

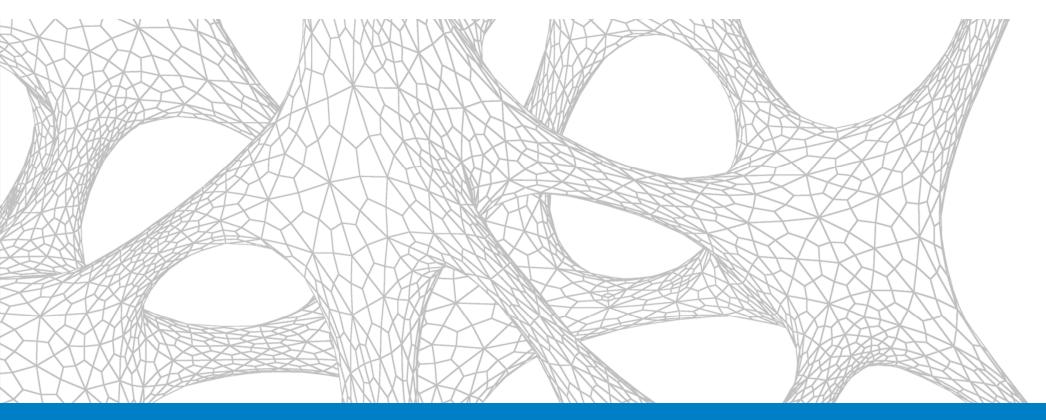
# Topology Optimization in Autodesk Nastran In-CAD

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- Topology Optimization Basics
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- GE Bracket Challenge Problem
- Live Demo Problems



# Learning Objectives

# **Learning Objectives**

- Understand the basics of Topology Optimization in Autodesk Nastran In-CAD
- Learn how to modify an existing design to remove unnecessary material and make it more efficient and how to generate a design from an empty design space
- Understand the limitations of Topology Optimization in Autodesk Nastran In-CAD
- Understand the workflow involved in setting up and performing a Topology Optimization and how to generate an optimized design



### Definitions

# **Definitions**

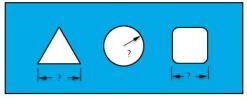
- **Objective** The goal of the design analysis
- Design Constraint Specific limits on results such as displacement at point, temperature, stress, etc.
- Manufacturing Constraint Specifies how a design region will be manufactured such as extruded along and axis or symmetric about a plane
- **Compliance** The inverse of stiffness
- Volume Fraction The ratio of full volume to reduced volume (effectively the same as mass fraction when density is constant in a design region)
- Design Sensitivity The gradient (change) of the objective (or constraint) with respect to the design variable (element density)

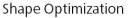


# **Topology Optimization Basics**

# **Topology Optimization**

- Shape optimization: Maintain the topology, change dimensions
- Topology optimization: Determine layouts

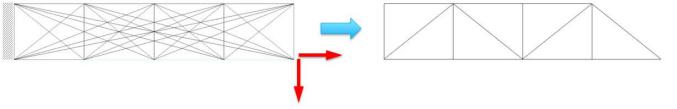






**Topology Optimization** 

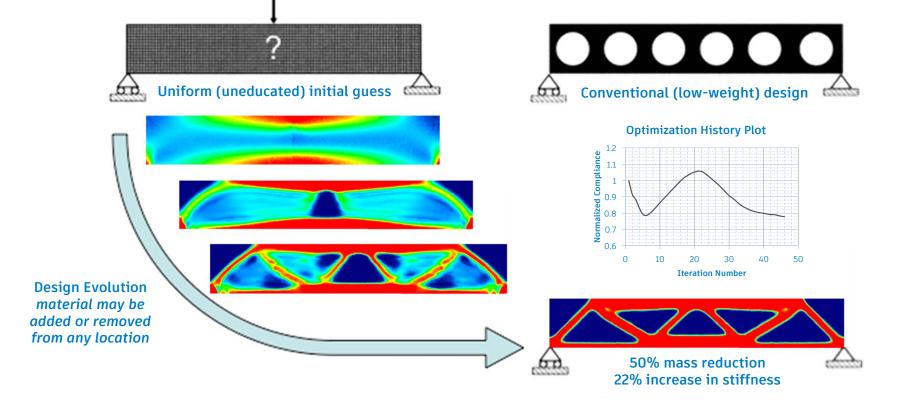
- Method with Finite Element Analysis
  - Initial method...truss



