numesys
NUMERICAL SYSTEMS

Ahmet OKUDAN, MSc.
Uzman Uygulama Mühendisi

Ansys ile Topoloji Optimizasyonu

Sürdürülebilir Tasarım ve Üretim

3D Design FEA electromagnetics CFD digital twin systems modeling simulation optimization customization multiphysics semiconductors embedded software optics HPC additive manufacturing

Ansys CERTIFIED ELITE CHANNEL PARTNER

Ahmet Okudan, MSc

2014 – Sakarya Üni Makine Müh.
2014 – 2015 FMC Hydraulic Simülasyon Müh.
2015 – 2019 Vaden Originals Simülasyon + Tasarım Müh.
2019 – Konya Teknik Üni Makine Müh. Yüksek Lisans
2019 – Numesys İleri Mühendislik Hizmetleri A.Ş –
Uzman Yapısal Uygulama Mühendisi

2018 – Udemy Instructor

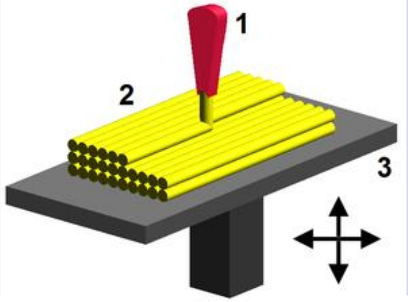
Konya

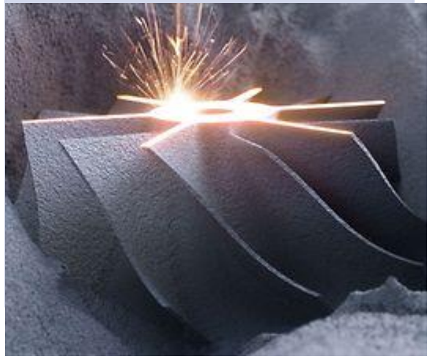

Forged Steel UCA


Stamped Steel UCA

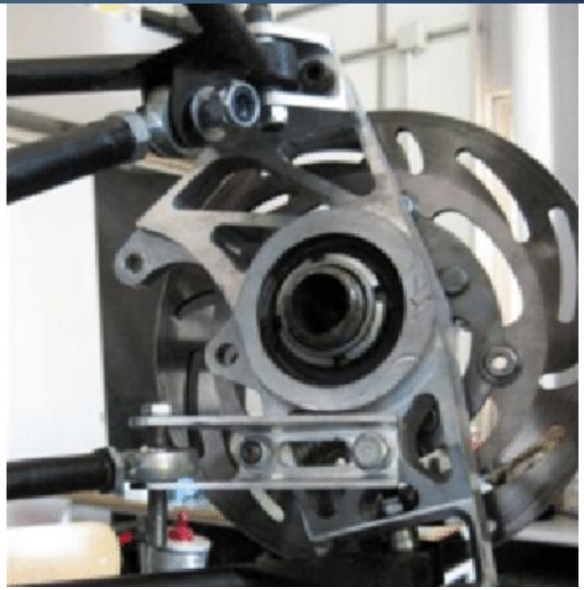
F/P Analizi

FMD/SLA	SLS/SLM	CASTING	FORGED/ INJECTION	STAMP/ MILLING
• 250 €/kg	• 1000 €/kg	• 2 €/kg	• 3 €/kg	• 5 €/kg
• 0.1 kg/h	• 1kg/h	• -	• 1000kg/h	• 100kg/h
• 50.000 €	• 300.000 €	• 10.000 €	• 200.000 €	• 200.000 €





- Geleneksel imalat yöntemlerinin kısıtları, tasarımların şekil yapısını belirleyen birincil unsurdur.
- Takımların ulaşamadığı kısımlarda fazladan malzeme bulunabilir.
- Geleneksel tasarım, bilgi birikimi ve tecrübeye dayalıdır. Optimum şekli bulmak yorucu olabilir.

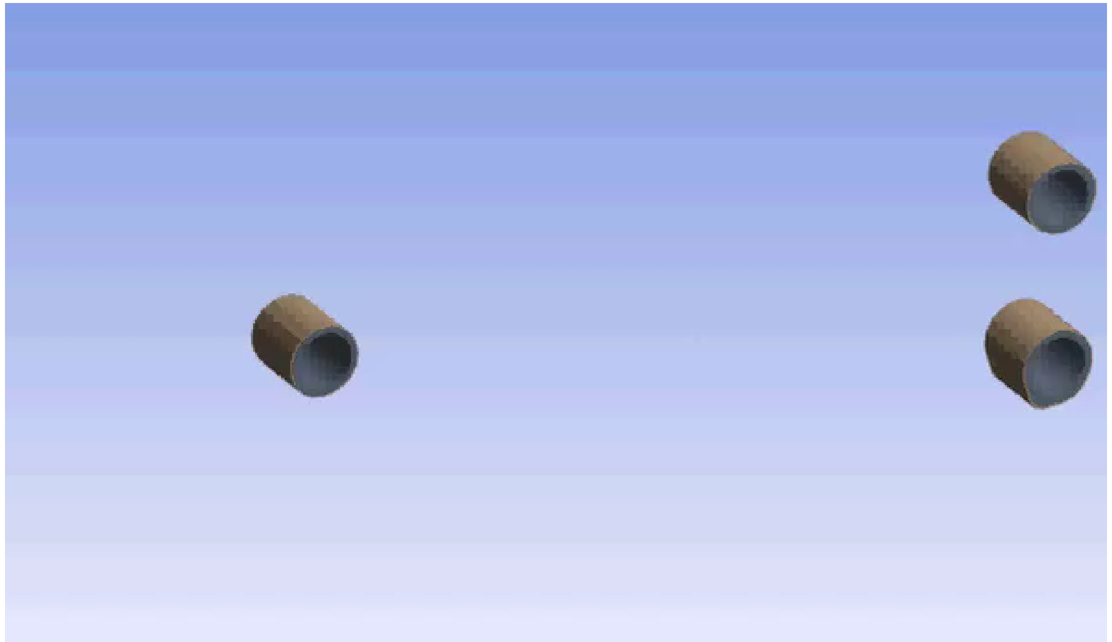


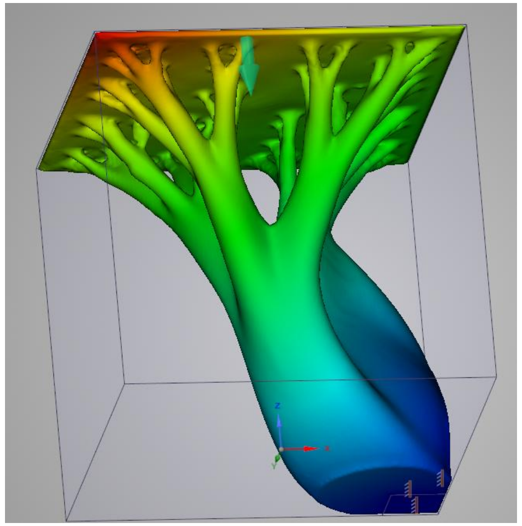
[1] Aks Başı – CNC işleme ile üretilmiş.

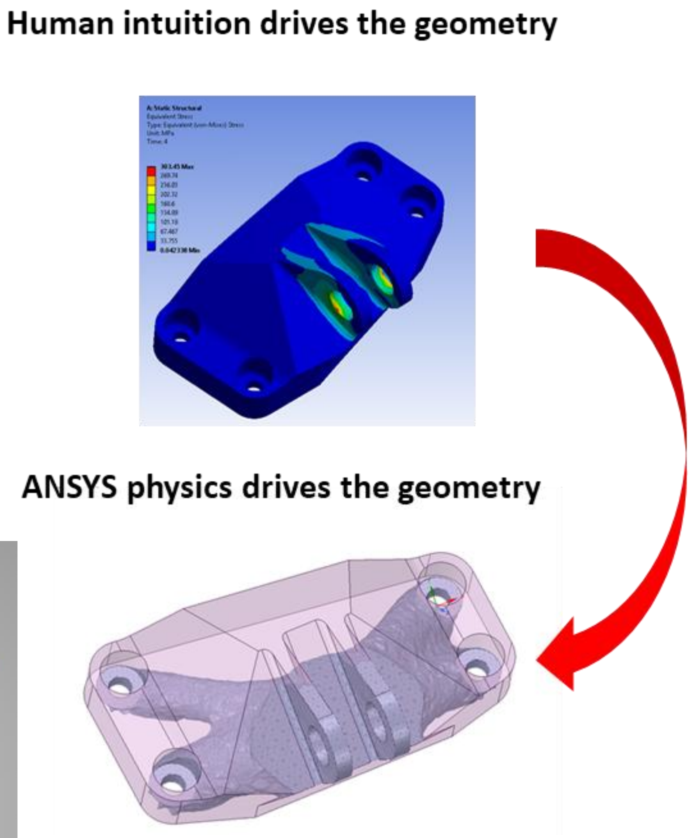
[1] Muzzupappa, Maurizio & Barbieri, Loris & Bruno, Fabio. (2011). Integration of topology optimization tools and knowledge management into the virtual Product Development Process of automotive components. Int. J. of Product Development. 14. 14 - 33. 10.1504/IJPD.2011.042291.

Topoloji Optimizasyonu (Yerleşim Eniyileme) Nedir?

“Belirli kısıtlamalara dayanarak, bir şeklin, belirli bir hacimdeki yerleşiminin, fizik güdümlü olarak en verimli ifadesini bulmaya çalışmaktır.”







Neden Topoloji Optimizasyonu Yapıyoruz?

- Performans ve tasarımı geliştirmek.
- Hafifletmek
- Talaş miktarını ve işleme enerjisini azaltmak
- Geniş malzeme seçeneği ile çalışabilmek.

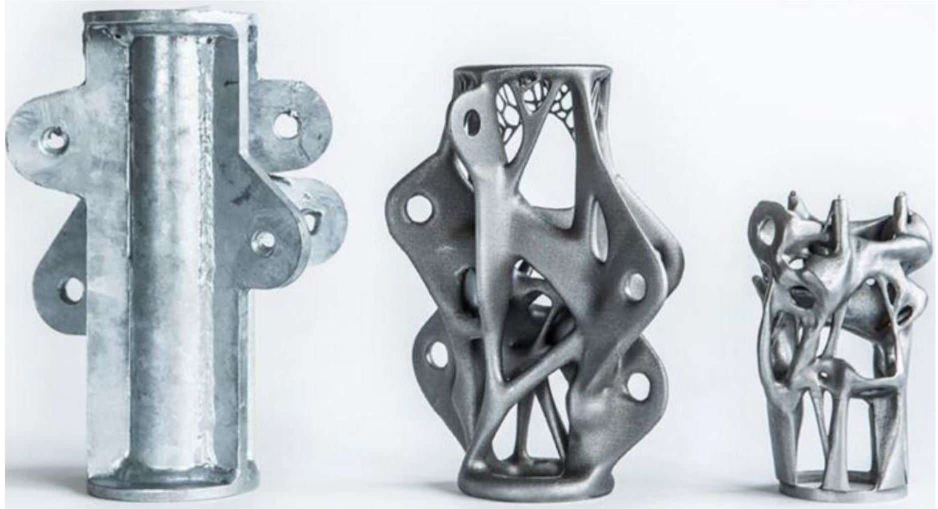
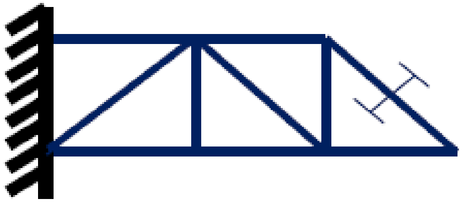
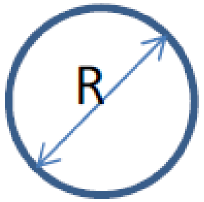
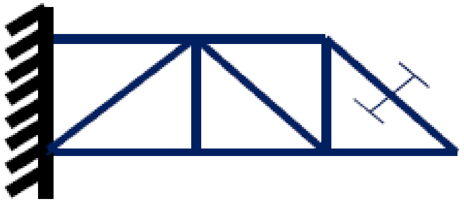
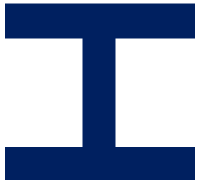
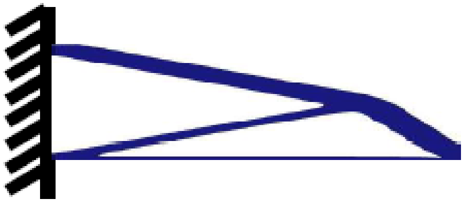


Figure 1.1–Organic optimised shapes produced by topology optimisation. From (Galjaard et al. 2015)

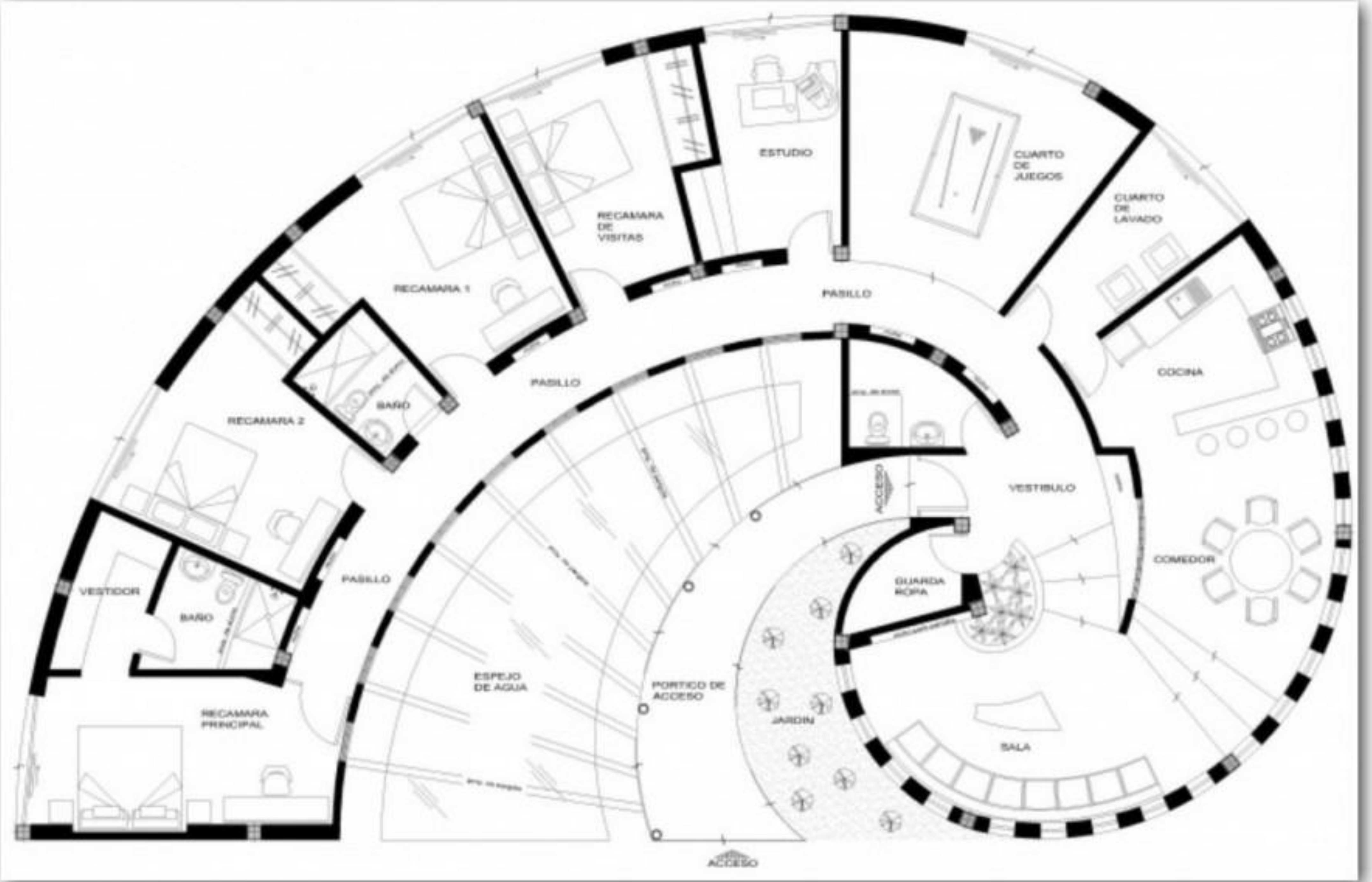
Optimizasyon Hiyerarşisi

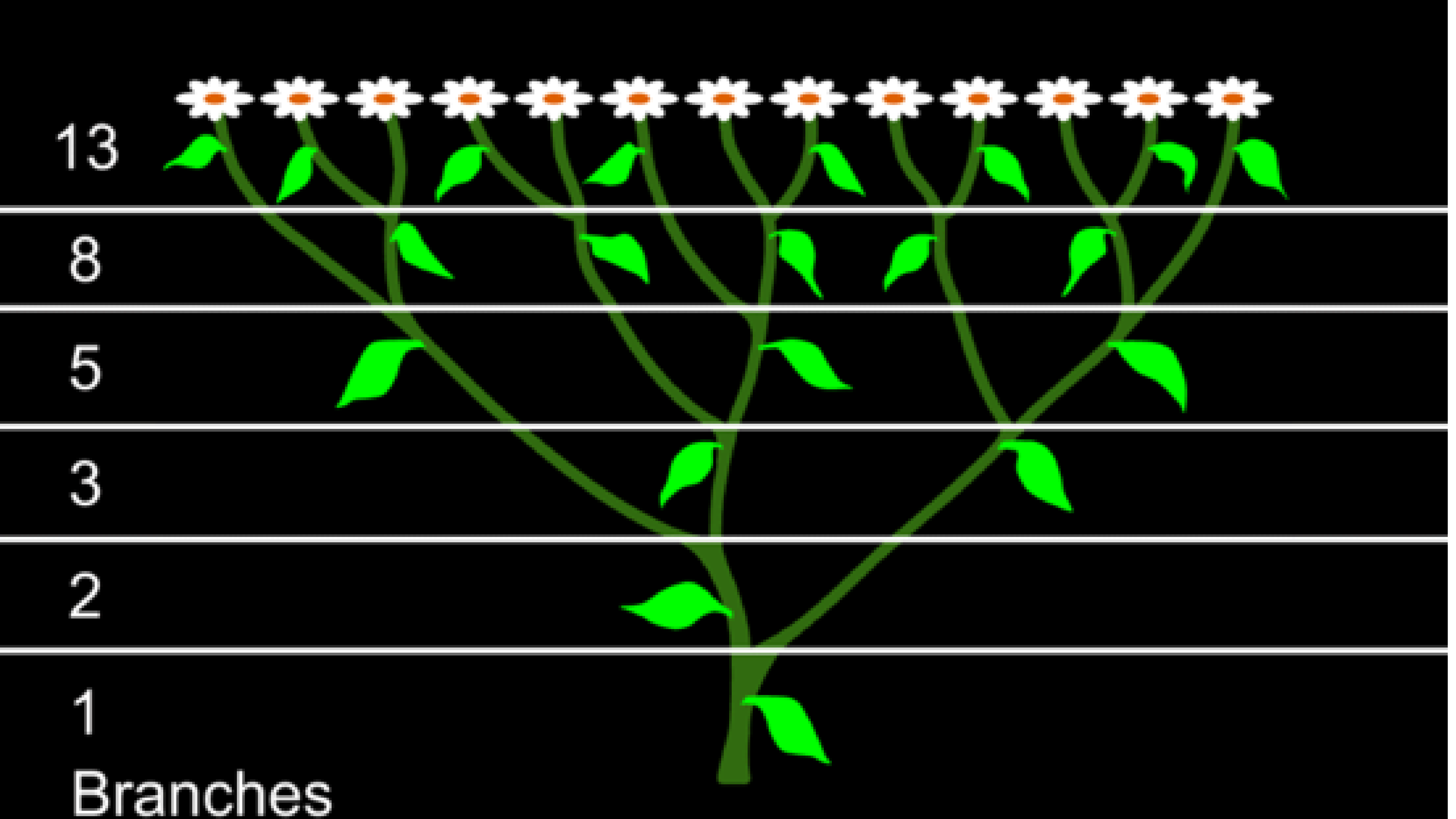
Initial design domain	Solution parameter
 Sizing optimization: Known structural connectivity and known cross-section shape, but unknown shape geometry	 Optimal cross-section radius
 Shape optimization: Known structural connectivity but unknown cross-section shape	 Optimal cross-section shape
 Topology optimization: Unknown structural connectivity, shape and size	 Optimal topology


*Stuttgart Havaalanı

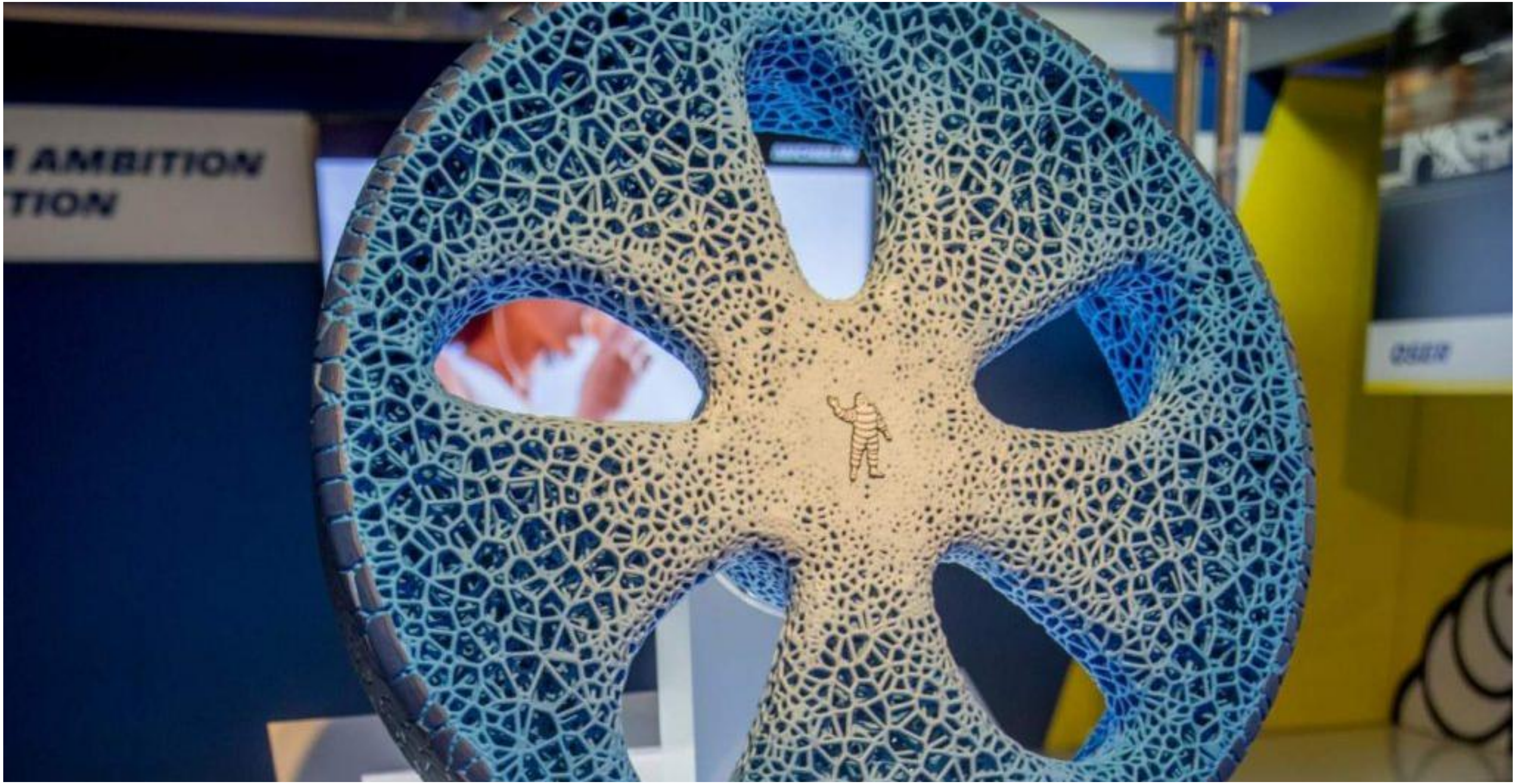
En iyi Optimizasyon, ilhamın doğadan alınması ile gerçekleştirilir.


