EXPERTS HUB APDA SUMMER INTERNSHIP 2021 Batch 5 - PROJECT

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Content

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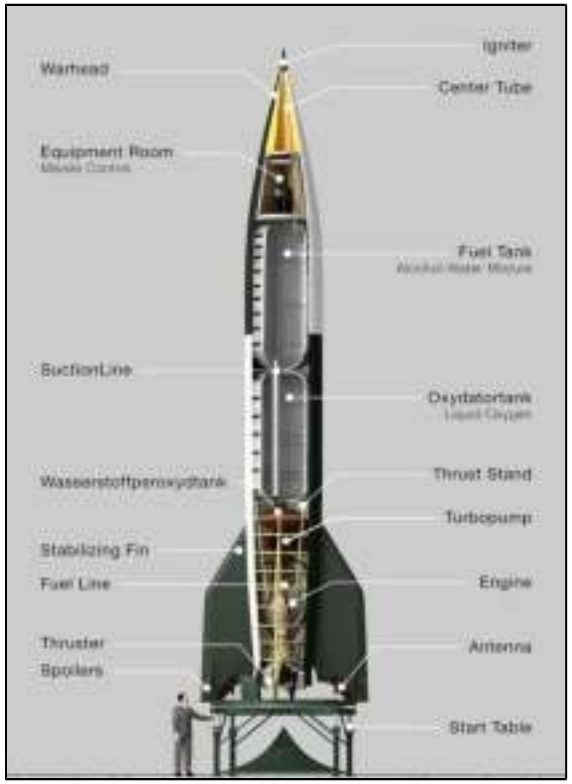
Problem Statement

Problem Statement

- Design and Analyse Ballistic Missile Shell
- Validate the design by doing structural analysis and flow analysis.



2

Team structure & Roles

Team structure & Roles

As I was doing this project individually all the below roles and jobs were done by me. This helped me to gain more skills and I liked this learning process.

1. Design Engineer
2. FEA Engineer
3. CFD Engineer
4. Analysis & Validation Engineer

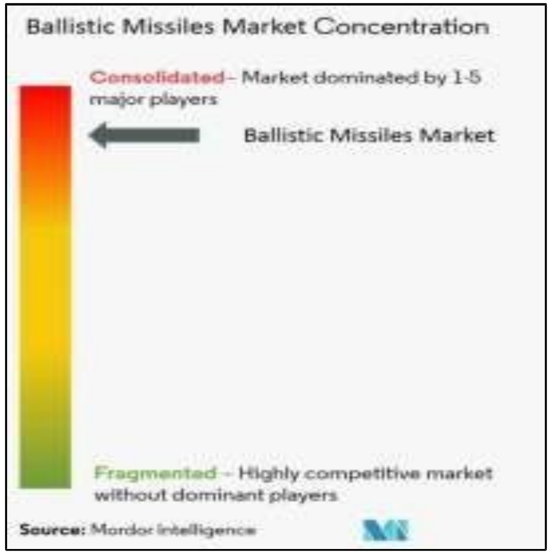
3

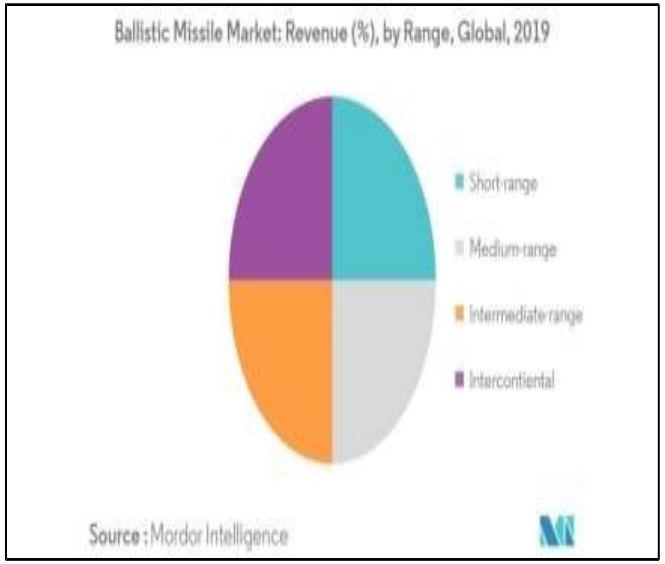
Current Market Trends

Current Market Trends

1.The ballistic missile market is anticipated to grow at a CAGR of above 6% during the forecast period (2020 - 2025).
2.The increasing national security concerns and border threats are driving the demand for the ballistic missile market during the forecast period.

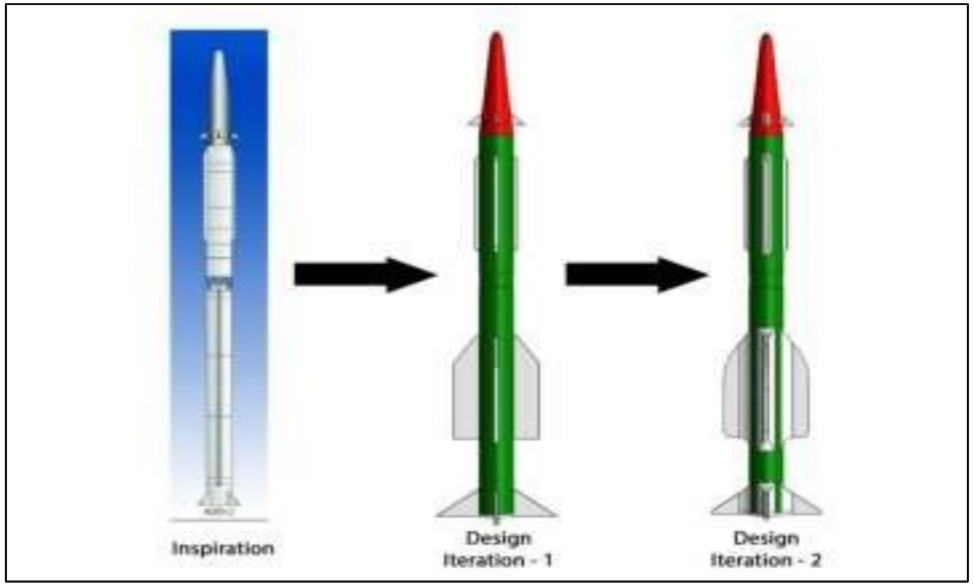
Key Market Trends
1.Intercontinental Segment is Projected to Have the Highest Growth During the Forecast Period
2.Asia-Pacific Region is Projected to Have the Highest Growth During the Forecast Period
3.Competitive Landscape

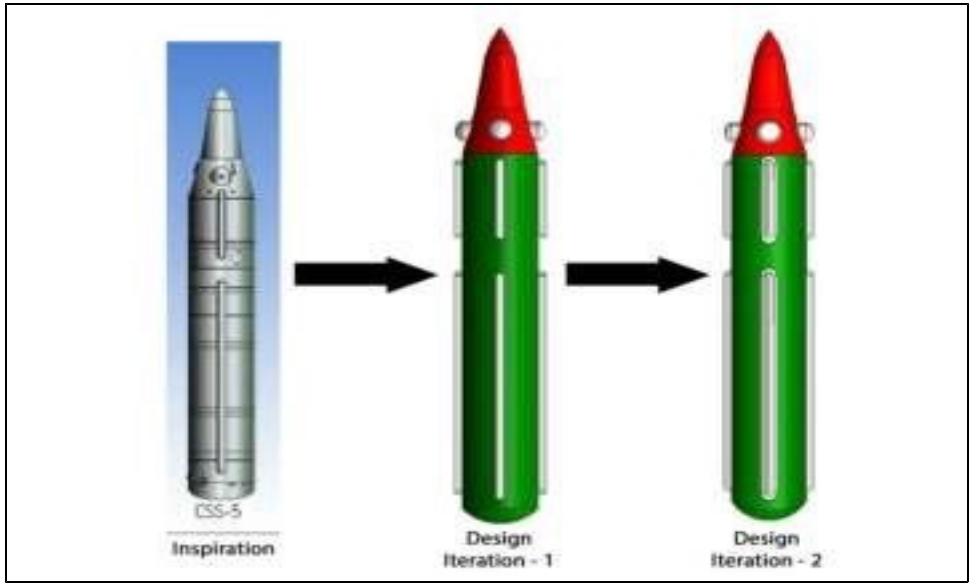


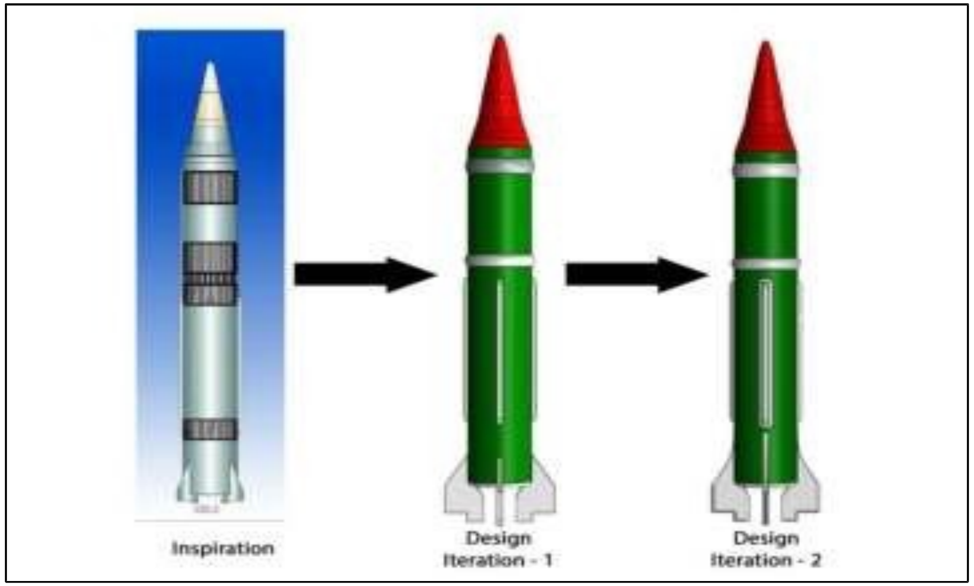


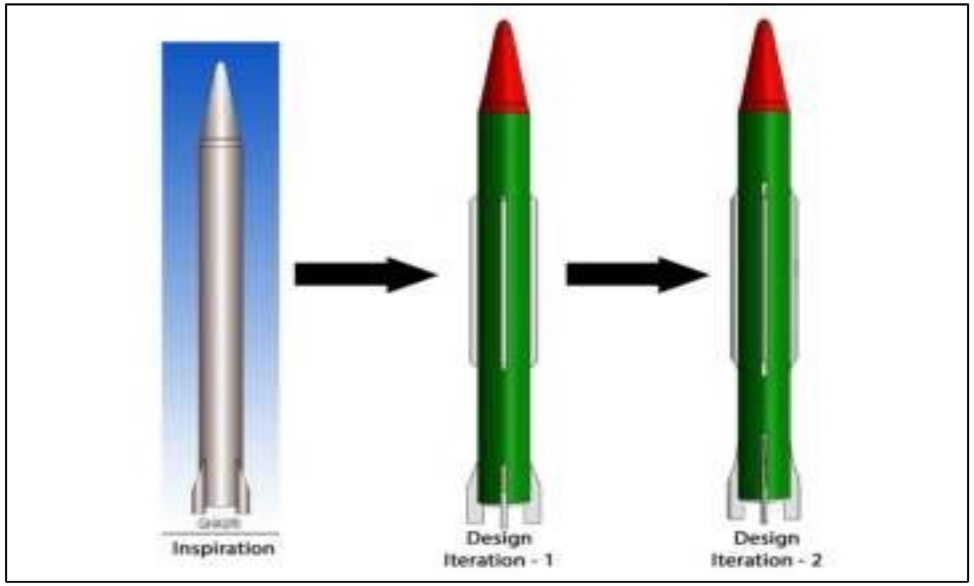
4

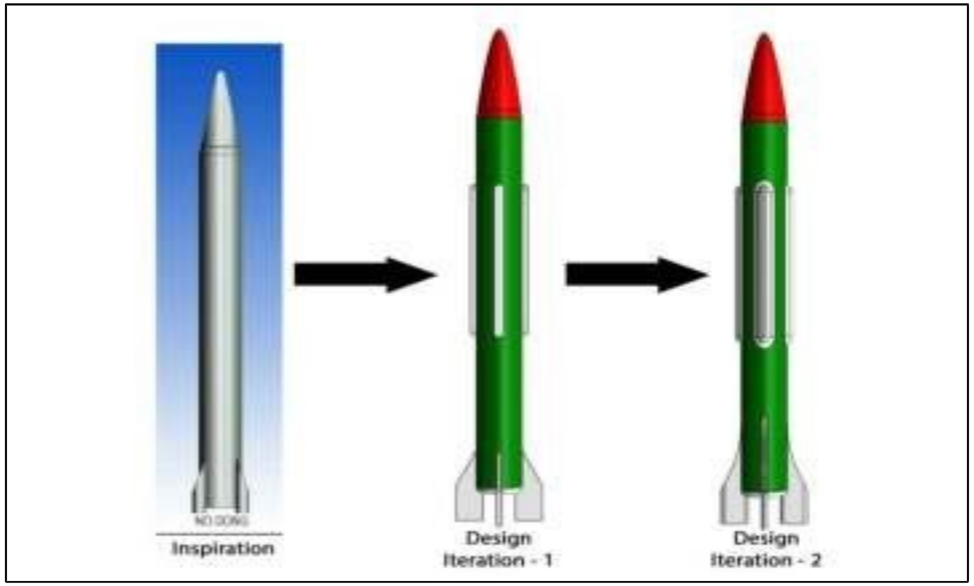
Design Options considered


Inspiration
Design
Iteration - 1
Design
Iteration - 2

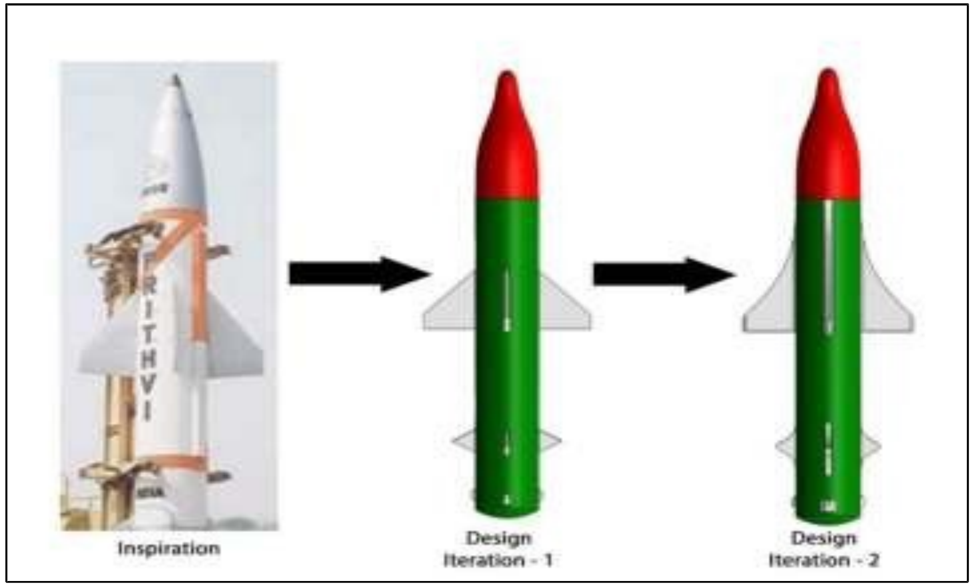

CSS-5
Inspiration
Design
Iteration - 1
Design
Iteration - 2


Inspiration
Design
Iteration - 1
Design
Iteration - 2

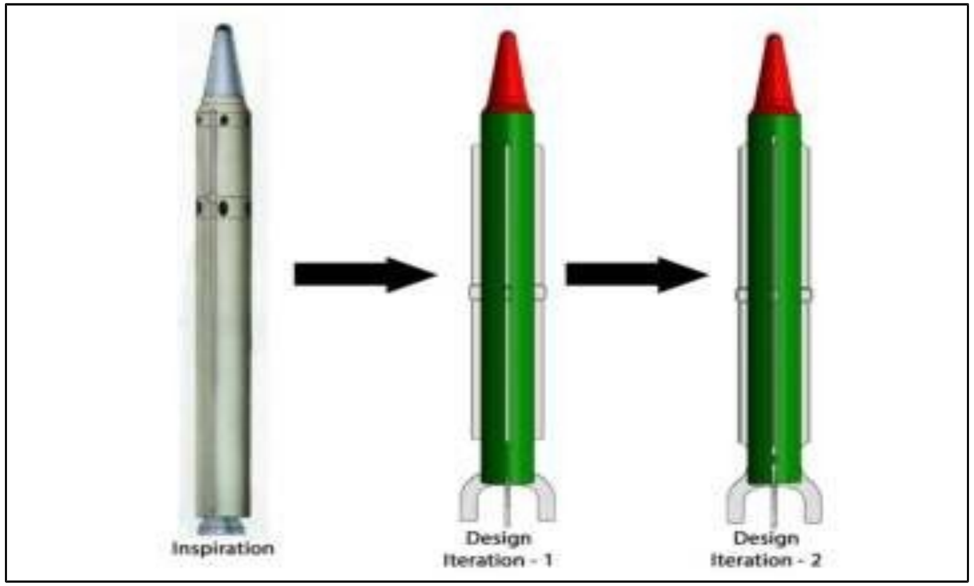

Inspiration
Design
Iteration - 1
Design
Iteration - 2



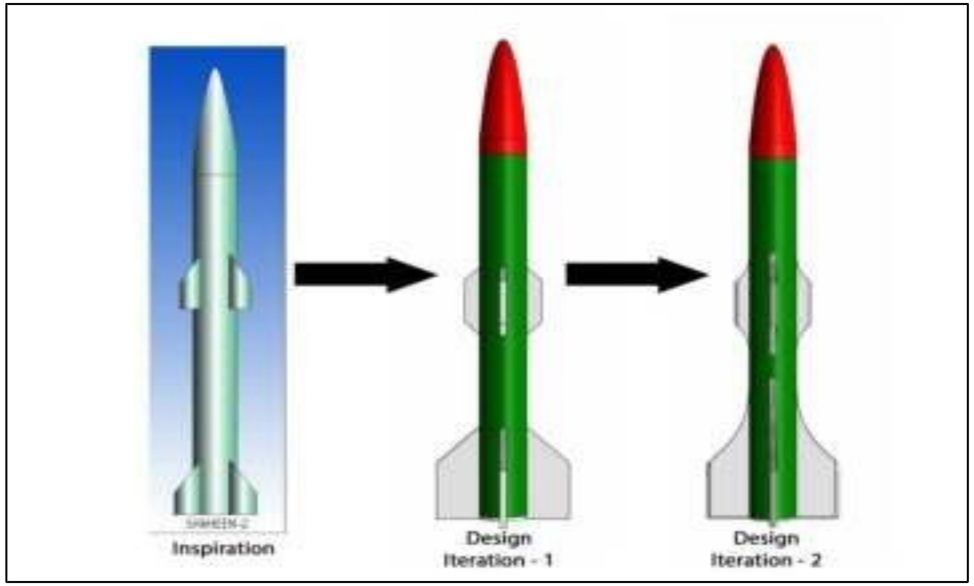
Inspiration
Design Iteration - 1
Design Iteration - 2



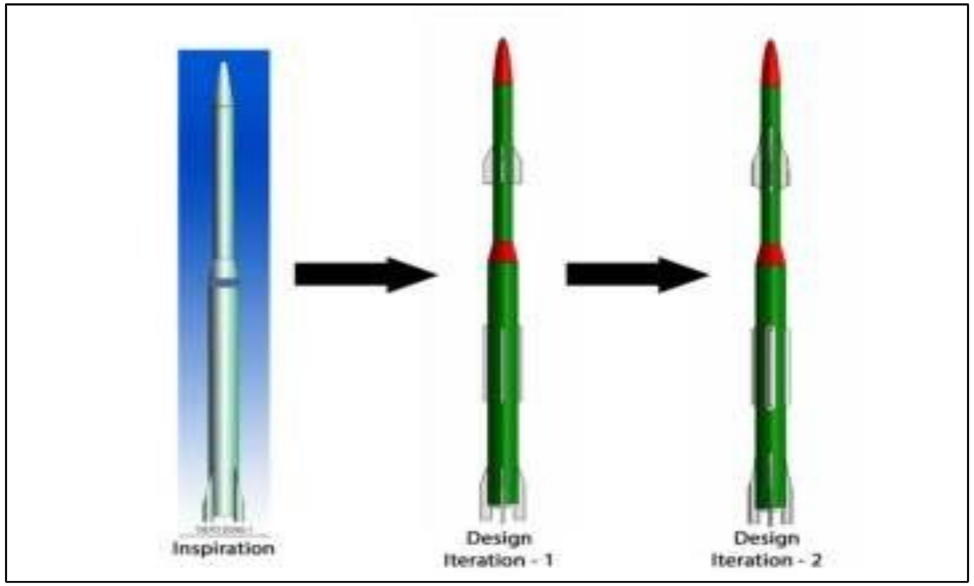
PRITHVI
Inspiration
Design Iteration - 1
Design Iteration - 2

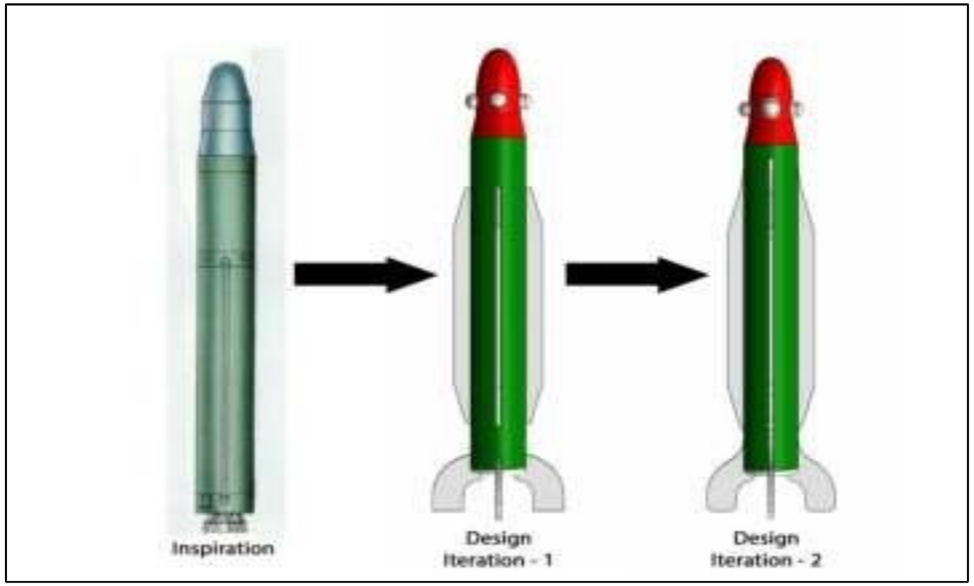


Inspiration
Design Iteration - 1
Design Iteration - 2

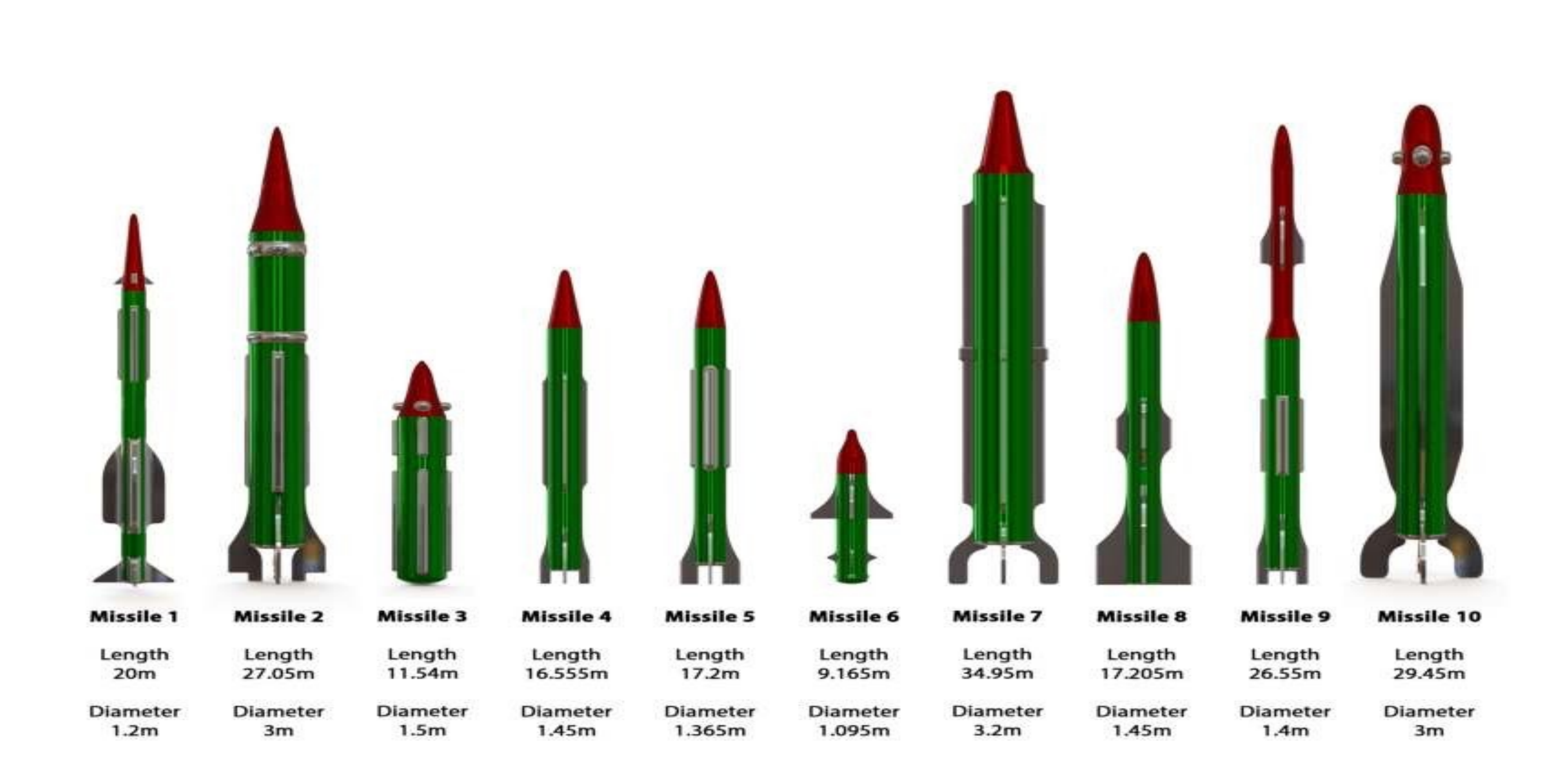


Inspiration
Design Iteration - 1
Design Iteration - 2





I have designed ten missiles, each with two design iterations. The supports, fins, and spoilers are engineered to reduce the Magnus effect and stabilize motion at higher velocities. In the second design iterations, all missiles were modified with filleting to enhance aerodynamic stability. My designs were inspired by the AGNI2, CSS2, CSS5, GHAURI, NODONG, PRITHVI2, RS36, SHAHEEN2, TAEPO DONG1, and UR 100N missile systems. The modifications from the original models are evident in the accompanying images. Notably, the tenth missile was specifically designed to maximize impact while ensuring superior aerodynamic stability.



Dimensions of ballistic missiles

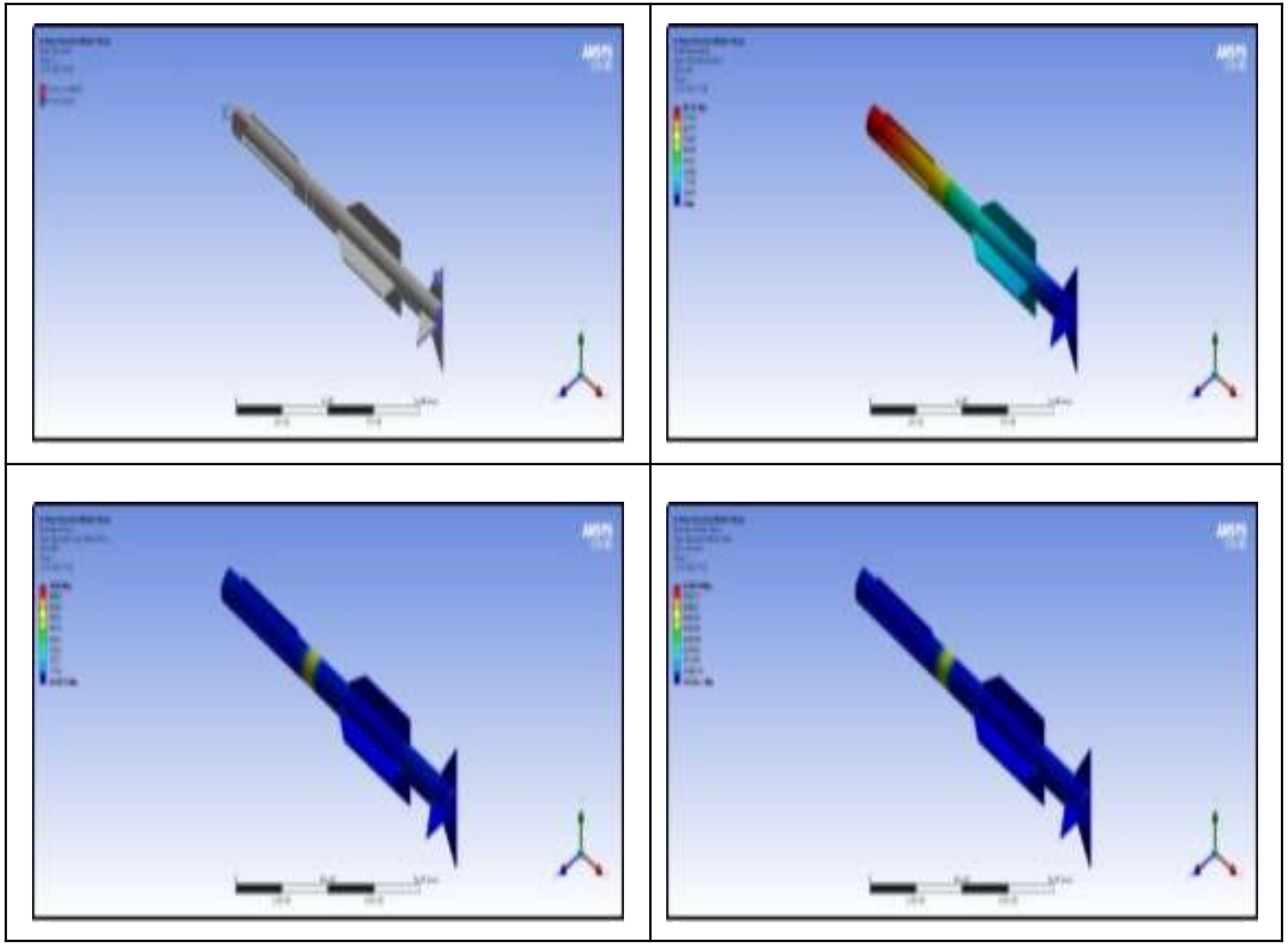
5

Concept Validation

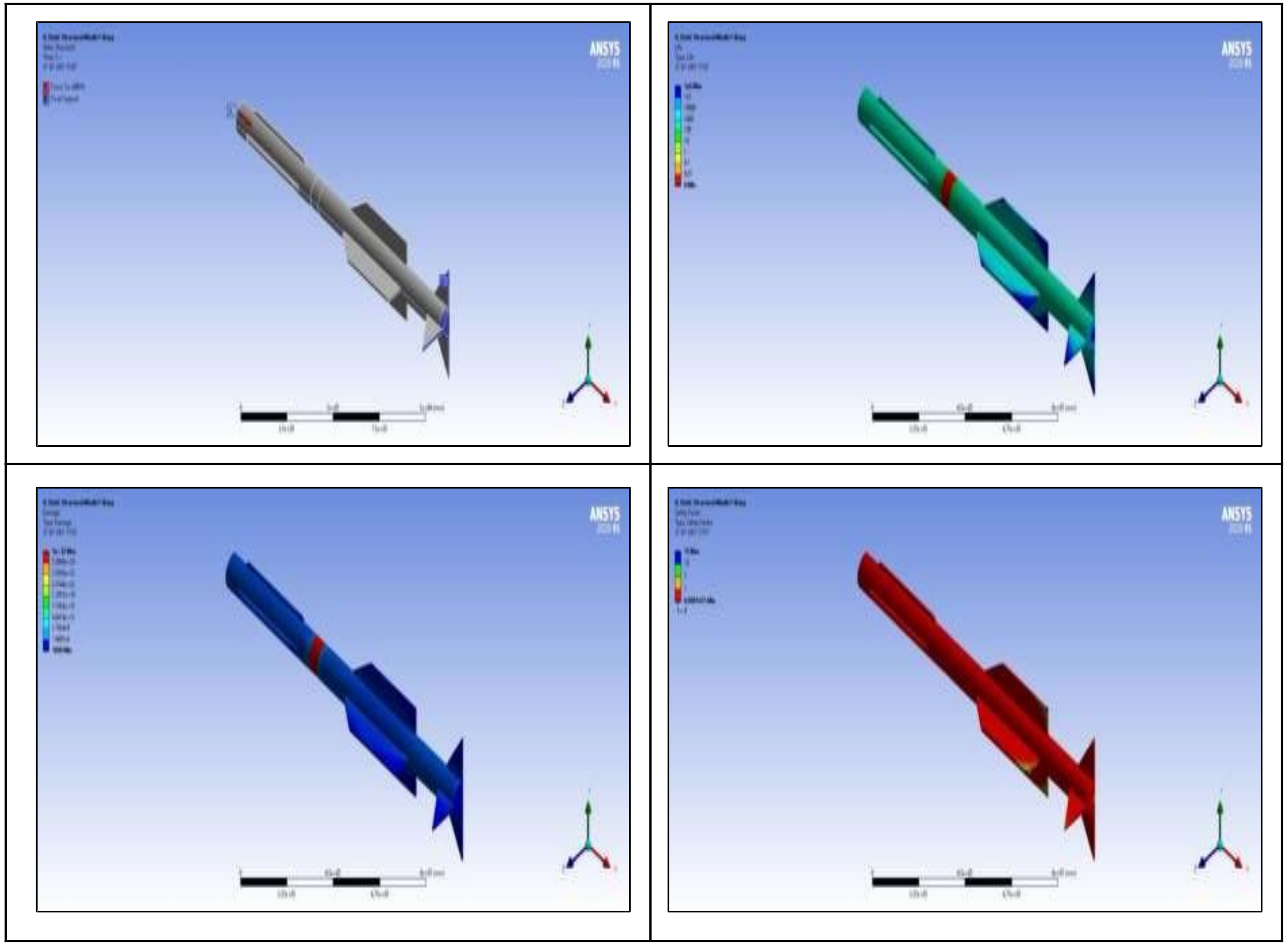
Structural analysis

The steady structural analysis of ballistic missile shells is done to look at aspects including damage, life, factor of safety, total deformation, and stress to see how much of a great impact they could have at a certain speed.

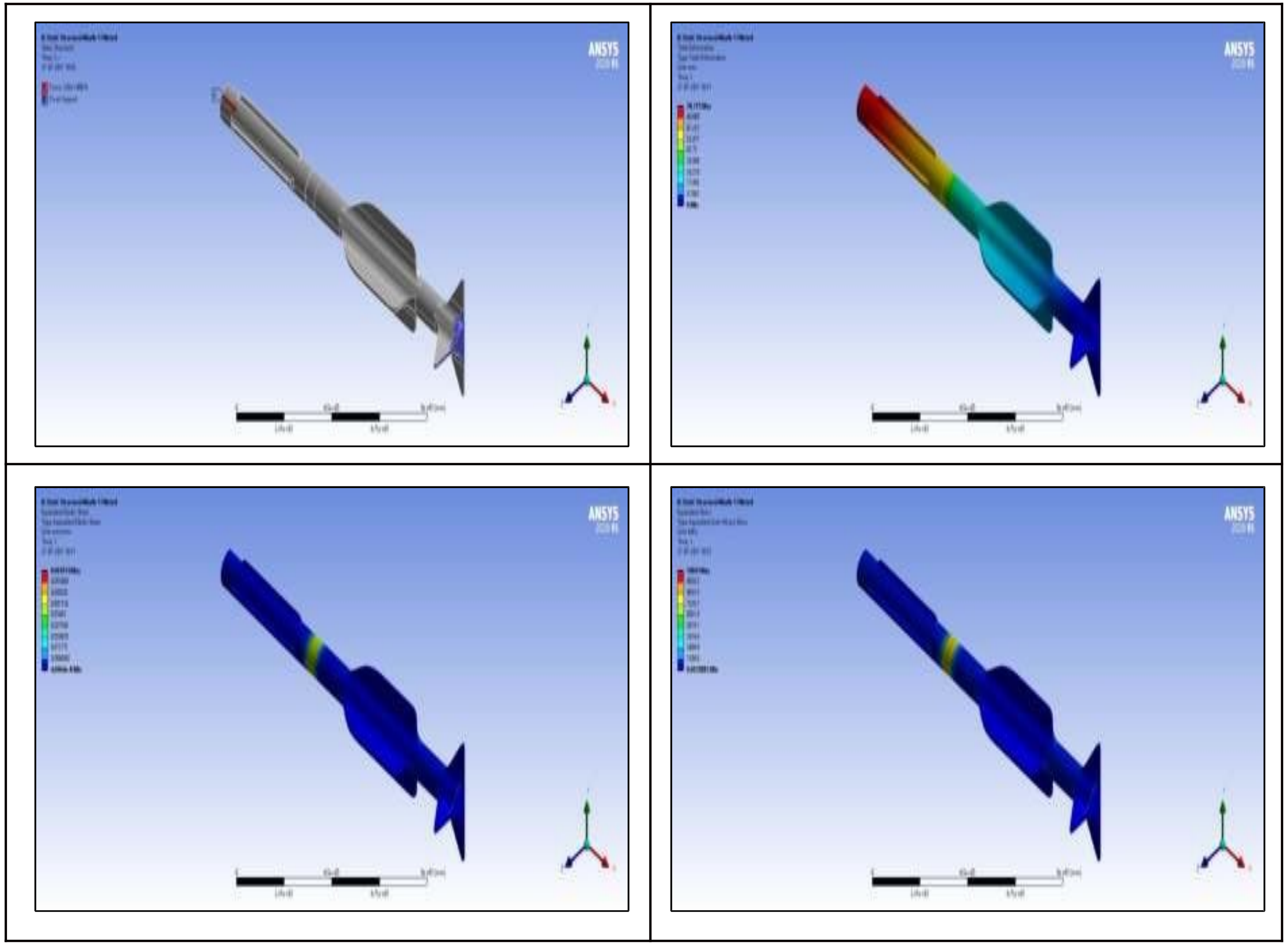
Static Structural Mesh Details		
Model	Nodes	Elements
Missile 1 Sharp	4982684	3390289
Missile 1 Filleted	5549003	3763876
Missile 2 Sharp	3278245	2233166
Missile 2 Filleted	3349778	2274152
Missile 3 Sharp	2834431	1936867
Missile 3 Filleted	3001207	2040948
Missile 4 Sharp	3648766	2481560
Missile 4 Filleted	1980647	1344014
Missile 5 Sharp	2023447	1251311
Missile 5 Filleted	1787527	1222191
Missile 6 Sharp	1467468	991902
Missile 6 Filleted	1786011	1212920
Missile 7 Sharp	261366	1816634
Missile 7 Filleted	555330	345222
Missile 8 Sharp	268849	19998228
Missile 8 Filleted	1240791	778050
Missile 9 Sharp	2493583	1709694
Missile 9 Filleted	1041082	608152
Missile 10 Sharp	974275	566784
Missile 10 Filleted	4147767	2438864



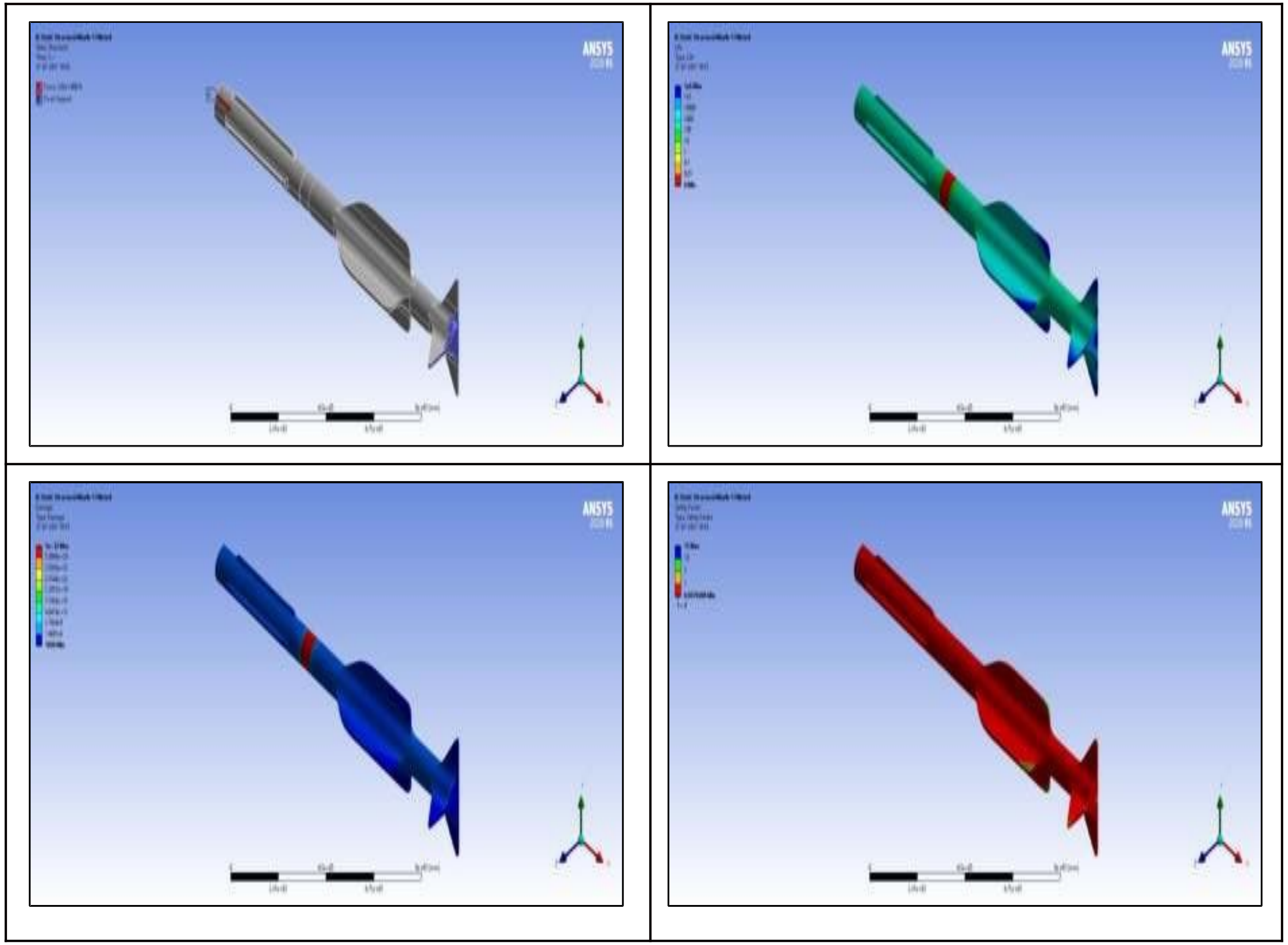
Static structural analysis for missile 1 - sharp



