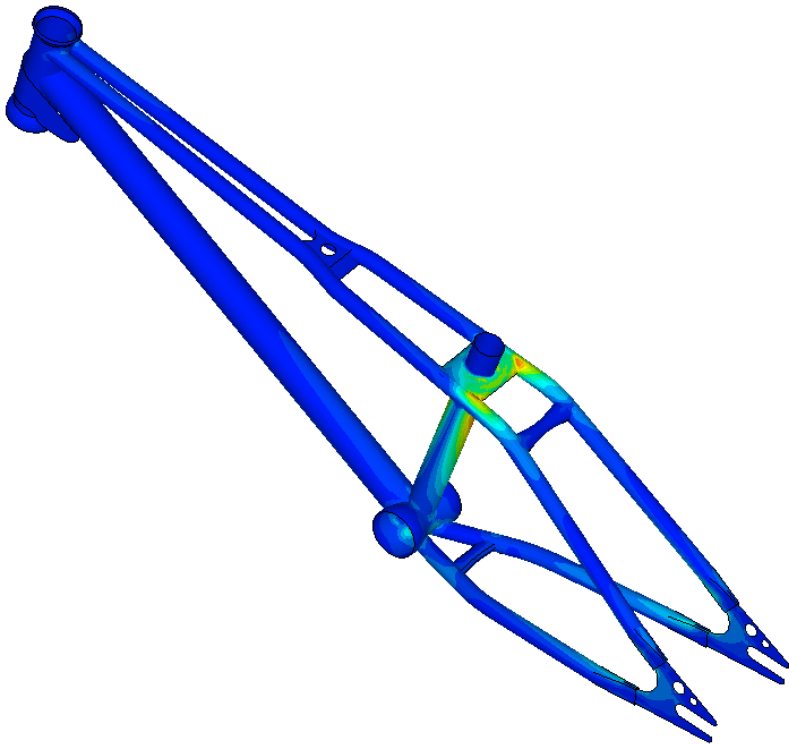
Ti Frame (16mm CS) – Resultant Disps (True Scale x 20)



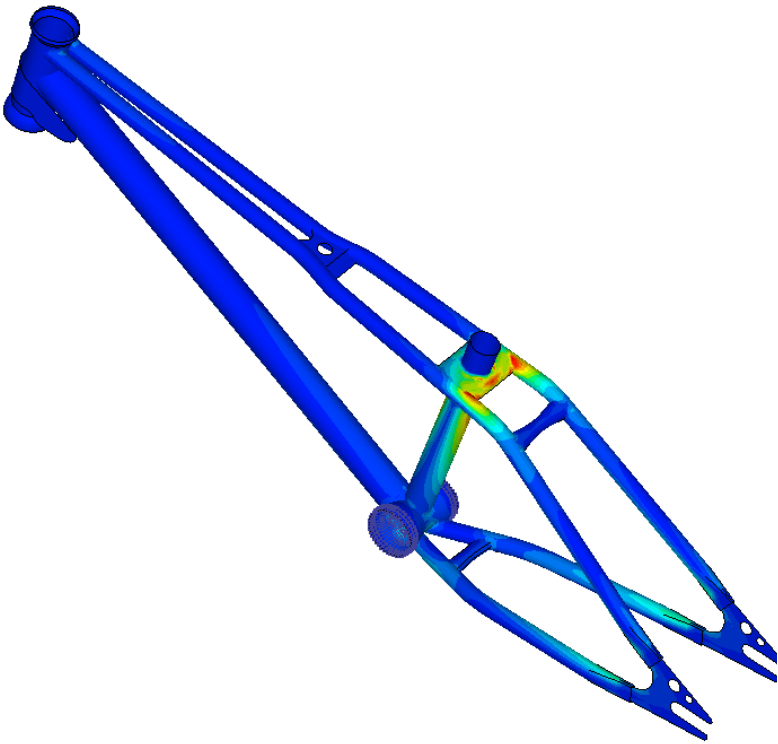
Ti Frame (19mm CS) – Resultant Disps (True Scale x 20)