ESTUDIO
CUARTO DE JUEGOS
CUARTO DE LAVADO
RECAMARA DE VISITAS
RECAMARA 1
PASILLO
COCINA
PASILLO
BAÑO
RECAMARA 2
VESTIBULO
ACCESO
COMEDOR
PASILLO
VESTIDOR
BAÑO
GUARDA ROPA
ESPEJO DE AGUA
PORTICO DE ACCESO
RECAMARA PRINCIPAL
JARDIN
SALA
ACCESO



13
8
5
3
2
1
Branches


AMBITION

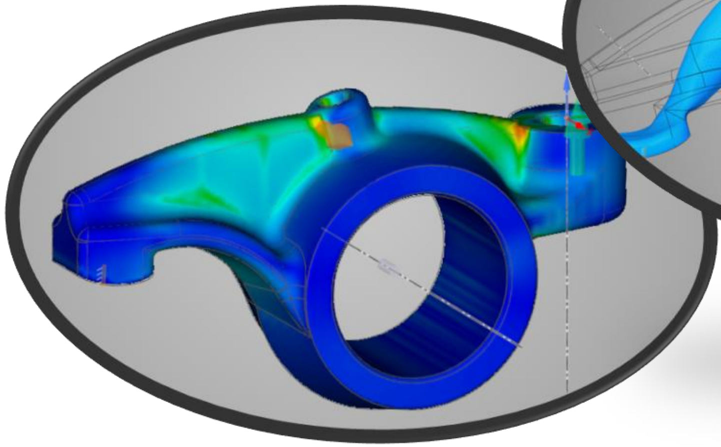
ANSYS®

DISCOVERY

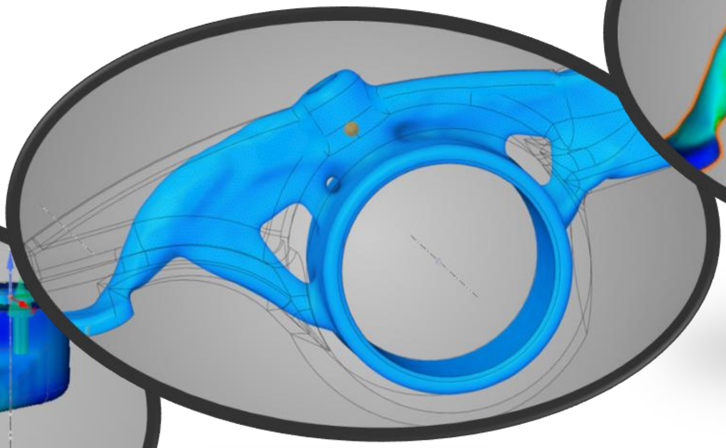
Topoloji Optimizasyonu İş Akışı

Ansys

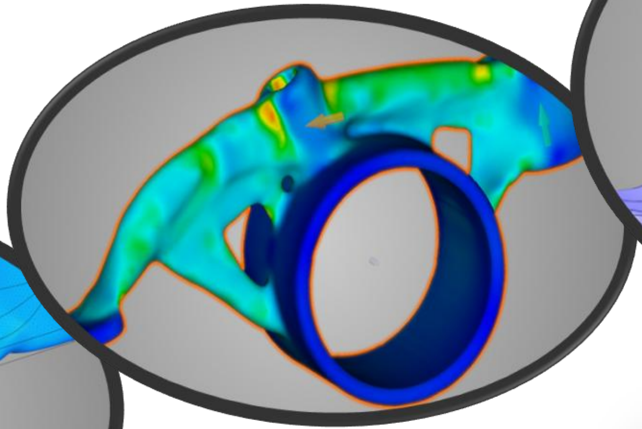
Sonlu Elemanlar Analizi



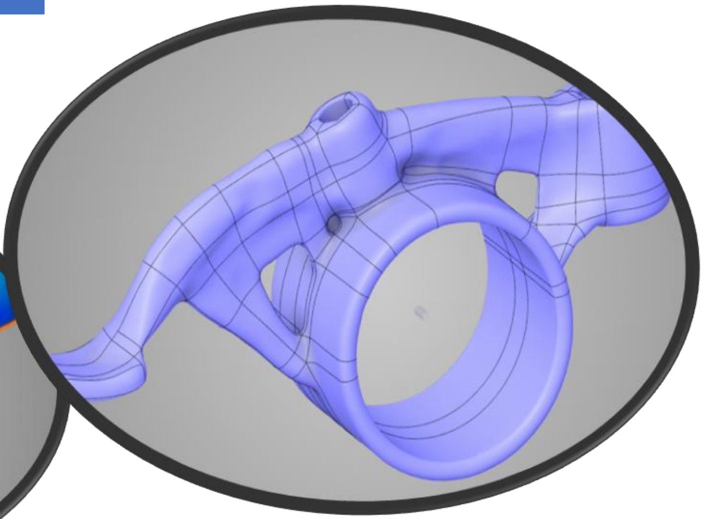
Yerleşim Eniyileme



Validasyon Doğrulama



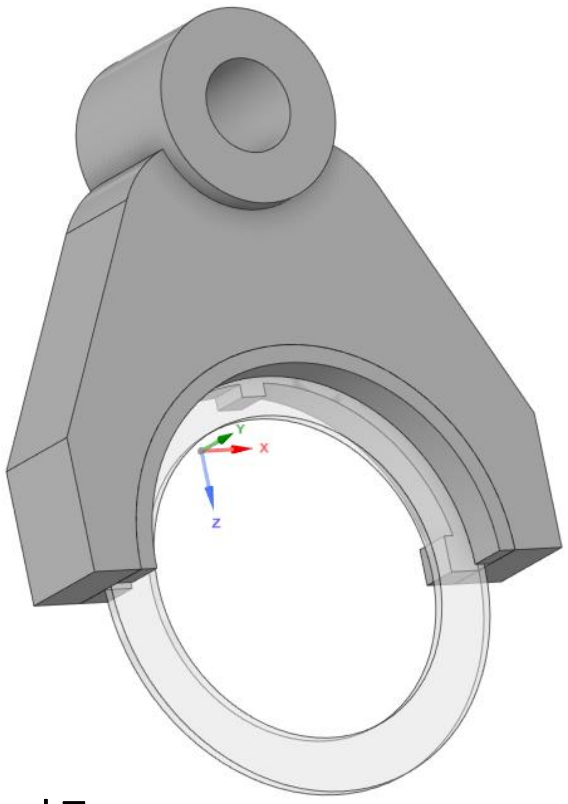
Geometri Oluşumu



Vaka Analizi – Vites Çatalı Yerleşim Eniyileme Çalışması

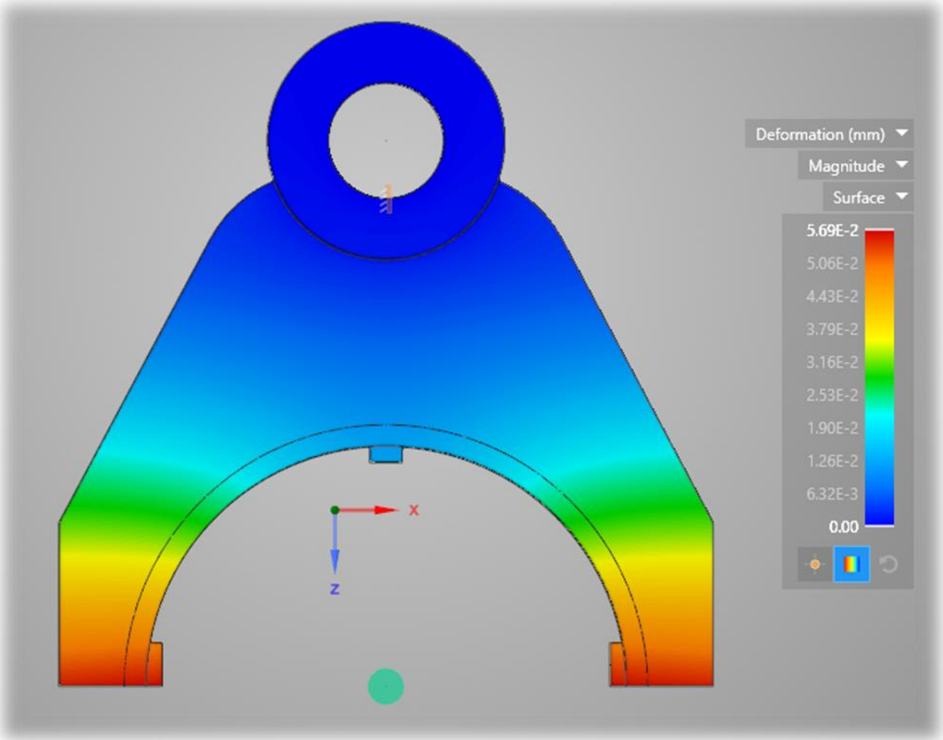
- Malzeme – Döküm A380 Alüminyum Alaşım
- Orijinal parçanın güvenlik katsayısı çok yüksek
- Dökümle üretilmiş
- Yerleşim eniyileme işe yarayacak mı?
  - Sonuçlar rijitlik ve sağlamlık açısından değerlendirilebilir mi?
  - Üretilebilirlik?
    - Sonuç geometri katmanlı üretim yerine döküme uygun olabilir mi?

Özellik	Original
Mass [g]	491

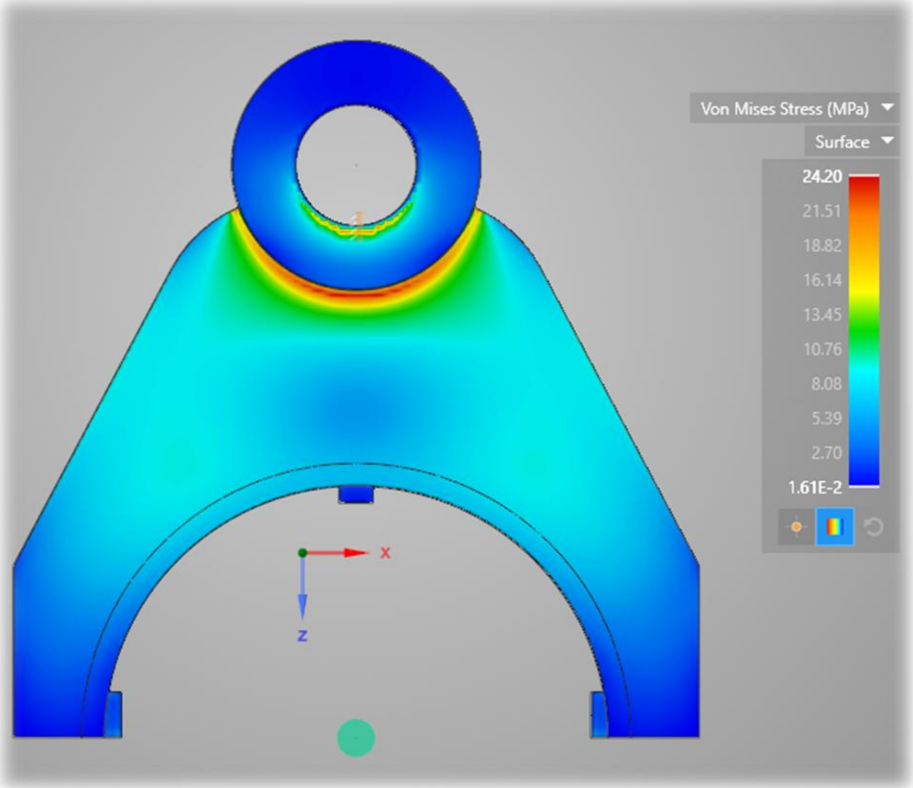


Orijinal Tasarım

- Orijinal modelin, Sonlu elemanlar analizi ile gerilme ve sehiminin tespiti

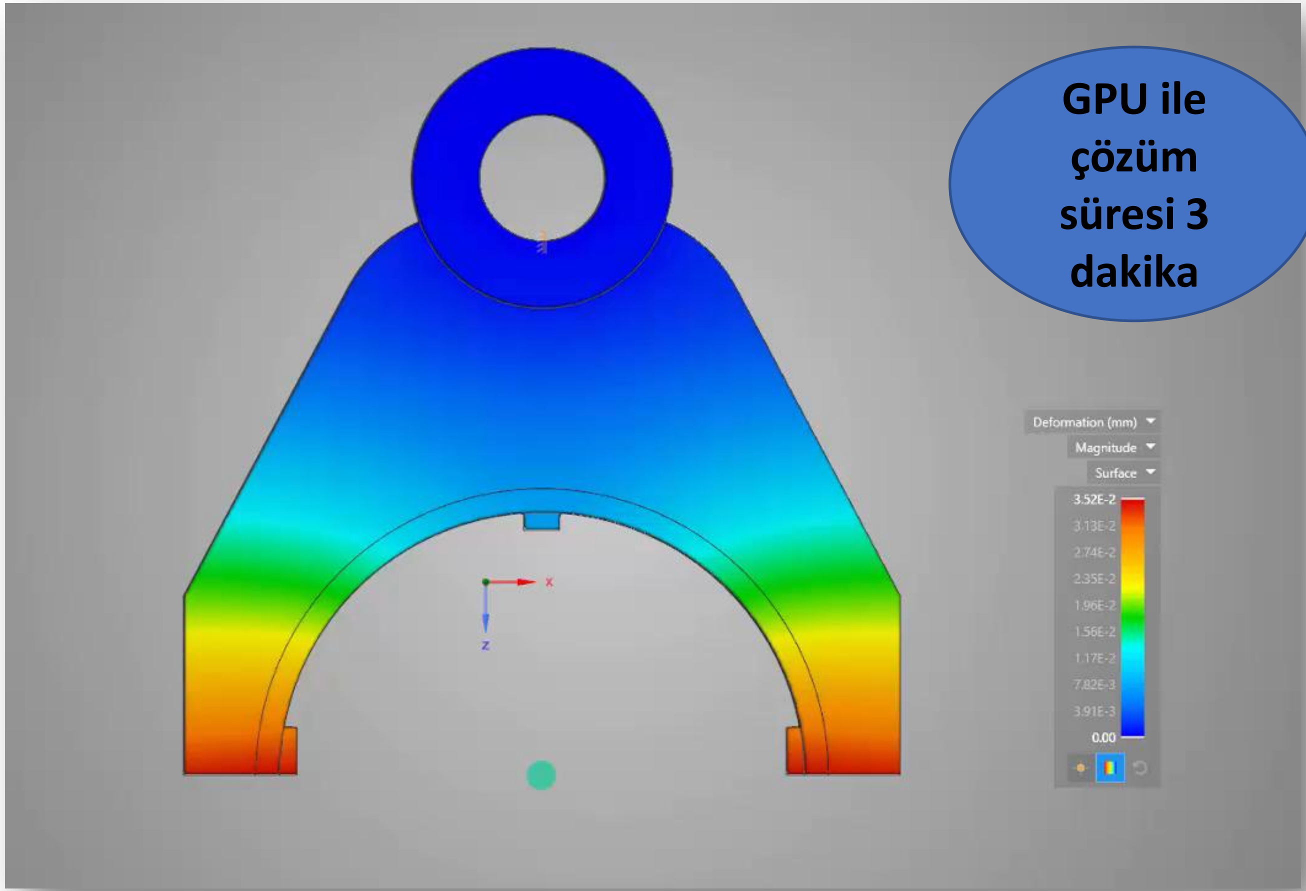


Total deformation: 0.059mm

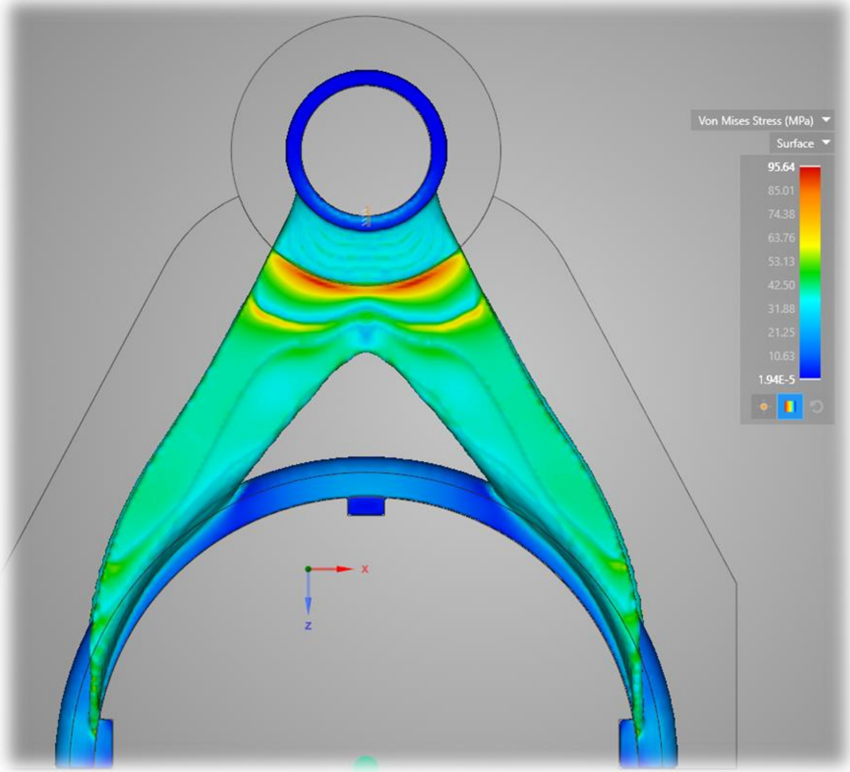


Equivalent Von Mises Stress: 24.2MPa

- Ansys Discovery Live – level set topology optimization
- %85 Hacim azaltma kriterine göre

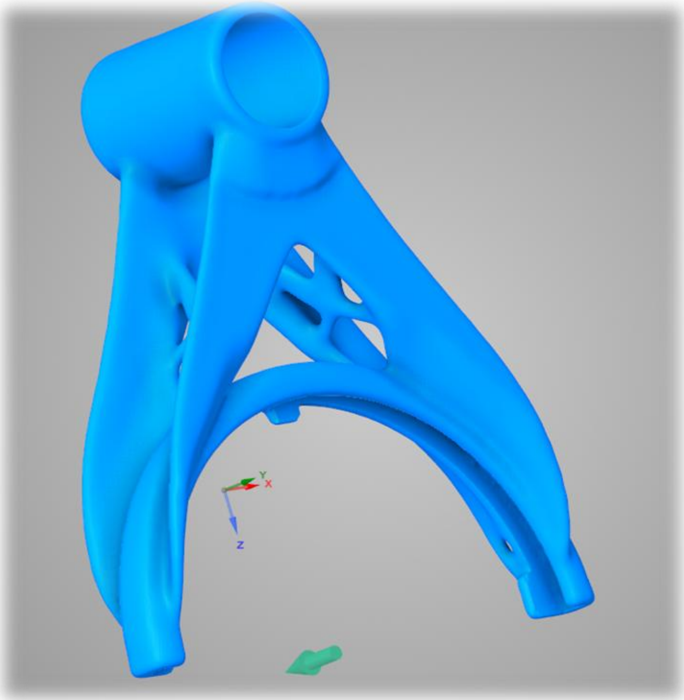


GPU ile çözüm süresi 3 dakika

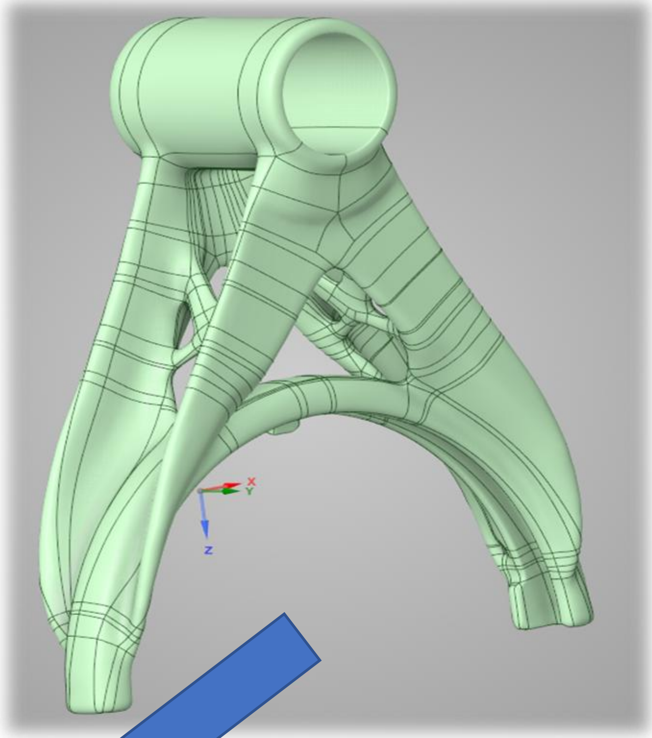


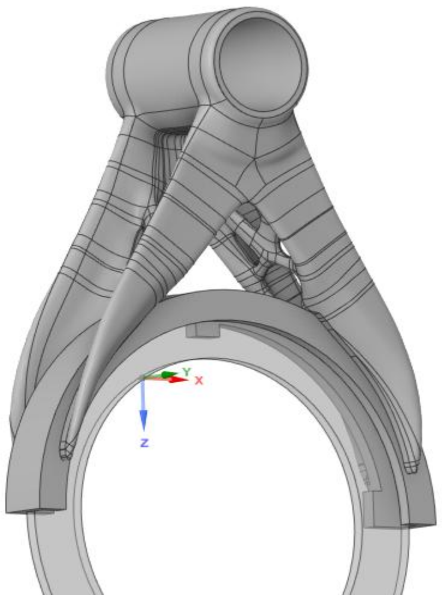
Equivalent Von Mises Stress: 95.64MPa

SpaceClaim AutoSkin komutu ile STL veriden CAD geometriye geçiş



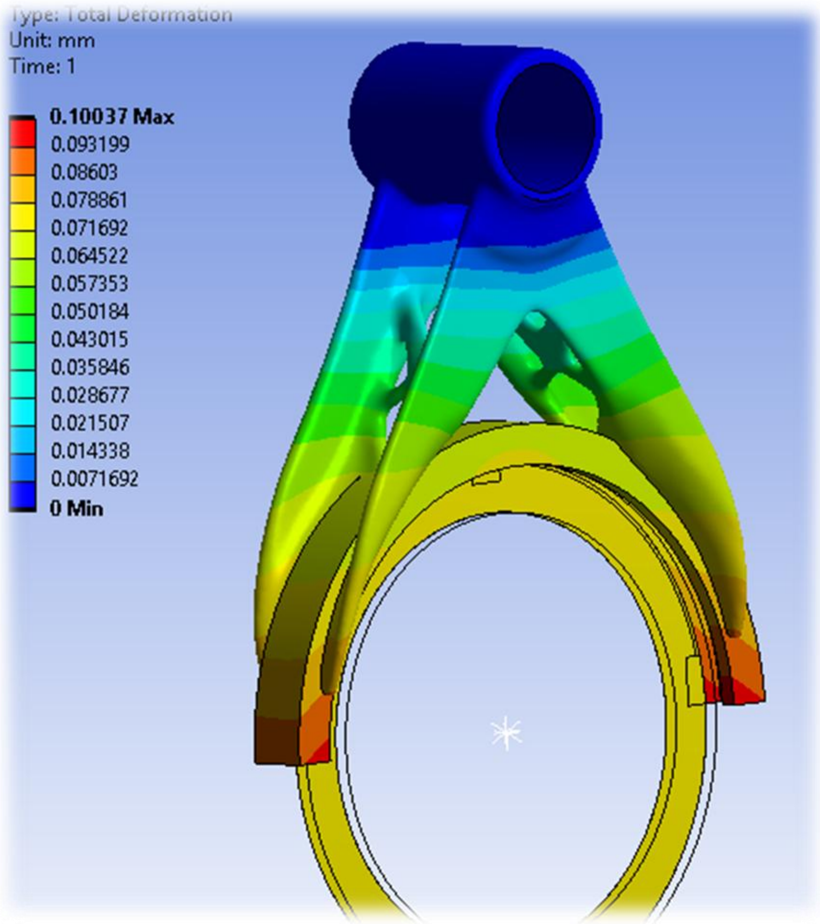
SpaceClaim
Direct Modeller
- AutoSkin



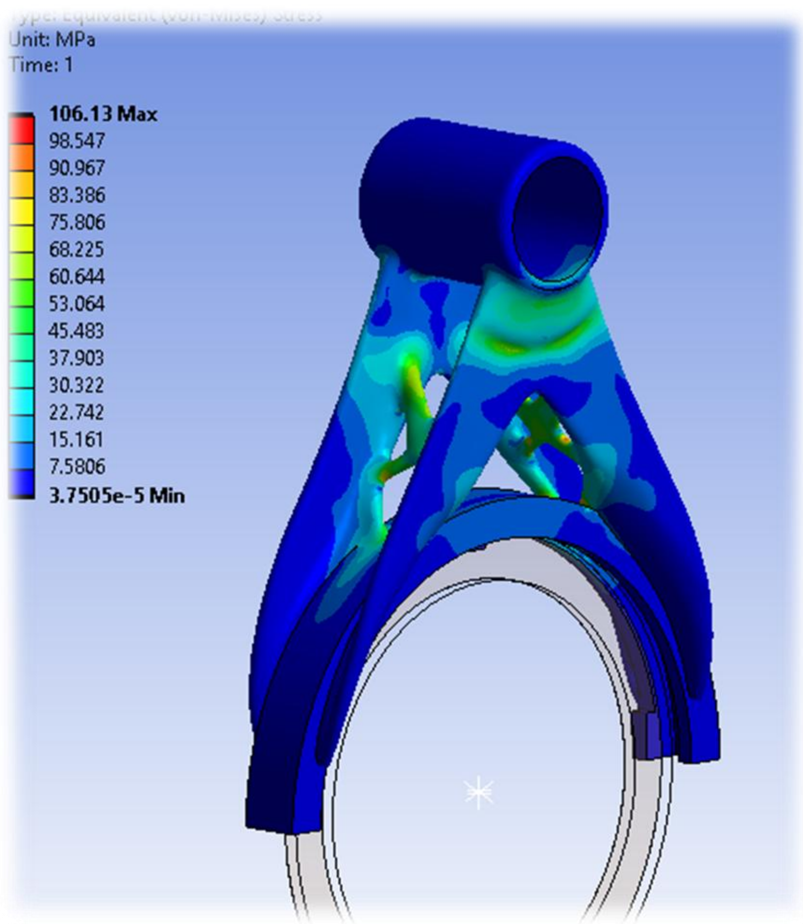


İşleme bölgelerinin düzenlenmesi

• Doğrulama: Ansys Workbench ile Doğrusal Olmayan Yapısal Analiz



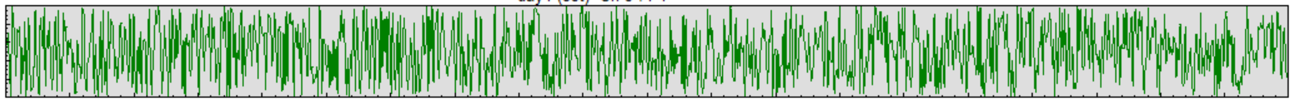
Total deformation: 0.1mm

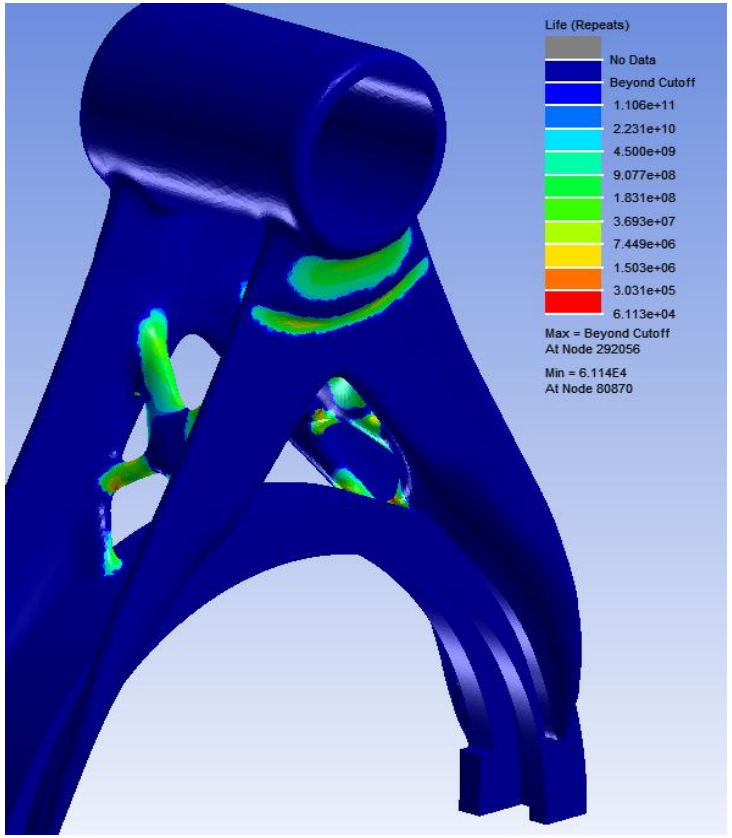


Equivalent Von Mises Stress: 106.13 MPa

- Doğrulama: Dayanlılık Analizi
  - Tipik çalışma şartları altında:
    - 5 senelik çalışma ömrü
  - Maksimum gerilme bölgesinde 6.114E+4 çevrim ömrü
  - Hasar başlangıcı, ince federlerde görülecektir. Bu durum çatlak ilerlemesinin bütün yapıyı etkilemesinde önemli bir unsurdur.

1 günlük saha verisi





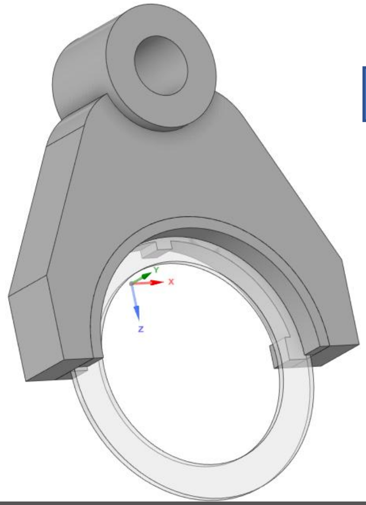
Minimum Ömür: 6.114E+4 cycles

(Calculated using Ansys nCode)

Özet

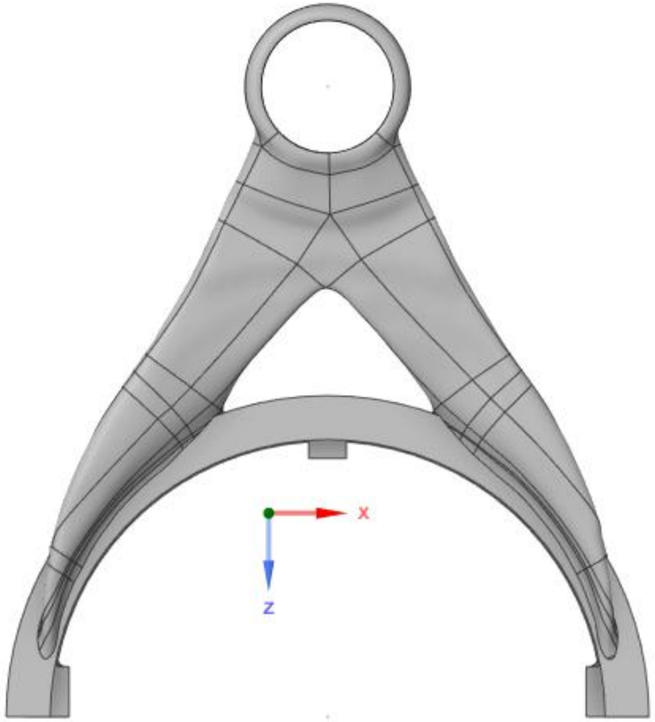
- Vites çatalı
  - Malzeme: A380 Al Döküm
  - Doğrulama ile orijinal geometriye çok yakın rijitlik ve sehim bulunmuştur.
  - 6.114E+4 minimum ömür tespit edilmiştir.
  - Parça döküm yöntemi ile imalata uygundur.