- Change member area and remove when area goes to zero
- Discrete variables, predetermined nodal locations

# **Topology Optimization with FEA**

- Determination of optimal principal material distribution for a given problem
- A powerful tool for concept design stage



# **Topology Optimization Using SIMP - Nastran**

For fixed mesh, determine density (x<sub>e</sub>) of each element

Structural volume

- Element stiffness [k<sub>e</sub>] = (x<sub>e</sub>)<sup>p</sup>[k<sub>0</sub>]
- SIMP = Solid Isotropic Material Penalization

(Not limited to isotropic materials)

 $x_e = 0$ : void  $x_e = 1$ : material Design variable

 $V(\mathbf{x}) = \sum_{i=1}^{NE} x_e v_0$   $v_0$ : volume of an element

- Exponent p:
  - Reduce grey area, force zero or one
  - Typically, p = 3

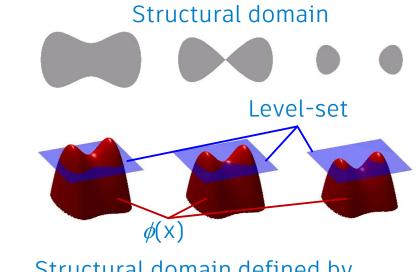
# **Topology Optimization Using Level-Set**

- Front or boundary tracking method
- Commonly used in image processing, moving boundary problems, multiphase problems, movies, etc.
- Structural domain is defined by level-set function f(x)

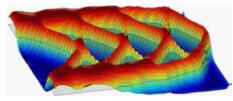
$$\rho = \begin{cases} \mathbf{0} : \phi < \mathbf{0} \\ \mathbf{1} : \phi \ge \mathbf{0} \end{cases}$$

- Level-set function f(x) is defined using nodal values and interpolation
- Boundary = zero level-set

$$\phi$$
 (**x**) = C



Structural domain defined by different level-set values



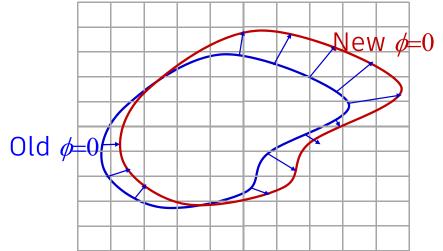
Level-set function  $\phi(x)$ 

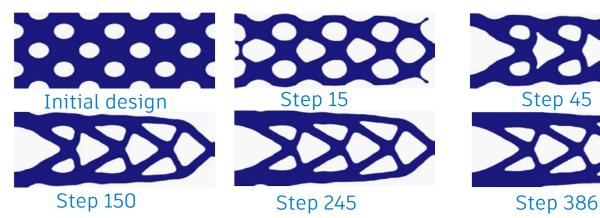


Structural domain

# **Topology Optimization Using Level-Set**

- How to change the shape?
  - Moving the boundary of level-set (solving Jacobi-Hamilton diff. eq.)
  - Introducing new holes
  - Merging holes





Z. Luo Appl. Mech. Eng. 2013

### **Misconception of Level-Set Method**

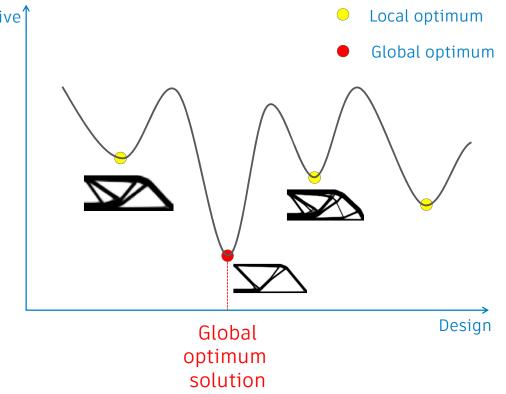
- Smooth and crisp boundary descriptions
  - Most level-set methods do not use clear boundary information in FEA simulation, but the same grey-scale information
  - It is claimed by some that level-set is more accurate than SIMP
    - In reality, when the boundary cuts an element, the level-set calculates the volume fraction (similar concept as SIMP) of the boundary and use it for FEA simulation
    - The quality of FEA result will be the same as SIMP