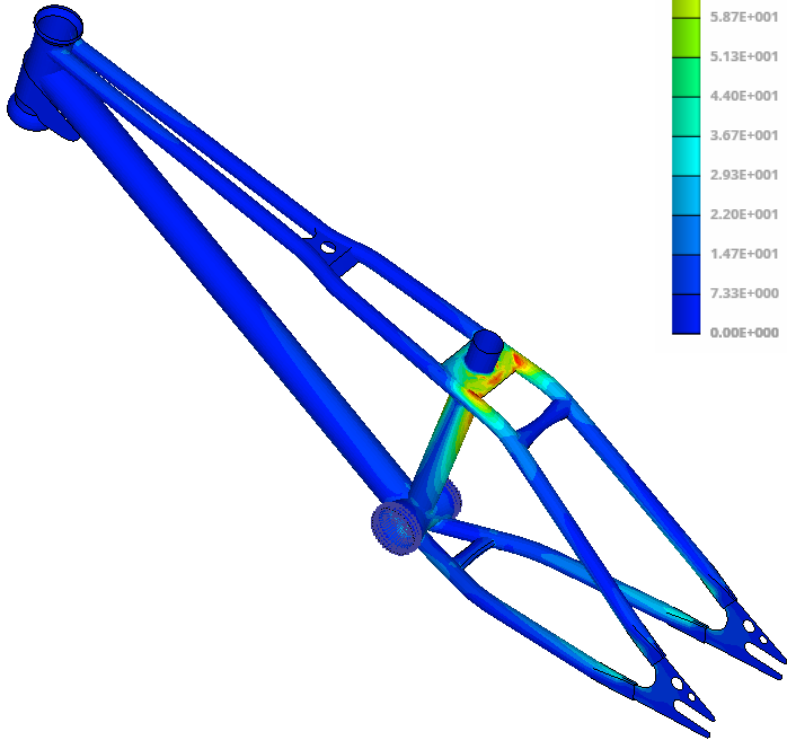
VM Stress, Max Top/Bottom, Averaged



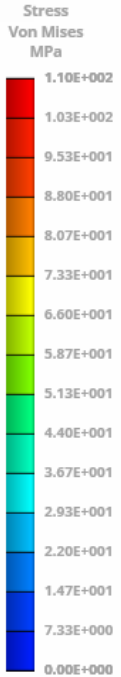
Steel Frame



Ti Frame (16mm CS)

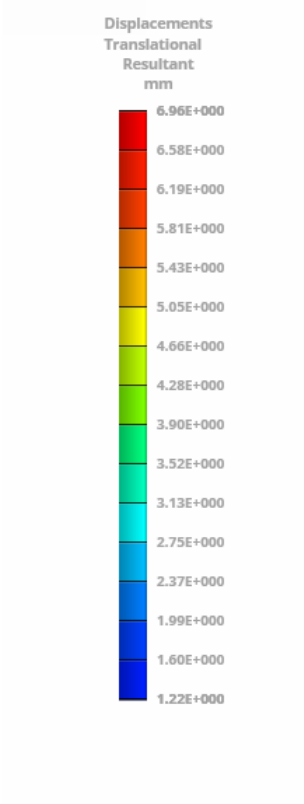
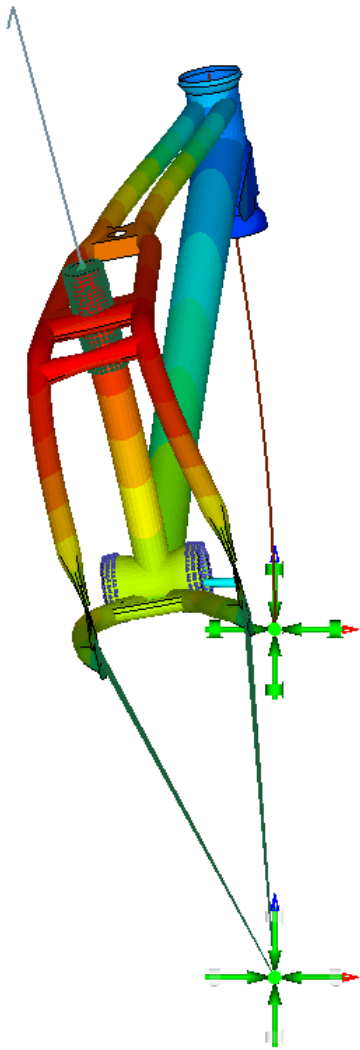
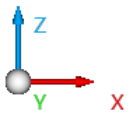


Ti Frame (19mm CS)

