

Altair Teknoloji Konferansı Türkiye 2023

24 Ekim 2023
Crowne Plaza, Bursa



Altair SimSolid Yazılımı İle Yapısal Analiz Uygulamaları

İlyas YILMAZ – Yalçın ŞENSOY

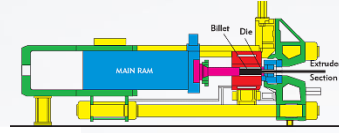
İçerik

- Hakkımızda (Yeşilova Holding)
- SimSolid
- Yeşilova Arge SimSolid Kullanıcı Deneyimi
- Sonuçlar

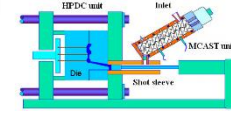
Yeşilova Holding



- **Otomotiv**
- **Raylı sistemler**



1990



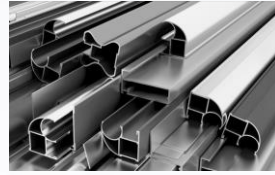
1993



2016



- **Mobilya**
- **Beyaz Eşya**



1975



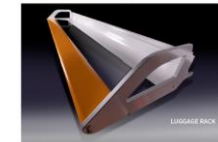
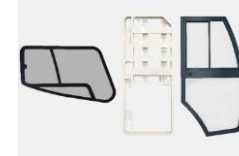
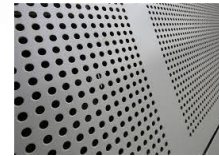
1988



2018



- **İnşaat**



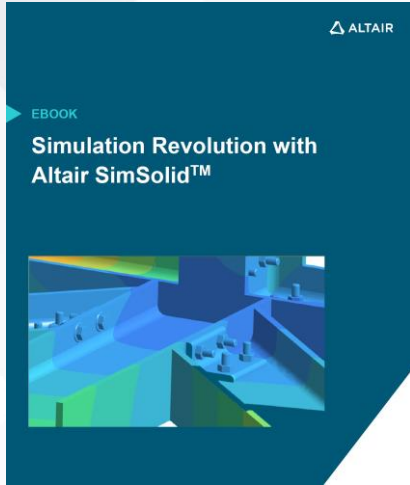
- **Enerji**

SimSolid

Geleneksel sonlu elemanlar analizlerinde en çok zamanı alan geometrik basitleştirme ve sonlu elemanlar ağı oluşturma işlemlerini ortadan kaldırarak yüksek kapasiteli bir bilgisayara ihtiyaç duymadan dakikalar içerisinde yüksek doğrulukta tasarımlarınızı inceleyebilmenizi sağlayan bilgisayar destekli analizleri için devrim niteliğinde görülen bir analiz yazılımıdır.

Geometri temizliği (Küçük özellikleri temizleme ,bağlantı elemanları). Yok Mesh (Boyut , Kalite) . Yok

Tasarımı iyileştirmek için yapısal performansın tasarım sürecinin erken safhalarında anlaşılması ve optimize edilmesi gerekir; yani gerçek dünyadaki parça ve montajların gelişen tasarım varyantlarına hızlı geri bildirim alınması gerekir. **Ayrıntılı stres araştırmalarına yönelik DEĞİLDİR.** Bunun için sistem doğrulama aşamasındaki geleneksel FEA hala kullanılmaktadır.



Theoretical Background of SimSolid by Victor Apanovitch
by Girish Mudigonda
created 3mo ago (edited 3mo ago) in Altair Products

The SimSolid computational engine is based on extension to the theory of external approximations. External approximations are a generalization of Finite Element Method (FEM) in terms that:

- Absolutely arbitrary geometrical shapes can be used as "finite elements".
- Basis functions which approximate the field of interest in the "element" can be of arbitrary class and are independent of the "element" shape.
- The degrees of freedom are integrals over corresponding geometrical entities.
- Multi-pass adaptive analysis to control the solution accuracy.

Watch the video below to learn more.

Control of displacement boundary conditions in SimSolid

$\int_{\Gamma_{DB}} g \cdot U \, dG = 0, \quad \int_{\Gamma_{DB}} g \cdot V \, dG = 0,$
 $g = \{1, t, t^2, t^3, \dots\}$

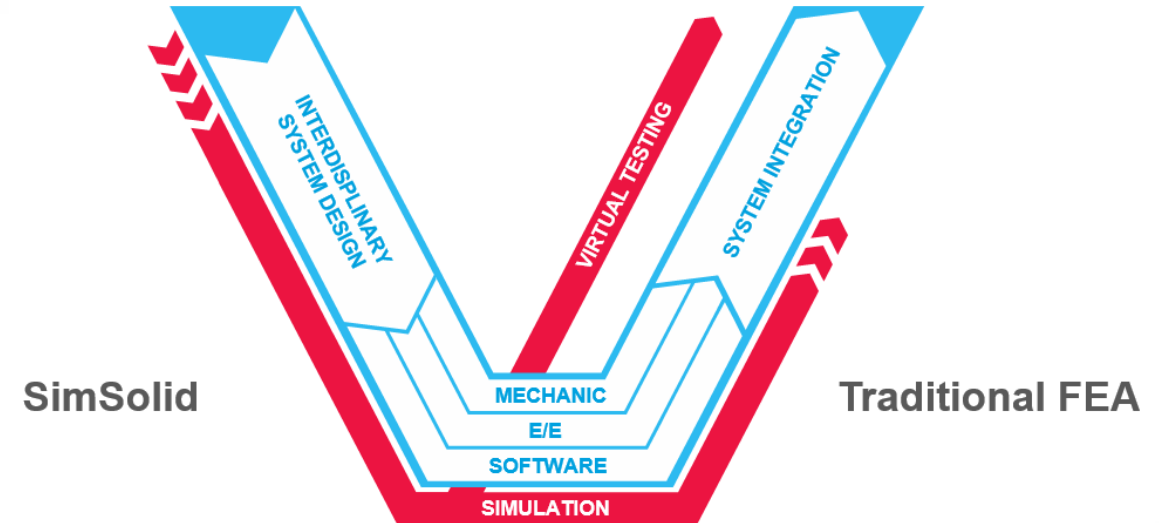
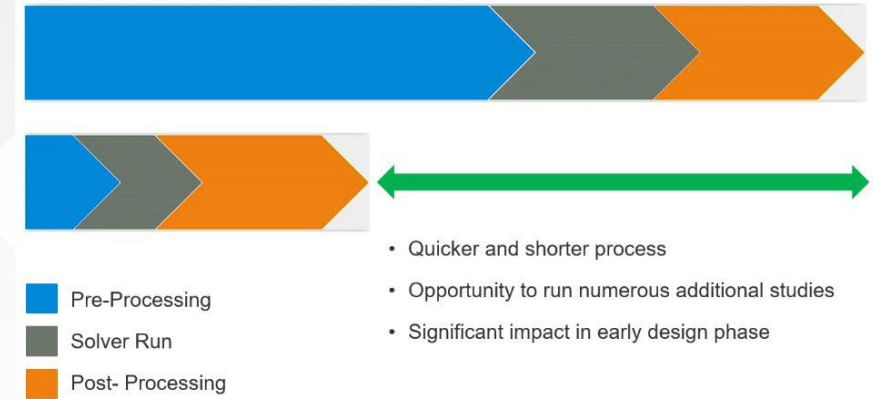
Displacement vector

One boundary DOF: $g = \{1\}$, $\int_{\Gamma} U \, dG = 0$

Two boundary DOFs: $g = \{1, t\}$, $\int_{\Gamma} t \cdot U \, dG = 0$

Three boundary DOFs: $g = \{1, t, t^2\}$, $\int_{\Gamma} t^2 \cdot U \, dG = 0$

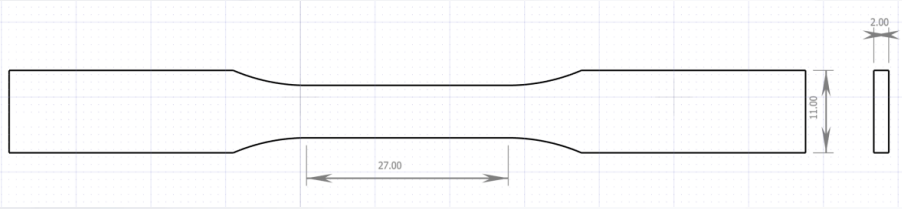
- Ce'a Approximation Variationnelle des problèmes aux limites. Ann. Inst. Fourier, 1964, Vol. 14, pp. 345-444
- Aubin, Jean-Pierre. Approximation of elliptic boundary value problems. Wiley-Interscience, 1972
- Apanovitch, V. The method of external finite element approximations. Minsk, 1991, ISBN 5-339-00597-6



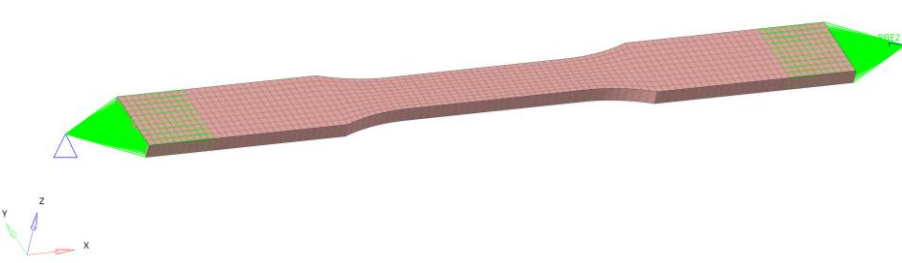
Çekme Numunesi

Malzeme kartı inceleme

Numune Ölçüleri



FEM Modeli



Malzeme Standartı

Çizelge 42 – Alaşım EN AW-6063 [AMg0,7Si]

Temper	Boyutlar mm		R _m MPa		R _{0,2} MPa		A %	A _{50mm} %	HBW Tipik değer
	D ^a	S ^b	En az	En çok	En az	En çok	En az	En az	
O, H111	≤ 200	≤ 200	-	130	-	-	18	16	25
T4 ^c	≤ 150 150 < D ≤ 200	≤ 150 150 < S ≤ 200	130 120	-	65 65	-	14 12	12 -	50 50
T5	≤ 200	≤ 200	175	-	130	-	8	6	65
T6 ^d	≤ 150 150 < D ≤ 200	≤ 150 150 < S ≤ 200	215 195	-	170 160	-	10 10	8 -	75 75
T66 ^e	≤ 200	≤ 200	245	-	200	-	10	8	80

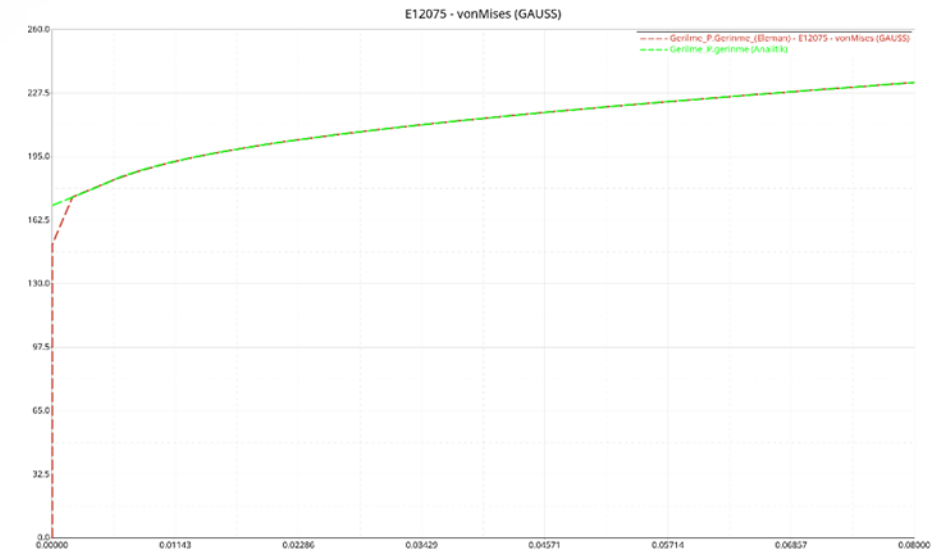
Temper	Et kalınlığı t mm	R _m MPa		R _{0,2} MPa		A %	A _{50mm} %	HBW Tipik değer
		En az	En çok	En az	En çok	En az	En az	
O, H111	≤ 25	-	130	-	-	18	16	25
T4 ^c	≤ 10 10 < t ≤ 25	130 120	-	65 65	-	14 12	12 10	50 50
T5	≤ 25	175	-	130	-	8	6	65
T6 ^d	≤ 25	215	-	170	-	10	8	75
T66 ^e	≤ 25	245	-	200	-	10	8	80

Temper	Et kalınlığı t mm	R _m MPa		R _{0,2} MPa		A %	A _{50mm} %	HBW Tipik değer
		En az	En çok	En az	En çok	En az	En az	
T4 ^c	≤ 25	130	-	65	-	14	12	50
T5	≤ 3 3 < t ≤ 25	175 160	-	130 110	-	8 7	6 5	65 65
T6 ^d	≤ 10 10 < t ≤ 25	215 195	-	170 160	-	8 8	6 6	75 75
T64 ^{ff}	≤ 15	180	-	120	-	12	10	65
T66 ^e	≤ 10 10 < t ≤ 25	245 225	-	200 180	-	8 8	6 6	80 80

^a D : Yuvarlak çubuk için çap.
^b S : Kare ve altıgen çubuklar için paralel yüzler arasındaki mesafe, dikdörtgen çubuklar için kalınlık.
^c Özellikler, basınç altında soğutulmuş elde edilebilir.
^d Ergme kalitesi.
^e Bir profilin kesiti birden fazla sayıda belirtilmiş mekanik özellik gruplarına giriyorsa, belirtilmiş en küçük değer bütün profil kesitleri için geçerli kabul edilmelidir.

Ramberg Osgood ifadesine göre gerilme gerinme diyagramı oluşturuldu.

$$\epsilon = \frac{\sigma}{E} + \left(\frac{\sigma}{H}\right)^{1/n}$$



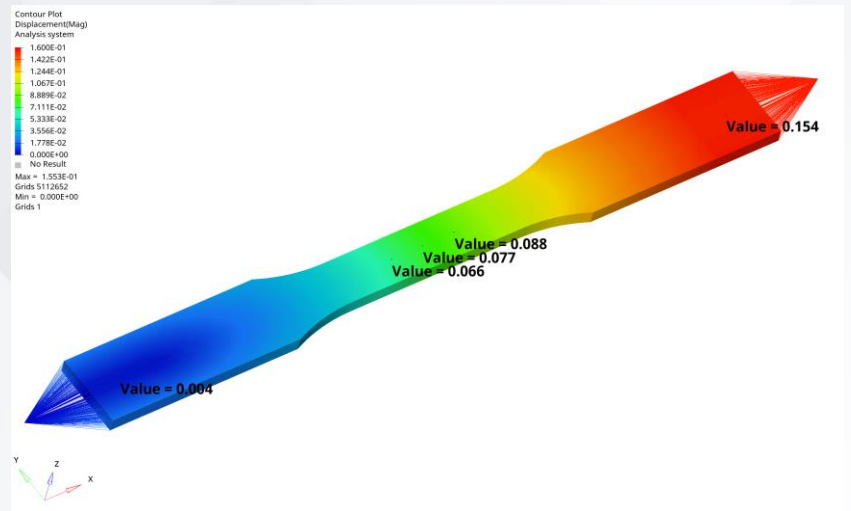
Gerilme- Gerinme Grafiği

Standartlarda yer alan akma çekme gerilmelerine ve uzama değerlerine göre Ramberg Osgood ampirik ifadesi kullanılarak malzeme gerilme gerinme diyagramı oluşturulmuş. Plastik gerinme ve gerçek gerilme değerleri OptiStruct yazılımında tanımlanmıştır. Analitik ifade analiz sonuçlarının eşleşmesi kontrol edilmiştir.

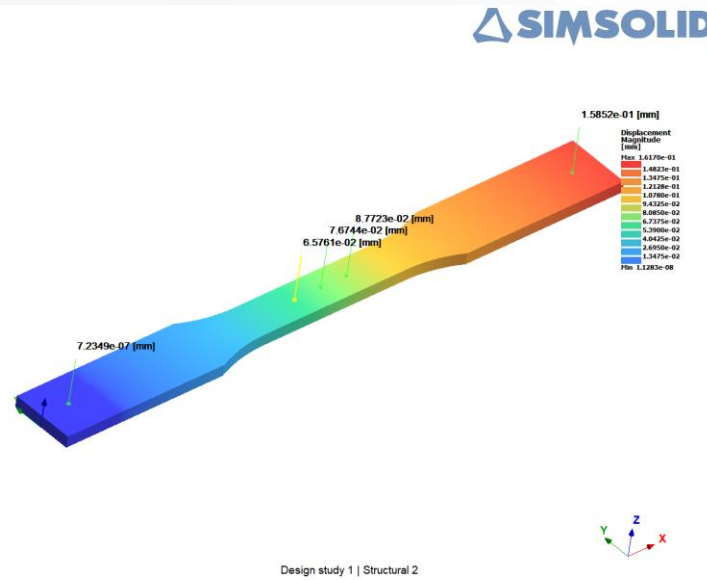
Çekme Numunesi

2150 N kuvvet altında sonuçların karşılaştırması. (Deplasman) Akma gerilmesinin %10 altına denk gelen gerilme değeri ($2150/14=154$ [MPa])

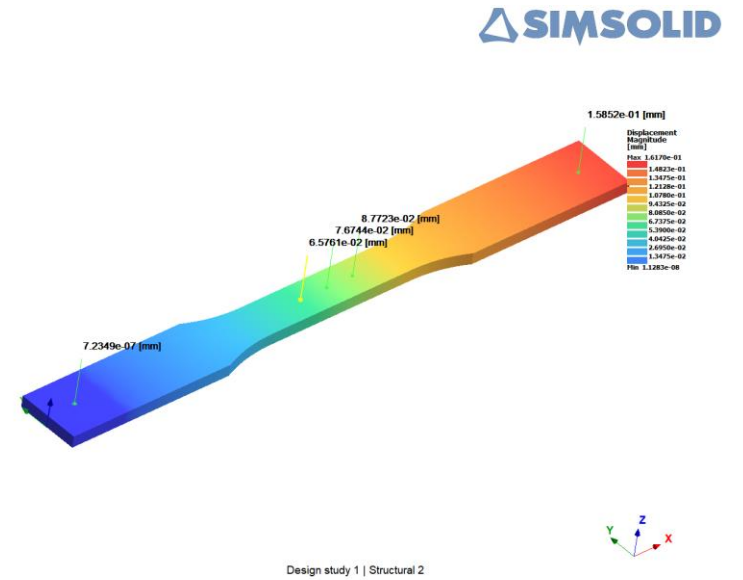
FEM



SimSolid (Adapt for Stiffness)



SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
0.154	0.159

2.9%

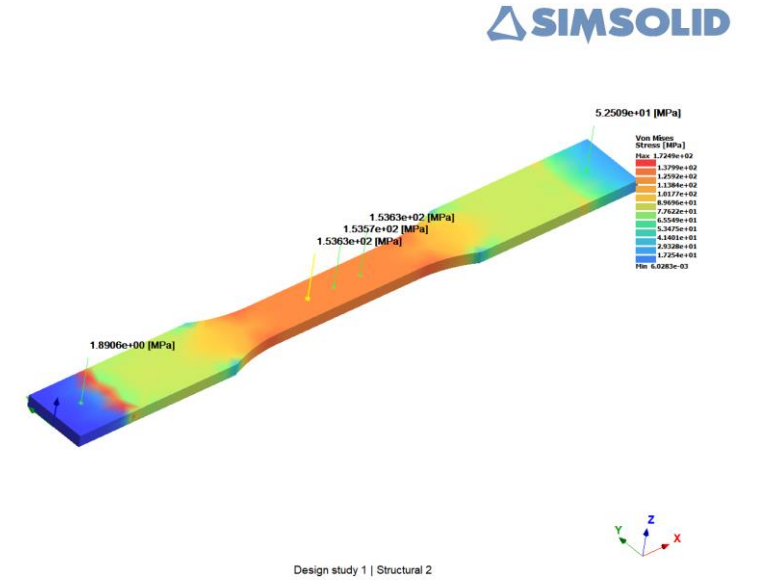
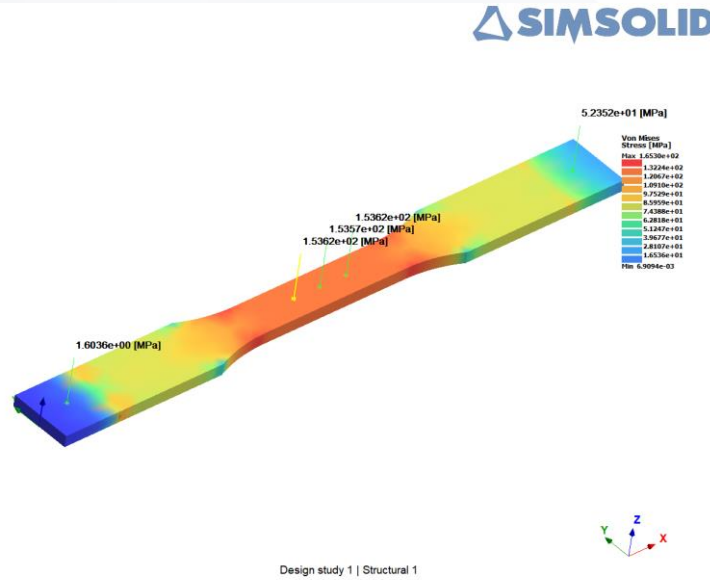
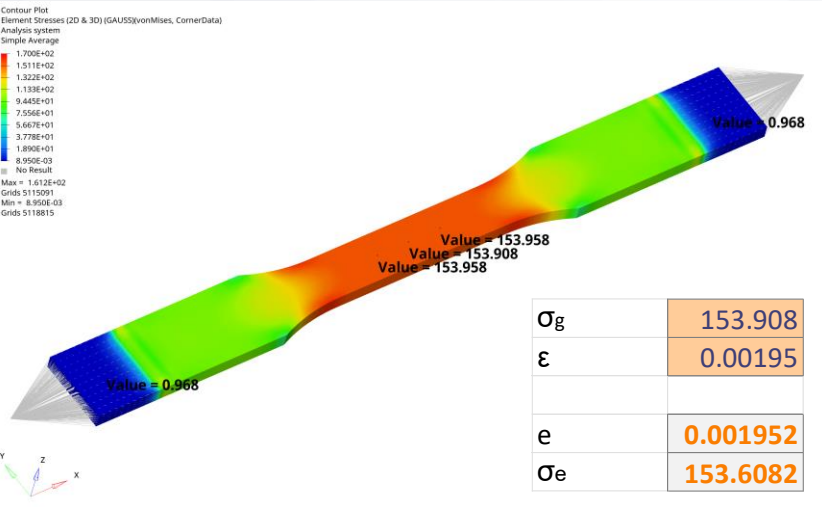
Çekme Numunesi

2150 N kuvvet altında sonuçların karşılaştırması. (Gerilme) Akma gerilmesinin %10 altına denk gelen gerilme değeri ($2150/14=154$ [MPa])

FEM

SimSolid (Adapt for Stiffness)

SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
153.91	153.57
	-0.2%

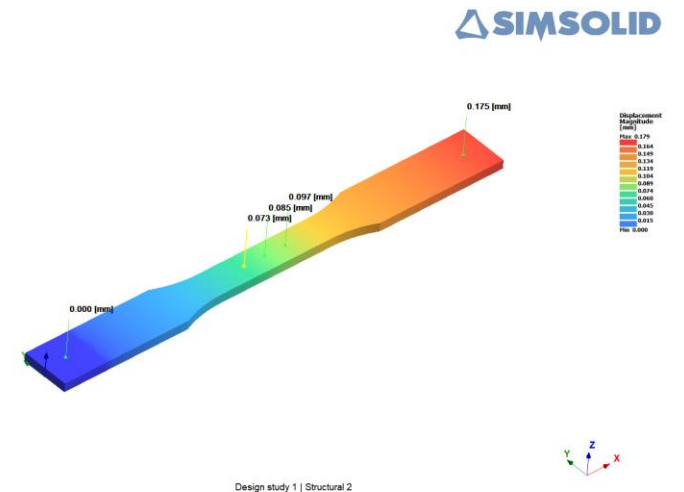
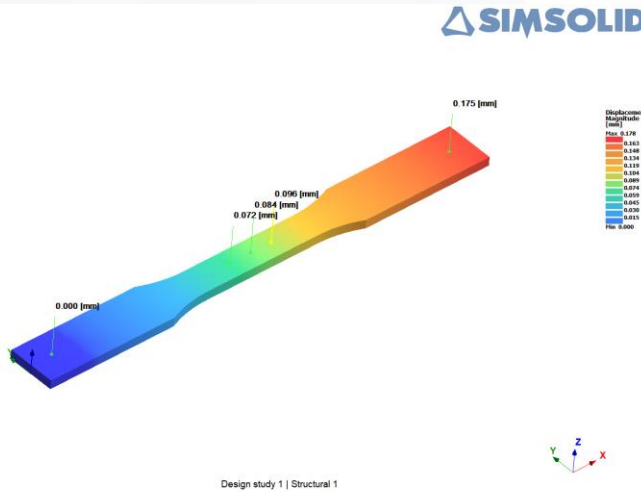
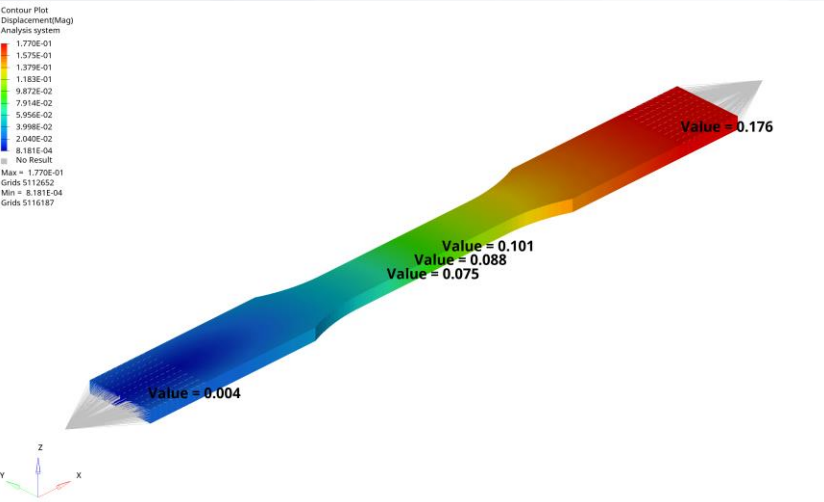
Çekme Numunesi

2380 N kuvvet altında sonuçların karşılaştırması. (Deplasman) Akma gerilmesine denk gelen kuvvet

FEM

SimSolid (Adapt for Stiffness)

SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
0.176	0.175
	-0.6%

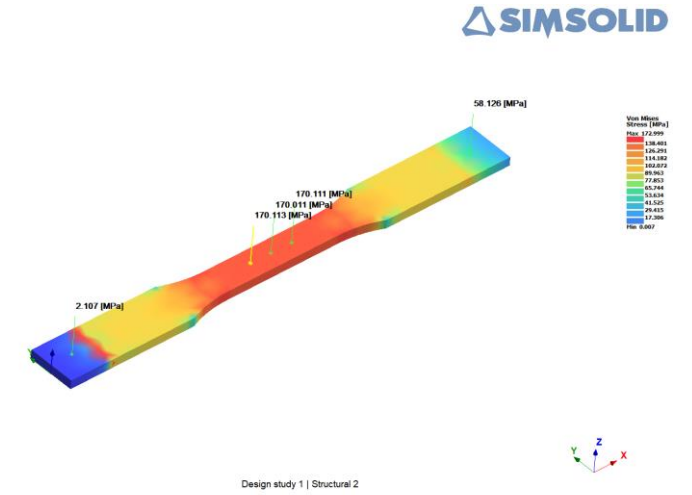
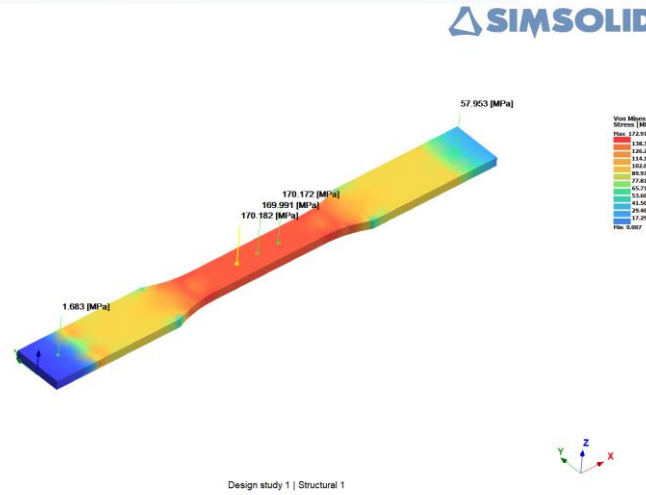
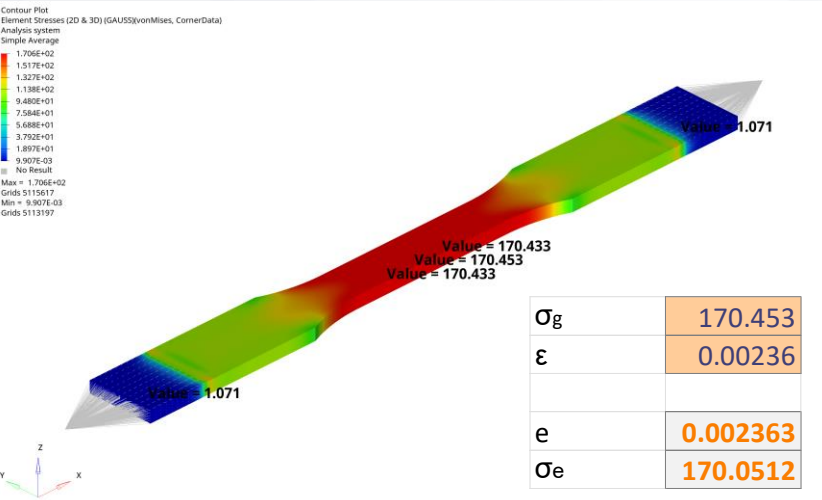
Çekme Numunesi

2380 N kuvvet altında sonuçların karşılaştırması. (Gerilme) Akma gerilmesine denk gelen kuvvet

FEM

SimSolid (Adapt for Stiffness)

SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
170.05	170.01
	0.0%

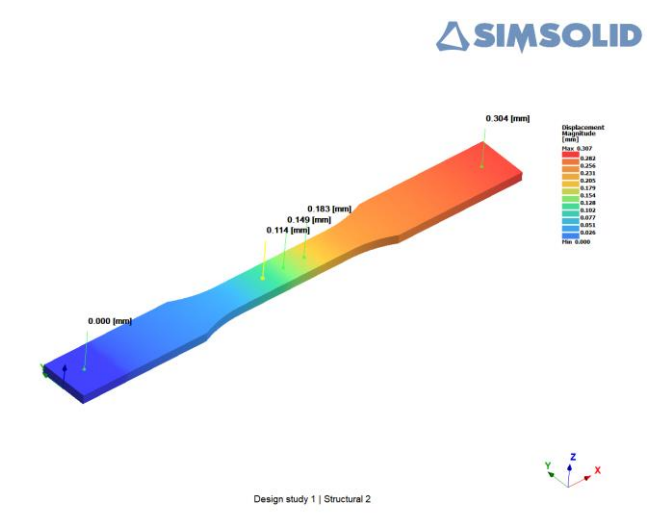
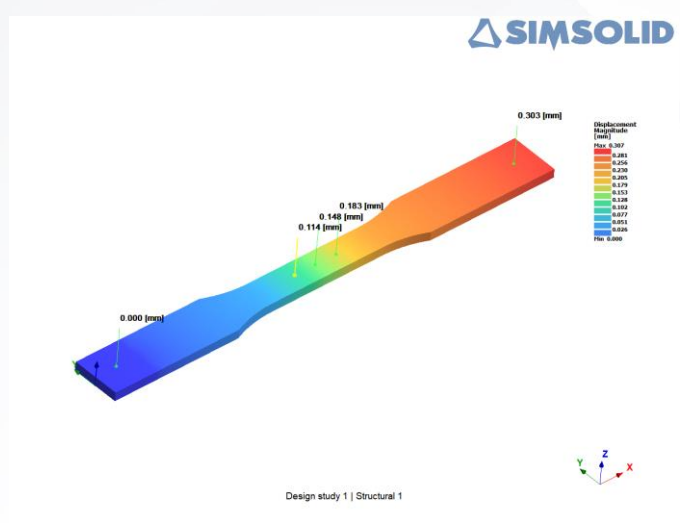
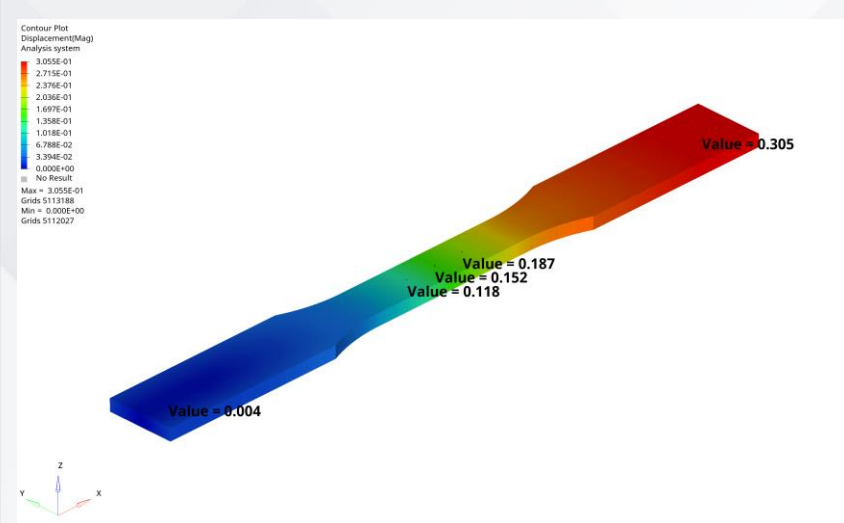
Çekme Numunesi

2500 N kuvvet altında sonuçların karşılaştırması. (Deplasman) $(2380 \cdot (1+0.05))$

FEM

SimSolid (Adapt for Stiffness)

SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
0.305	0.304
	-0.3%

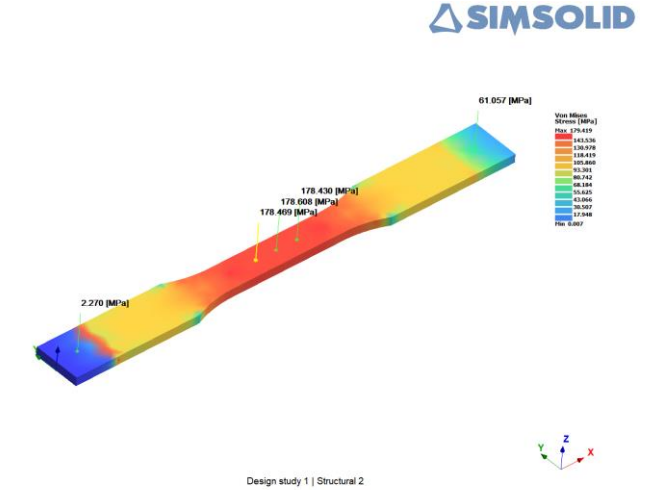
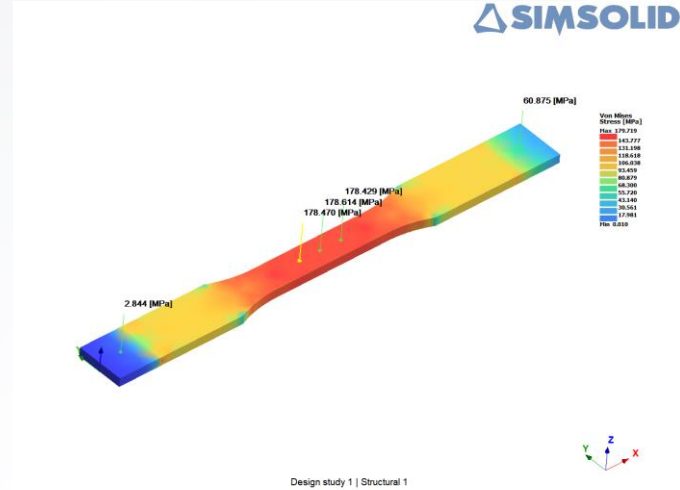
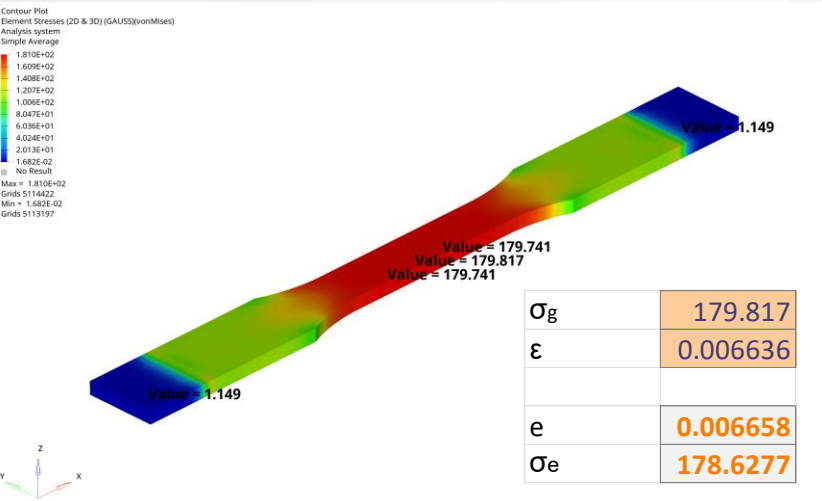
Çekme Numunesi

2500 N kuvvet altında sonuçların karşılaştırması. (Gerilme) (2500/14=178.57)

FEM

SimSolid (Adapt for Stiffness)

SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
178.63	178.61
	0.0%

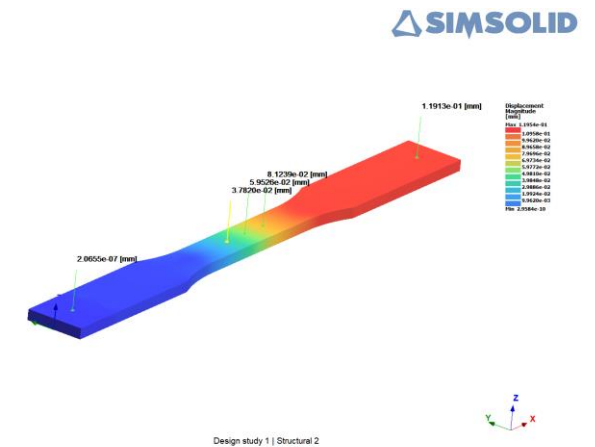
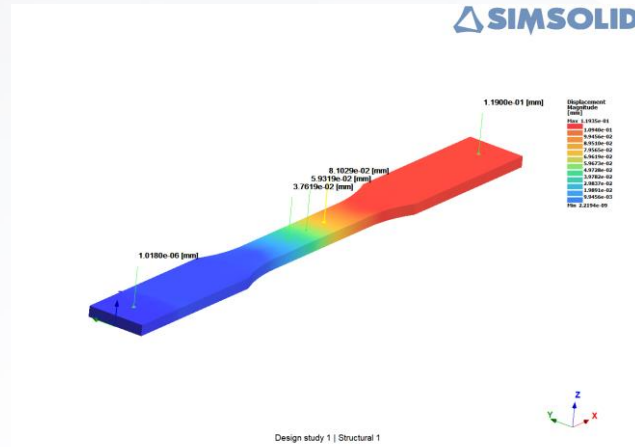
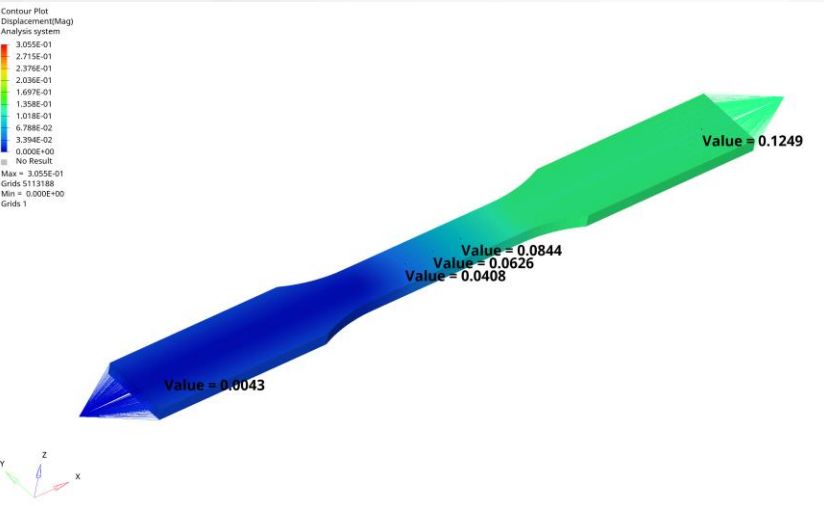
Çekme Numunesi