#### **Density method versus Level-Set Method**

Density method (SIMP)	Level Set					
Difficult to define objective and constraints on the boundary	Explicit formulation objective and constraints on the interface and boundary					
Need an extra process to integrate shape and topology optimization (generate geometry)	Convenient to integrate the shape and topology optimization					
Versatile in terms of additive design	Restricted to evolve geometry from existing boundaries					
Holes and cutouts can be introduced anytime during optimization	Difficult to introduce a new hole, affecting the convergence					
Well studied convergence	Convergence is strongly influenced by spatial gradients near the boundary					
Optimum results are insensitive to starting volume fraction	The results strongly depend on starting guess					
Most mature method (most commercial software uses the density method)	Presence of unresolved challenges (regularization, spatial gradients control, member size control, etc)					
Need filtering to prevent checker-boarding	Need special treatments on the boundary in order to prevent oscillation and too-fast growth					

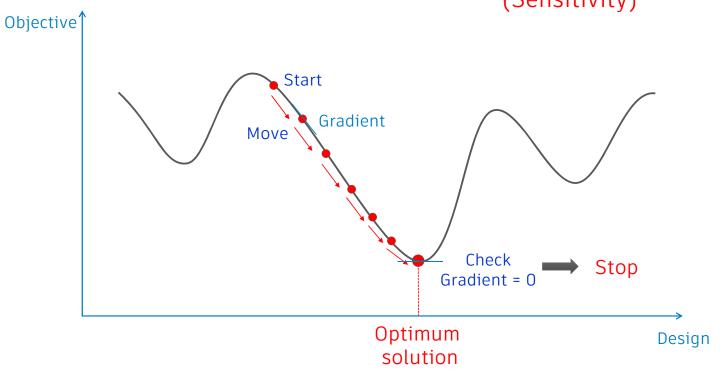
# **Global Versus Local Minimum**

- Optimization algorithm Objective searches for local minimum...global minimum is not guaranteed
- Starting with different initial volume fractions and different mesh densities will result in different designs



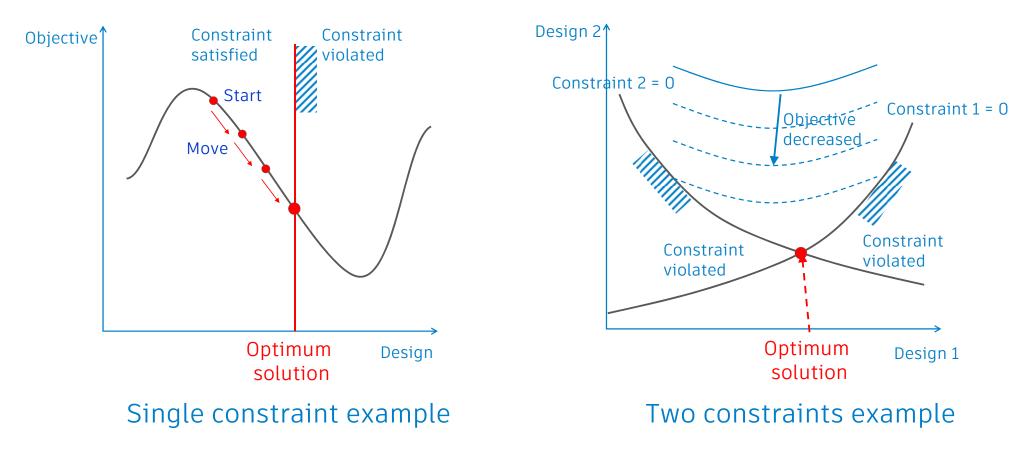
## **Gradient-based Methods**

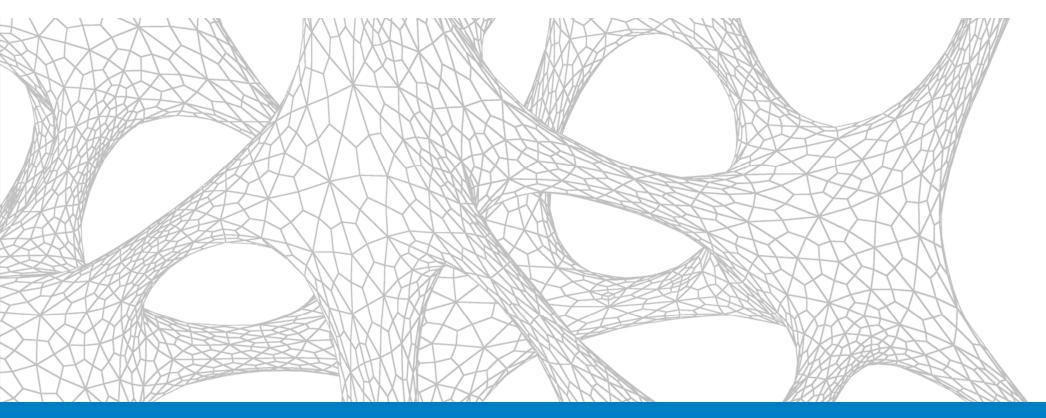
We do not know the function before optimization We can only evaluate the function and gradient at a given design (Sensitivity)