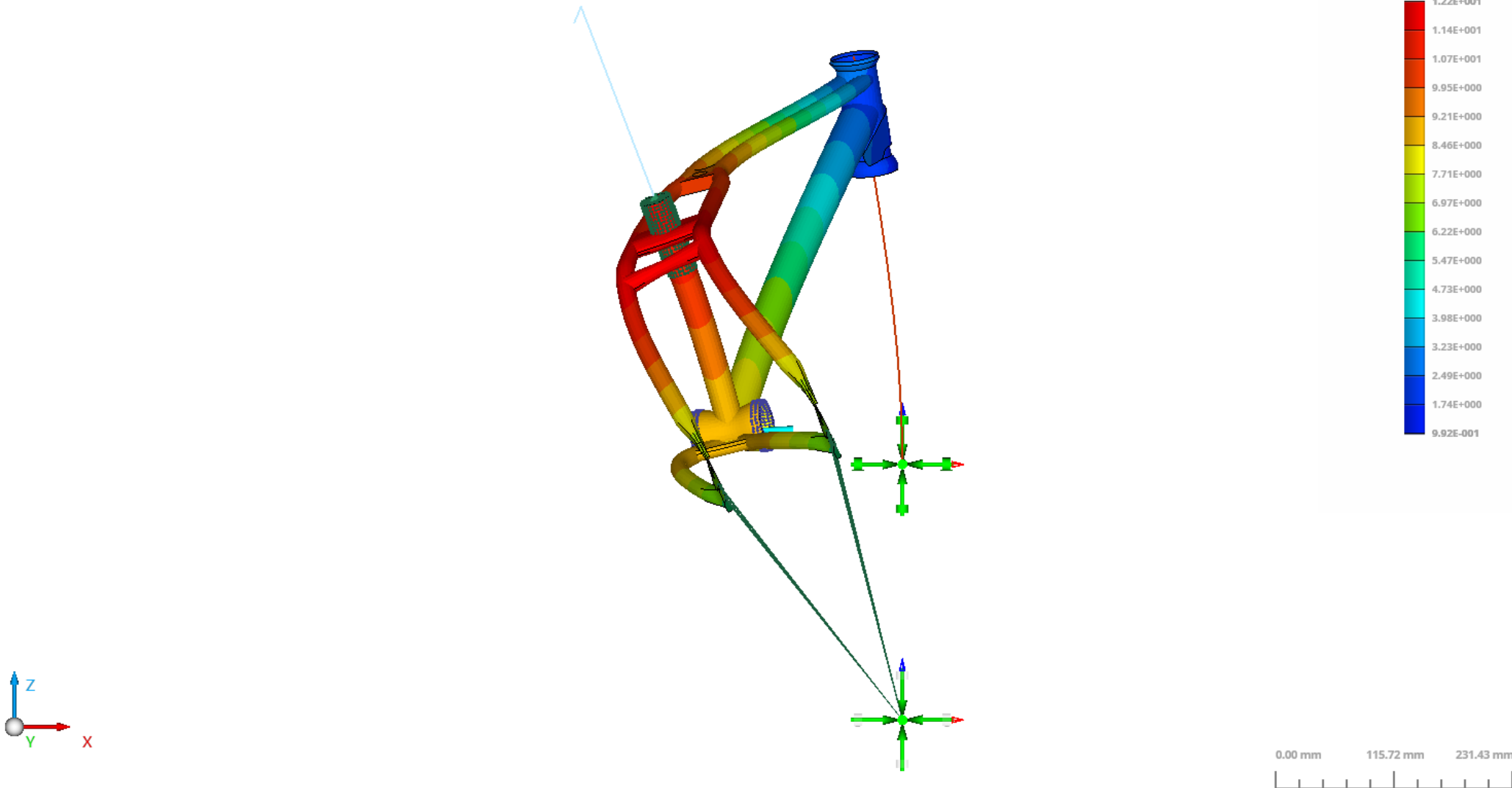


LC03_BB_Side

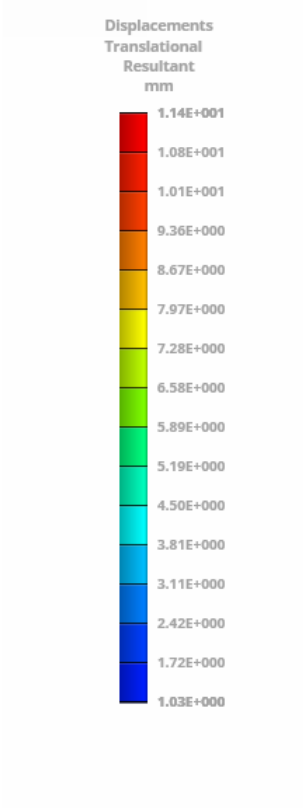
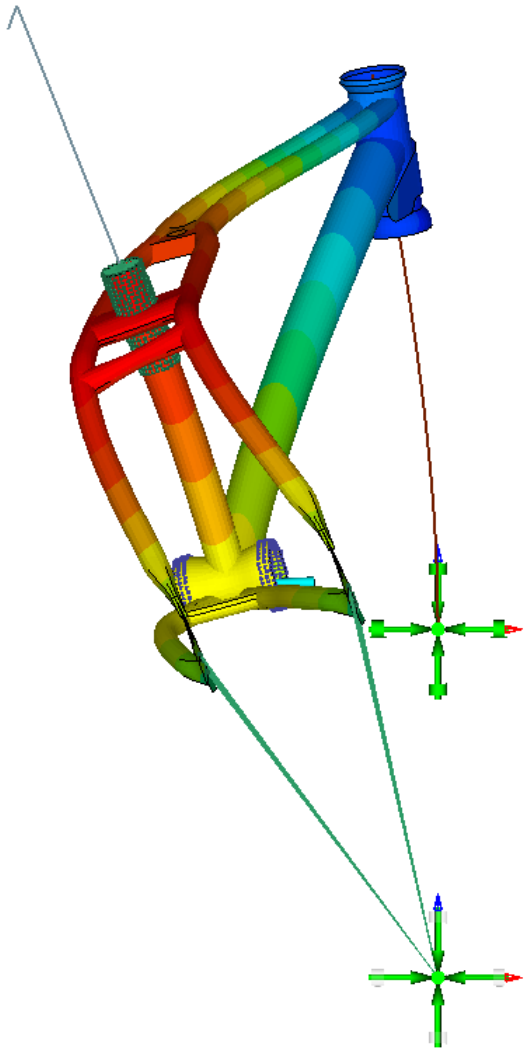
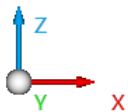
Steel Frame – Resultant Disps (True Scale x 20)