2500 N kuvvet altında sonuçların karşılaştırması. (Kalıcı deplasman)

FEM

SimSolid (Adapt for Stiffness)

SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
0.125	0.119

-4.6%

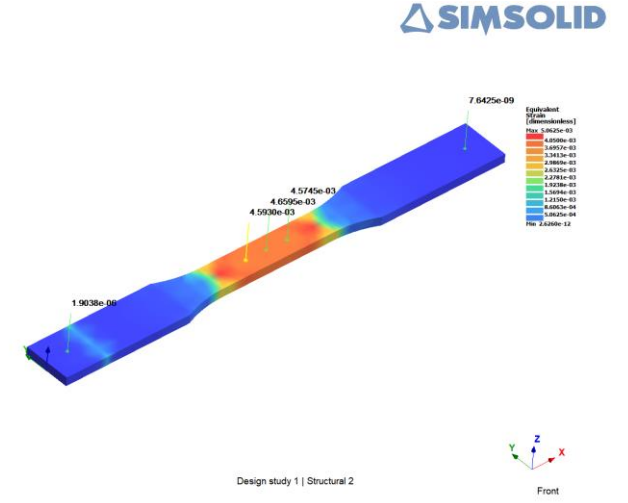
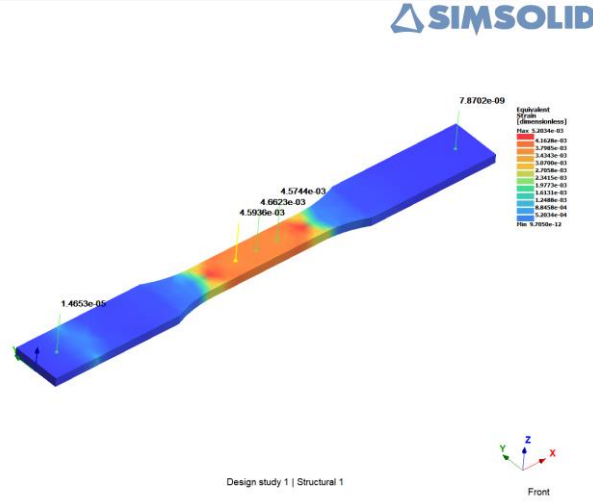
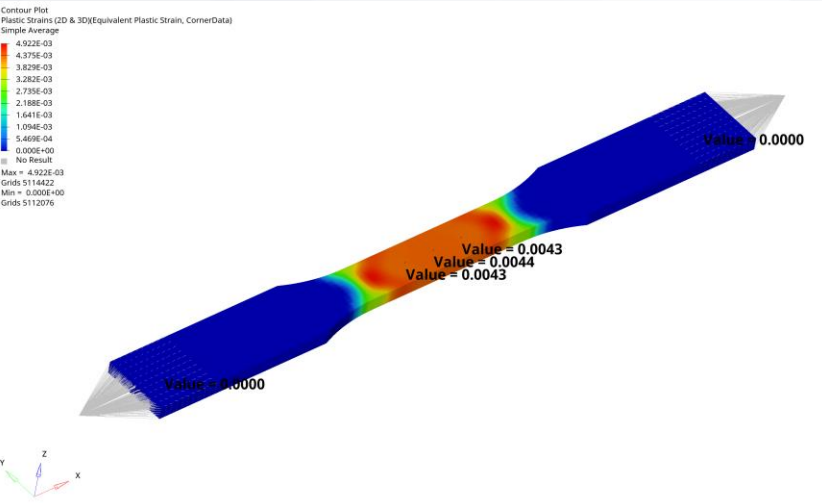
Çekme Numunesi

2500 N kuvvet altında sonuçların karşılaştırması. (Plastik gerinme)

FEM

SimSolid (Adapt for Stiffness)

SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
0.004	0.005
	6.0%

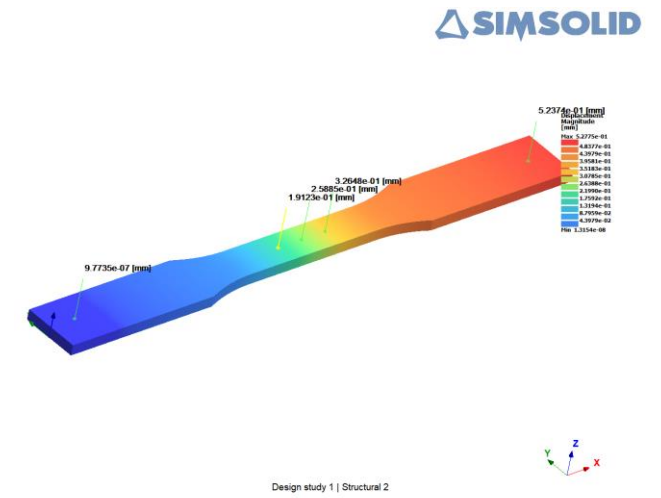
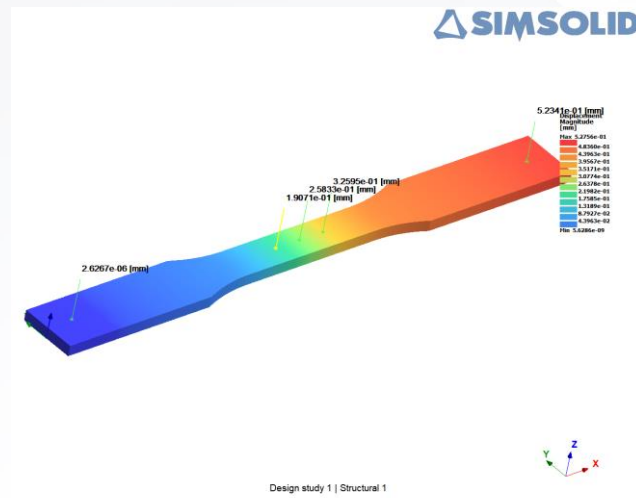
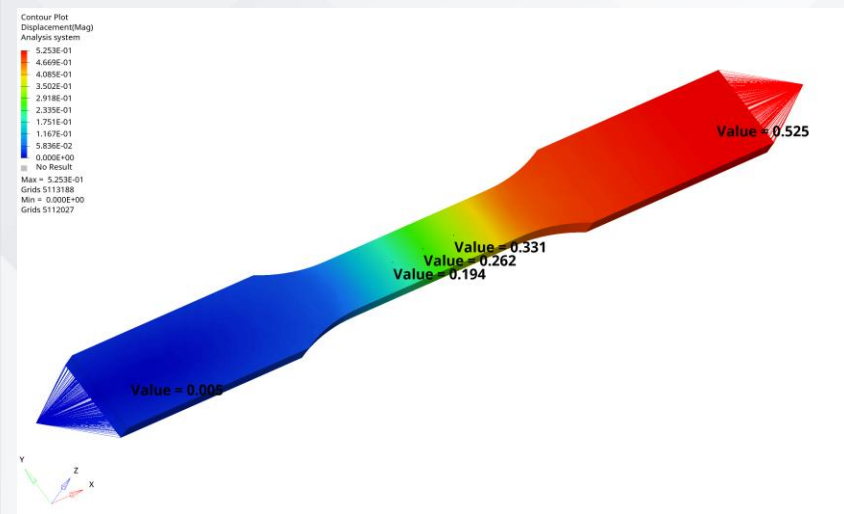
Çekme Numunesi

2650 N kuvvet altında sonuçların karşılaştırması. (Deplasman) (%1 plastik gerinme)

FEM

SimSolid (Adapt for Stiffness)

SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
0.525	0.524

-0.2%

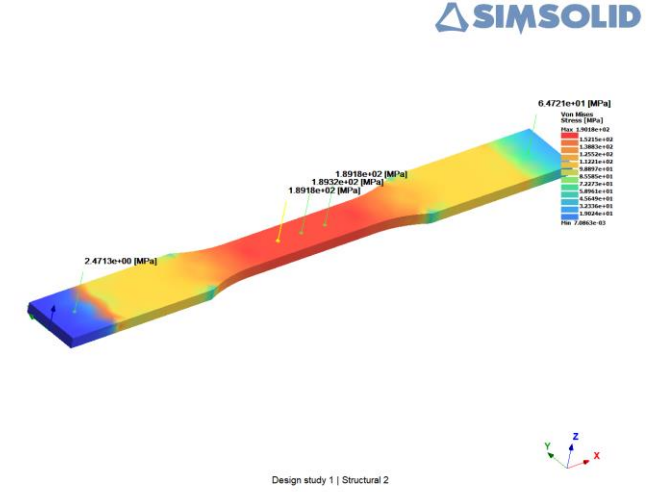
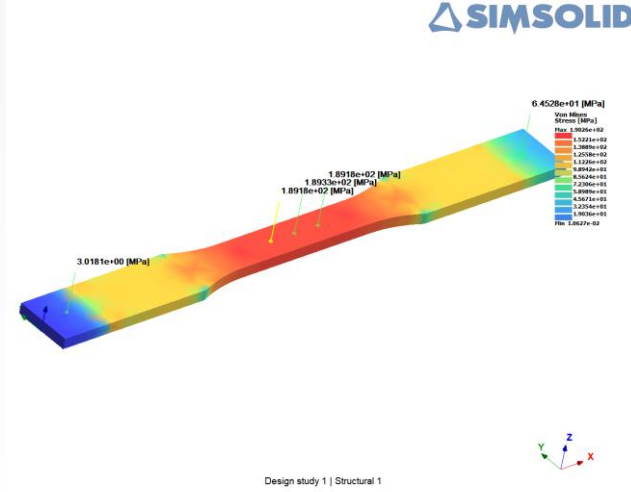
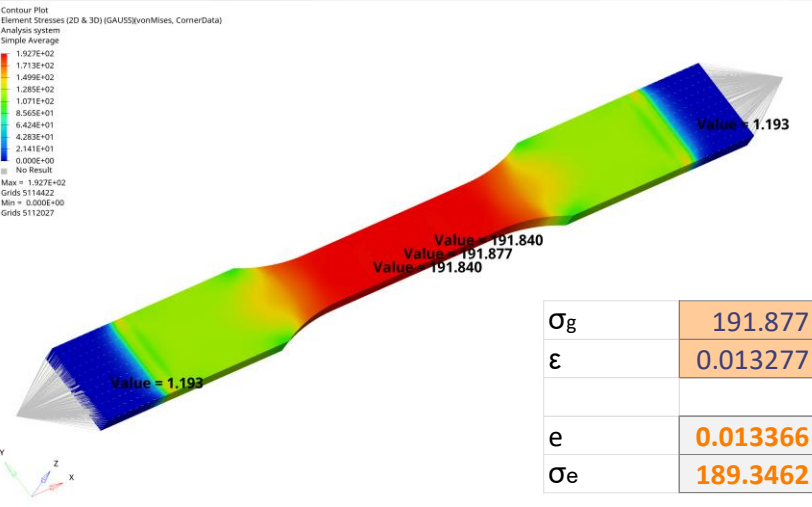
Çekme Numunesi

2650 N kuvvet altında sonuçların karşılaştırması. (Gerilme)

FEM

SimSolid (Adapt for Stiffness)

SimSolid (Adapt for Stress)

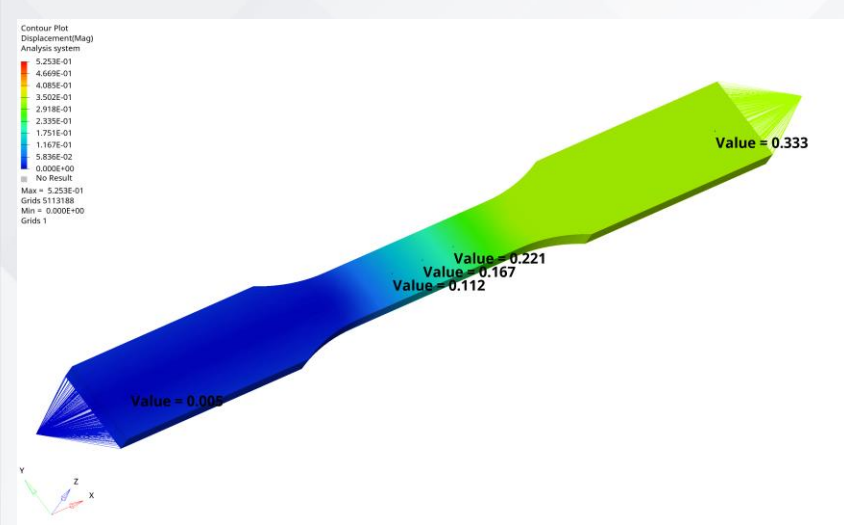


FEM	SimSolid (Adapt for Stress)
189.35	189.32
	0.0%

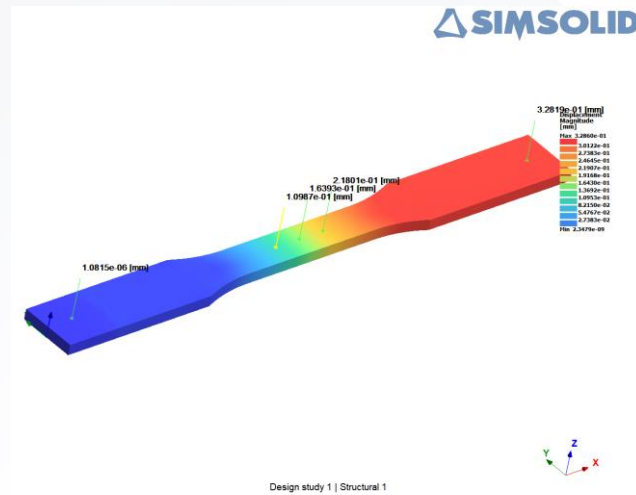
Çekme Numunesi

2650 N kuvvet altında sonuçların karşılaştırması. (Kalıcı Deplasman)

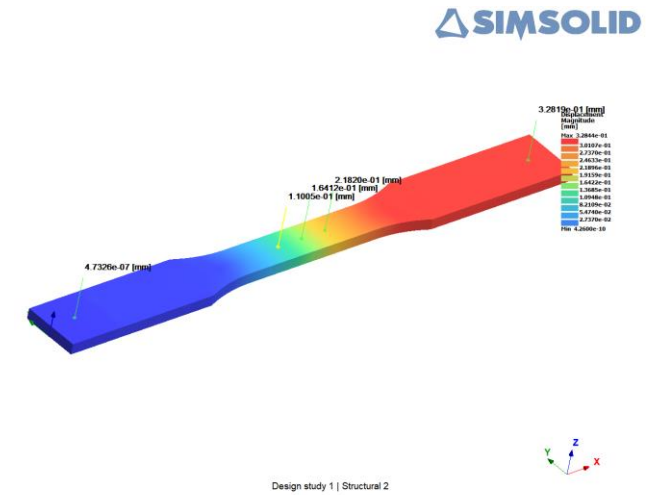
FEM



SimSolid (Adapt for Stiffness)



SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
0.333	0.328

-1.4%

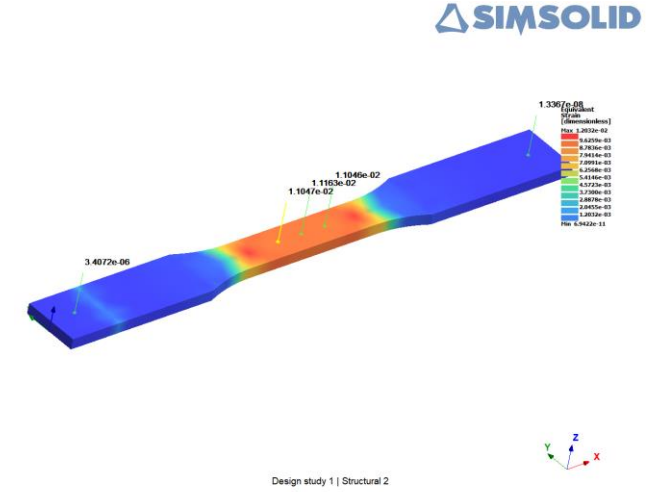
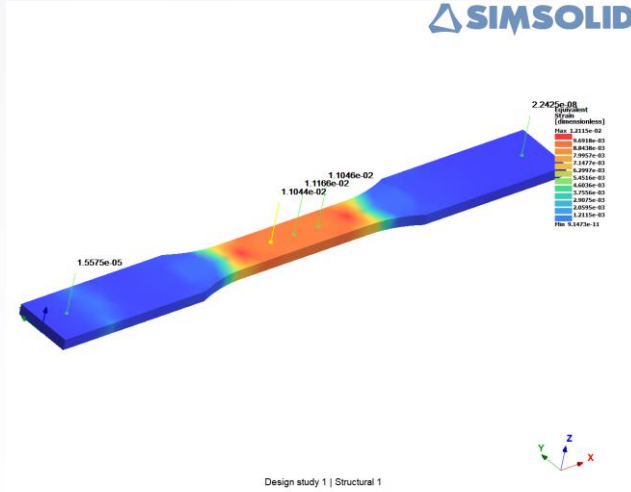
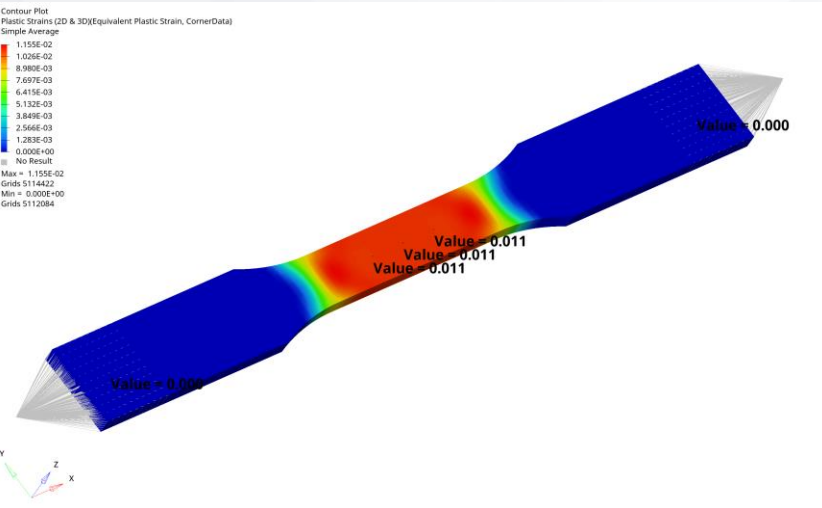
Çekme Numunesi

2650 N kuvvet altında sonuçların karşılaştırması. (Plastik Gerinme)

FEM

SimSolid (Adapt for Stiffness)

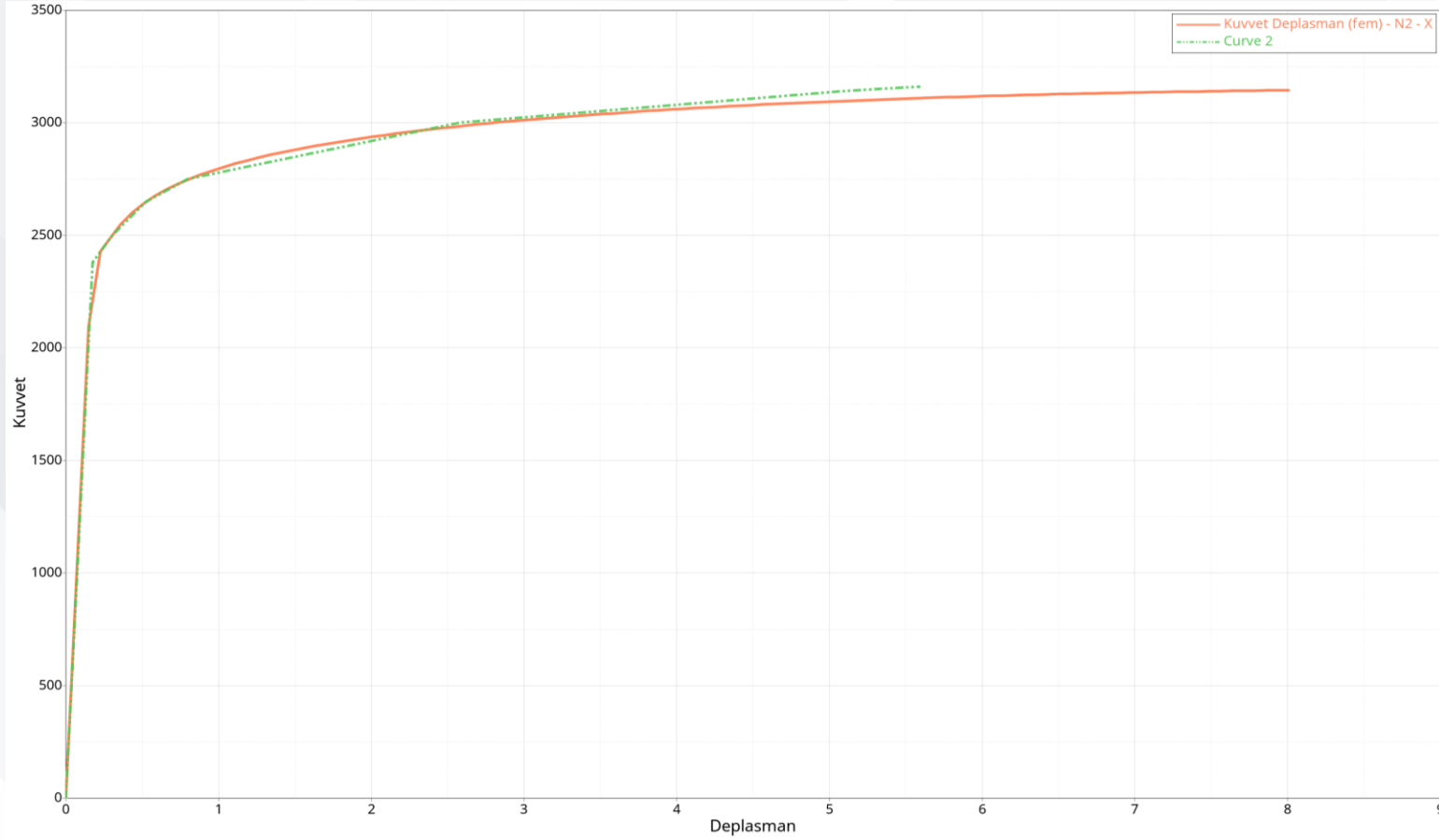
SimSolid (Adapt for Stress)



