On-site Repair Application of Additive Manufacturing

Additive Manufacturing Course

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By,

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Contents

Objective

- **The objective of the project is to analyze and demonstrate the use of wire-arc additive manufacturing for repair of a defective steel bracket.**

Problem Statement

- There is a bracket to be used in the Pump applications.
- This steel bracket is to be fixed at its 6 bolt locations and usually takes 1000N force on each face side of the component holding location.
- Eventually, due to these loading conditions, there will be a high-stress concentration at the critical edge of this feature, leading to a crack.
- Instead of discarding and replacing the bracket completely, we will use wire-arc additive manufacturing to repair the bracket.
- This manufacturing method fills in this tiny gap created due to cracks with a uniformly layered material and increases the operating life span of the bracket.

Methodology

Geometry variants

- **Analysis was carried out for three different geometric variants of the bracket.**
- **The first simulation involved a bracket without any defect.**
- **The second geometry is a bracket with defect.**
- **The third geometry involved a bracket after repairing the defect site using additive manufacturing FEM simulation.**

Methodology

Materials selection and its properties

- **The materials used for this simulation are Structural steel, Titanium alloy, and polyethylene. A comparison study is done between the three materials to evaluate the material selection for this application.**

Material Properties:

- **Structural Steel-**
- Ultimate Tensile Strength: 460 MPa
- Elastic Modulus: 200 GPa
- Melting Temperature: 1350°C

- **Titanium Alloy-**
- Ultimate Tensile Strength: 1070 MPa
- Elastic Modulus: 114 GPa
- Melting Temperature: 1660°C

- **Polyethylene-**
- Ultimate Tensile Strength: 30 MPa
- Elastic Modulus: 1 GPa
- Melting Temperature: 115°C

Methodology

Meshing parameters considered

Static structural analysis for bracket without Defect

- **An adaptive sizing mesh was used for this analysis with a resolution of 7 for three different materials.**

Static structural analysis for bracket with defect

- **An adaptive sizing mesh was used to produce a fine mesh of resolution 7 for all different materials**

Transient Thermal for bracket with repair

- **An automatically generated mesh was used for this application as we wanted to reduce the number of elements in the additively manufactured site. The repair site was filled using 11 elements for the three different materials. In this way the, the element birth and death was simulated easily.**

Methodology

Loads and boundary conditions considered

Static Structural analysis for bracket without defect

- **A remote displacement boundary condition with zero displacement was applied at all 6 bolting locations. A force load of 1000N was applied at each face of the component holding site. The force was chosen based on the ultimate tensile strength of the different materials and a high safety factor value was achieved.**

Static Structural Analysis for bracket with defect

- **The same loads and boundary conditions were applied as that of the brackets without defect.**

Methodology

Loads and boundary conditions considered

Transient thermal analysis for bracket with repair

- **A thermal load heat flux of 1$\times 10^{-3}\ W/mm^3$ was used to simulate the heat load while performing the wire additive manufacturing process for Structural steel and titanium alloy due its high melting point.**
- **Polyethylene on the other hand was given a thermal load of 1$\times 10^{-6}\ W/mm^3$ to account for its low melting point.**
- **A Convection load with a film coefficient of 1$\times 10^{-6}\ W/mm^3$ was applied over the whole surface to simulate the convection heat transfer taking place while additively manufacturing the repair site.**

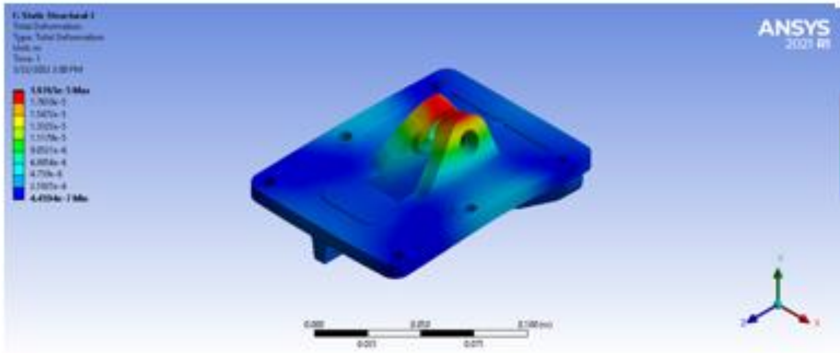
Static Structural analysis for bracket with repair

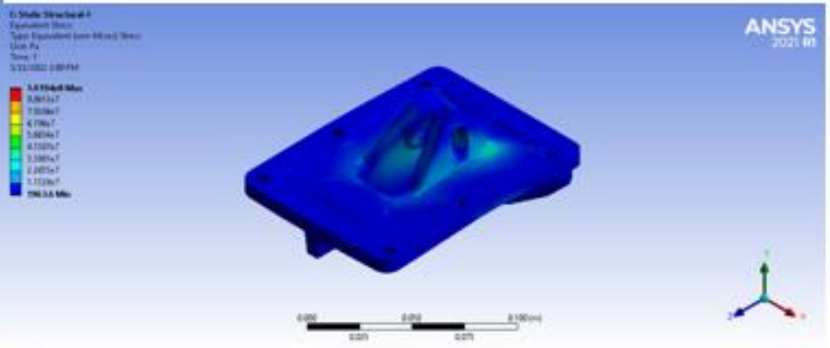
- **A force load of 1000 N on each face of the component holding site was applied. A fixed remote displacement boundary condition was applied at all the bolting sites within the component.**
- **Moreover, all the loads and boundary conditions from the transient thermal simulation were transferred to account for stress while additively manufacturing the repair site.**