# How Constraints Play in Optimization?

#### Most cases, constraints determine optimal design





# **Objectives and Constraints**

#### In-CAD Topology Optimization Objectives

Objective	Min/Max/Either	Multiple Load Cases	Solution Sequence
Compliance	Min	Yes	LS
Compliance Index	Min	Yes	LS
Max Displacement Component in Model	Min	No	LS
Specific Grid Point Displacement Component	Min	No	LS
Max Constraint Force Component in Model	Min	No	LS
Specific Constraint Force Component	Min	No	LS
Stress of a Specific TOPVAR Region	Min	No	LS
Stress of all TOPVAR Regions	Min	No	LS
Volume Fraction (Mass Fraction) of a specific TOPVAR Region	Min	Yes	LS
Volume Fraction (Mass Fraction) of all TOPVAR Regions	Min	Yes	LS
Thermal Energy of a Specific TOPVAR Region (Compliance)	Min	Yes	LSSHT
Thermal Energy of all TOPVAR Regions (Compliance)	Min	Yes	LSSHT
Average Temperature of a Specific Set of Nodes	Either	No	LSSHT
Delta Temperature of a Specific Set of Nodes	Either	No	LSSHT
Global Temperature of a Specific Set of Nodes	Either	No	LSSHT
Normal Modes Frequency	Max	Yes	NM
Normal Modes Eigenvalue	Мах	Yes	NM
Buckling Modes Eigenvalue (load factor)	Мах	No	LB

LS = Linear Statics, LSSHT = Linear Steady-State Heat Transfer, NM= Normal Modes, LB = Linear Buckling

#### In-CAD Topology Optimization Design Constraints

Design Constraints	Range	Multiple Load Cases	Individual Load Cases	Solution Sequence
Compliance	Range	Yes	Yes	LS
Compliance Index	< Upper	Yes	Yes	LS
Max Displacement Component in Model	< Upper	Yes	Yes	LS
Specific Grid Point Displacement Component	Range	Yes	Yes	LS
Max Constraint Force Component in Model	< Upper	Yes	Yes	LS
Specific Constraint Force Component	Range	Yes	Yes	LS
Stress of a Specific TOPVAR Region	< Upper	Yes	Yes	LS
Stress of all TOPVAR Regions	< Upper	Yes	Yes	LS
Volume Fraction (Mass Fraction) of a specific TOPVAR Region	< Upper	Yes	Yes	LS
Volume Fraction (Mass Fraction) of all TOPVAR Regions	< Upper	Yes	Yes	LS
Thermal Energy of a Specific TOPVAR Region	Range	Yes	Yes	LSSHT
Thermal Energy of all TOPVAR Regions	Range	Yes	Yes	LSSHT
Average Temperature of a Specific Set of Nodes	Range	Yes	Yes	LSSHT
Delta Temperature of a Specific Set of Nodes	Range	Yes	Yes	LSSHT
Global Temperature of a Specific Set of Nodes	Range	Yes	Yes	LSSHT
Normal Modes Frequency	> Lower	No	No	NM
Normal Modes Eigenvalue	Range	No	No	NM
Buckling Modes Eigenvalue (load factor)	Range	No	No	LB

LS = Linear Statics, LSSHT = Linear Steady-State Heat Transfer, NM= Normal Modes, LB = Linear Buckling

#### **Maximum Stress Constraint**

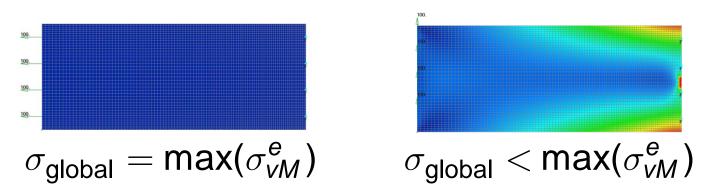
- We want to limit max stress, but...
  - Discontinuous and oscillating
  - Occurs at a localized small number of elements
- We need a smooth and global stress
  - Approximately the same as local, max stress

$$\sigma_{\text{global}} \equiv \sigma_{\text{max}} \left\{ \frac{1}{N} \sum_{e=1}^{N} \left( \frac{\sqrt{\rho_e} \sigma_{vM}^e}{\sigma_{\text{max}}} \right)^p \right\}^{\frac{1}{p}} \le \sigma_{\text{max}}$$