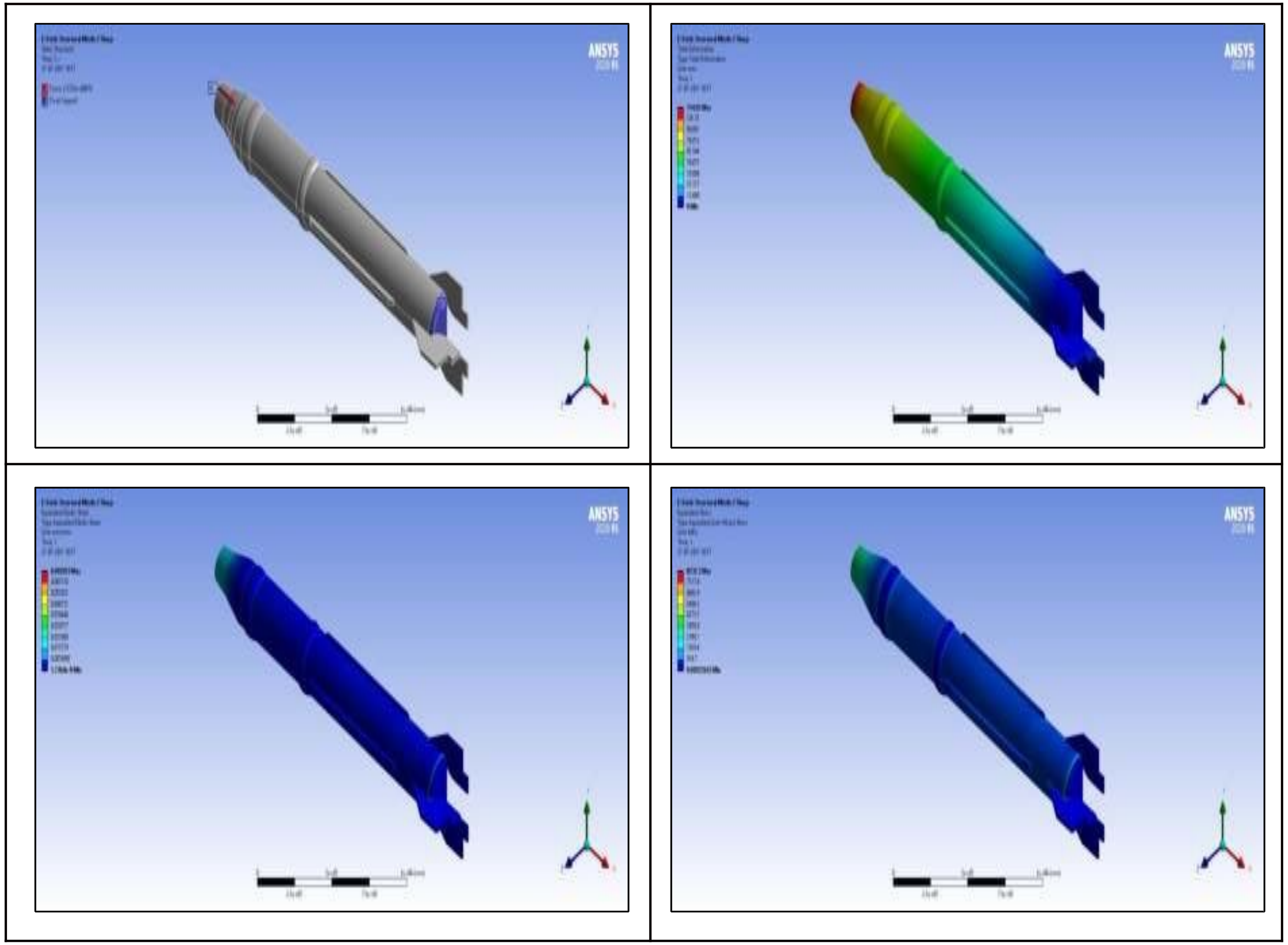
Fatigue analysis for missile 1 - sharp



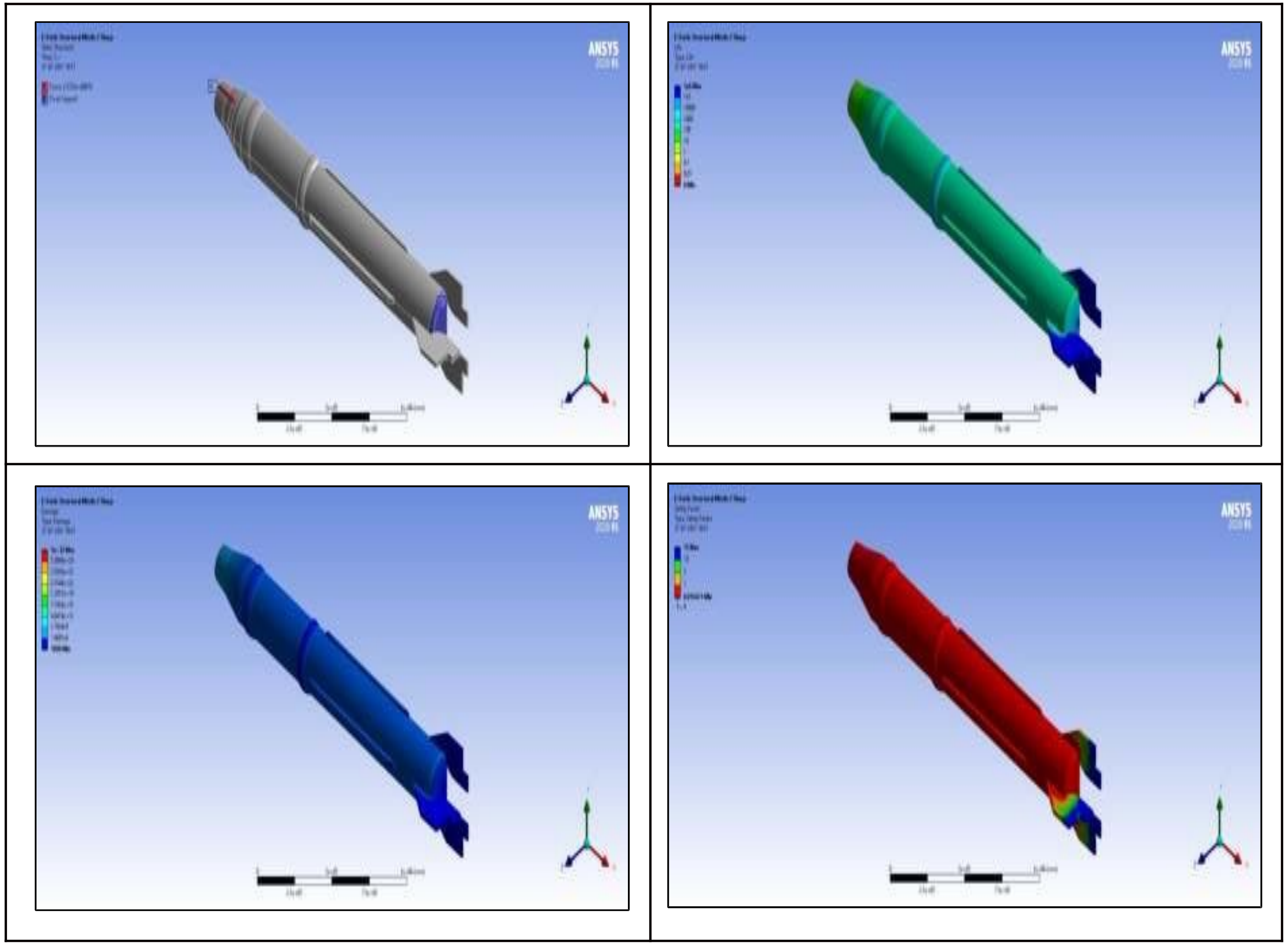
Static structural analysis for missile 1 - filleted



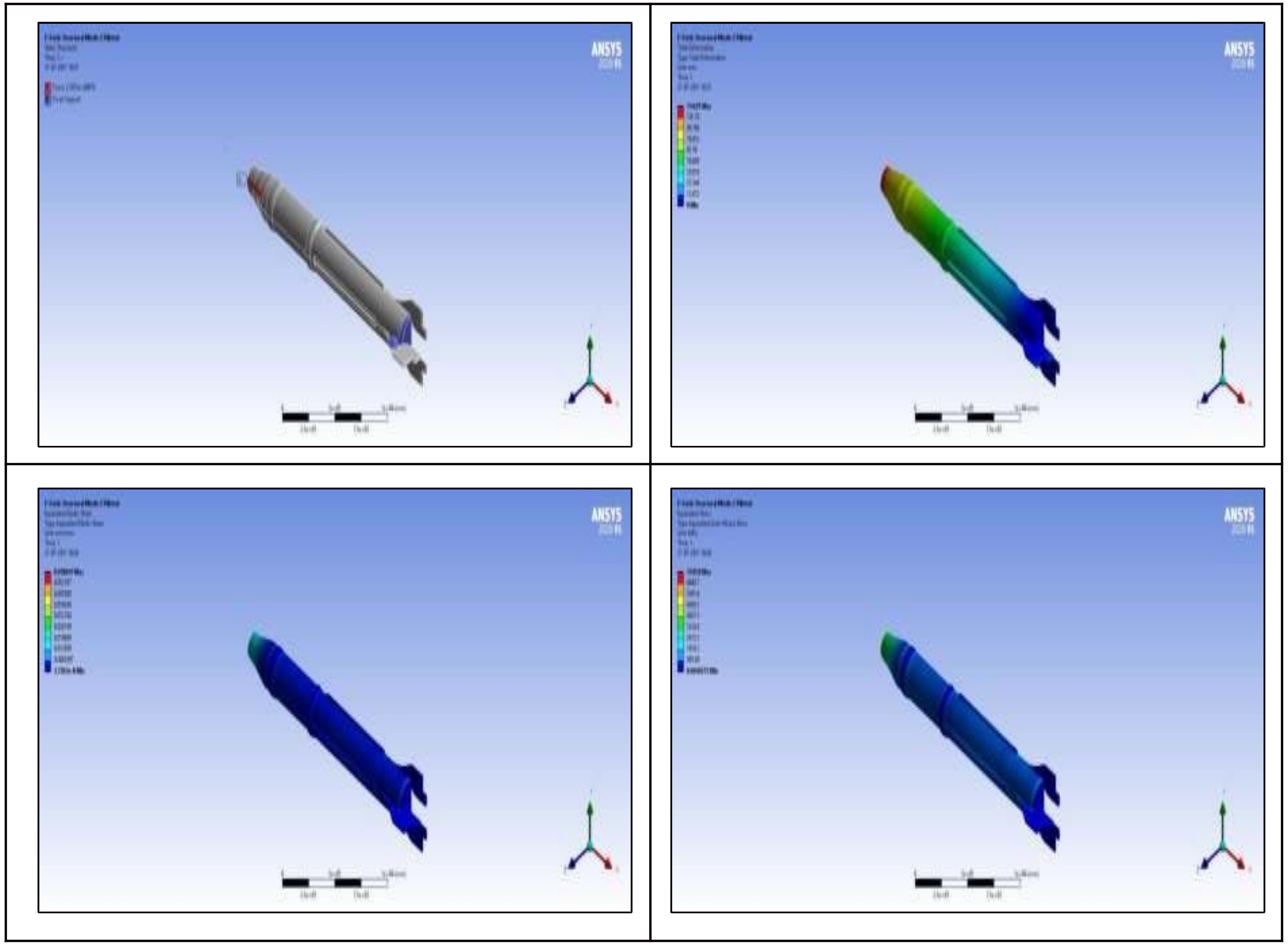
Fatigue analysis for missile 1 - filleted



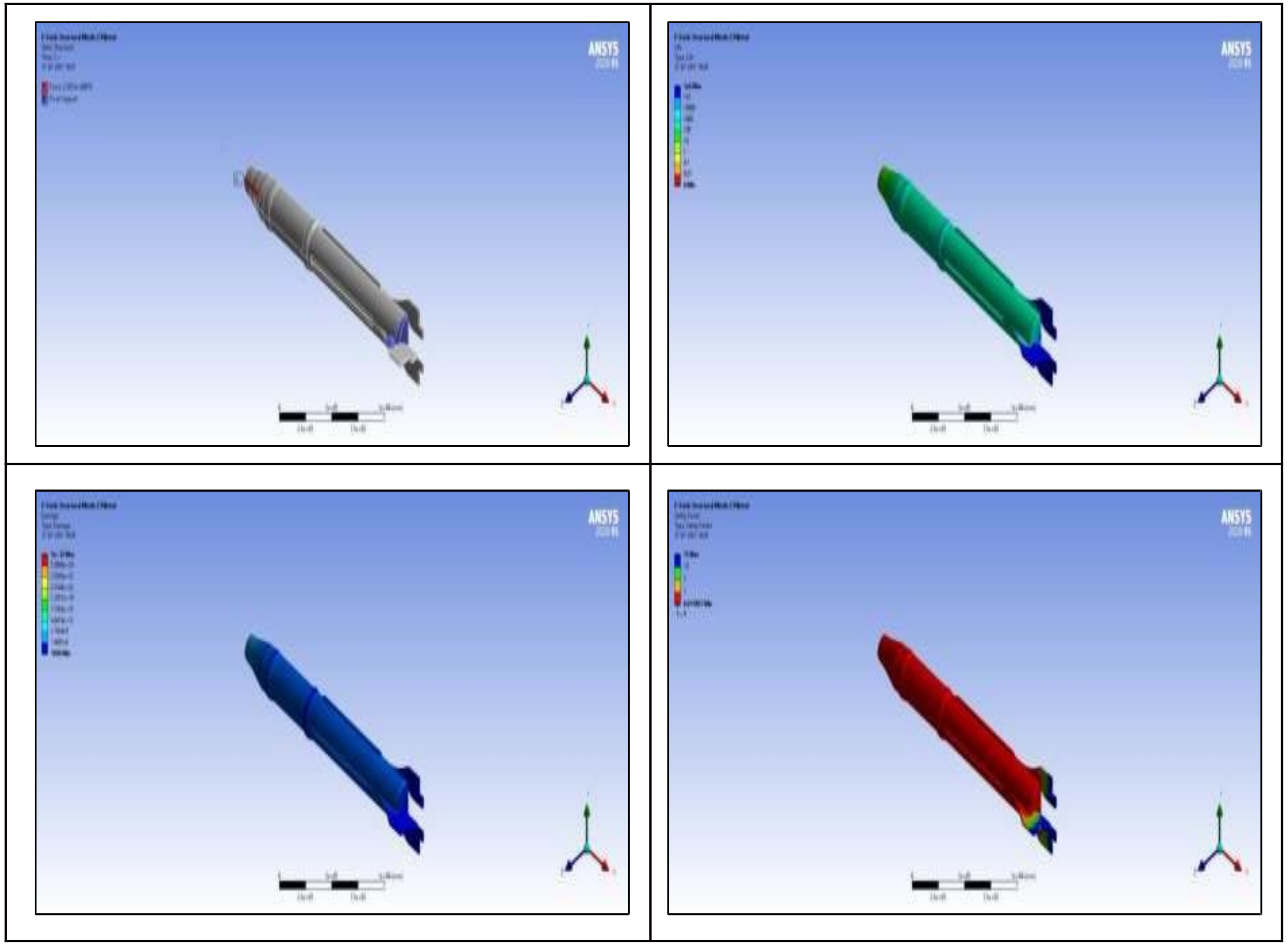
Static structural analysis for missile 2 - sharp



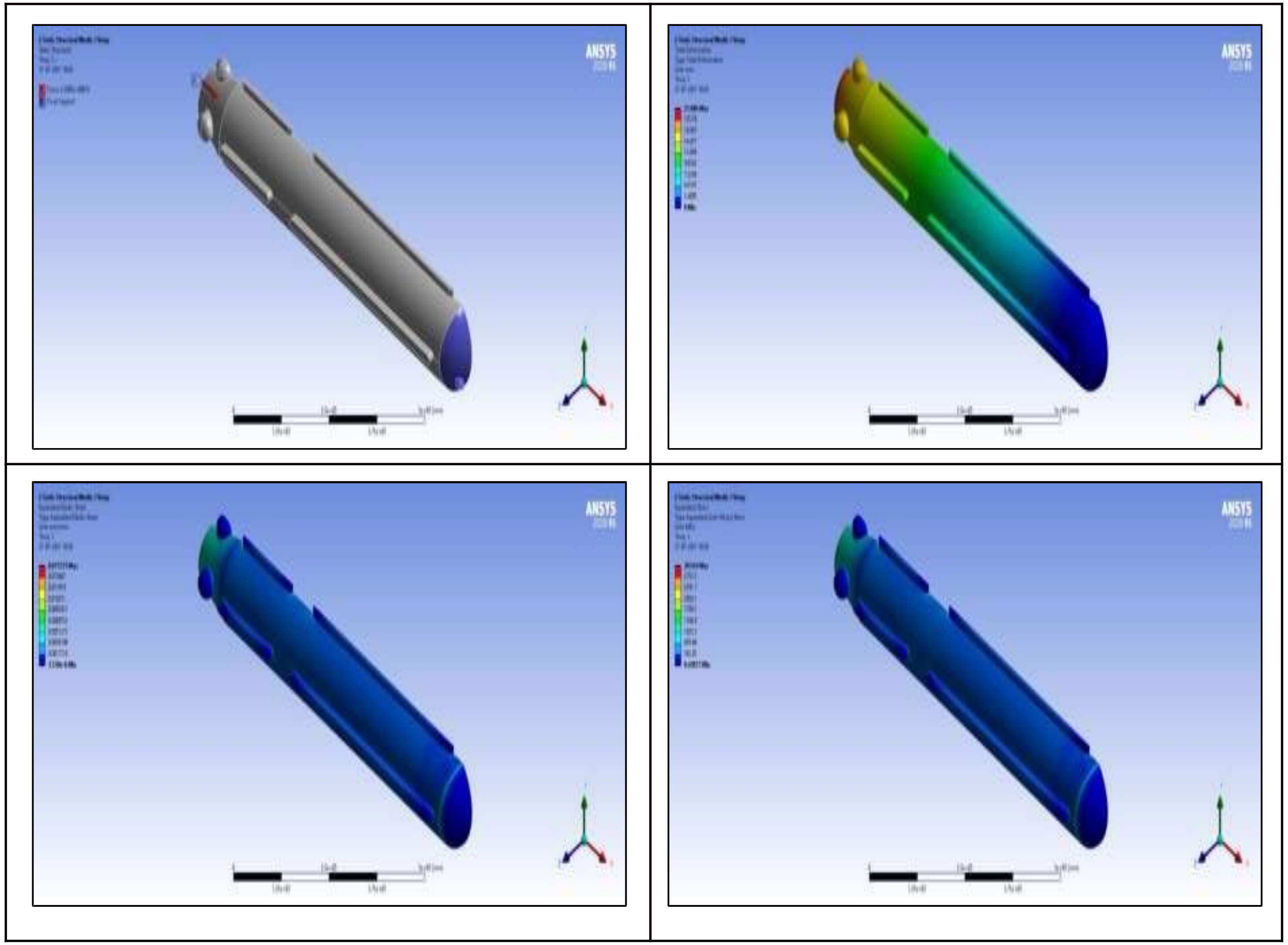
Fatigue analysis for missile 2 - sharp



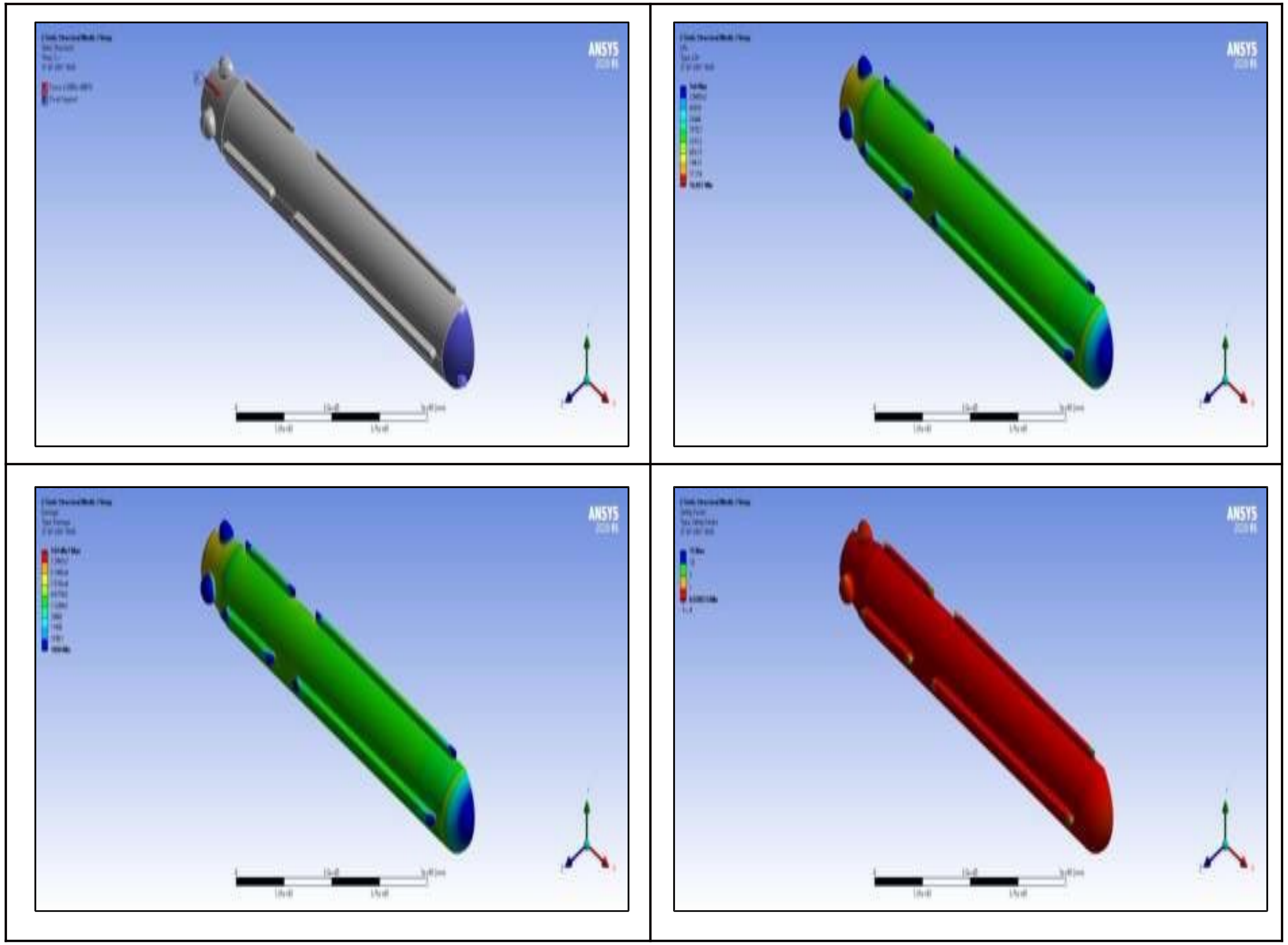
Static structural analysis for missile 2 - filleted



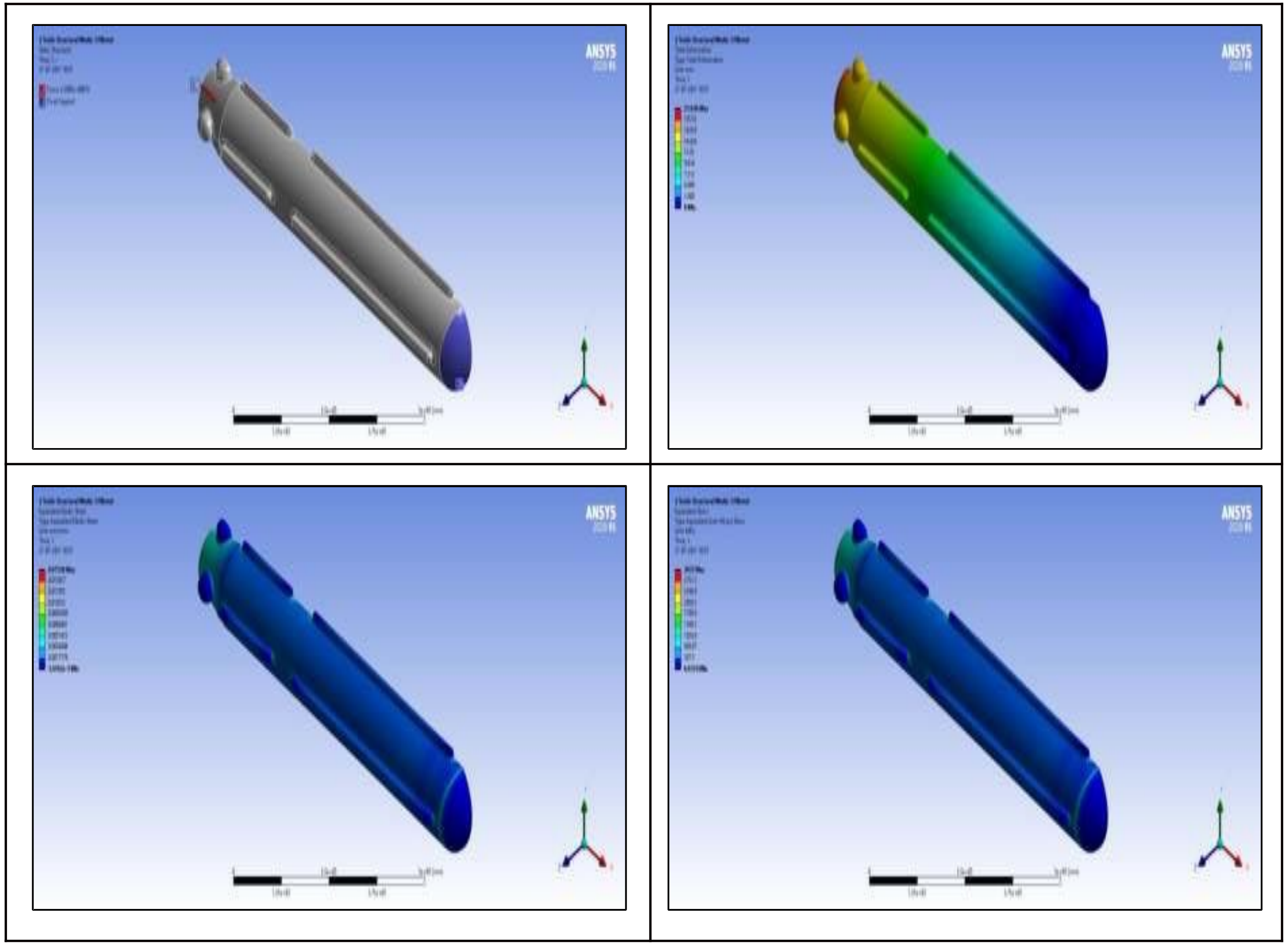
Fatigue analysis for missile 2 - filleted



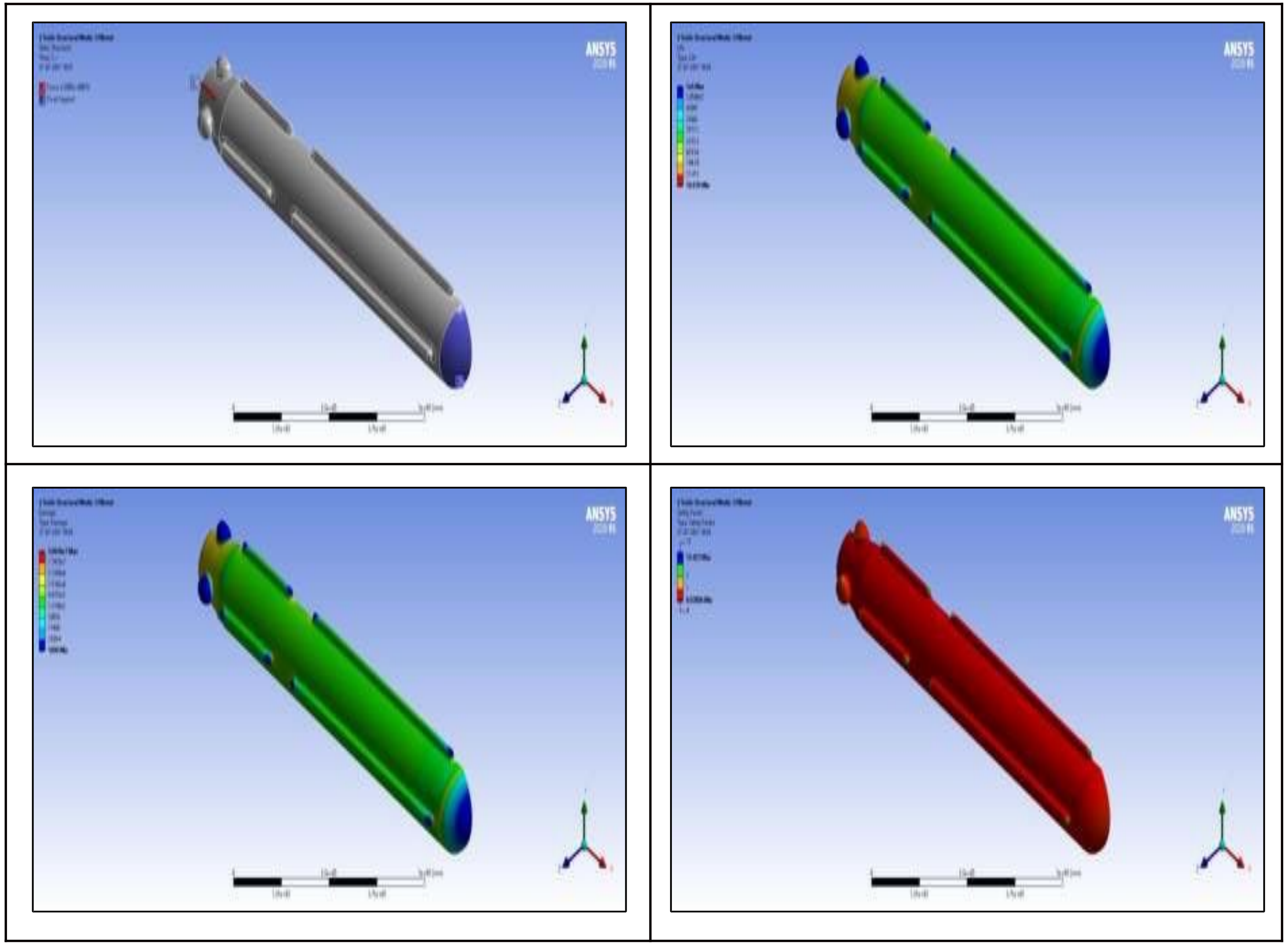
Static structural analysis for missile 3 - sharp



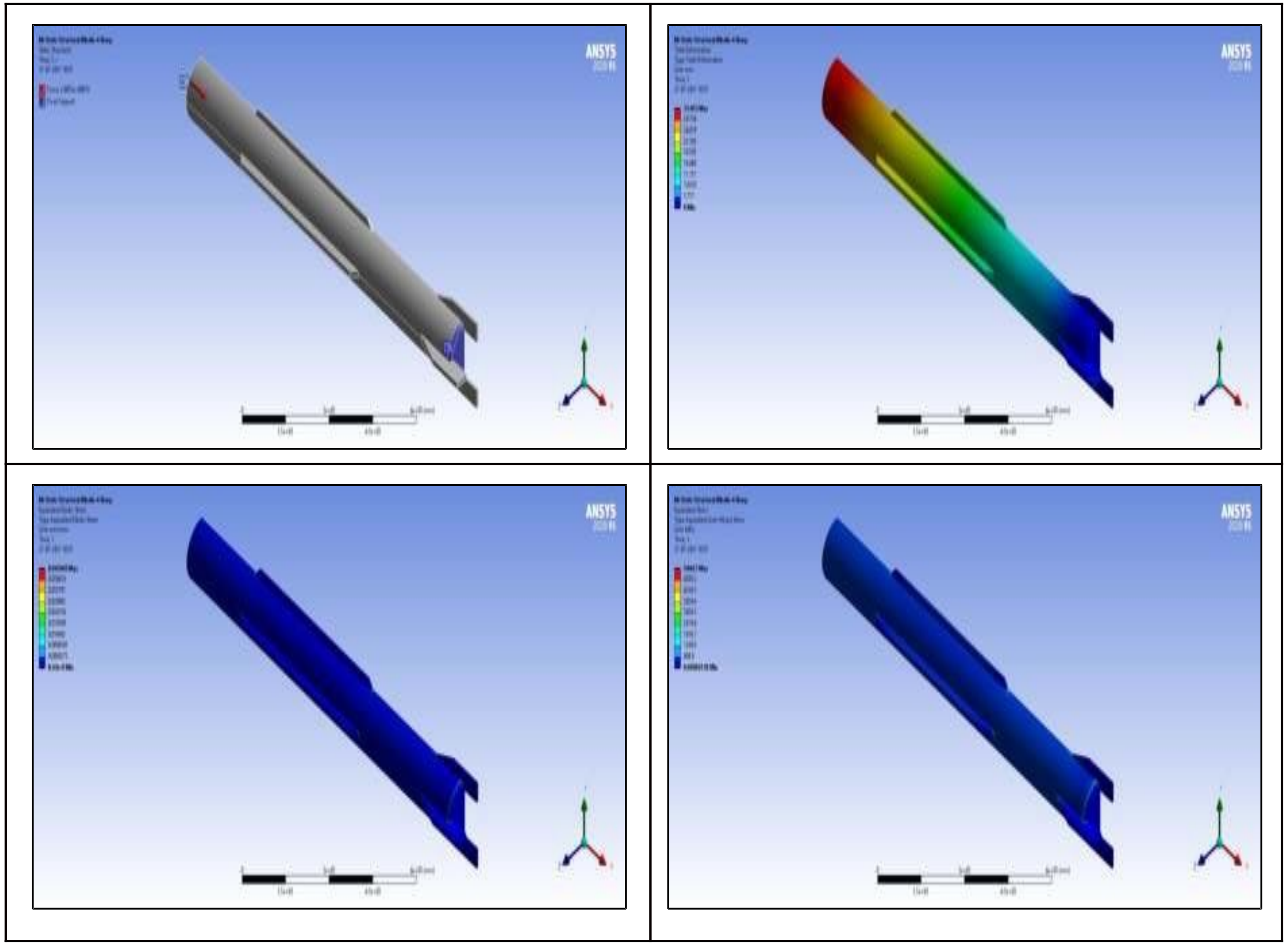
Fatigue analysis for missile 3 - sharp



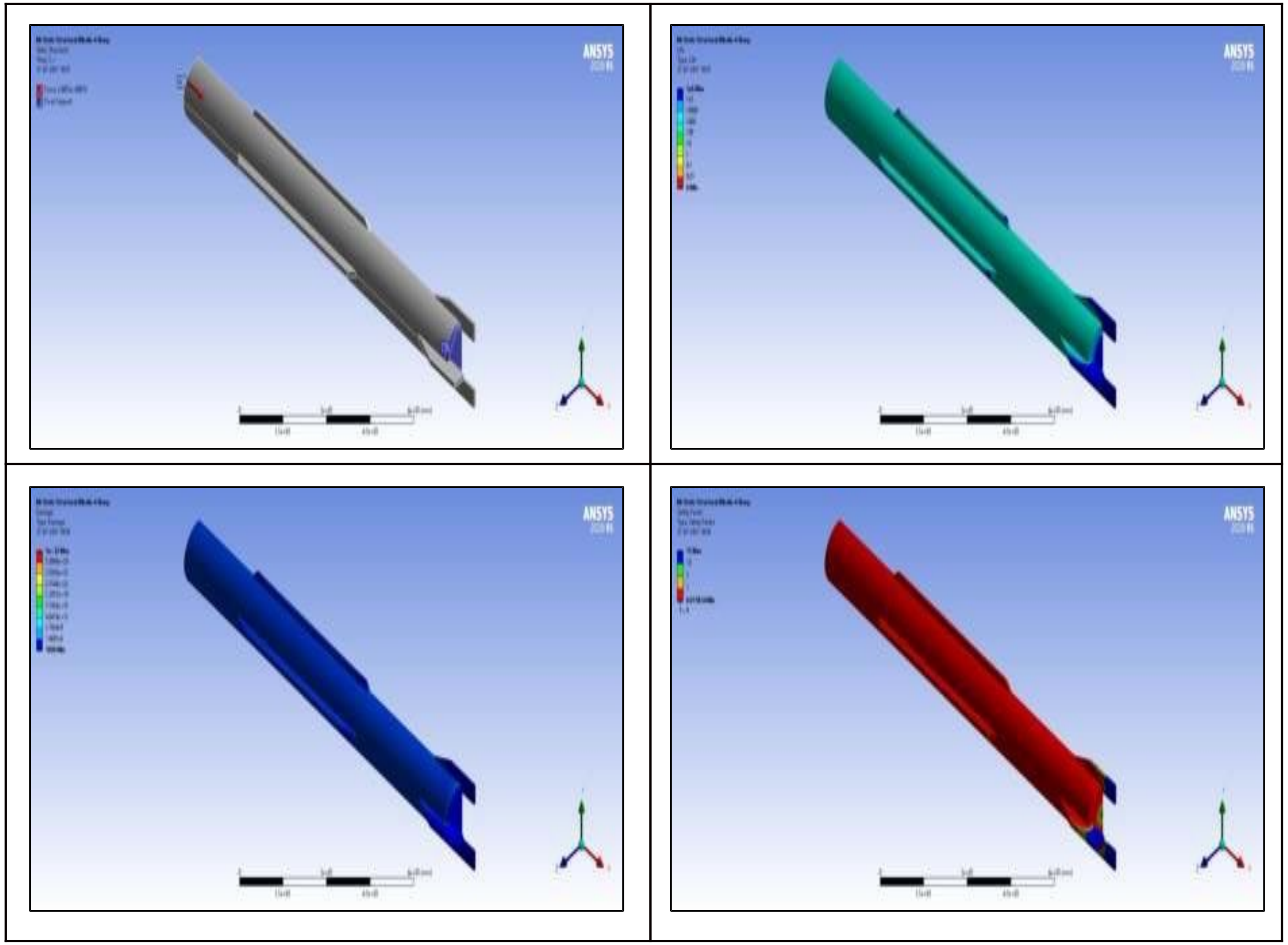
Static structural analysis for missile 3 - filleted



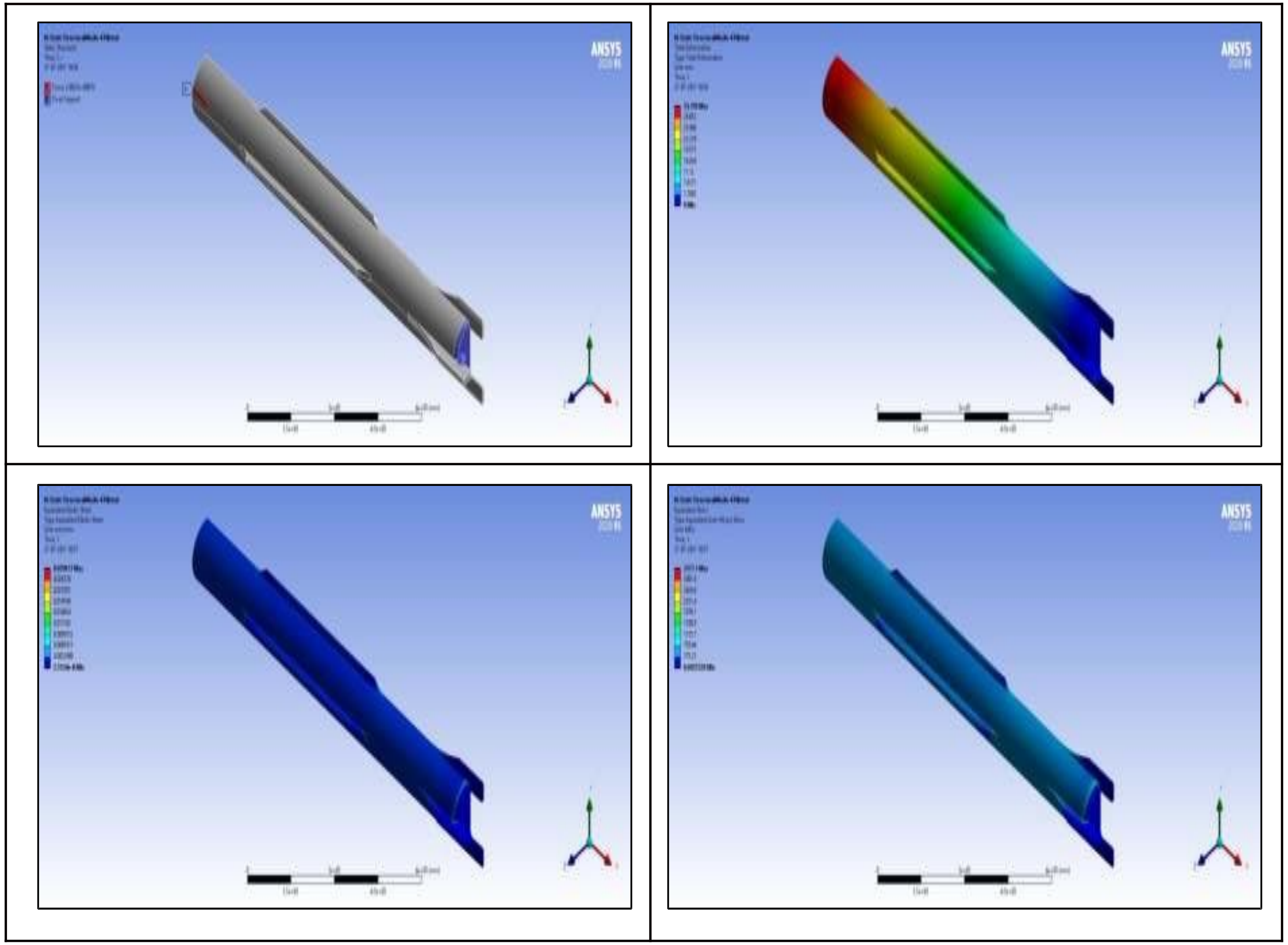
Fatigue analysis for missile 3 - filleted



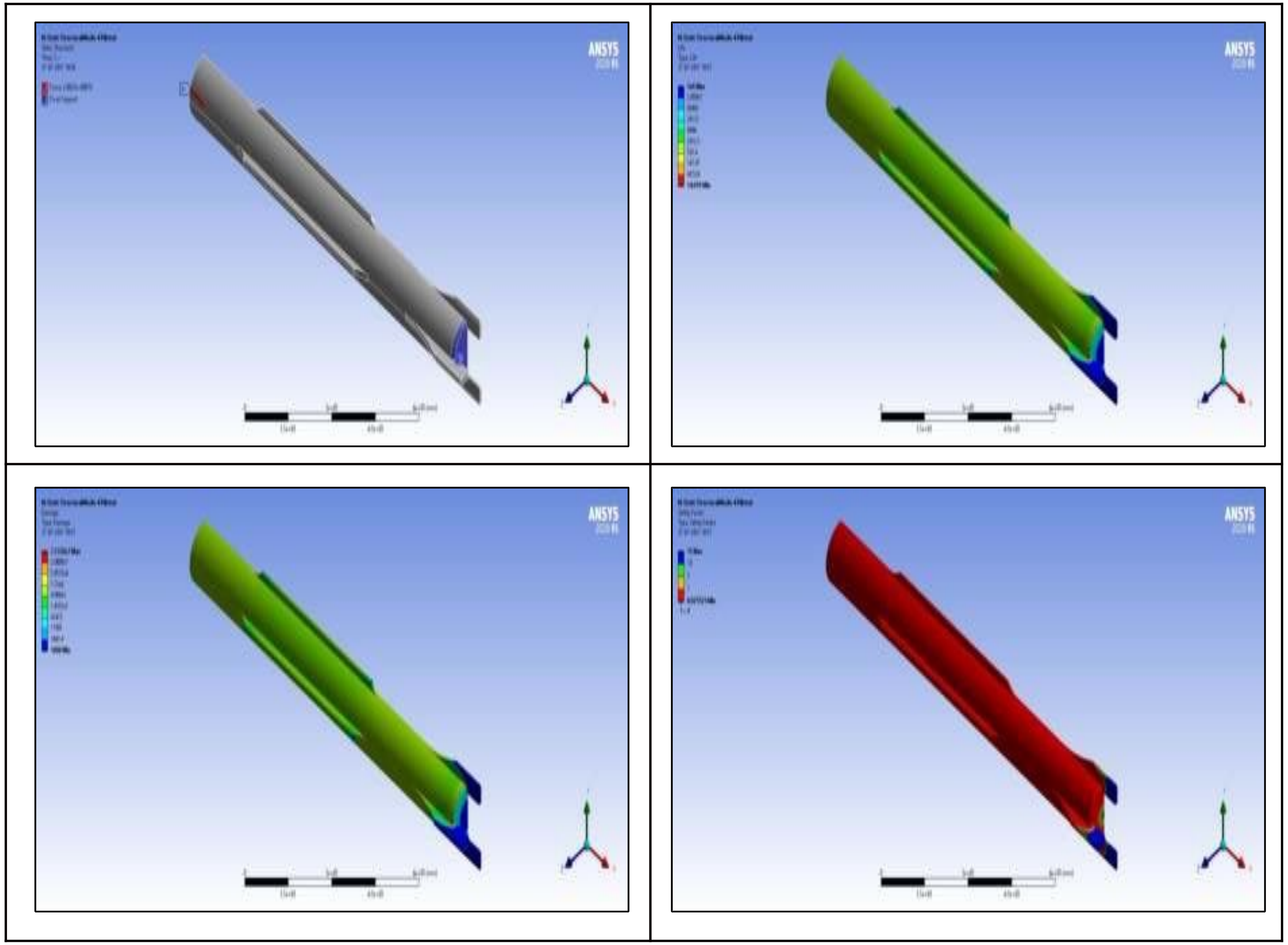
Static structural analysis for missile 4 - sharp