Özellik	Orjinal	Yeni
Mass [g]	491	78.6

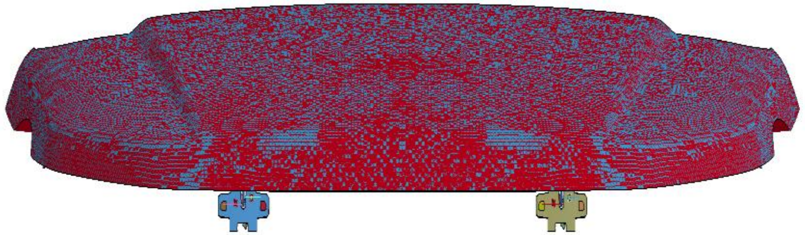


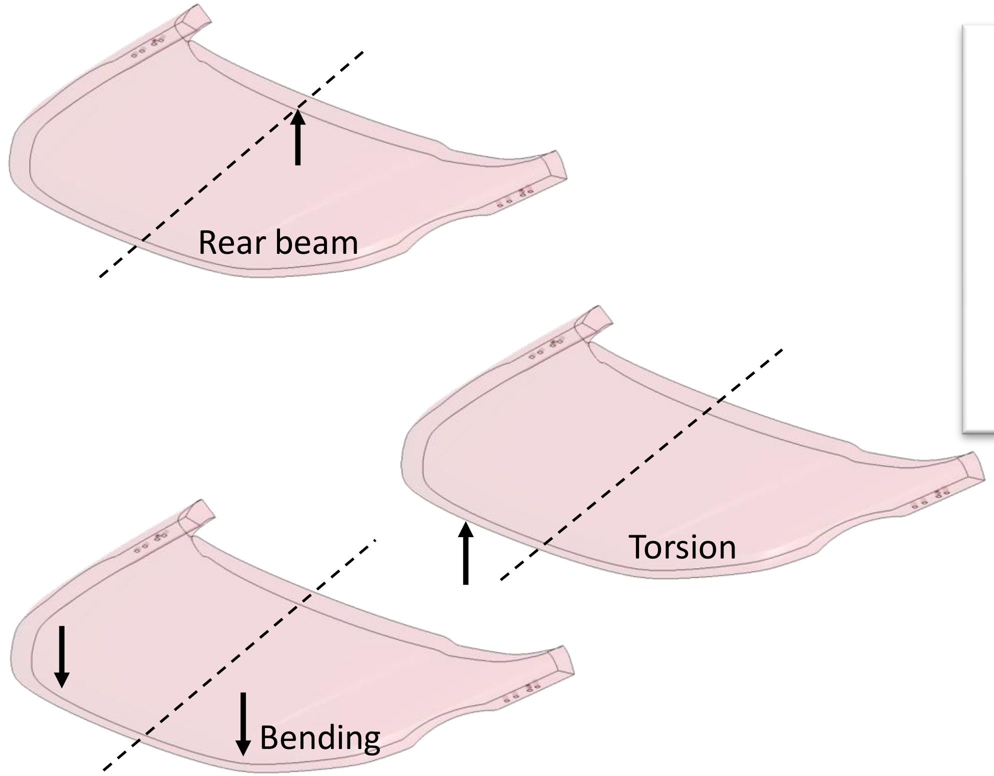
Orjinal

84% Kütle azaltımı

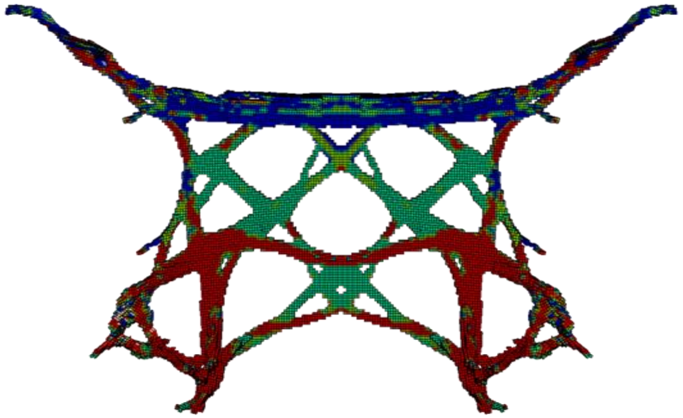


Eniyilenmiş Tasarım





Optimum

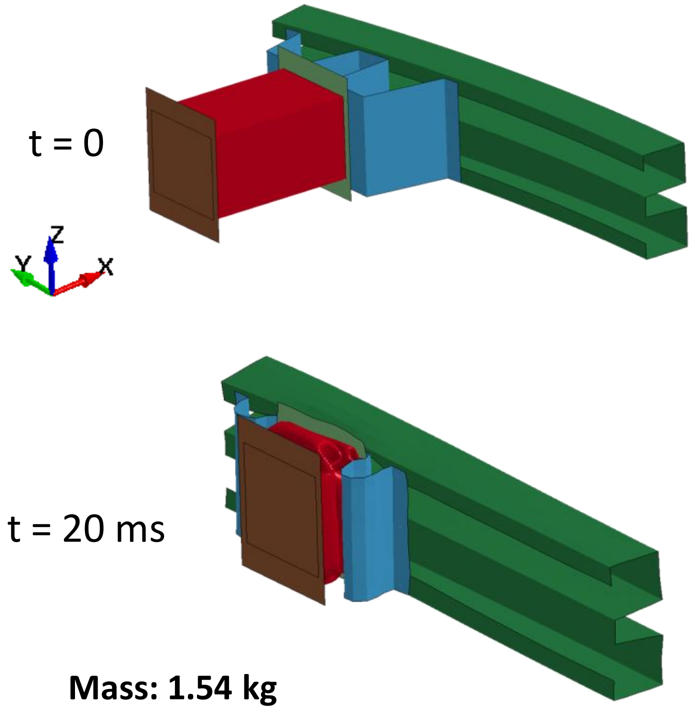


Design Contribution Plot
(Rear beam, torsion, bending)

Model by courtesy of Jaguar Land Rover

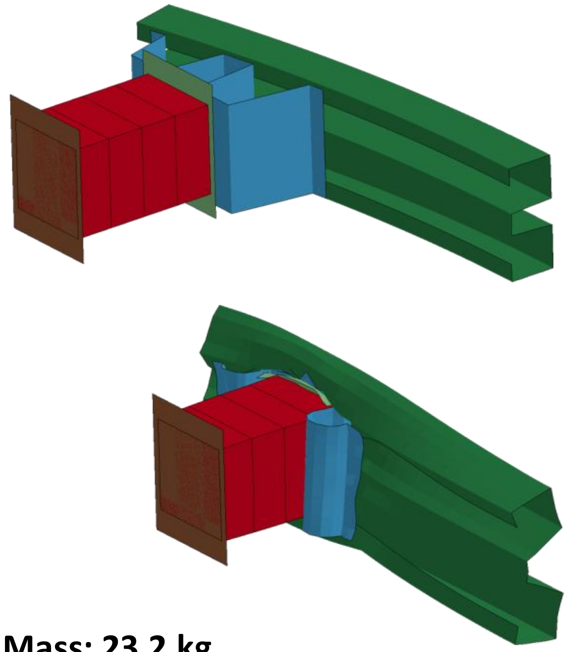
Uygulama: Çarpışma Dayanıklılığı

Reference: Shell structure



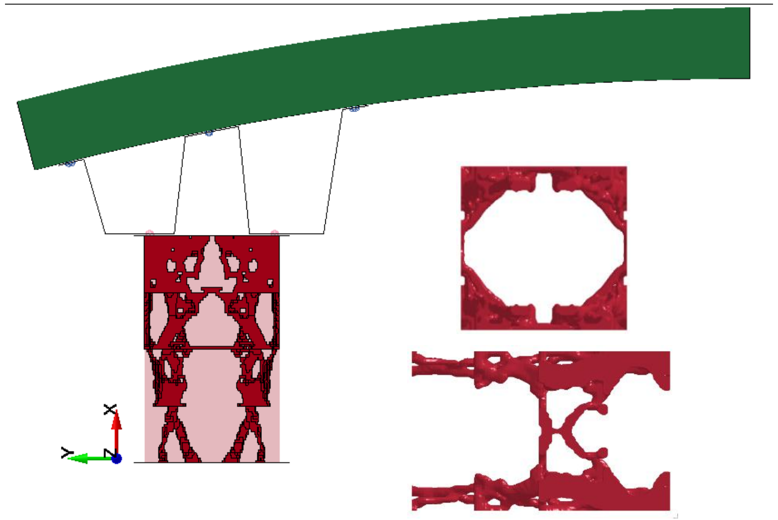
Mass: 1.54 kg
Scaled IE: 1
Scaled Peak Accel: 1

Baseline: Solid block



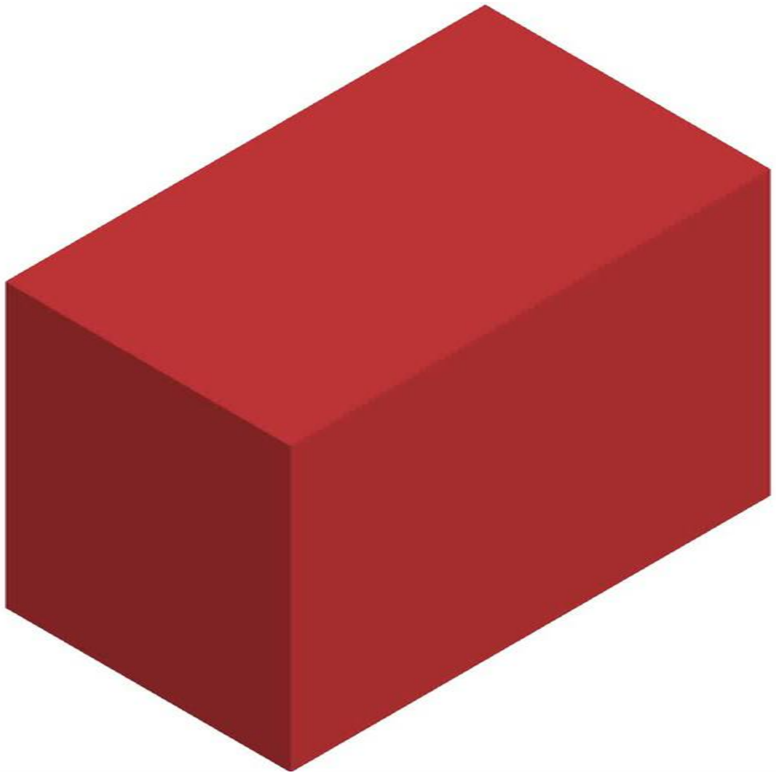
Mass: 23.2 kg
Scaled IE: 1.56
Scaled Peak Accel: 0.51

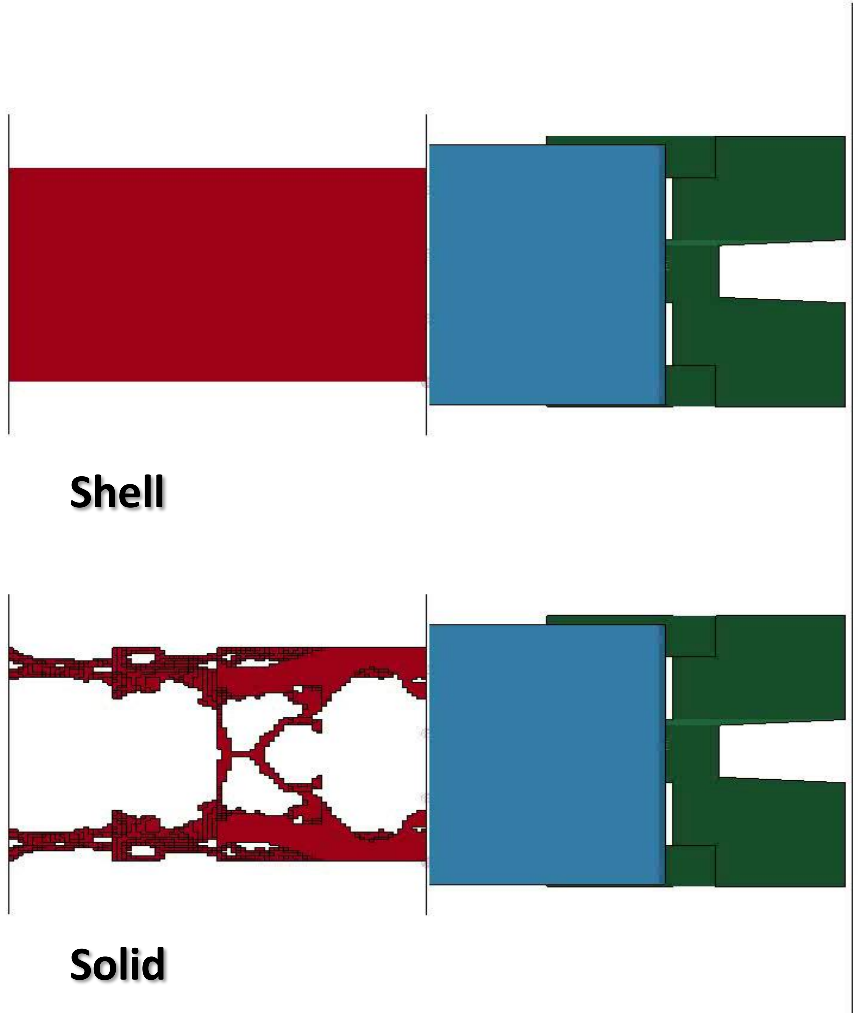
Optimal Solid structure



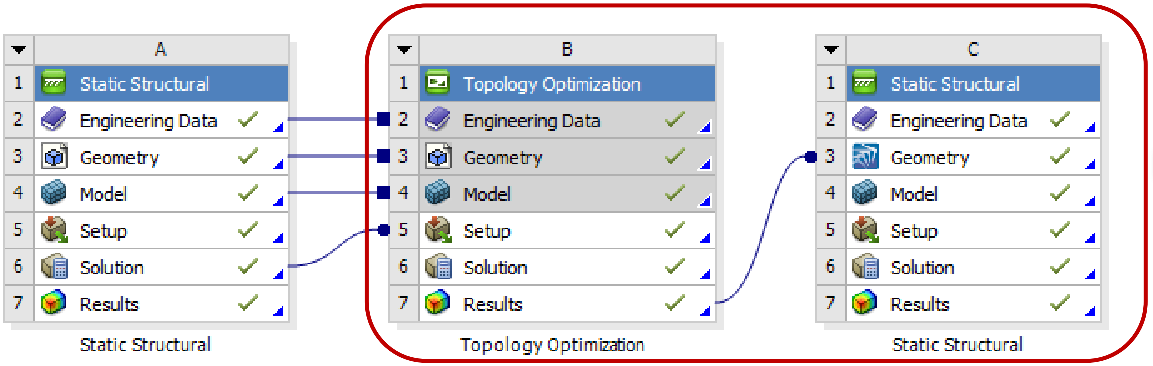
Mass: 1.31 kg (↓15%)
Scaled IE: 1
Scaled Peak Accel: 0.62 (↓38%)

Applications: Crash





Otomatik Validasyon – Ansys Workbench



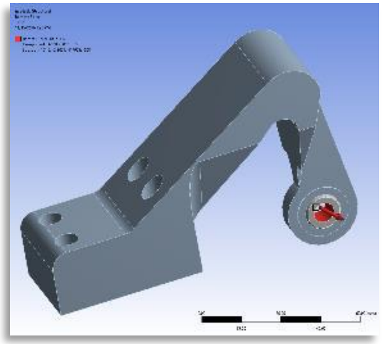
Export Optimized Geometry

Print

Static Structural (or Modal) Problem Set up

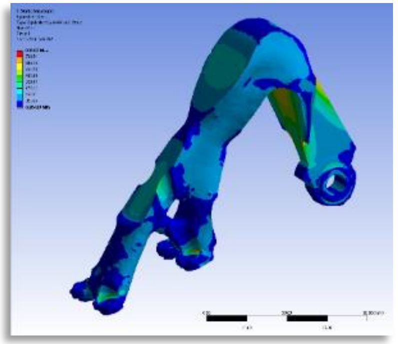
Design Optimization

Design Validation



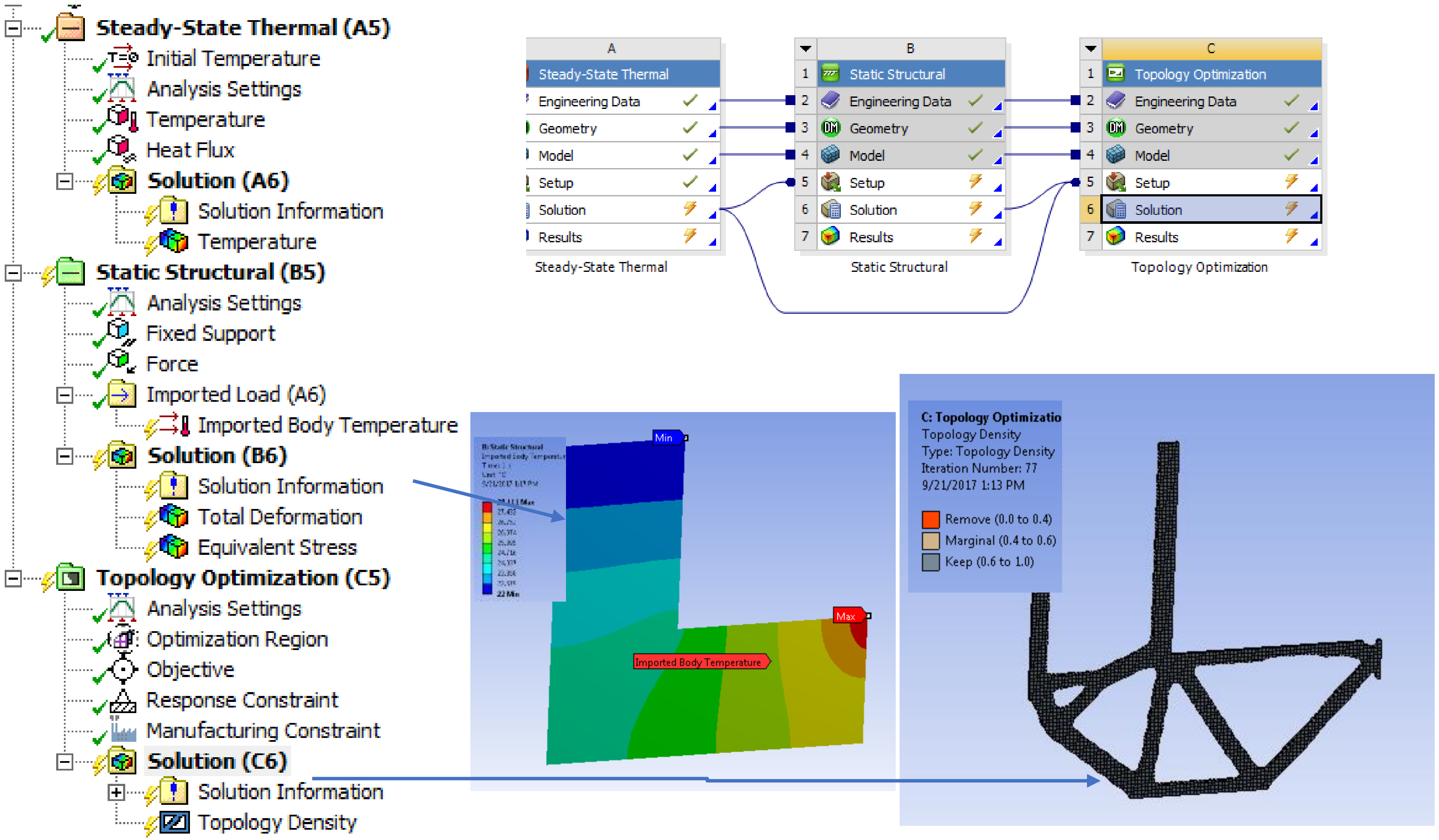
Original Assembly

Optimized Part

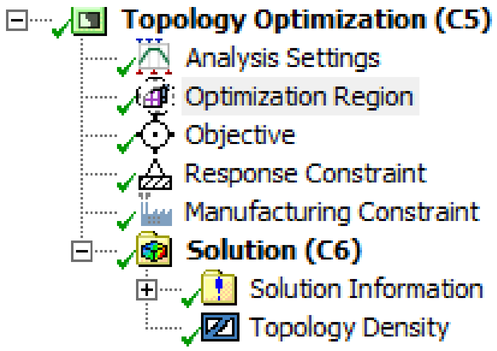


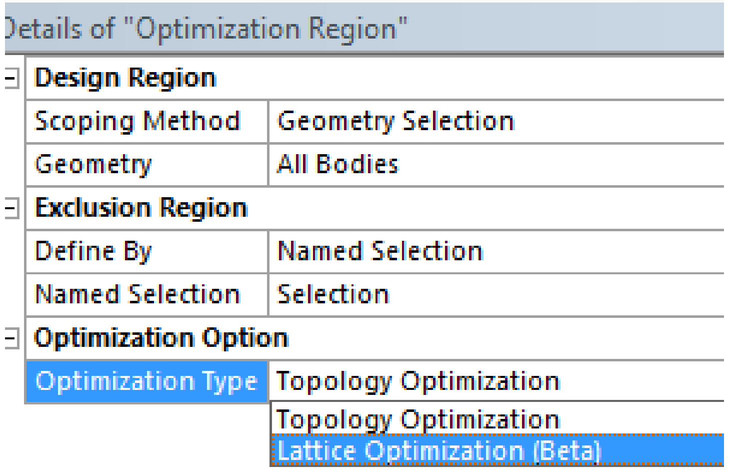
Validate Design

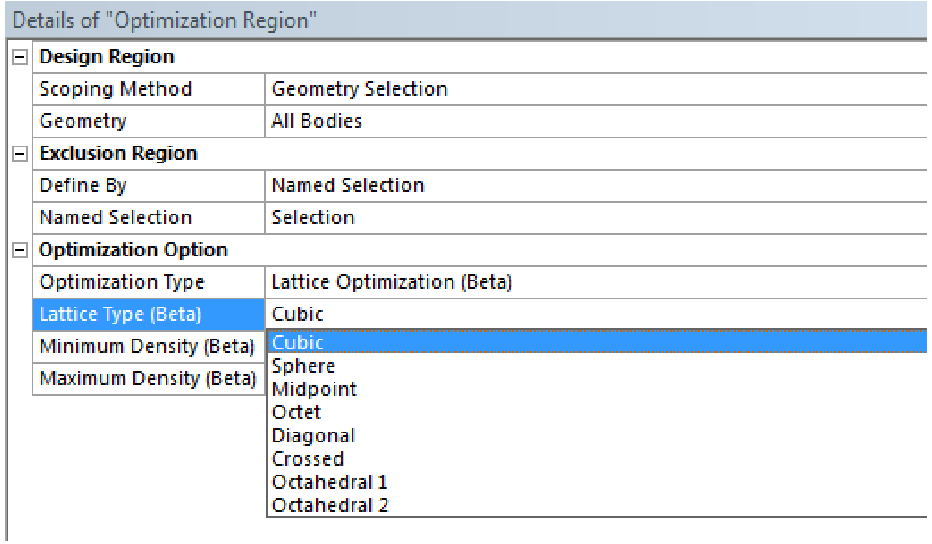
Isıl ve yapısal yüklemeler ile birlikte yerleşim eniyileme

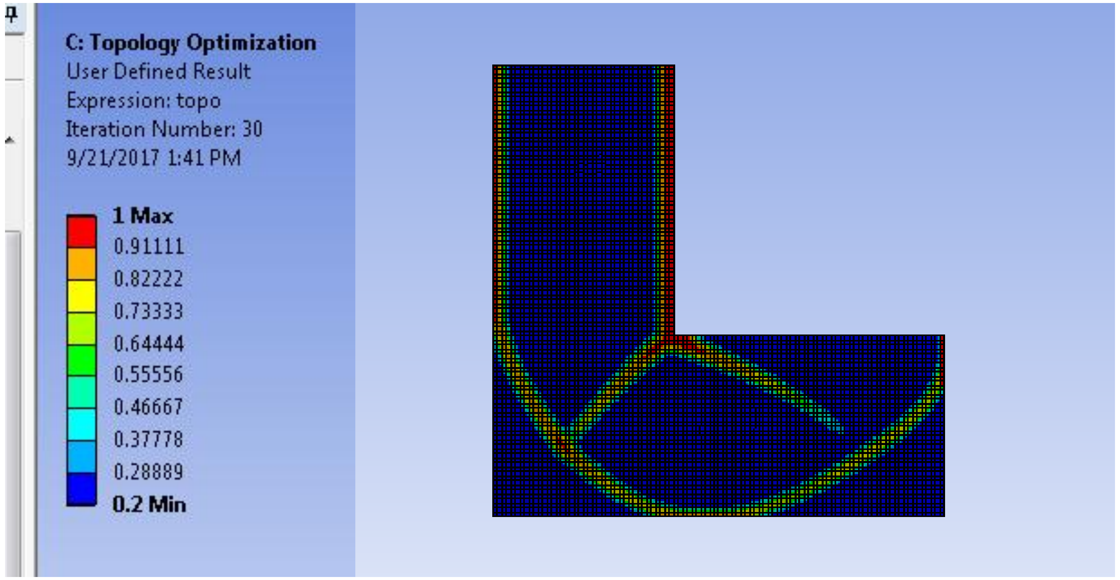


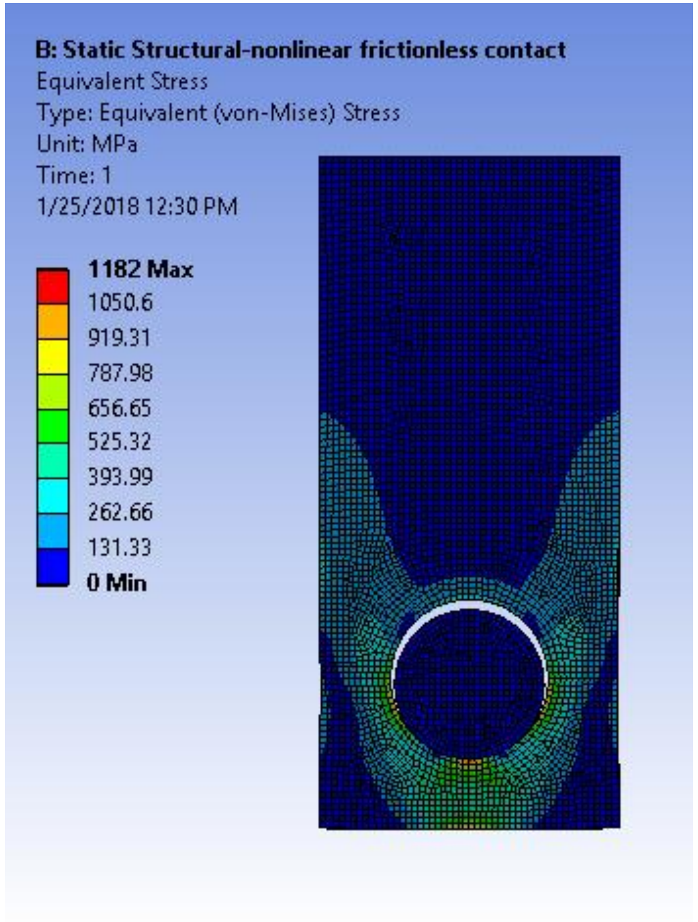
Beta support of Lattice optimization for eight lattice structures