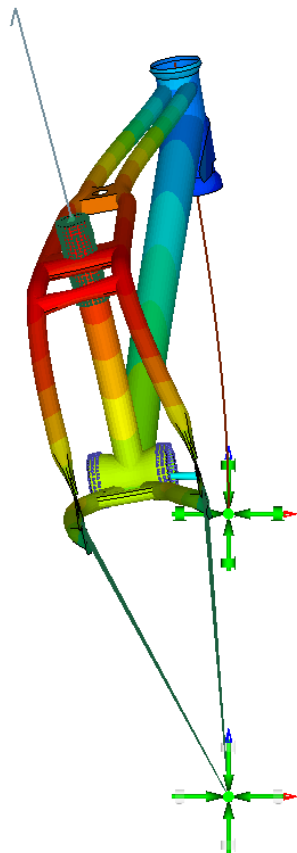
Ti Frame (16mm CS) – Resultant Disps (True Scale x 20)



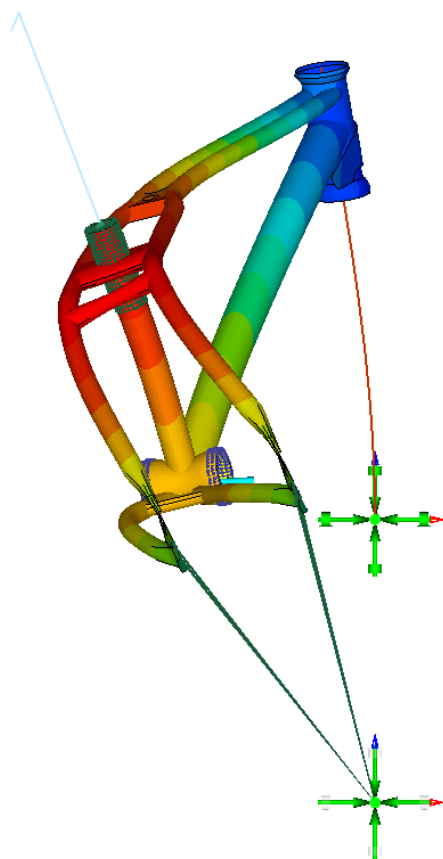
Ti Frame (19mm CS) – Resultant Disps (True Scale x 20)



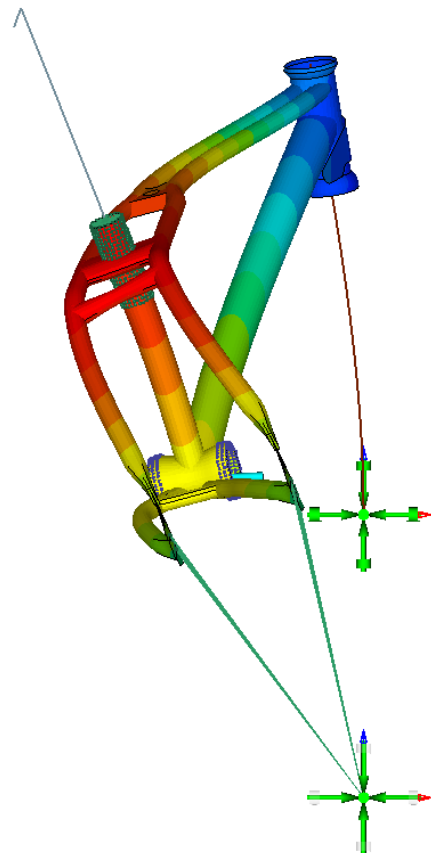
Resultant Disps (True Scale x 20)