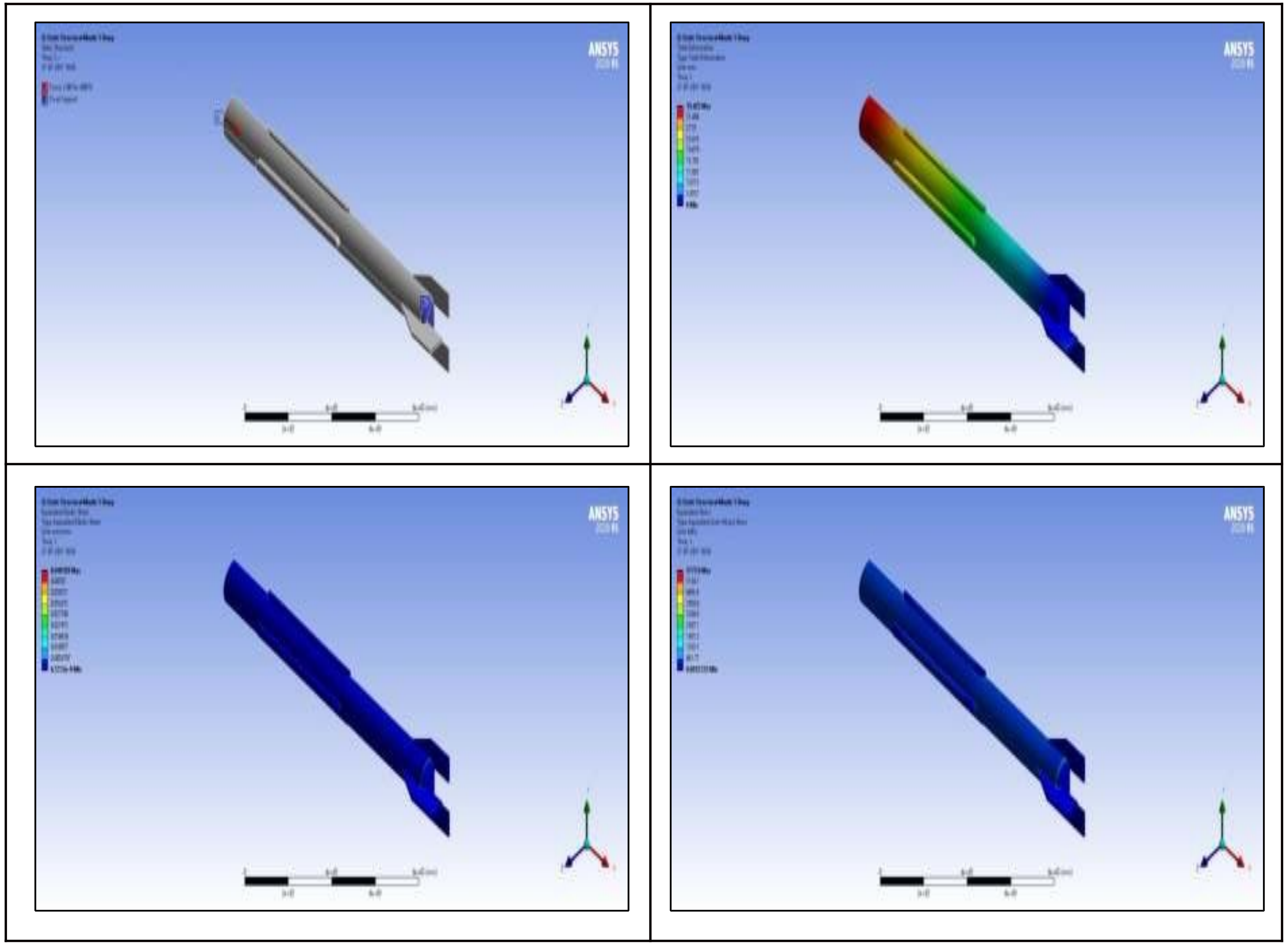
Fatigue analysis for missile 4 - sharp



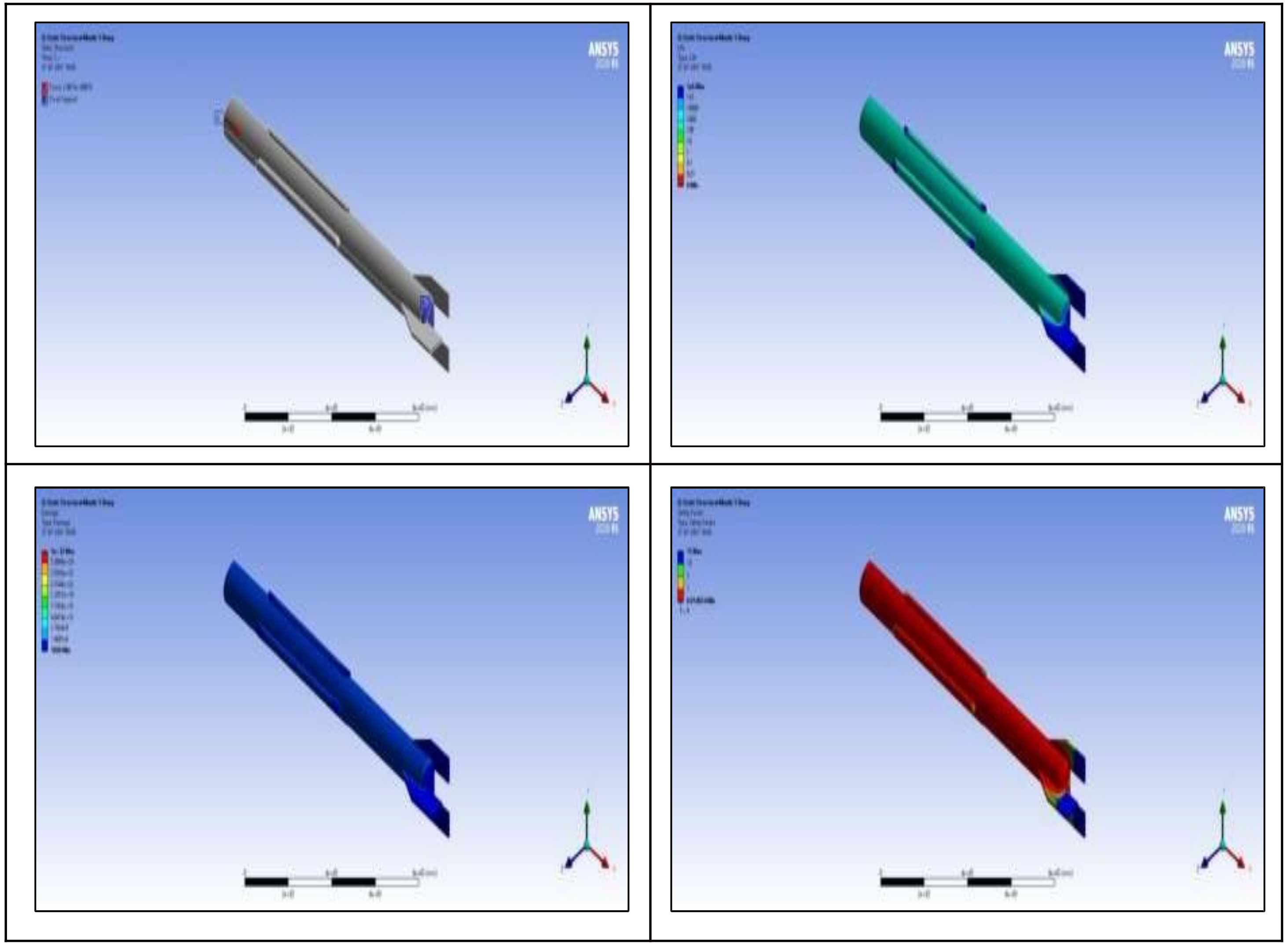
Static structural analysis for missile 4 - filleted



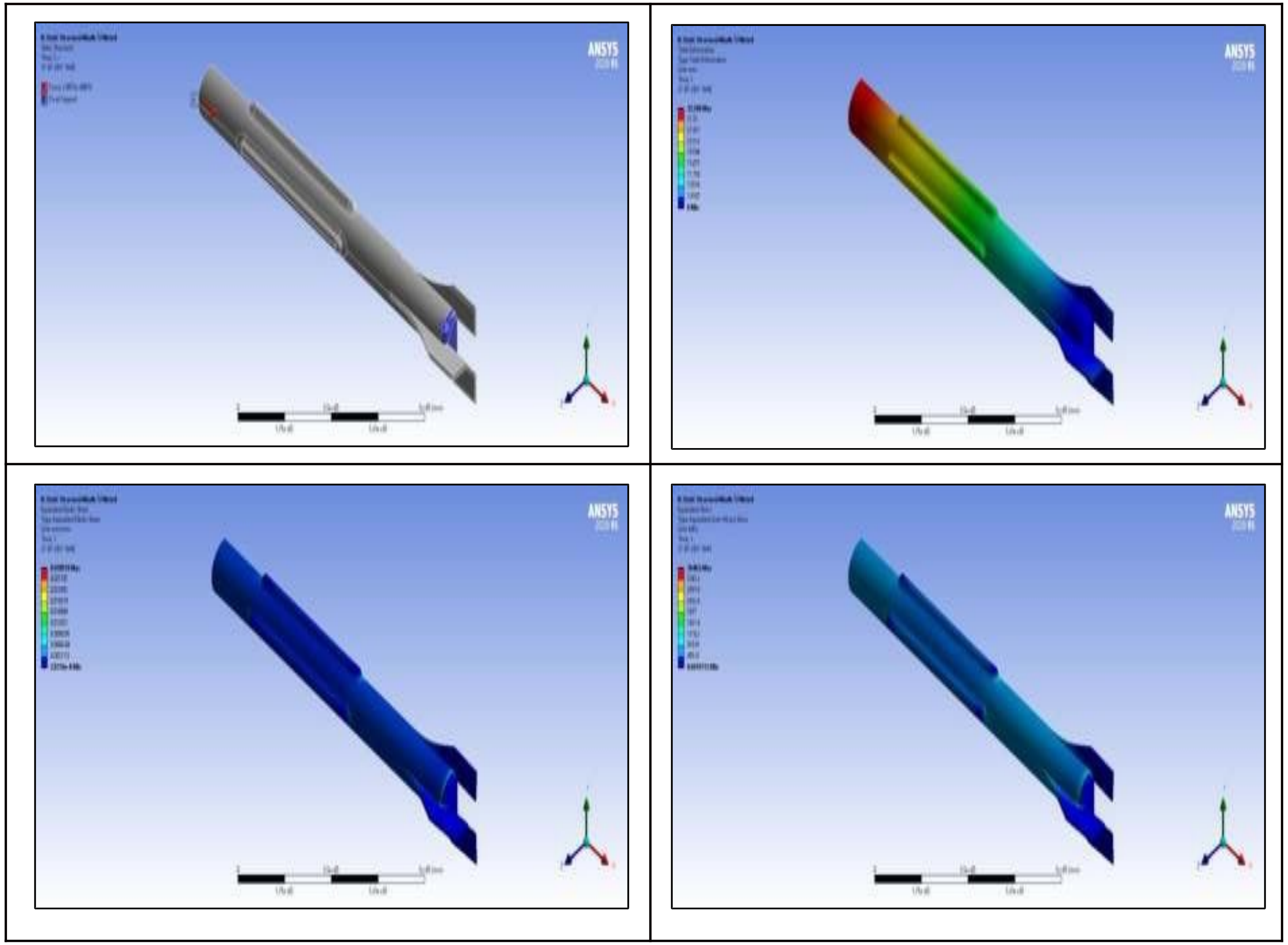
Fatigue analysis for missile 4 - filleted



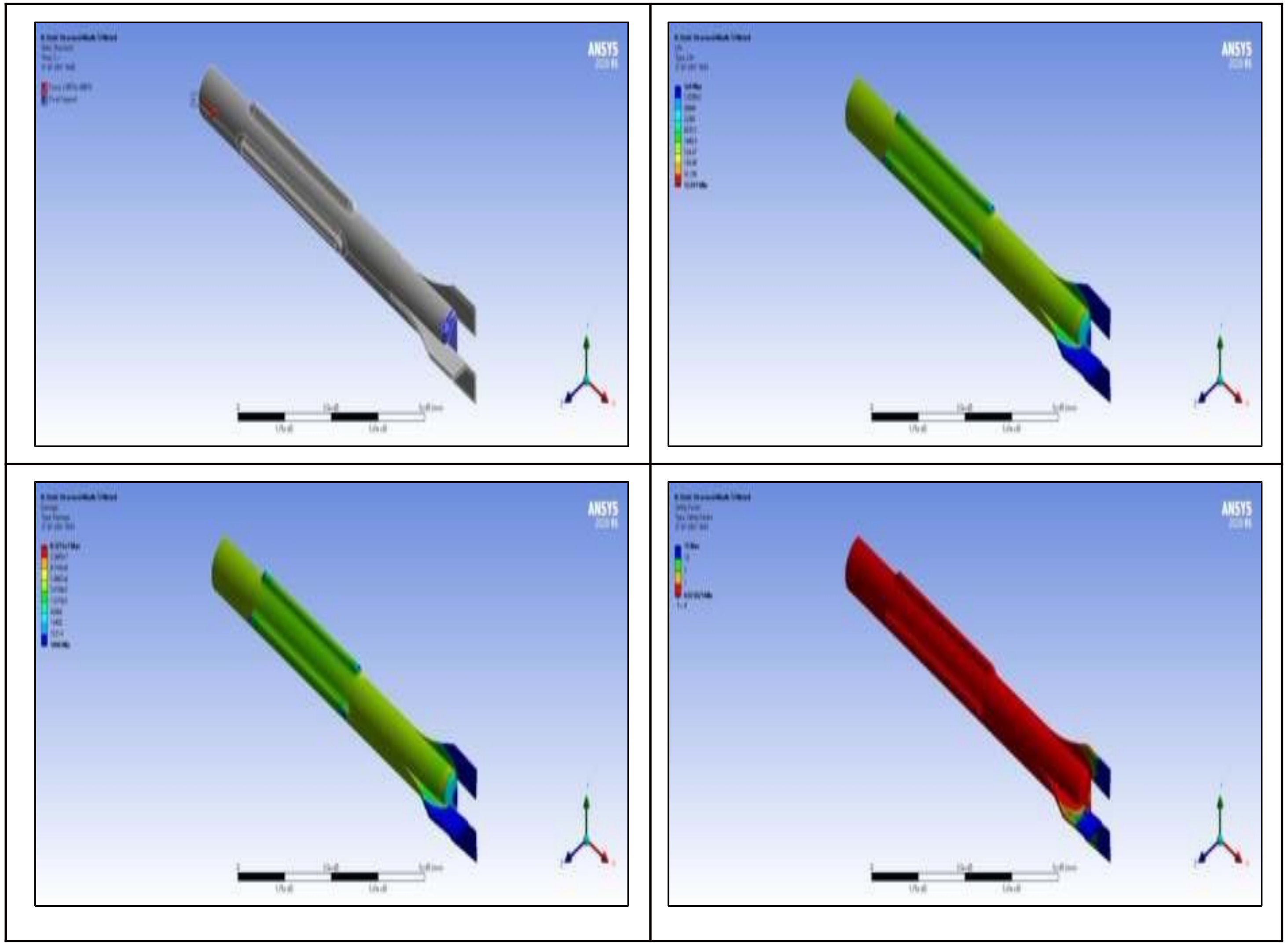
Static structural analysis for missile 5 - sharp



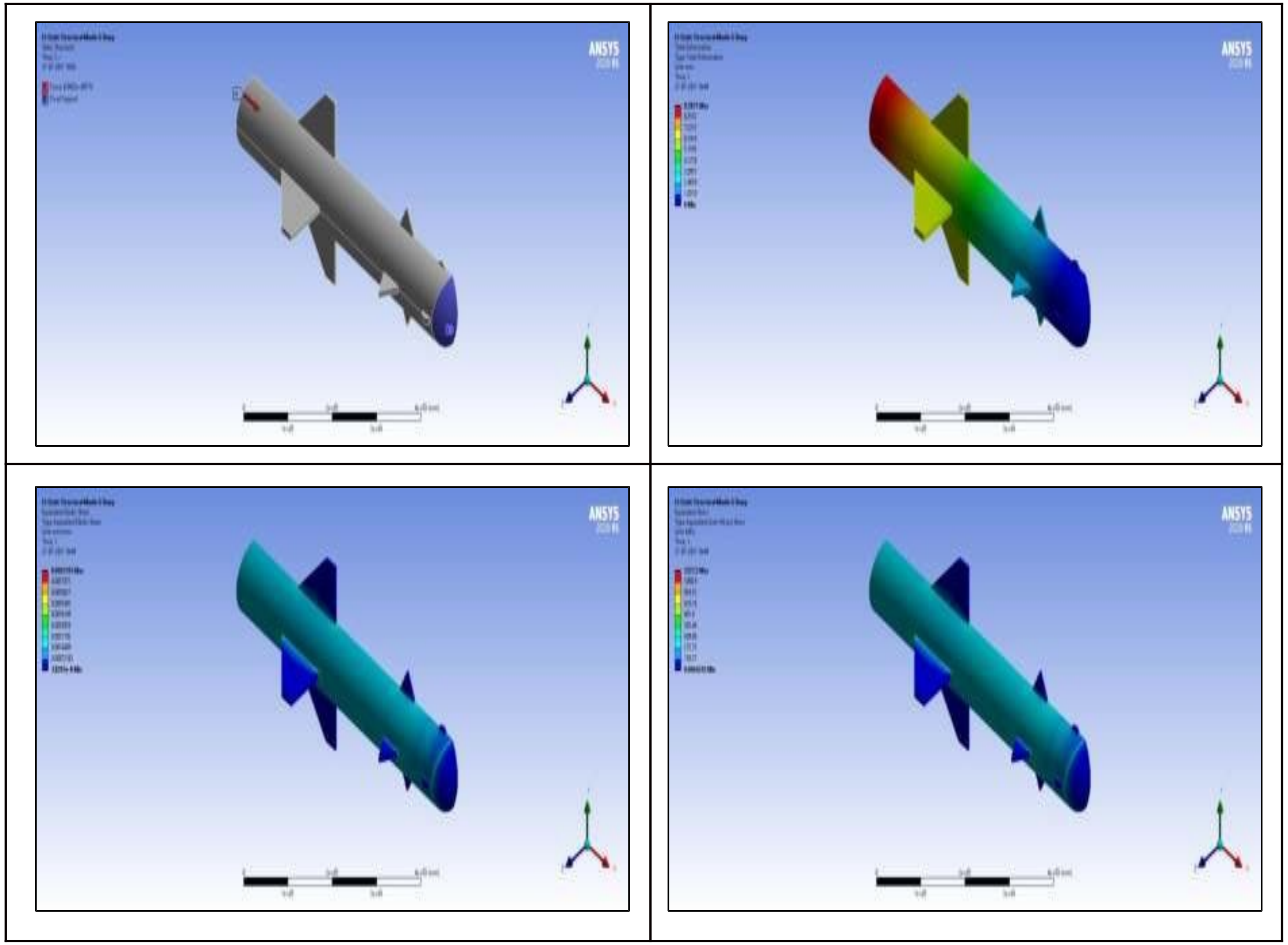
Fatigue analysis for missile 5 - sharp



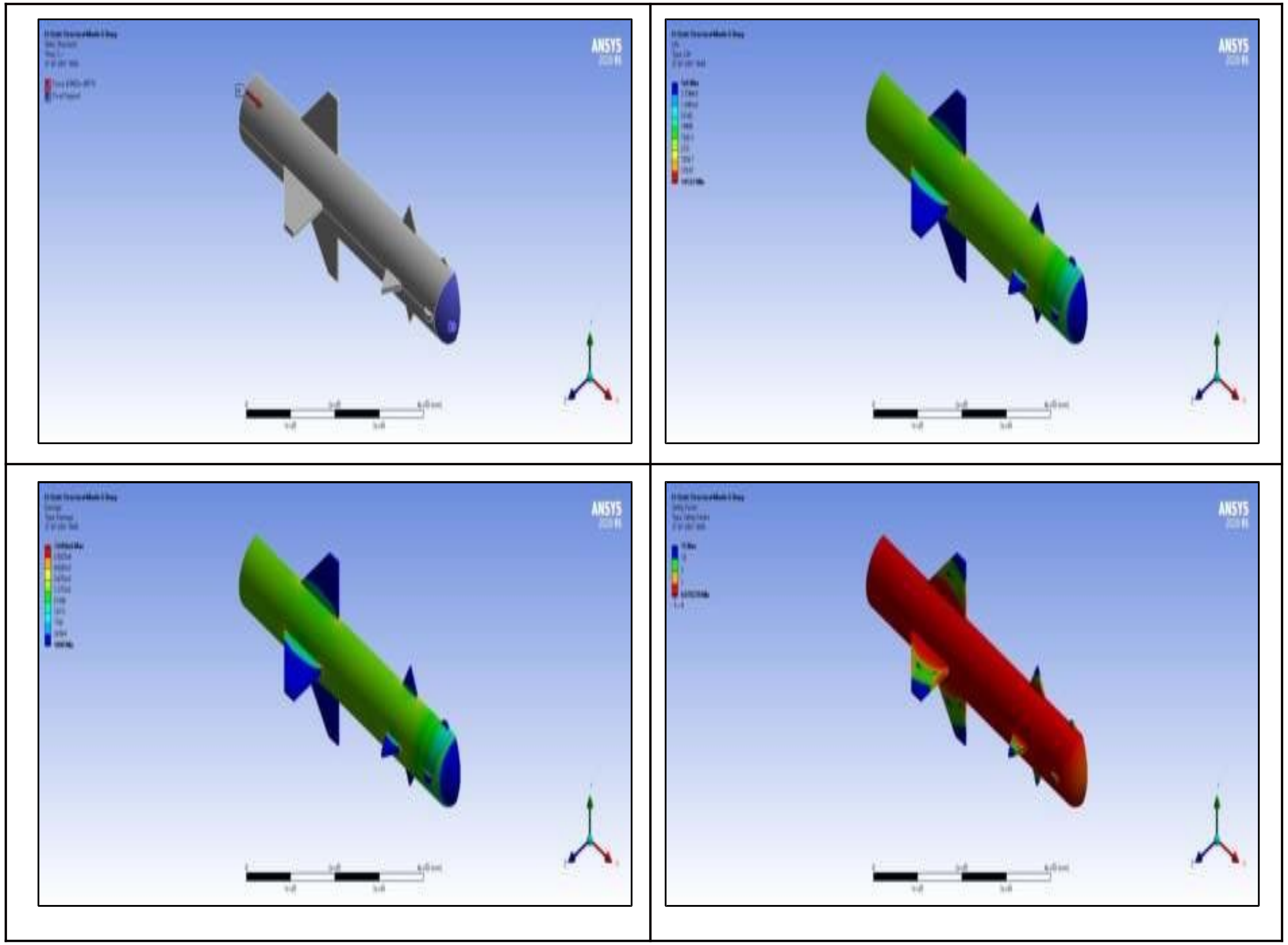
Static structural analysis for missile 5 - filleted



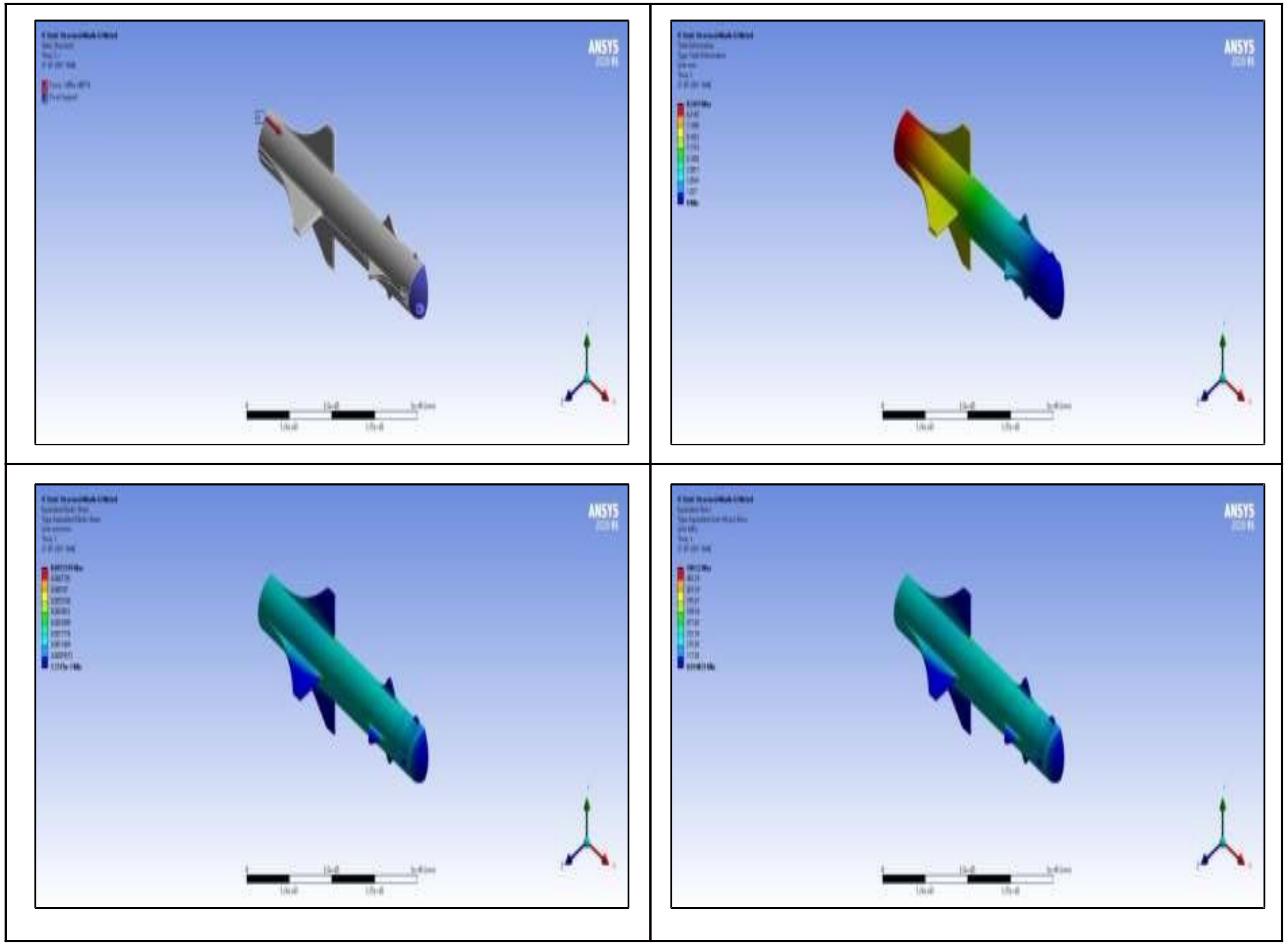
Fatigue analysis for missile 5 - filleted



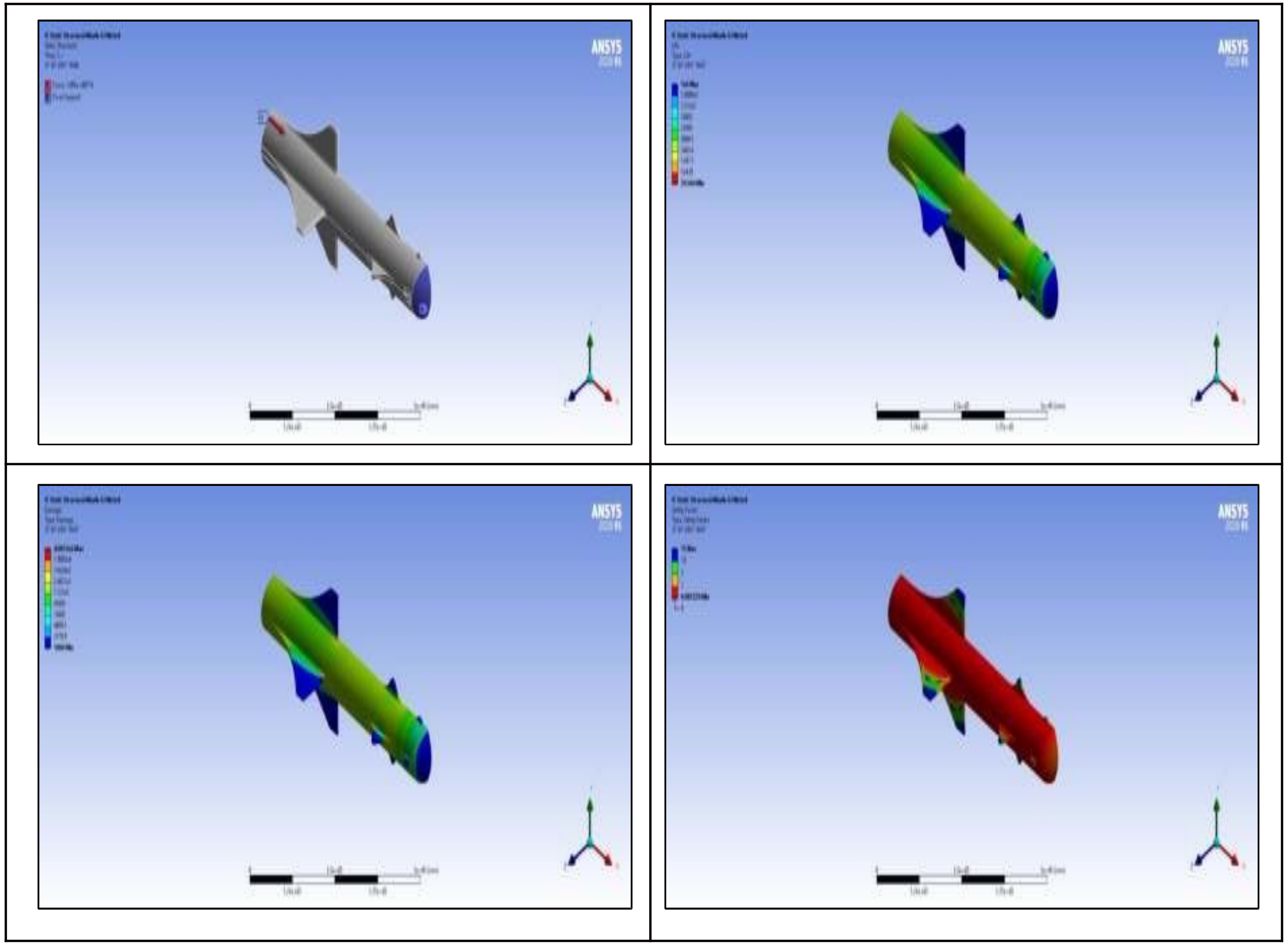
Static structural analysis for missile 6 - sharp



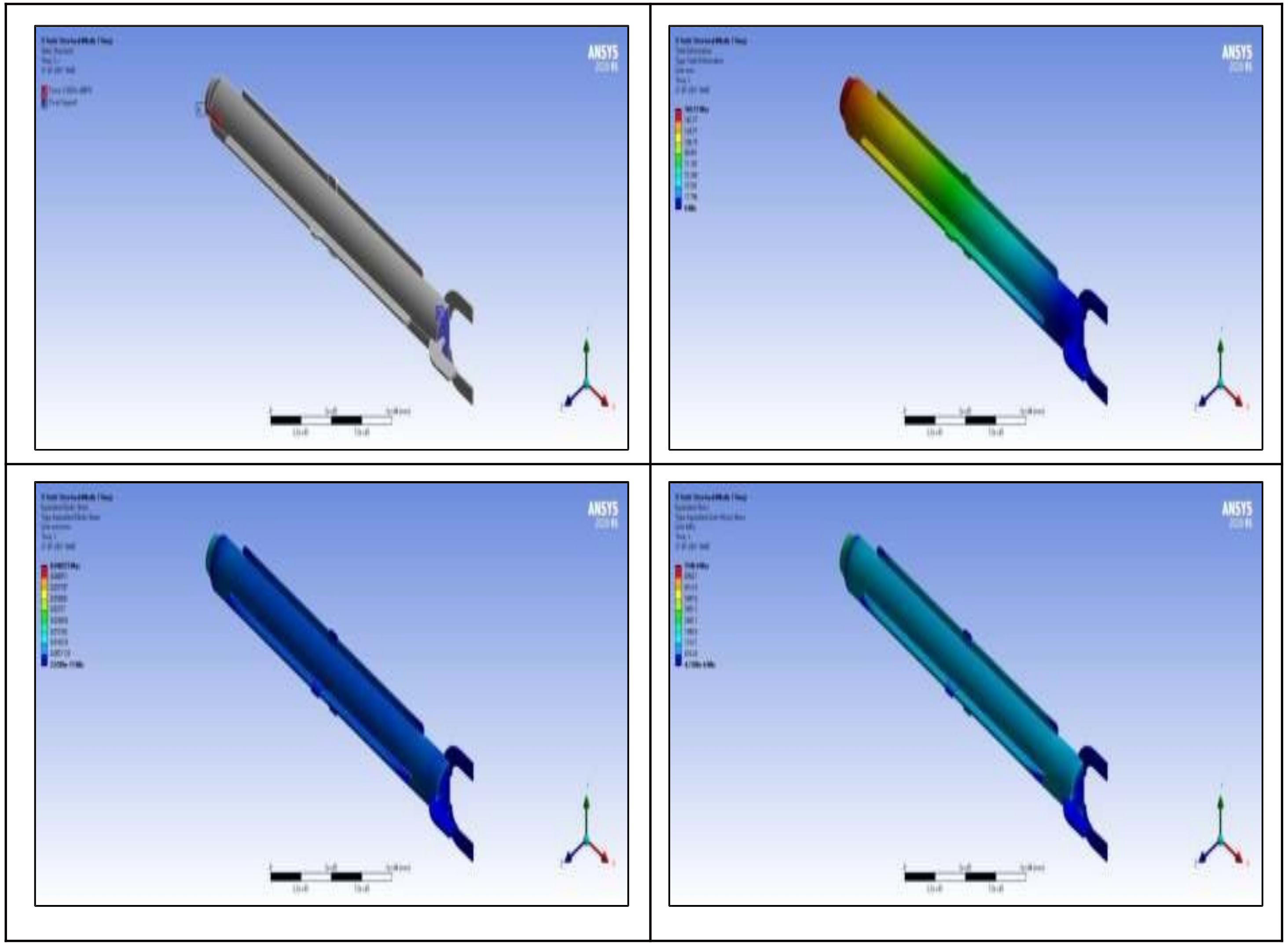
Fatigue analysis for missile 6 - sharp



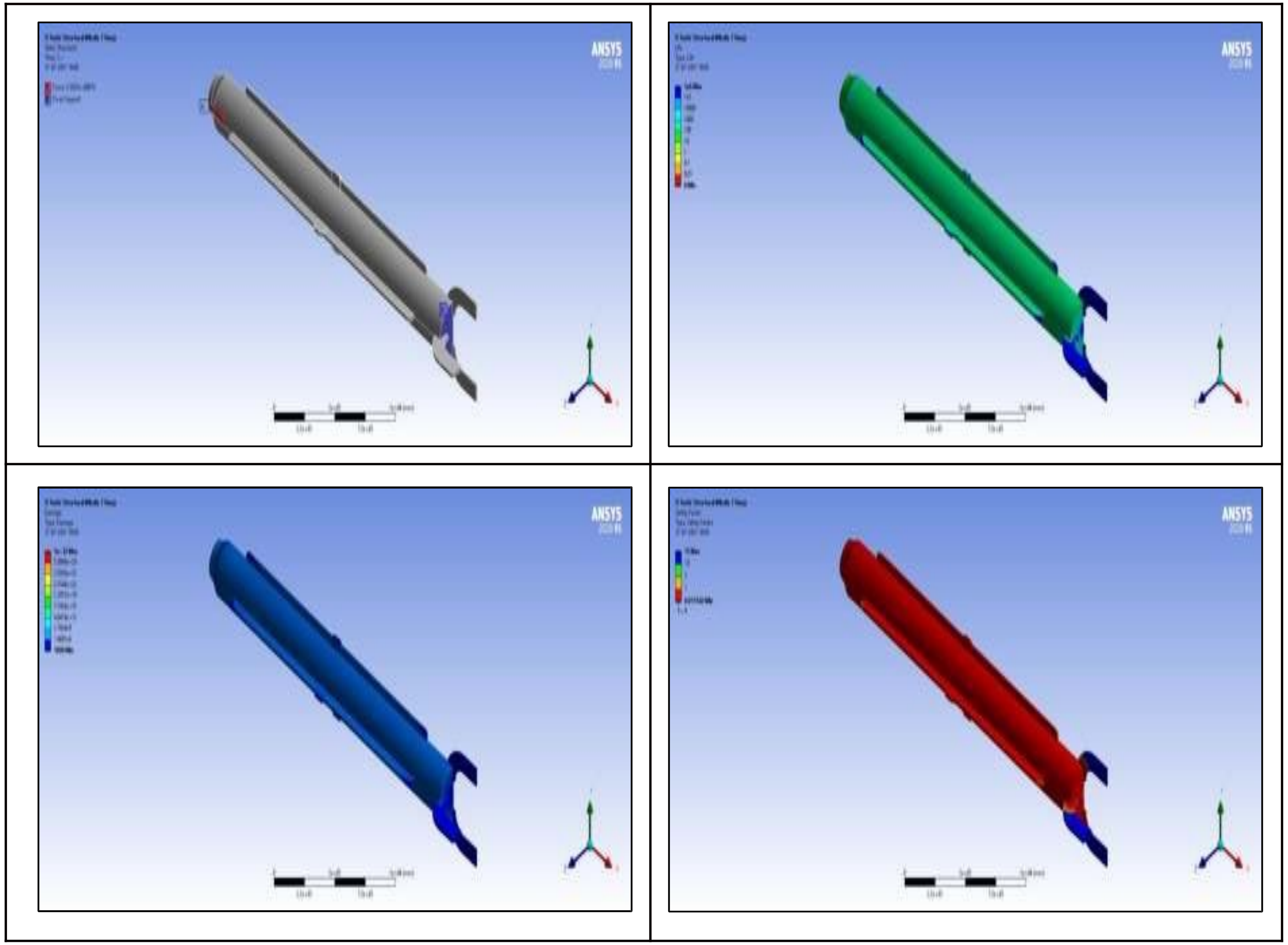
Static structural analysis for missile 6 - filleted



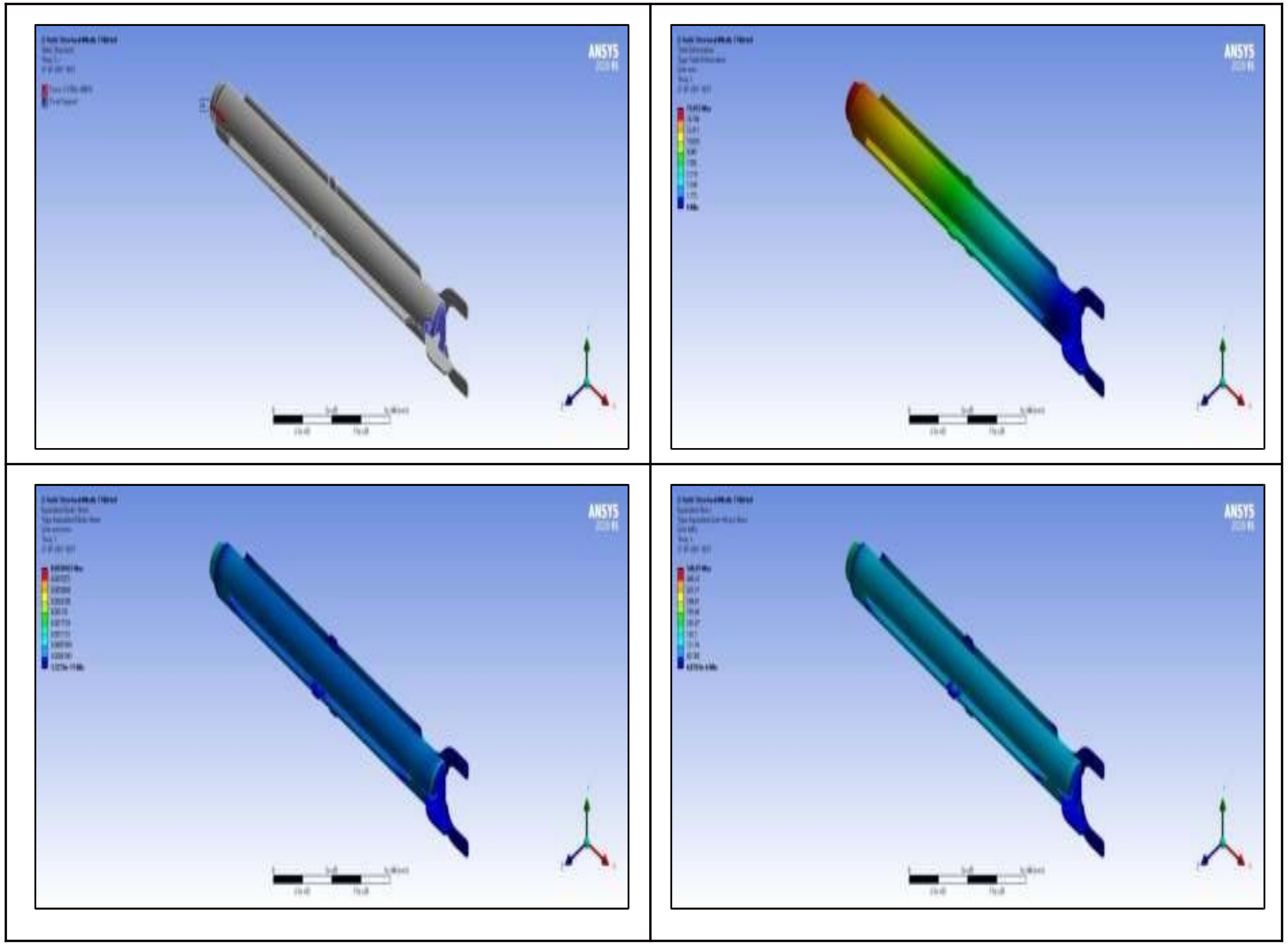
Fatigue analysis for missile 6 - filleted