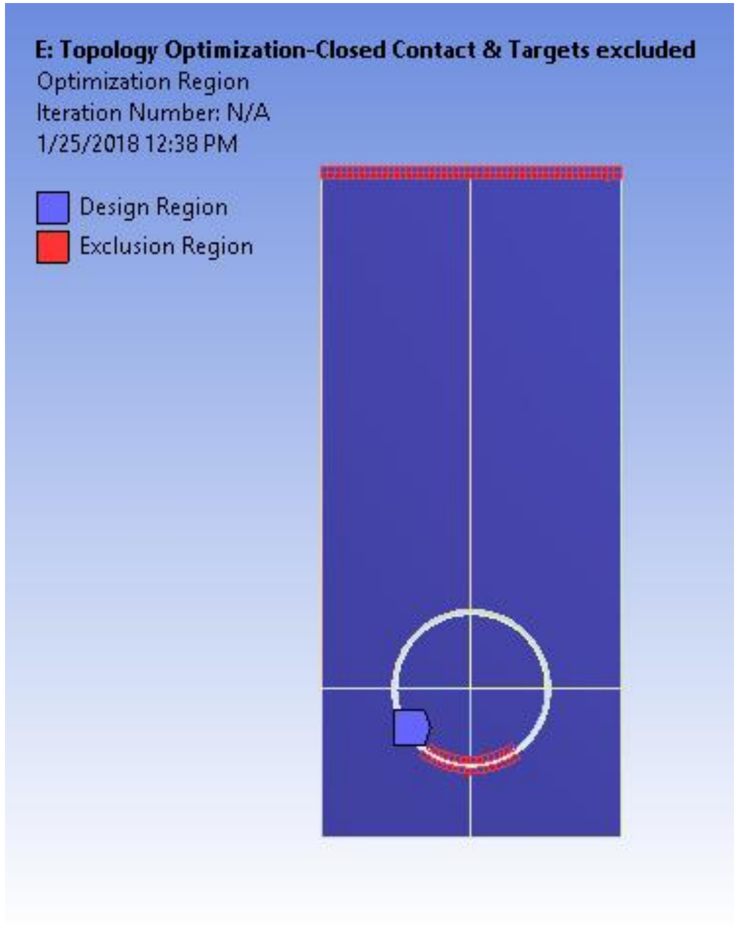


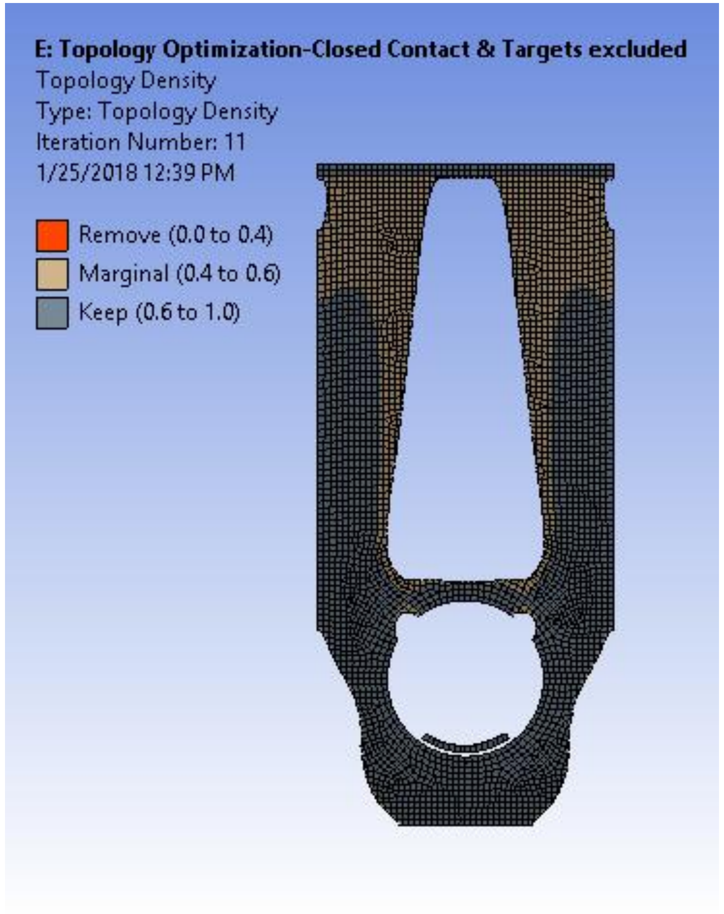







B: Static Structural-nonlinear frictionless contact
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
1/25/2018 12:30 PM
1182 Max
1050.6
919.31
787.98
656.65
525.32
393.99
262.66
131.33
0 Min


E: Topology Optimization-Closed Contact & Targets excluded
Optimization Region
Iteration Number: N/A
1/25/2018 12:38 PM
Design Region
Exclusion Region


E: Topology Optimization-Closed Contact & Targets excluded
Topology Density
Type: Topology Density
Iteration Number: 11
1/25/2018 12:39 PM
Remove (0.0 to 0.4)
Marginal (0.4 to 0.6)
Keep (0.6 to 1.0)

Topology Optimization demonstration on Cantilever beam using Extrusion Manufacturing constraint:

(1)

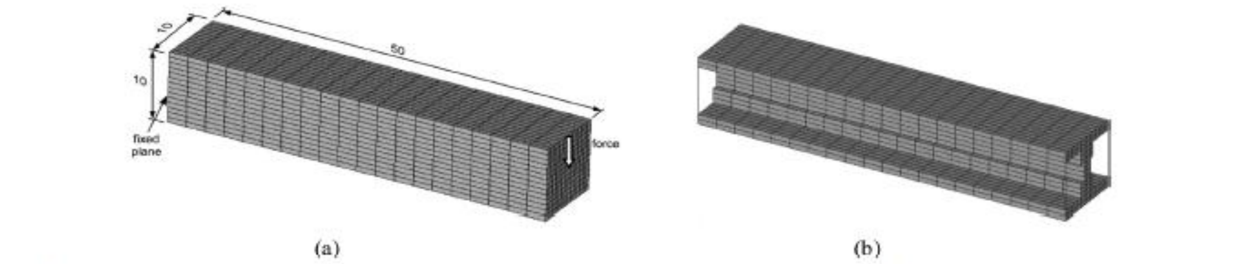
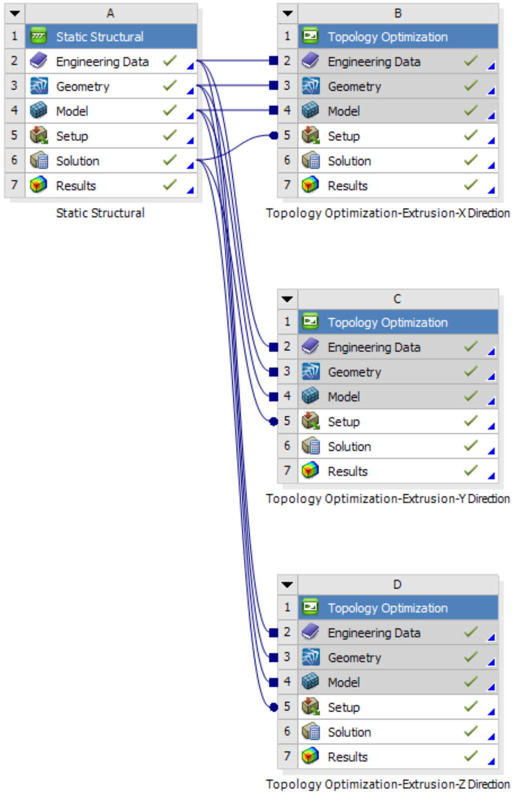
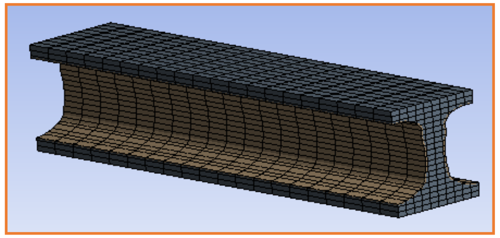
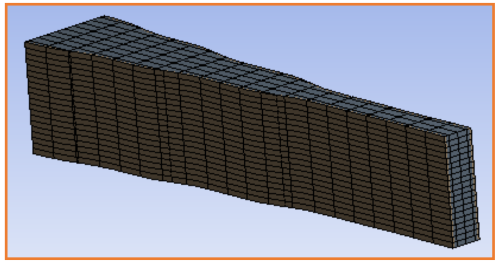


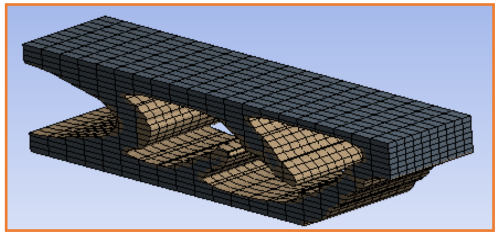
Fig. 31. Result obtained by using the extrusion constraint: (a) design domain discretized into 3920 elements; (b) beam profile "I" obtained by using a 30% volume constraint (C* = 74.3).

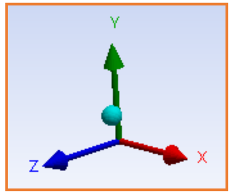
(2)



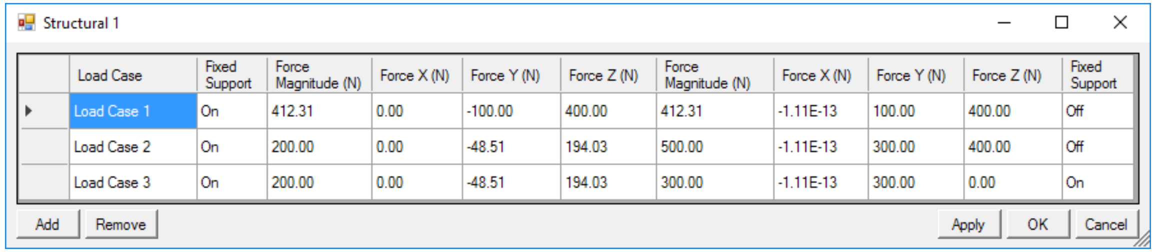








Çoklu Yükleme Senaryosu

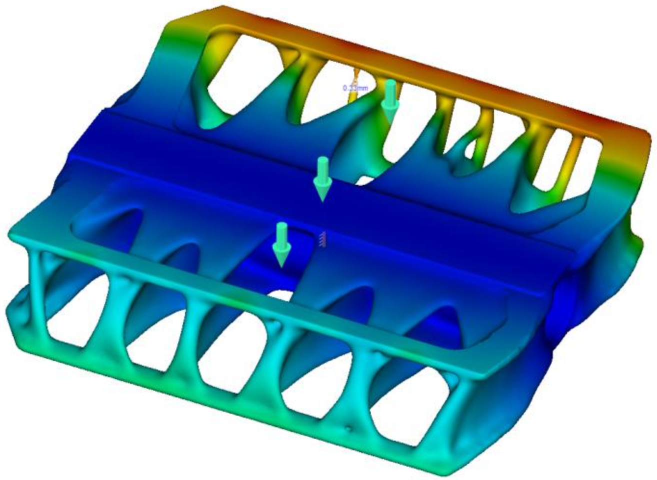


Structural 1

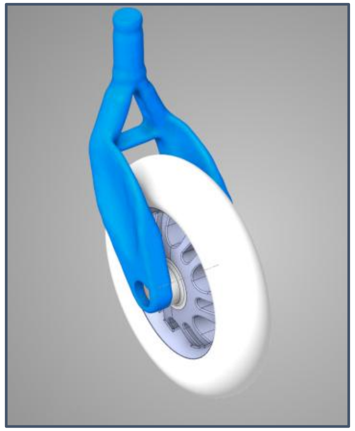
	Load Case	Fixed Support	Force Magnitude (N)	Force X (N)	Force Y (N)	Force Z (N)	Force Magnitude (N)	Force X (N)	Force Y (N)	Force Z (N)	Fixed Support
▸	Load Case 1	On	412.31	0.00	-100.00	400.00	412.31	-1.11E-13	100.00	400.00	Off
	Load Case 2	On	200.00	0.00	-48.51	194.03	500.00	-1.11E-13	300.00	400.00	Off
	Load Case 3	On	200.00	0.00	-48.51	194.03	300.00	-1.11E-13	300.00	0.00	On

Add Remove Apply OK Cancel

- Farklı yükleme senaryolarını farklı ağırlık çarpanları ile değerlendirebilirsiniz.
- Her bir farklı yükleme senaryosu farklı sınır koşulları ve farklı fiziksel girdiler ile tasarlanabilir.

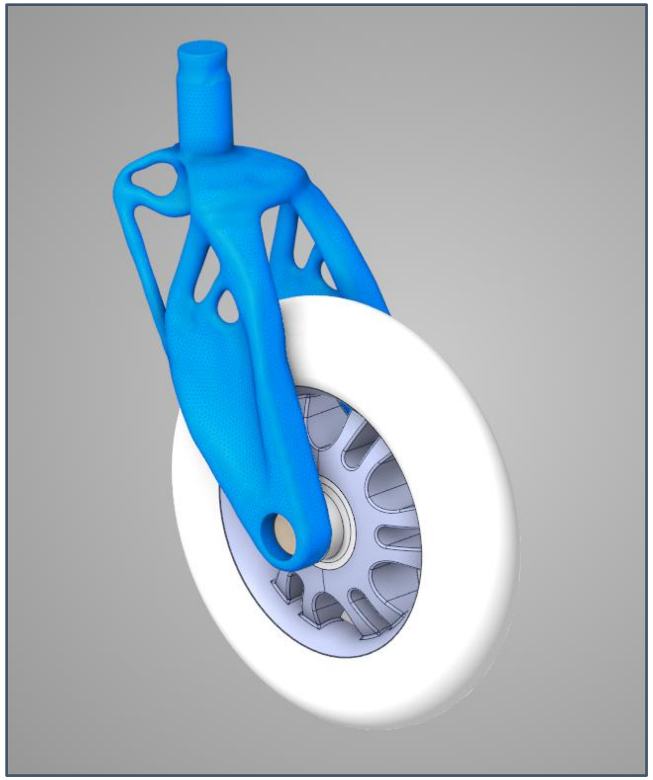


Bisiklet pedalının çoklu yükleme ile optimizasyonu



Load Case 1 (only)

Load Case 2 (only)



Both load cases (single combined result)

Çoklu Baskı Deneyimi

No more 5S

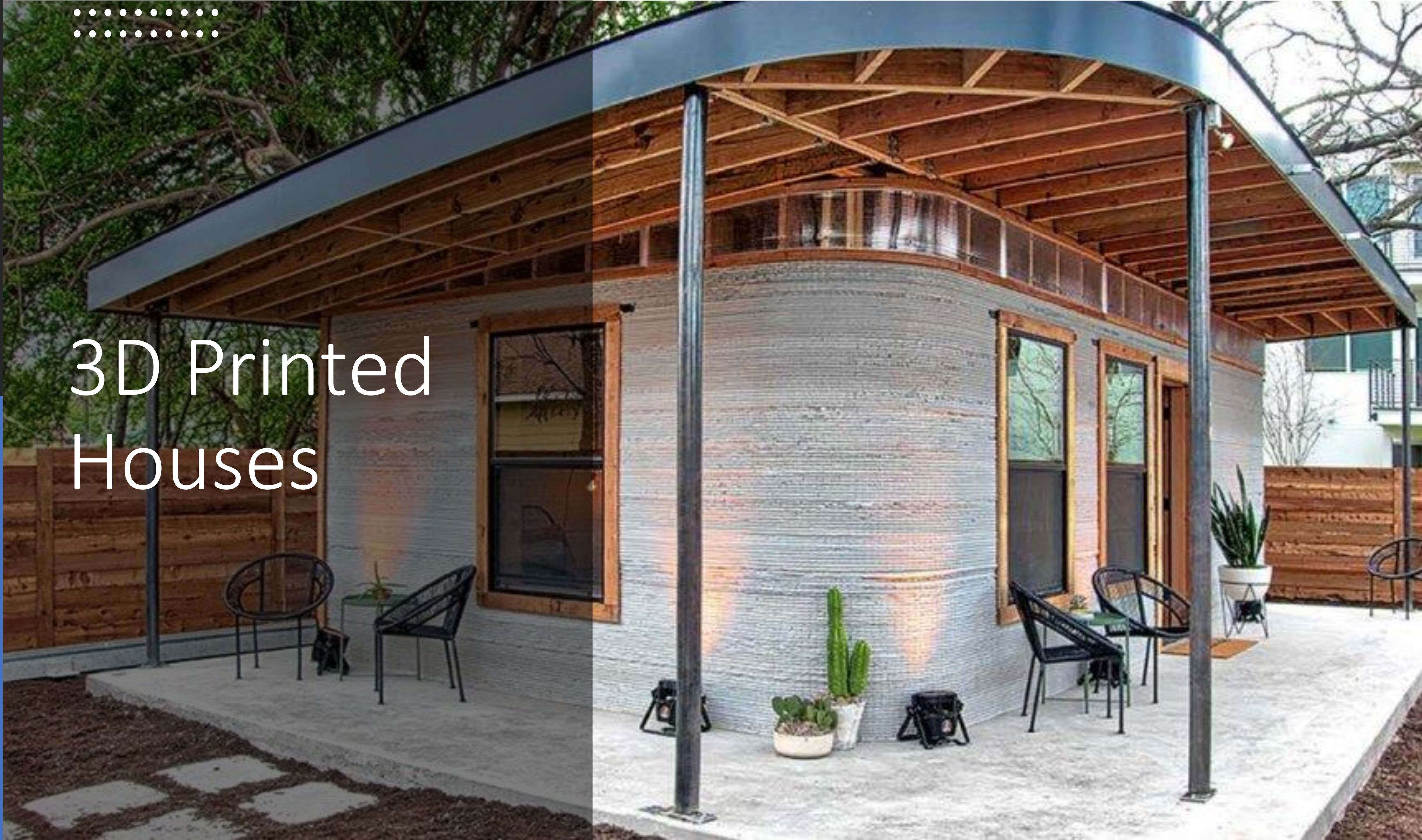
Generative Design Örnekleri

Optimizasyon Girdisi:
- Isı transferinin maksimize edilmesi
- Kütlenin minimize edilmesi

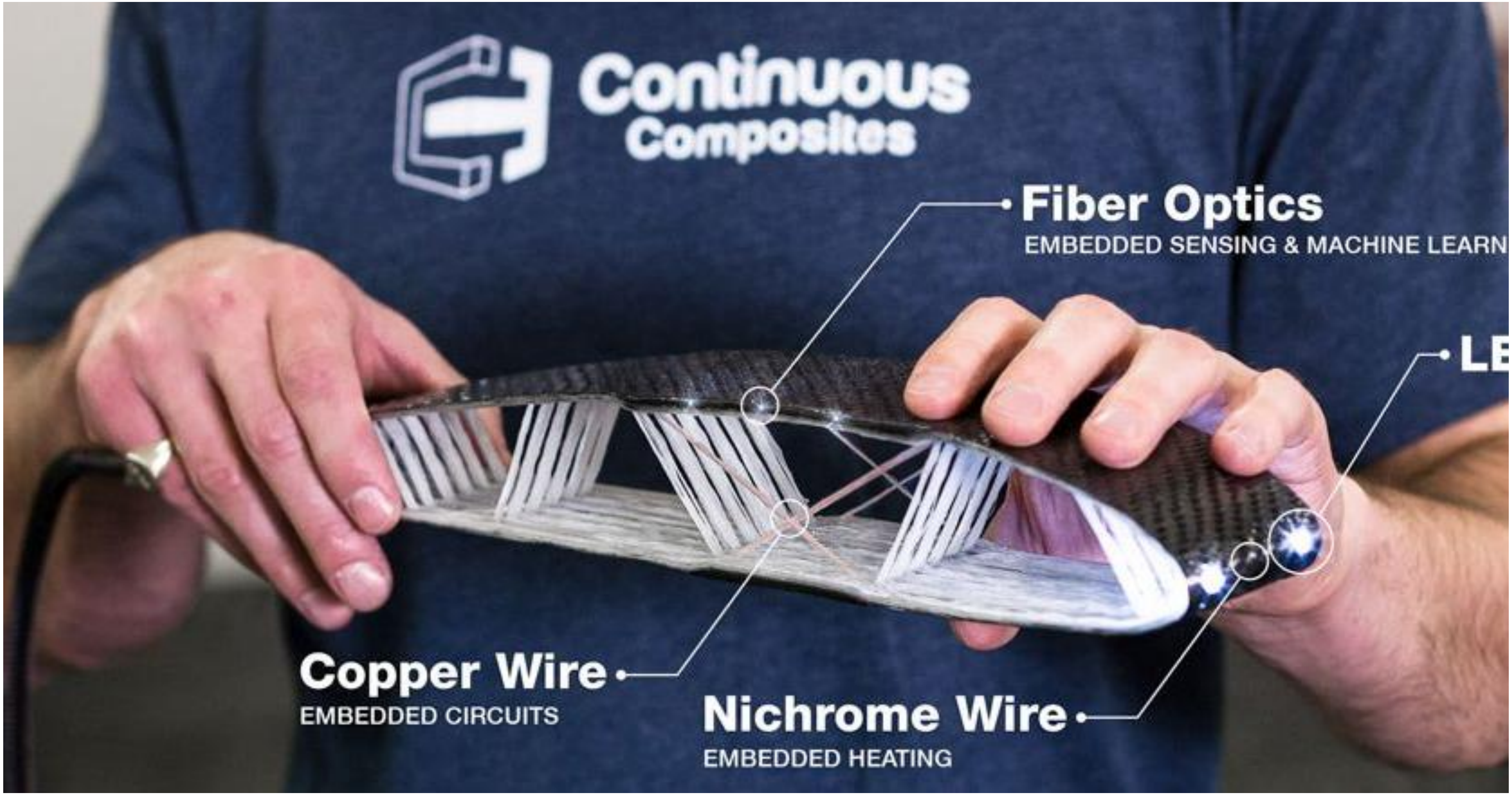
2030’da her evde bir yazıcı

- Ulaşılabilirlik
- Açık kaynak
- Malzeme temini
- Herkes tasarımcı olabilir
- Sipariş bekleme süresi bitecek

3D Printed Houses

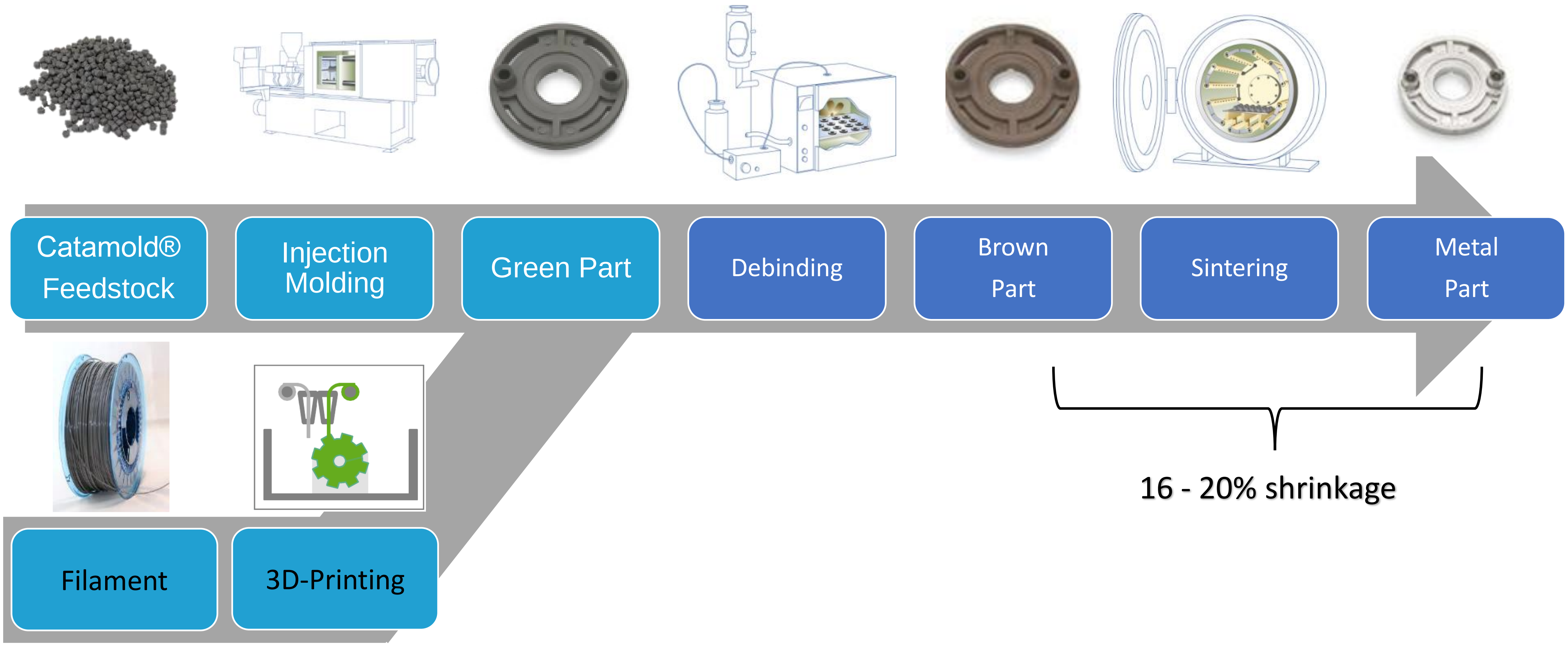


ICON
newstory
ICON
newstory


Continuous
Composites
Fiber Optics
EMBEDDED SENSING & MACHINE LEARN
Copper Wire
EMBEDDED CIRCUITS
Nichrome Wire
EMBEDDED HEATING


Orijinal Part: 2.300 €
Printed Cost: 50€
Epoxy Shrink: 5 €
Working for three years
[redacted]