Steel Frame

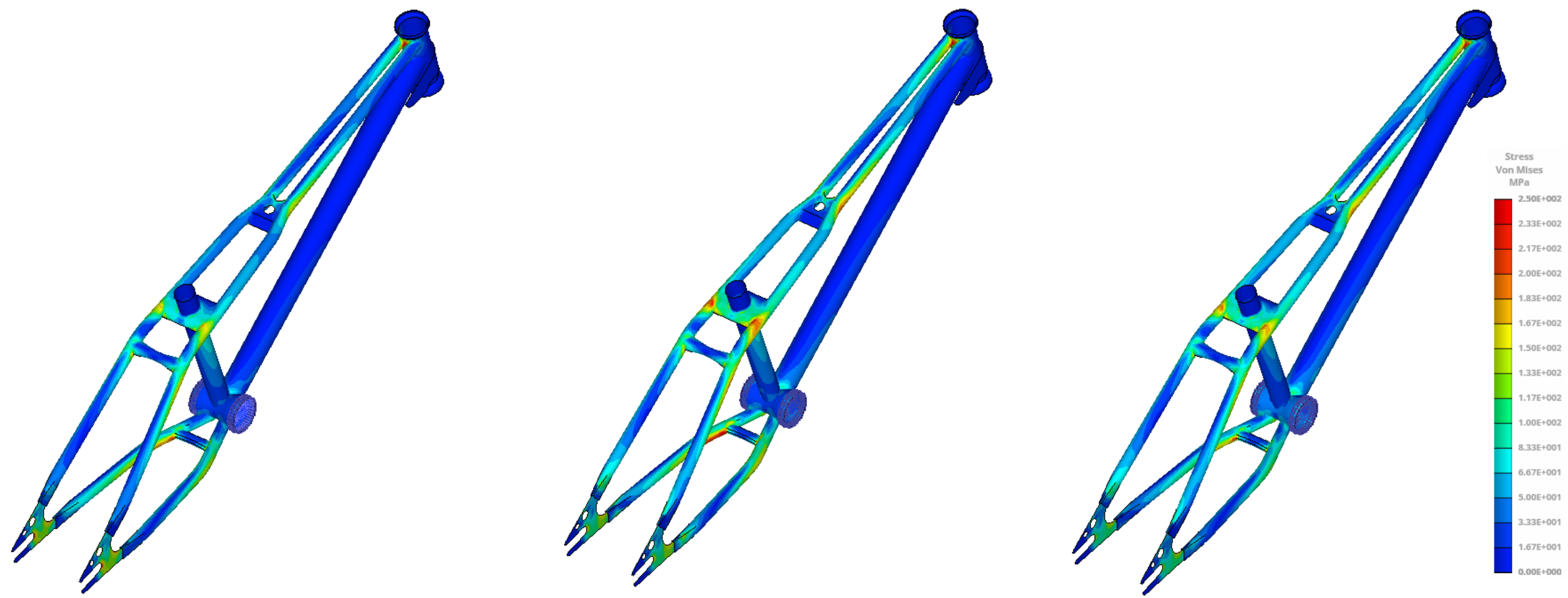


Ti Frame (16mm CS)



Ti Frame (19mm CS)

VM Stress, Max Top/Bottom, Averaged



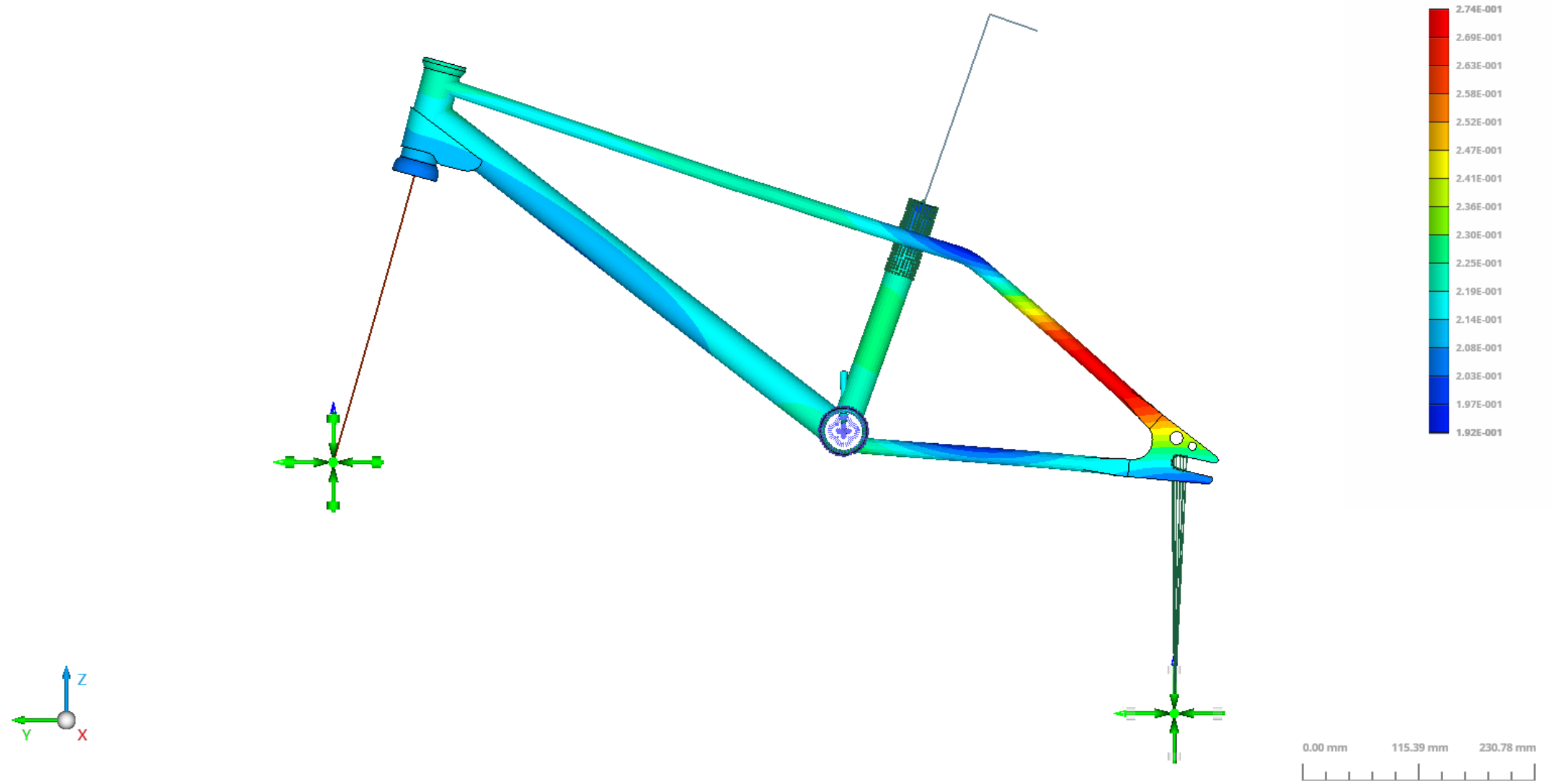
Steel Frame

Ti Frame (16mm CS)