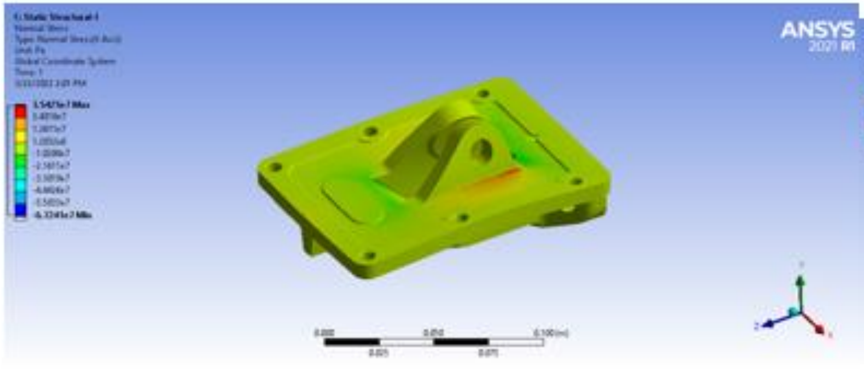
Observations and Results

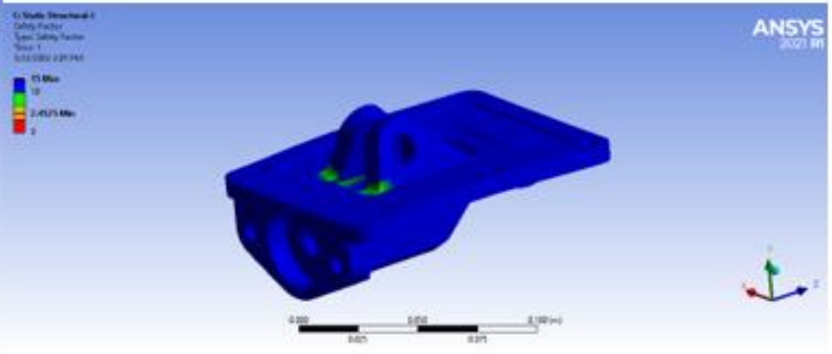
I. Static structural analysis for bracket without defect

Structural Steel- (Order of images: Deformation, Von mises Stress, Normal Stress, Factor of safety)