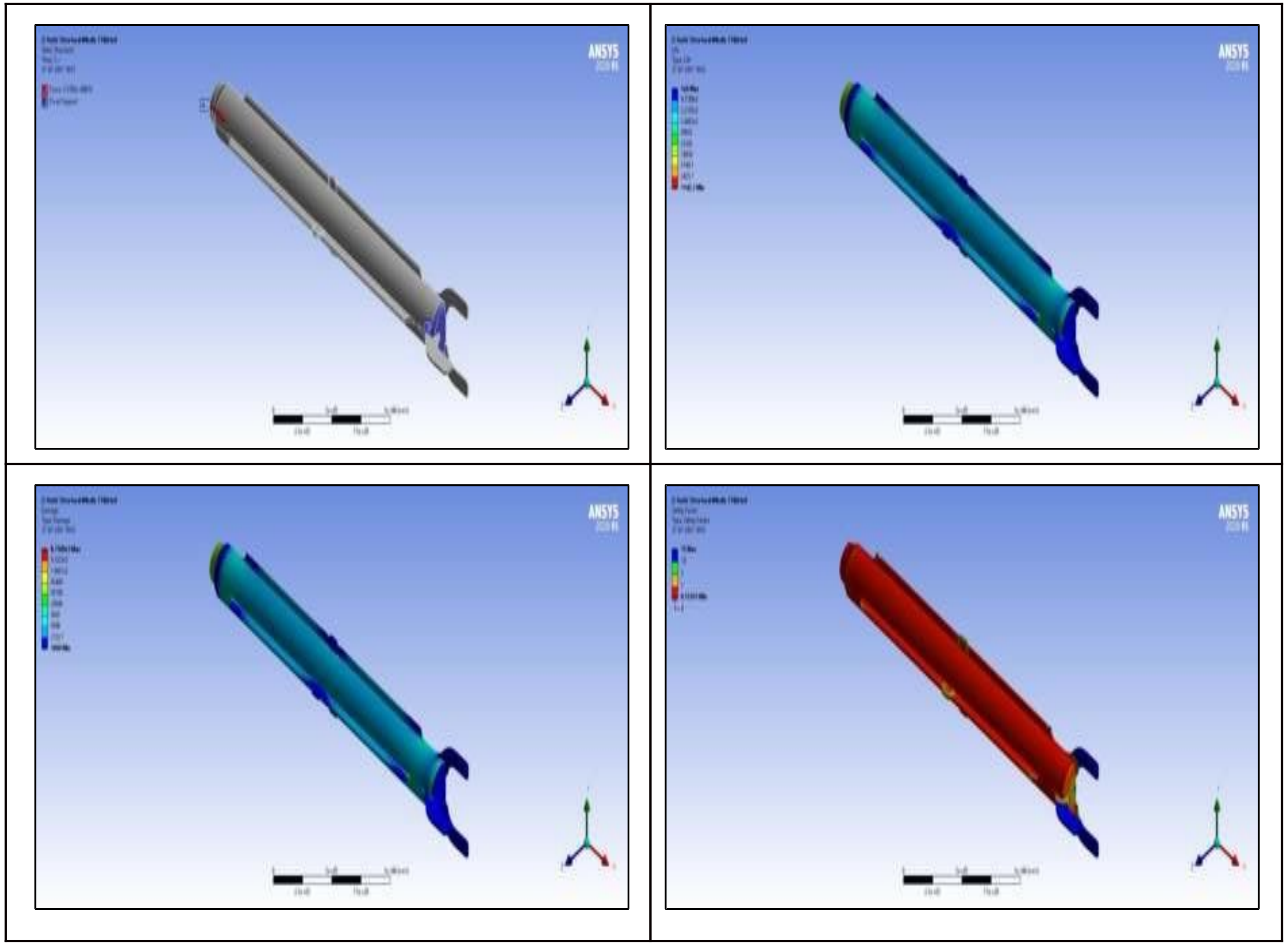
Static structural analysis for missile 7 - sharp



Fatigue analysis for missile 7 - sharp



Static structural analysis for missile 7 - filleted



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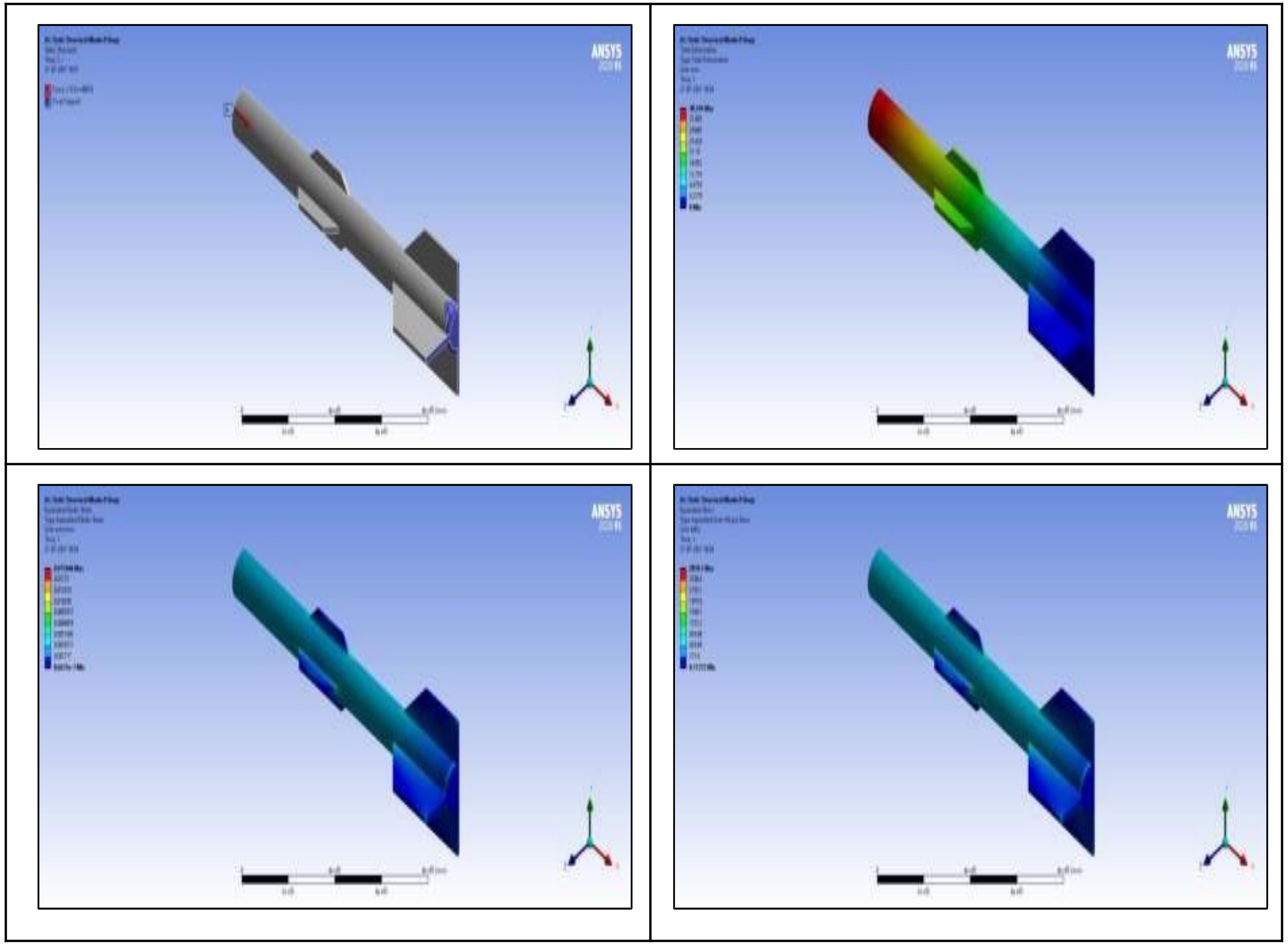
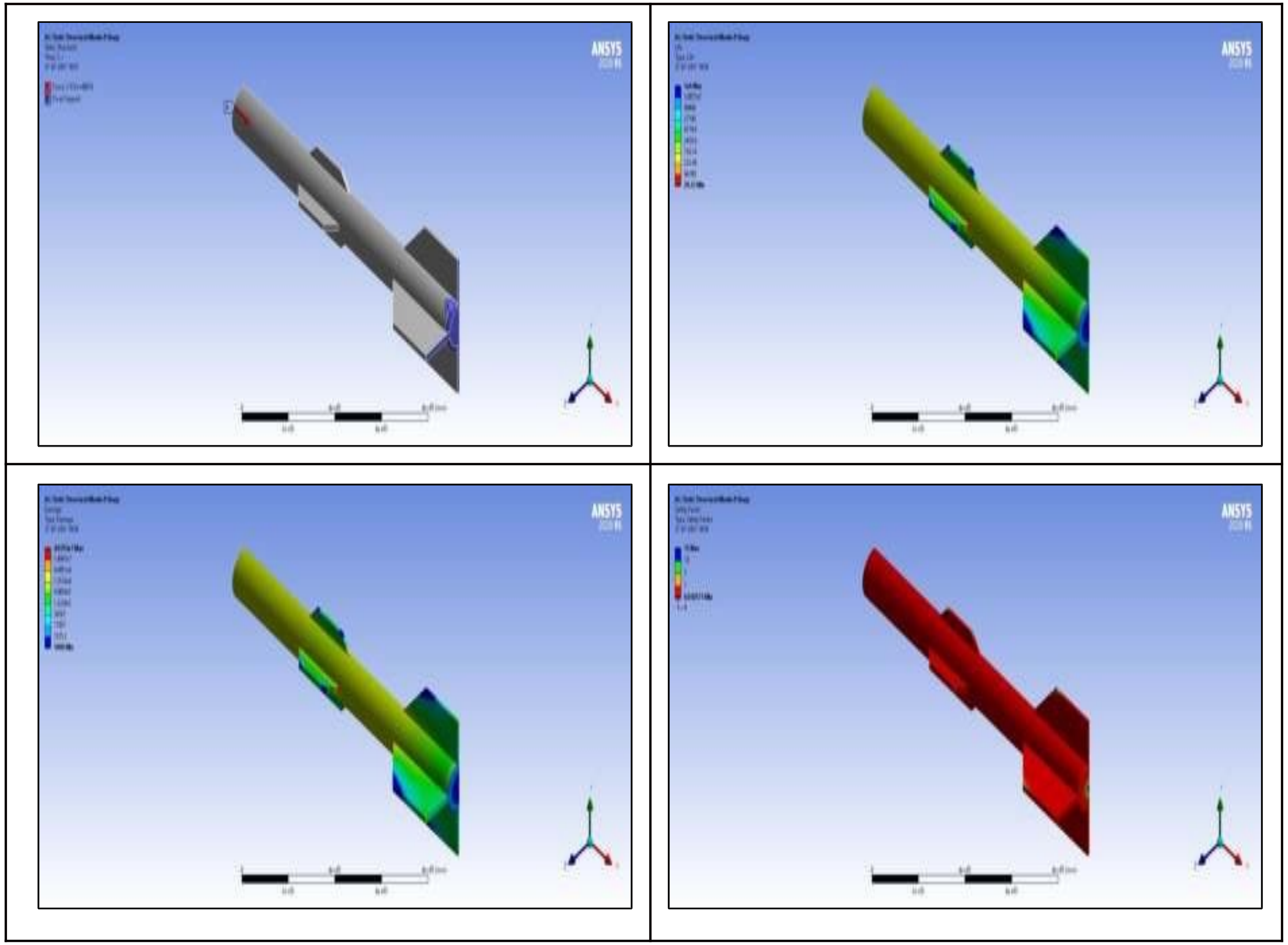
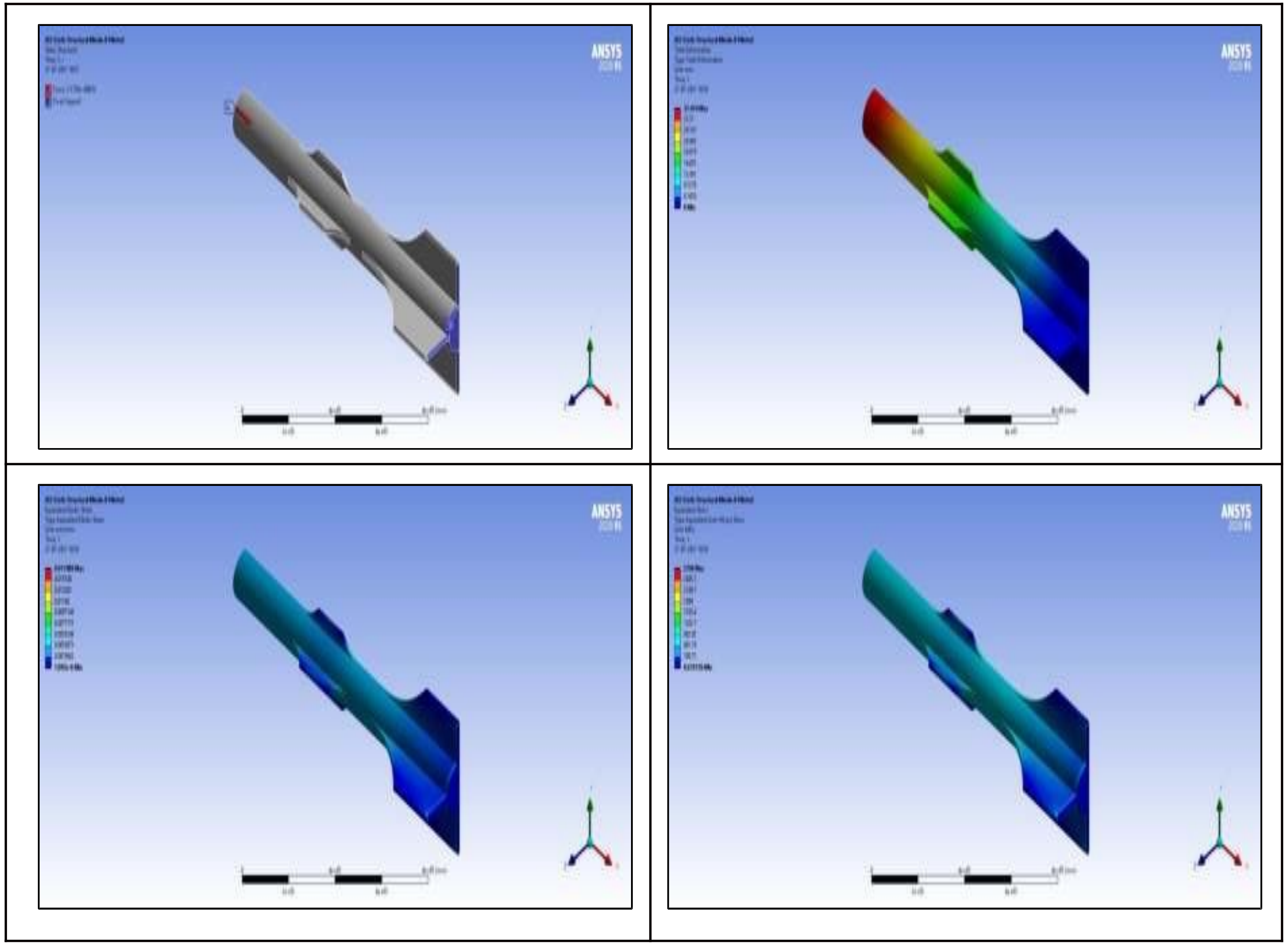


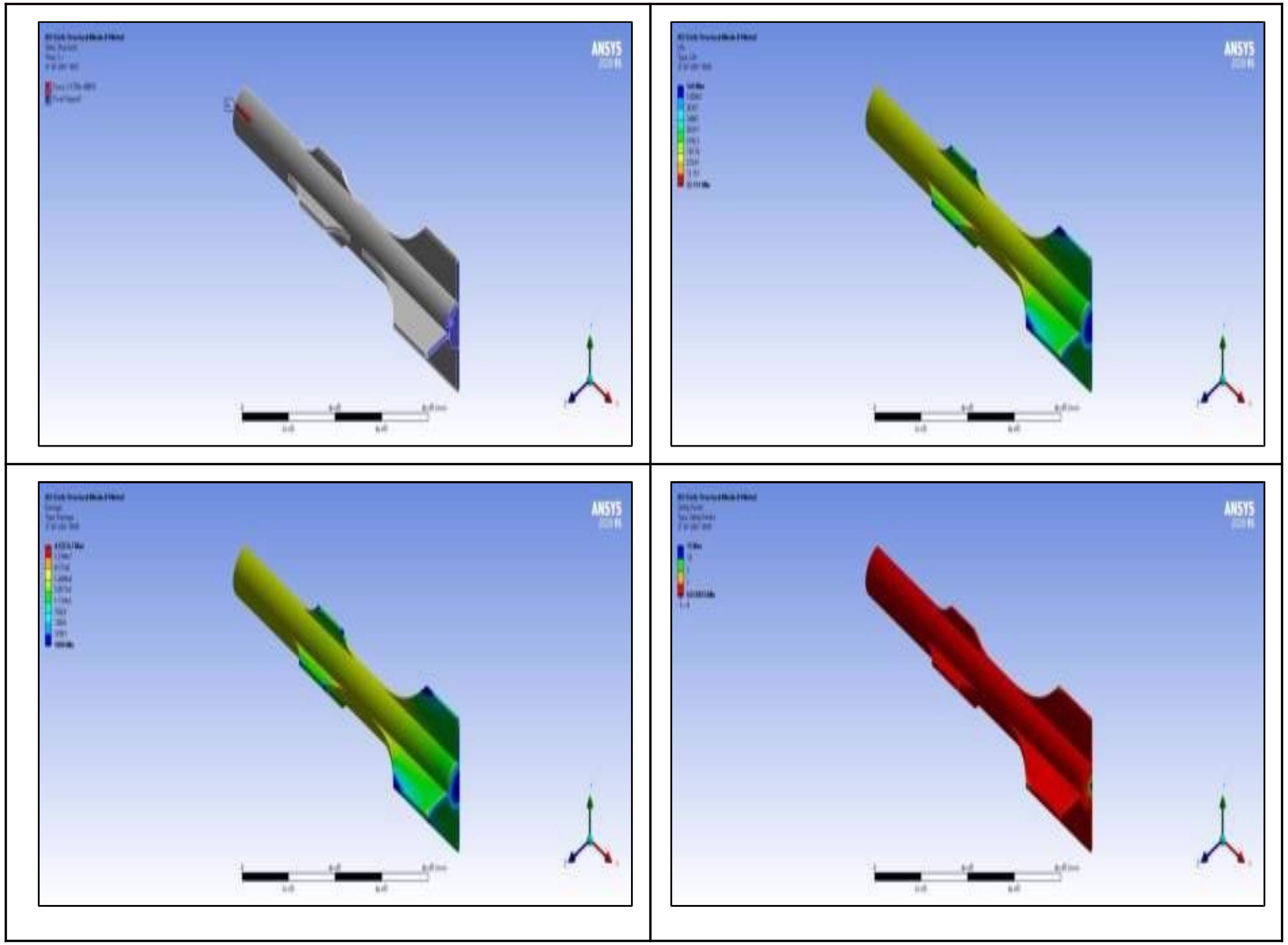
Static structural analysis for missile 8 - sharp



Fatigue analysis for missile 8 - sharp



Static structural analysis for missile 8 - filleted



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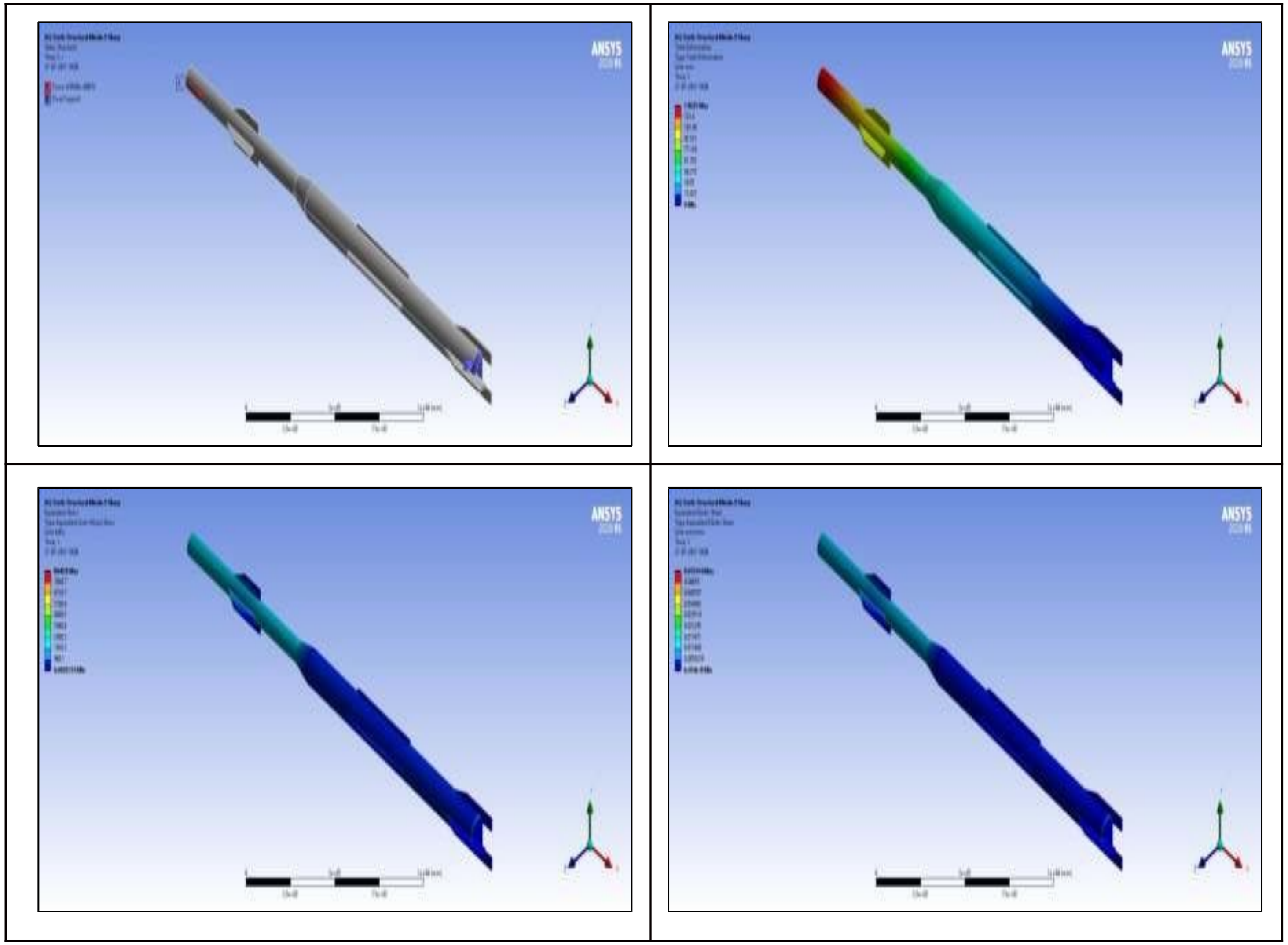
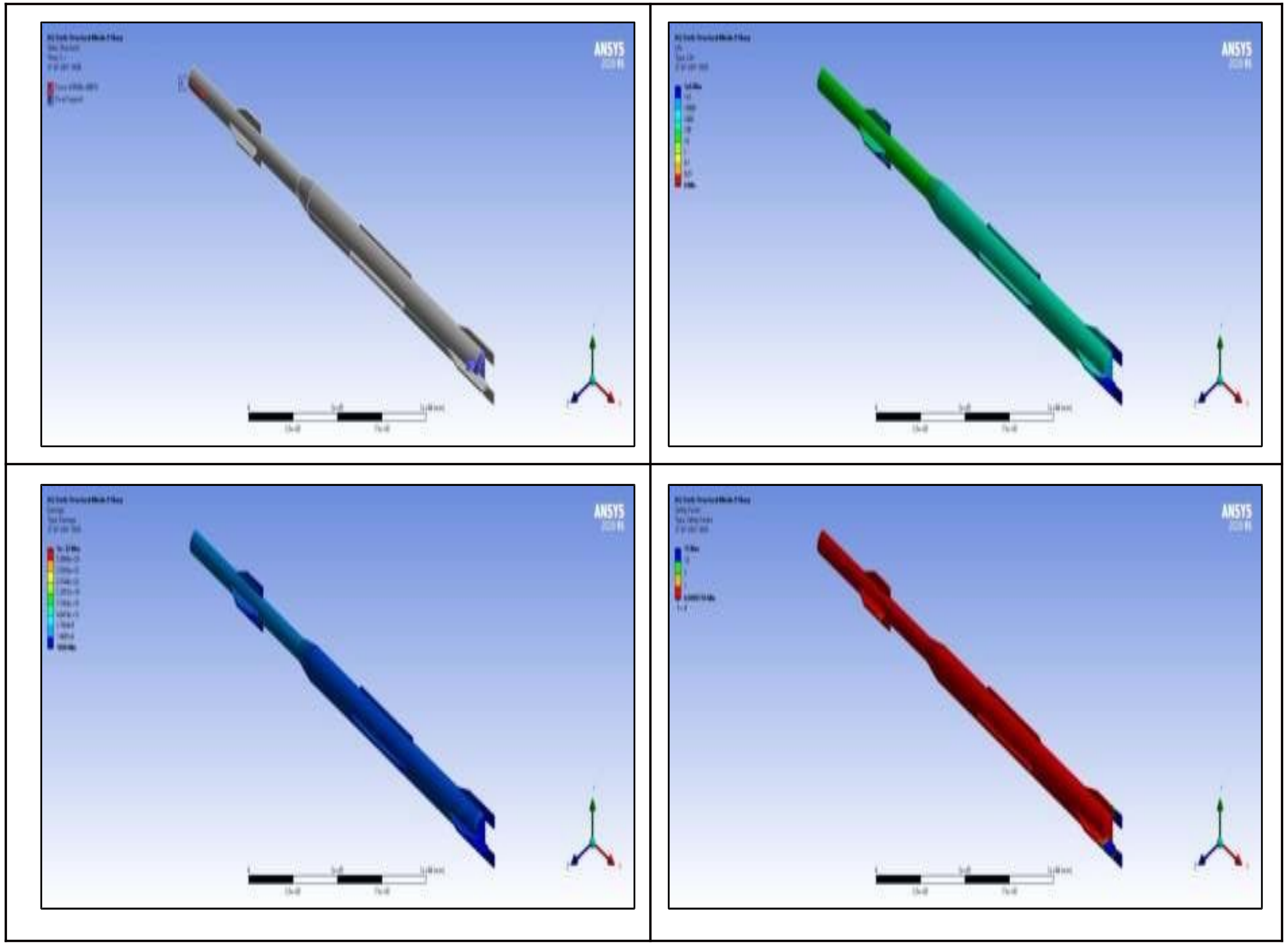
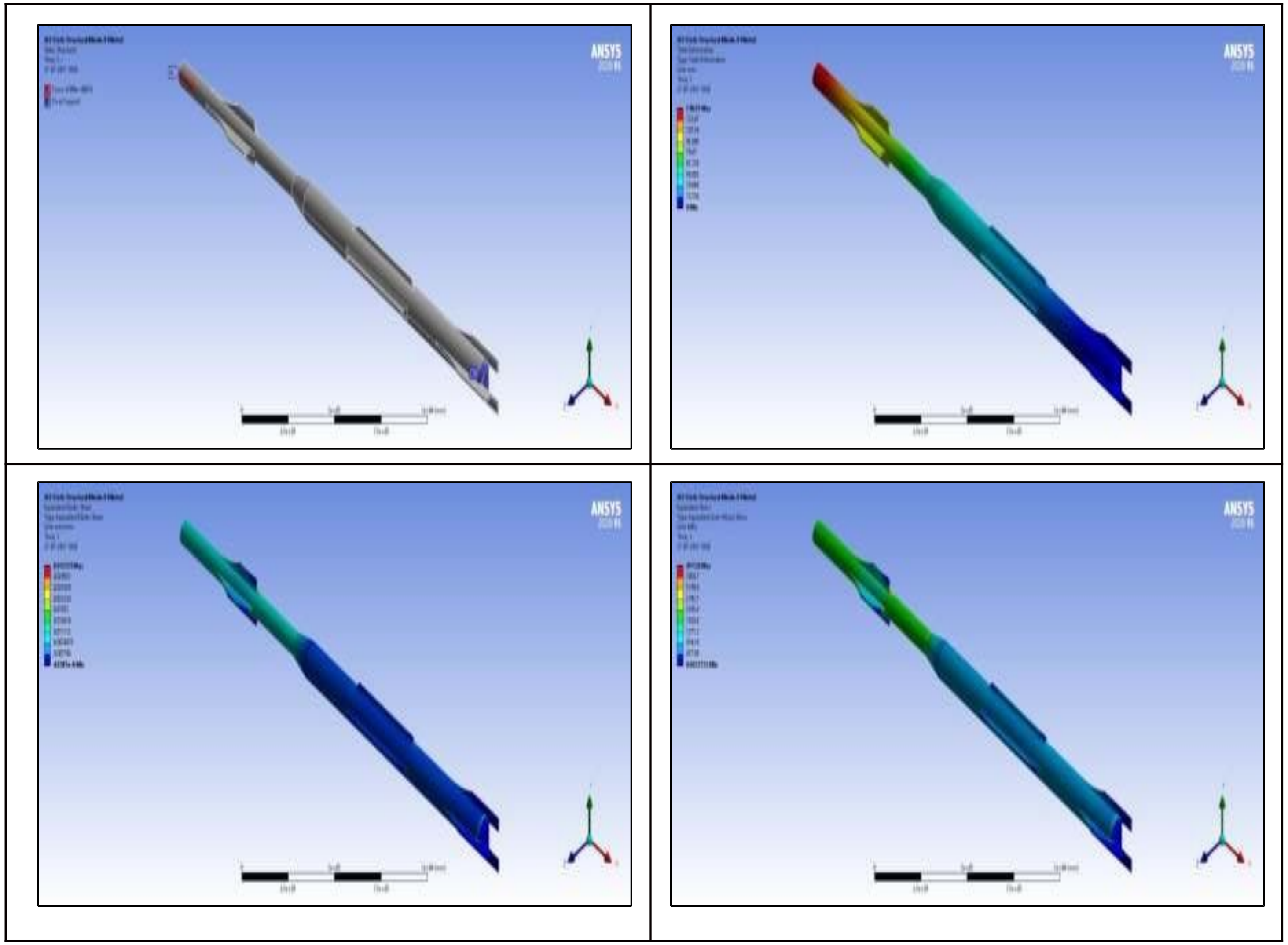


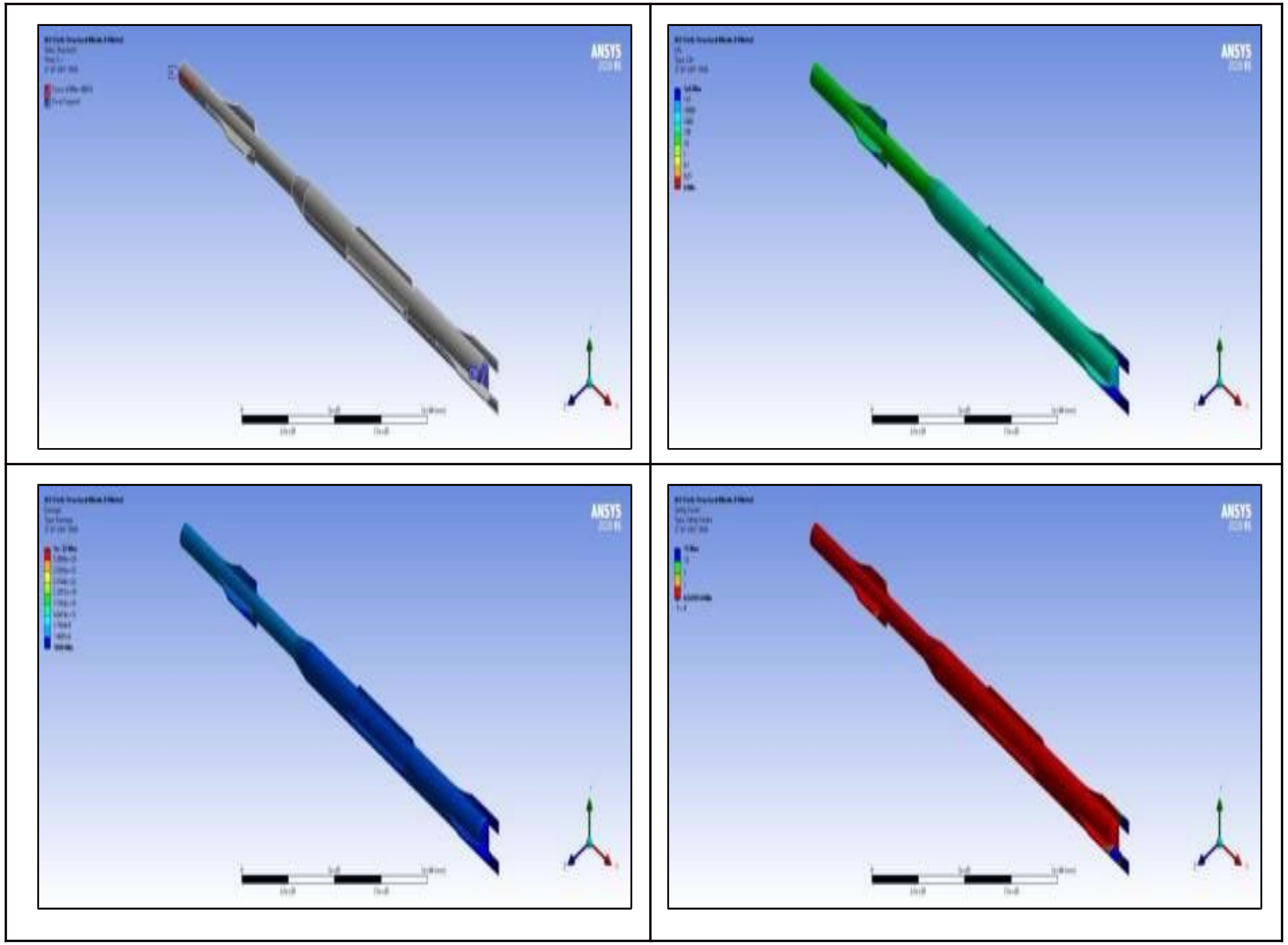
Static structural analysis for missile 9 - sharp



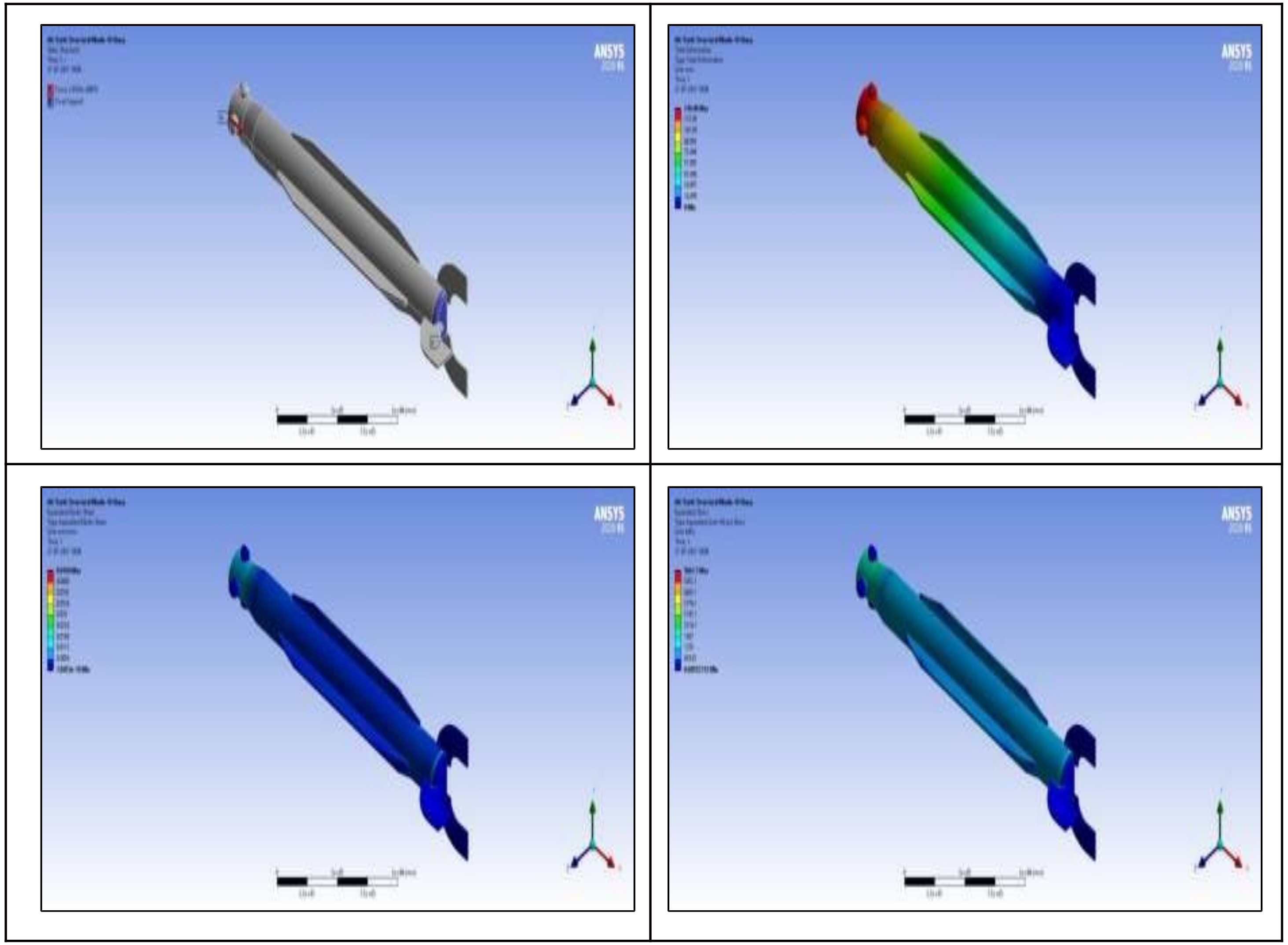
Fatigue analysis for missile 9 - sharp



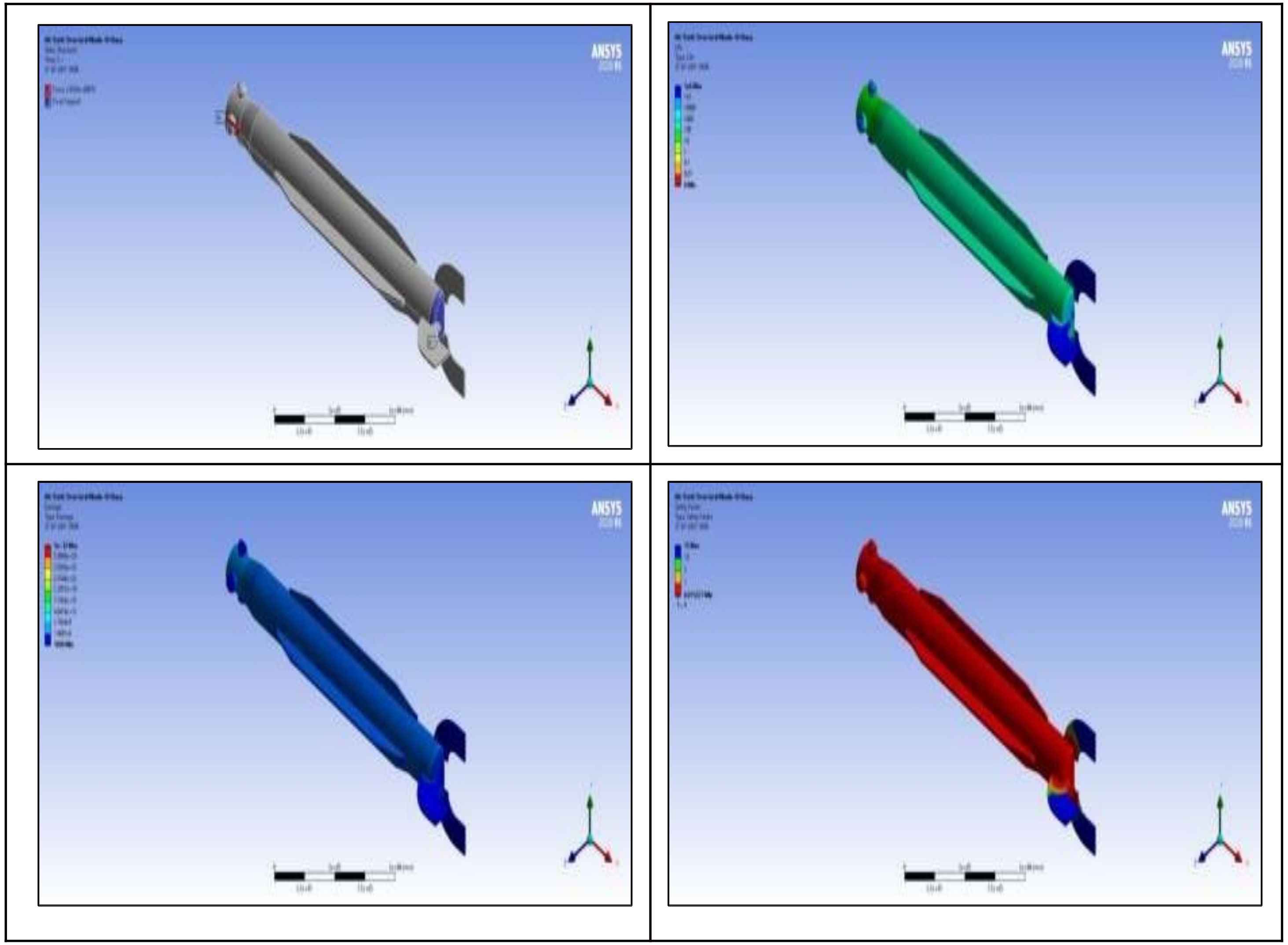
Static structural analysis for missile 9 - filleted



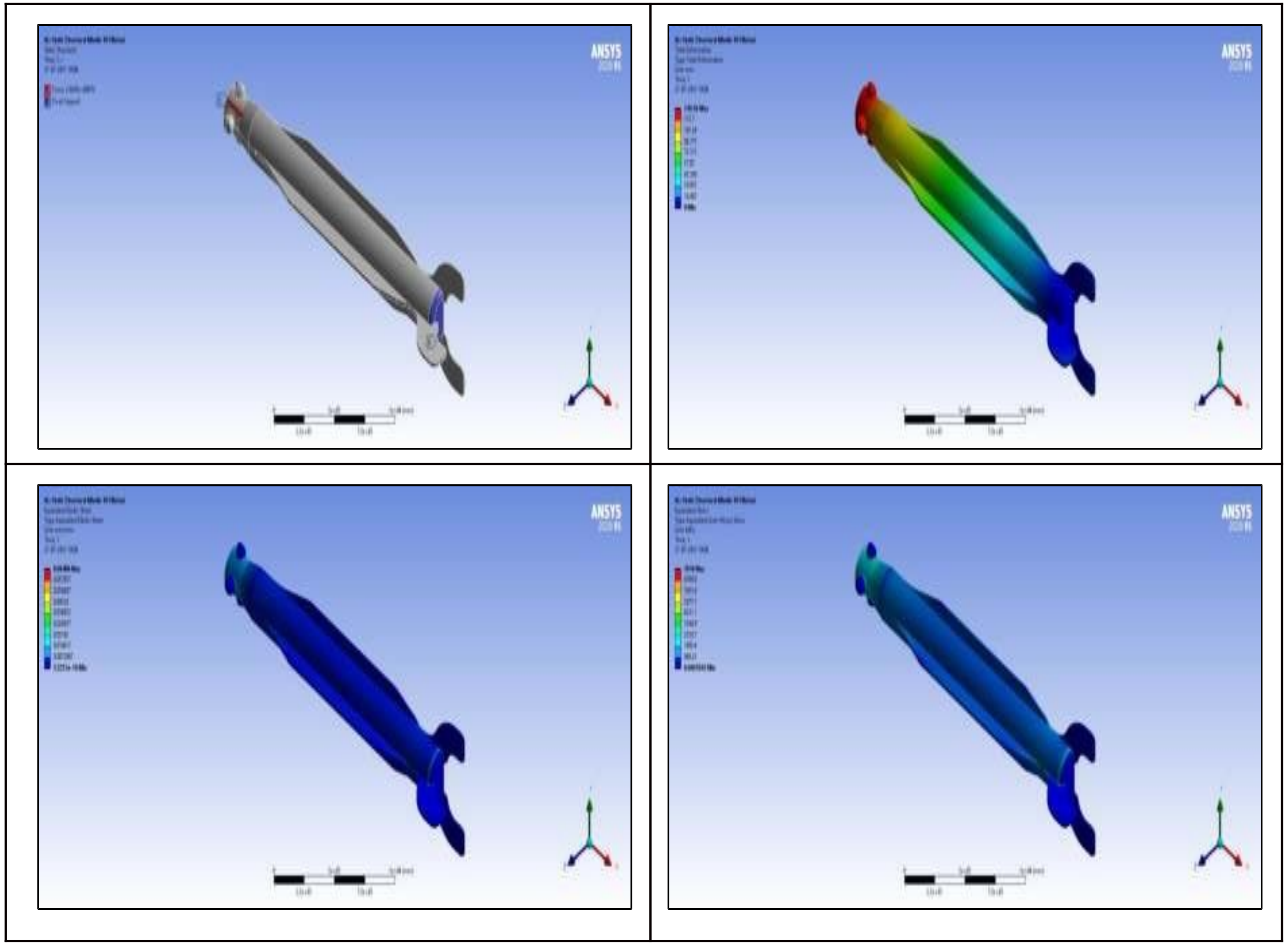
Fatigue analysis for missile 9 - filleted