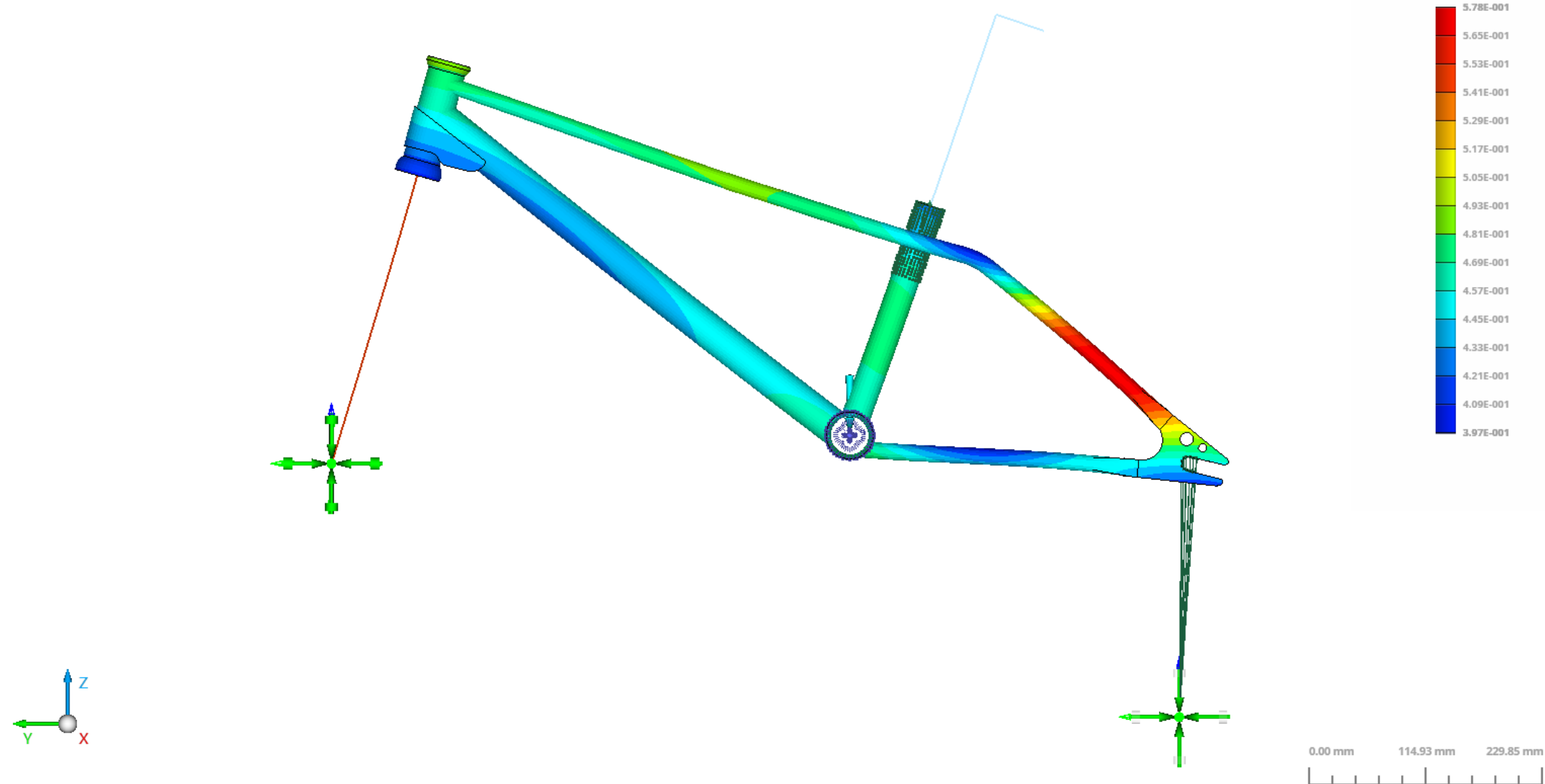
Ti Frame (19mm CS)