 $\sigma_{max}$ : allowable stress  $\sigma_{vM}$ : Von Mises stress N: # of TO elements p ~ 10: approximation exponent

#### **Global Stress Performance**

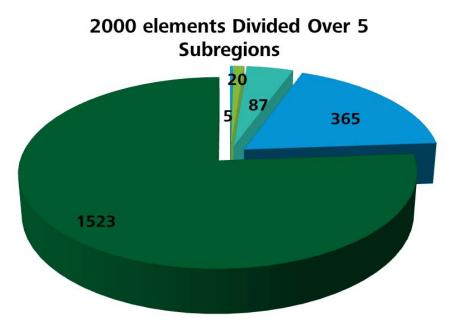
Global stress is good when stress is uniform



 So, it is necessary to group elements to have uniform stress with each group

#### **Global Stress Subdivisions**

- Divide domain into a user defined number of subdomains or sub-regions
- Number of elements in each subregion starts small and increases rapidly with higher stress elements in smaller sub-regions
- Use a sub-region update strategy to allow design convergence
- The number of sub-regions used is a tradeoff between performance and accuracy



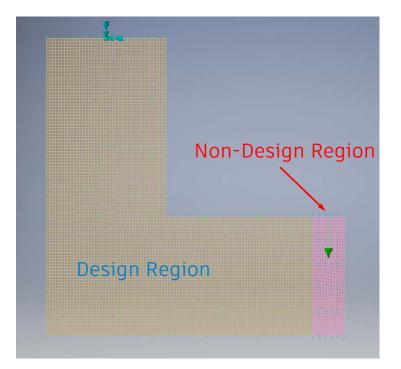
Subdivision/Constraint	Number of Elements				
1	5				
2	20				
3	87				
4	365				
5	1523				

#### **In-CAD Topology Optimization Manufacturing Constraints**

Manufacturing Constraints	Combinable With
Non-Design Regions	All
Minimum Member Size	All
Symmetry	Min Member Size
Design for Extrusion	Min Member Size
Design for Milling	Min Member Size
Design for AM	Min Member Size

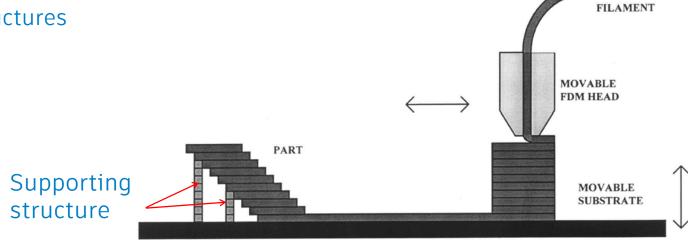
#### **Region-Based Topology Optimization**

- In-CAD allows for one design region
  - Default is property 1
  - Can be changed using Nastran Parameters if different
- All other properties or regions will not have material removed but can affect the design
- Ideally loads should be applied to non-design regions

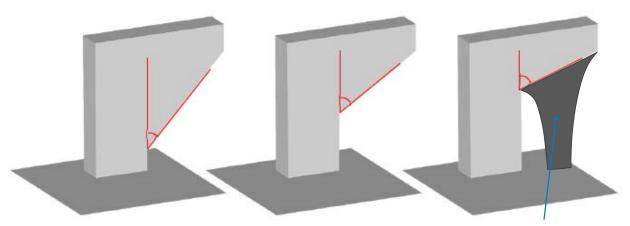


# **Additive Manufacturing Constraint**

- Additive Manufacturing (AM) 3D Printing
  - Bottom-up layer-by-layer manufacturing process
  - Allow for more manufacturing options
    - Possible for traditionally impossible designs
    - Flexible process time
    - Need supporting structures



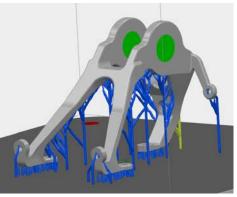
#### AM Limitation: Critical Overhang Angle