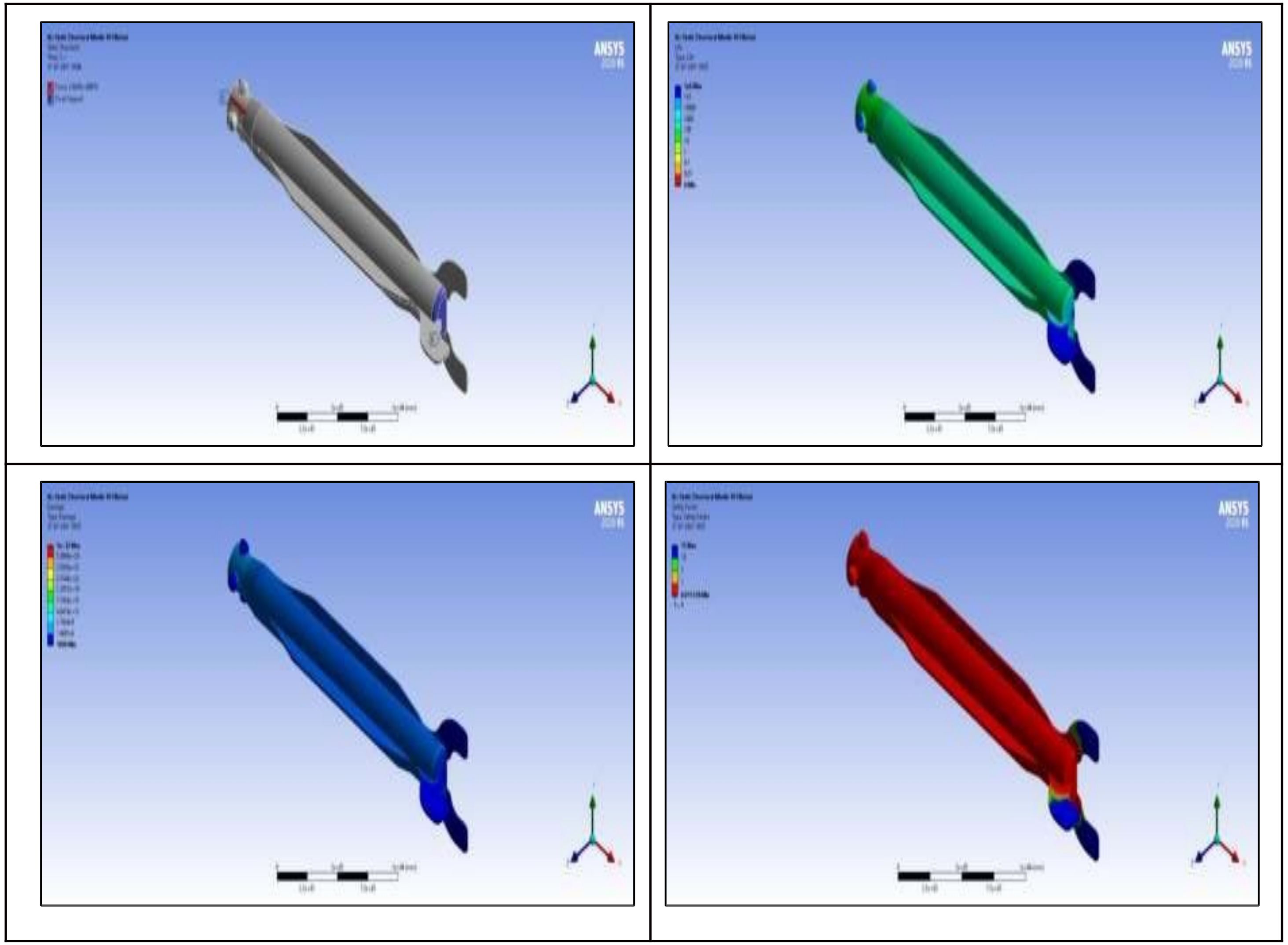
Static structural analysis for missile 10 - sharp



Fatigue analysis for missile 10 - sharp



Static structural analysis for missile 10 - filleted



Fatigue analysis for missile 10 - filleted

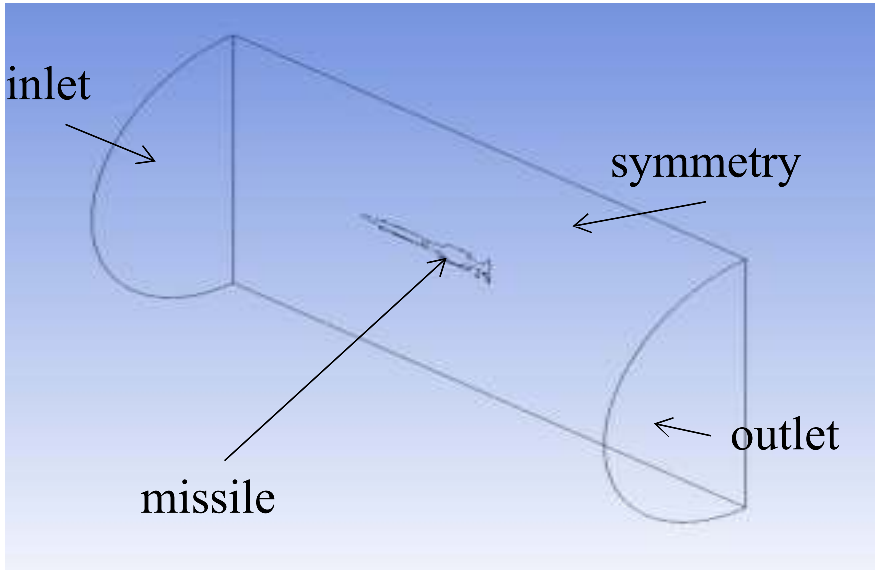
CFD Analysis

CFD analysis are frequently used are for example aerodynamics and hydrodynamics, where quantities such as lift and drag or field properties as pressures and velocities are obtained. From the results obtained the validation of missile shell design is done.

CFD Setup

Scaled with 0.125 factor

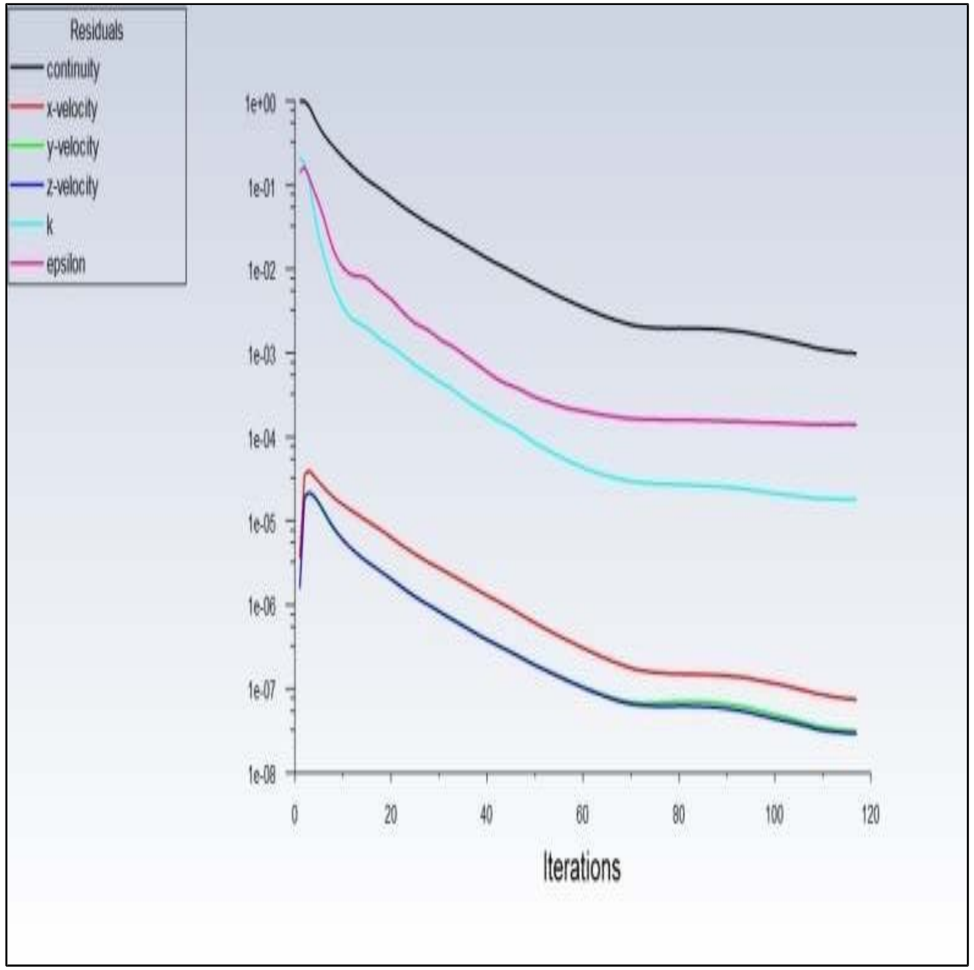
The enclosure was created of cylinder type with radius of 2.5m and +ve direction 5m, -ve direction 2.5m.

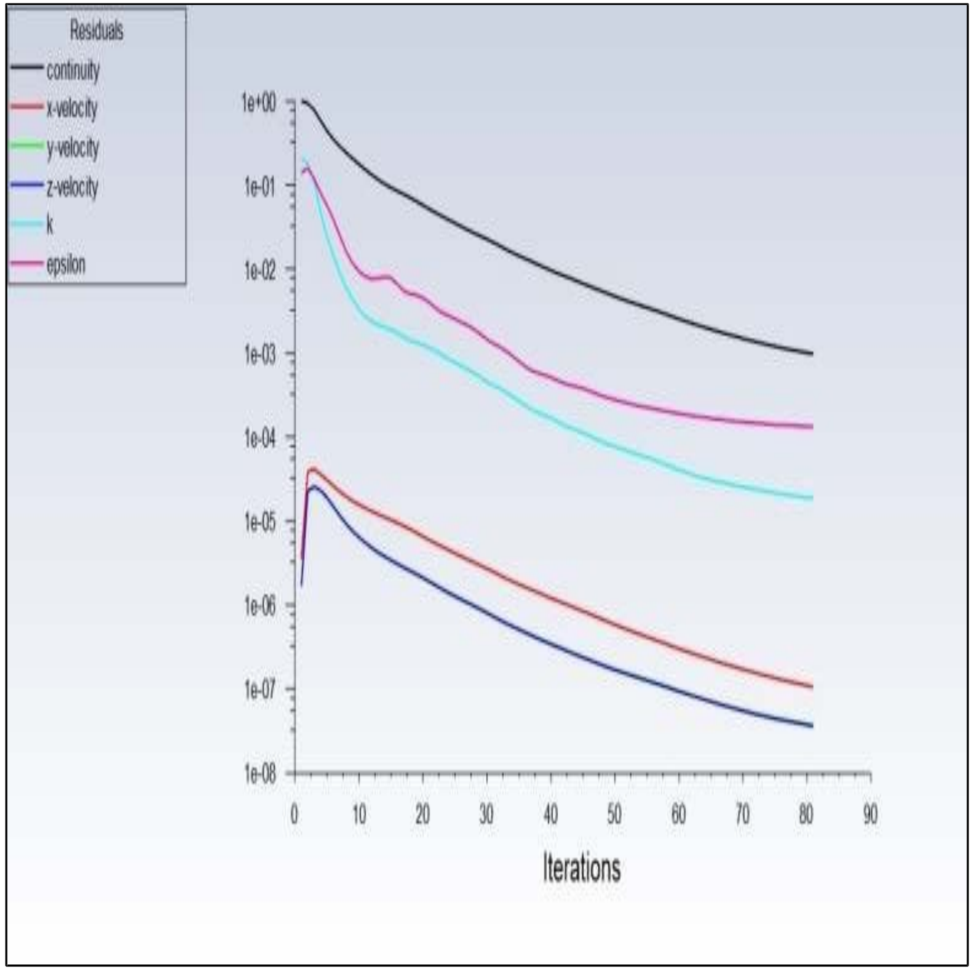


The k-eplsion turbulent model was used.

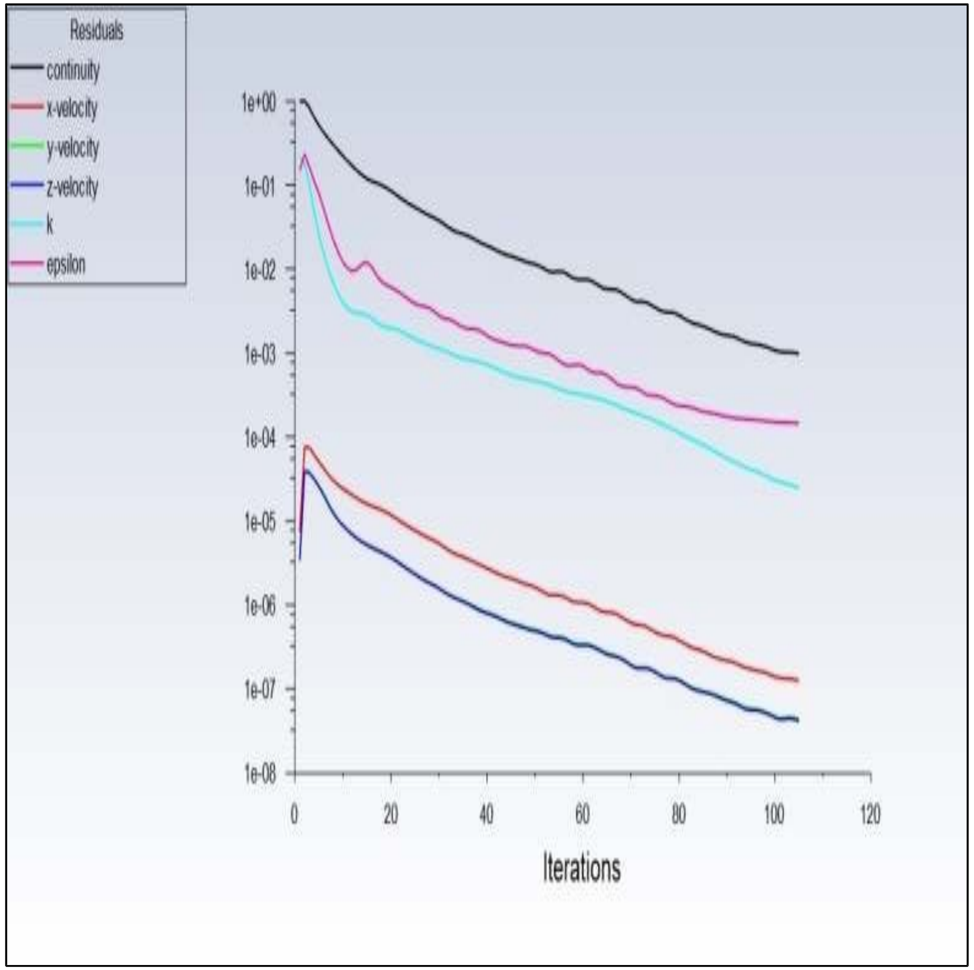
Face	Value
Inlet	5.0m/s (as sclaed to 0.125)
Outlet	OPa (Guage Pressure)
Missile	Wall
Symmetry	Symmetry

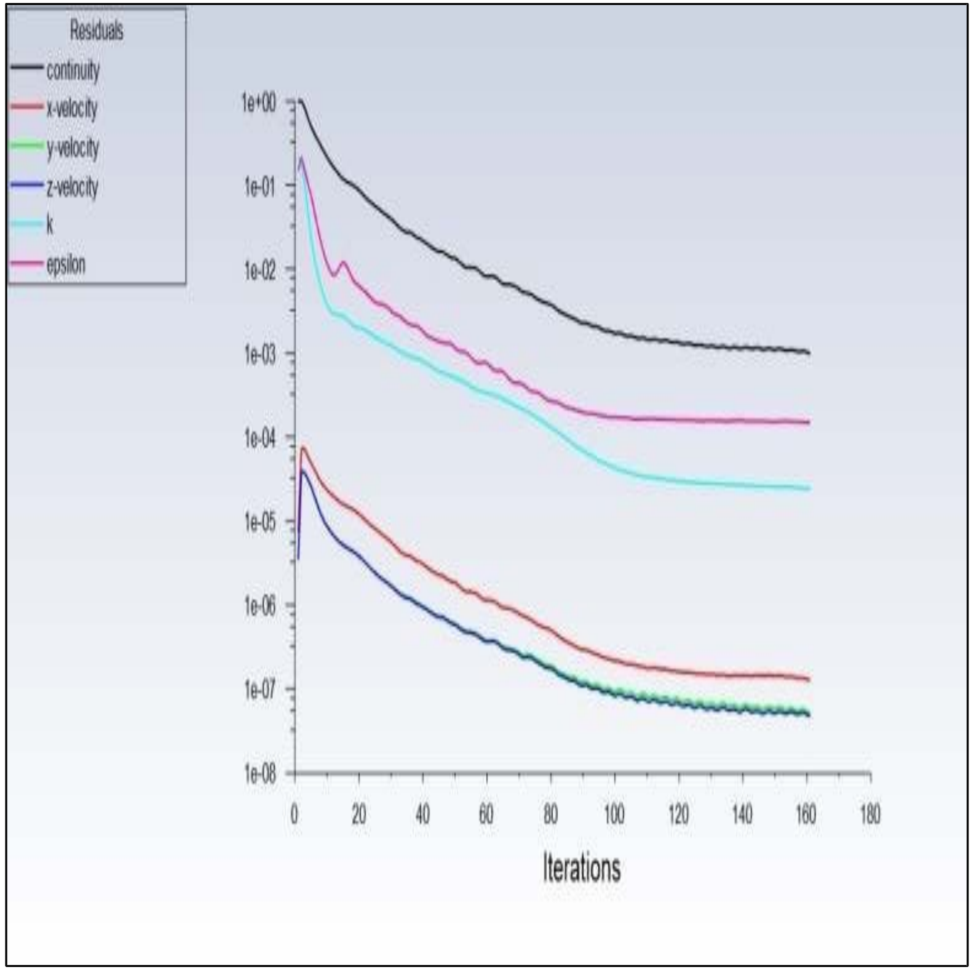
CFD Mesh Details		
Model	Nodes	Elements
Missile 1 Sharp	951684	5141841
Missile 1 Filleted	936310	5063464
Missile 2 Sharp	1961069	10560695
Missile 2 Filleted	1949497	10505577
Missile 3 Sharp	449406	2411649
Missile 3 Filleted	437201	2342617
Missile 4 Sharp	616539	3310570
Missile 4 Filleted	617756	3321520
Missile 5 Sharp	659863	3545989
Missile 5 Filleted	655972	3534278
Missile 6 Sharp	728672	3909138
Missile 6 Filleted	746058	4002691
Missile 7 Sharp	874757	4729807
Missile 7 Filleted	873182	4706202
Missile 8 Sharp	901974	4866944
Missile 8 Filleted	914728	4947308
Missile 9 Sharp	1003292	5435190
Missile 9 Filleted	991850	5377302
Missile 10 Sharp	862557	4677355
Missile 10 Filleted	797983	4299810



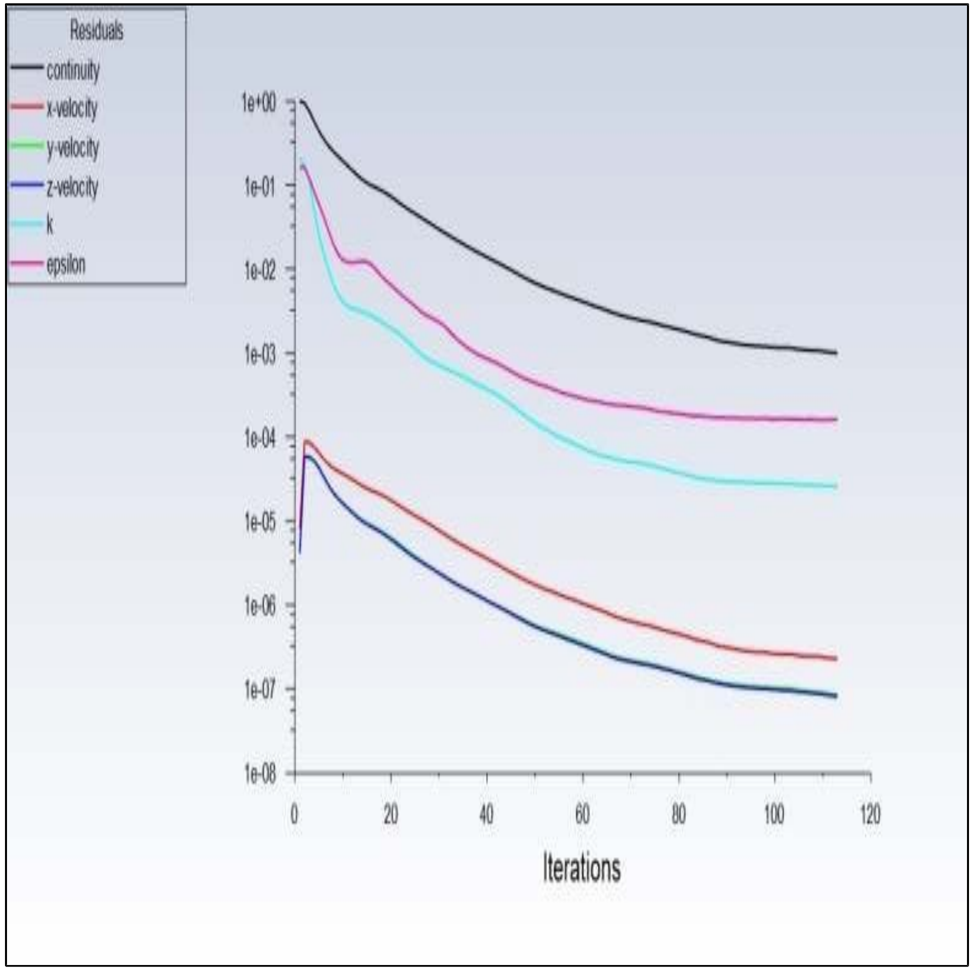


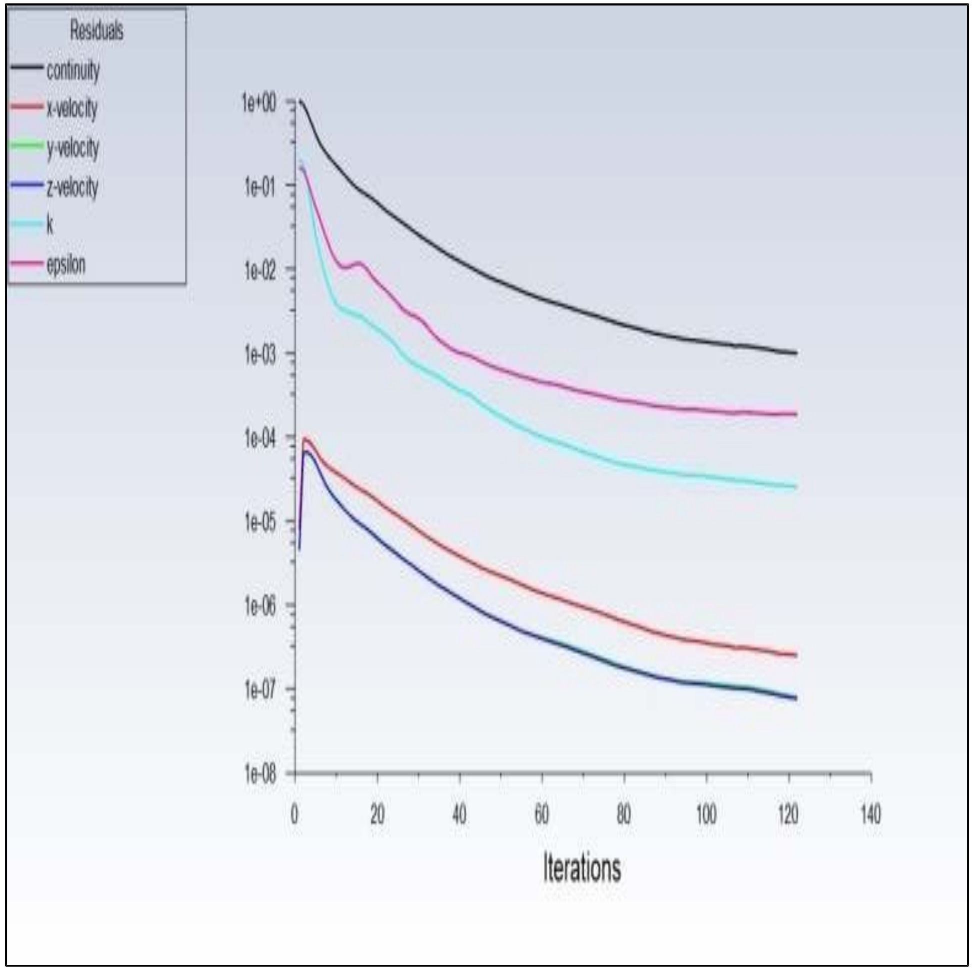
Residual plot for missile - 1 design iterations



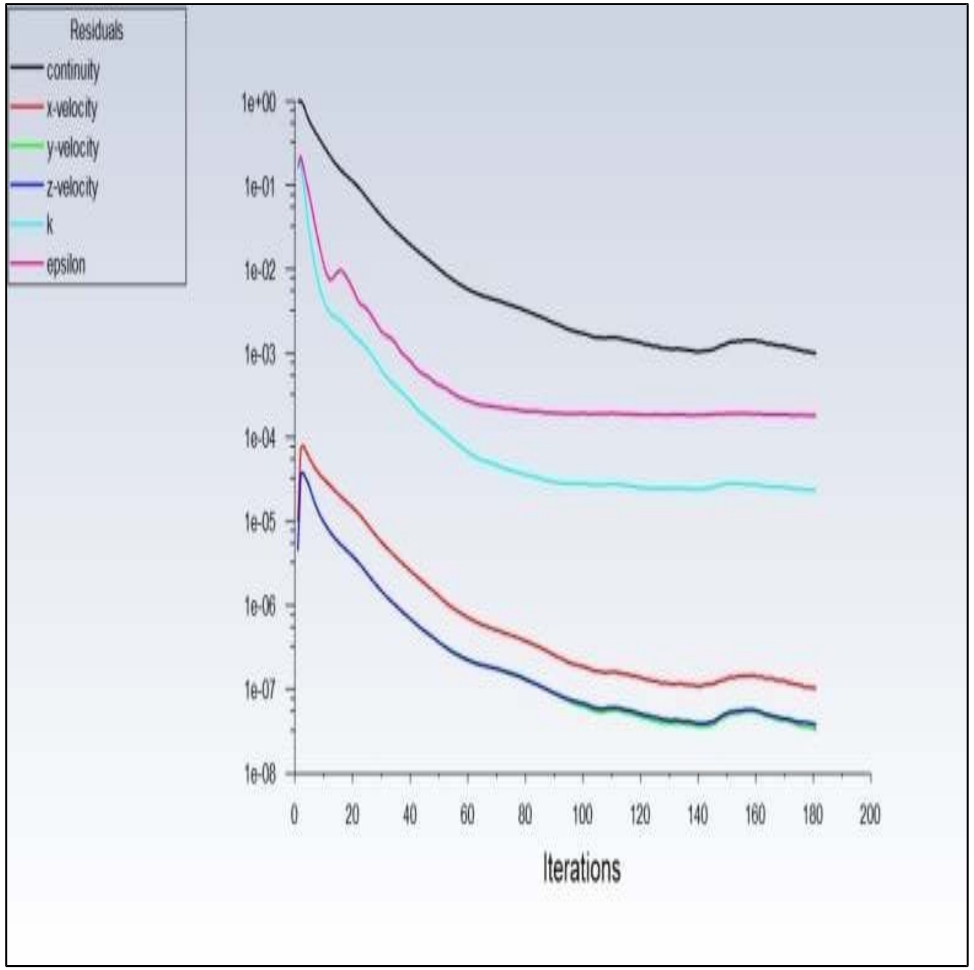


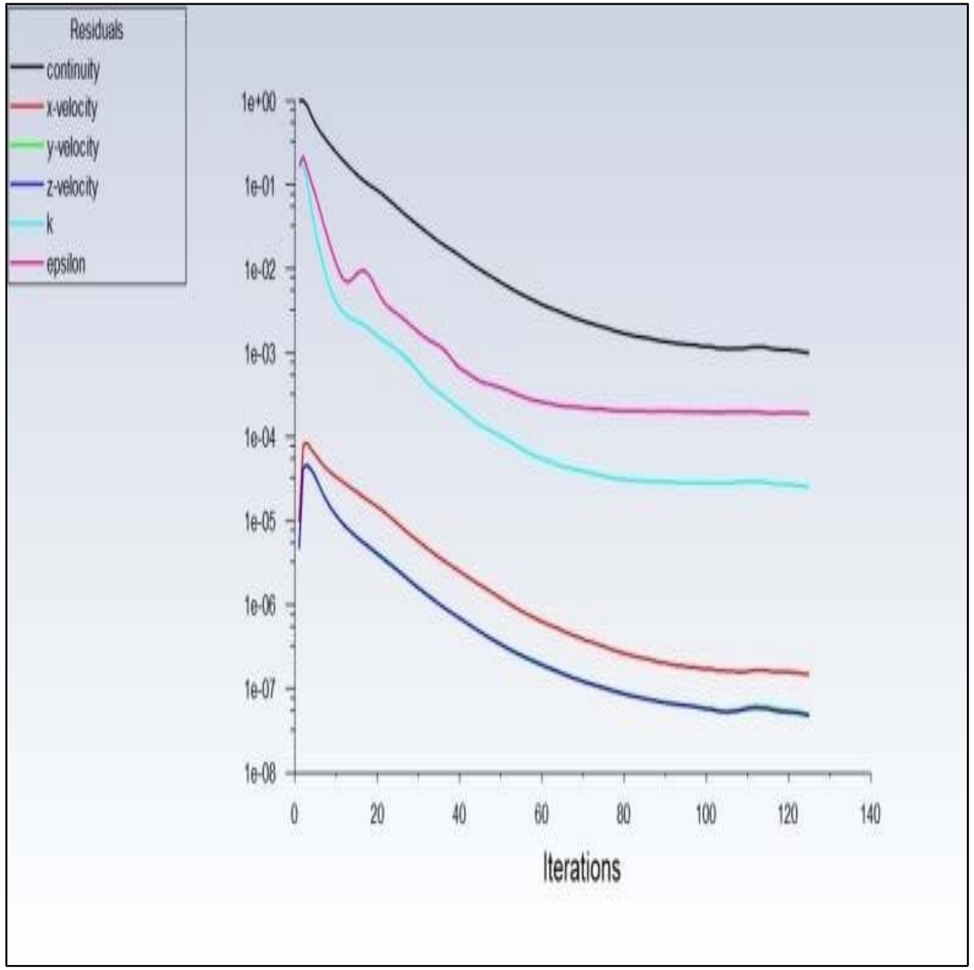
Residual plot for missile - 2 design iterations



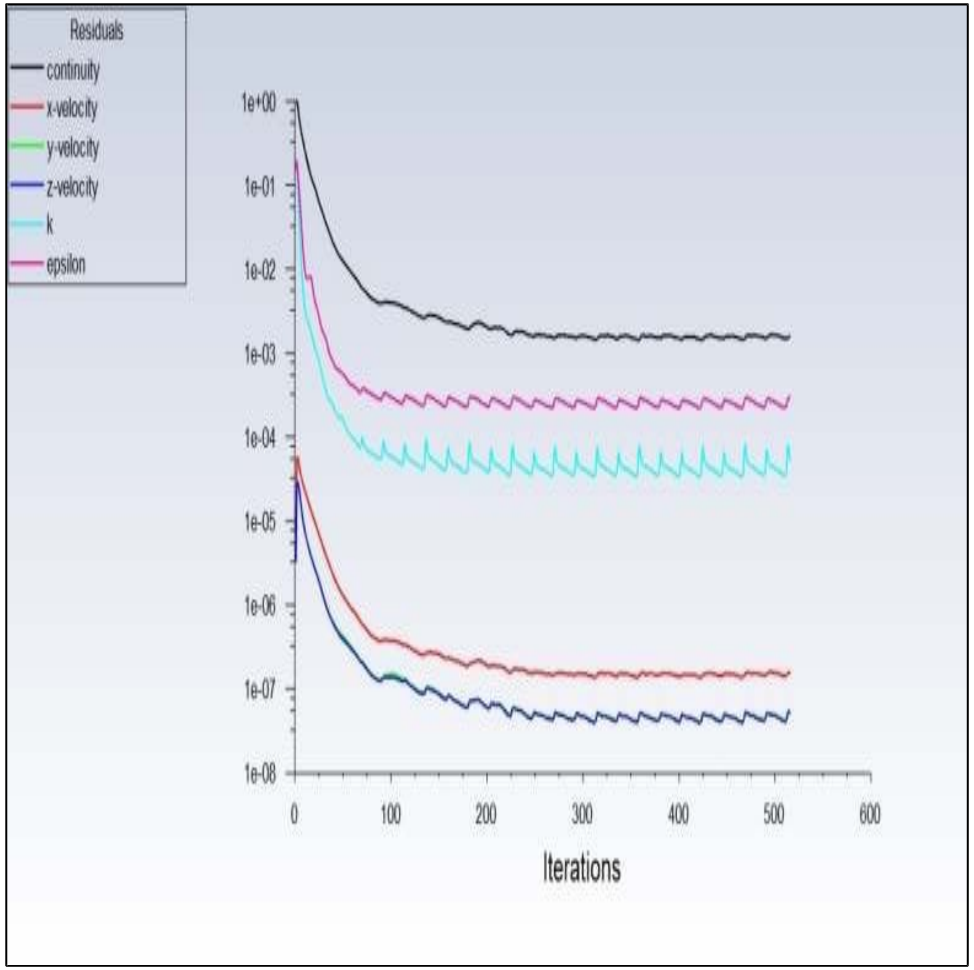


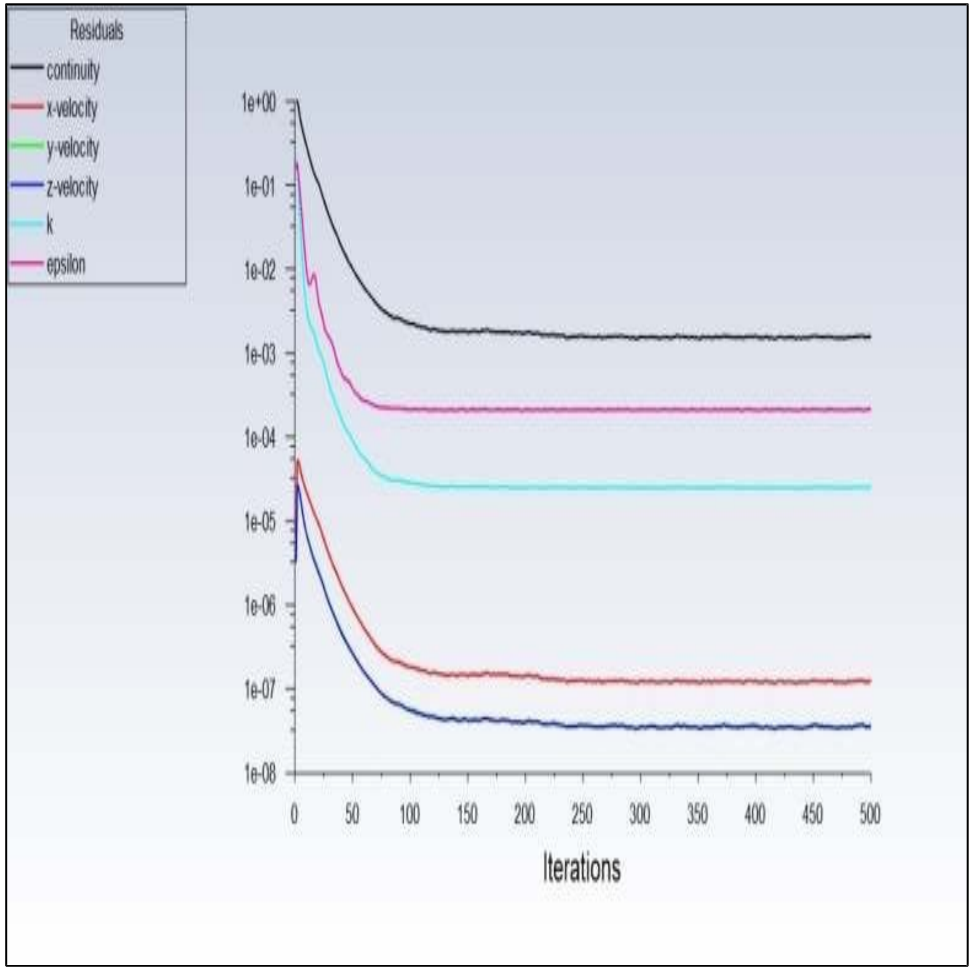
Residual plot for missile - 3 design iterations