FEM	SimSolid (Adapt for Stress)
0.011	0.011

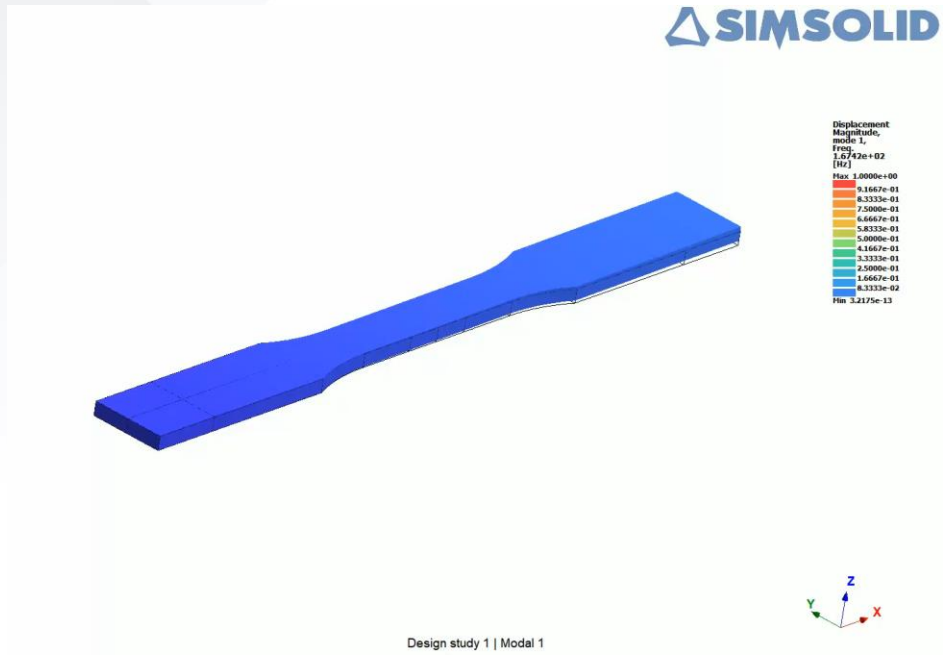
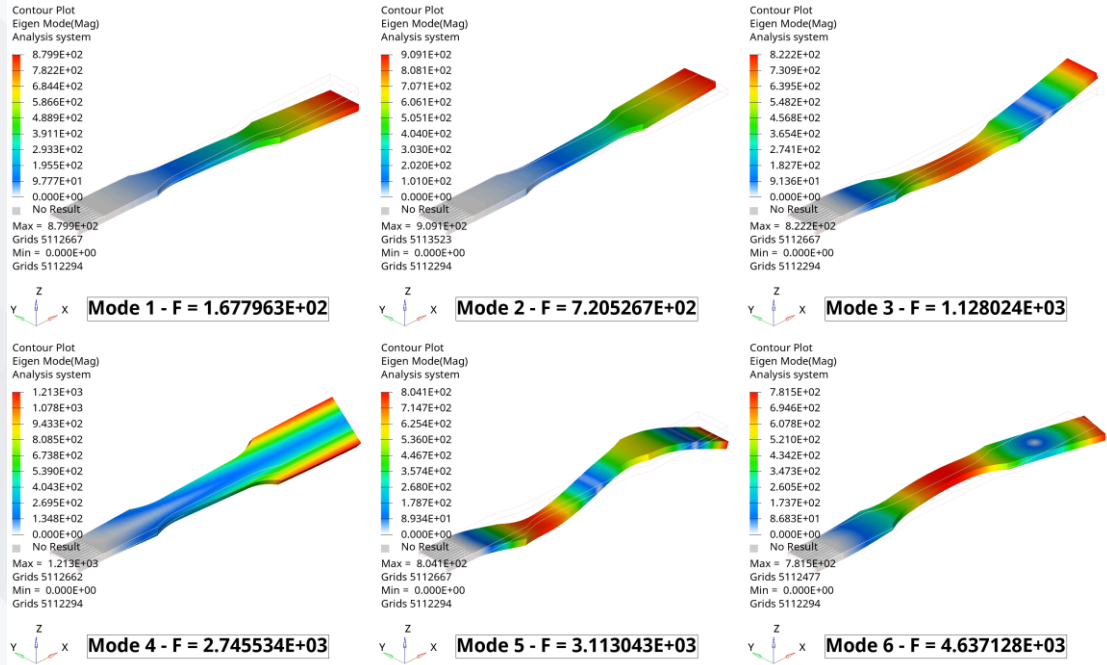
1.5%

Çekme Numunesi



FEM Analizinden elde edilen Kuvvet Deplasman Grafiği Karşılaştırma

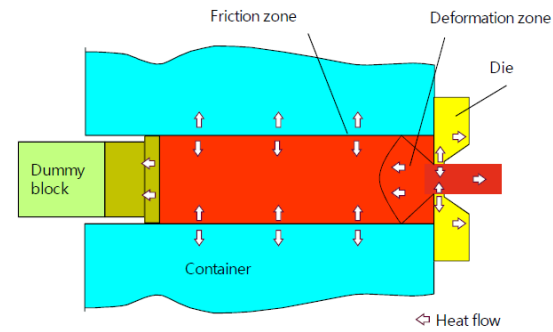
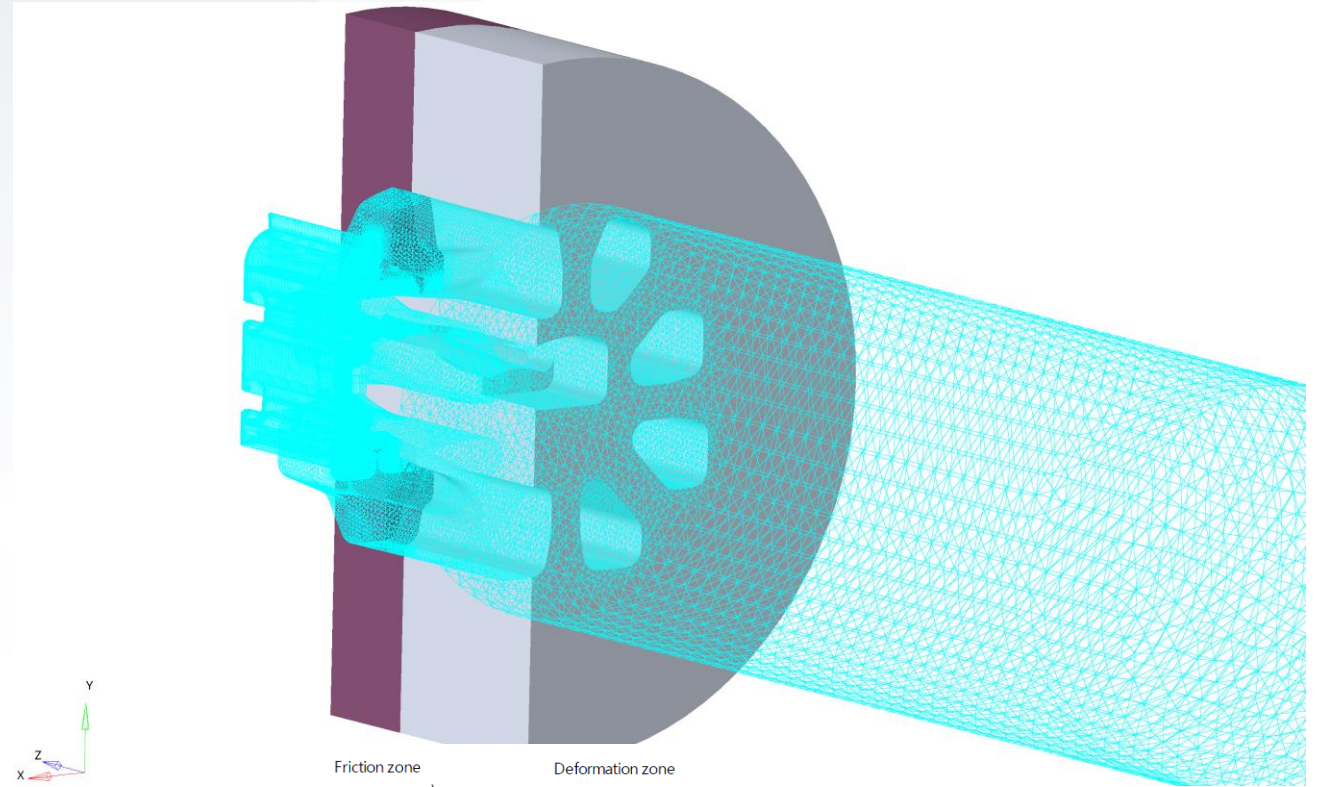
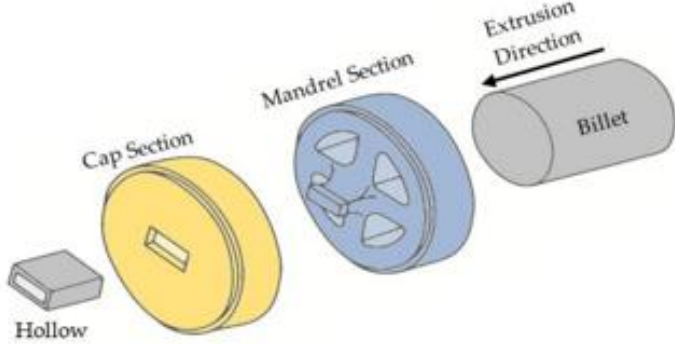
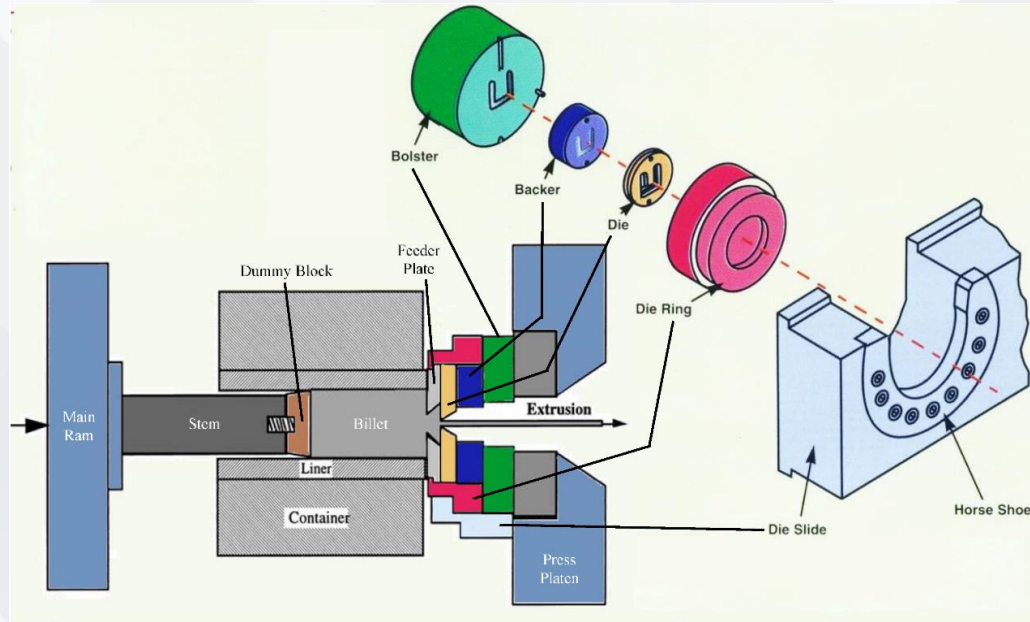
Çekme Numunesi (Modal)

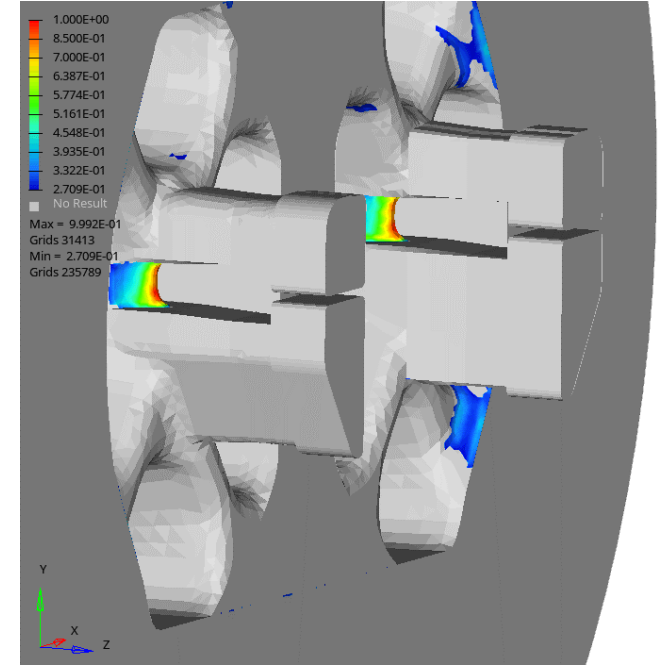
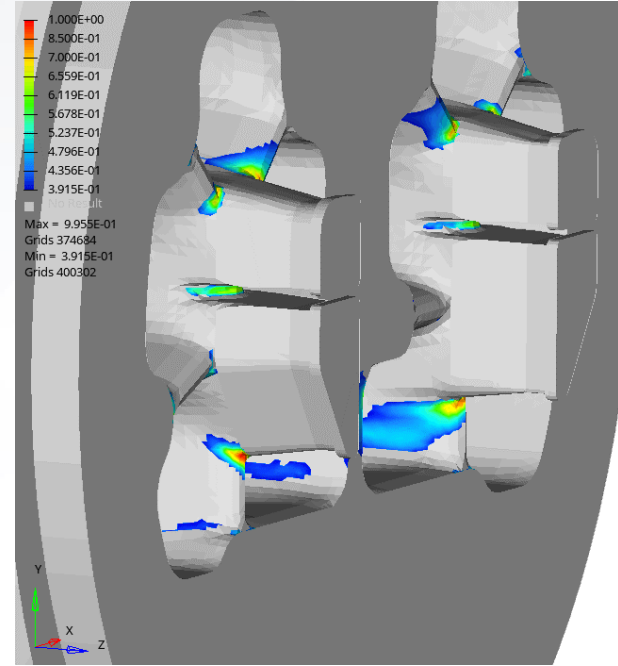
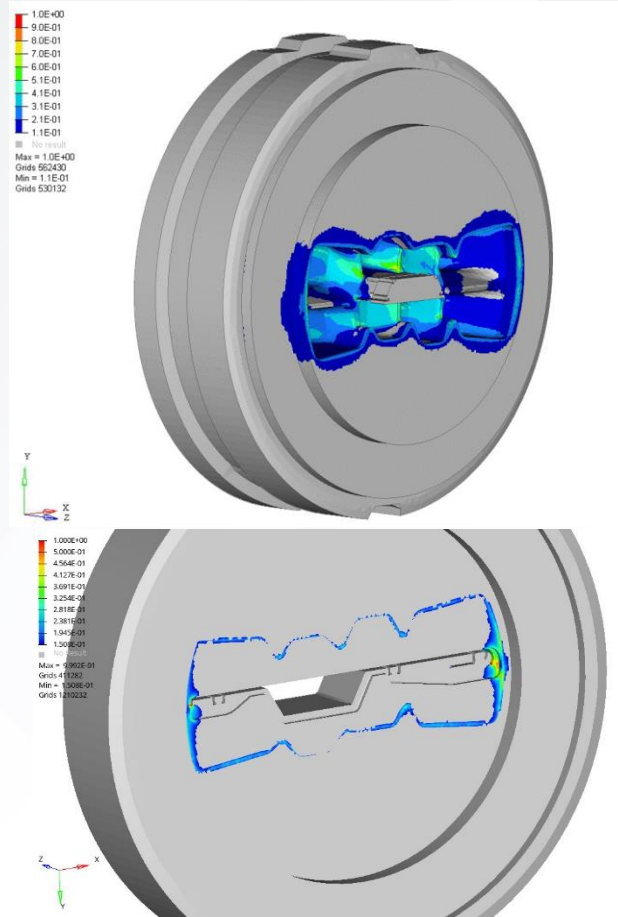


Design study 1 | Modal 1

Flexible mode	OptiStruct				SimSolid				Difference Frequency
	Frequency	X	Y	Z	Frequency	X	Y	Z	
1	167.8	0.0	0.0	52.3	167.1	0.0	0.0	52.4	-0.4%
2	720.5	0.0	49.0	0.0	718.9	0.0	49.1	0.0	-0.2%
3	1128.0	0.0	0.0	16.1	1122.9	0.0	0.0	16.1	-0.5%
4	2746.0	0.0	0.0	0.0	2721.0	0.0	0.0	0.0	-0.9%
5	3113.0	0.0	0.0	6.7	3096.1	0.0	0.0	6.7	-0.5%
6	4637.0	0.0	18.2	0.0	4623.2	0.0	18.3	0.0	-0.3%