LC04_BB_Down

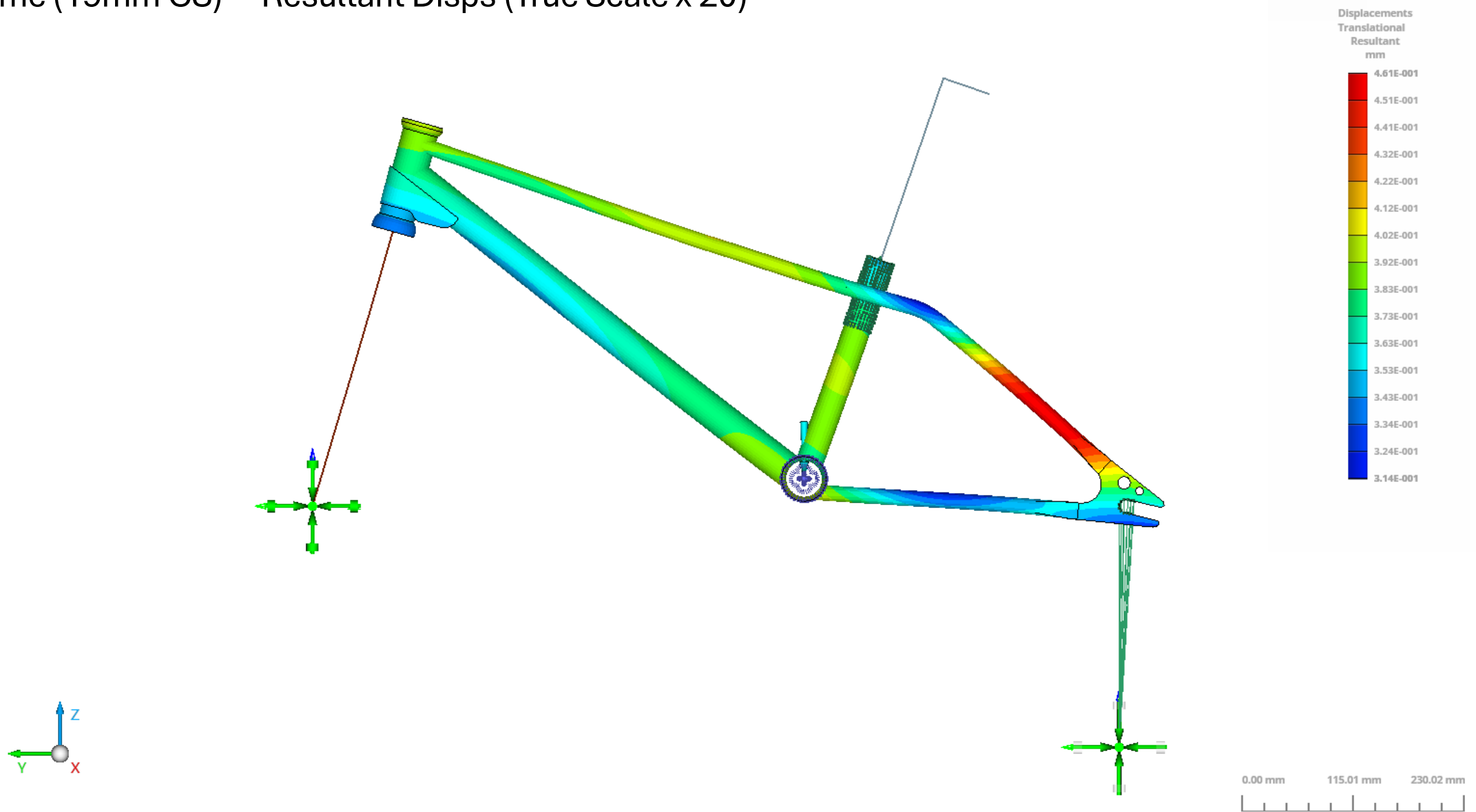
Steel Frame – Resultant Disps (True Scale x 20)



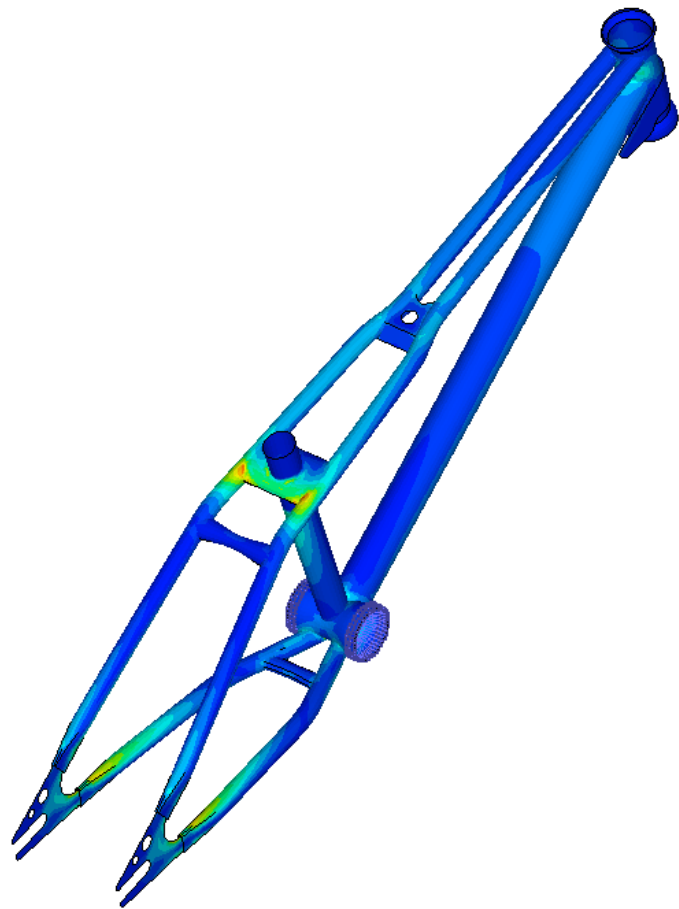
Ti Frame (16mm CS) – Resultant Disps (True Scale x 20)