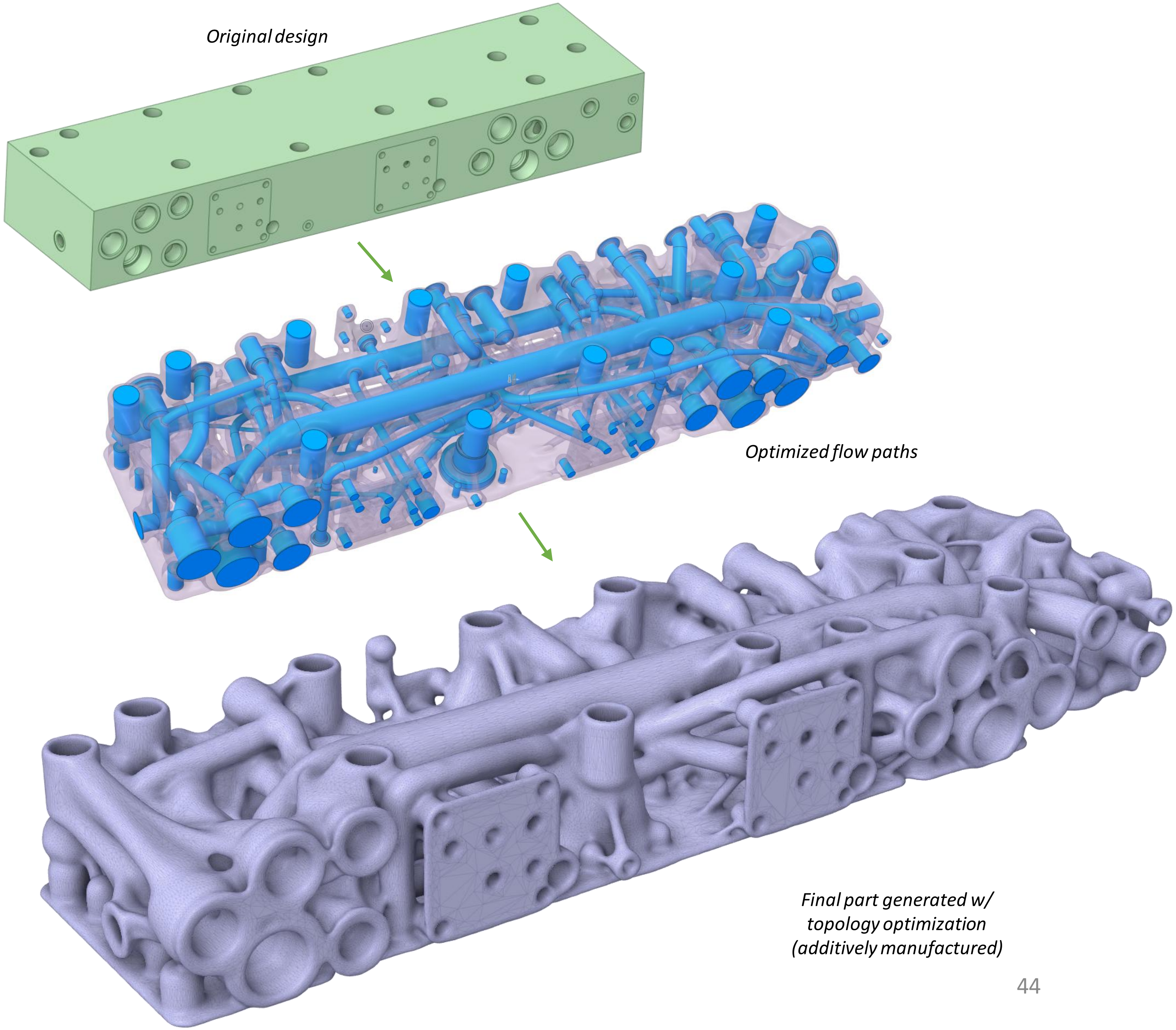
MIM & 3D Yazıcı: Hammaddeden Parçaya

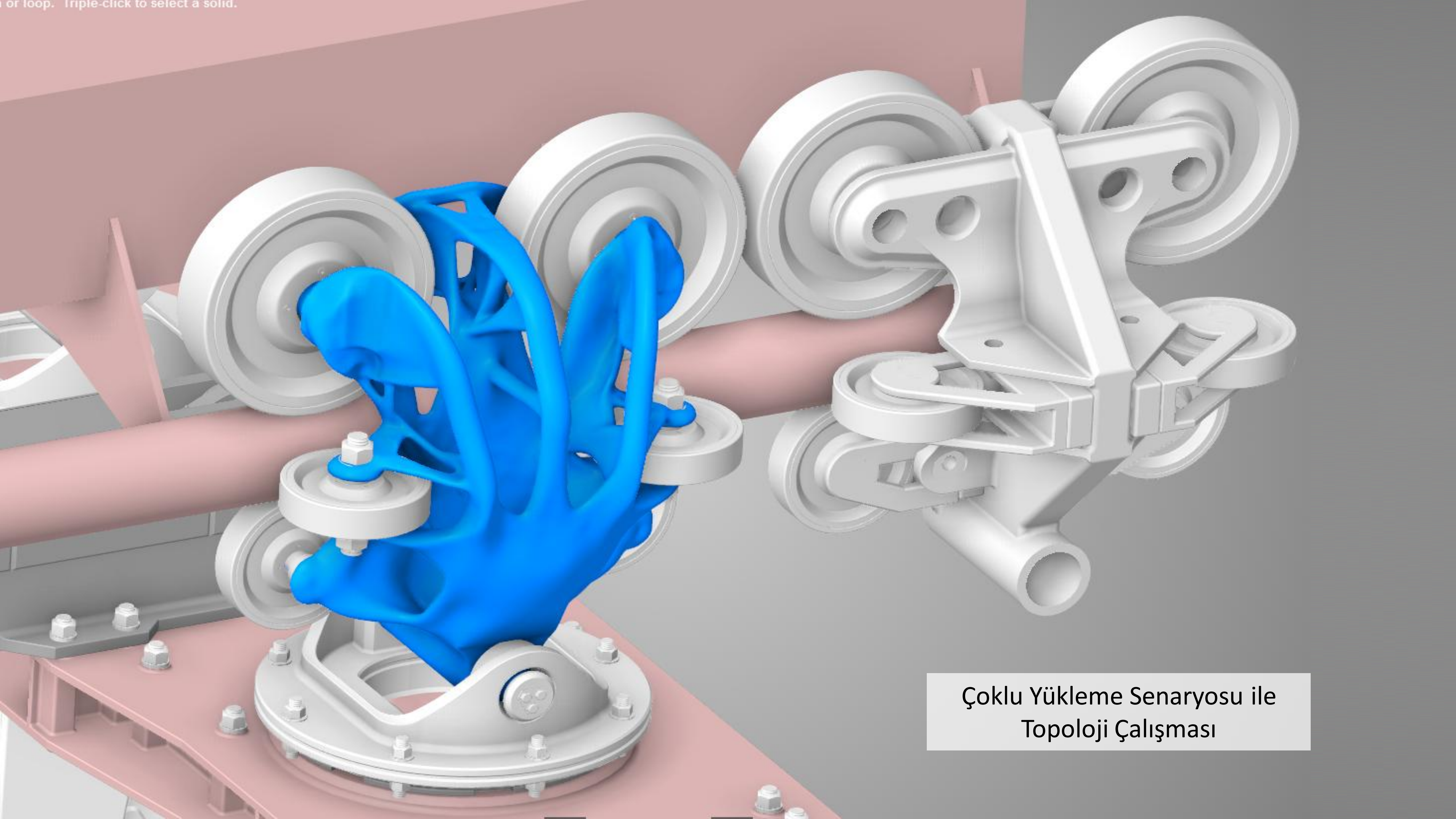


Hidrolik Yağ Manifoldu Vaka Analizi

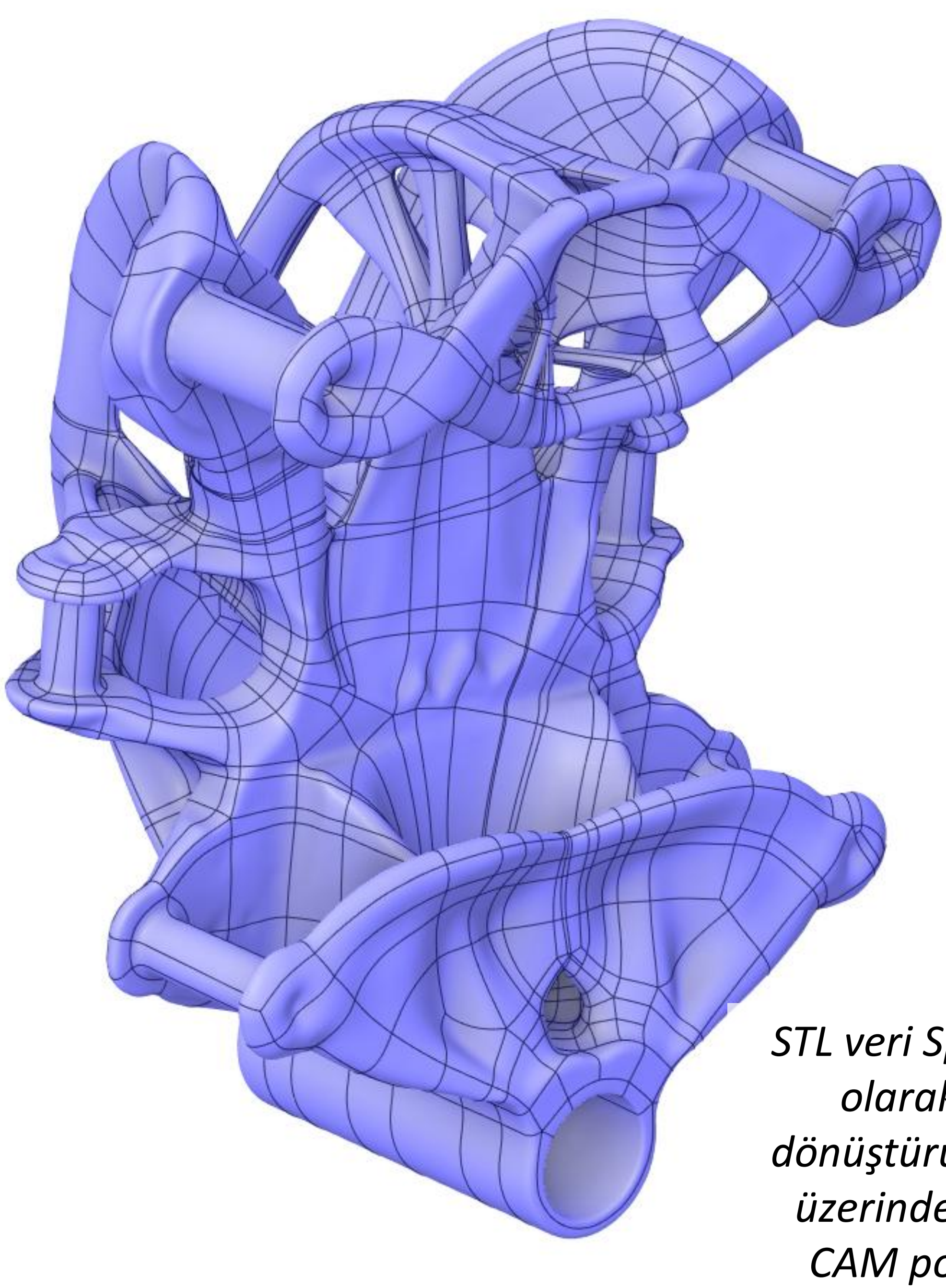
S.M.I.L.E.-FEM GmbH CADFEM

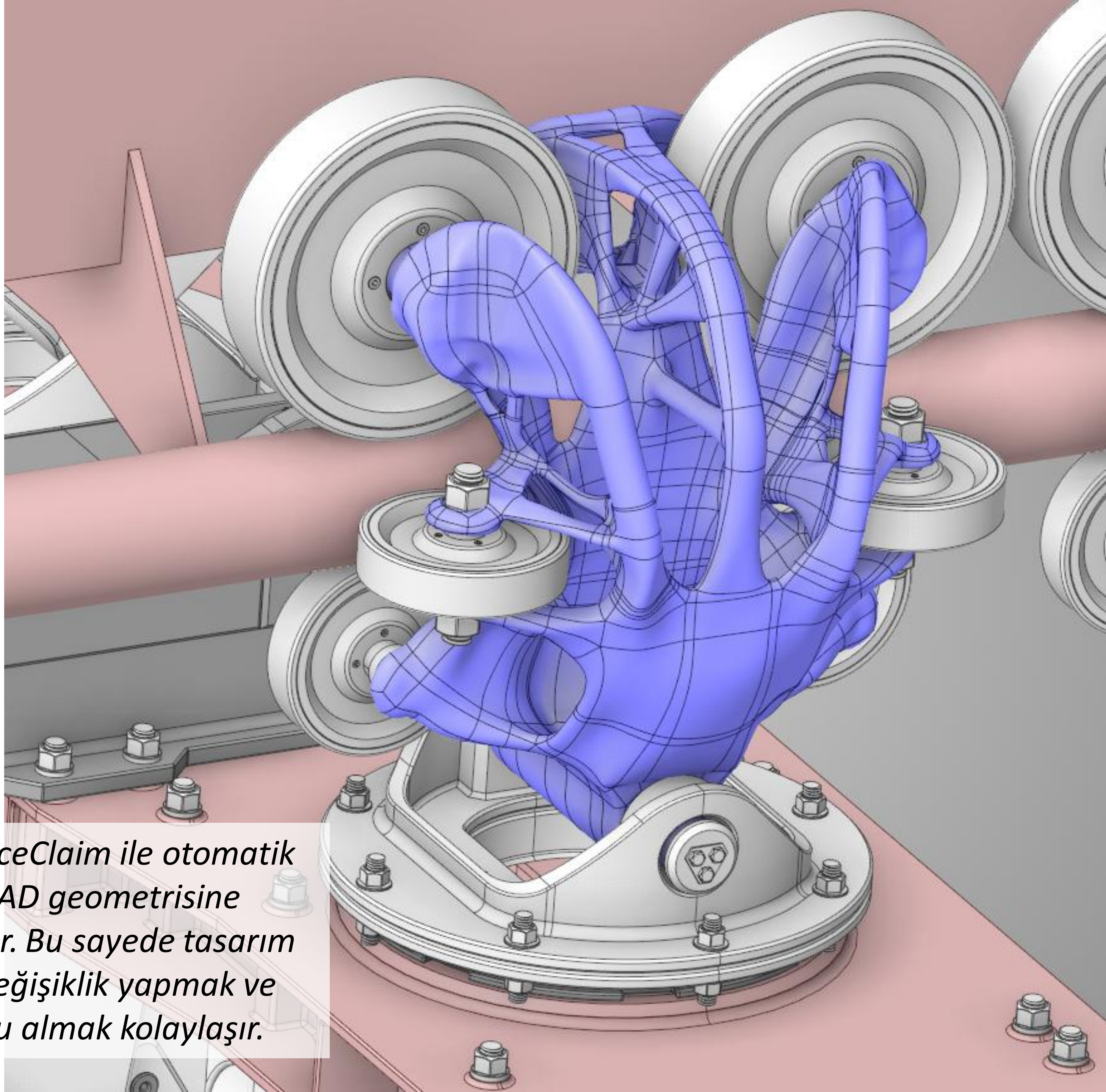
- Akış yolları Discovery Live CFD çözücüsü ile optimize edilmiştir.
- Hesaplama Ekran kartları ile 1 saatin altında geometri oluşturma süresi
- Çok karmaşık ve fazla girdili problem Ansys gücü ile çözülebilmiştir.
- Yeni parçada elde edilen değerler:
  - **76% kütle azaltımı**
  - **28% Uzunluktan kazanç**
  - **55% basınç kaybından kazanç (CFX ile doğrulanmıştır.)**
  - **Orijinal parça ile benzer rijitlik**





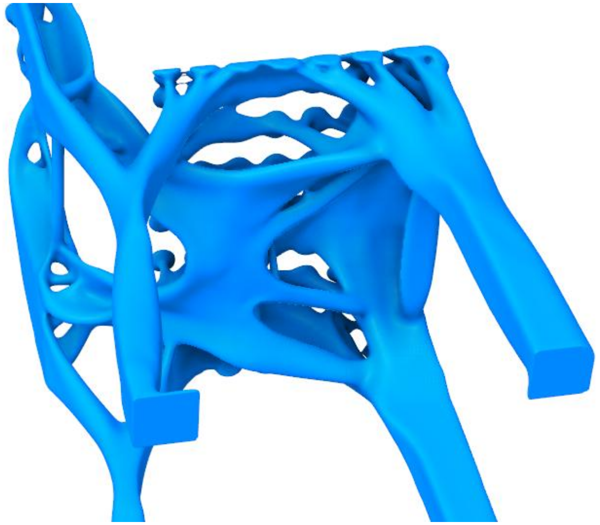
Çoklu Yükleme Senaryosu ile Topoloji Çalışması

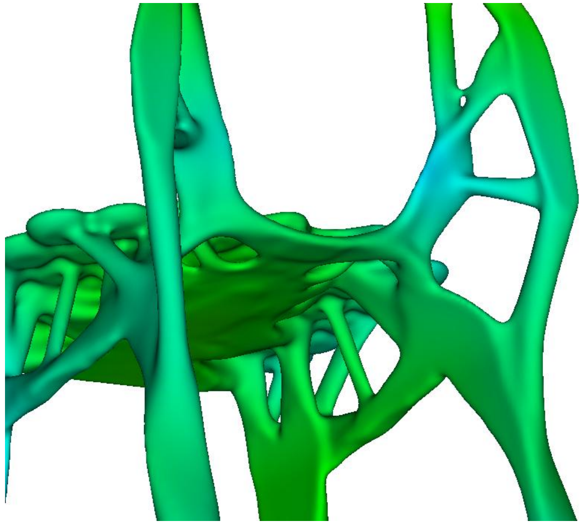




STL veri SpaceClaim ile otomatik olarak CAD geometrisine dönüştürülür. Bu sayede tasarım üzerinde değişiklik yapmak ve CAM postu almak kolaylaşır.

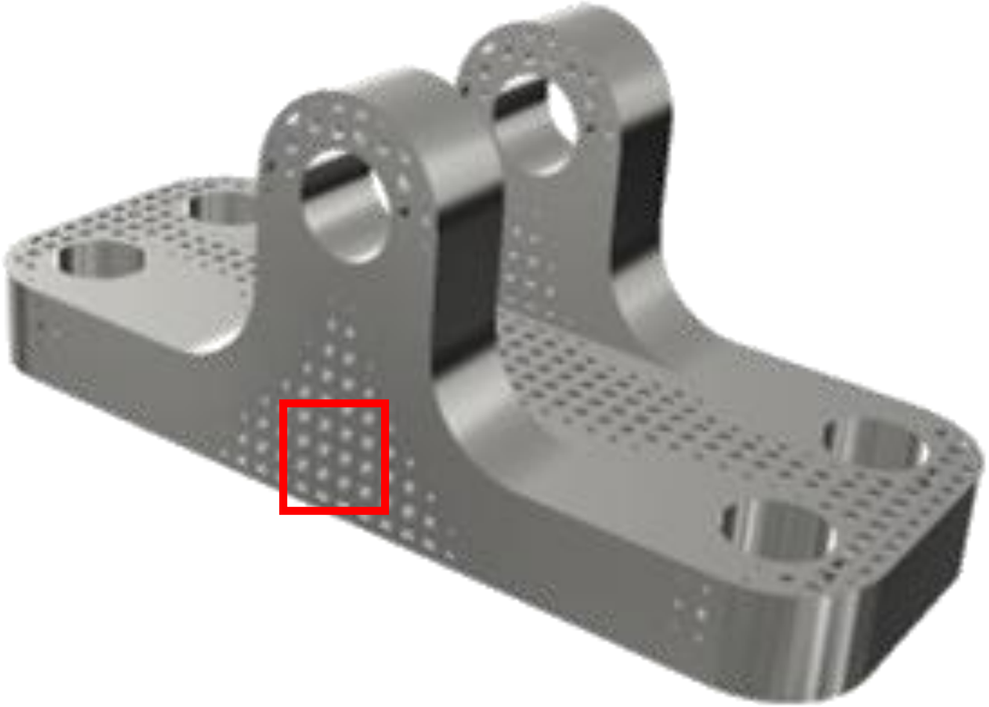
solid.

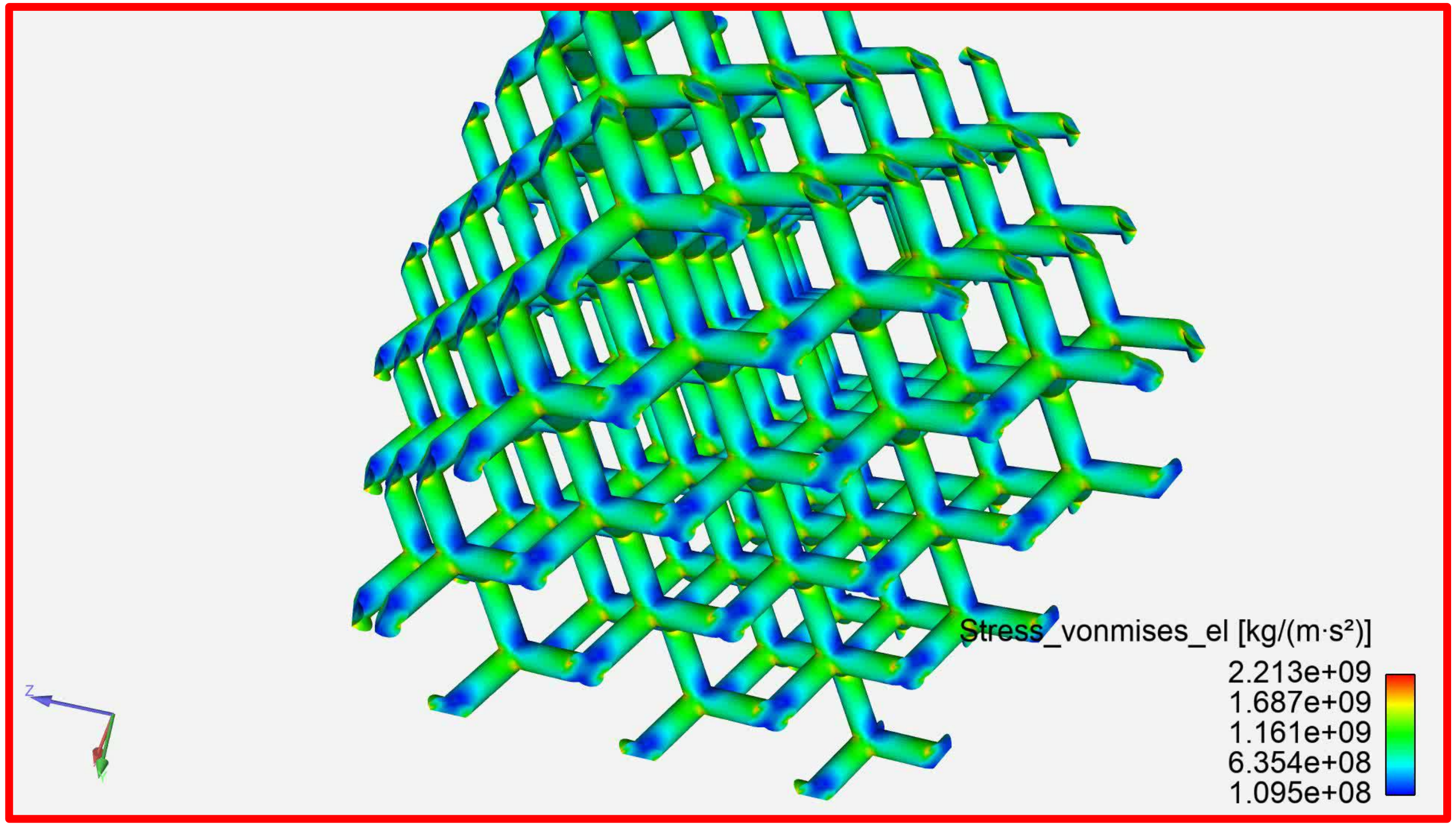




Lattice (Kiriş) Optimizasyonu

- ***Eklemeli İmalat için Optimizasyon***
- Lattice yapı oluşturma
  - Tekdüze veya rastsal Lattice yapı
  - Gerilme bazlı lattice yapı oluşturma

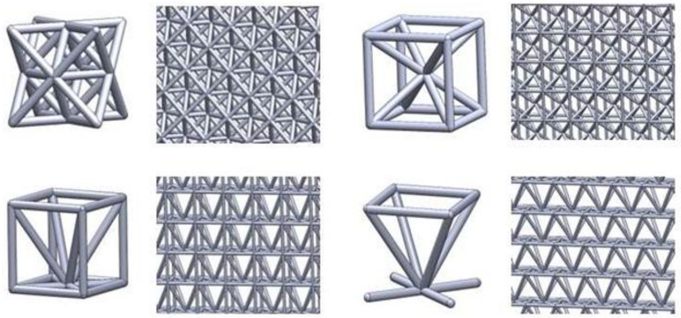




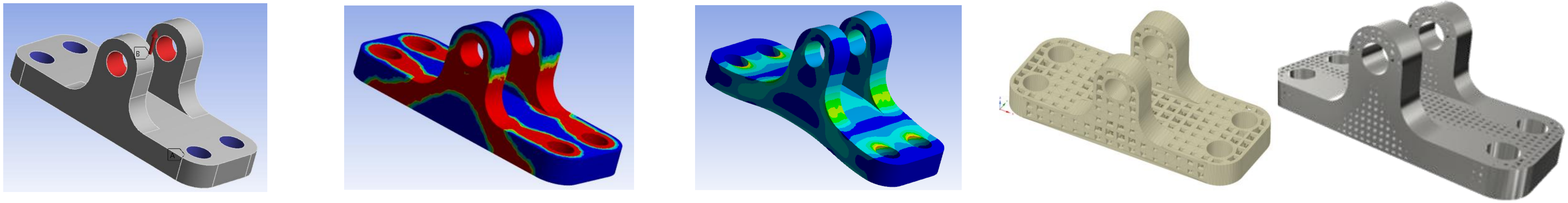
Lattice Optimization

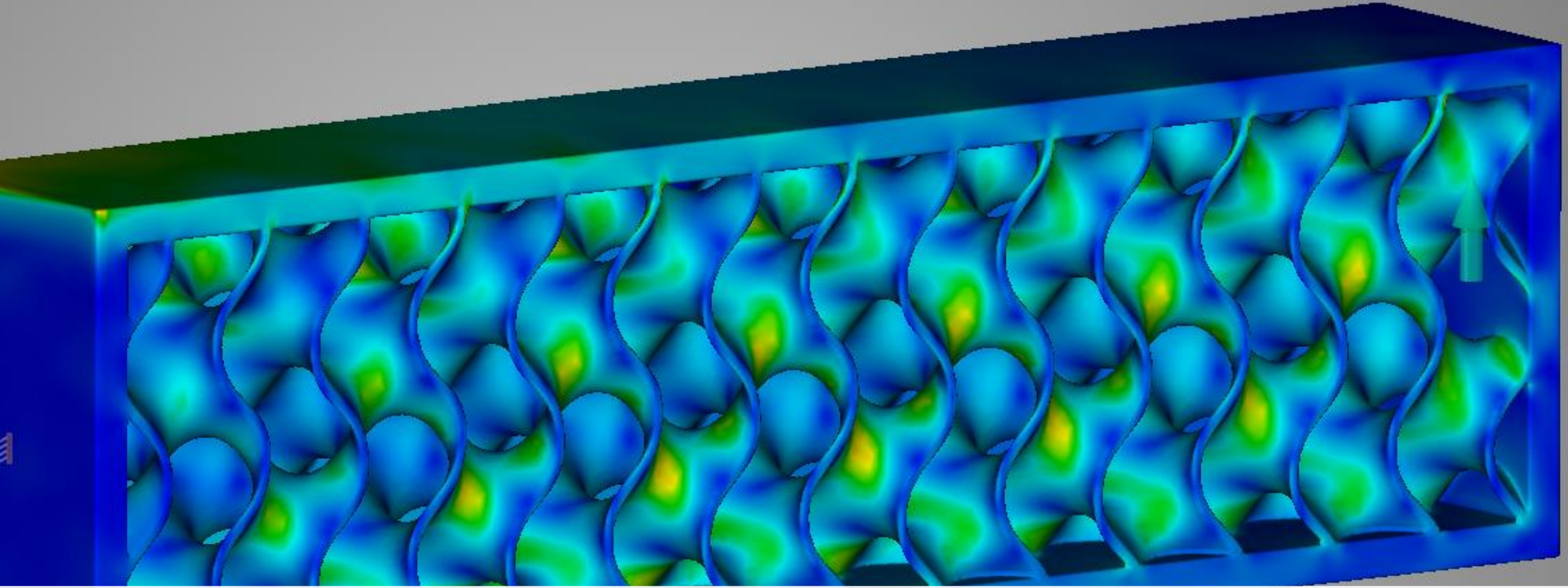
Lattice yoğunluğu tabanlı optimizasyon

- Homojenizasyon bazlı yakınsama
- Hücre şablonu kütüphanesi
- Tasarım doğrulama (birim hücre)
- Detaylı Lattice oluşturma (CAD)



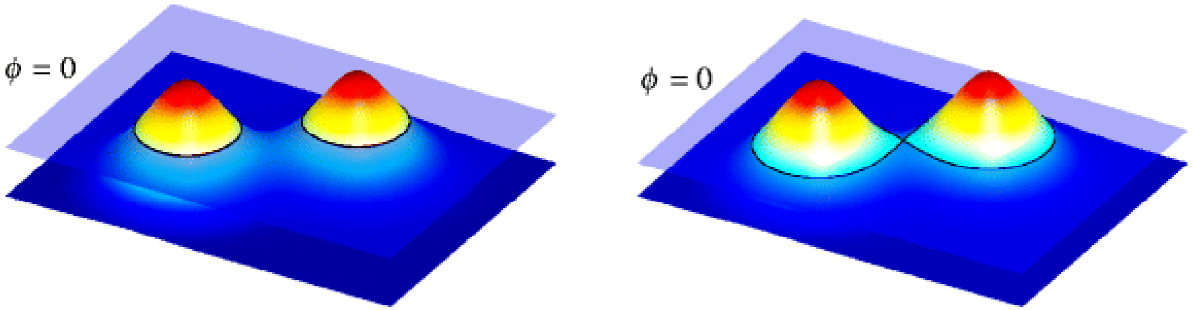
Structural Problem Set up → Lattice Density optimization → Design Validation on Homogenized Model → Generate Lattice Structure, Validate Manufacturability → Print





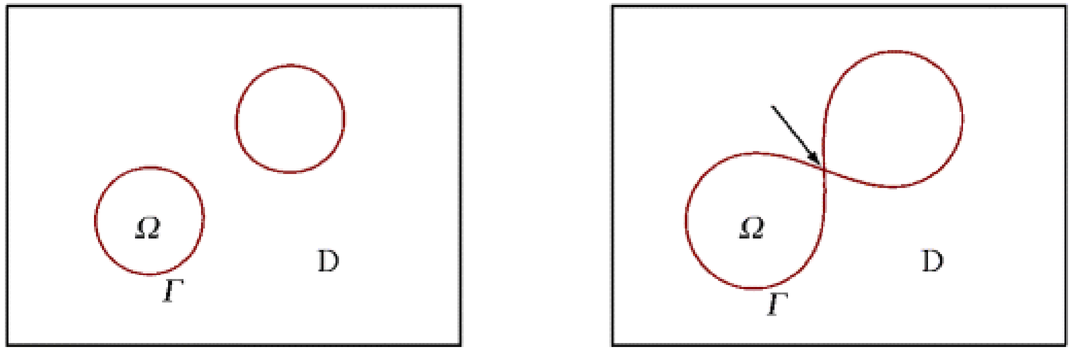
Lattice – Gyroid – Honeycomb pattern simulation

Level-set Topology Optimization



(a) An LSF ϕ.