Ekstrüzyon Kalıbı

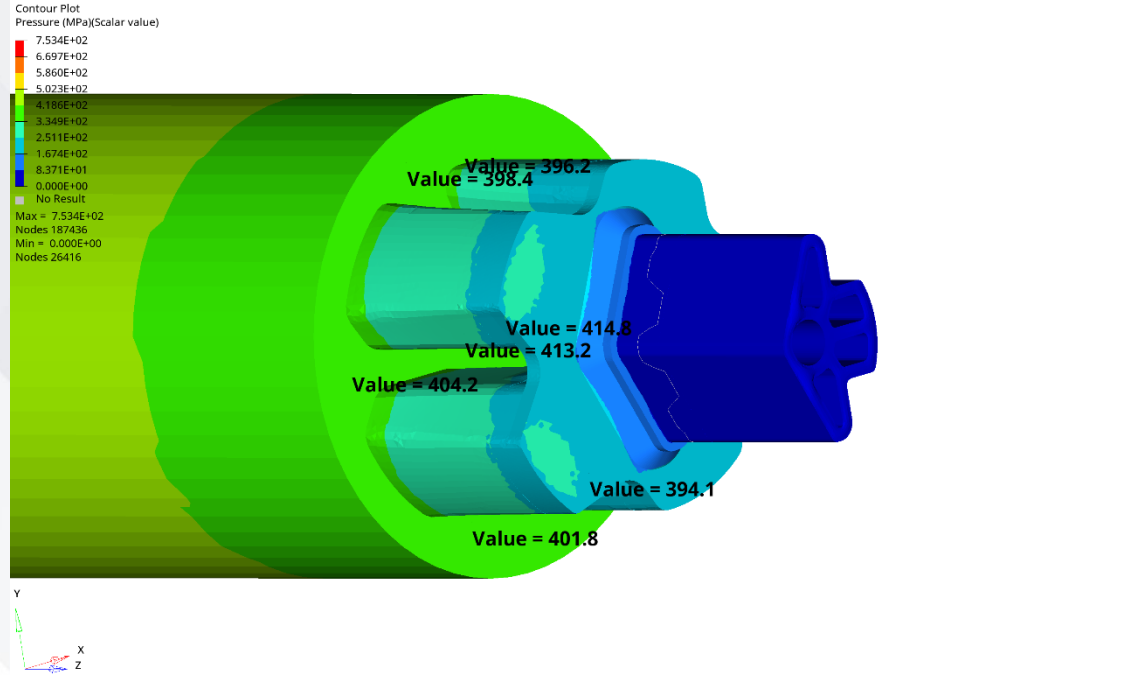


Ekstrüzyon Kalıbı

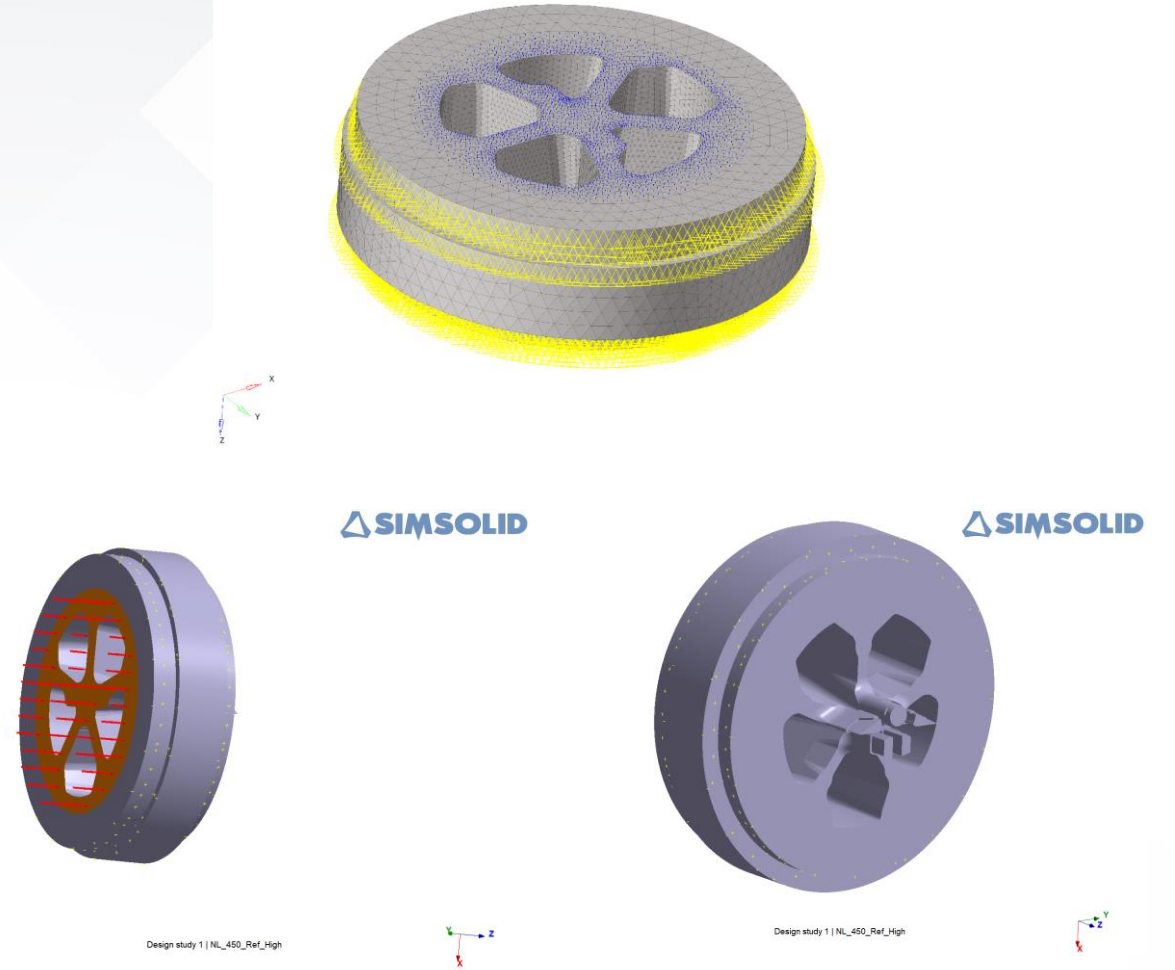
Ekstrüzyon sırasında kalıpta oluşan esnemeler profil toleransları ve kalıp ömrü açısından önem teşkil etmektedir. Kalıp mukavemeti incelenerek optimum kalıp tasarımı gerçekleştirilir.

Ekstrüzyon Kalıbı

Basınc

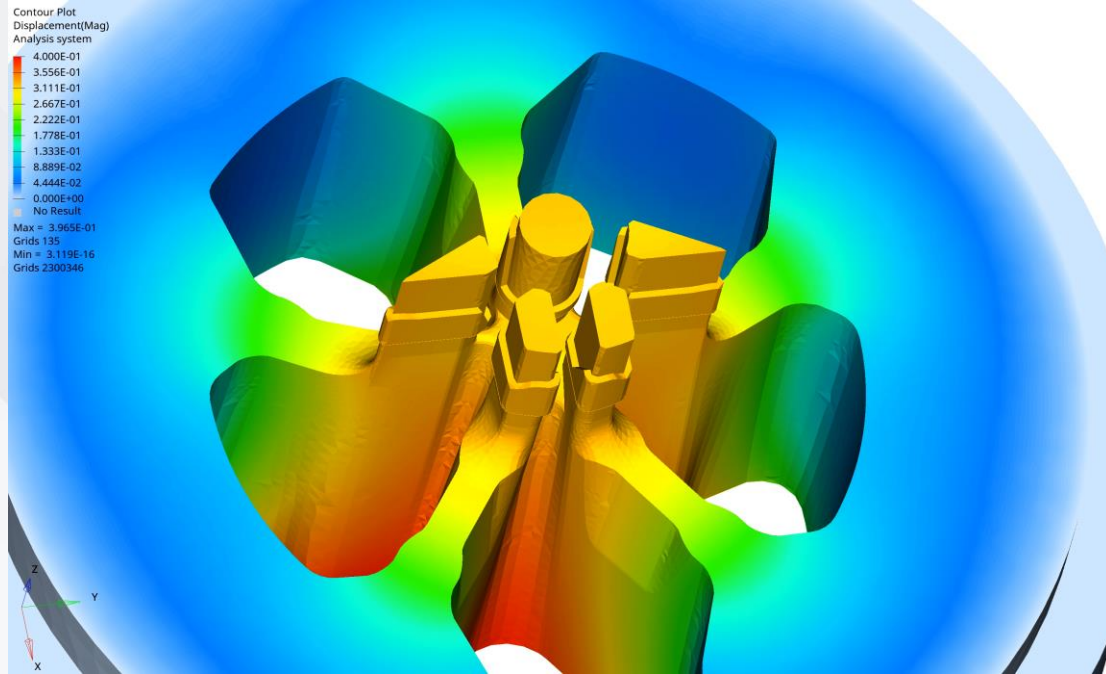


Sınır Şartları



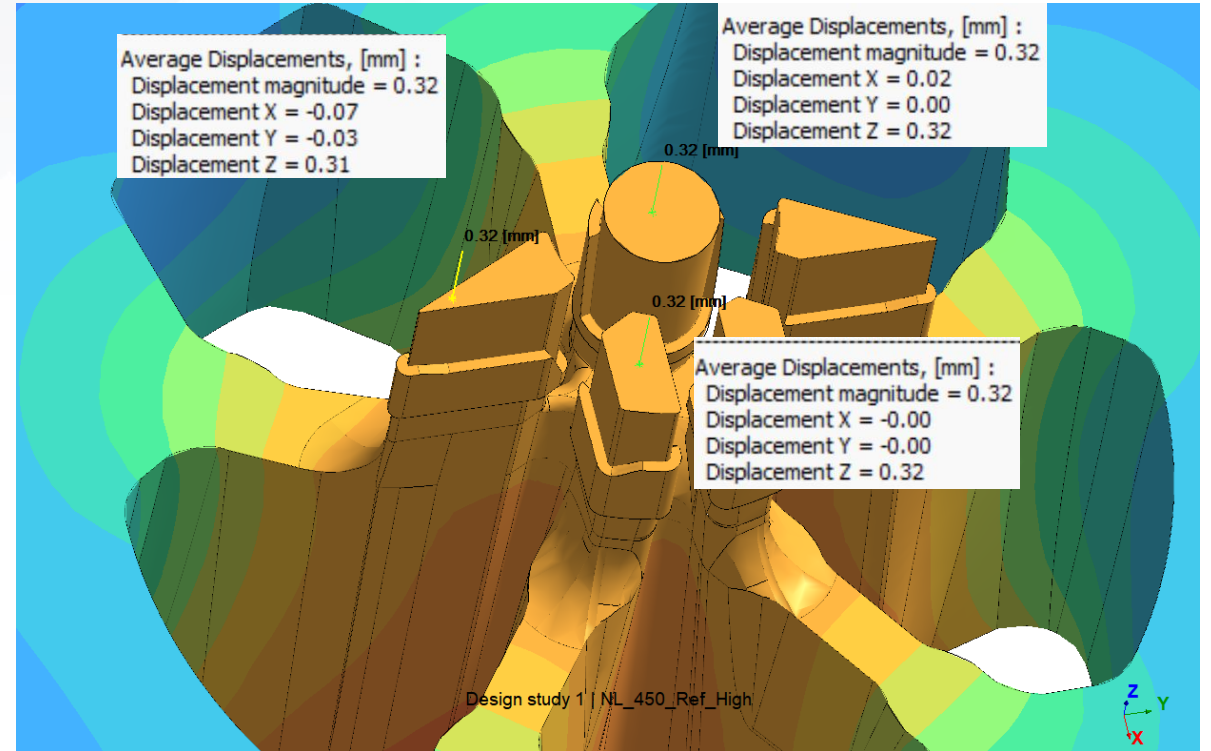
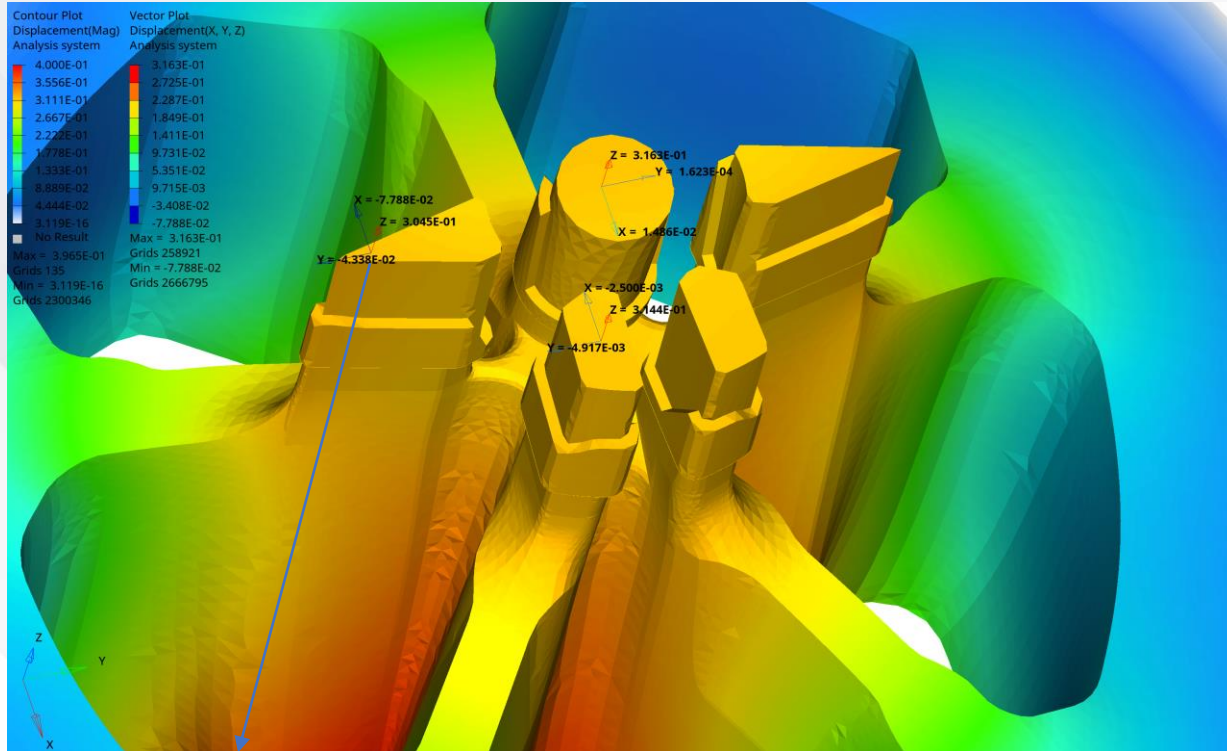
Ekstrüzyon Kalıbı

Deplasman karşılaştırma

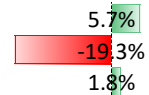


Ekstrüzyon Kalıbı

Deplasman karşılaştırma

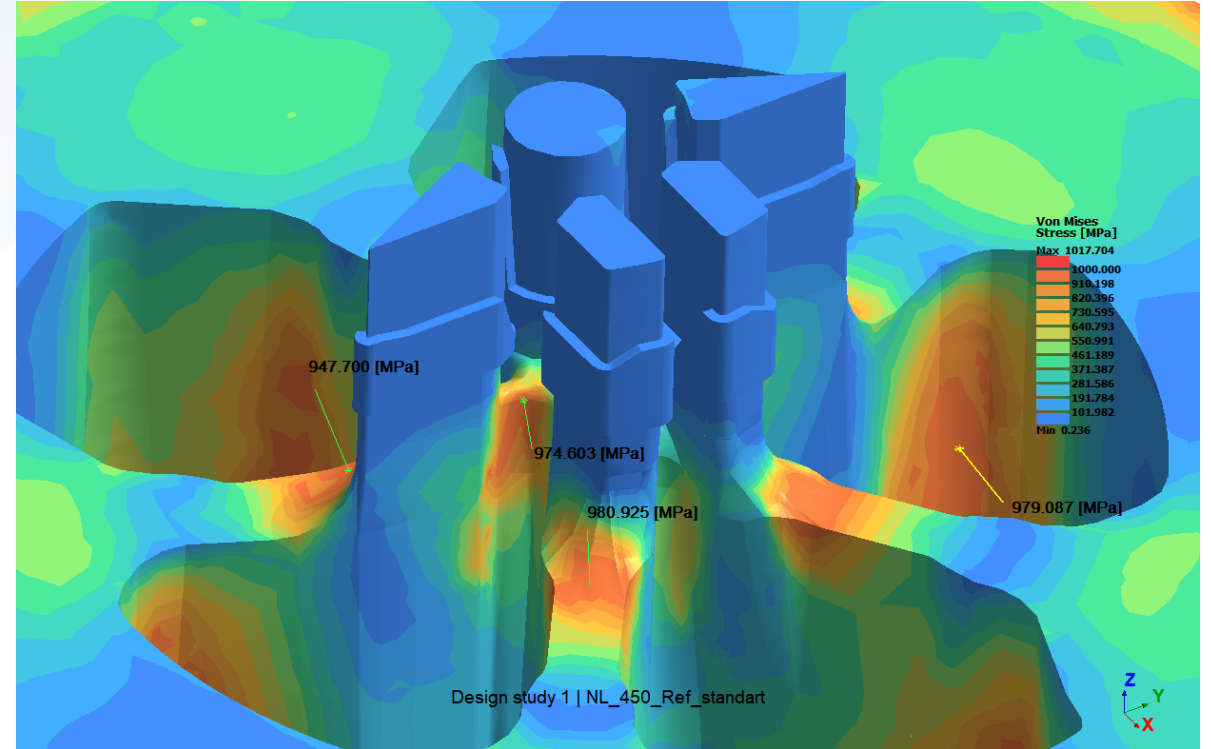
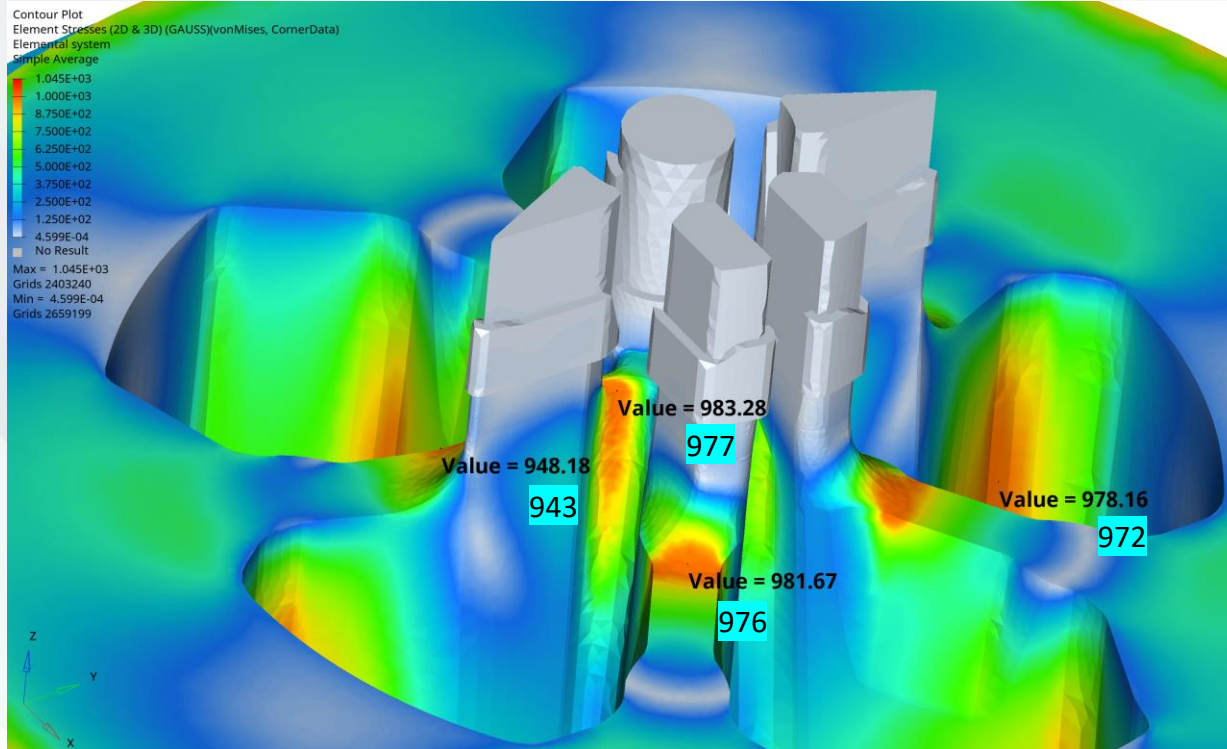