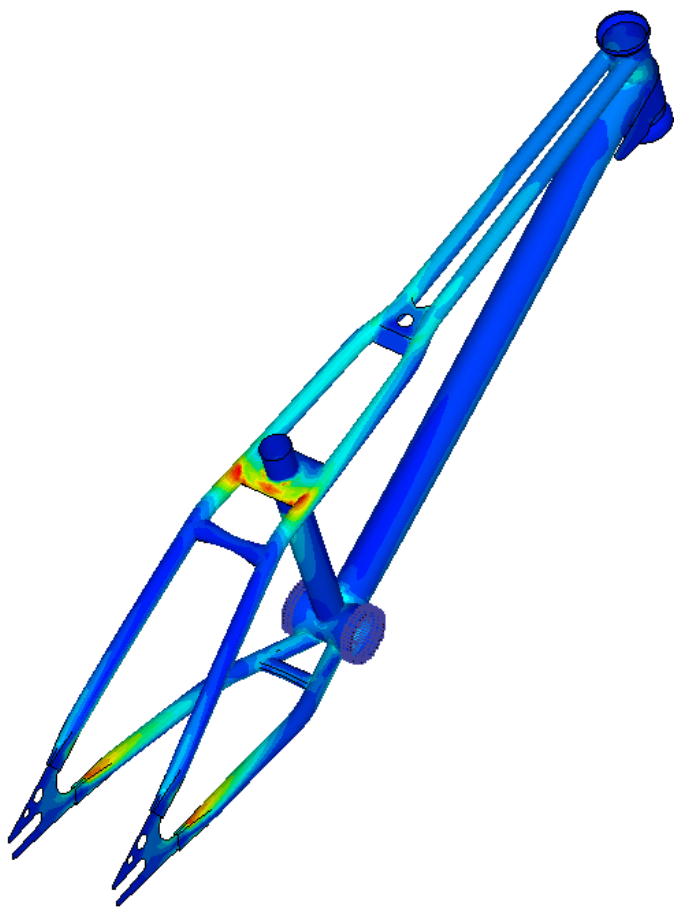
Ti Frame (19mm CS) – Resultant Disps (True Scale x 20)



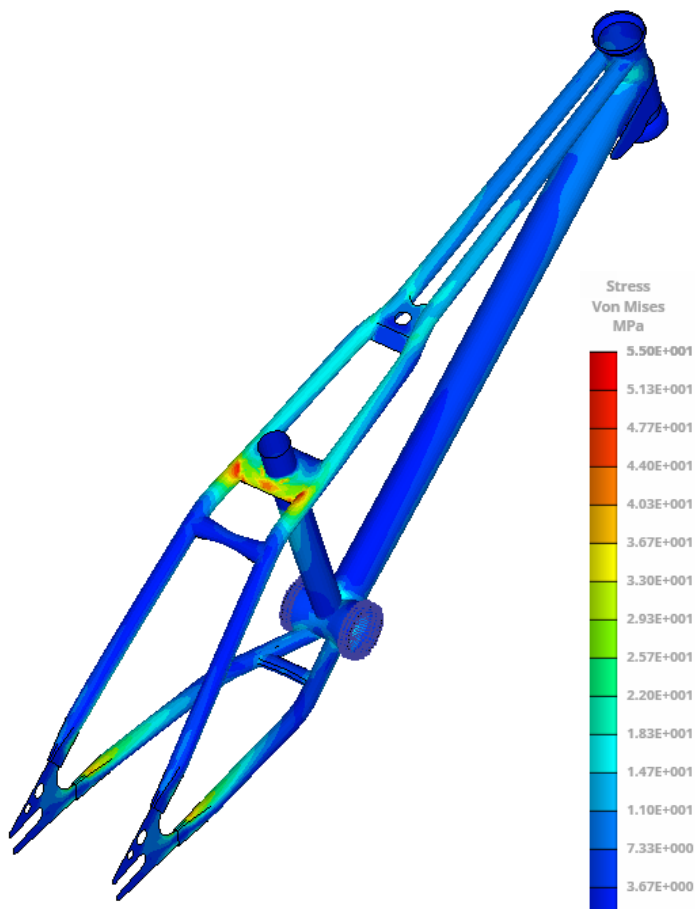
VM Stress, Max Top/Bottom, Averaged



Steel Frame



Ti Frame (16mm CS)



Ti Frame (19mm CS)