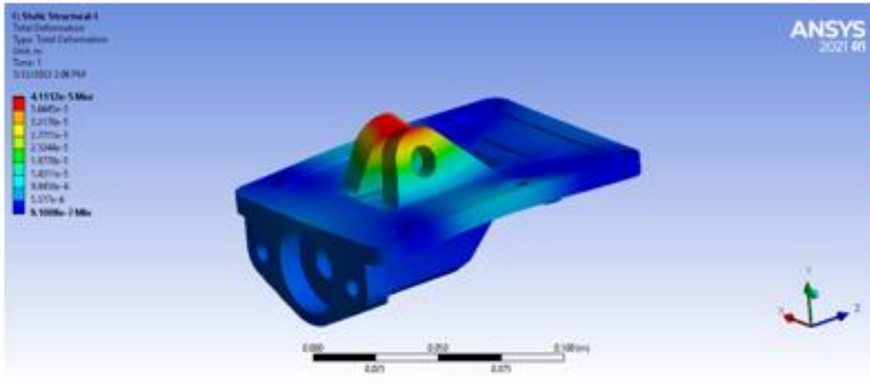


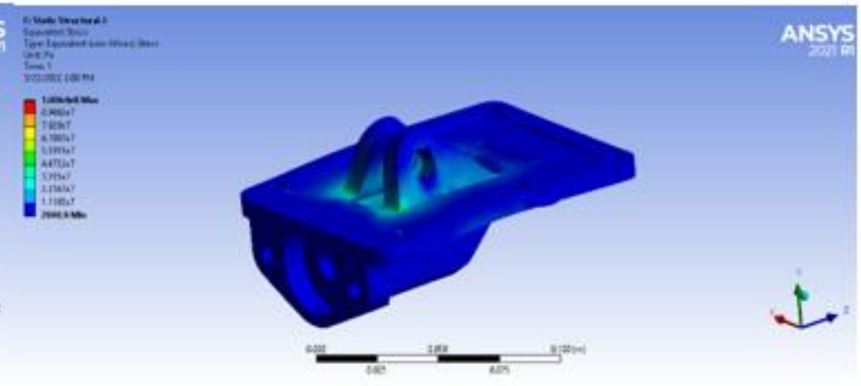


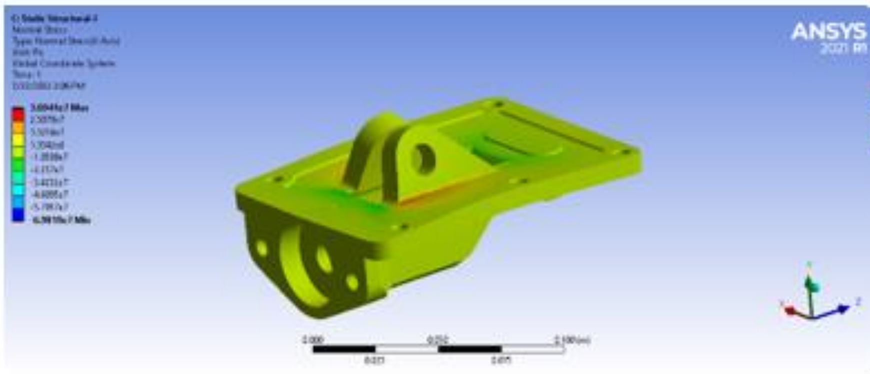


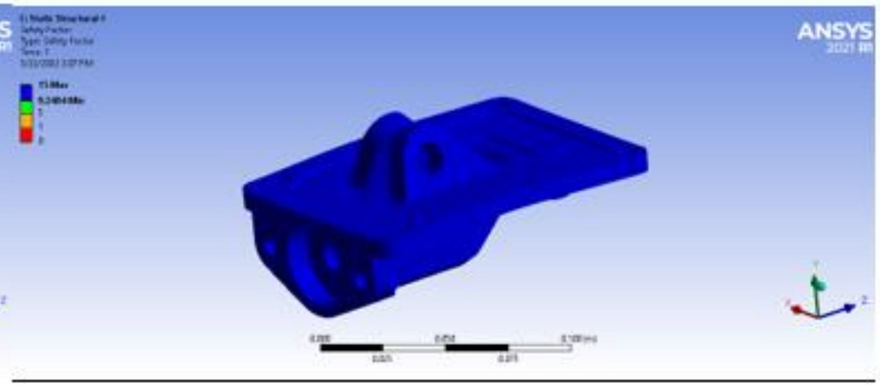
Observations and Results

Titanium Alloy-



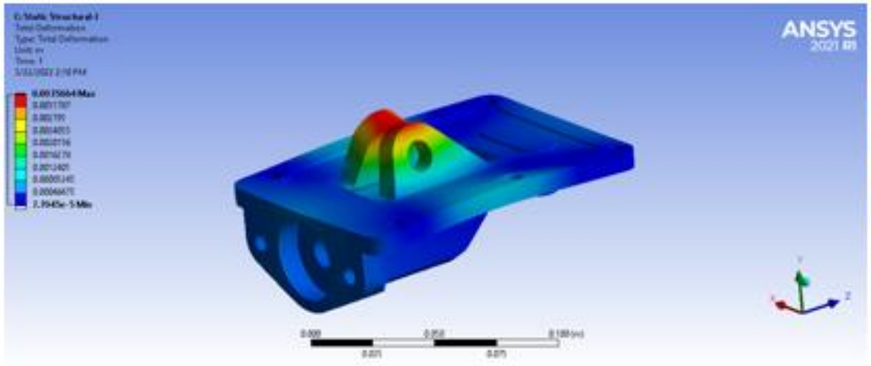


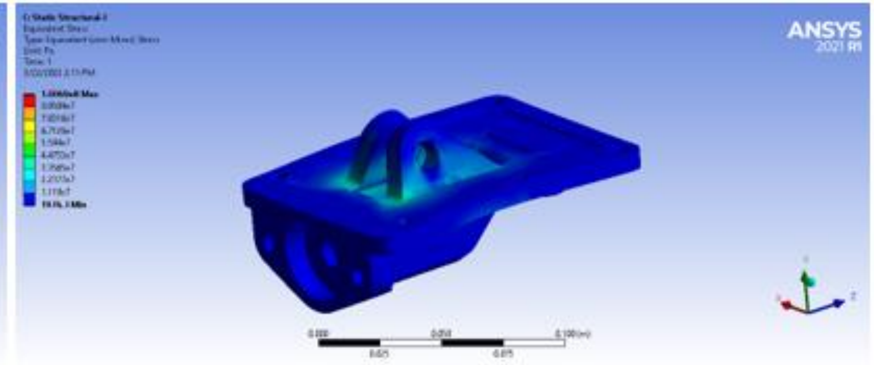


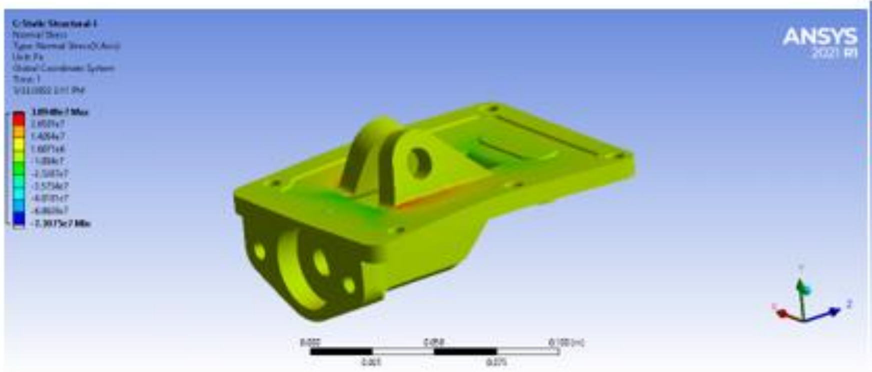


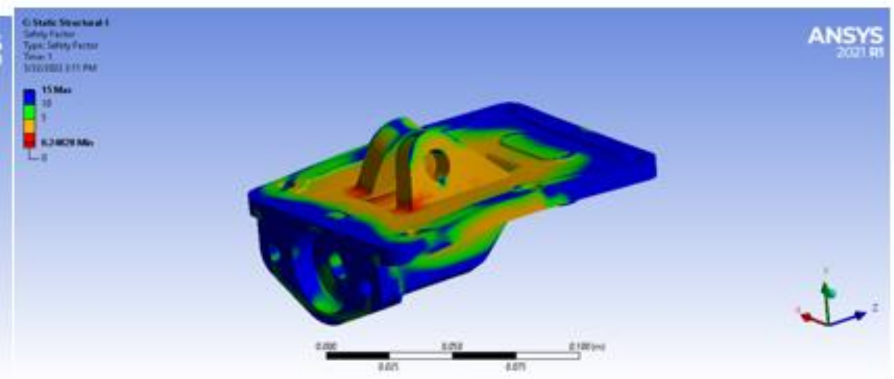