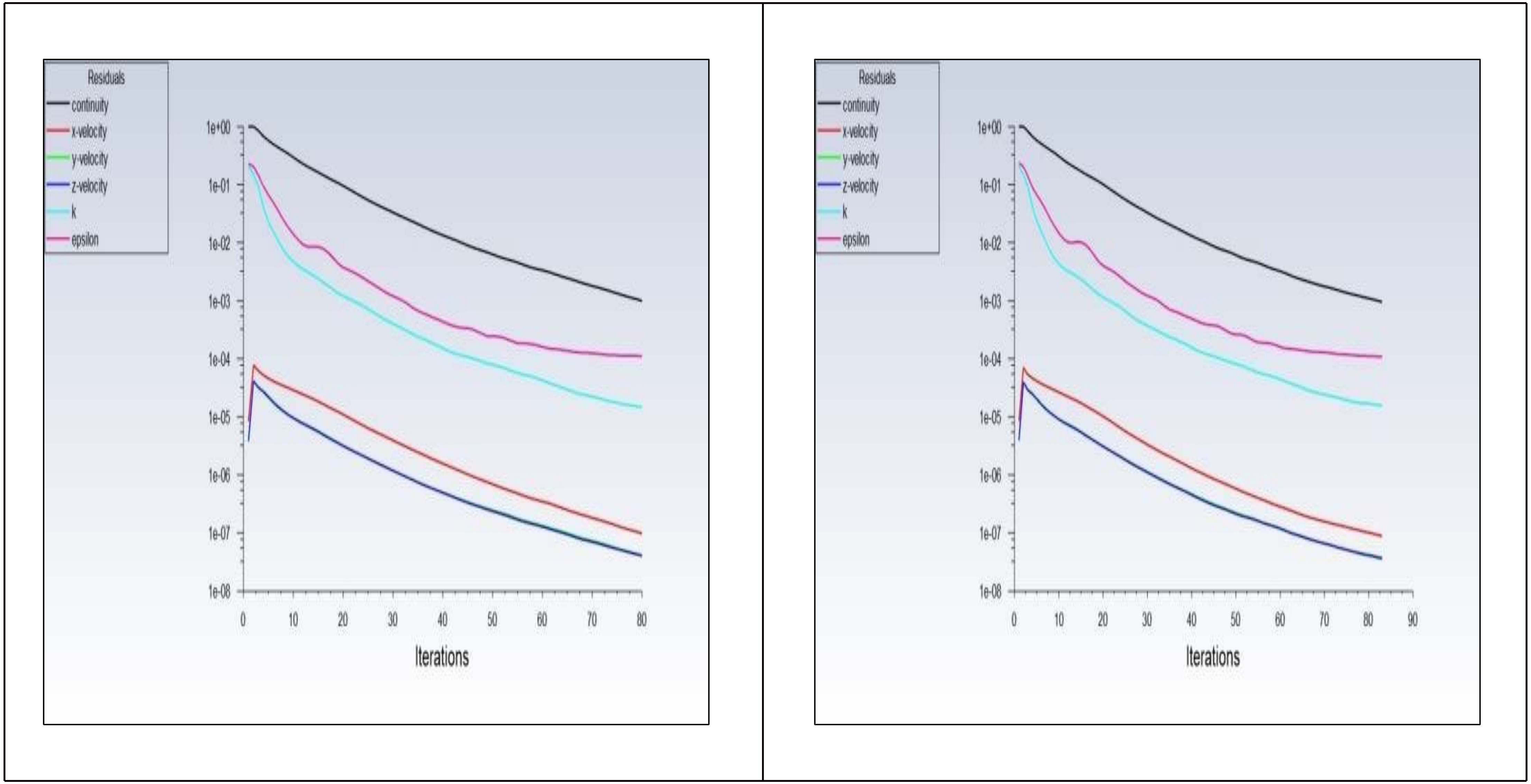


Residual plot for missile - 4 design iterations

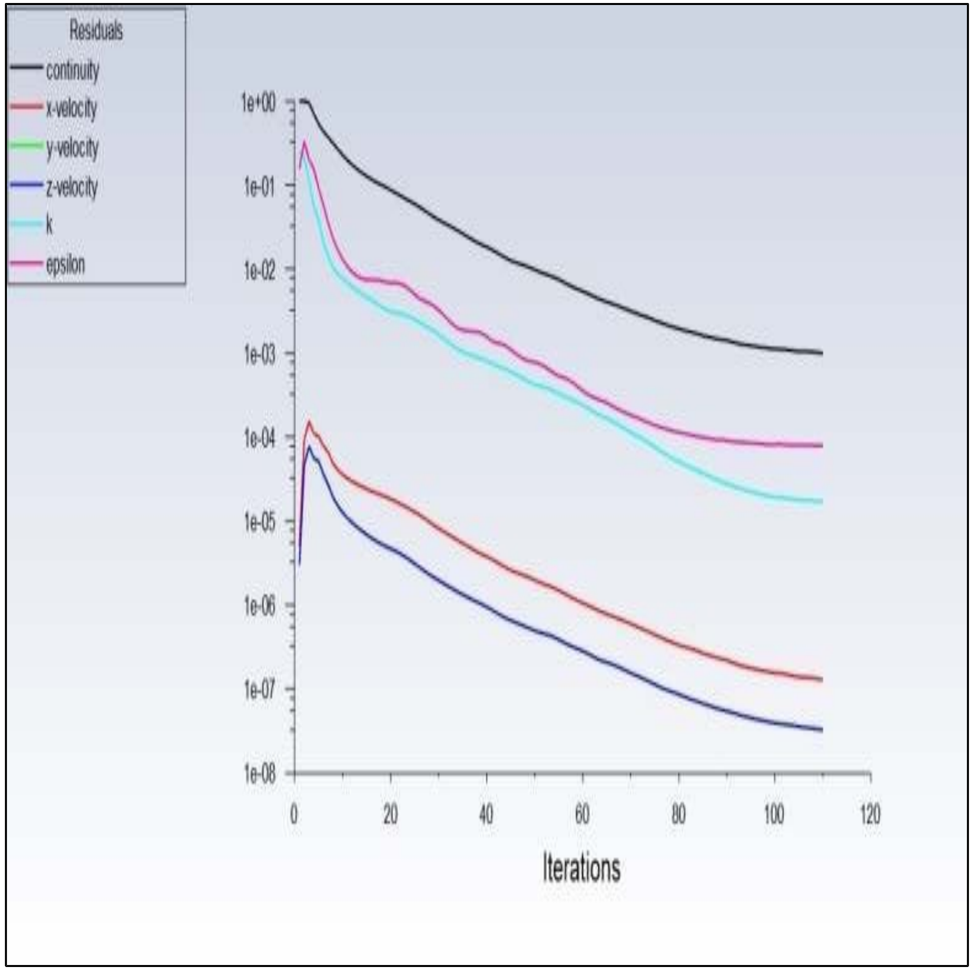


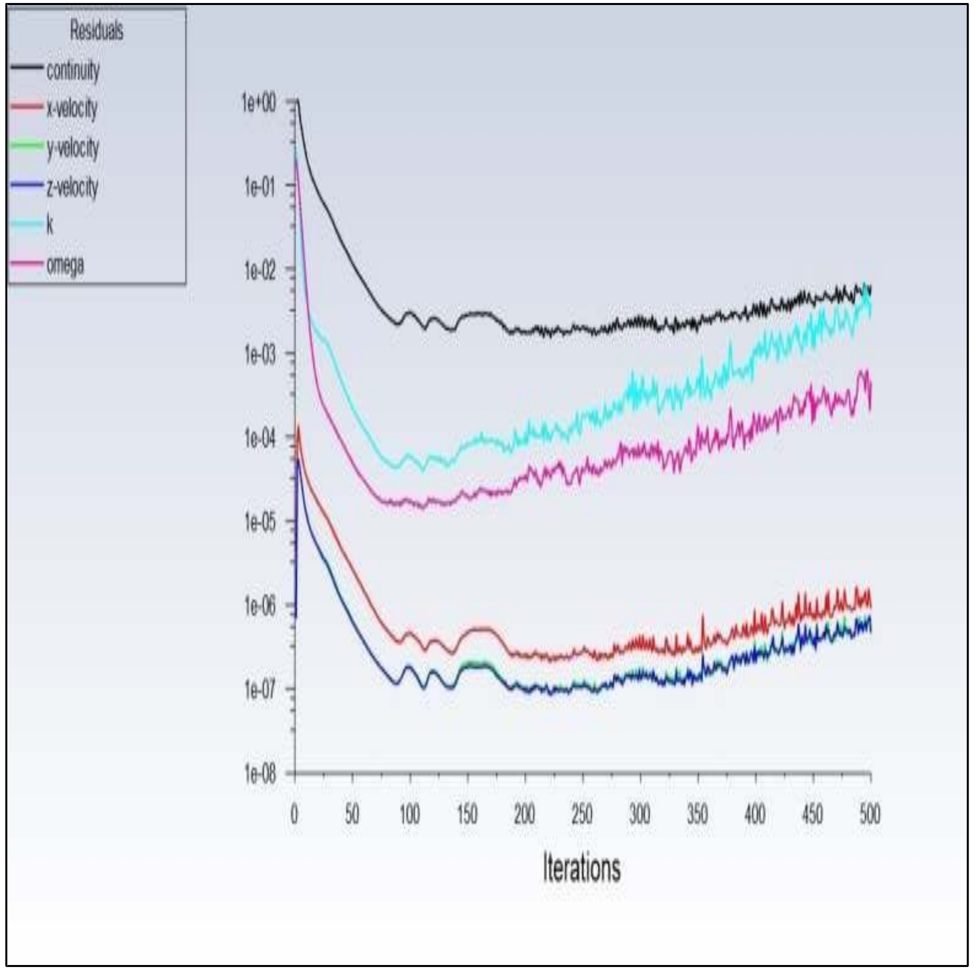


Residual plot for missile - 5 design iterations

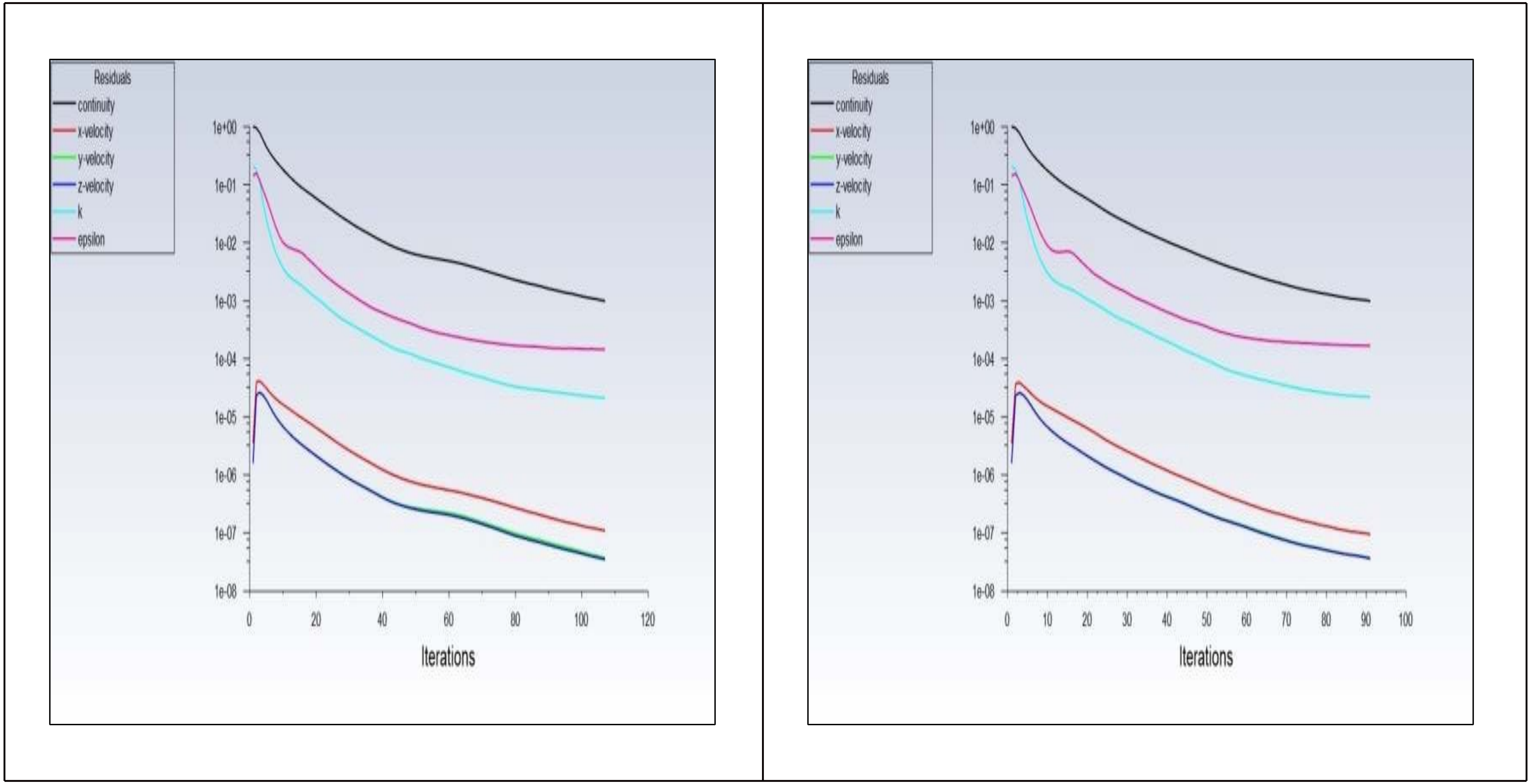


Residual plot for missile - 6 design iterations

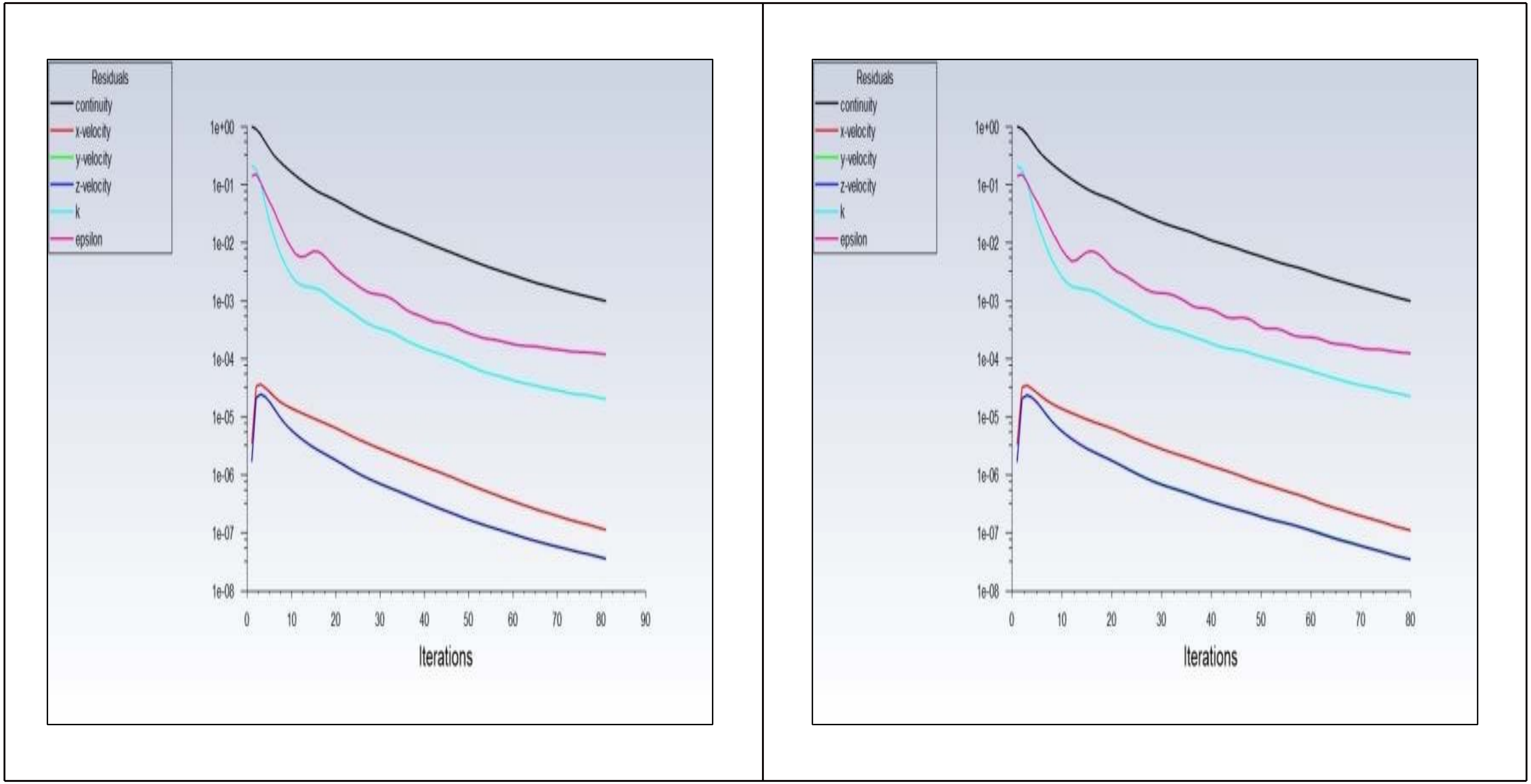




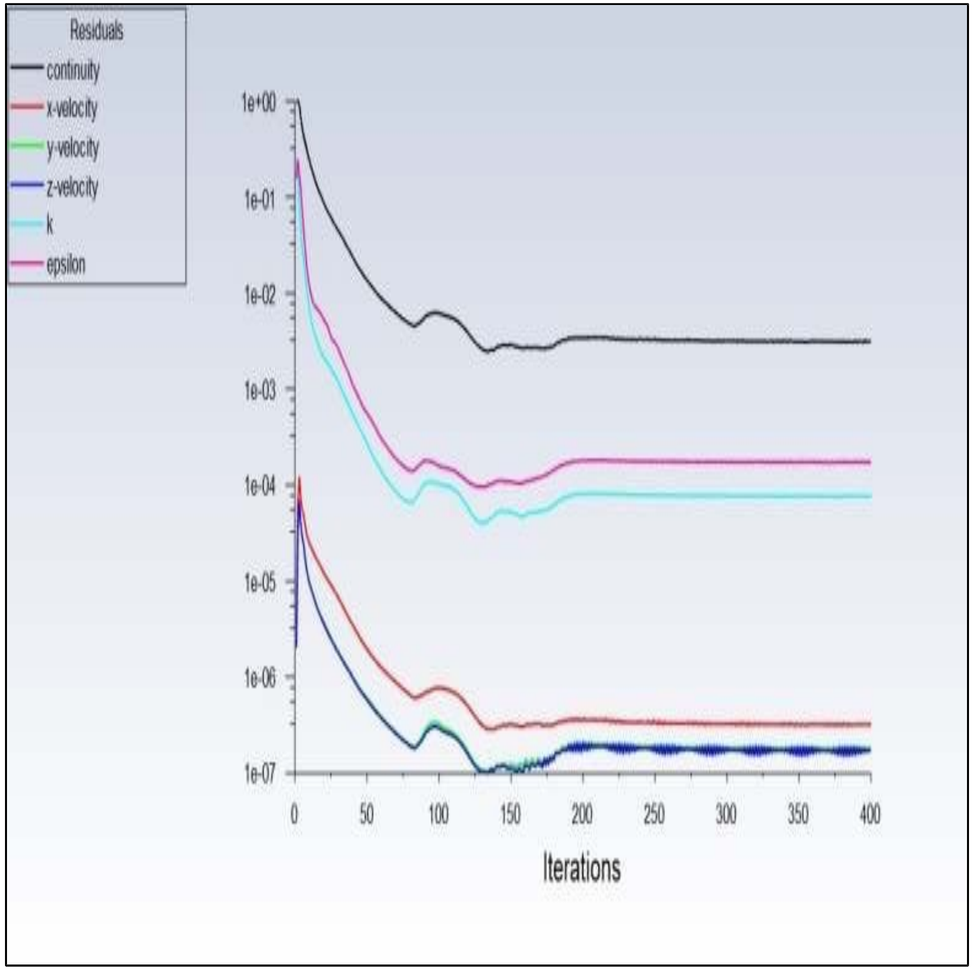
Residual plot for missile - 7 design iterations

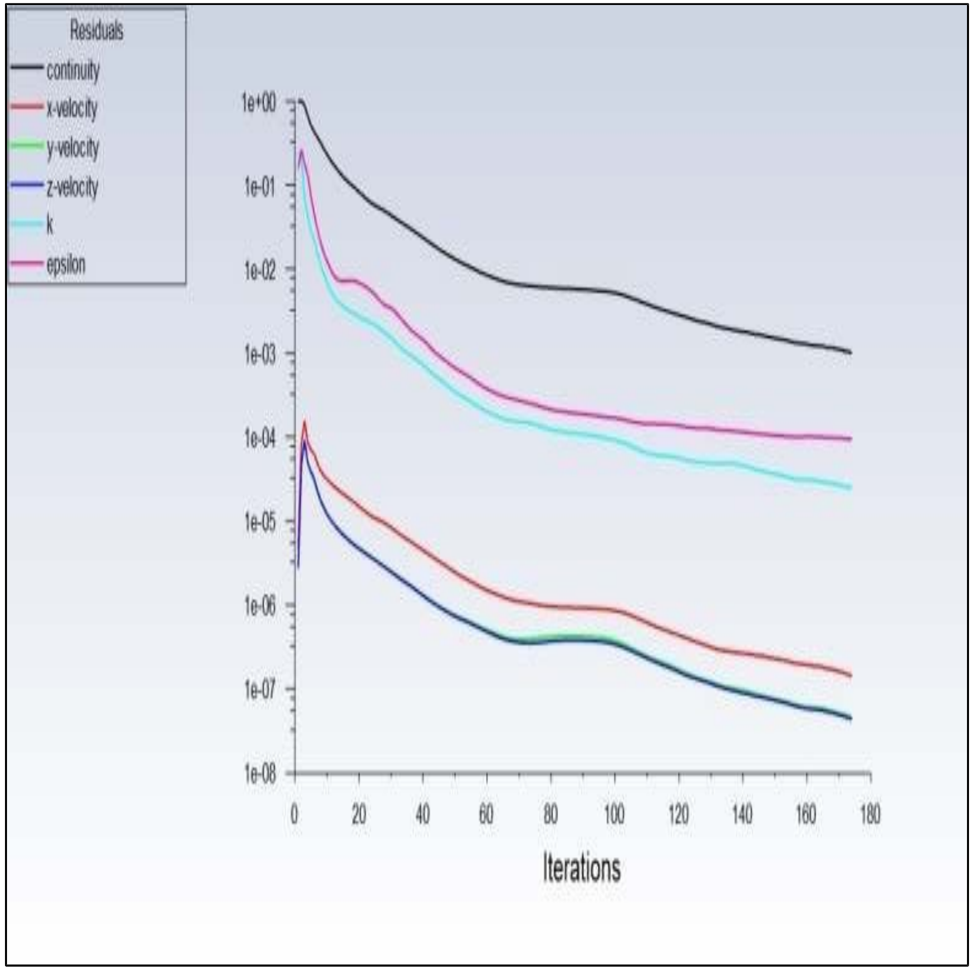


Residual plot for missile - 8 design iterations

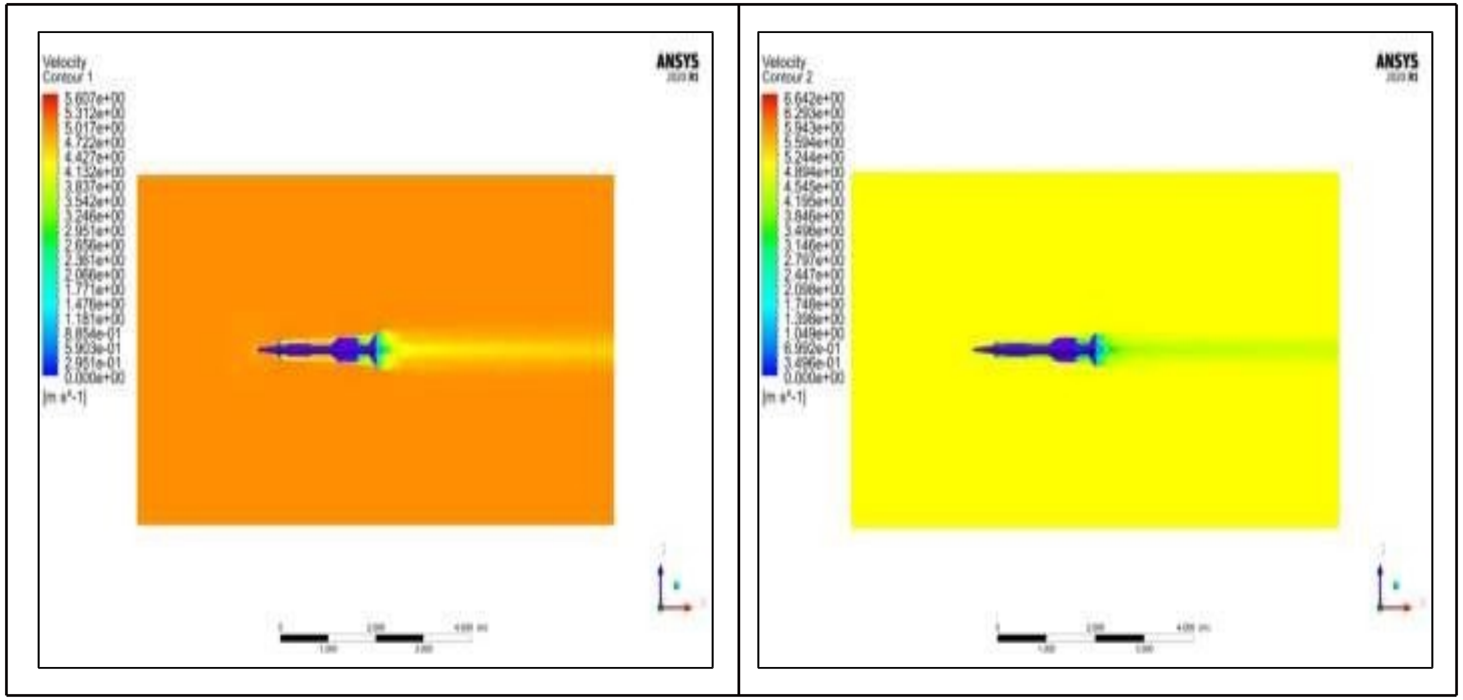


Residual plot for missile - 9 design iterations

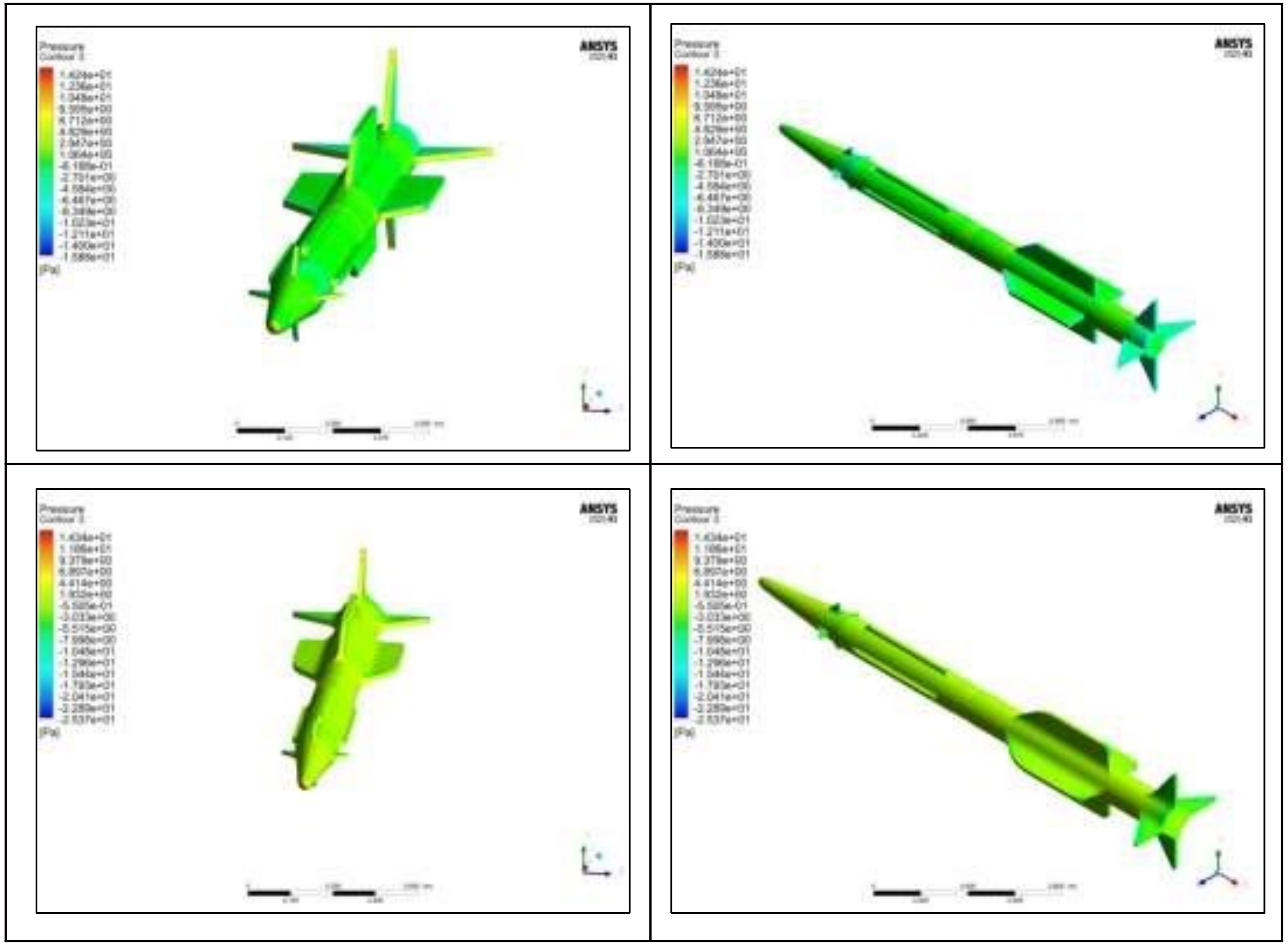




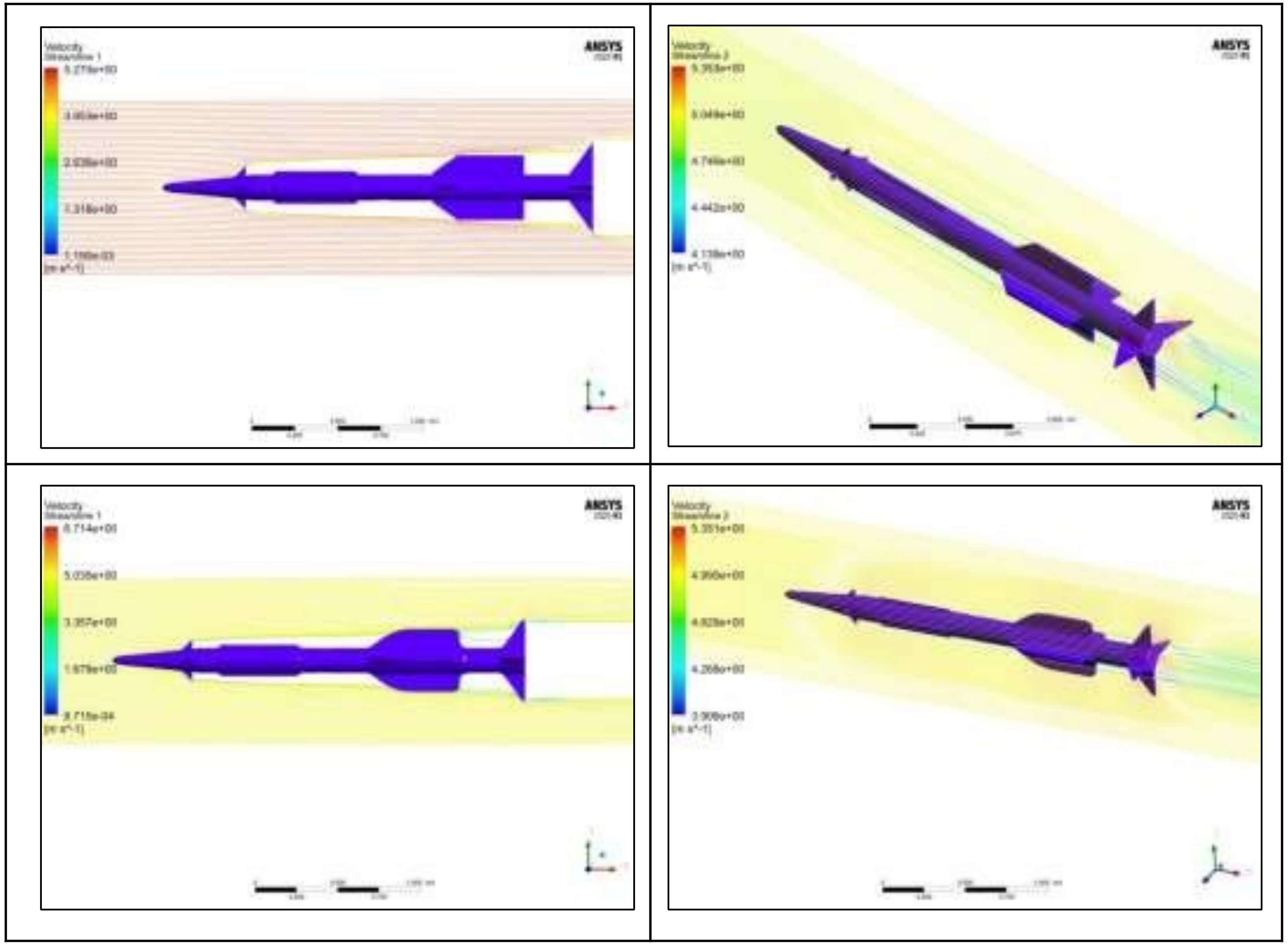
Residual plot for missile - 10 design iterations



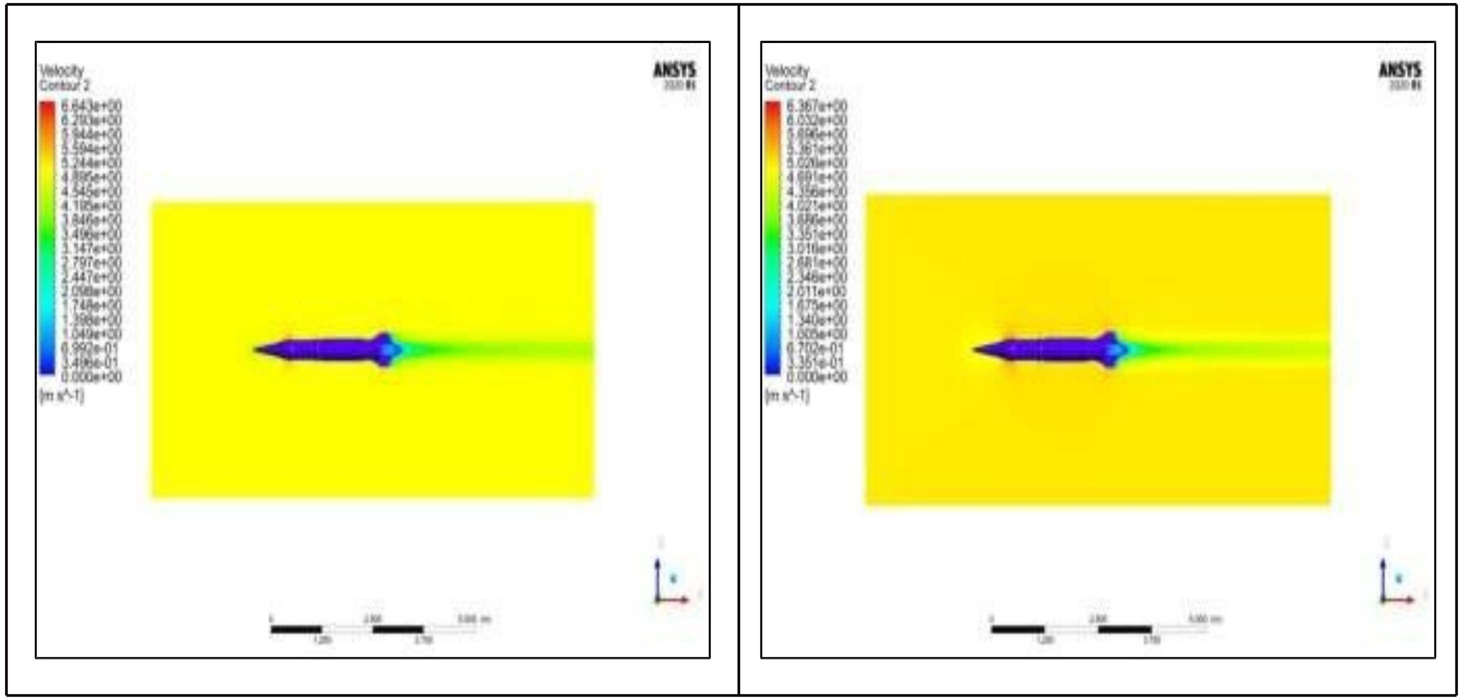
Comparision of VELOCITY
for missile 1 design iterations



Comparison of Pressure
for missile 1 design iterations



Comparision of Streamlines
for missile 1 design iterations



Comparision of VELOCITY
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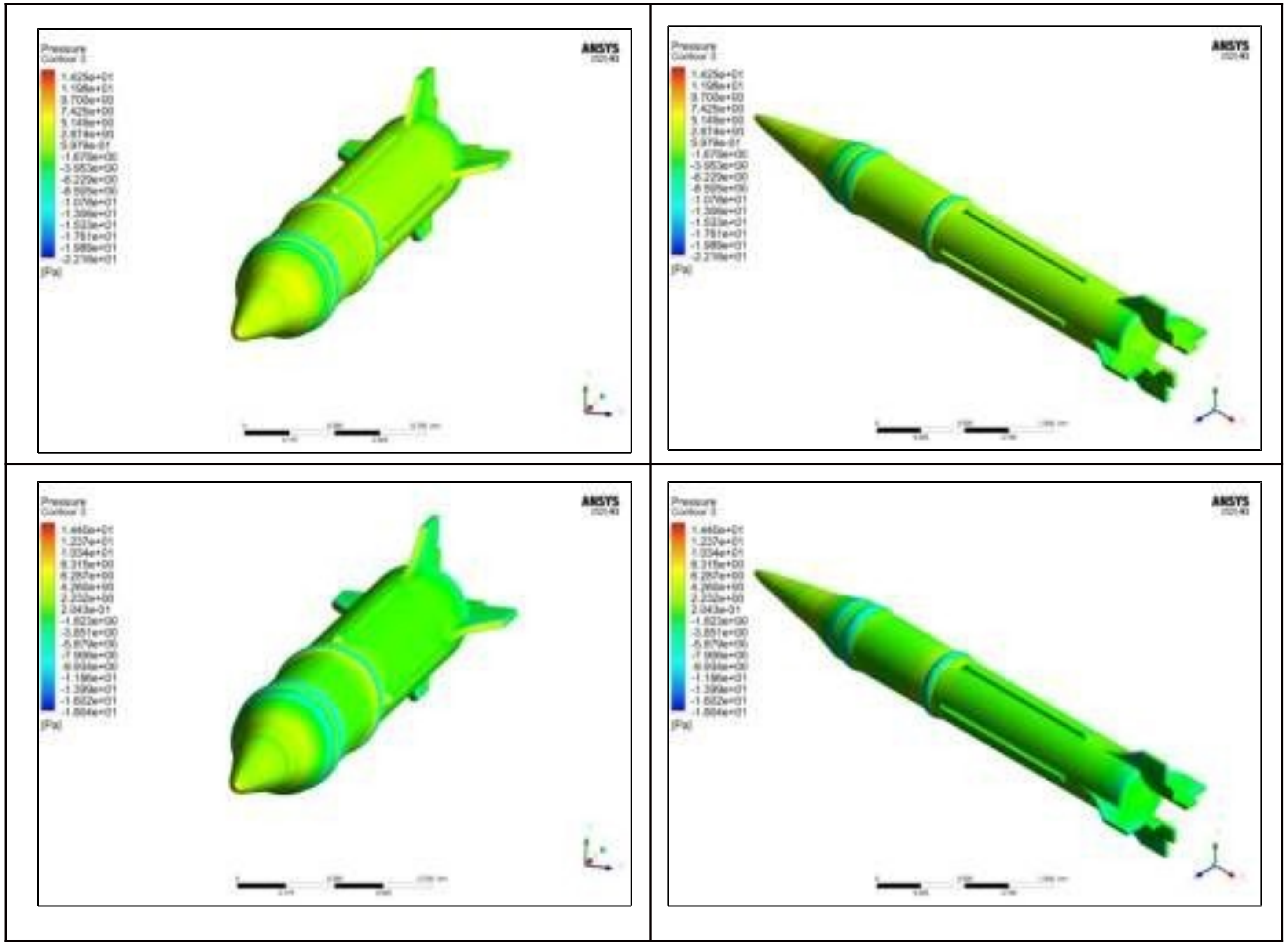
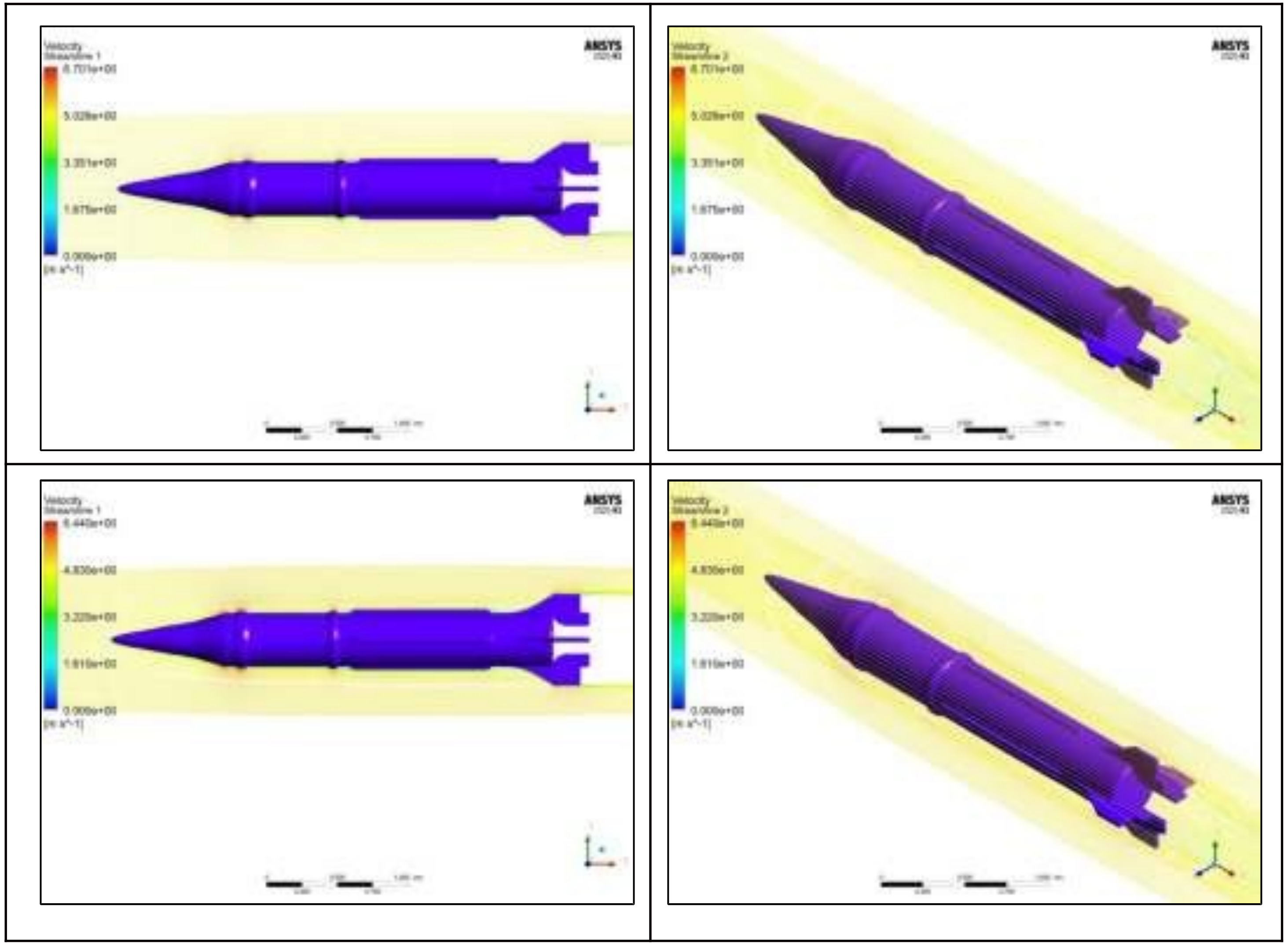
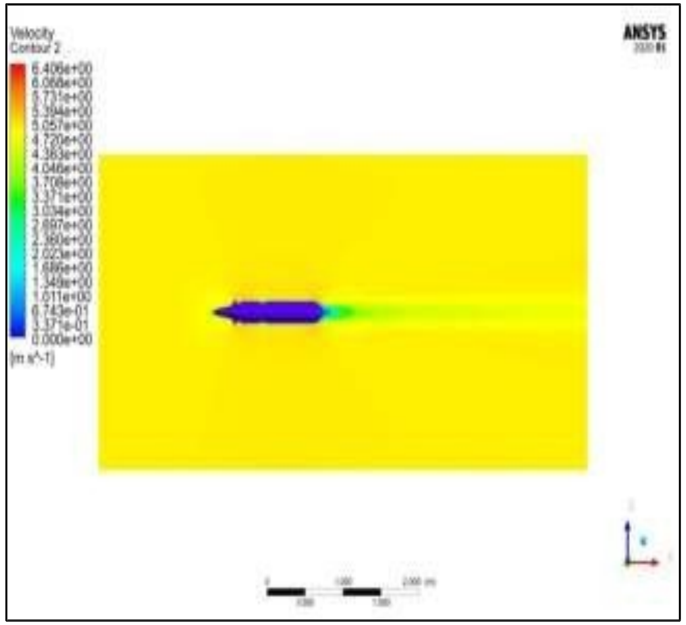
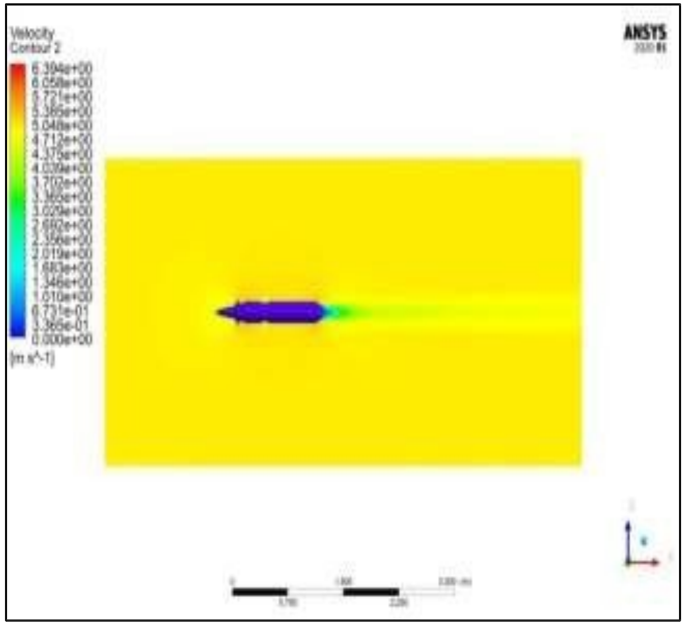