	FEM	SimSolid
X	-0.08	-0.08
Y	-0.04	-0.03
Z	0.30	0.31



Ekstrüzyon Kalıbı

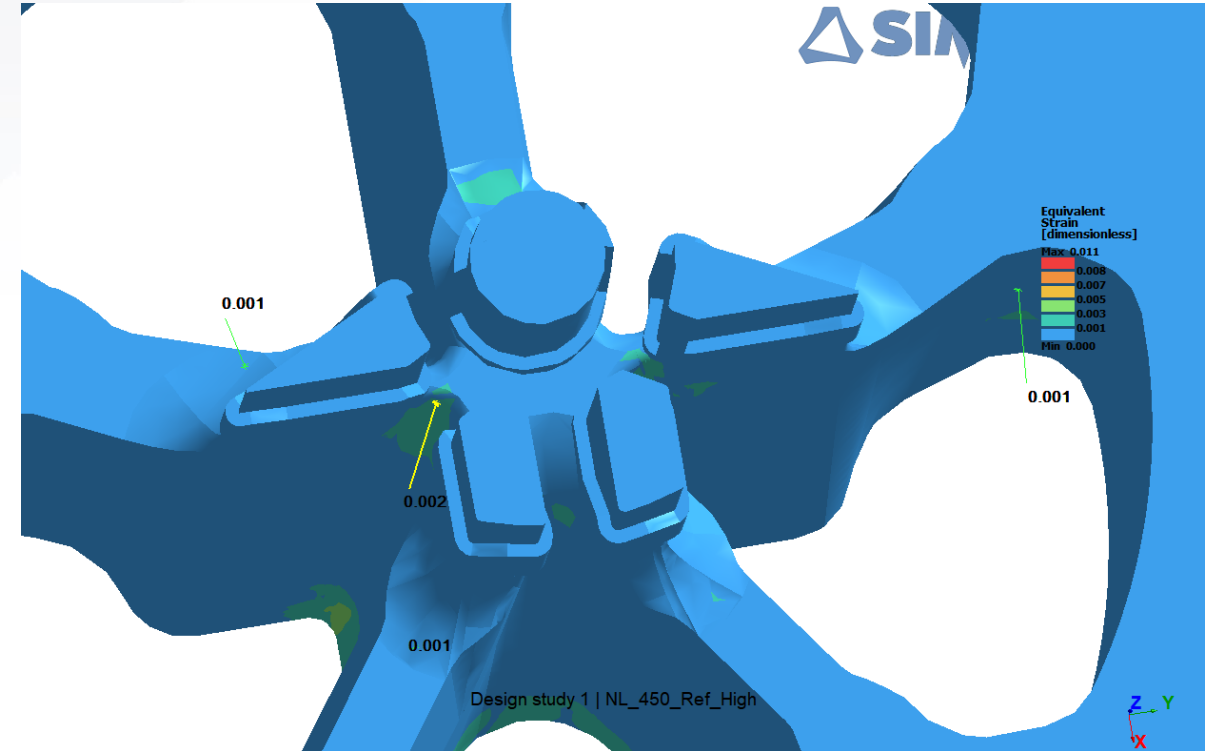
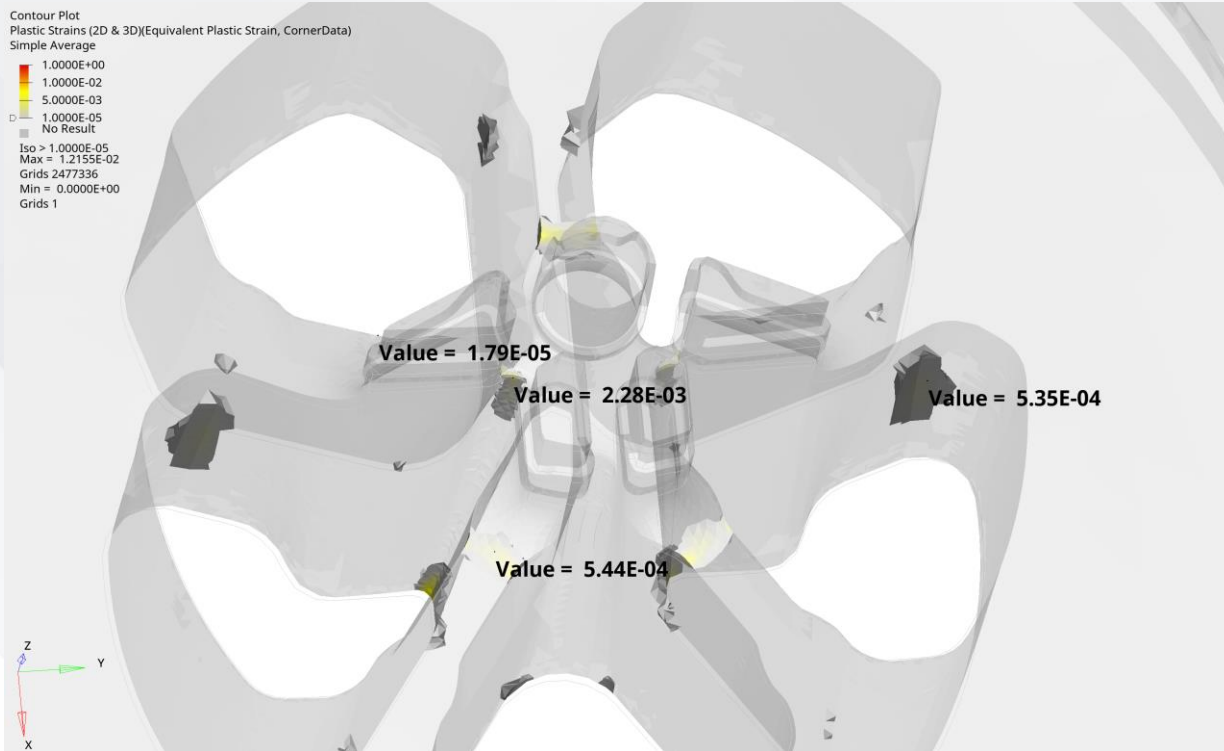
Gerilme karşılaştırma



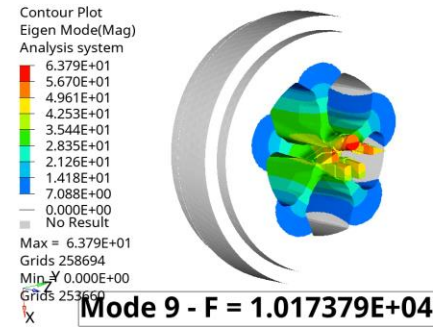
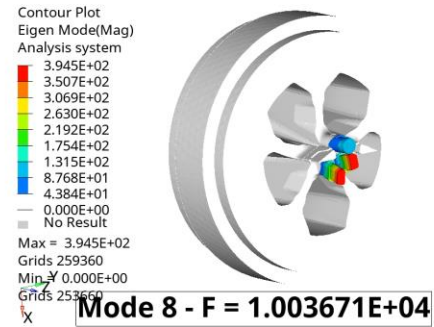
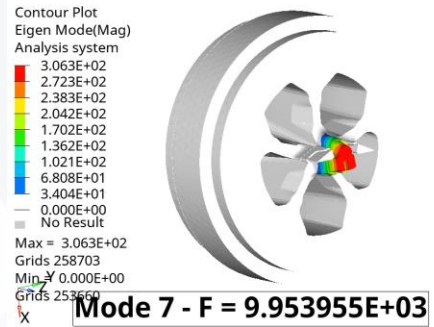
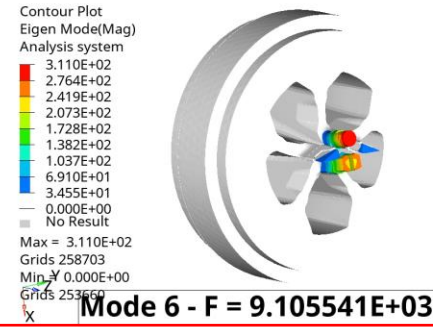
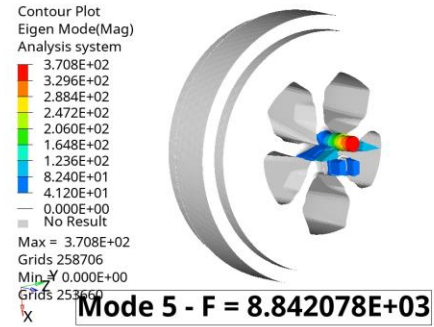
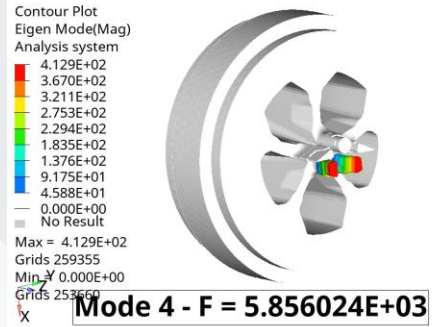
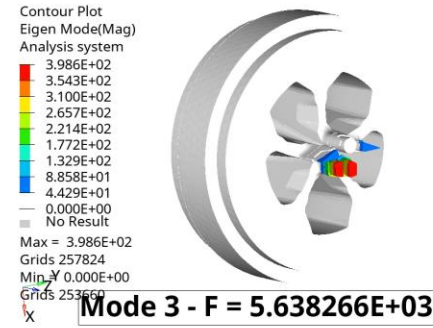
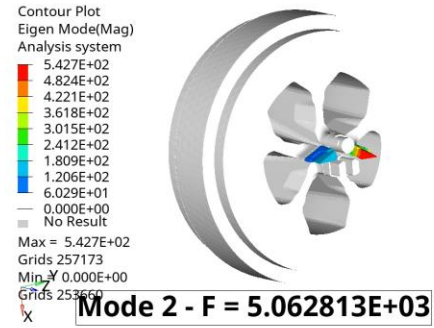
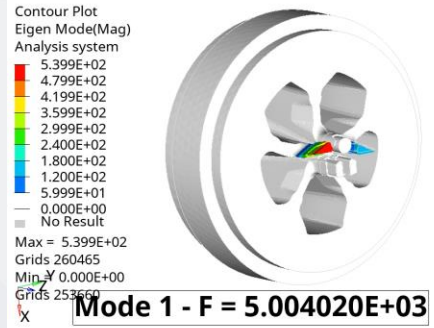
	FEM	SimSolid	
1	943.00	947.00	0.4%
2	976.00	980.00	0.4%
3	977.00	975.00	-0.2%
4	972.00	979.00	0.7%

Ekstrüzyon Kalıbı

Plastik gerinme karşılaştırma



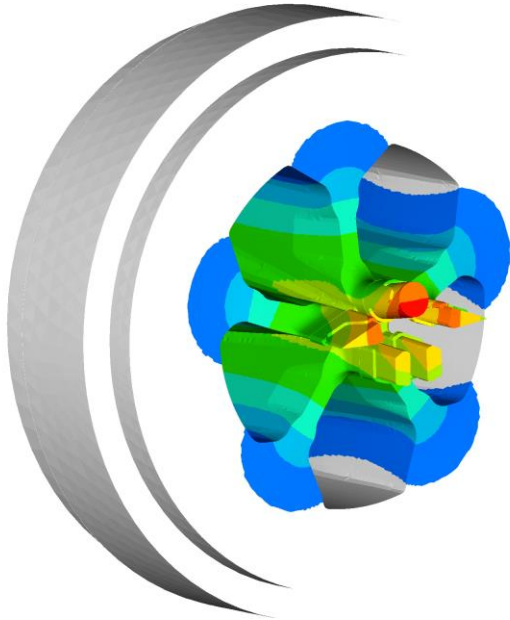
Ekstrüzyon Kalıbı (Modal)



Mode	Frequency	X-TRANS	Y-TRANS	Z-TRANS
1	5.00E+03	0%	0%	0%
2	5.06E+03	0%	0%	0%
3	5.64E+03	0%	0%	0%
4	5.86E+03	0%	0%	0%
5	8.84E+03	0%	1%	0%
6	9.11E+03	1%	0%	0%
7	9.95E+03	0%	0%	0%
8	1.00E+04	0%	0%	0%
9	1.02E+04	0%	0%	27%
10	1.07E+04	0%	1%	0%

Ekstrüzyon Kalıbı (Modal)

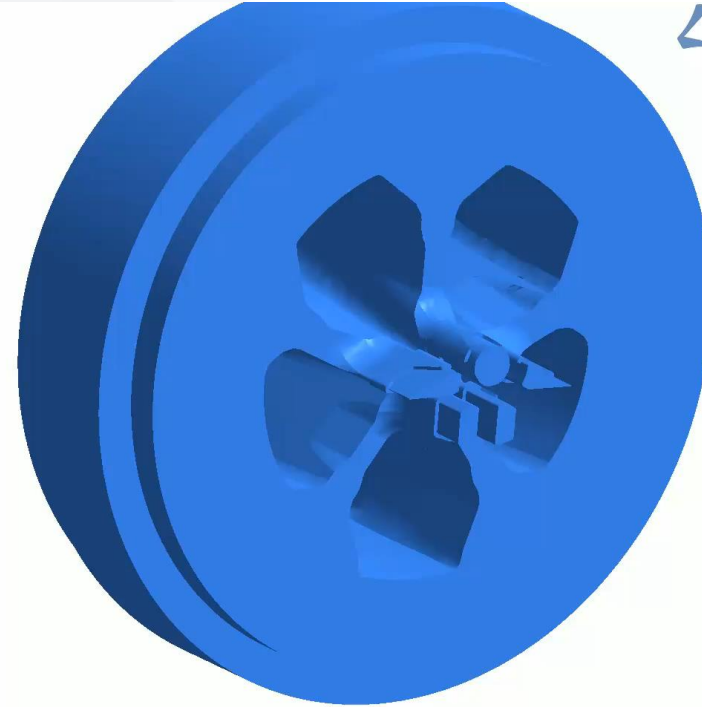
Contour Plot
Eigen Mode(Mag)
Analysis system
6.379E+01
5.670E+01
4.961E+01
4.253E+01
3.544E+01
2.835E+01
2.126E+01
1.418E+01
7.088E+00
0.000E+00
No Result
Max = 6.379E+01
Grids 258694
Min = 0.000E+00
Grids 253660



Mode 9 - F = 1.017379E+04

SIMSOLID

Displacement
Magnitude,
mode 1,
Fres.
1.0399e+04
[Hz]
Max 1.0000e+00
9.1667e-01
8.3333e-01
7.5000e-01
6.6667e-01
5.8333e-01
5.0000e-01
4.1667e-01
3.3333e-01
2.5000e-01
1.6667e-01
8.3333e-02
Min 3.2650e-08



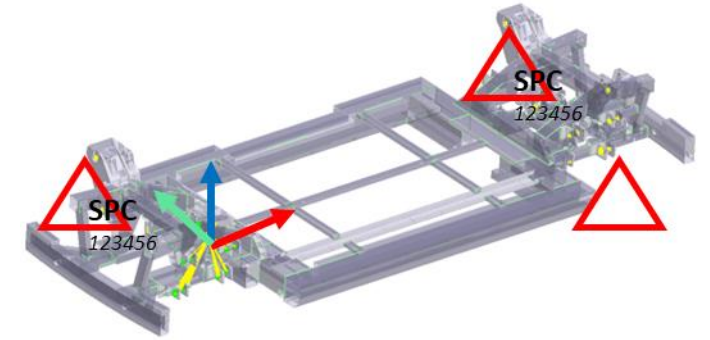
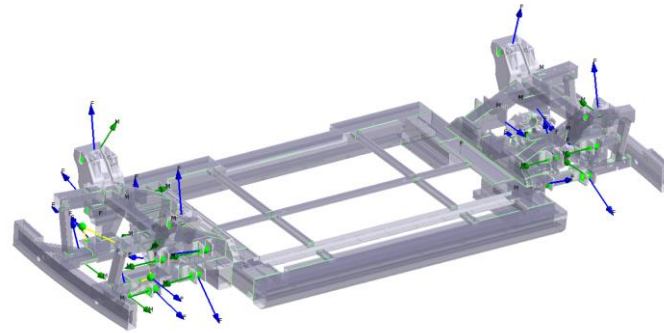
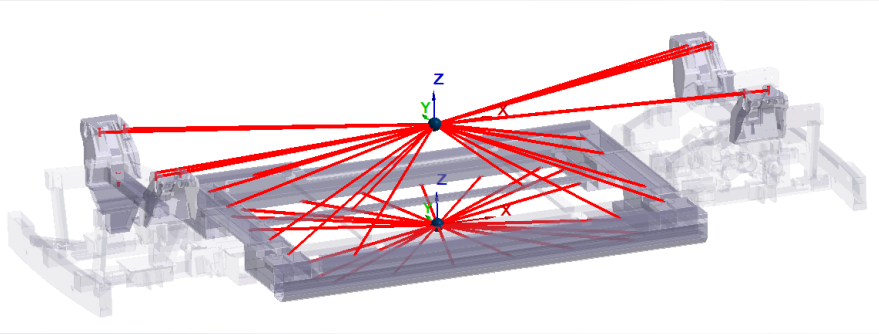
Design study 1 | Modal 6

FEM	SimSolid (Adapt for Stress)
10173.79	10399.00

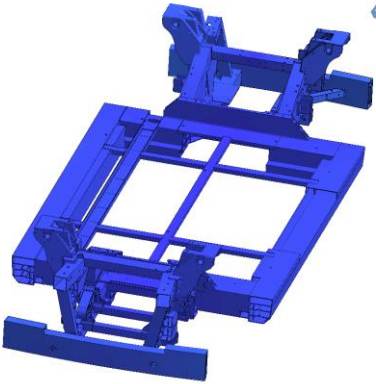
2.2%

Sase Geliştirme

Modal, Inertia relief ve rijitlik analizleri



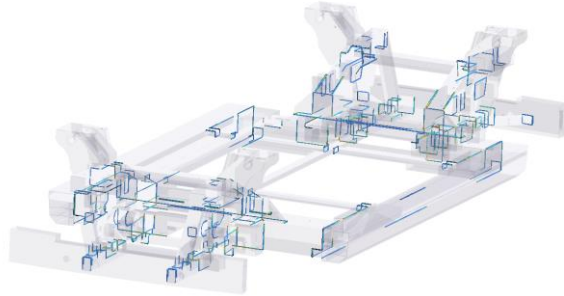
 SIMSOLID



Design study 1 | Modal 1



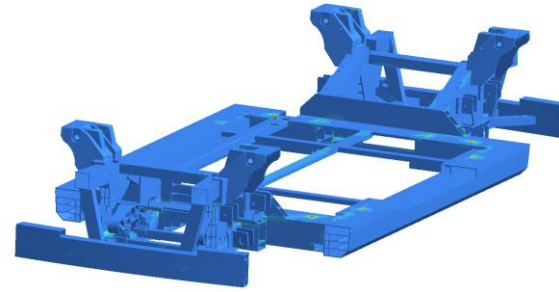
 SIMSOLID



Design study 1 | Vertical_impact_NL_stress



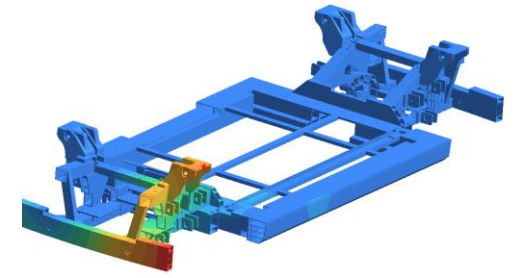
 SIMSOLID



Design study 1 | Vertical_impact_NL_stress



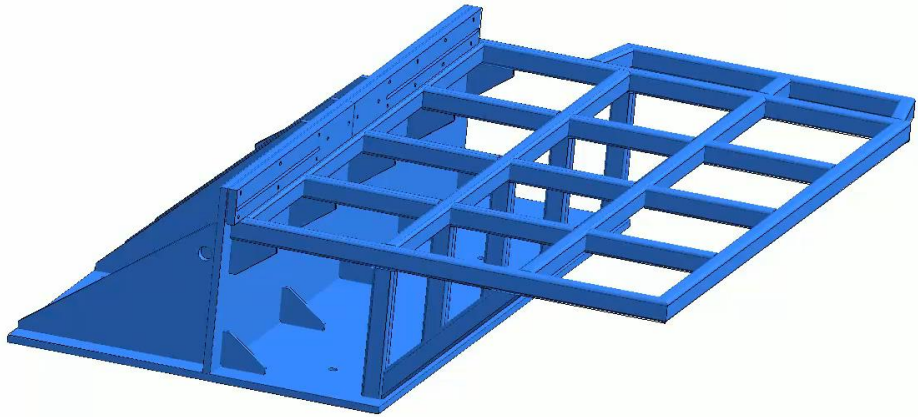
 SIMSOLID



Design study 1 | Kx



Fikstür

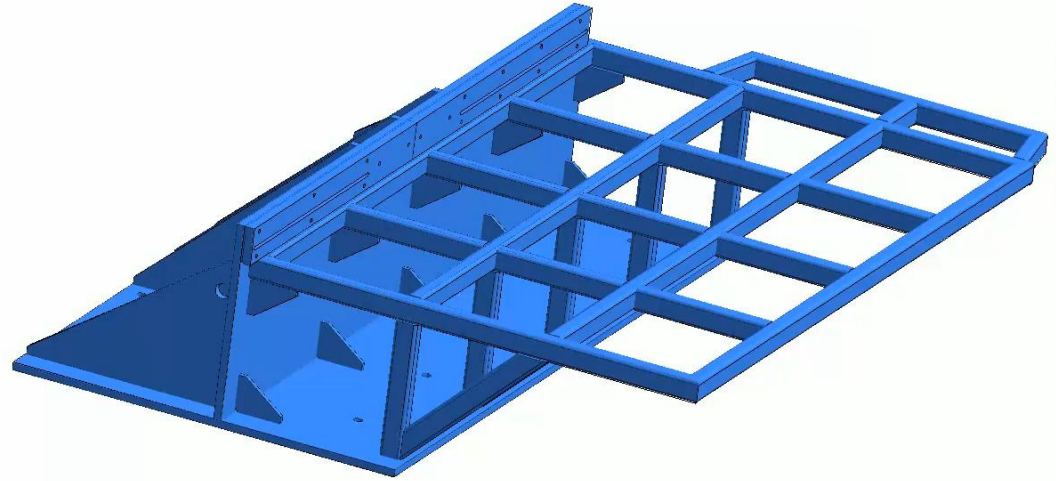


Displacement
Magnitude
[mm]