Observations and Results

Polyethylene-





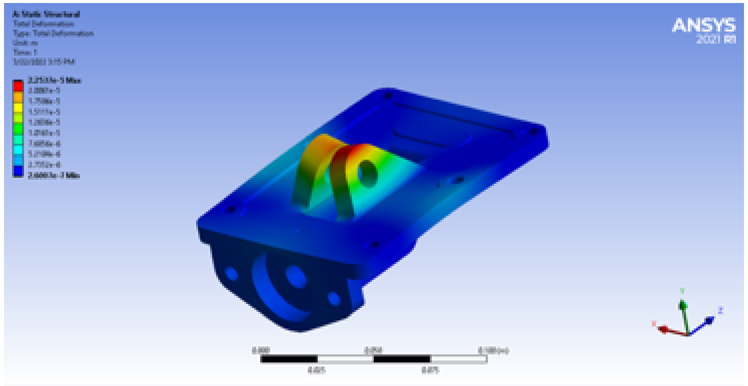


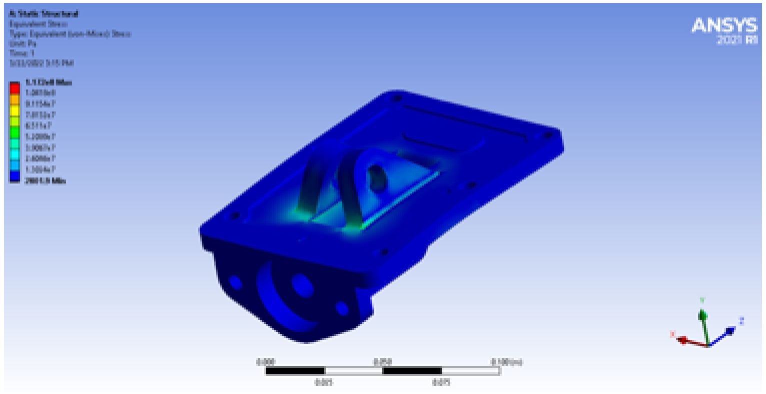


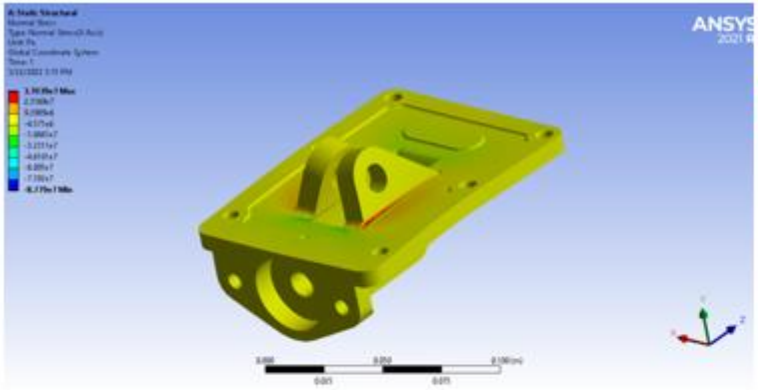
Observations and Results

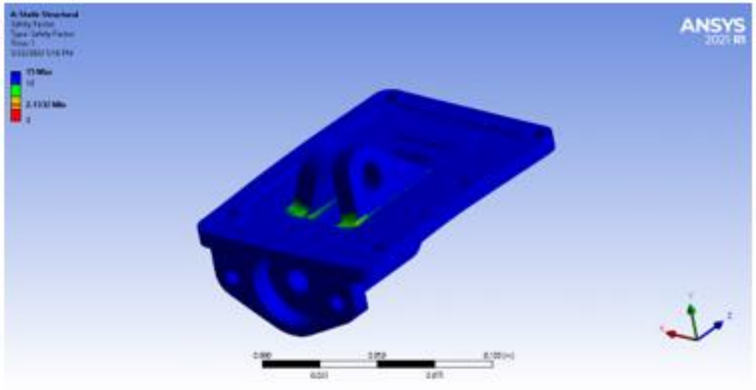
II. Static Structural Analysis for bracket with defect

Structural Steel- (Order of images: Deformation, Von mises Stress, Normal Stress, Factor of safety)