Manufacturable

Supporting structure

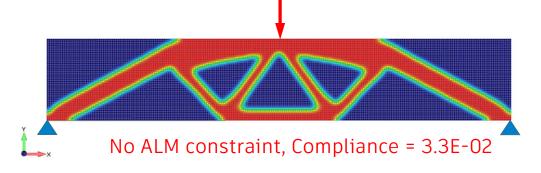
- Overhang structure must be removed using machining
  - Manually design overhang structure
  - Requires extra cost
  - Sometimes impossible to remove (inside feature)



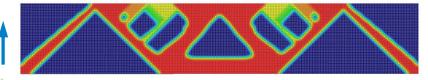
# **Existing Solutions to Overhang Problem**

- Adjust part orientation
- Adjust part itself
- Add support structures
- The aim is to include overhang restrictions in topology optimization
  - No need for support structures: less material usage
  - Less pre-processing for AM
  - Less post-processing: faster production, lower costs

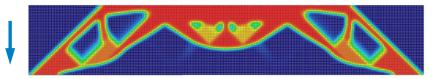
### Additive Manufacturing Constraint - ALM



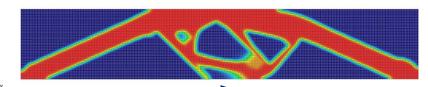
- Fixed at lower corners and point loaded at the top, mid-span
- Objective is minimize compliance (maximize stiffness)
- Constraint is fixed volume fraction of 0.4 (reduce volume to 40% of its original)
- Manufacturing constraints: ALM or Additive Manufacturing, 45 deg. max overhang angle



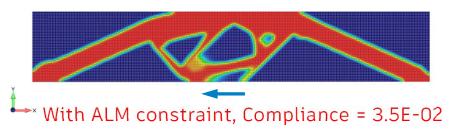
With ALM constraint, Compliance = 5.9E-02



With ALM constraint, Compliance = 1.2E-01

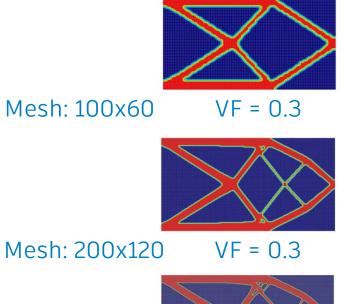


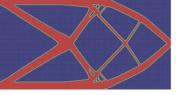
With ALM constraint, Compliance = 3.5E-02



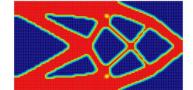
#### **Effect of Mesh Density and Volume Fraction Constraint**

**Objective:** minimize compliance, Constraint: Volume fraction (VF)





Mesh: 400x240 VF = 0.3



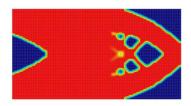
VF = 0.5



VF = 0.5



VF = 0.5



VF = 0.8



VF = 0.8



VF = 0.8

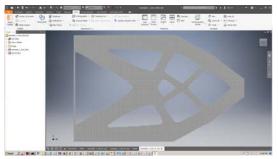
#### **Minimum Member Size Manufacturing Constraint**

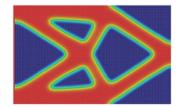


- Fixed at one end and edge loaded at the other end
- Objective is minimize mass
- Constraint is maximum vertical displacement at loaded edge
- Manufacturing constraint: minimum member size (prevents non-designable feature generation)

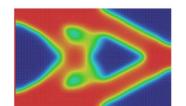


Min member size = <u>2.0</u> 50.6% mass reduction

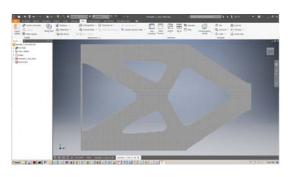


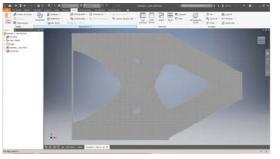


Min member size = 4.047.2% mass reduction

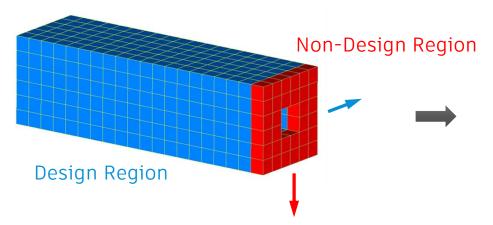


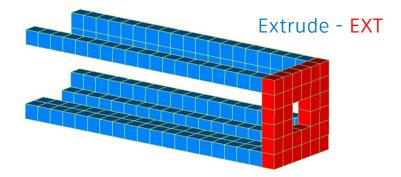
Min member size = <u>6.0</u> 40.4% mass reduction