Max	8.3014e-01
	7.6096e-01
	6.9179e-01
	6.2261e-01
	5.5343e-01
	4.8425e-01
	4.1507e-01
	3.4589e-01
	2.7672e-01
	2.0754e-01
	1.3836e-01
	6.9181e-02
Min	3.0755e-06

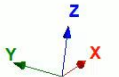


Design study 1 | Structural 1



Von Mises
Stress [MPa]

Max	3.6322e+02
	1.5000e+02
	1.3864e+02
	1.2727e+02
	1.1591e+02
	1.0454e+02
	9.3177e+01
	8.1812e+01
	7.0448e+01
	5.9083e+01
	4.7719e+01
	3.6354e+01
Min	3.5574e-02



Design study 1 | Structural 1

Koltuk



Displacement
Magnitude
[mm]

Max	2.8075e+01
	2.5736e+01
	2.3396e+01
	2.1057e+01
	1.8717e+01
	1.6377e+01
	1.4038e+01
	1.1698e+01
	9.3585e+00
	7.0189e+00
	4.6793e+00
	2.3397e+00
Min	4.3179e-05



Koltuk | Analiz



Von Mises
Stress [MPa]

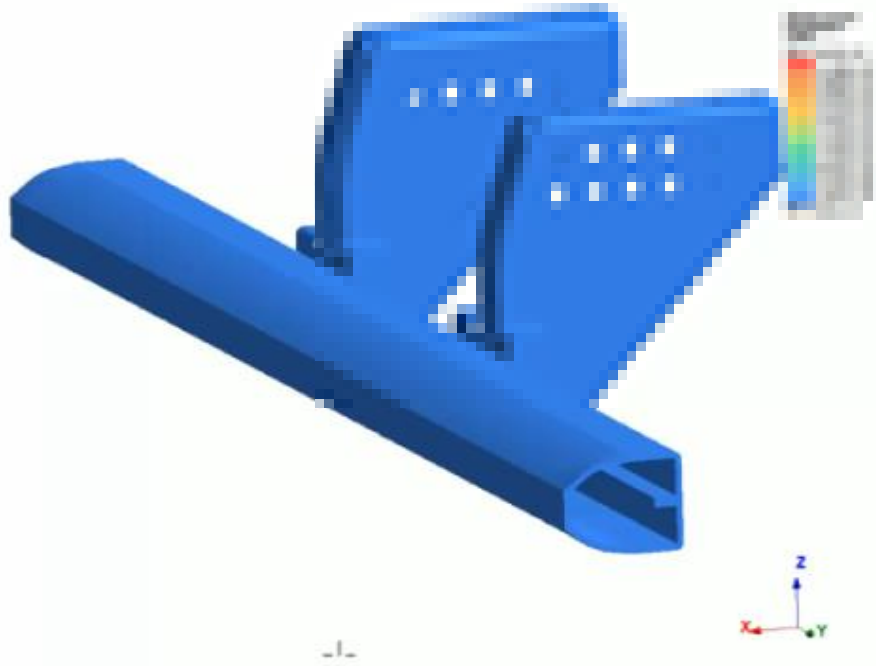
Max	1.6737e+03
	1.6000e+02
	1.4500e+02
	1.3000e+02
	1.1500e+02
	1.0000e+02
	8.5000e+01
	7.0000e+01
	5.5000e+01
	4.0000e+01
	2.5000e+01
	1.0000e+01
Min	1.9733e-02



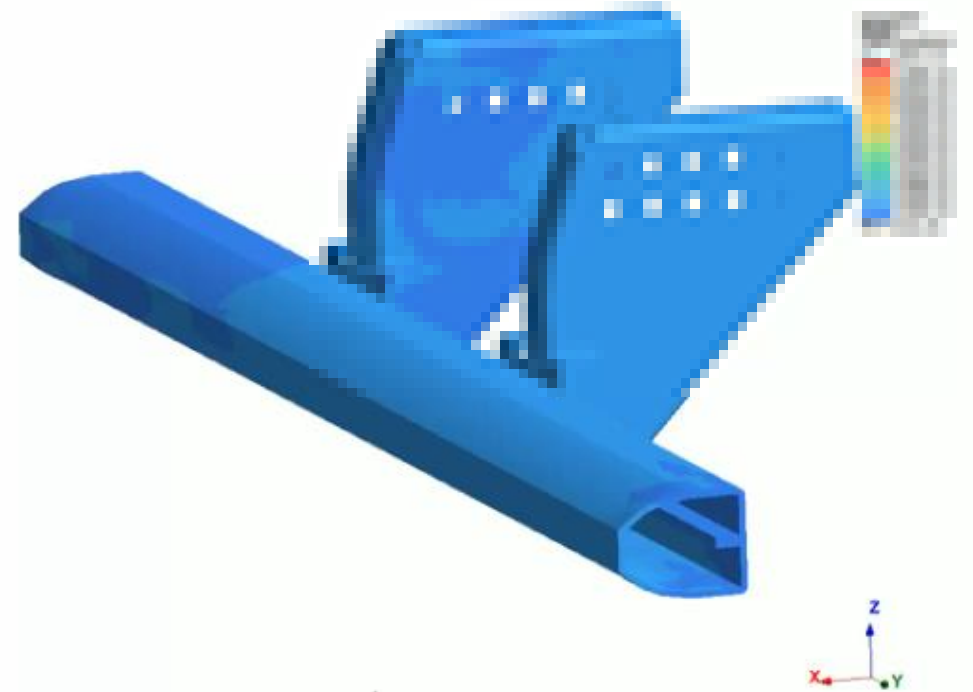
Koltuk | Analiz

Arka Alt Koruma

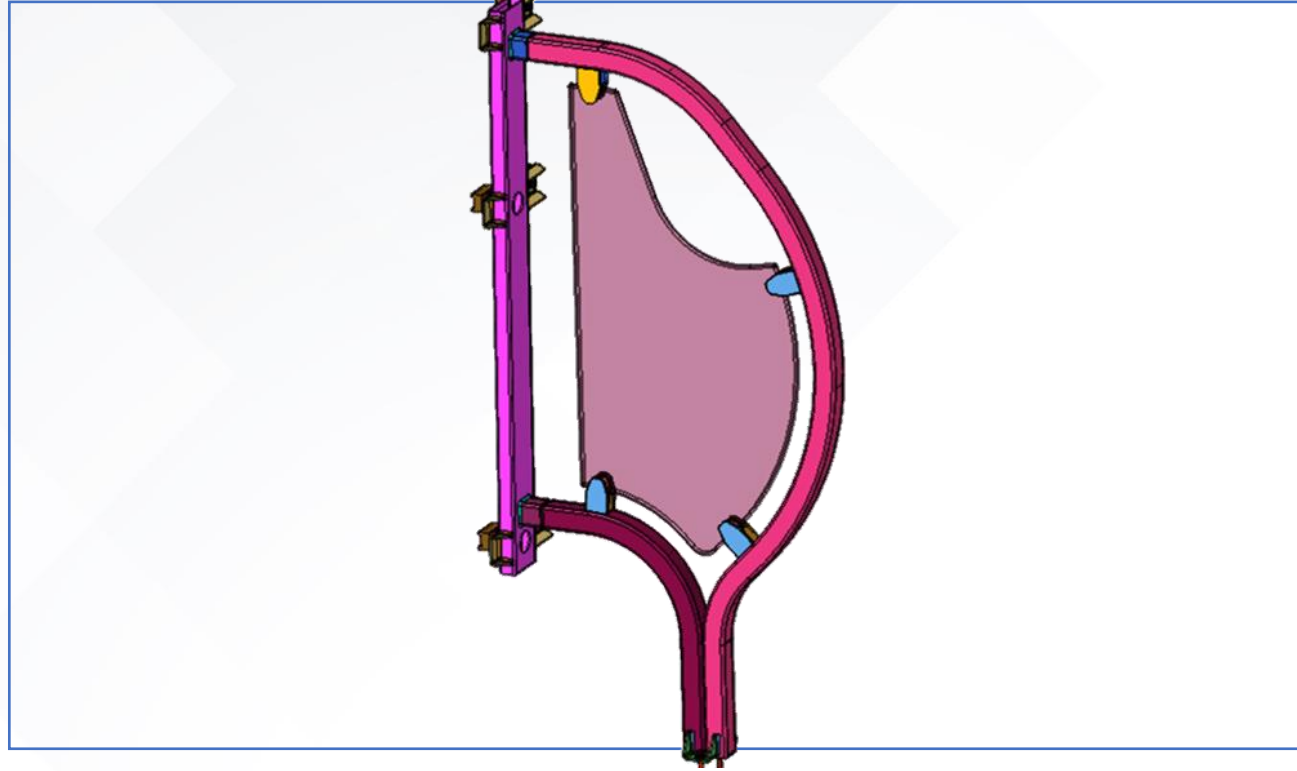
△ SIMULIA
SIMULIA SOLID

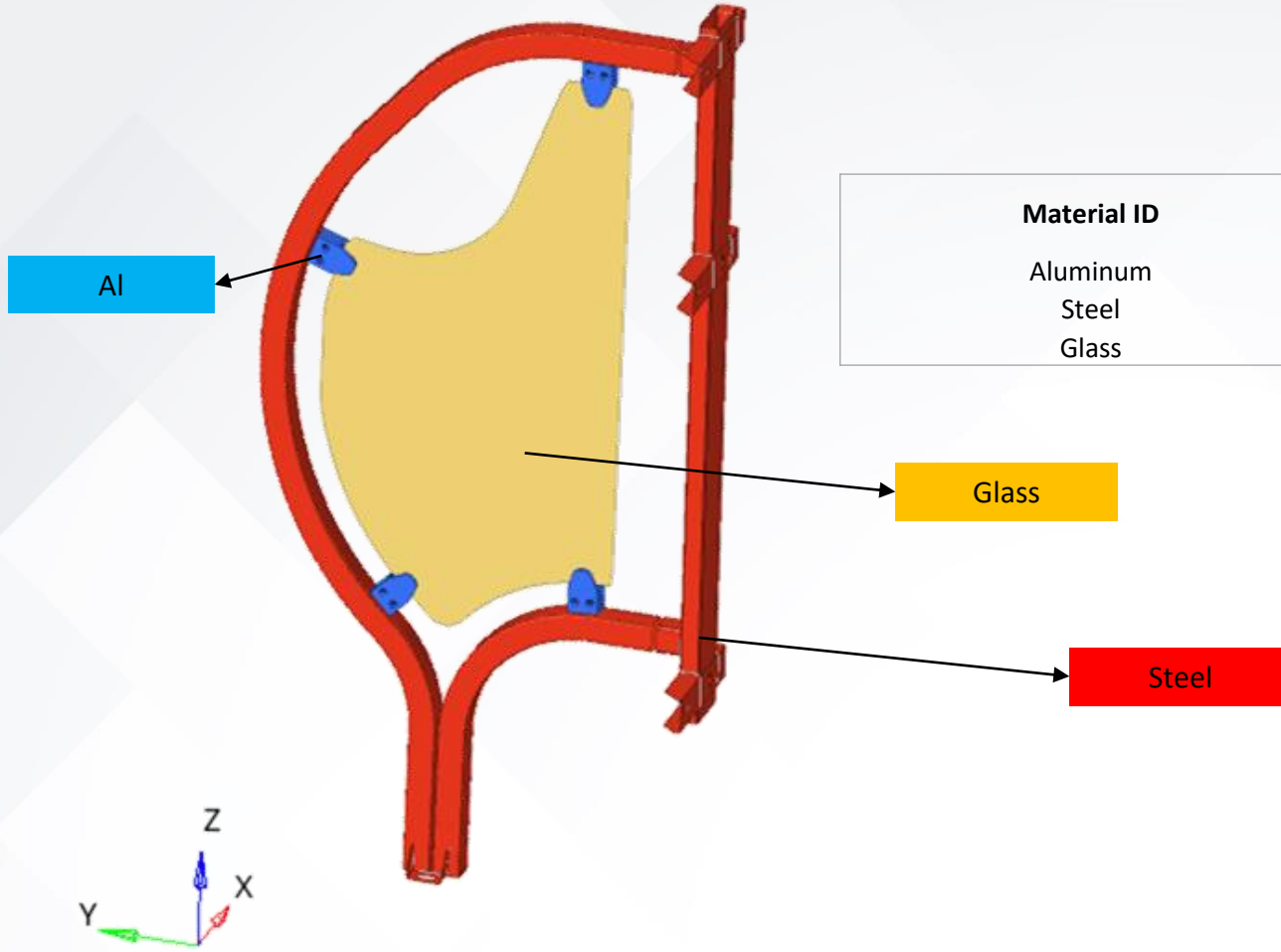


△ SIMULIA
SIMULIA SOLID



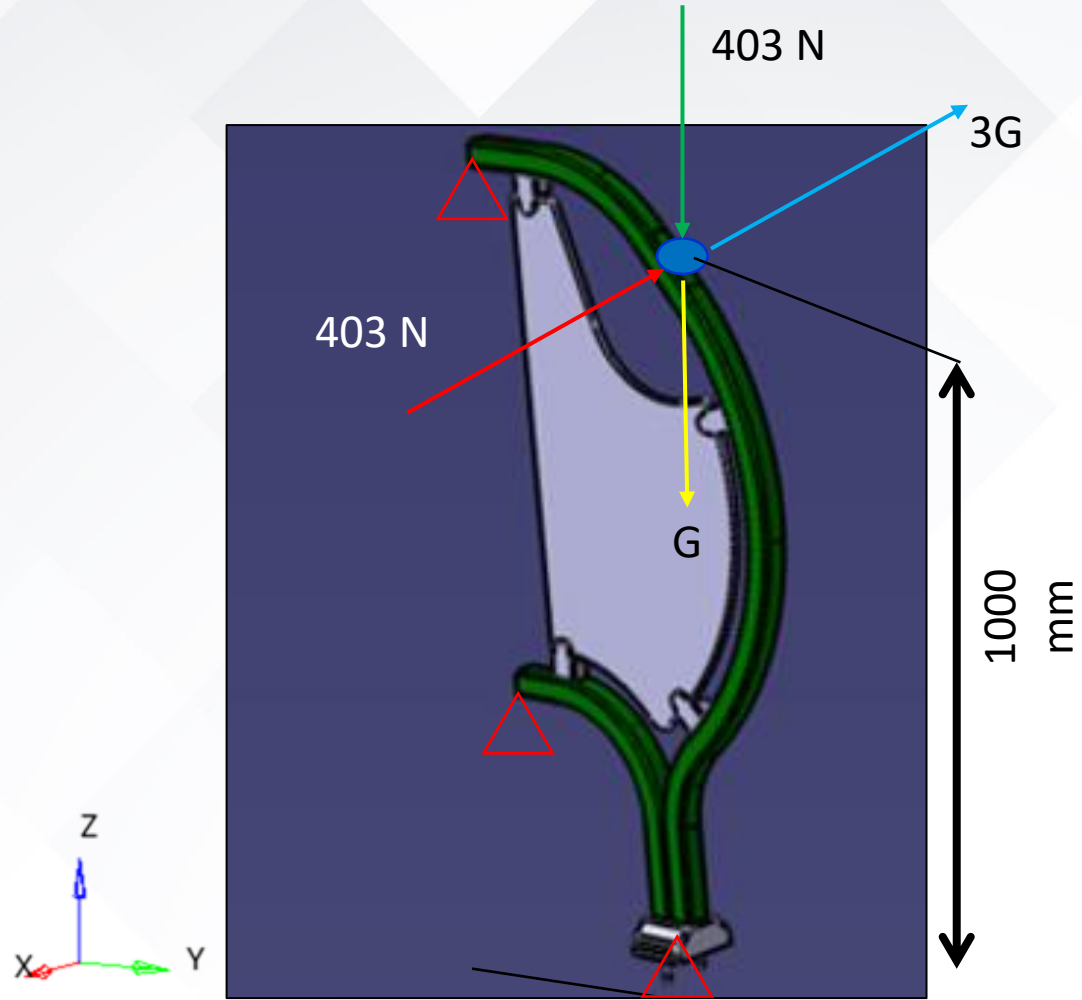
Rüzgarlık Bar



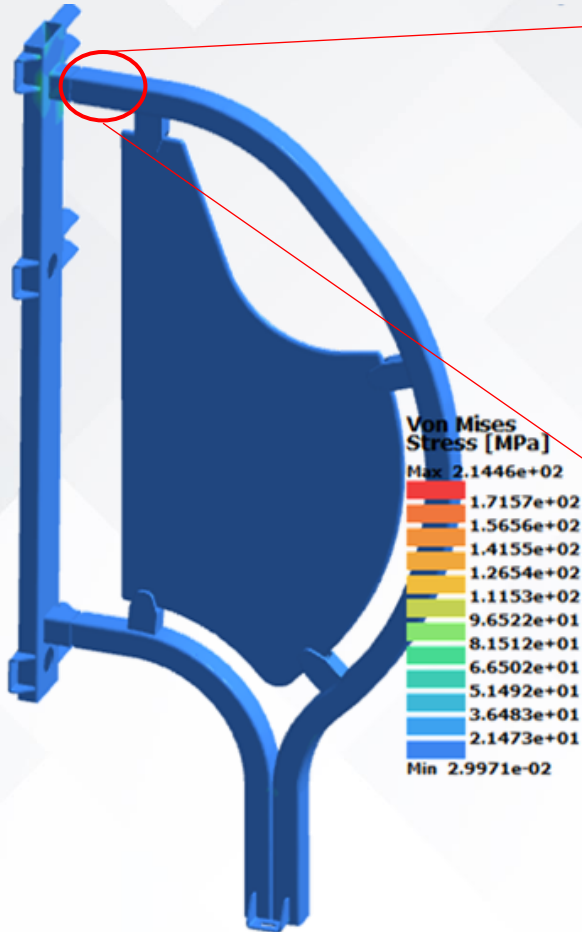
Rüzgarlık Bar

Material ID	Density [kg/m3]	Module of Elasticity [MPa]	Yield Stress [MPa]	Ultimate Tensile Stress [MPa]
Aluminum	2700	70000	170	215
Steel	7850	210000	235	330
Glass	2500	70000	50	52