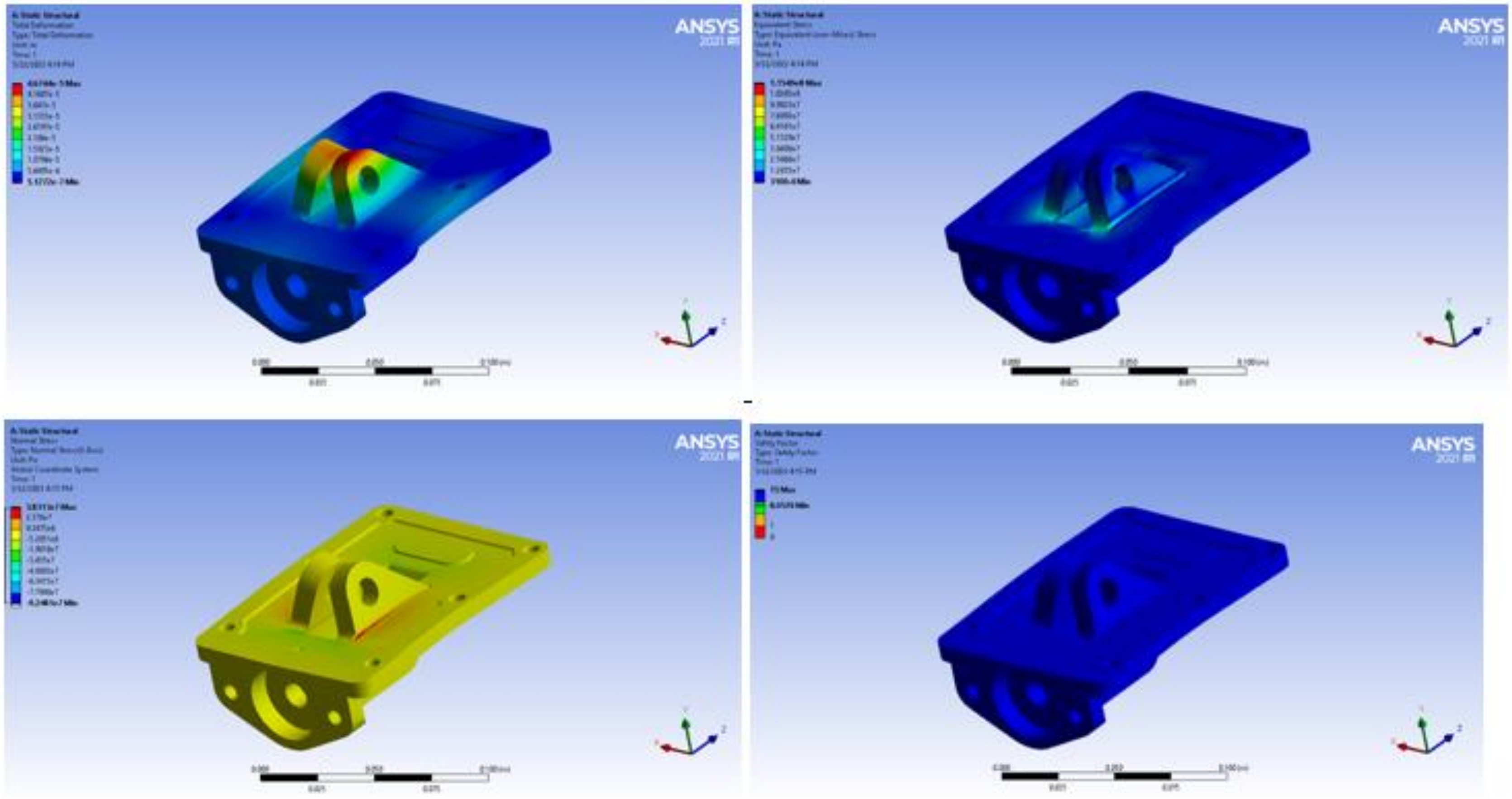






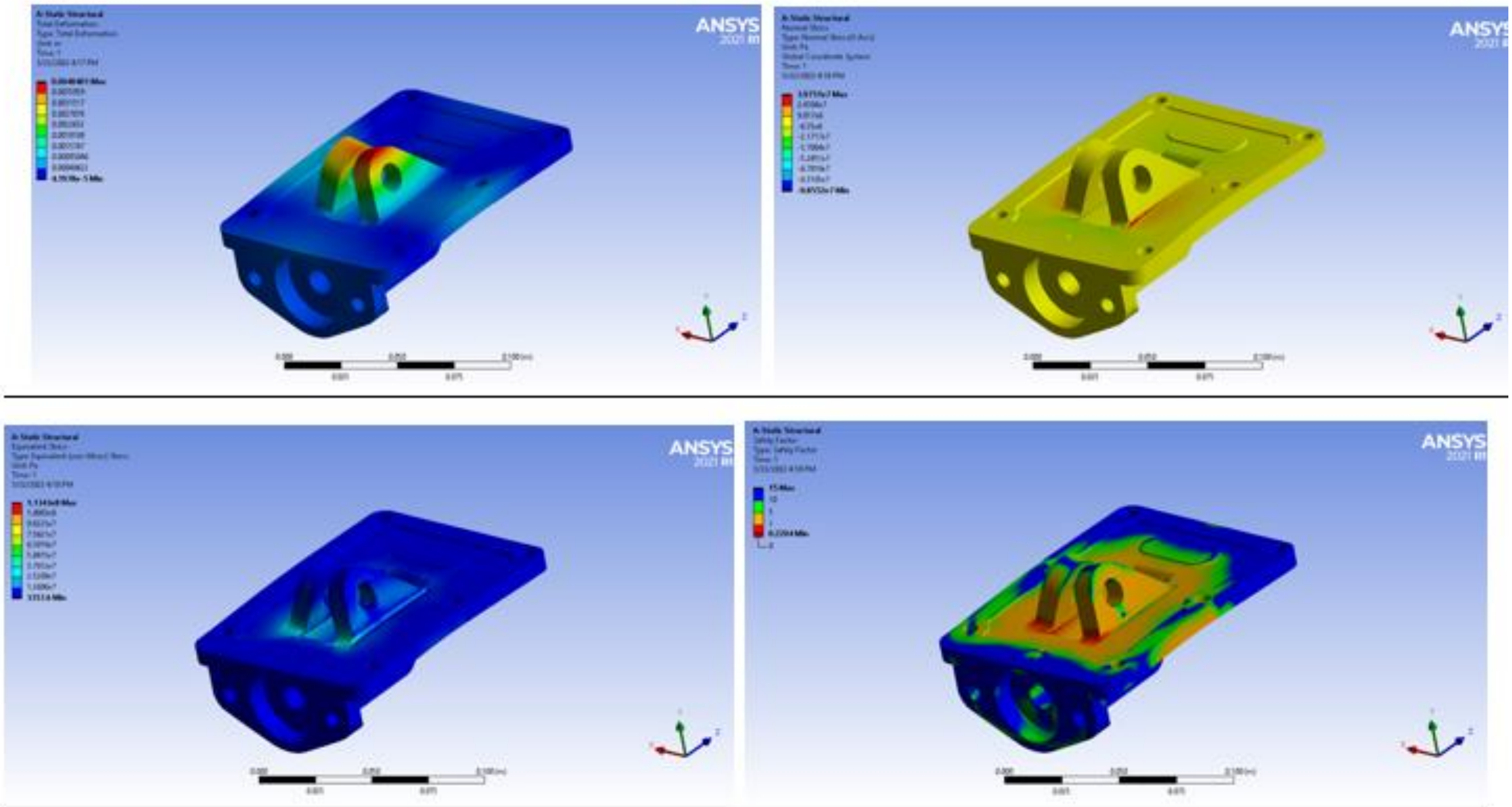
Observations and Results

Titanium Alloy



Observations and Results

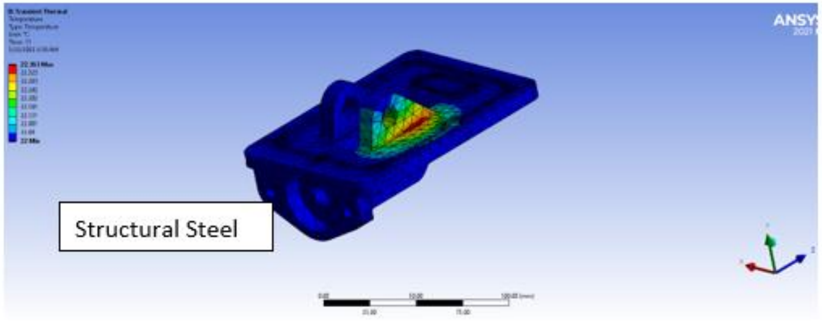
Polyethylene