Comparison of Pressure
for missile 2 design iterations

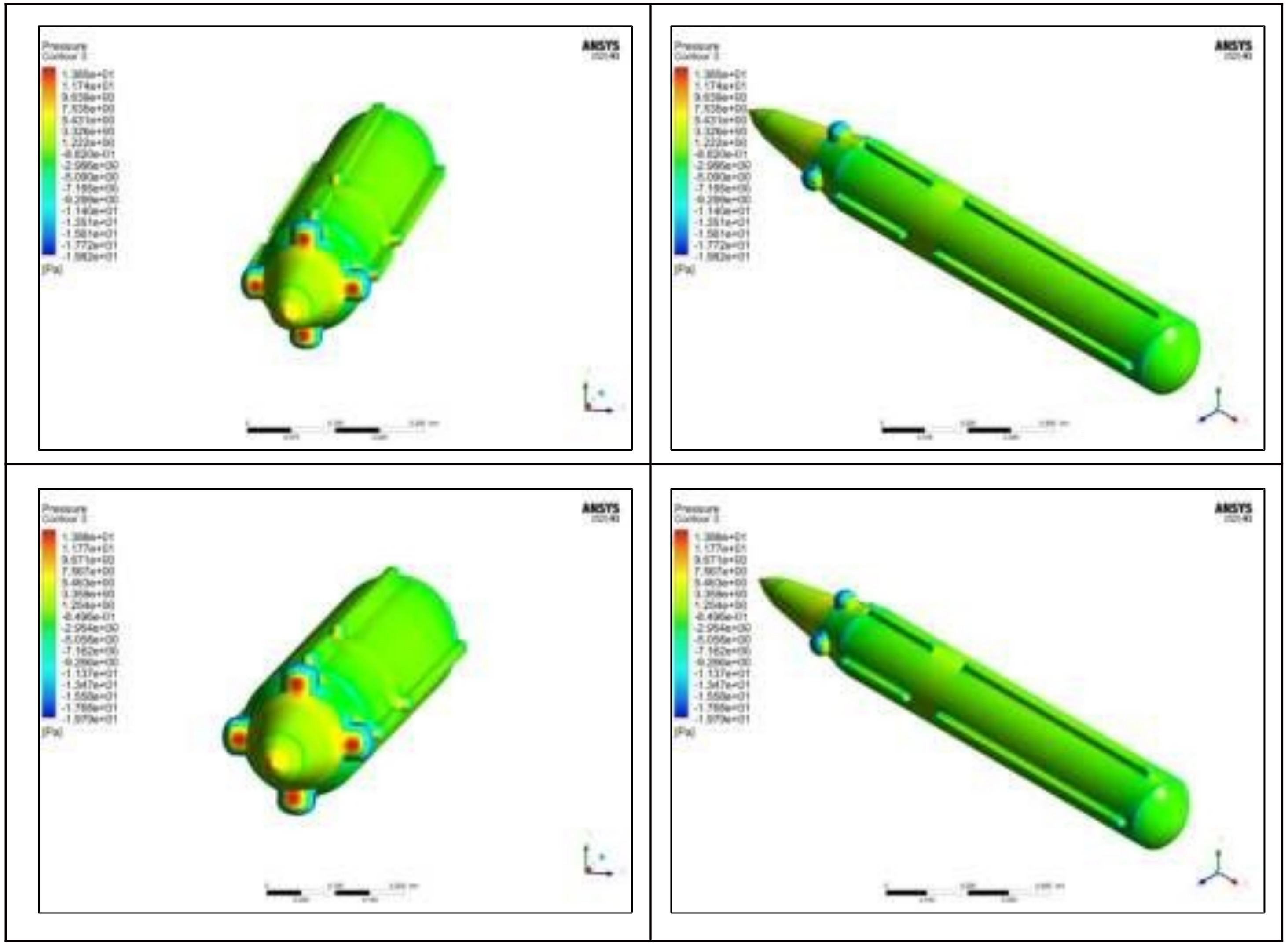


Comparision of Streamlines
for missile 2 design iterations

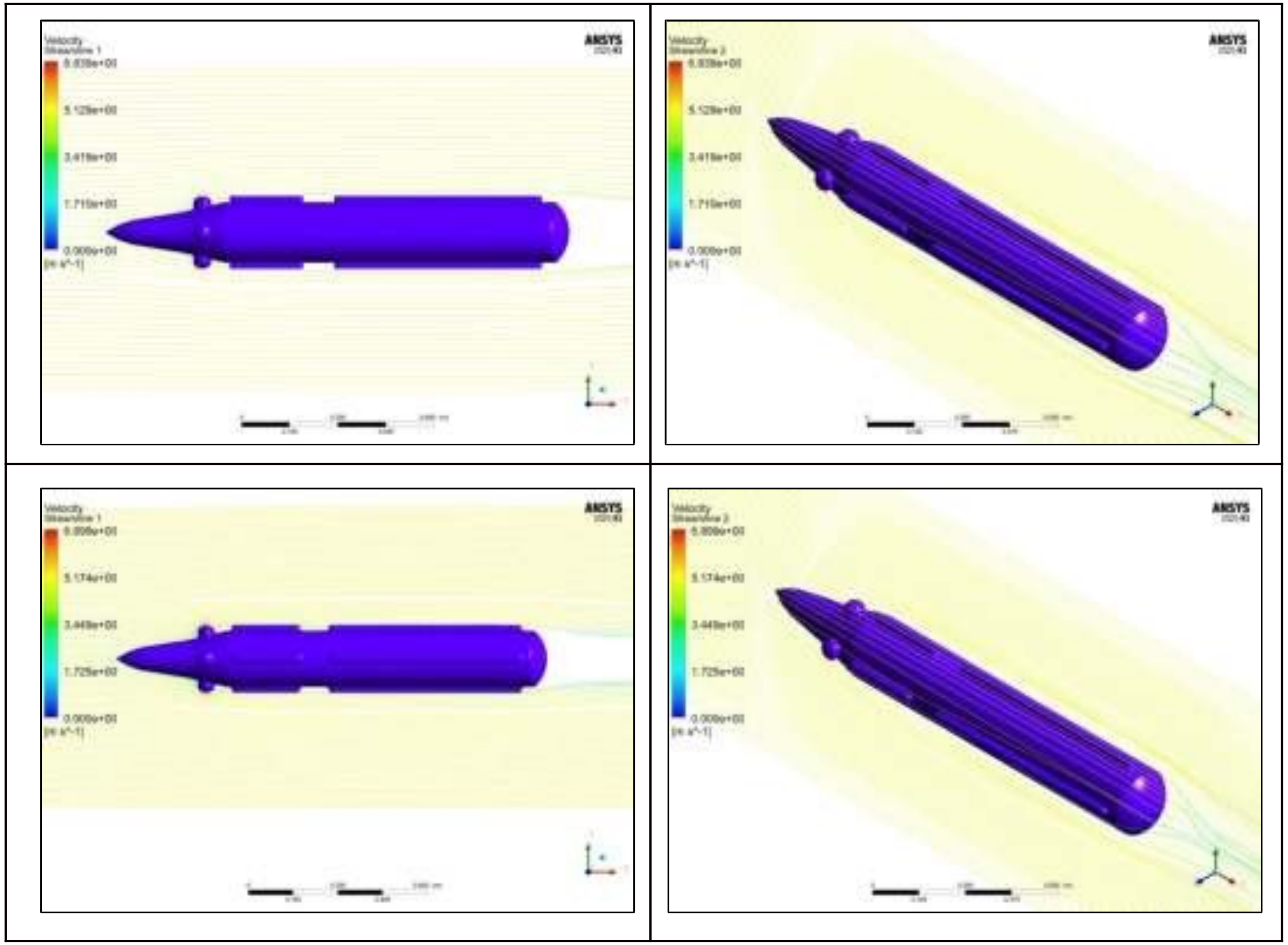




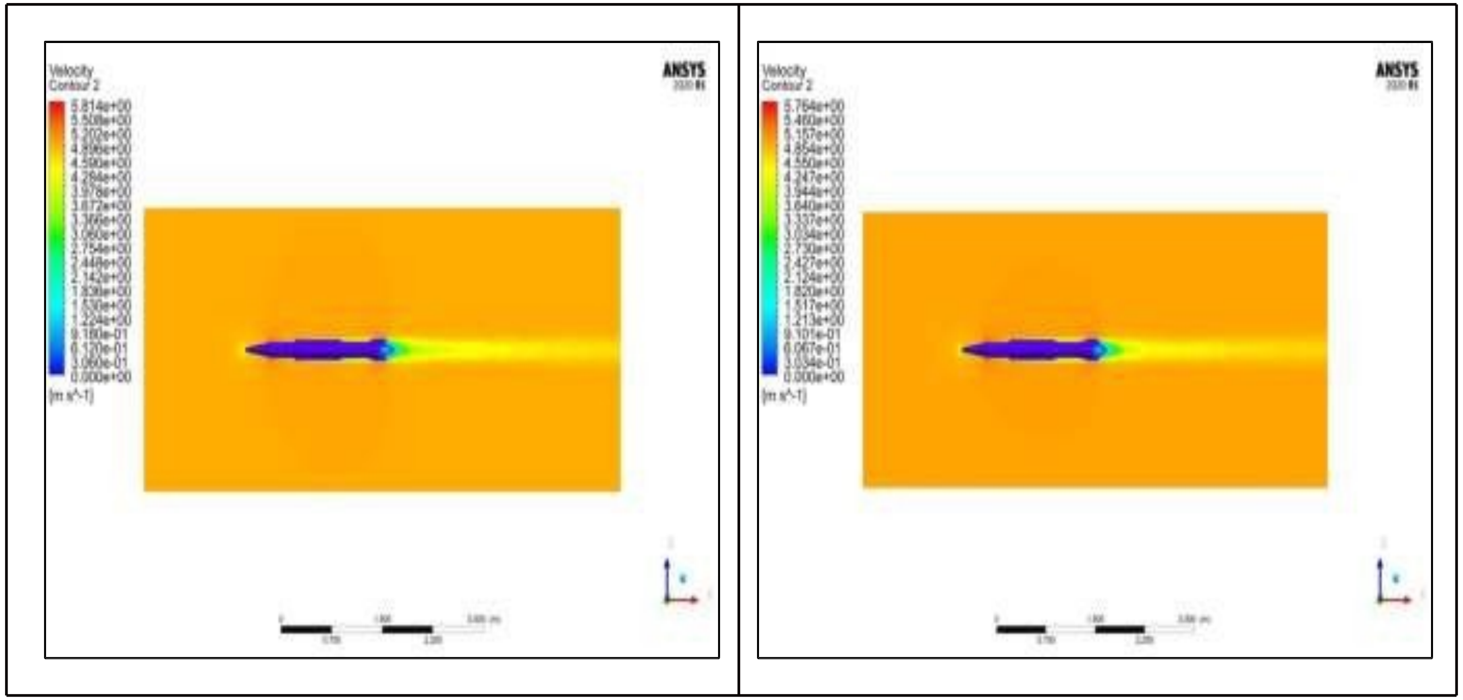
Comparision of VELOCITY
for missile 3 design iterations



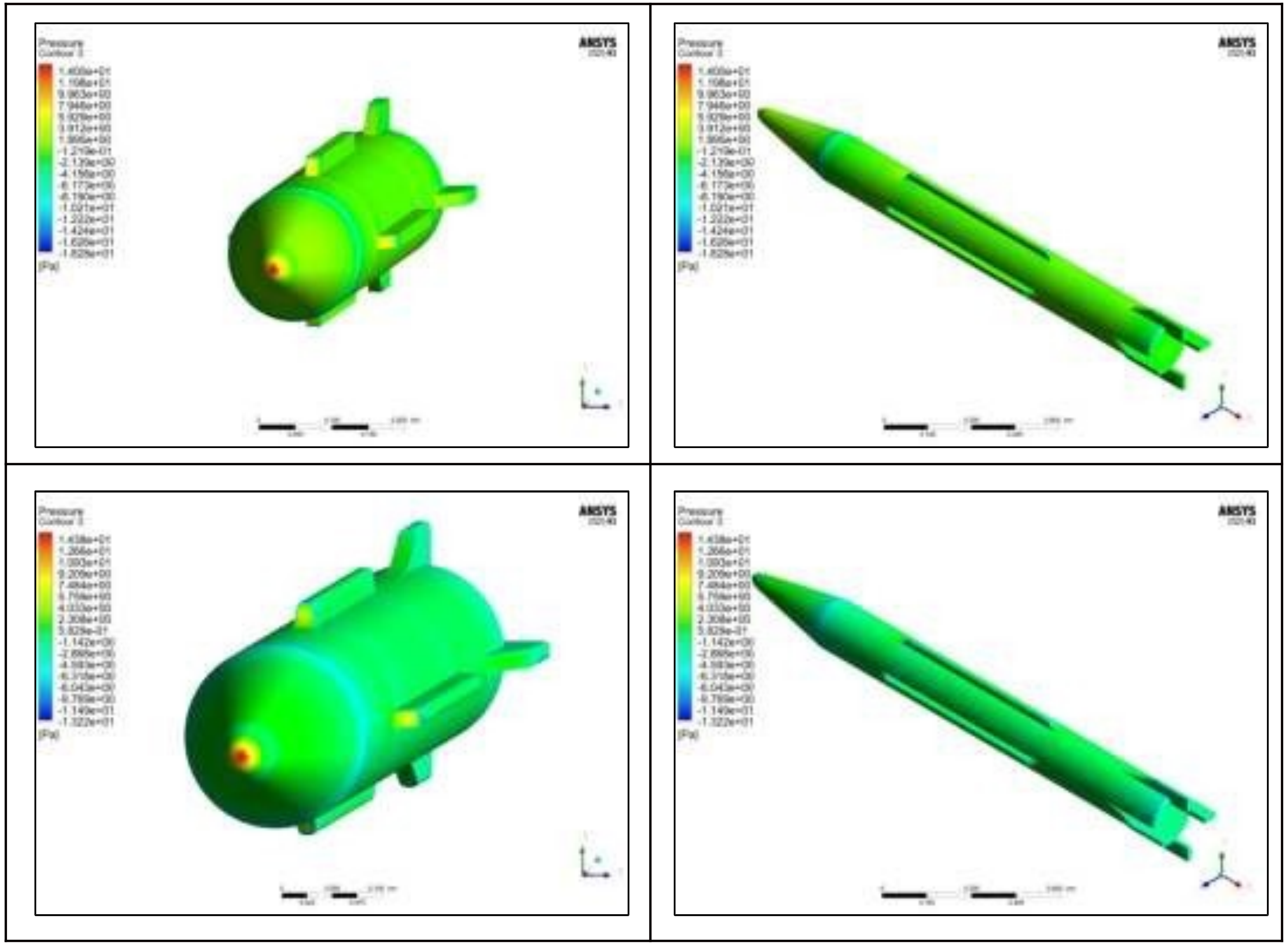
Comparison of Pressure
for missile 3 design iterations



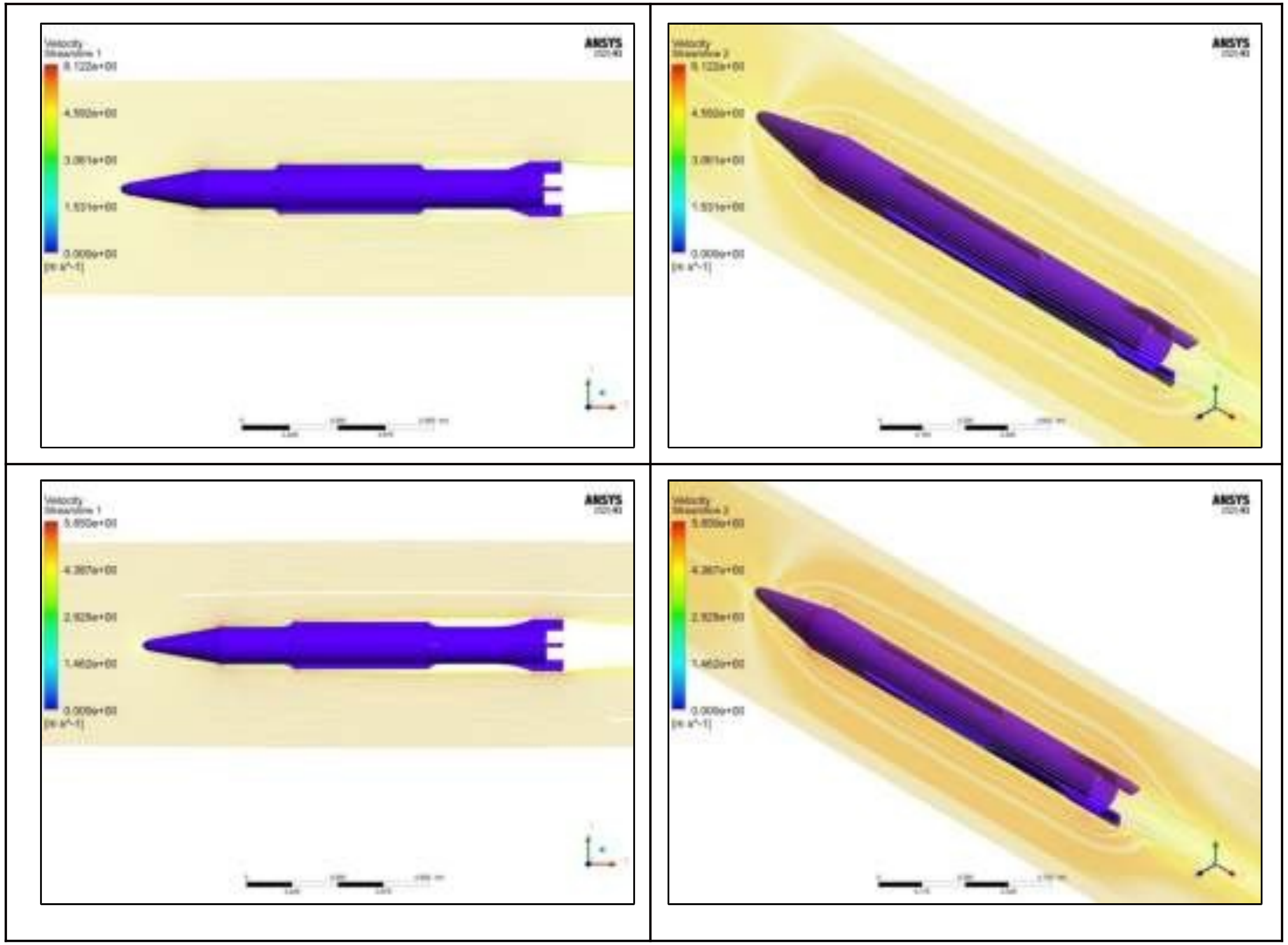
Comparision of Streamlines
for missile 3 design iterations



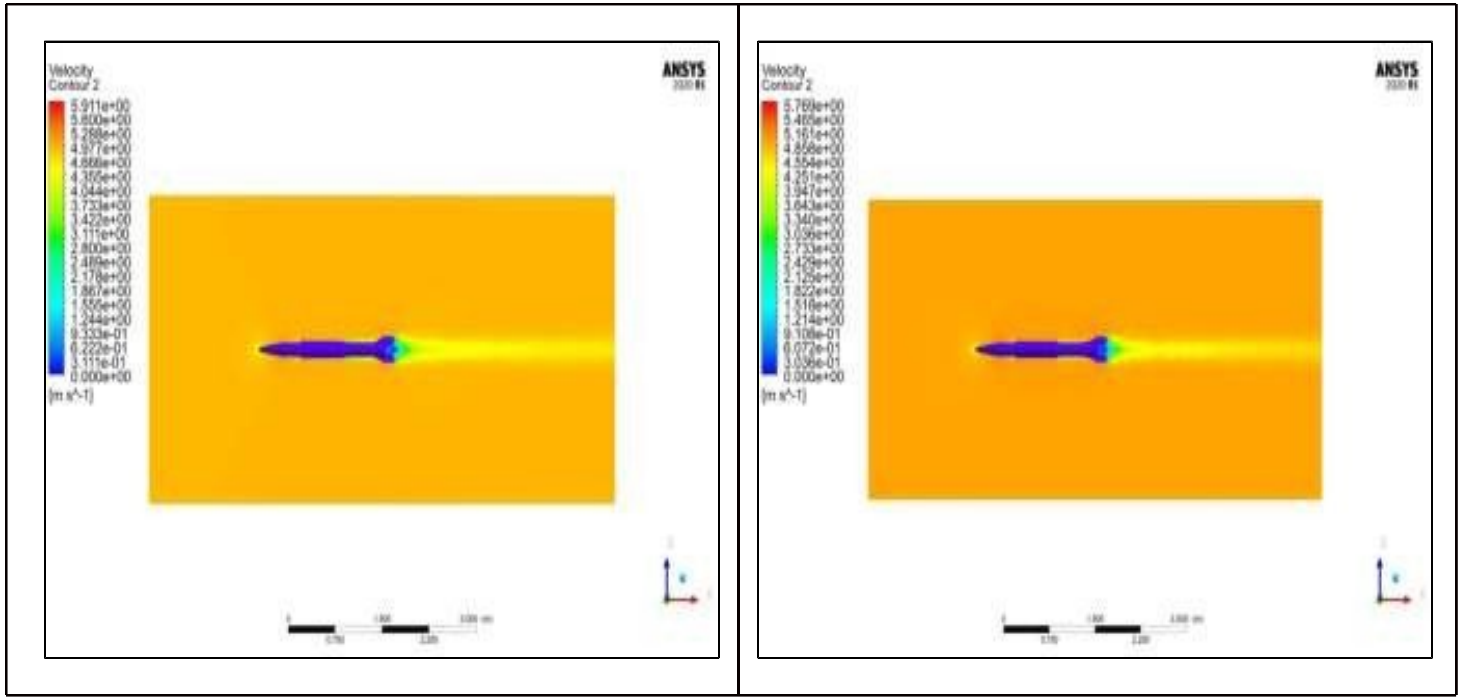
Comparision of VELOCITY
for missile 4 design iterations



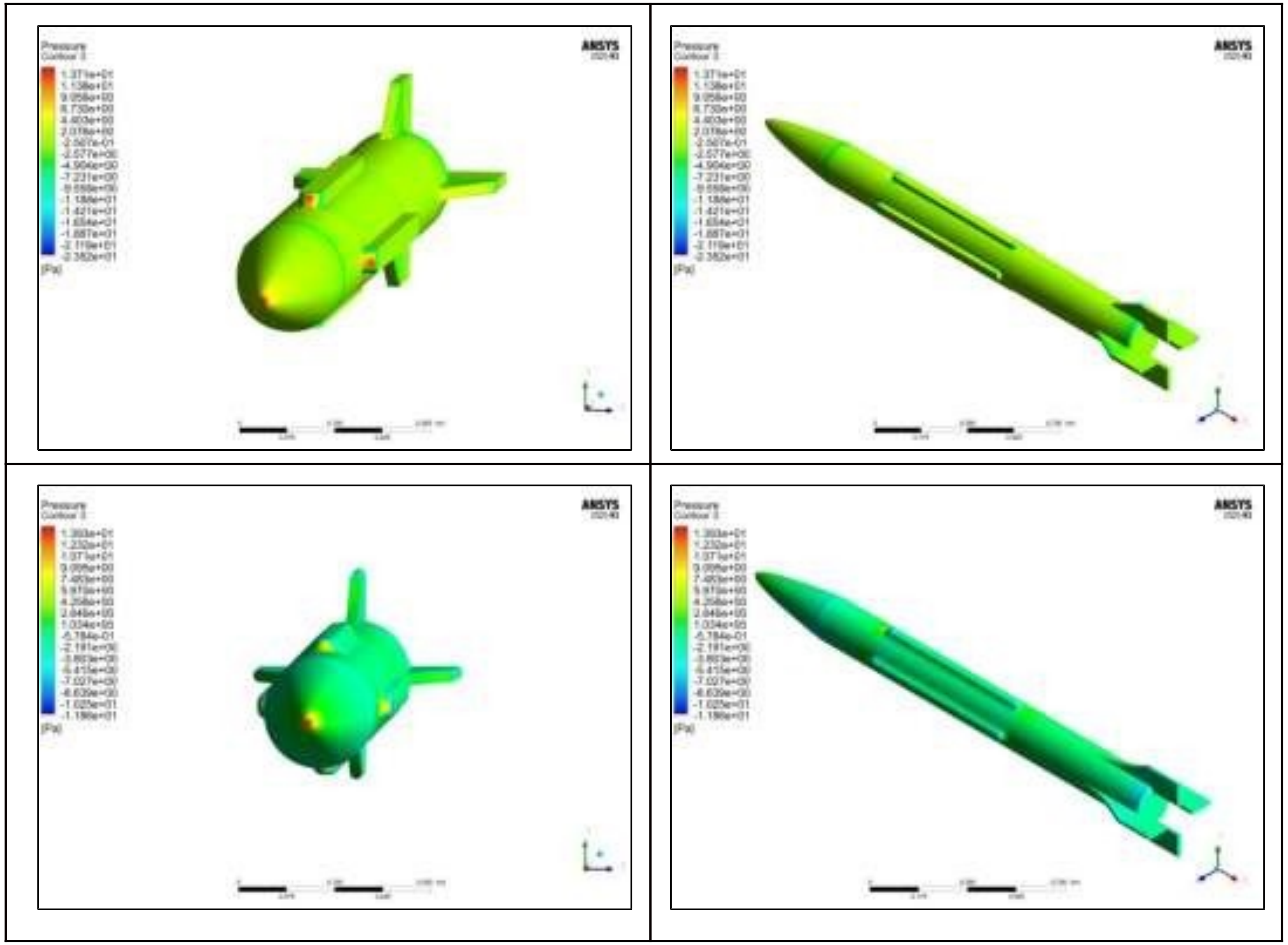
Comparison of Pressure
for missile 4 design iterations



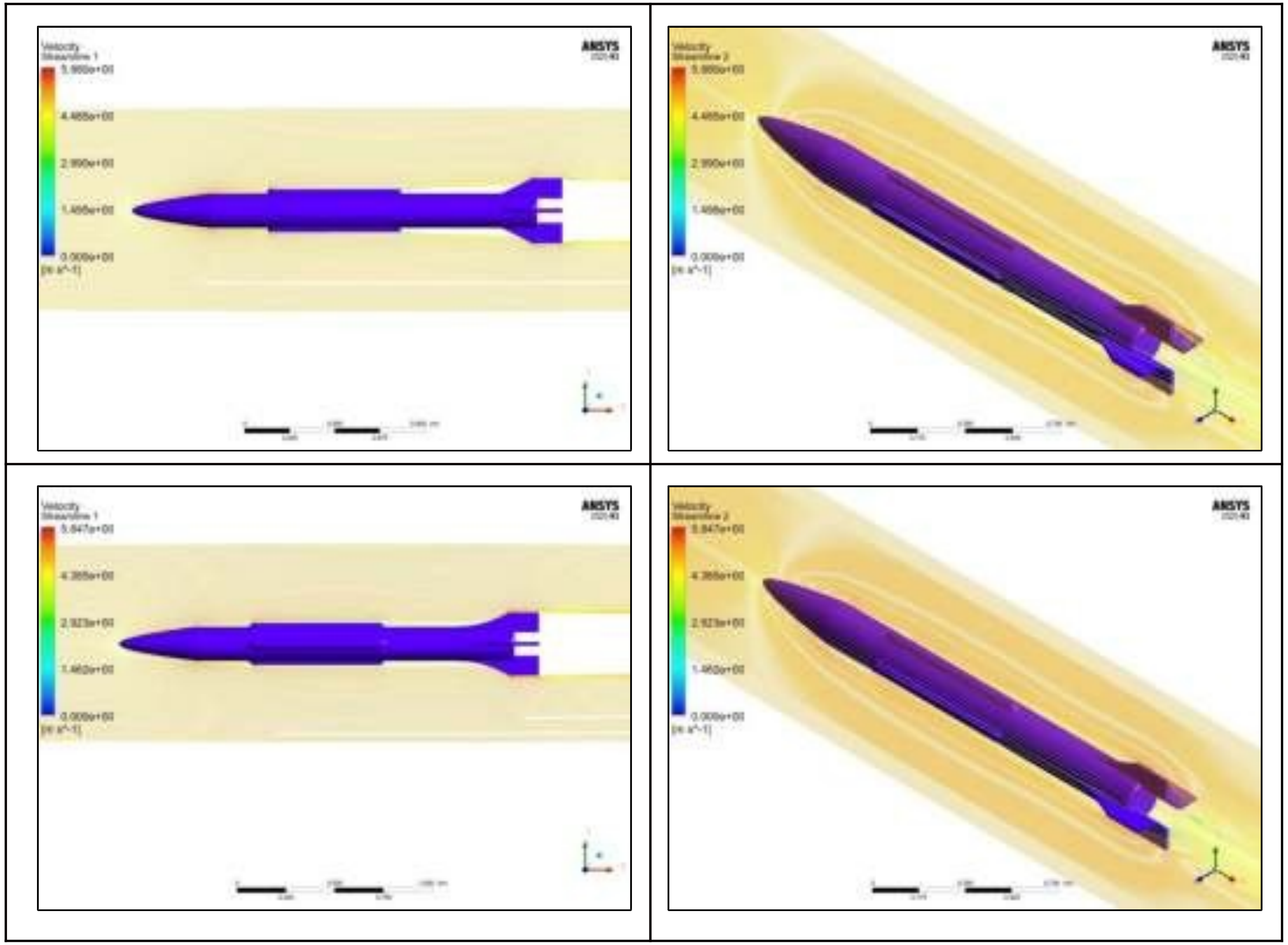
Comparision of Streamlines
for missile 4 design iterations



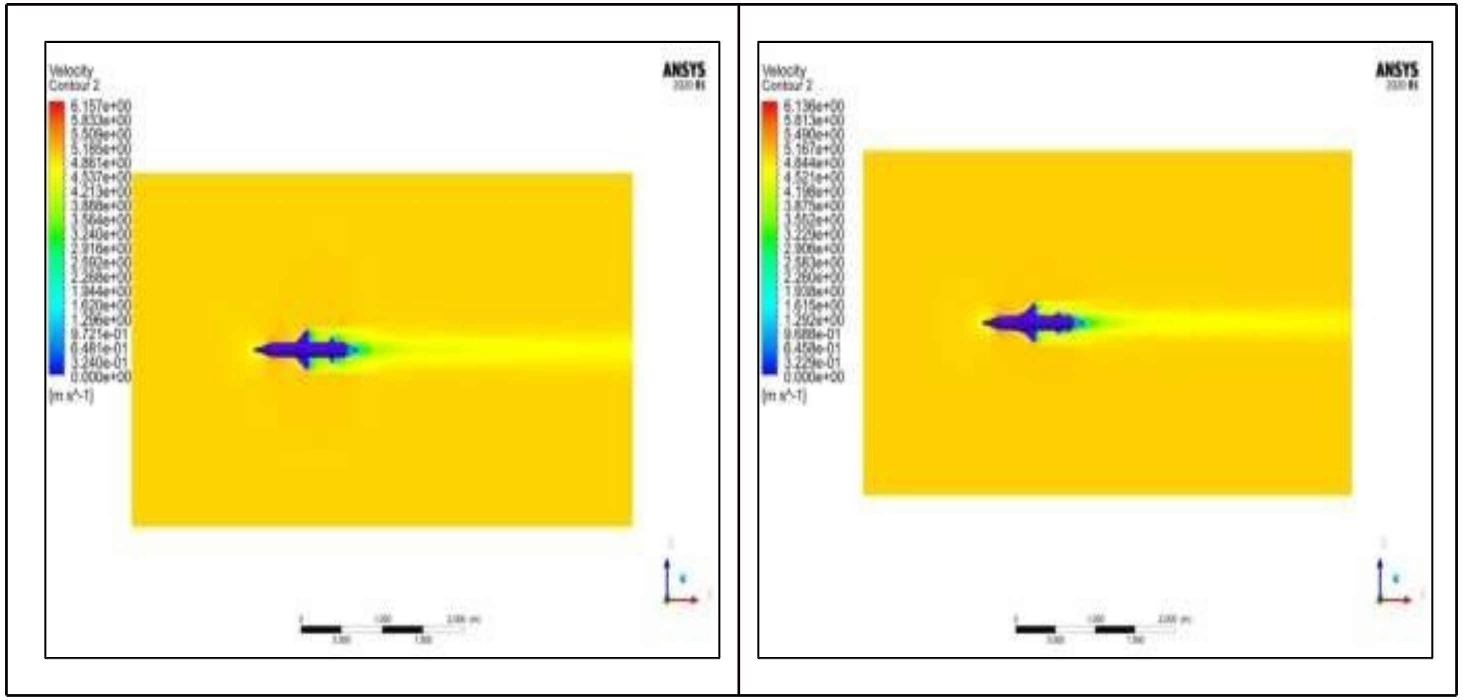
Comparision of VELOCITY
for missile 5 design iterations



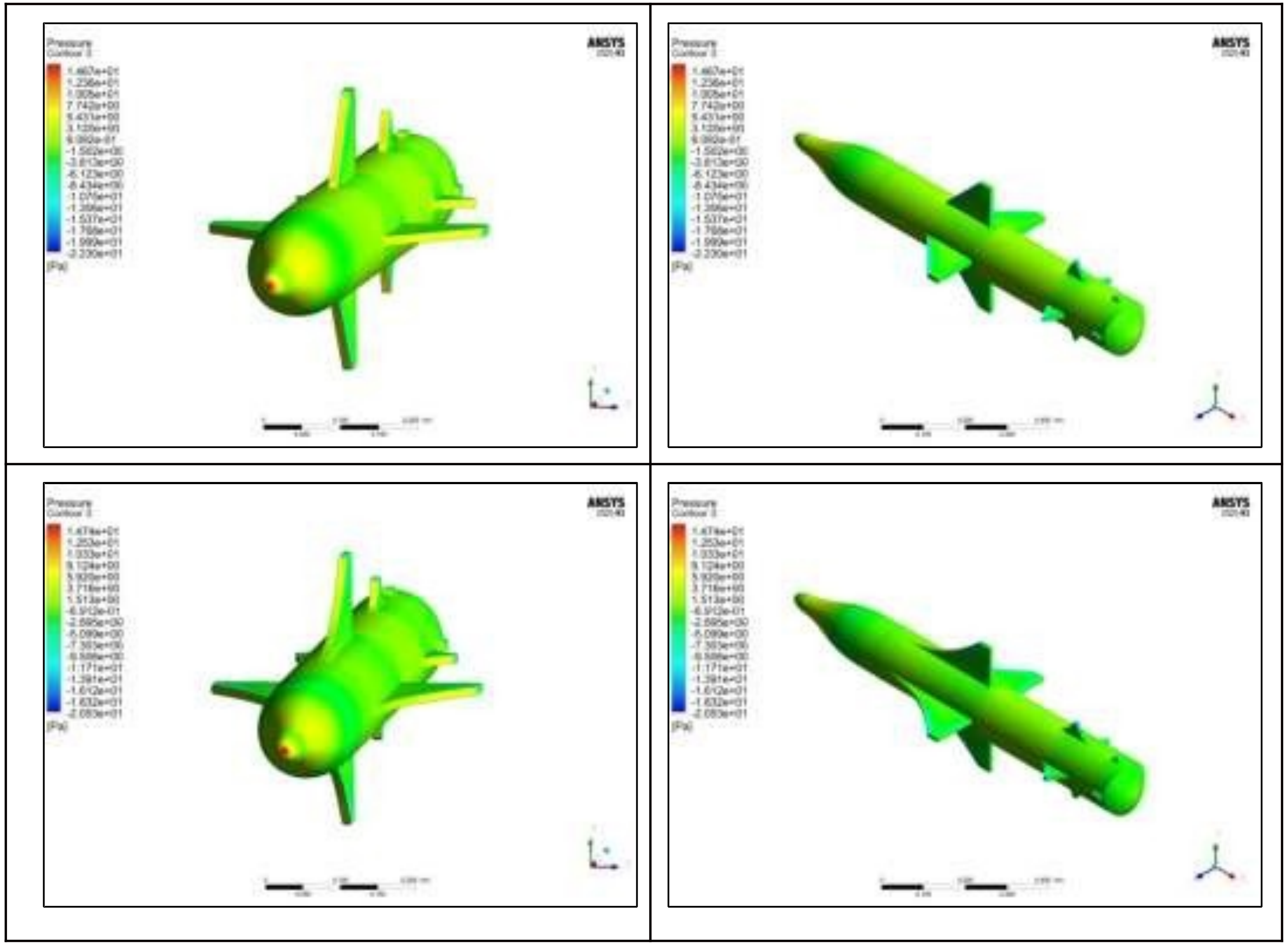
Comparison of Pressure
for missile 5 design iterations



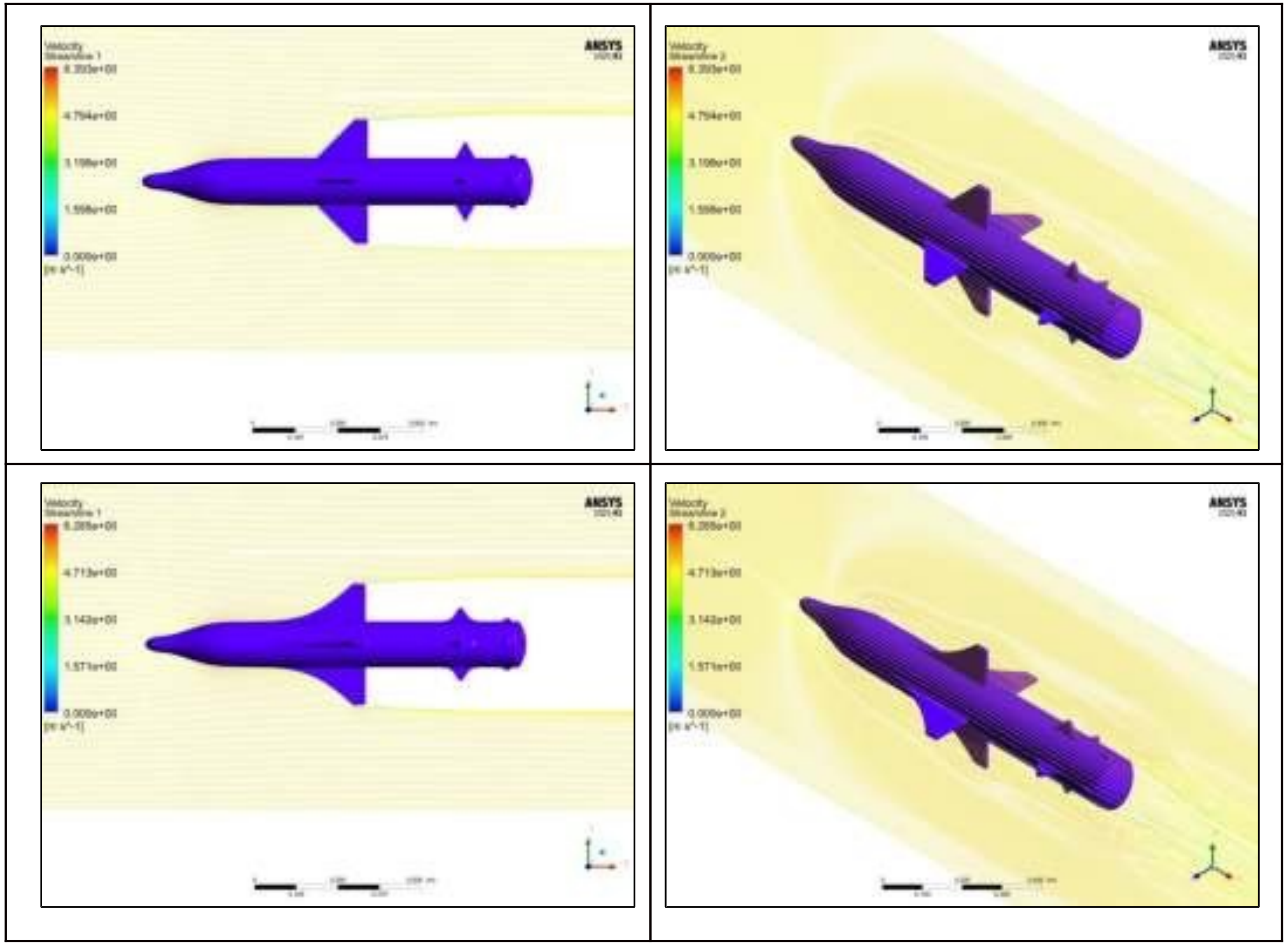
Comparision of Streamlines
for missile 5 design iterations



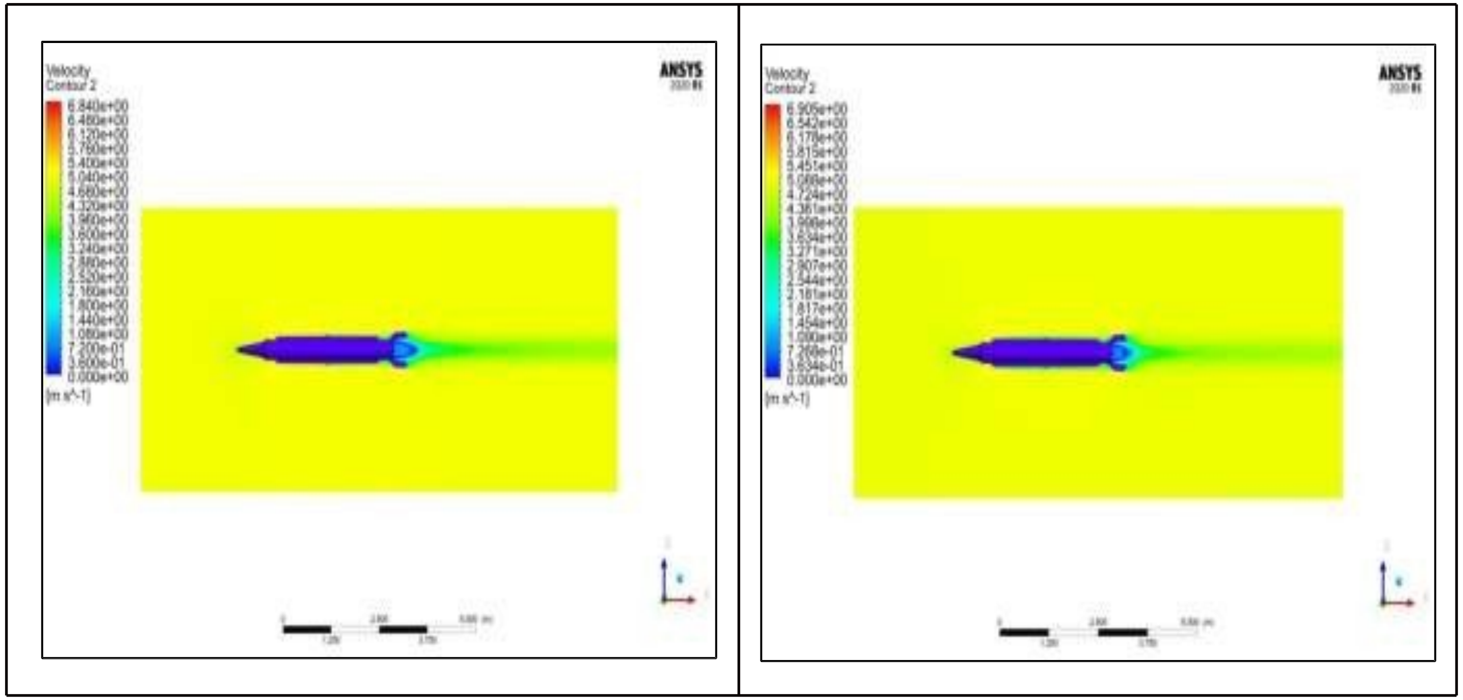
Comparision of VELOCITY
for missile 6 design iterations