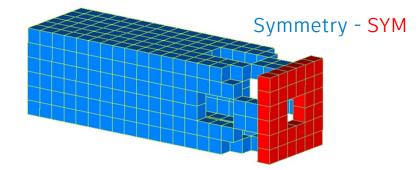


### **Extrude and Symmetry Manufacturing Constraints**

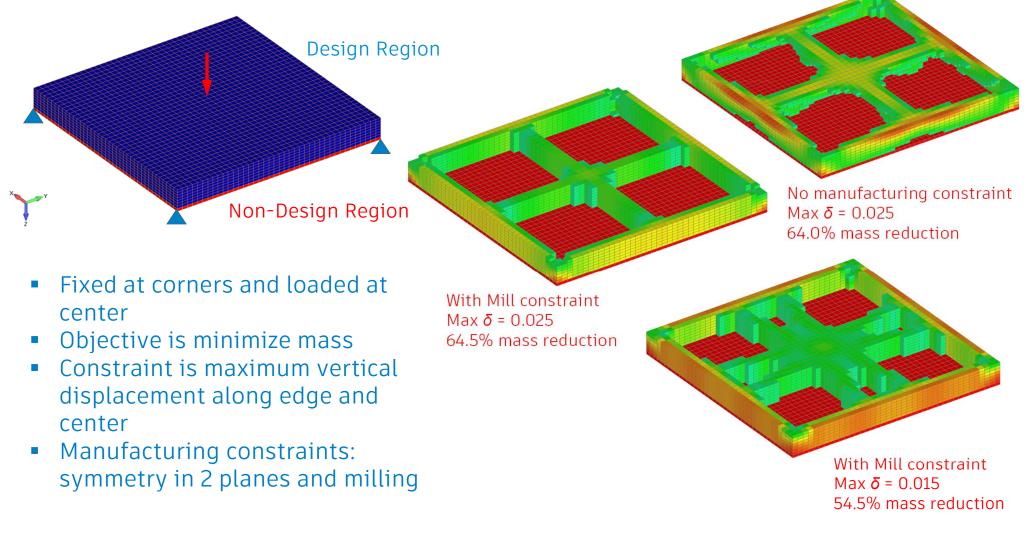




- Fixed at one end and symmetrically point loaded at the other end with 2 separate load cases
- Global max displacement design constraint limited to 0.3 in the direction of load in each load case
- Objective is minimize mass/volume
- Manufacturing constraints: extrusion, symmetry



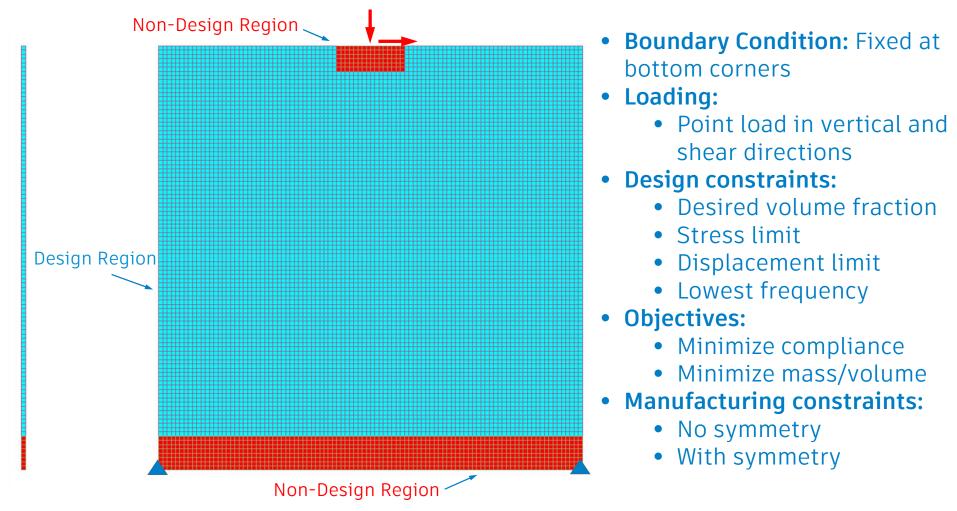
#### Milling Manufacturing Constraint - MILL