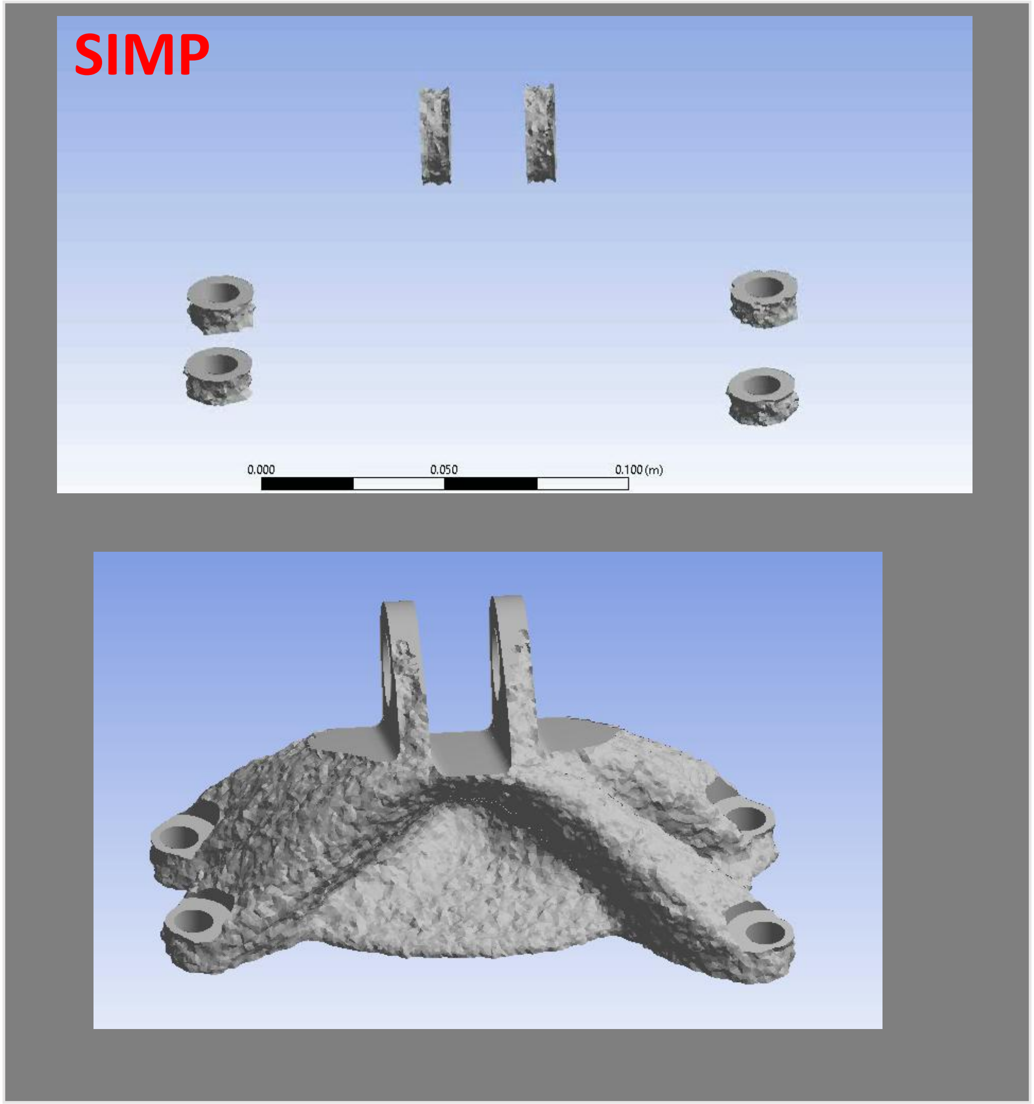
(b) An altered LSF ϕ.

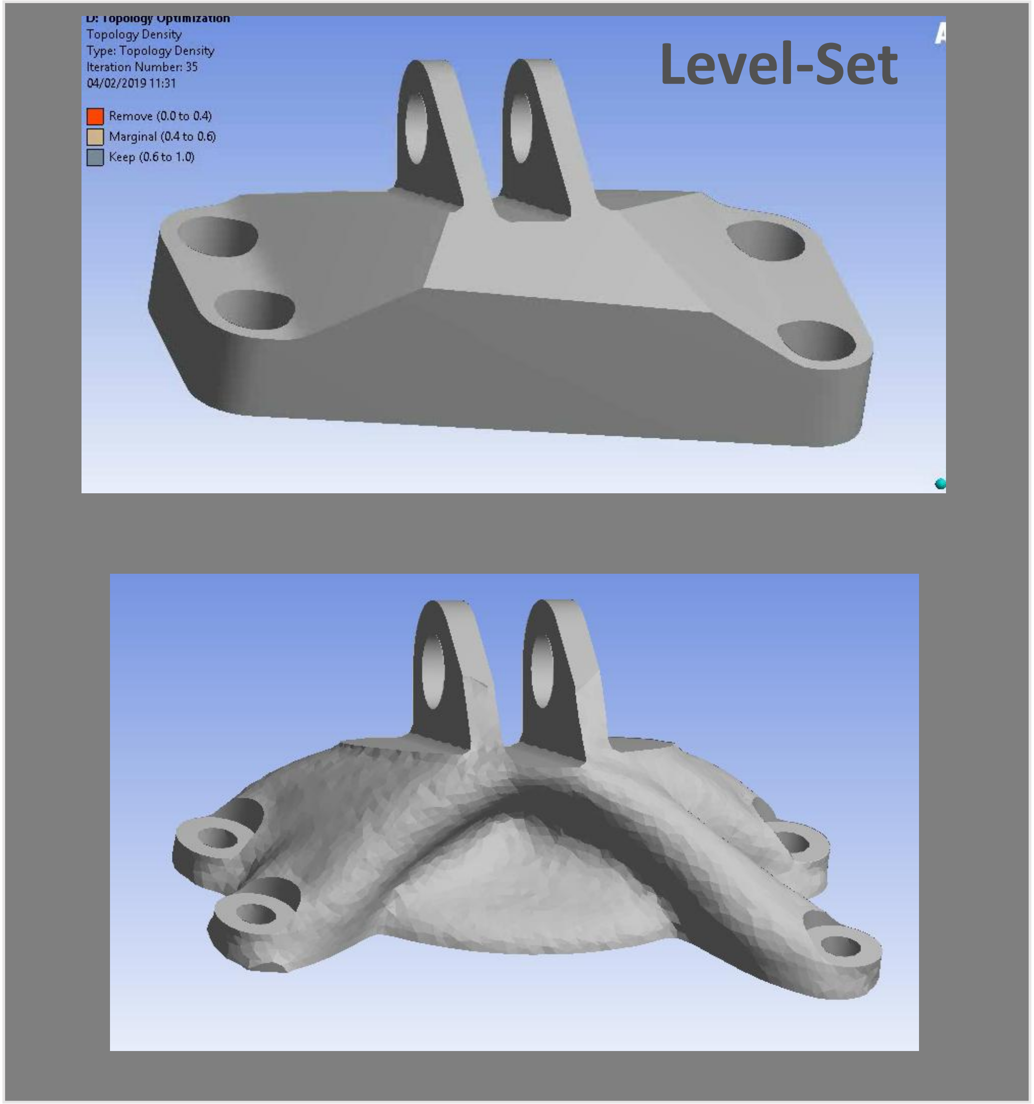


(c) The material domain Ω corresponding to Fig. 5a with big features.

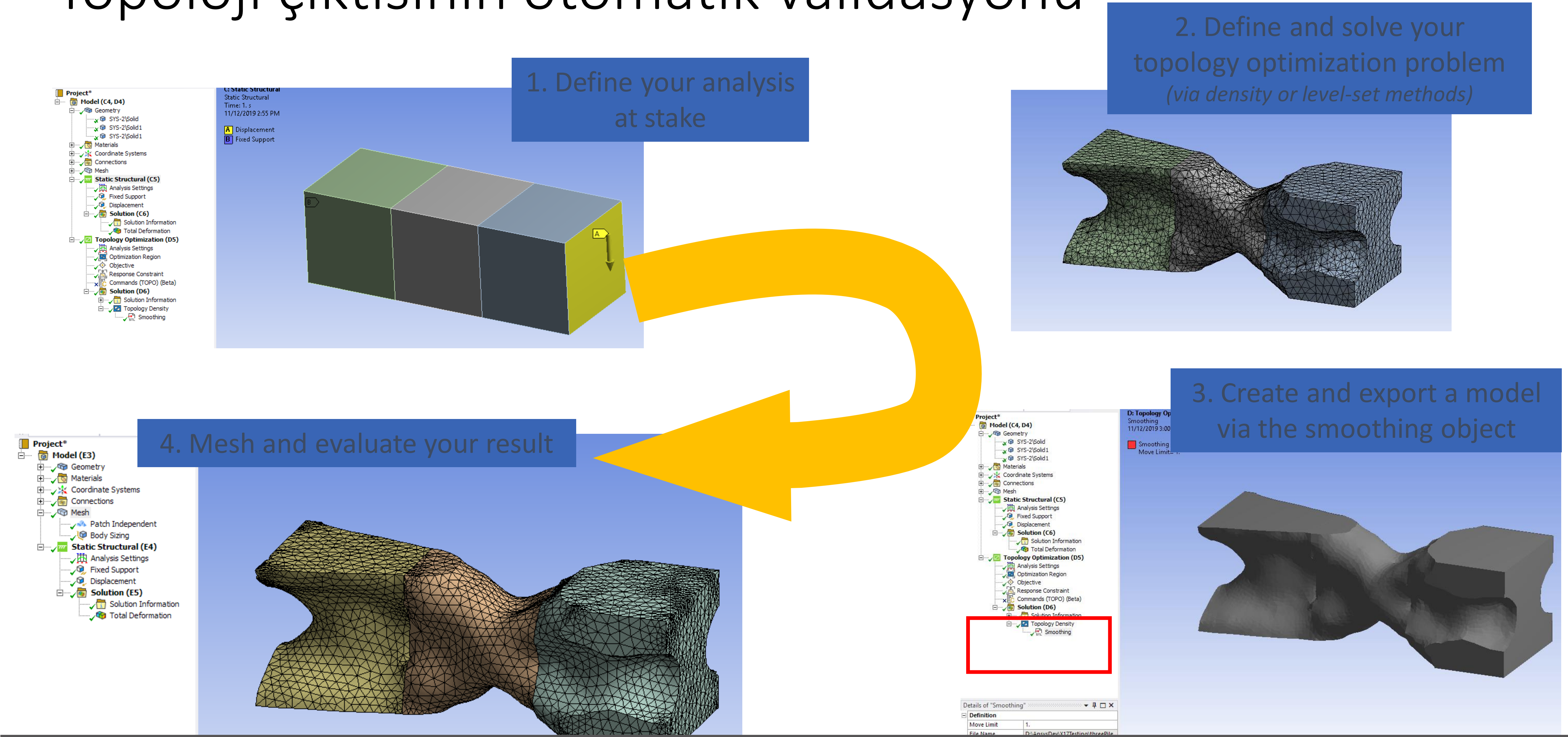
(d) The altered material domain Ω corresponding to Fig. 5b with a small feature.

SIMP VS. Level Set Methods



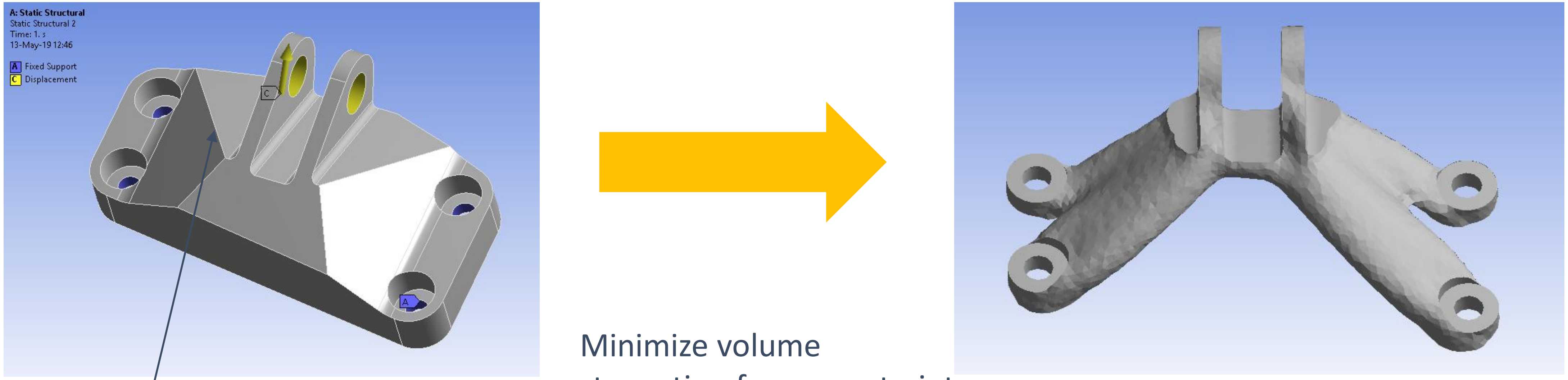


Topoloji çıktısının otomatik validasyonu



Tepki kuvveti bağımlı eniyileme

- Tepki kuvveti bağımlı eniyileme, bağlantı noktalarınızdaki cidarların optimizasyonu için daha elverişli bir yöntemdir.

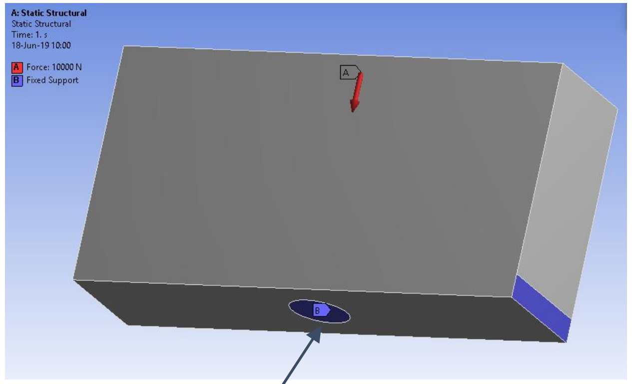


Minimize volume
st reaction force constraint

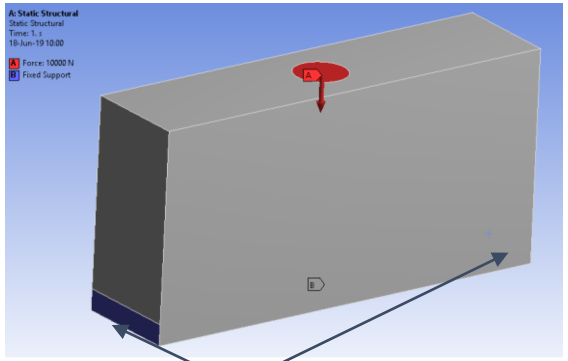
$$\begin{cases} \min_{\Omega} Vol(\Omega) \\ st : RF(\Omega) = \int_A \lambda_z ds \geq 22kN \end{cases}$$

The reaction force is computed over The **FACE A** (ie prescribed disp)

Reaction-Force Criterion



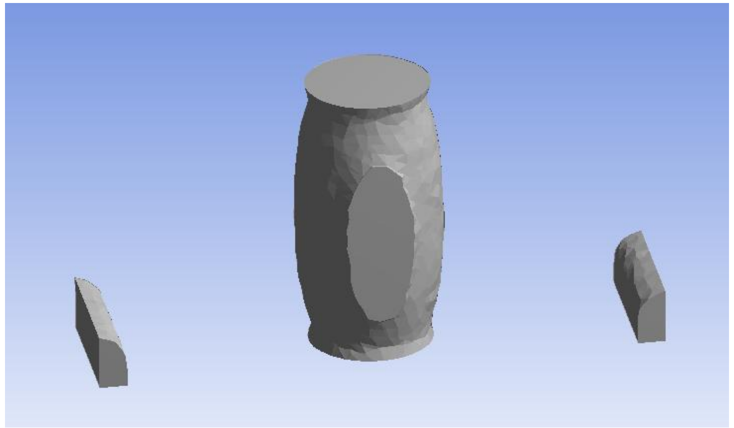
FACE A



FACEs B

min compliance st volume (20%)

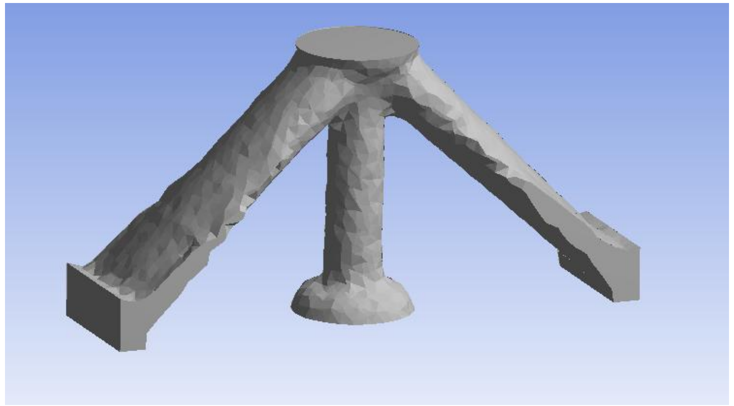
(the clamped parts (B) are not crucial so they have been disconnected)



(a) min compliance st vol and RF

$$\begin{cases} \min_{\Omega} compliance(\Omega) \\ vol(\Omega) \leq 20\%, \quad RF_A \leq 5kN \end{cases}$$

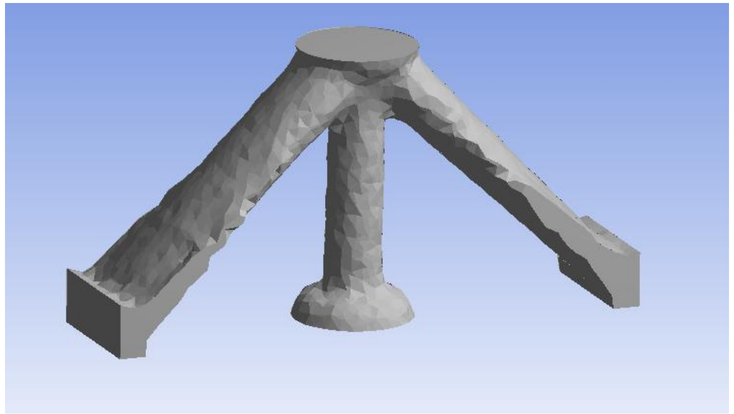
(this constraint aims to limit the force that goes through the face A)



(b) min compliance st vol and RF

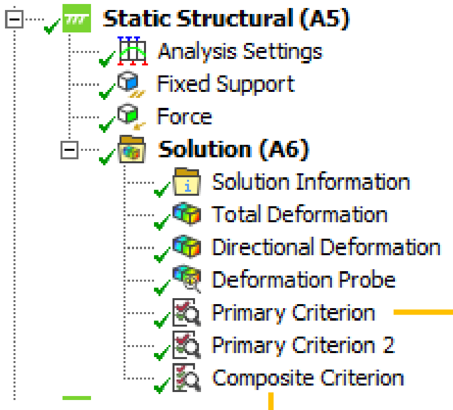
$$\begin{cases} \min_{\Omega} compliance(\Omega) \\ vol(\Omega) \leq 20\%, \quad RF_B \geq 5kN \end{cases}$$

(by contrast, this constraint aims to have a minimal force that goes through the faces B)



Kullanıcı tanımlı kritere göre eniyileme

- Tanımlanan kritere göre (örn: X yönündeki sehim'in belirli bir değer aralığında kalması gibi) eleman yoğunluğunun görüntülenmesi



Details of "Primary Criterion"

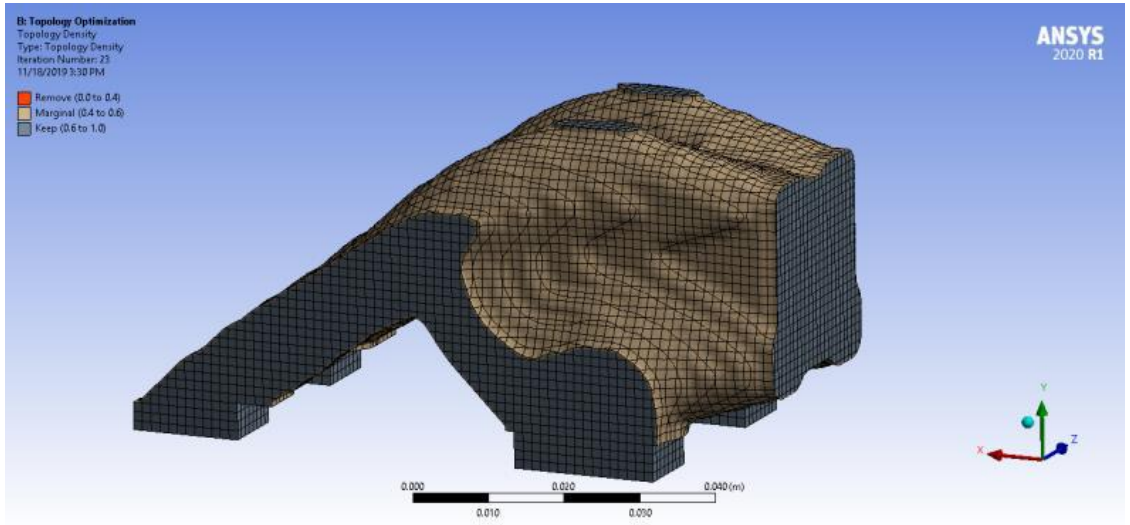
Definition	
Base Result	Displacement
Suppressed	No
Results	
Value	1.4784e-004 m
Scoping	
Scoping Method	Named Selection
Named Selection	Upper Points
Load Step Selection	
Step	1
Vector Reduction	
Coordinate System	Nodal Coordinate System
Vector Reduction	X
Spatial Reduction	
Spatial Reduction	Average
Method	Discrete

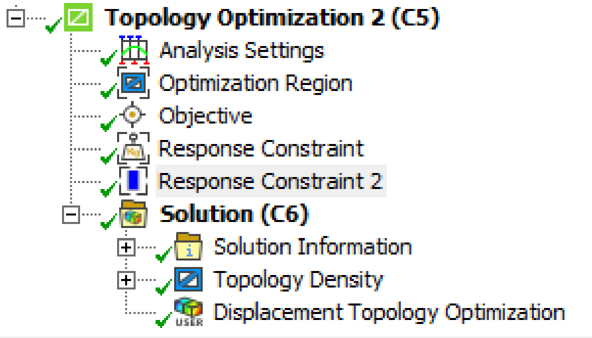
Worksheet

Composite Criterion

Add | Delete | Delete All

Primary Criterion Selection	Coefficient
Primary Criterion	1
Primary Criterion 2	-1



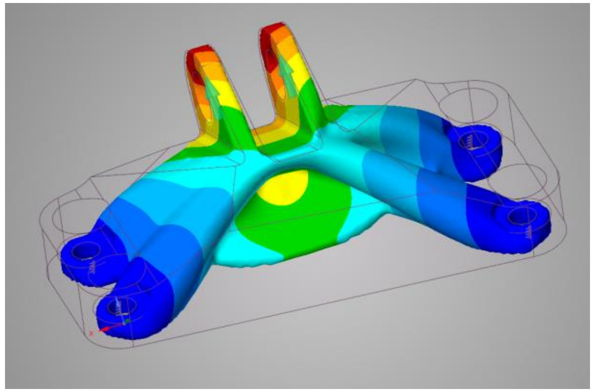


Details of "Response Constraint 2"

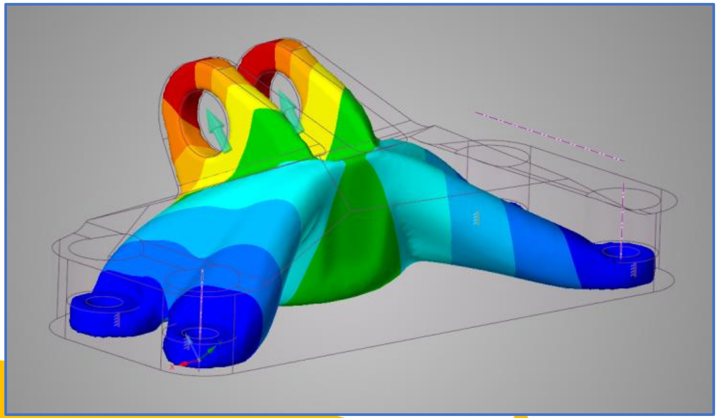
Definition	
Type	Response Constraint
Response	Criterion
Criterion	Composite Criterion
Initial Value	5.4384e-005 m
Lower Bound	Free
Upper Bound	0. m
Suppressed	No

Discovery Live

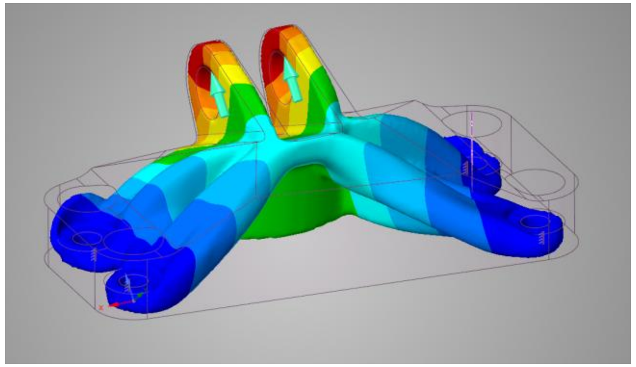
Minimum compliance st volume

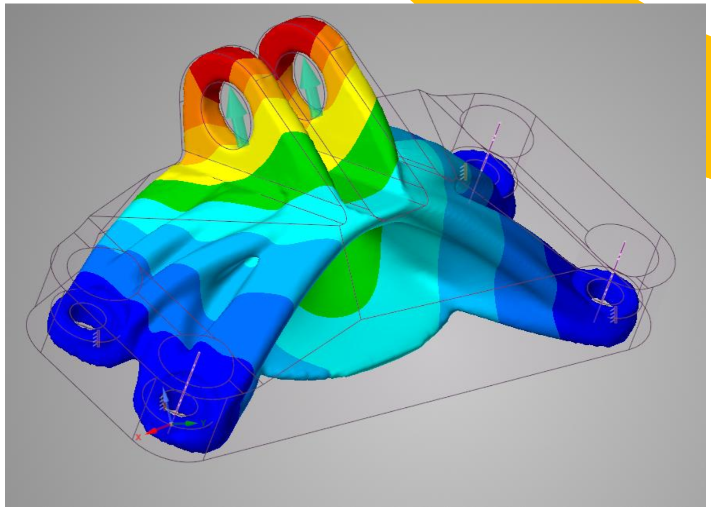


+ Bi-directional pull out constraint

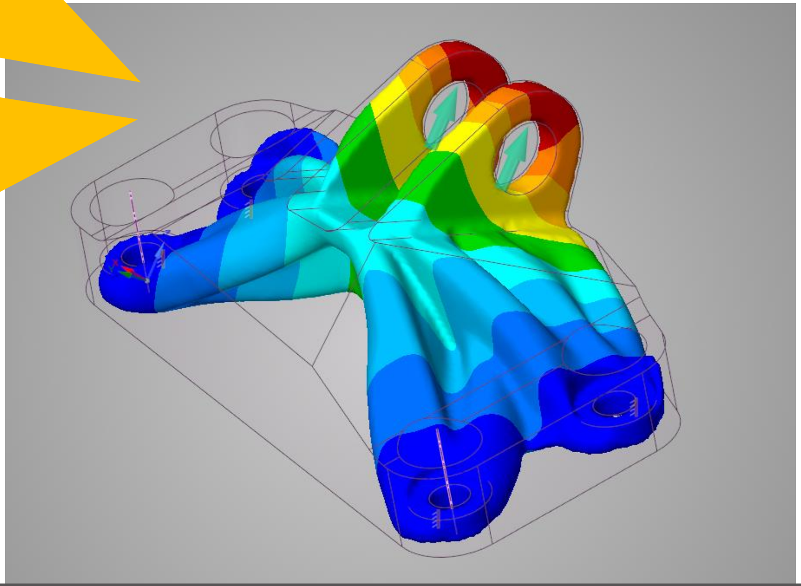


Minimum compliance
st volume, max thickness and pull out constraints





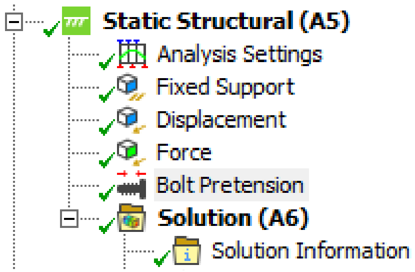
+ Maximum thickness constraint



Density-Based Topology Optimization

Cıvata Ön Gerilmeli Senaryolar.