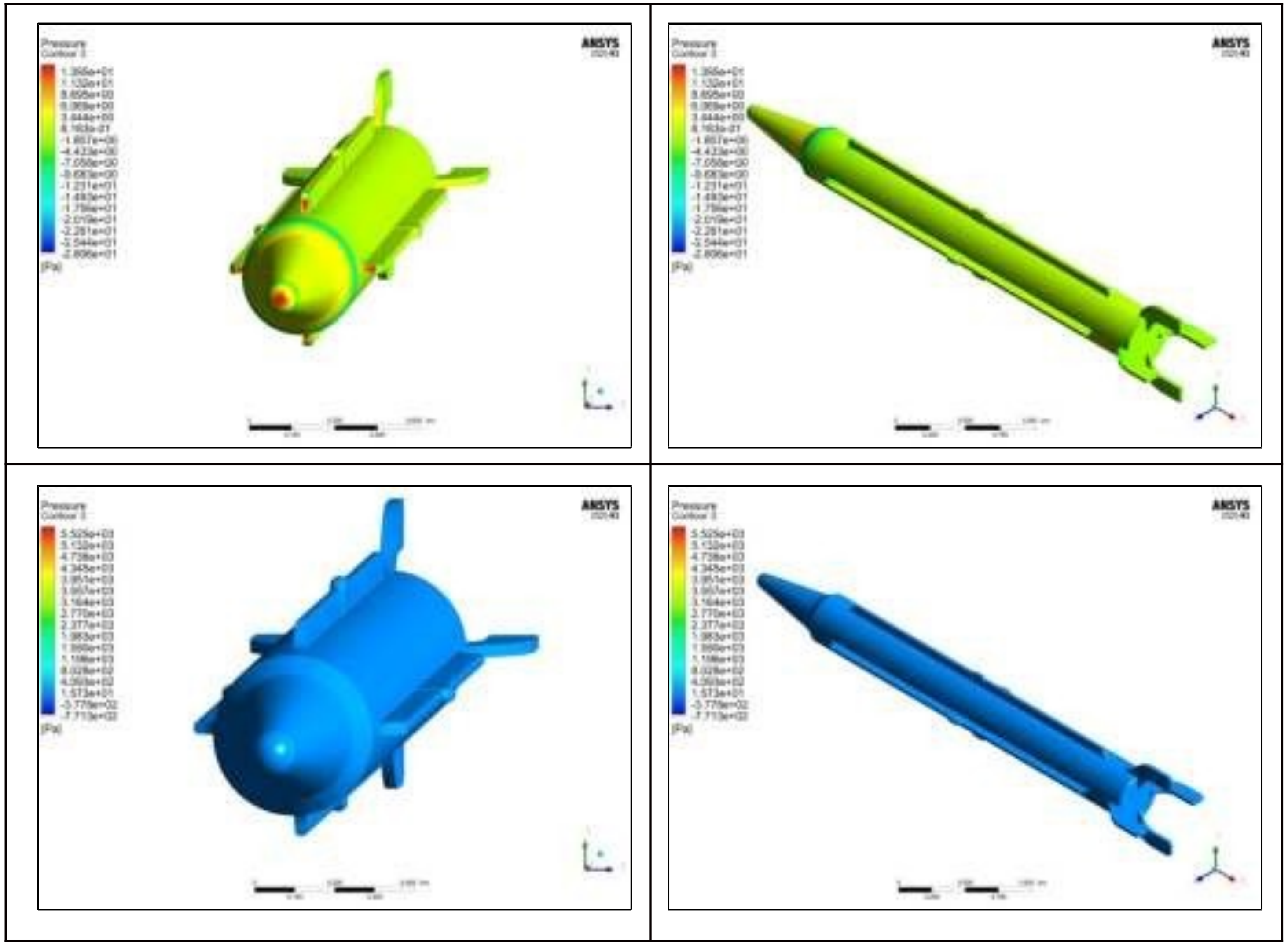
Comparison of Pressure
for missile 6 design iterations



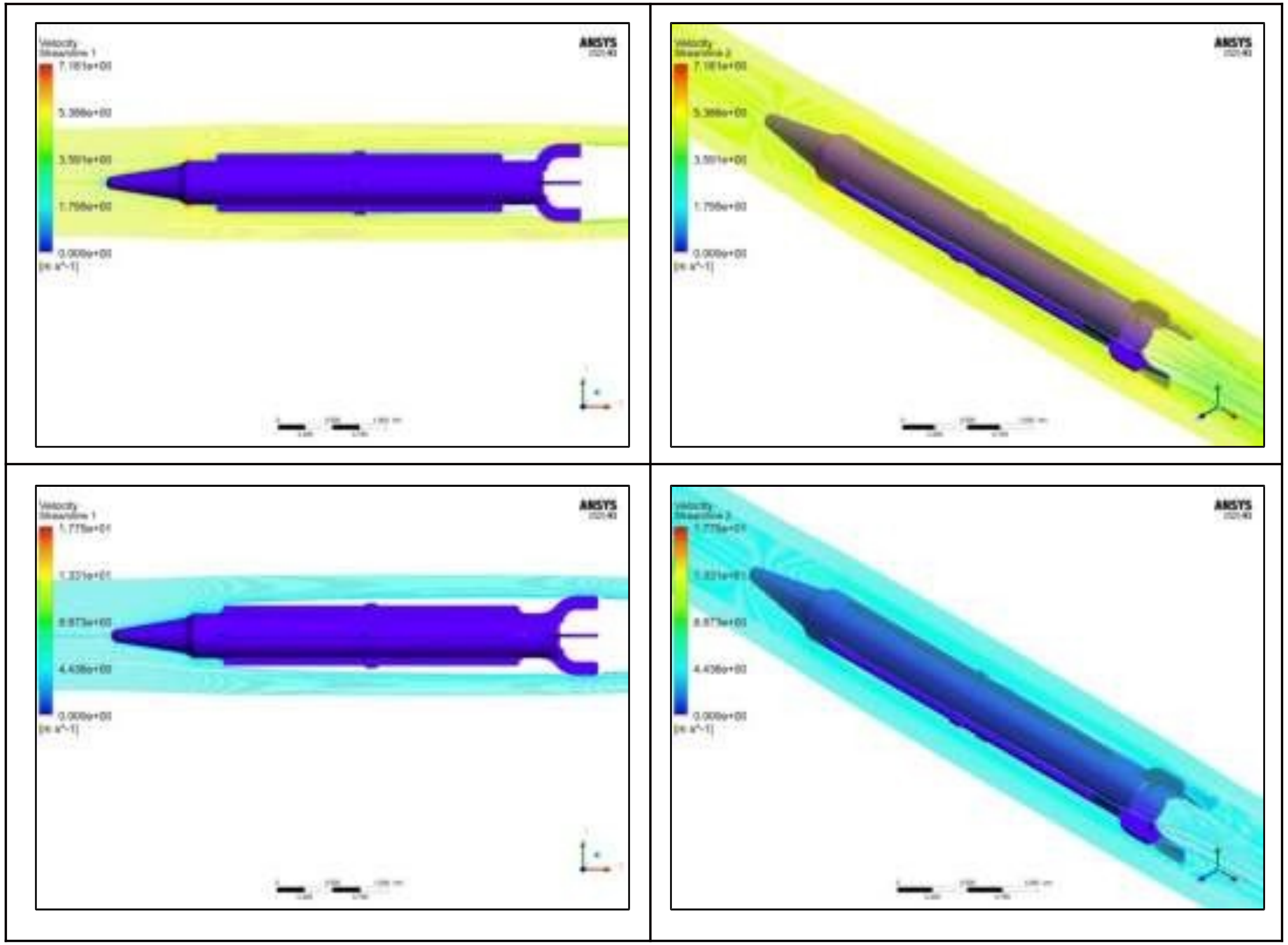
Comparision of Streamlines
for missile 6 design iterations



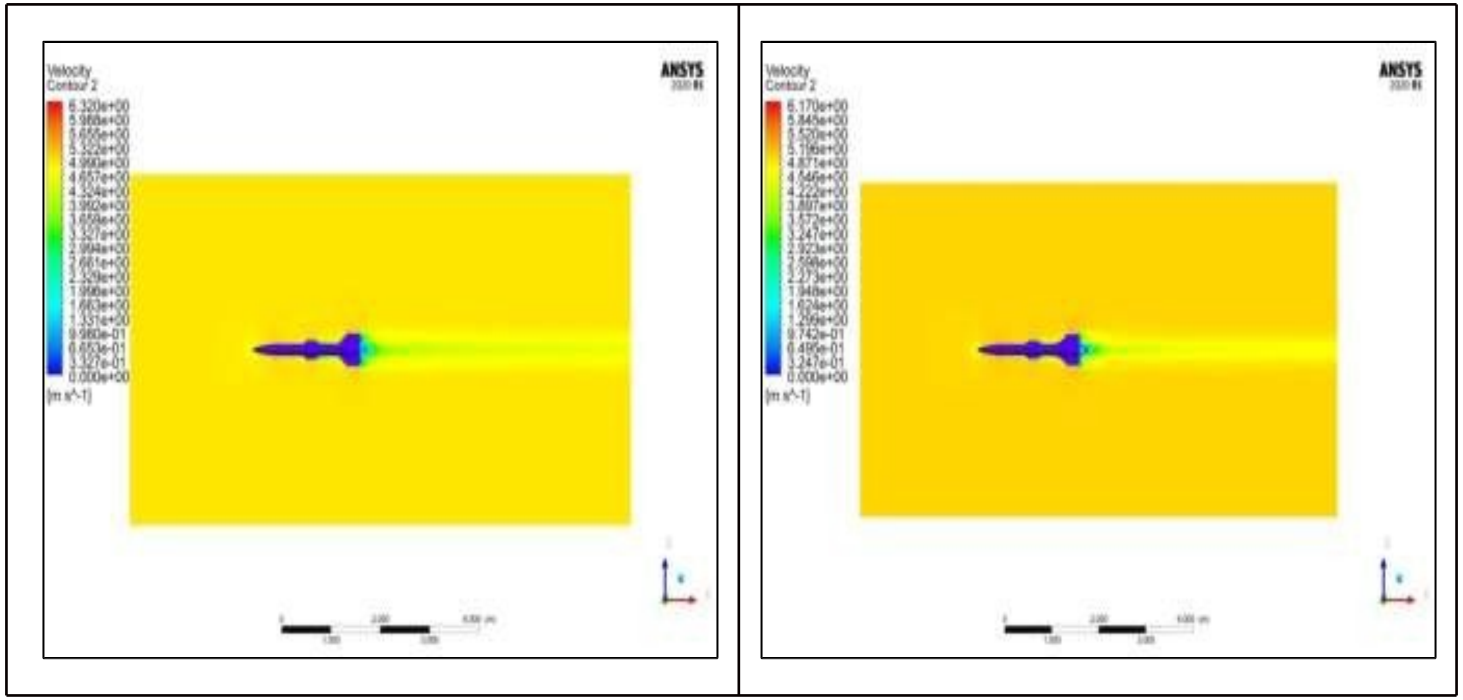
Comparision of VELOCITY
for missile 7 design iterations



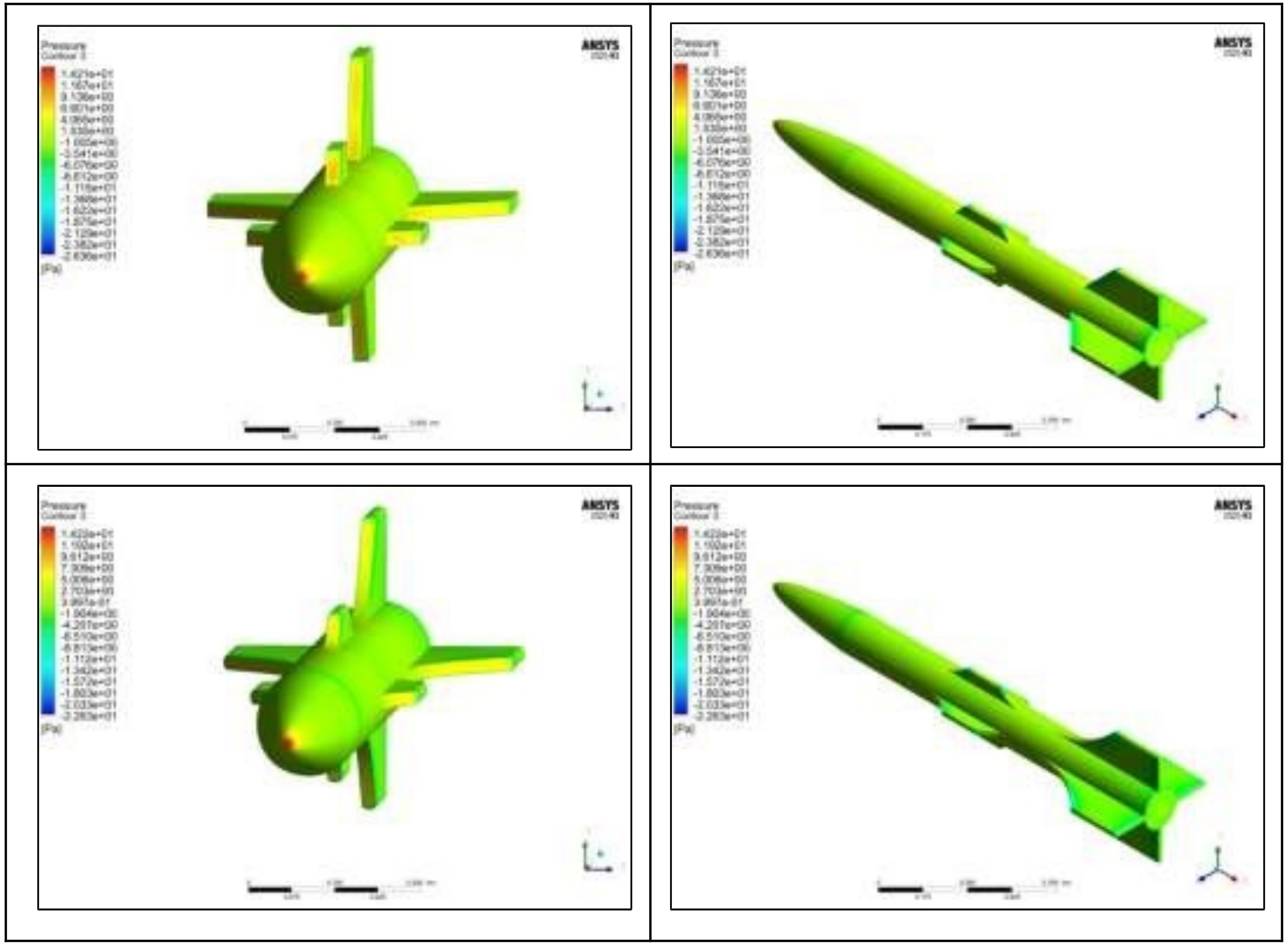
Comparison of Pressure
for missile 7 design iterations



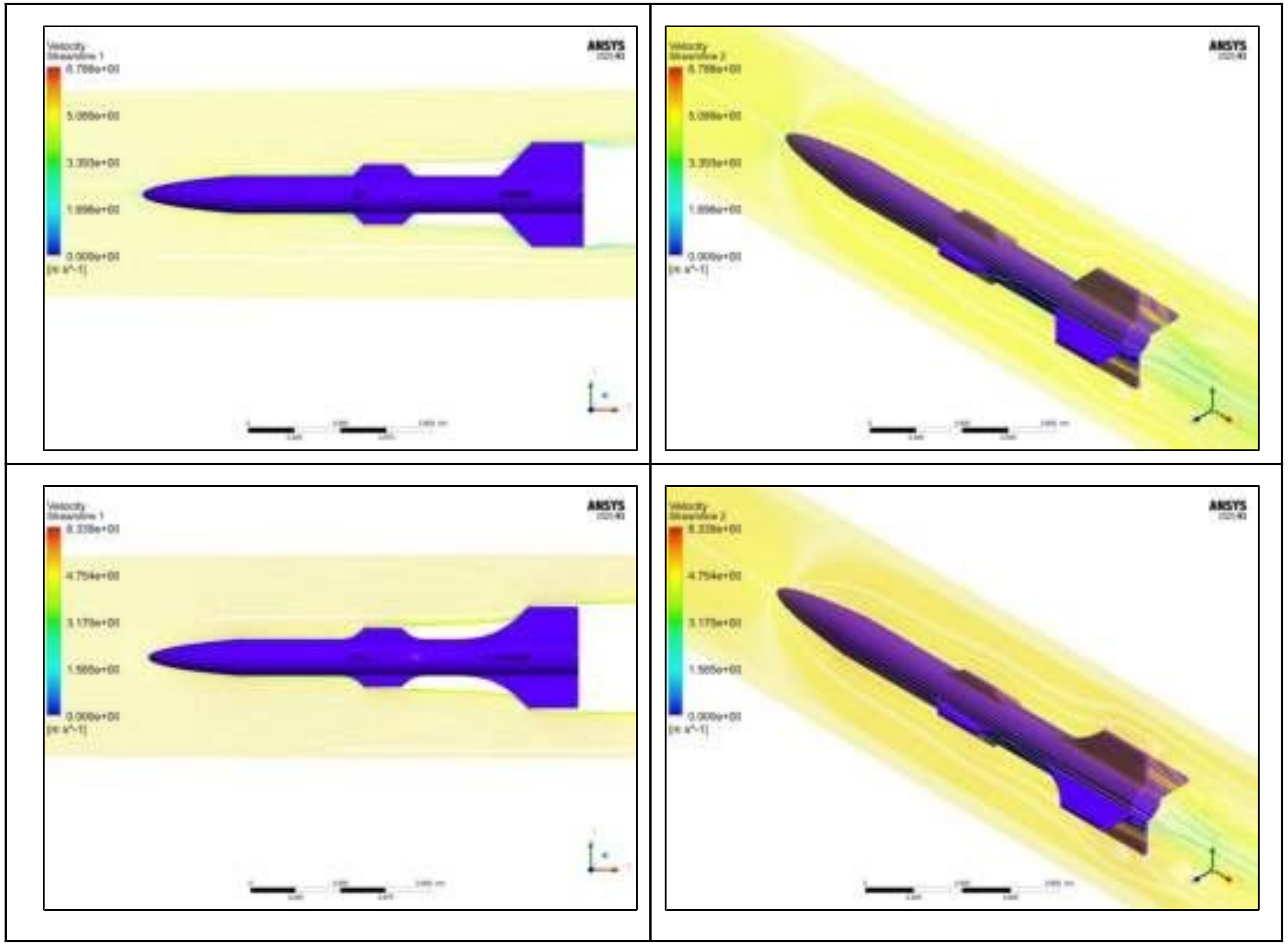
Comparision of Streamlines
for missile 7 design iterations



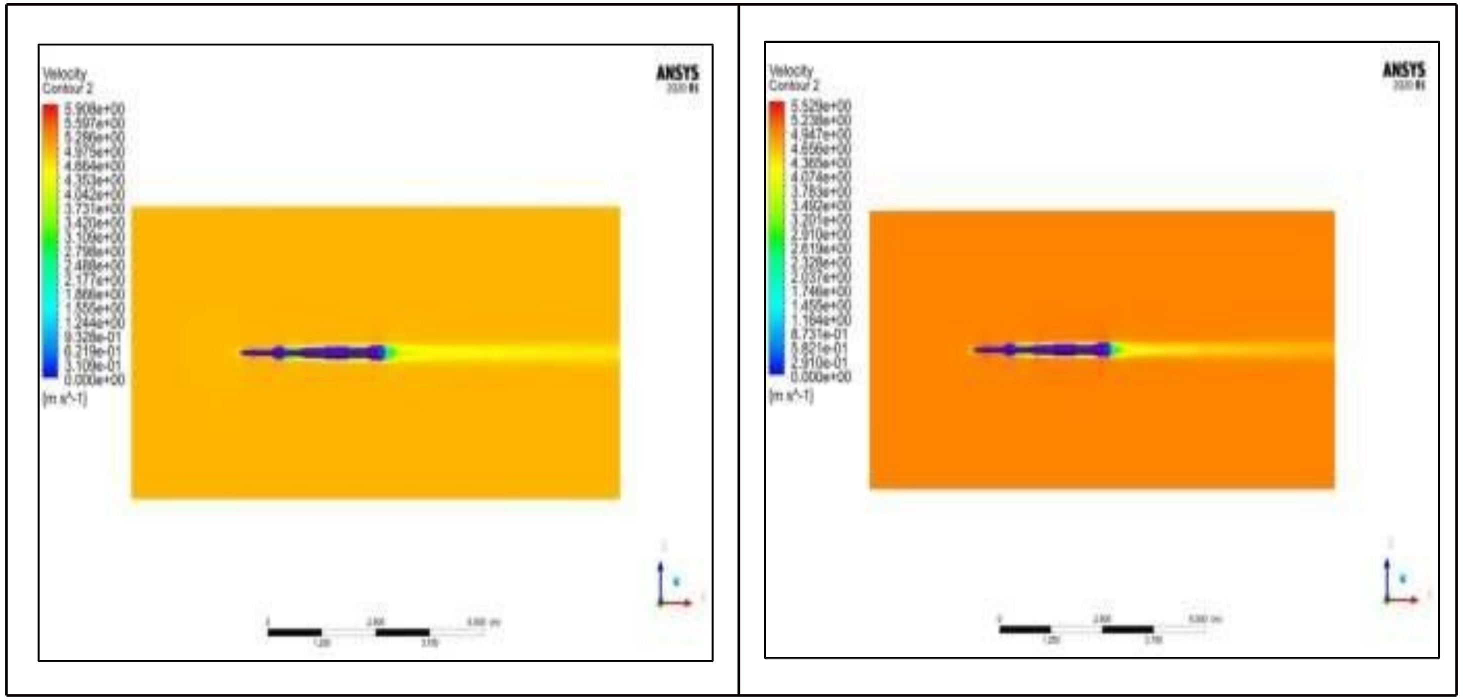
Comparision of VELOCITY
for missile 8 design iterations



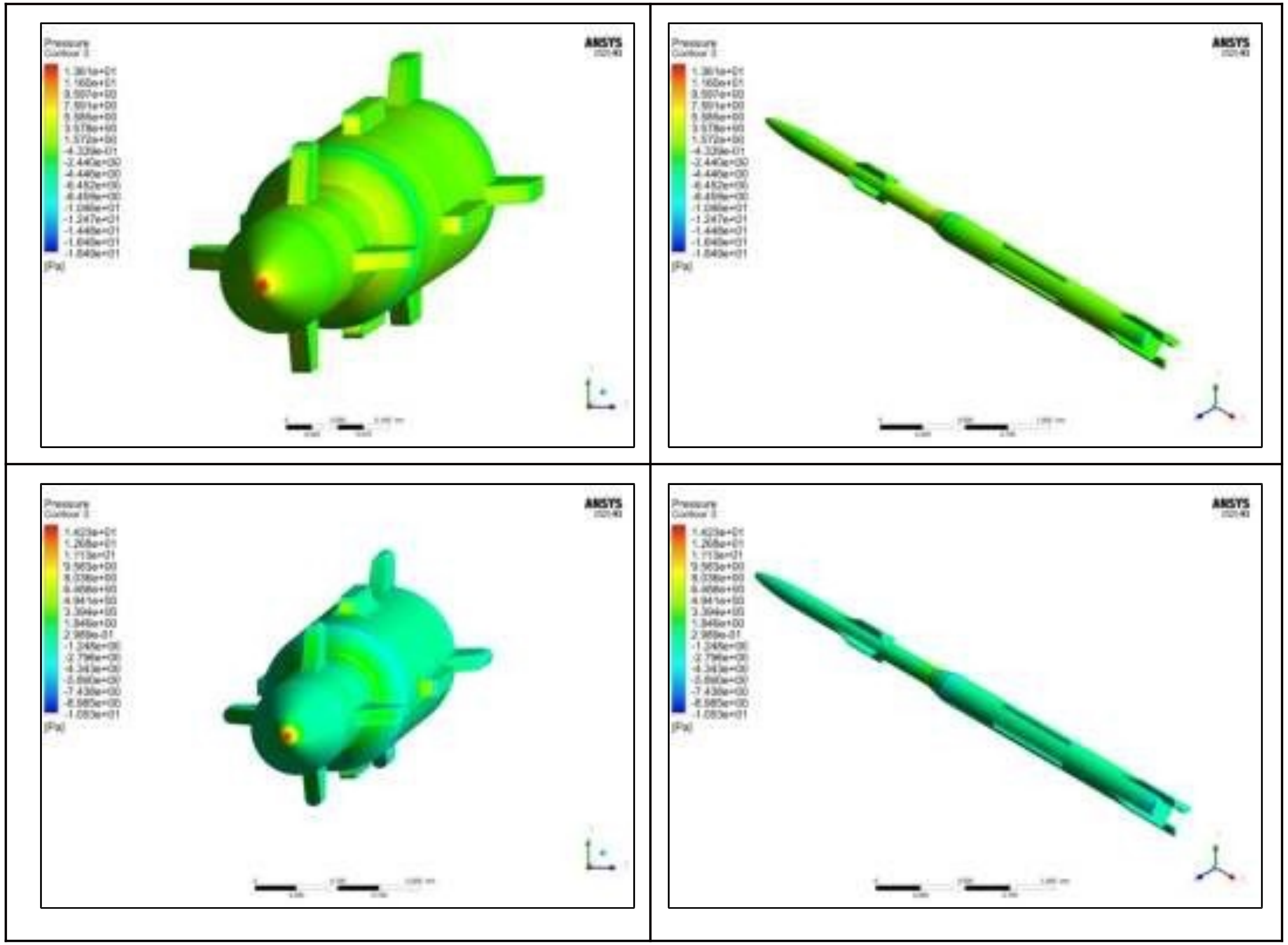
Comparison of Pressure
for missile 8 design iterations



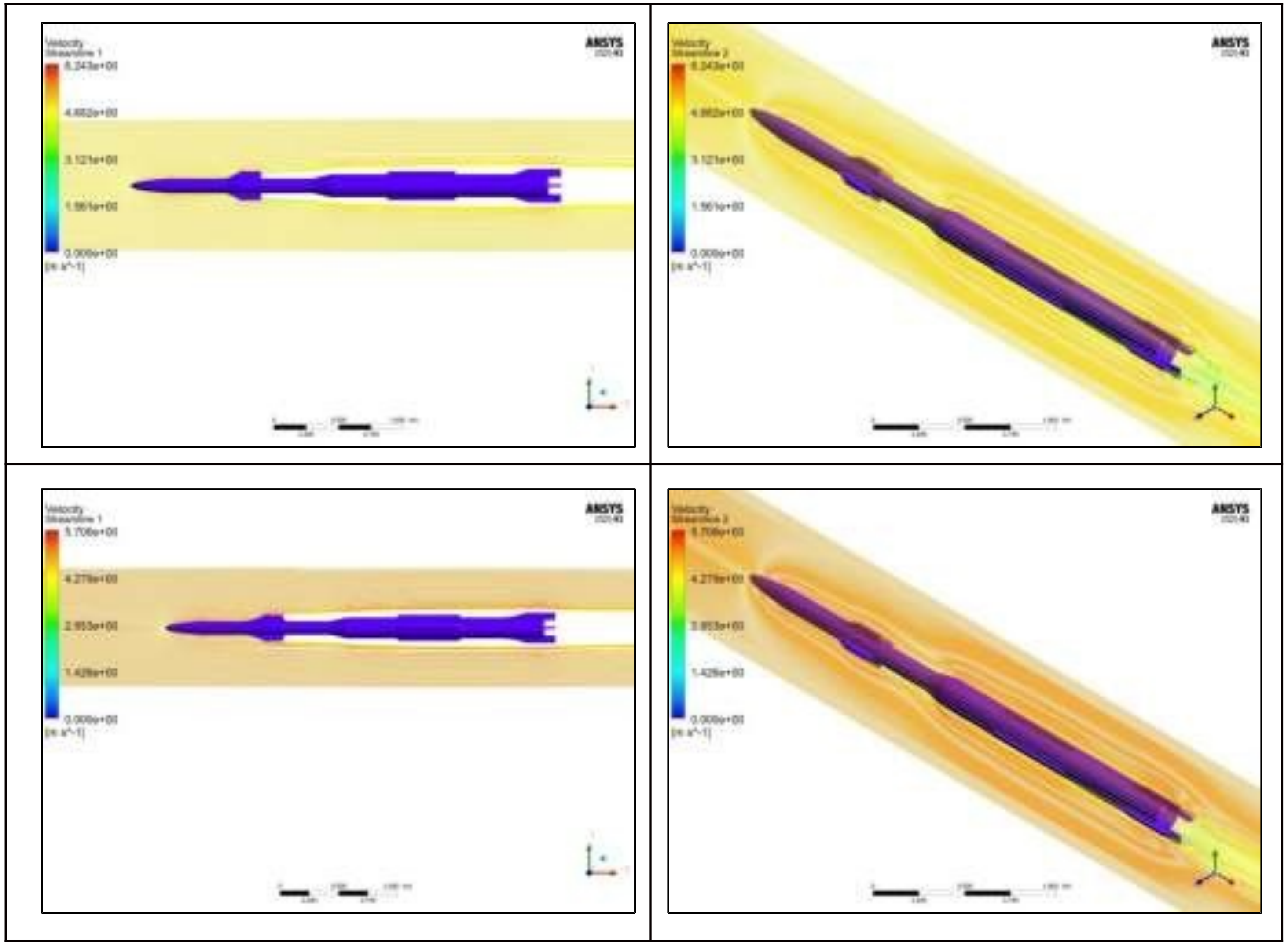
Comparision of Streamlines
for missile 8 design iterations



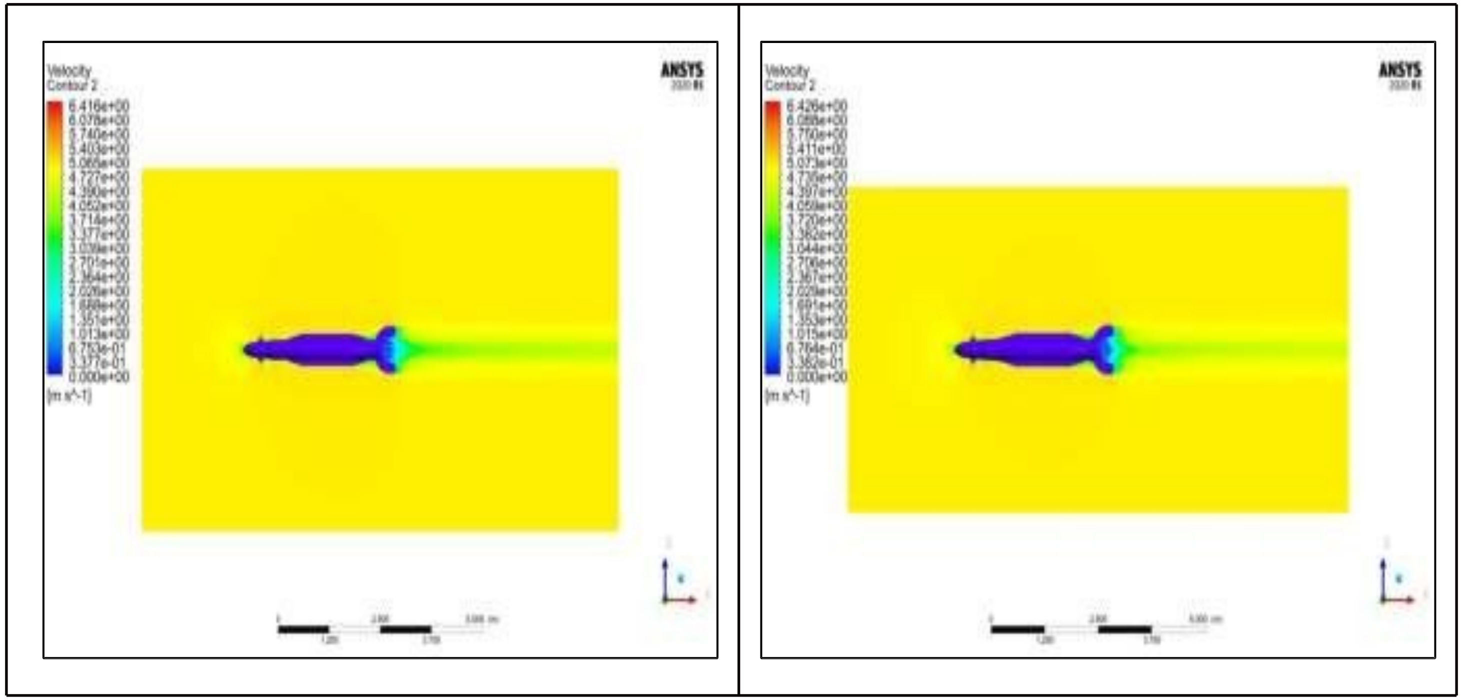
Comparision of VELOCITY
for missile 9 design iterations



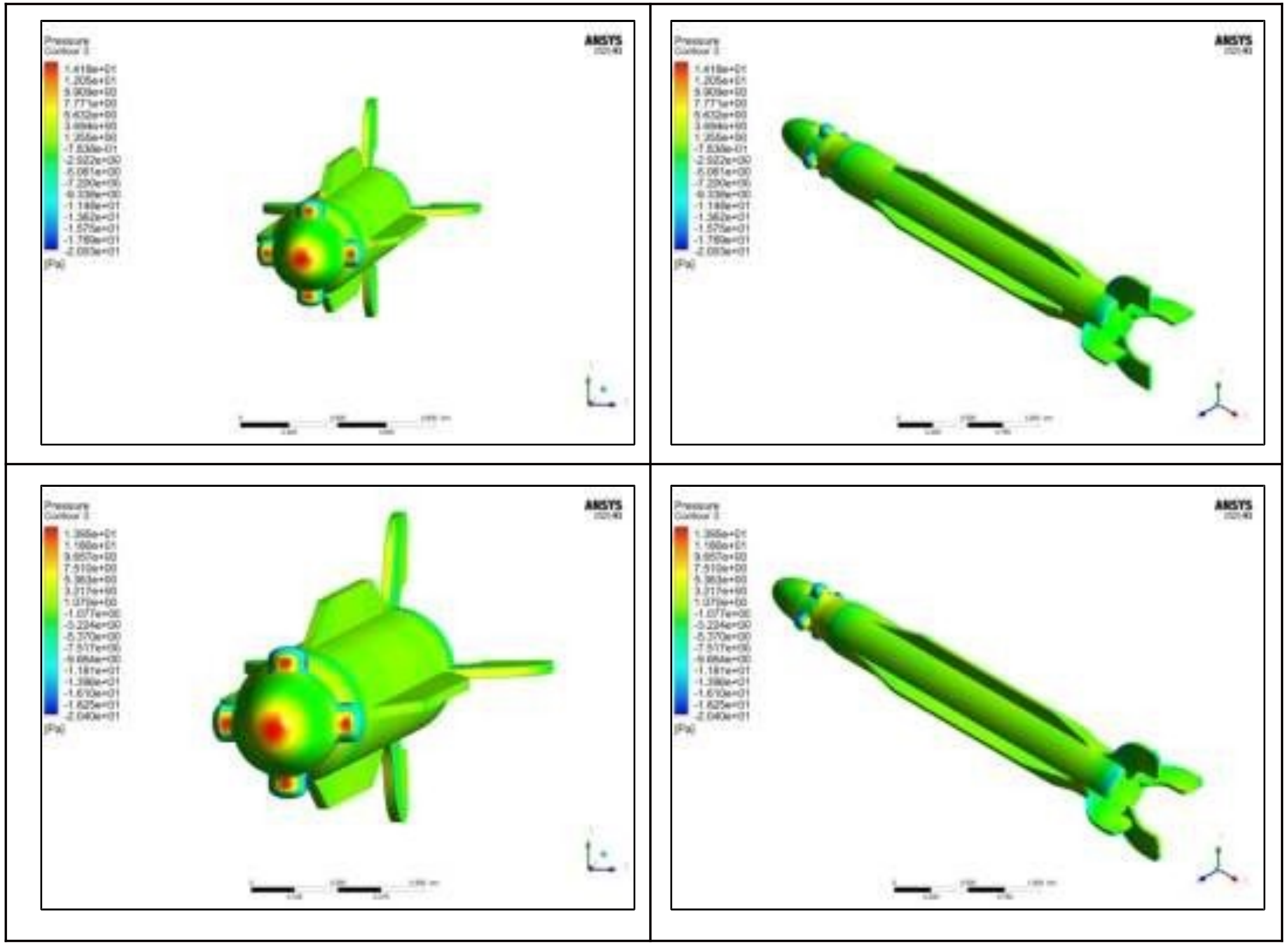
Comparison of Pressure
for missile 9 design iterations



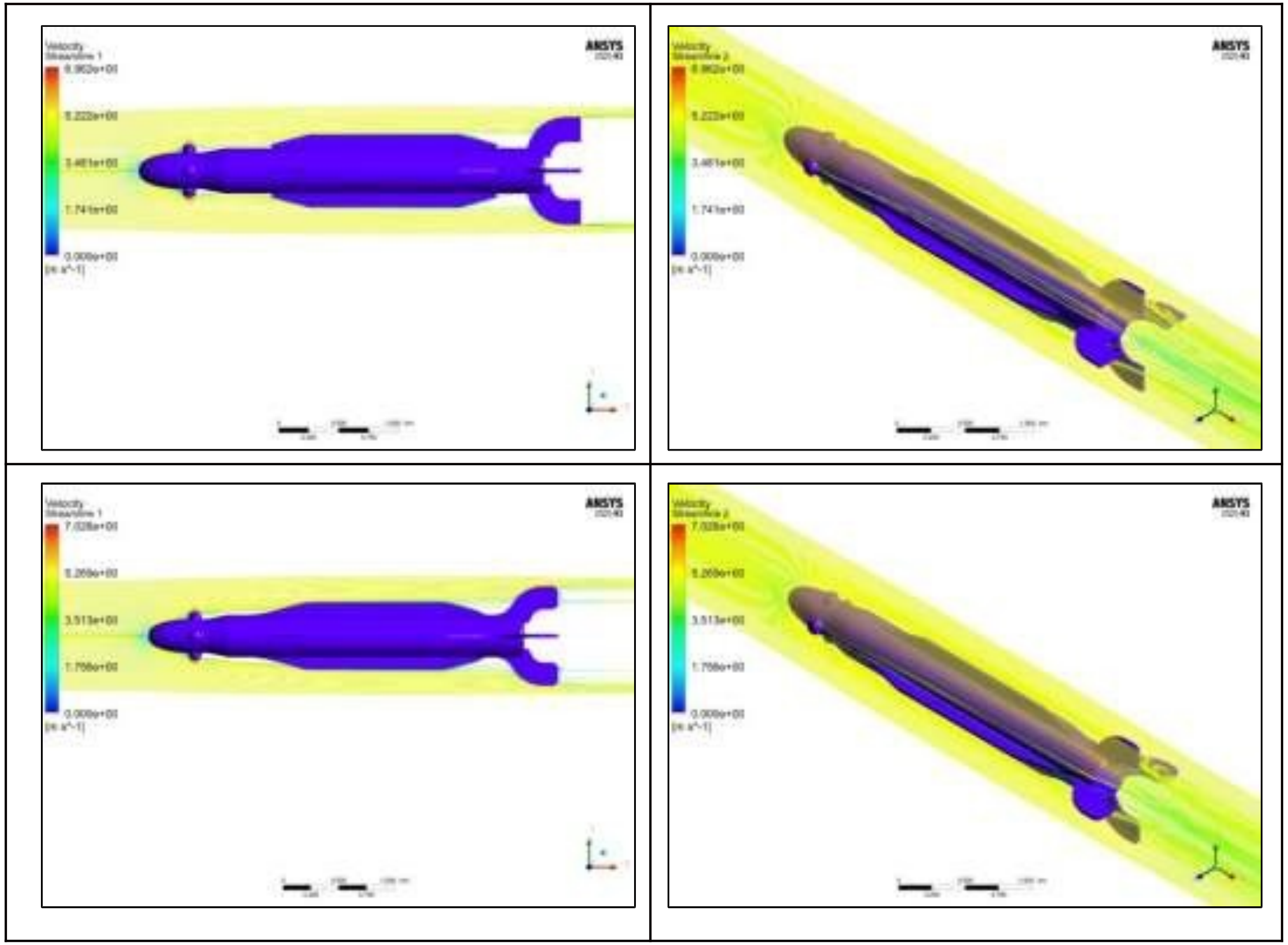
Comparision of Streamlines
for missile 9 design iterations



Comparision of VELOCITY
for missile 10 design iterations



Comparison of Pressure
for missile 10 design iterations



Comparision of Streamlines
for missile 10 design iterations

Drag & Lift Forces		
Model	Drag Force (N)	Lift Force (N)
Missile 1 Sharp	0.20758716	-0.00423198
Missile 1 Filleted	0.17911896	-0.004857337
Missile 2 Sharp	0.31493897	-0.002979353
Missile 2 Filleted	0.29636611	-0.001783583
Missile 3 Sharp	0.08234179	-0.004532901
Missile 3 Filleted	0.07572791	0.002910668
Missile 4 Sharp	0.084236751	-0.000182087
Missile 4 Filleted	0.081243515	0.001363666
Missile 5 Sharp	0.09302589	-0.000725668
Missile 5 Filleted	0.086394158	-0.002559048
Missile 6 Sharp	0.088460221	-0.000352476
Missile 6 Filleted	0.072421526	0.000895801
Missile 7 Sharp	0.48515777	0.000858015
Missile 7 Filleted	0.43193222	0.024347869
Missile 8 Sharp	0.19238013	0.013357251
Missile 8 Filleted	0.16000761	-0.000755073
Missile 9 Sharp	0.10727692	0.00089166
Missile 9 Filleted	0.10391117	-0.002794429
Missile 10 Sharp	0.5462592	-0.044705155
Missile 10 Filleted	0.46788704	0.013770241

6

SWOT Analysis

SWOT Analysis

1. **Strengths:**

1. Acts of aggression by North Korea and Iran to drive demand in the US and allied countries
2. High-precision systems enhance accuracy
3. Technological innovations such as the Iron Dome missile system to handle asymmetric threats

2. **Weaknesses:**

1. High cost of developing missiles and missile defense systems causing a drain on national budgets
2. Missile Technology Control Regime to adversely impact sales of missiles
3. Missile defense programs failing towards the end of advanced testing stage

3. **Opportunities:**

1. As fleet strength within Asia-Pacific increases, demand for anti-ship missiles is set to rise
2. The growing demand for unmanned combat aerial vehicles to increase the scope of the market
3. Development of the ALTBMD program to spur demand for missile defense system elements
4. Next generation of Navy missile defense to drive demand for Ballistic Missile Defense in Warships

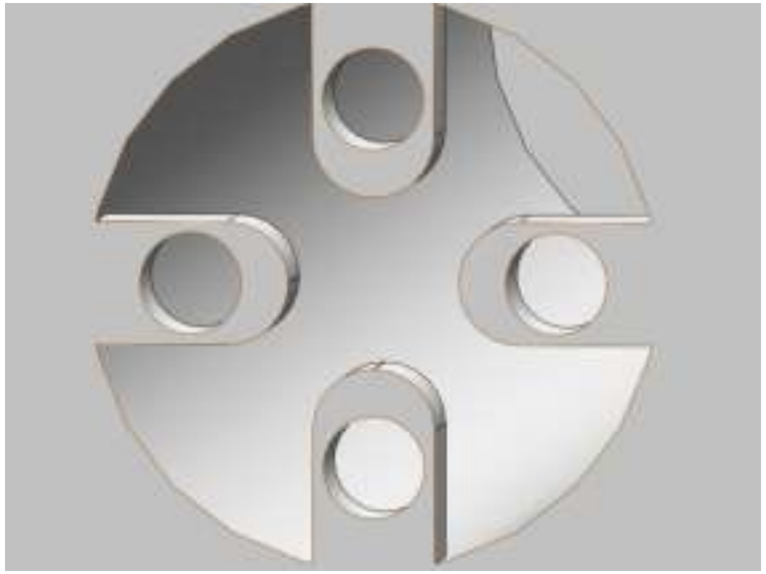
4. **Threats:**

1. Demand for missiles could be weakened by laser-guided bombs
2. US and European economic crisis
3. Across the board defense cuts to impact demand

7

DFMA study

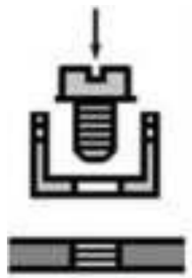
DFMA study



Brackets on main missile part

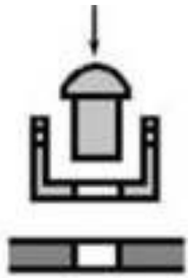
Holes on war head of missile

DFMA study



For mounting between main missile part and war head the screw can be used.

- Threadings must be done.
- 3 parts
- Requires a screwdriver.
- Needs careful allignment.
- Time consuming.
- It under goes more stress.



For mounting between main missile part and war head the rivet can be used.

- Just holes must be done.
- 2 parts
- Requires a rivet gun.
- Alignment not as delicate.
- Less Assembly time.
- Less stress than screws.

8

Conclusion

Conclusion

In conclusion, all of the missiles demonstrated significant impact and aerodynamic stability at speeds below 5000 m/s. However, some missile designs require speed optimization, as they have successfully endured up to 100 cycles in fatigue testing. The application of filleting to the sharp edges greatly contributed to reducing the overall volume of the missiles while enhancing their aerodynamic performance. For the assembly process, rivet joints are recommended due to their time efficiency and structural stability. I was particularly successful in achieving the design objectives for the tenth missile, which demonstrated both greater impact potential and improved aerodynamic stability. Overall, this project provided a valuable learning experience, giving me substantial exposure to missile research and development.

THANK YOU