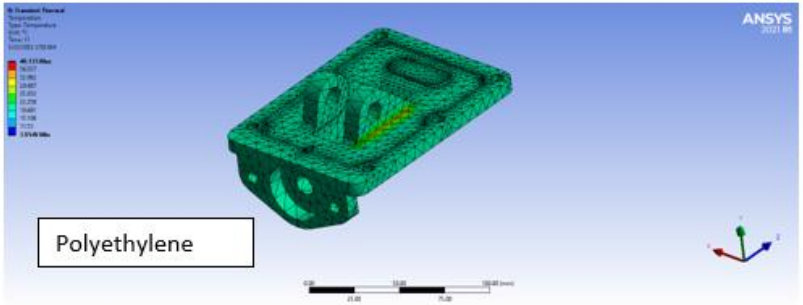


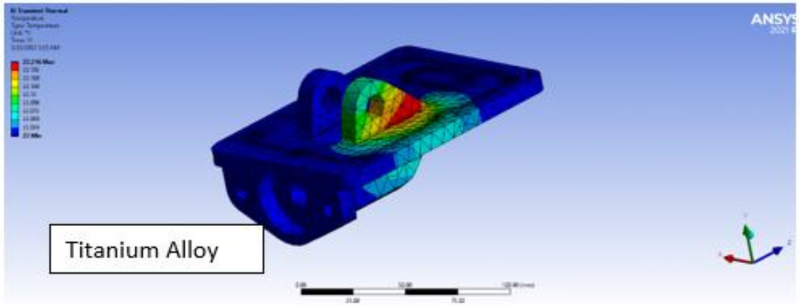
Observations and Results

III. Transient Thermal for bracket with repair

Temperature Contours



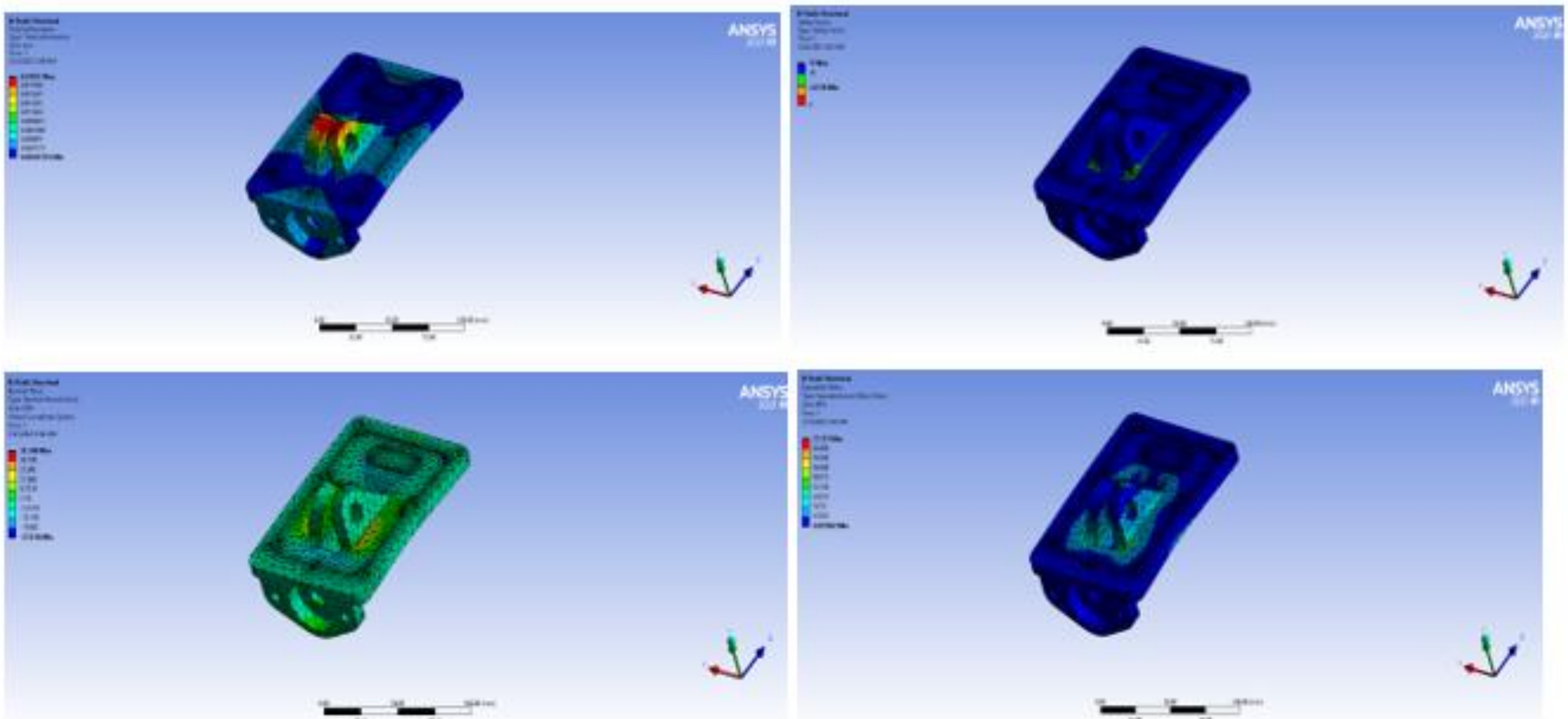