- Yoğunluk tabanlı topoloji optimizasyonu çözümleme algoritması, senaryoda cıvata öngerilmesi bulunması durumunu desteklemektedir.

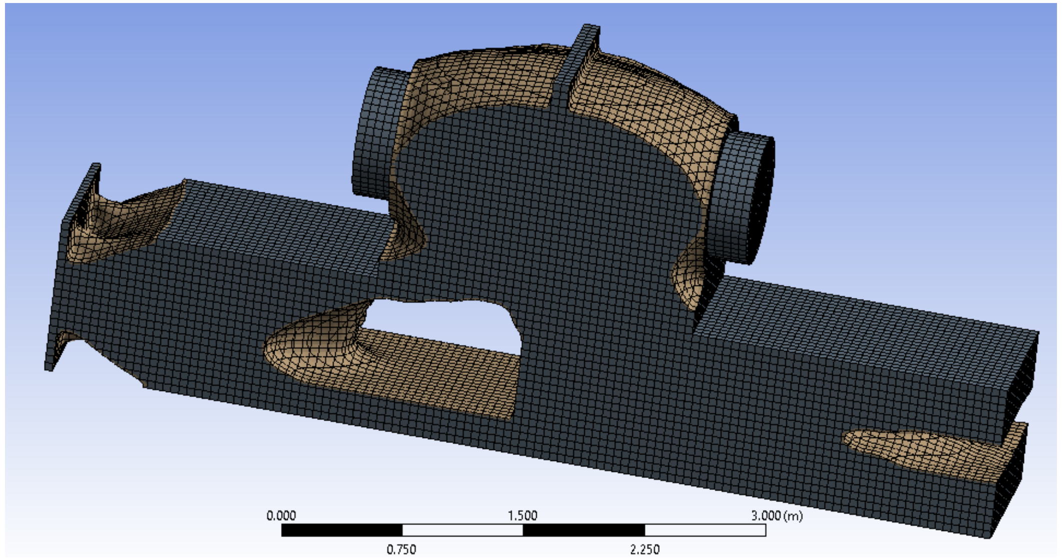


Details of "Bolt Pretension"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
ID (Beta)	72
Type	Bolt Pretension
Suppressed	No
Define By	Load
Preload	1.e+006 N
Advanced	
Solve Behavior	Combined

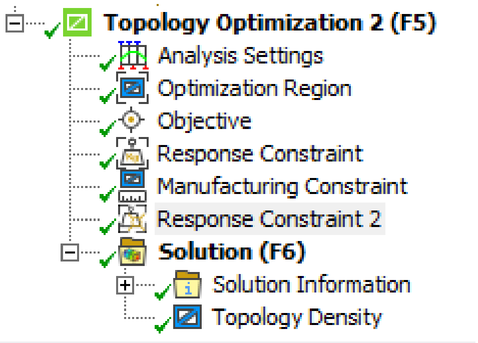
Details of "Bolt Pretension"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
ID (Beta)	72
Type	Bolt Pretension
Suppressed	No
Define By	Lock
Advanced	
Solve Behavior	Combined



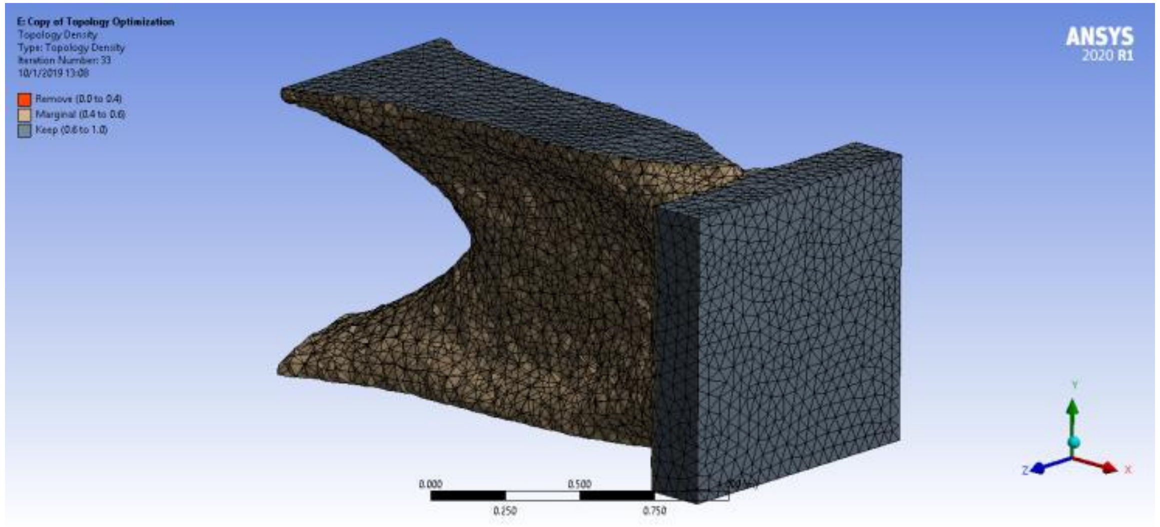
Kütle Merkezi bağımlılığı (Beta)

- SIMP veya LS algoritmalarında kütle merkezi korunmak sureti ile eniyileme yapılabilir.



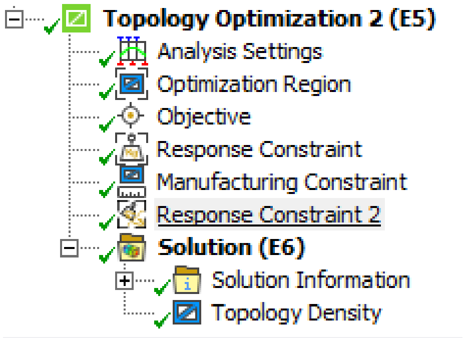
Details of "Response Constraint 2"

Scope	
Scoping Method	Optimization Region
Optimization Region Selection	Optimization Region
Definition	
Type	Response Constraint
Response	Center Of Gravity
Minimum Value	1.25 m
Maximum Value	Free
Suppressed	No
Location and Orientation	
Axis	X Axis



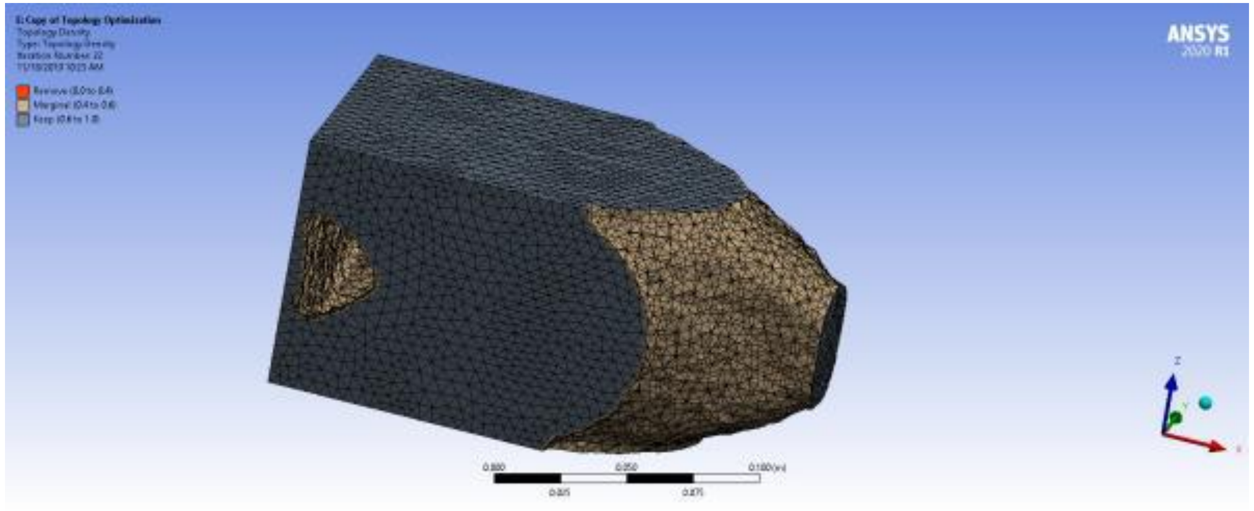
Atalet momenti bağımlılığı(Beta)

- SIMP ve LT algoritmaları ile çalışabilmektedir.



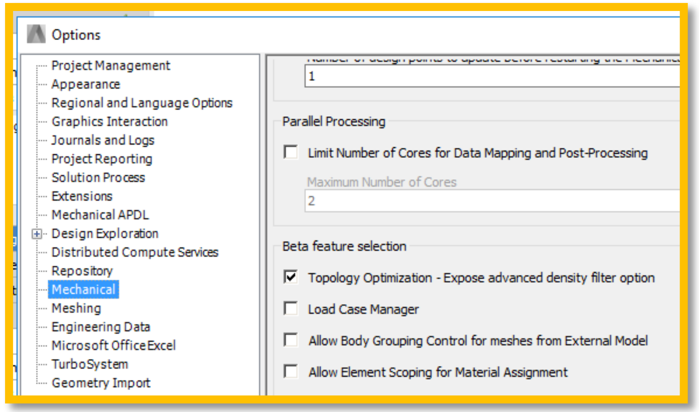
Details of "Response Constraint 2"

Scope	
Scoping Method	Geometry Selection
Definition	
Type	Response Constraint
Response	Moment Of Inertia
Define By	Absolute Range
Minimum Value	1.5e-002 kg·m²
Maximum Value	1. kg·m²
Suppressed	No
Location and Orientation	
Coordinate System	Coordinate System
Axis	X Axis

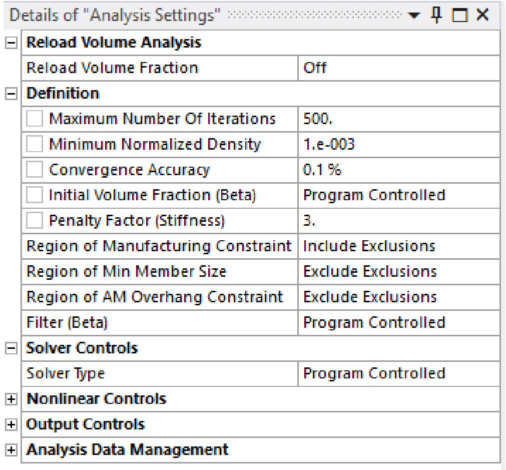


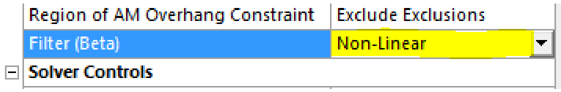
Gelişmiş Filtre(Beta)

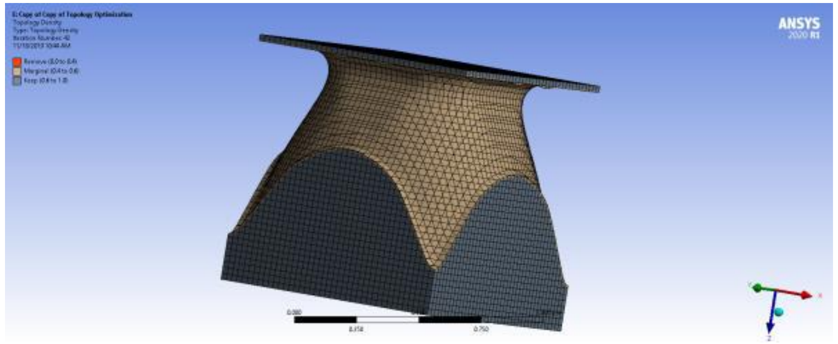
- Sınır koşulları için daha hızlı geometri dolduran ve boşaltma alanında daha hızlı member (feder) üreten bir algoritmadır.



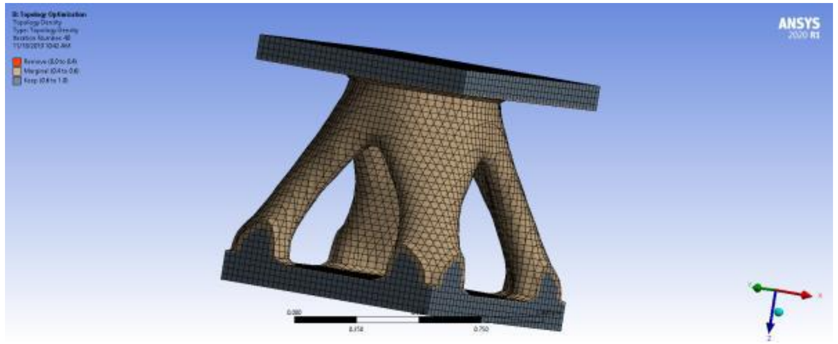
Select **"Non-Linear"** as filter in **"Analysis Settings"**





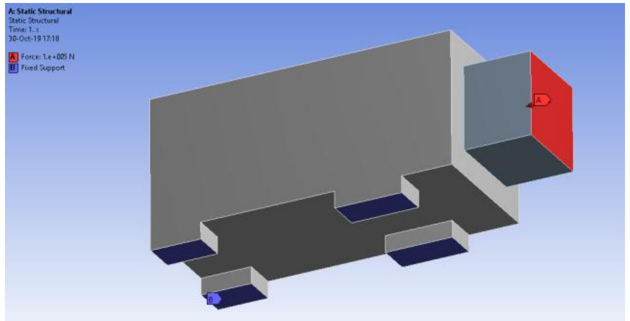


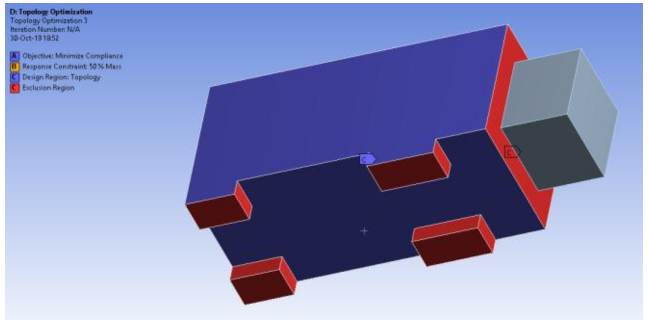
Default, linear filter

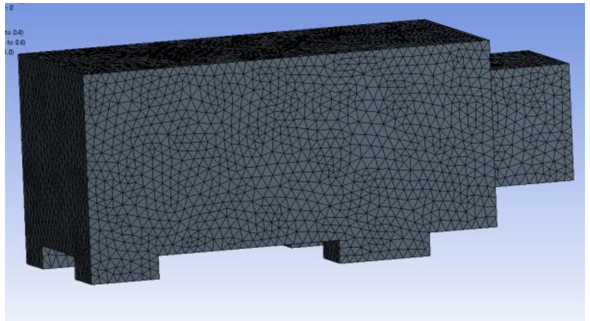


Non-linear filter

Node-Based
Shape Optimization
(Beta)







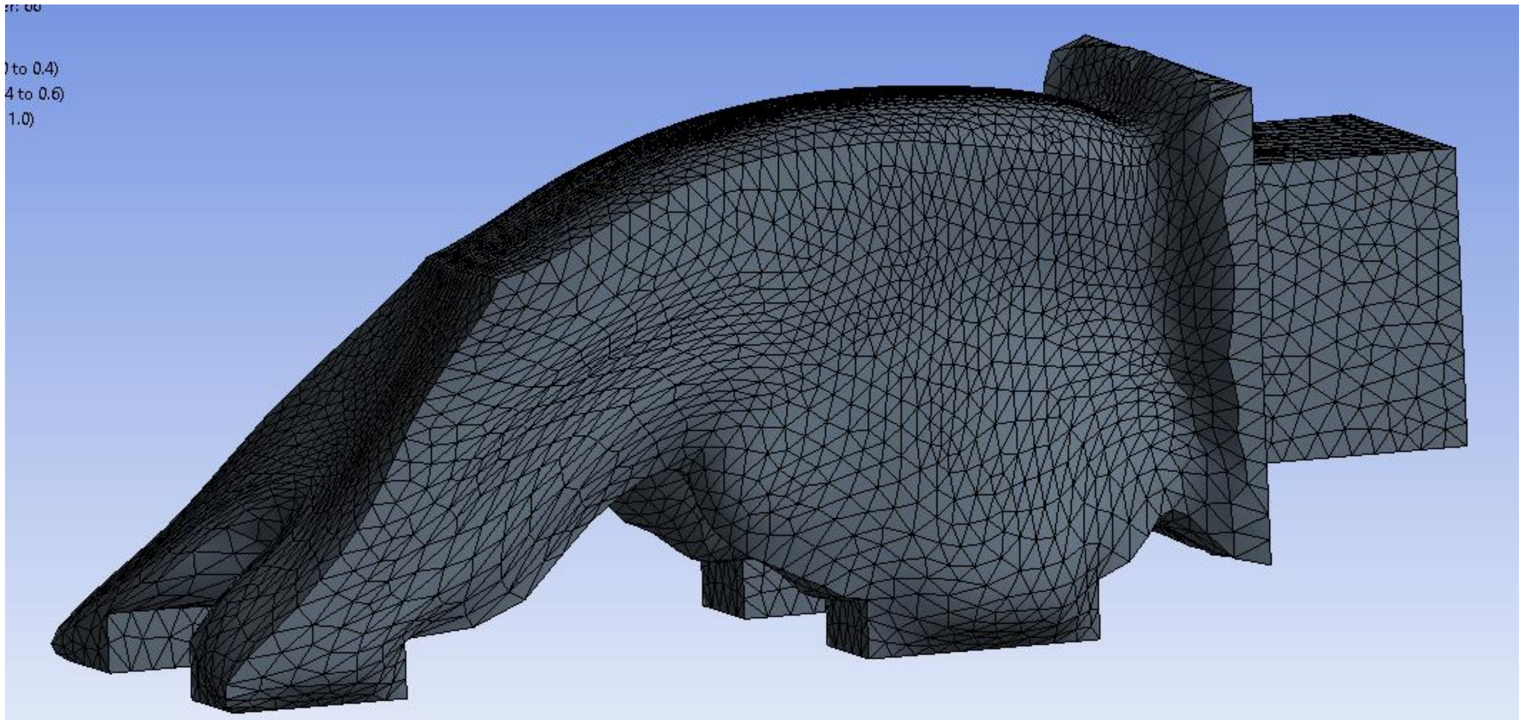
Gereksinimler:

- Statik lineer analiz
- Mavi yüzeylerde optimizasyon koşturulur
- Optimizasyon kriteri:

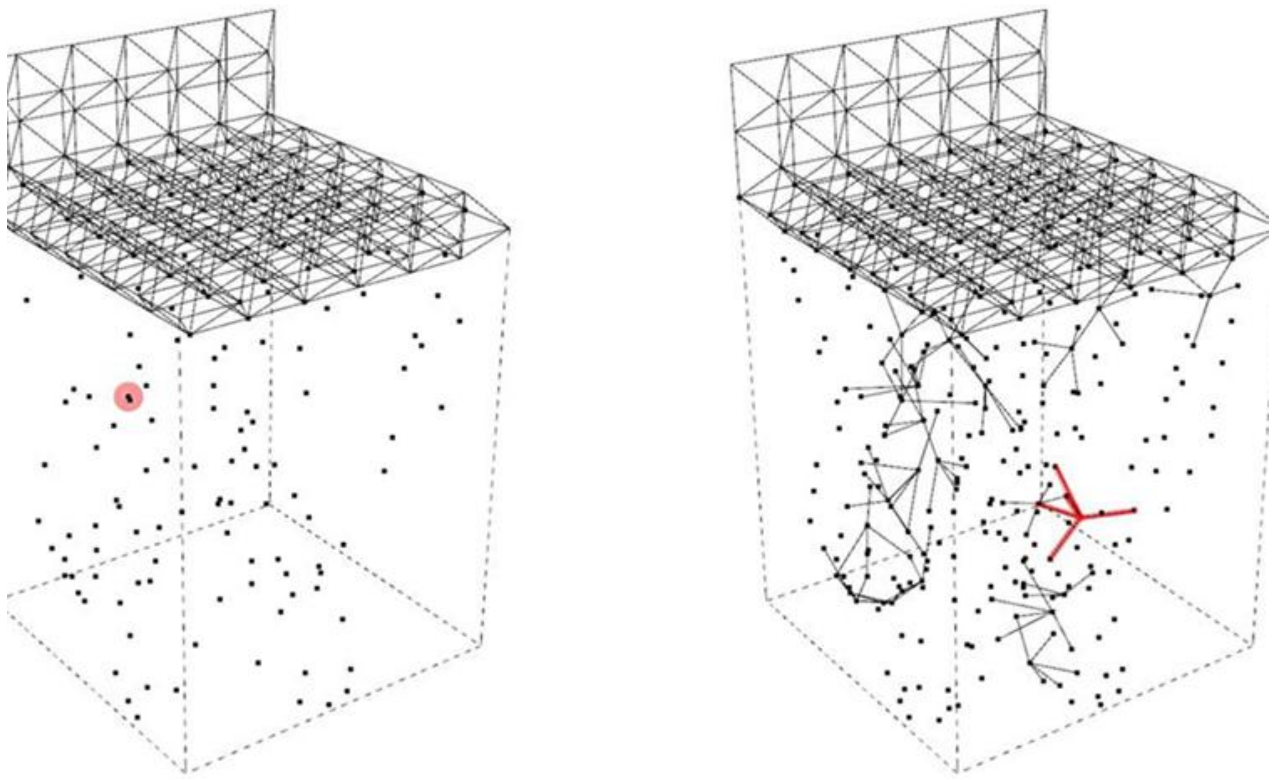
$$\begin{cases} \min\limits_{\Omega} compliance(\Omega) \\ st : vol \leq 50\% \end{cases}$$

Sonuçlar:

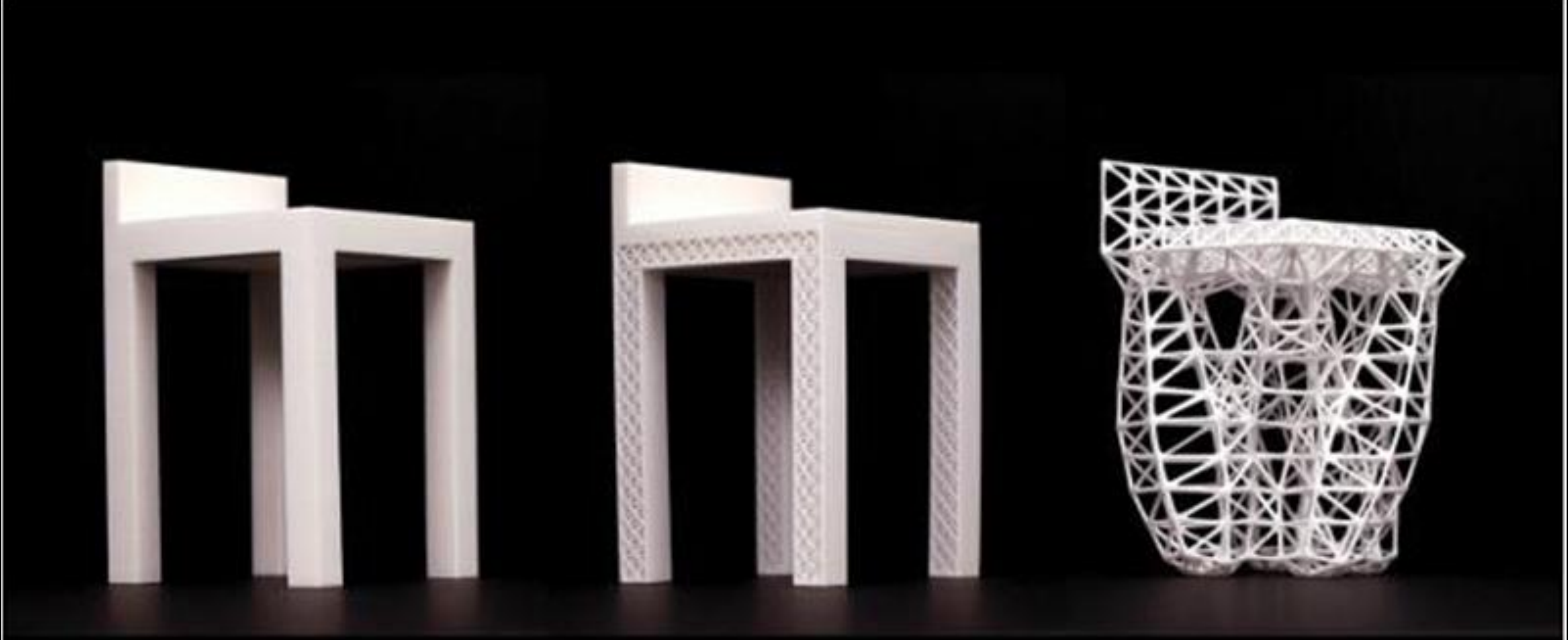
- Büyük mesh deformasyonu
- Daha yumuşak şekil eldesi
- Gerilmenin daha doğru tayini



Sınır Geometride Arama Algoritmaları



- Bu yöntemde belirli bir Boundary Box (Sınır kutusu) içinde veya nokta kümesinde Optimum geometriyi oluşturma için Arama algoritmalarını çalıştırır.