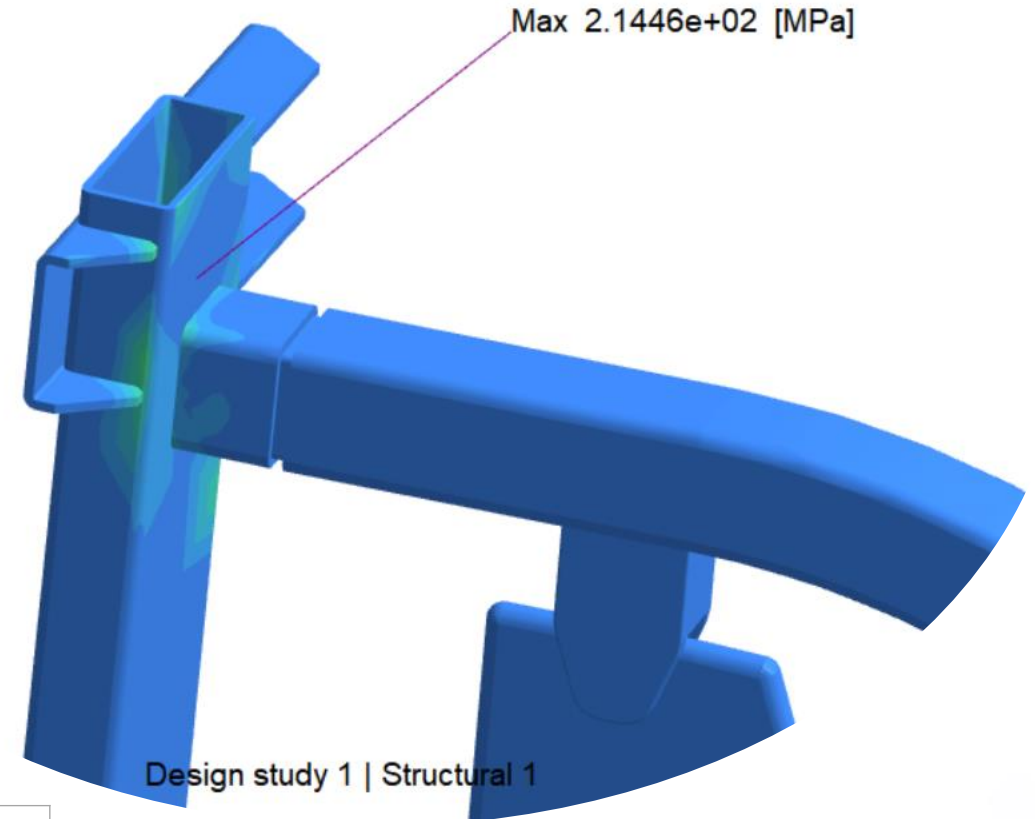
Rüzgarlık Bar



Rüzgarlık Bar



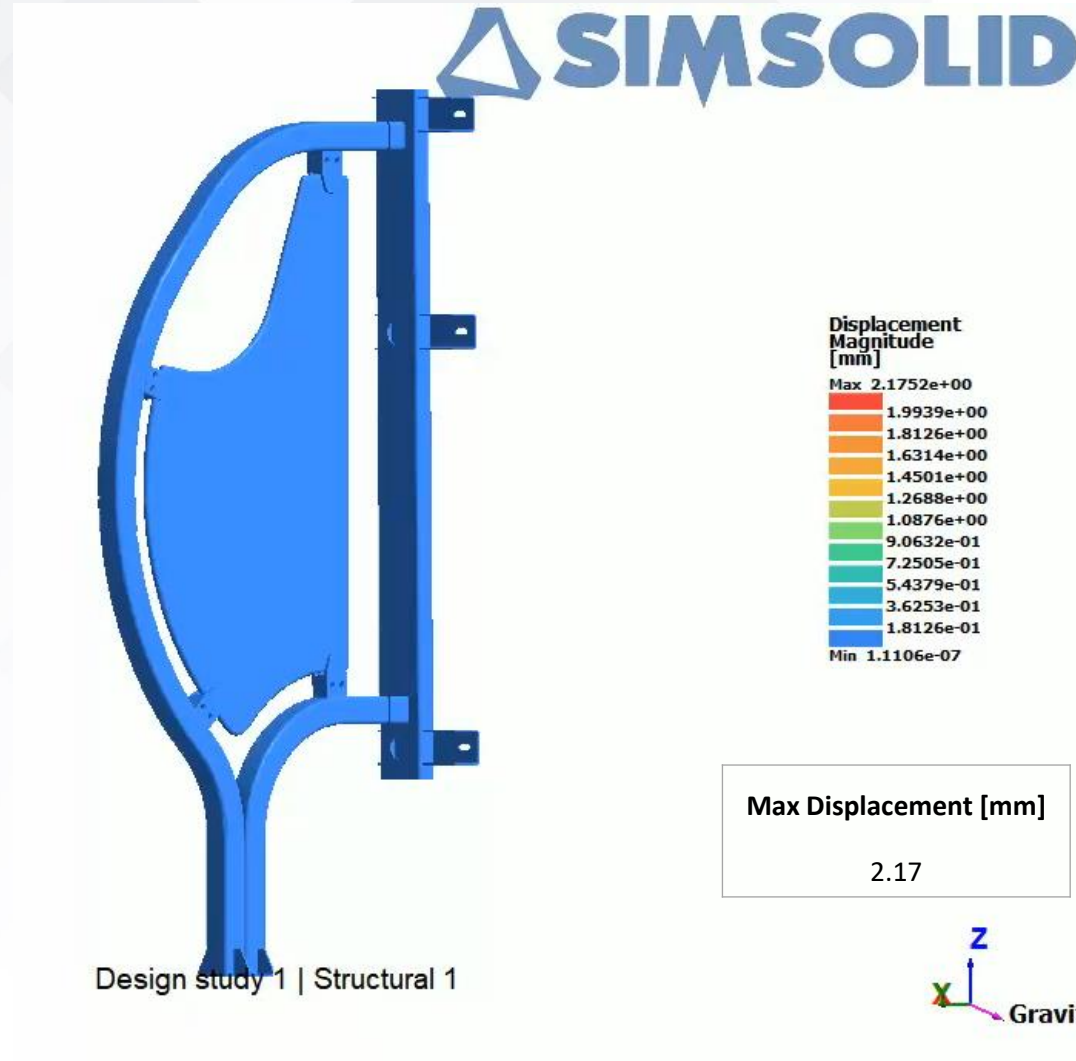
Design study 1 | Structural 1



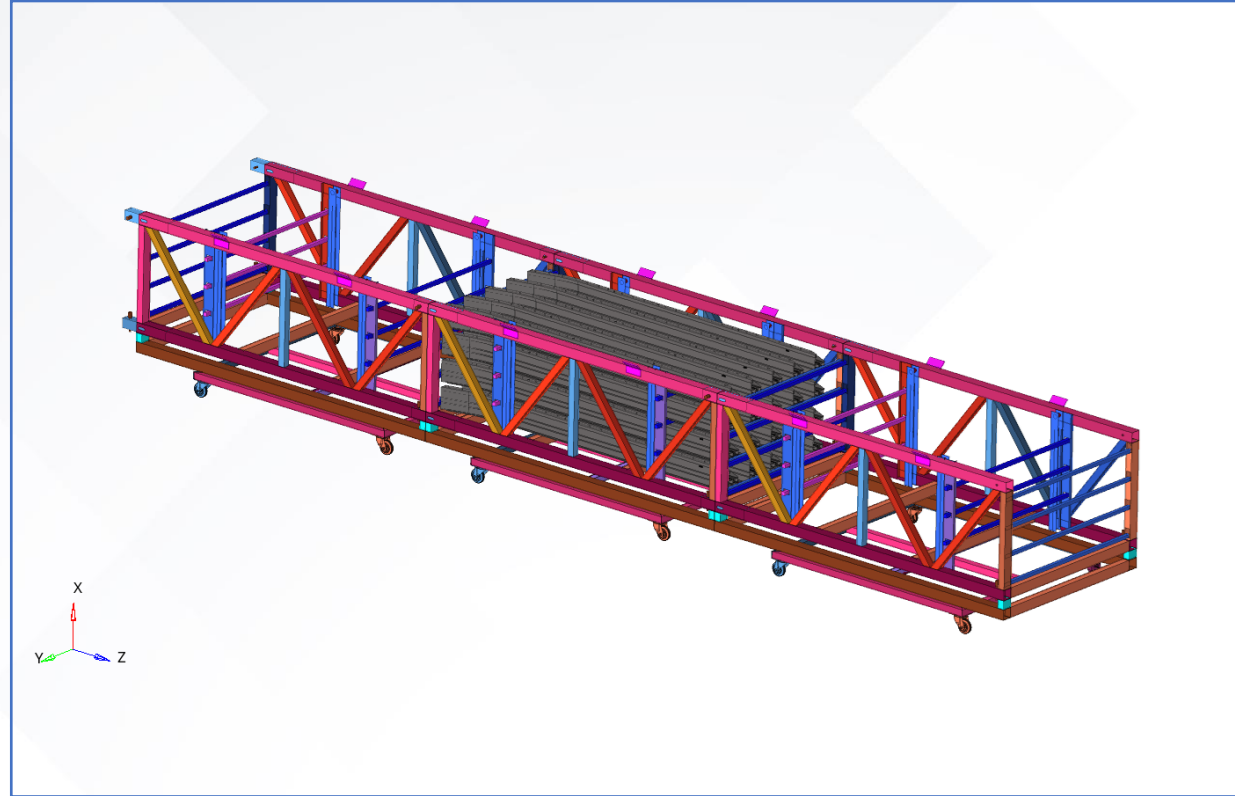
Design study 1 | Structural 1

Steel Yield Stress [MPa]	Max Stress [MPa]
235	214.5

Rüzgarlık Bar

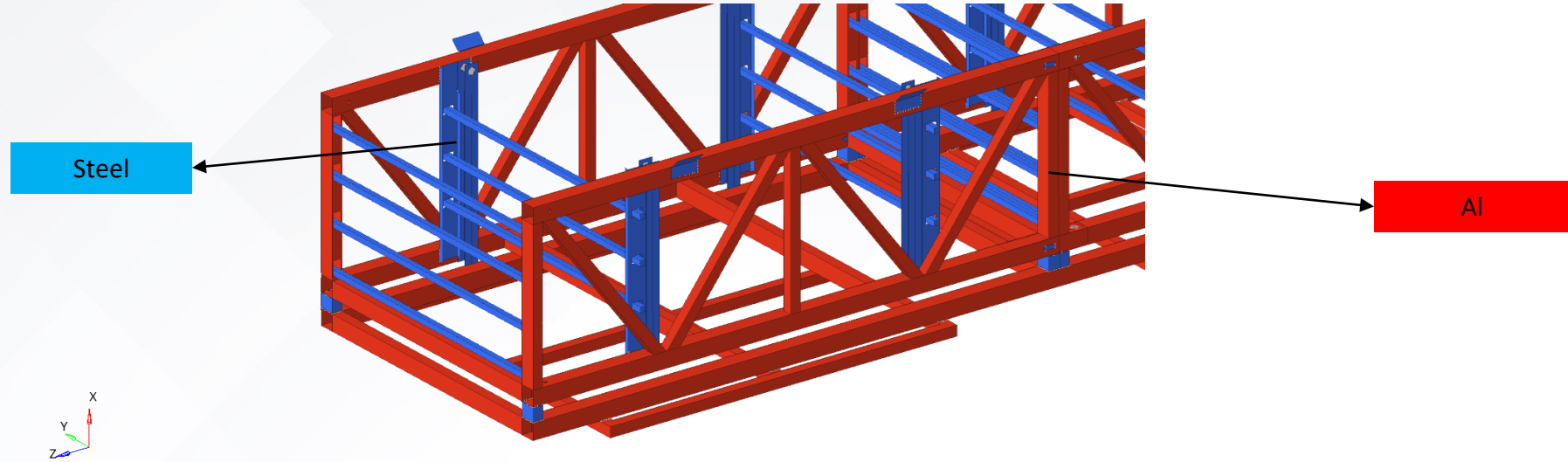


Termal Taşıyıcı Sepet



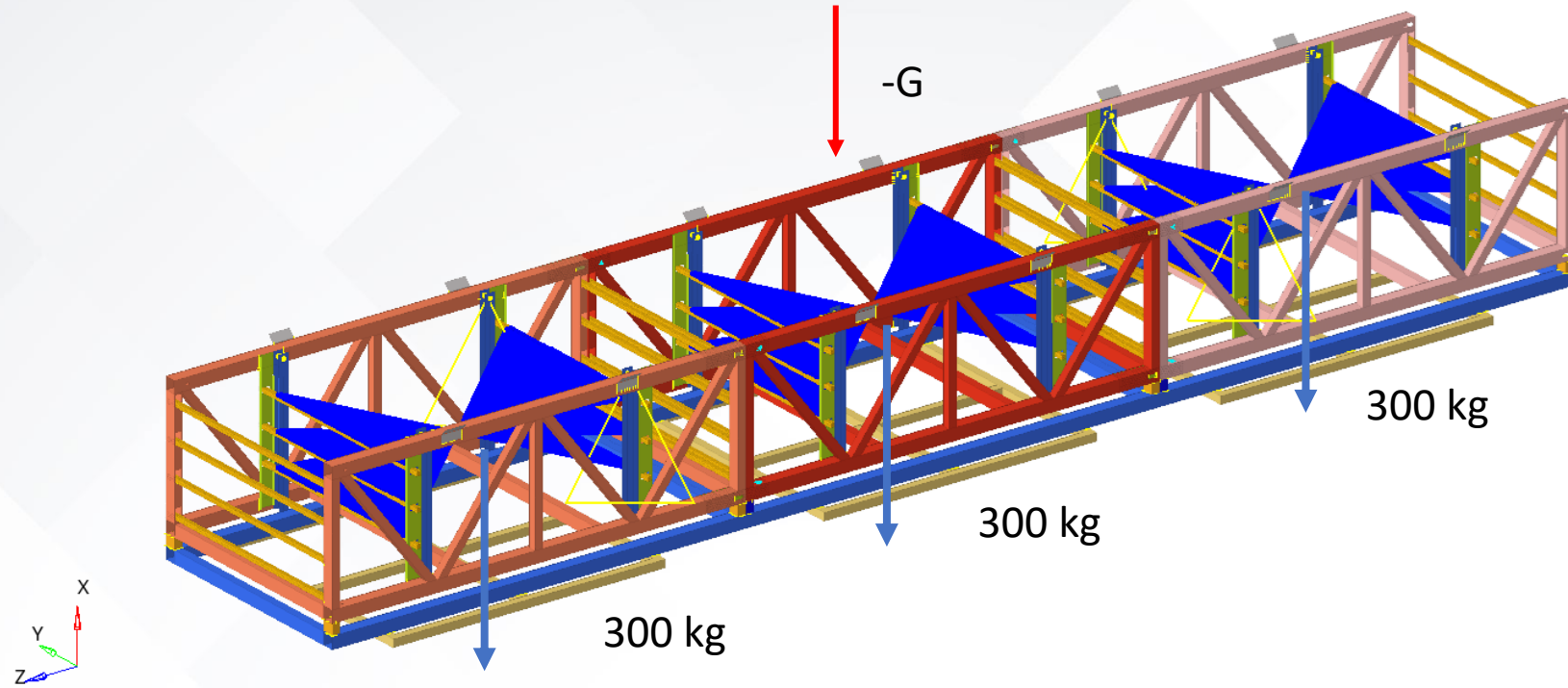
Termal Taşıyıcı Sepet

Properties of Materials

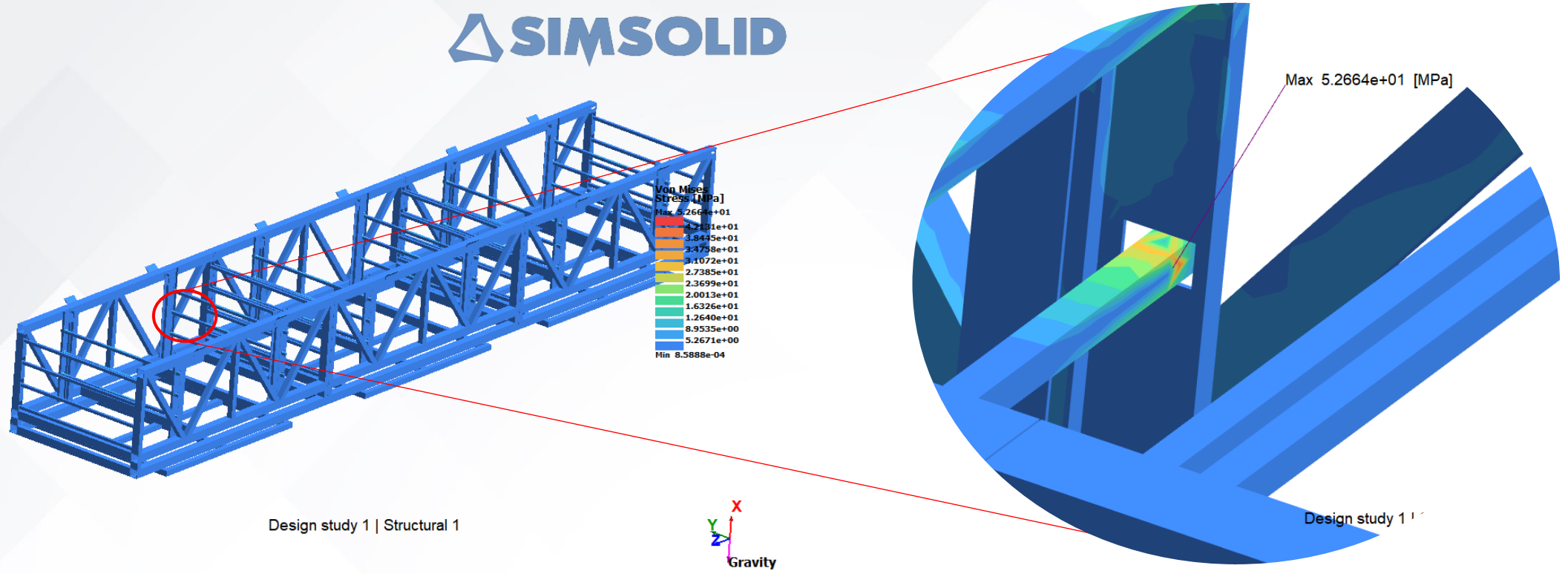


Material ID	Density [kg/m3]	Module of Elasticity [MPa]	Yield Stress [MPa]	Ultimate Tensile Stress [MPa]
AA 6063-T6	2700	70000	170	215
ST-37	7850	210000	235	330

Termal Taşıyıcı Sepet



Termal Taşıyıcı Sepet

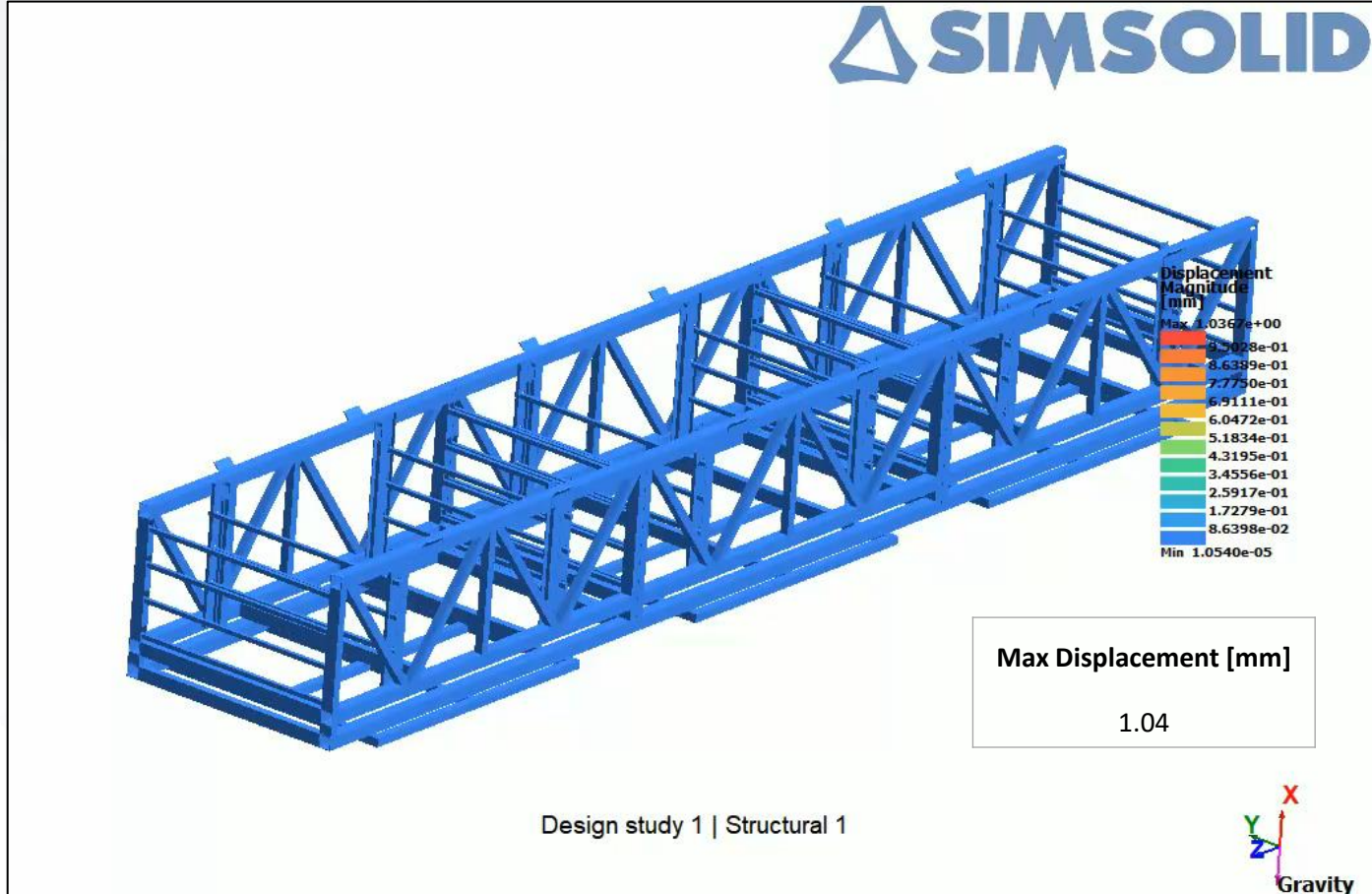


Design study 1 | Structural 1

Design study 1 | 1

Steel Yield Stress [MPa]	Max Stress [MPa]
235	52.7

Termal Taşıyıcı Sepet



Sonuçlar

- Sonlu elemanlar analizlerine geçmeden önce parça tasarım geometrisinde yapılabilecek ufak değişiklikler ile hazırladığımız analiz modeli ile analiz edilen sistem üzerindeki kontakları , parçanın genel davranışı , olası ciddi yüksek gerilmeleri ve yerlerinin tespitinde Lineer ve Nonlinear Statik analizlerde SimSolid faydalı bulunmuştur.
- Yapılan tüm analiz taleplerini bir fem analizi öncesinde SimSolid analizlerini sürecimize dahil etmekteyiz.

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