Observations and Results

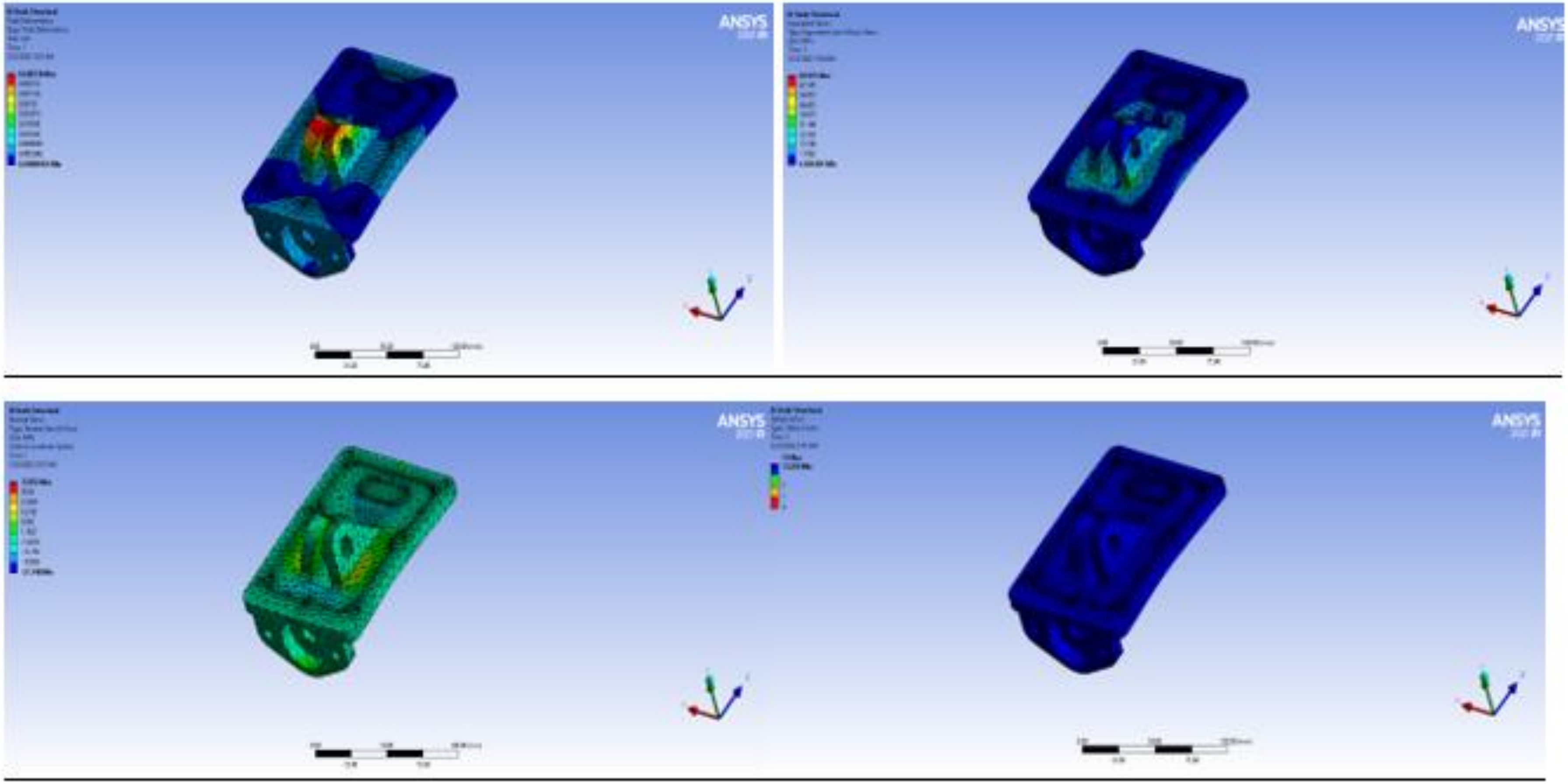
IV. Static Structural for bracket with repair

Structural Steel- (Order of images: Deformation, Von mises Stress, Normal Stress, Factor of safety)