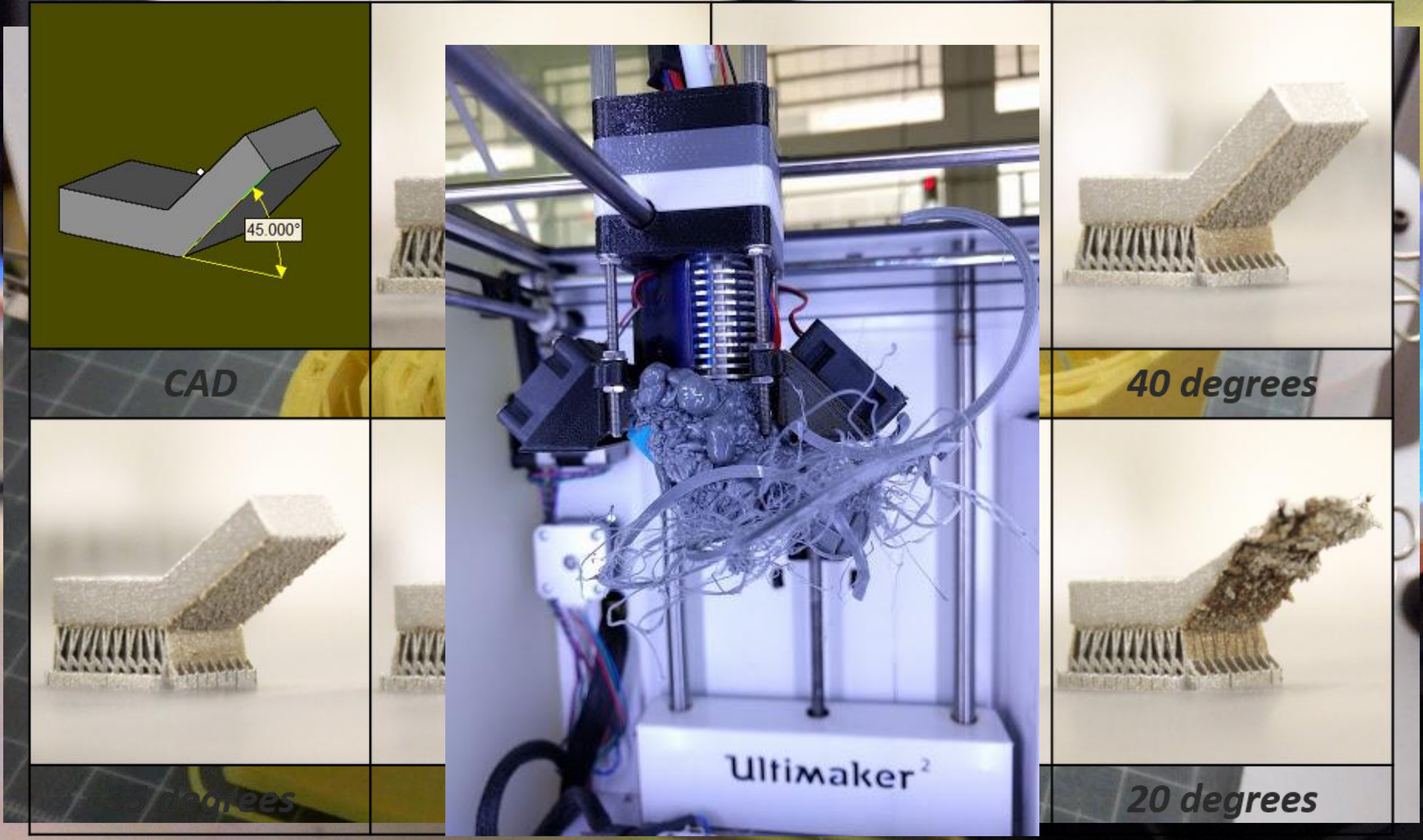
MODEL 1	MODEL 2	MODEL 3
Solid bars	Uniform lattice	Evolved lattice
Traditional design	Smart design with ALM	Evolutionary design with ALM
Weight:	Weight:	Weight:
10.3 kilograms	**4.1 kilograms**	**2.9 kilograms**
Displacement:	Displacement:	Displacement:
0.8 micrometers	**4.2 micrometers**	**6.1 micrometers**

Eklemeli İmalat Simülasyonu Çözümleri

Ansys

3B baskı için çok kolay bir yöntem

YOK


45.000°
CAD
40 degrees
20 degrees
Ultimaker 2

Automatic Distortion Compensation - example

Original Geometry

Compensated Geometry

Ansys Eklemeli İmalat Çözümleri

Eİ için Tasarım
- CAD Modelleme
- Topoloji Optimizasyonu
- Lattice yapı oluşturma

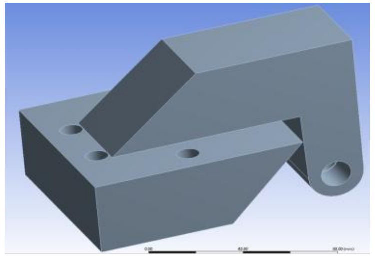
Kurulum
- STL iyileştirme ve geometri manüpilasyonu
- Part yerleşimi ve destek oluşturma
- Oryantasyon sihirbazı

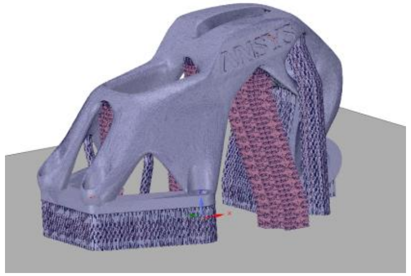
Proses Simülasyonu
- Metal katmanlı üretim simülasyonu
- Çarpılma karşılaştırma
- Tabla yapışma analizi

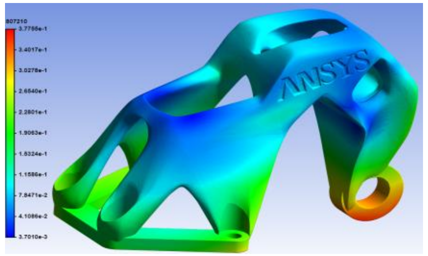
Malzeme Analizi
- Kür malzeme özellikleri
- Tanecik morfolojisi tahmini
- Eriyik malzeme ve porozite tahmini

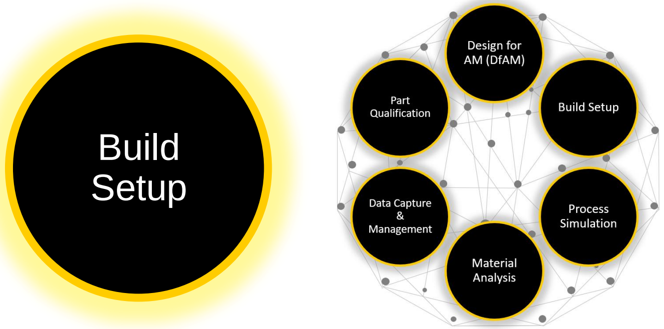
Veri toplama ve yönetme
- Sensör verisi toplama
- İzlenebilirlik
- Organizasyonda Eİ verinin birleştirilmesi, paylaşılması ve kontrolü

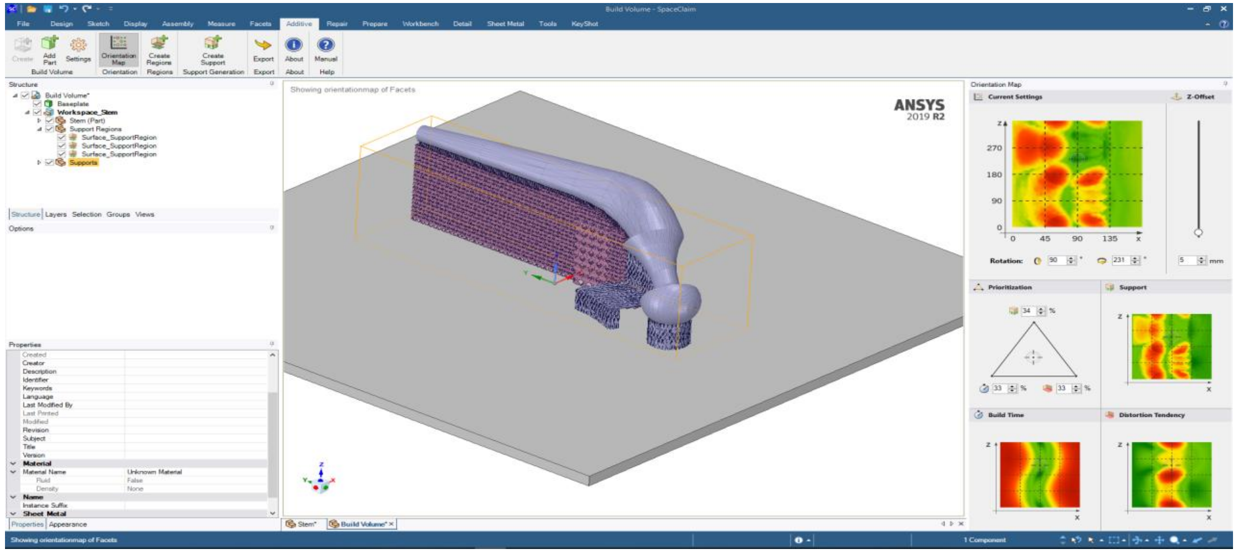
Parça Yeterliliği
- Tasarım Doğrulama
- Yapısal ve Termal analiz
- Sertifikasyon oluşturma ve kontrolü

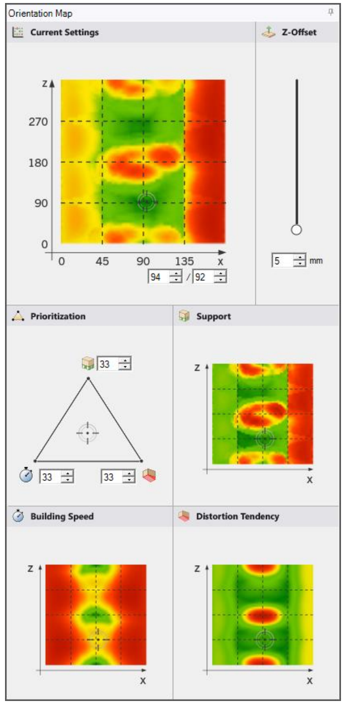


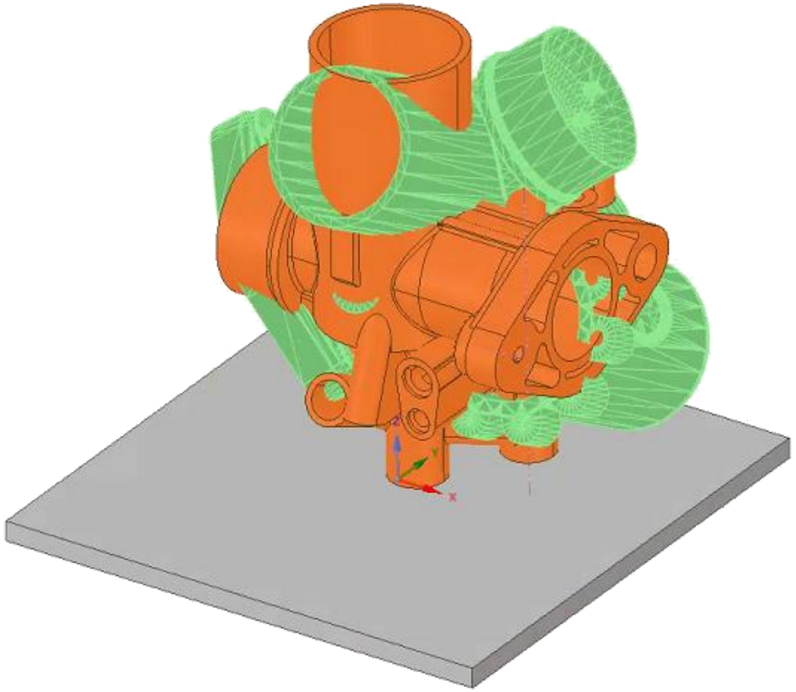








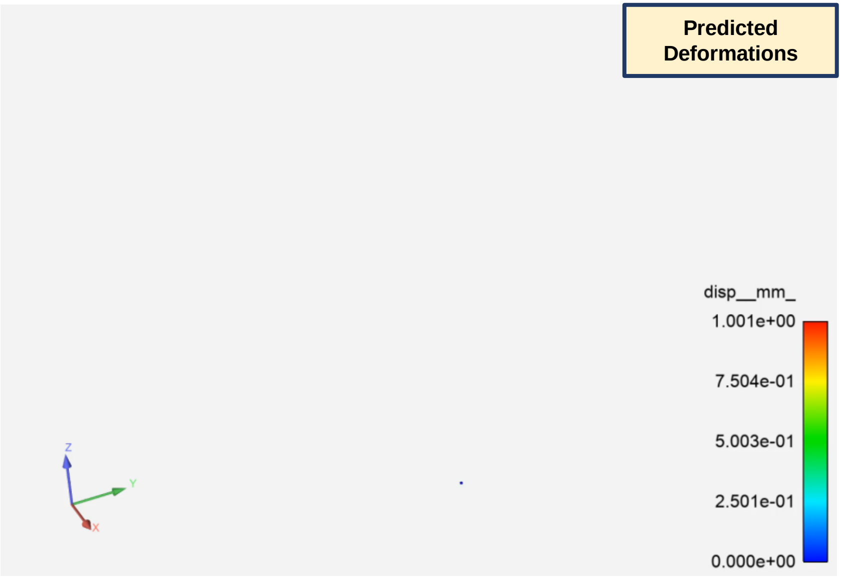


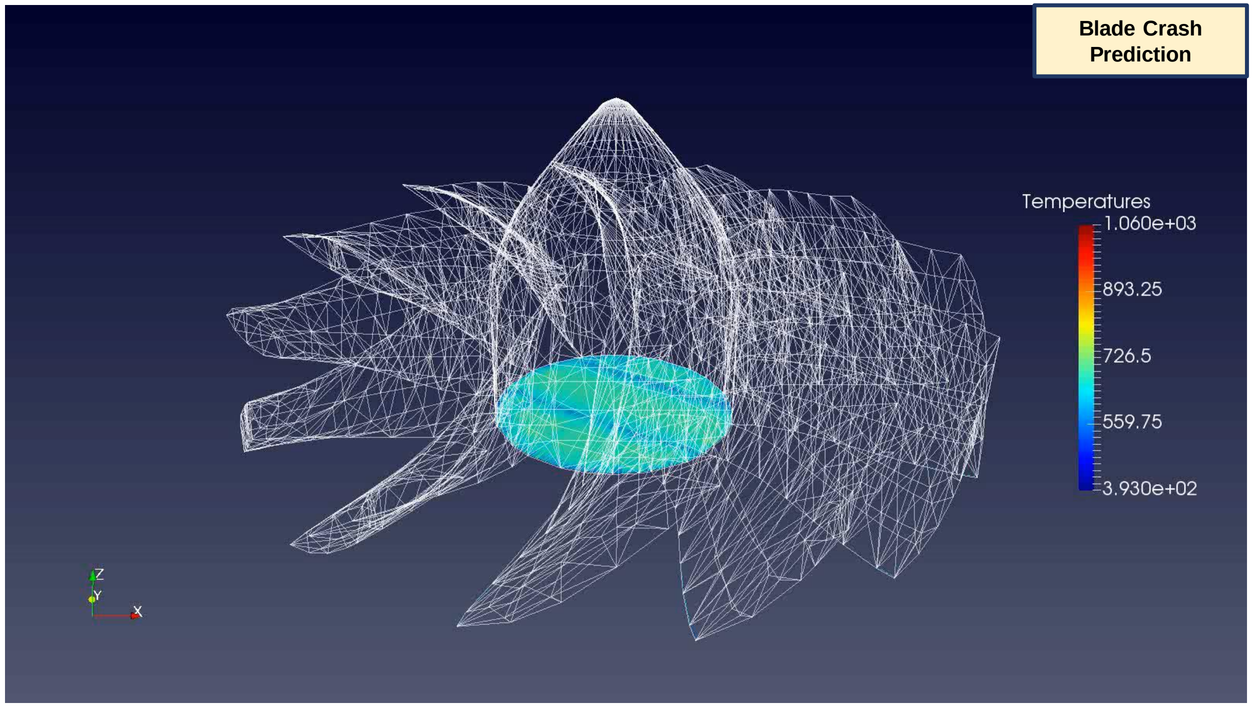


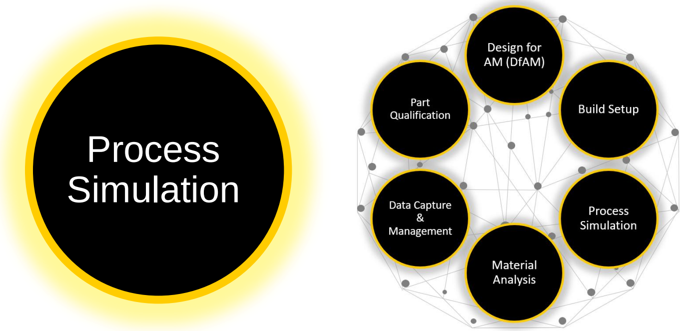
Parça Oryantasyonu eniyileme

Destek oluşturma ve eniyileme

Tarama yönü ve yolu optimizasyonu



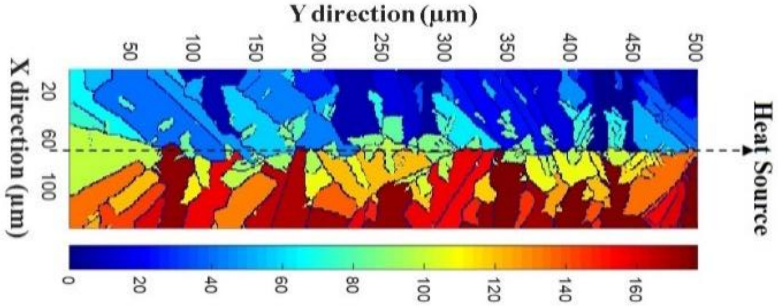


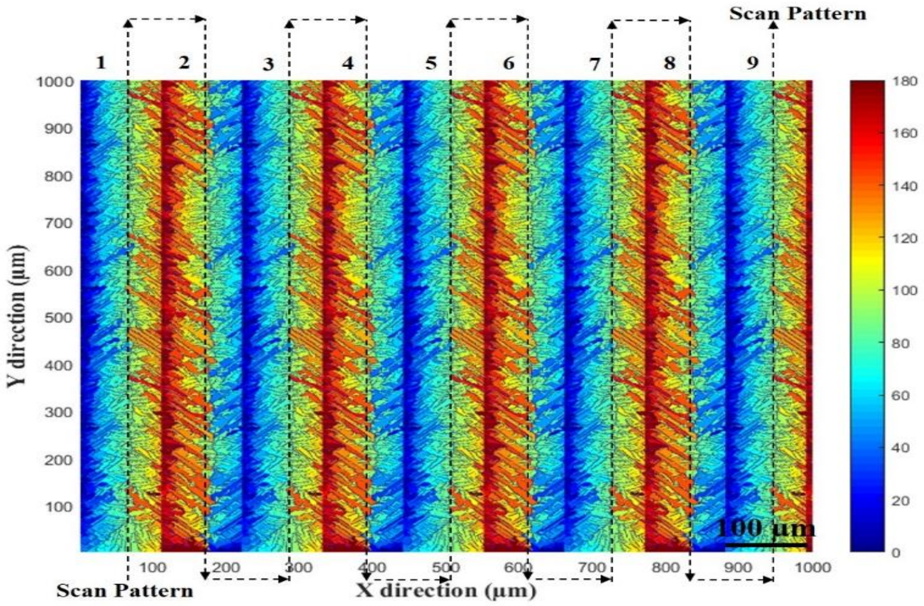


Proses Simülasyonu, Metal Eklemeli İmalat Üretiminin İLK KEZ doğru yapılması için kilit adımdır!

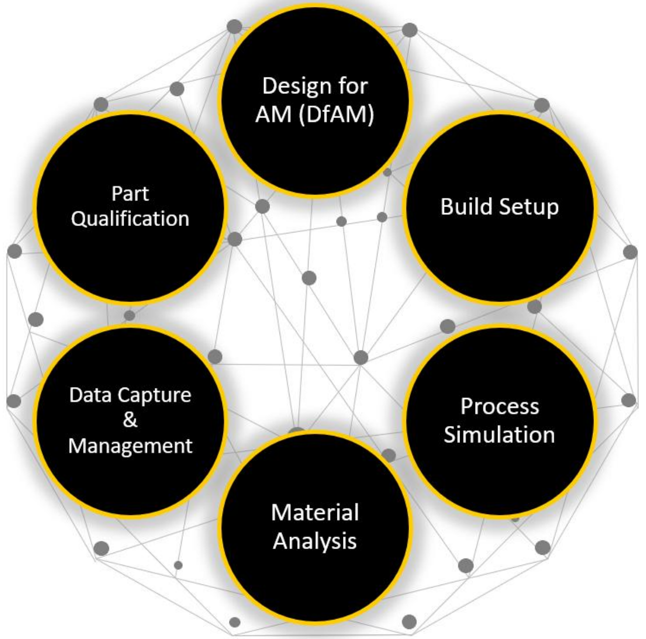
- Çarpılma tahmini
- Bıçak çarpması tahmini
- Gerilme ve şekil değiştirme belirleme
- Karışık destek yapı tipleri
- Post İşleme Oluşturma
- Tabladan çıkarma
- Destek kaldırma
- Isıl işlemler

Eriyik malzeme tahmini ve analizi

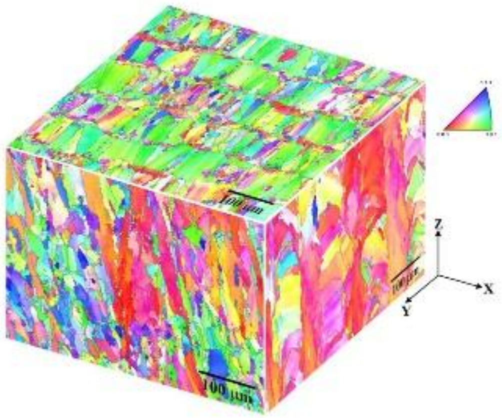


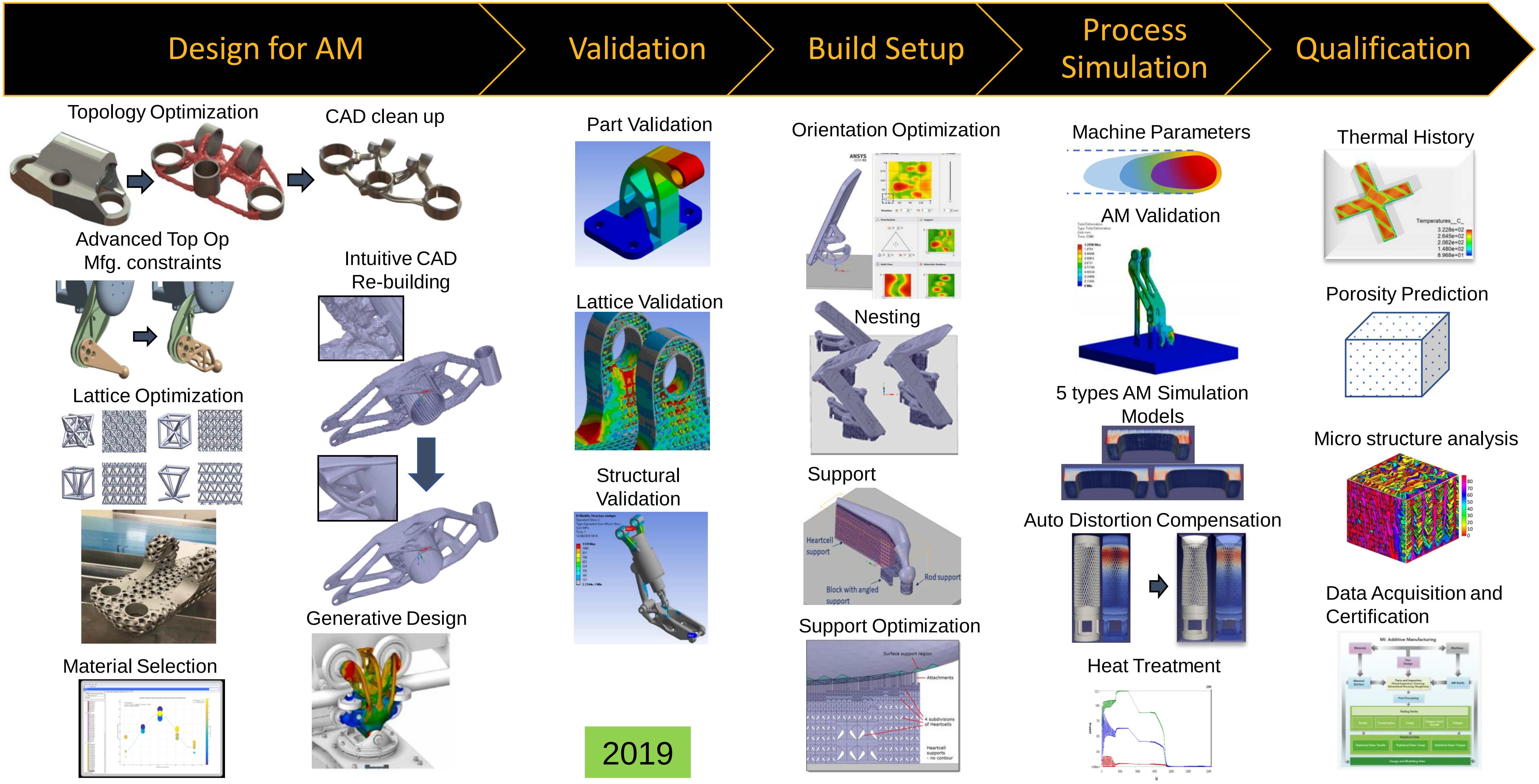


Porozite tahmini- % Mikroyapı porozite tahmini – tanecik sınırı – büyüklüğü ve oryantasyonu analizi



Termal sensör simülasyonu




Design for AM
Validation
Build Setup
Process Simulation
Qualification
Topology Optimization
CAD clean up
Advanced Top Op
Mfg. constraints
Intuitive CAD
Re-building
Lattice Optimization
Generative Design
Material Selection
Part Validation
Lattice Validation
Structural
Validation
2019
Orientation Optimization
Nesting
Support
Heartcell
support
Block with angled
support
Rod support
Support Optimization
Surface support region
Attachments
4 subdivisions
of Heartcells
Heartcell
supports
- no contour
Machine Parameters
AM Validation
5 types AM Simulation
Models
Auto Distortion Compensation
Heat Treatment
Thermal History
Temperatures__C_
3.228e+02
2.645e+02
2.062e+02
1.480e+02
8.968e+01
Porosity Prediction
Micro structure analysis
Data Acquisition and
Certification

Teşekkürler…