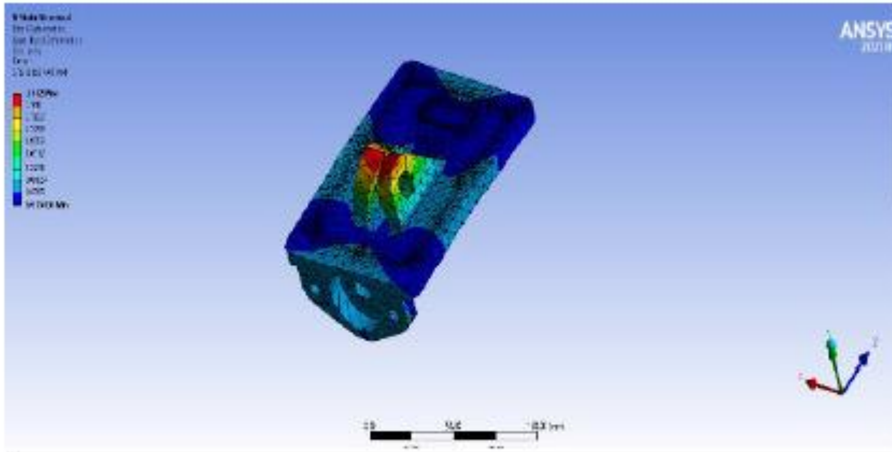
Observations and Results

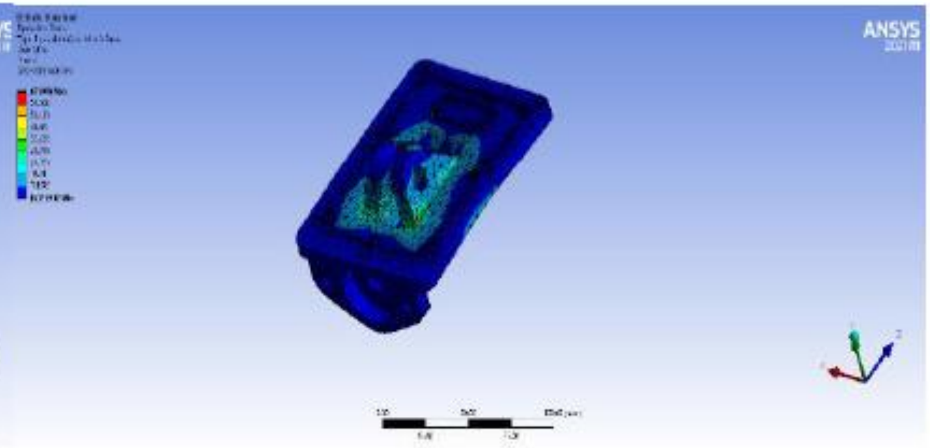
Titanium Alloy-

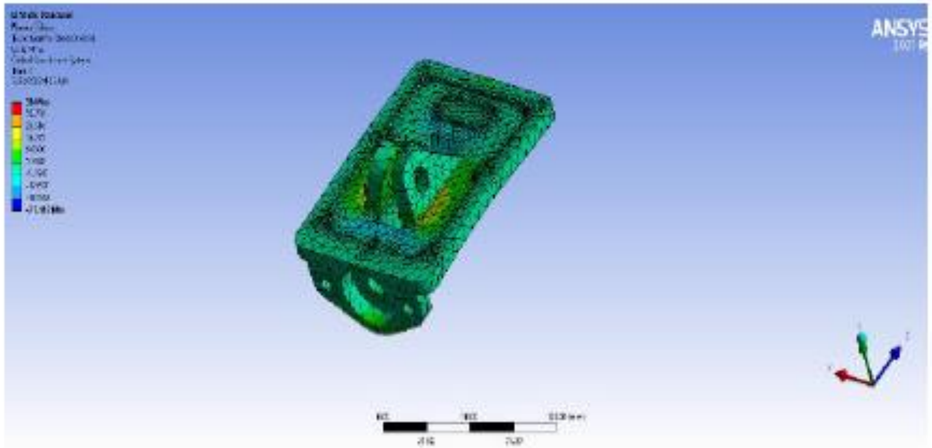


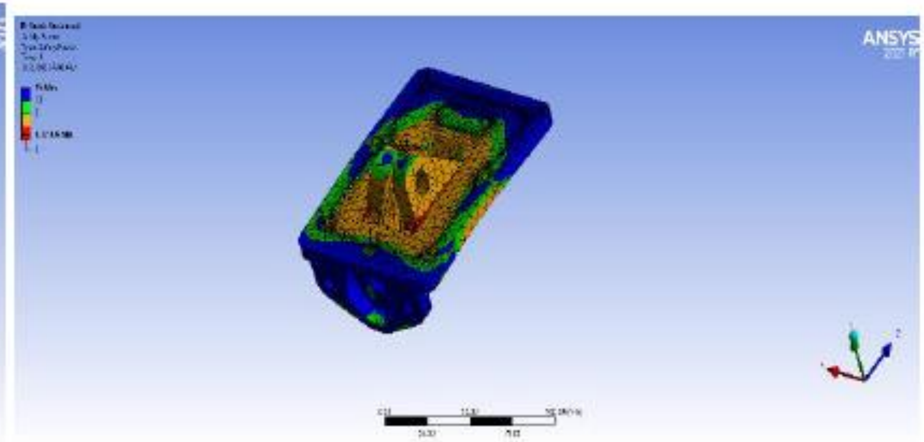
Observations and Results

Polyethylene-









Results

5. Results

In the following table are the results for different cases of simulation, materials and mechanical properties

Analysis	Material	Deformation (m)	Von mises (N/m^2)	Normal Stress (N/m^2)	Safety Factor
Static structural without defect	Structural steel	1.9765 e-5	9.01 e7	3.542e7	2.4525
	Titanium alloy	4.112e-5	1.0064 e8	3.69 e7	9.2
	Polyethylene	0.0035664	1.0069 e8	3.89 e7	0.248
Static structural with defect	Structural steel	2.53 e-5	1.172 e8	3.7039 e7	2.1332
	Titanium alloy	4.6744 e-5	1.1549 e8	3.8313 e7	8.0529
	Polyethylene	0.004040	1.1343 e8	3.975 e7	0.2204
Static Structural after defect	Structural steel	**1.95 e-5**	7.272 e7	3.73e7	**3.4378**
	Titanium alloy	**4.05 e-5**	6.995 e7	3.78e7	**13.294**
	Polyethylene	**3.532 e-3**	6.7 e7	3.8e7	**0.37309**

Conclusion

- Static structural analysis was carried out for three cases- bracket without defect, with defect and repair.
- After performing structural analysis for the bracket without defect we identified the stress concentration areas where failure is most likely to happen.
- The defective model was analyzed and then repaired using Direct energy deposition additive manufacturing technique.
- We can conclude that the additively repaired model improved its mechanical properties such as von mises stress, normal stress, and strain.
- Comparing the factor of safety for the different models, we can conclude that the repaired model has a higher factor of safety which makes additively manufacturing a highly efficient technique compared to other conventional manufacturing technique which involves a lot of time and cost.

Conclusion

- **Three different materials were used in this simulation and after comparing the results we can observe that structural steel has the lowest stress concentration and deformation owing to its materials properties but titanium alloy had the highest minimum factor of safety owing to its high ultimate tensile stress.**
- **Polyethylene on the other hand had the lowest factor of safety due to which it cannot be used in modelling such an application.**
- **Observing the temperature contours from the transient thermal analysis, we can observe that titanium alloy material has the lowest thermal stresses owing to its high specific heat capacity whereas polyethylene was exposed to high thermal stresses and temperature distributions within the body.**

Thank you

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