# In-CAD Topology Optimization User Interface

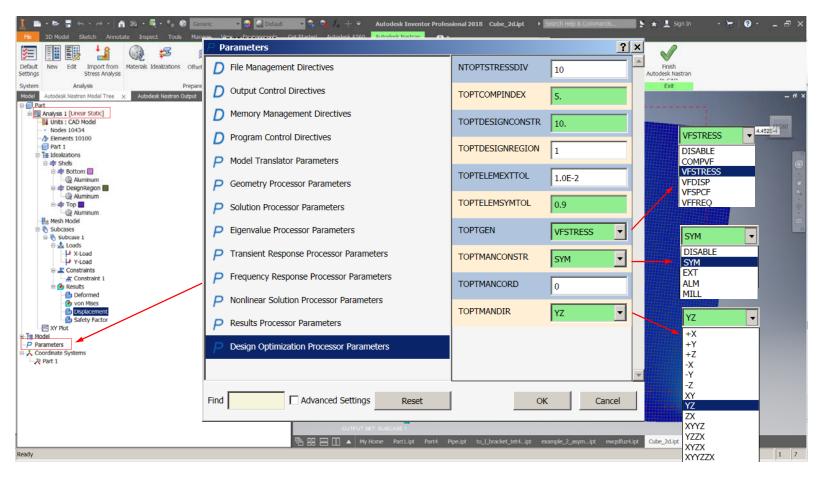
# **Example #1 Model Definition**



# **Topology Optimization Example #1**

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## **Topology Optimization Example #1**



#### **In-CAD Optimization Parameters - TOPTGEN**

Parameters		?
File Management Directives	MAXTOPTITER	200
Output Control Directives	NTOPTSTRESSDIV	10
Memory Management Directives	TOPTBTHRESHOLD	0.5
Program Control Directives	TOPTCOMPINDEX	1.0E+10
Model Translator Parameters		1.02+10
Geometry Processor Parameters	TOPTDATABASE	DELETE
Solution Processor Parameters	TOPTDESIGNCONSTR	5.
P Eigenvalue Processor Parameters	TOPTDESIGNREGION	3
P Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13
P Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2
P Results Processor Parameters	TOT TELEPISITINGE	
Design Optimization Processor Parameters	TOPTGEN	VFSTRESS
P Eigenvalue Processor Parameters	TOPTITERTOL	COMPVF VFSTRESS
P Transient Response Processor Parameters	TOPTMANCONSTR	VFDISP VFSPCF
P Frequency Response Processor Parameters	TOPTMANCORD	VFFREQ 0
P Nonlinear Solution Processor Parameters	TOPTMANDIR	
P Results Processor Parameters	TOPTMANDIK	XY •
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO 💌
	ТОРТМАХВЕТА	AUTO
ind	0	Cancel

Keyword	Objective	Design Constraint(s)	Solution Type
DISABLE	N/A	Topology optimization is disabled	N/A
COMPVF	Minimize compliance	Mass/volume fraction below	Linear Statics
VFSTRESS	Minimize mass	Max stress and compliance index in design region below a specified value	Linear Statics
VFDISP	Minimize mass	Max displacement and compliance index in model below a specified value	Linear Statics
VFSPCF	Minimize mass	Max reaction force and compliance index in model below a specified value	Linear Statics
VFFREQ	Minimize mass	Frequency above a specified value	Normal Modes

### **In-CAD Optimization Parameters - TOPTDESIGNCONSTR**

Parameters		?	1
File Management Directives	MAXTOPTITER	200	1
Output Control Directives	NTOPTSTRESSDIV	10	1
Memory Management Directives	TOPTBTHRESHOLD	0.5	1
Program Control Directives	TOPTCOMPINDEX	1.0E+10	1
Model Translator Parameters	TOPTPATABACE		1
Geometry Processor Parameters	TOPTDATABASE	DELETE	
P Solution Processor Parameters	TOPTDESIGNCONSTR	5.	
P Eigenvalue Processor Parameters	TOPTDESIGNREGION	3	
P Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13	1
P Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2	1
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2	1
P Results Processor Parameters	TOPTGEN		1
Design Optimization Processor Parameters	TOPTOEN	VFSTRESS	
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3	
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Description	Туре	Default
Topology design optimization design constraint value based on the TOPTGEN setting. See TOPTGEN.	Real > 0.0	1.0E+10

TOPTGEN Setting	TOPTDESIGNCONSTR Description
COMPVF	Volume fraction upper limit between 0.05 and 1.0
VFSTRESS	Stress upper limit
VFDISP	Displacement upper limit
VFSPCF	Reaction force upper limit
VFFREQ	Frequency lower limit

### **In-CAD Optimization Parameters - NTOPTSTRESSDIV**

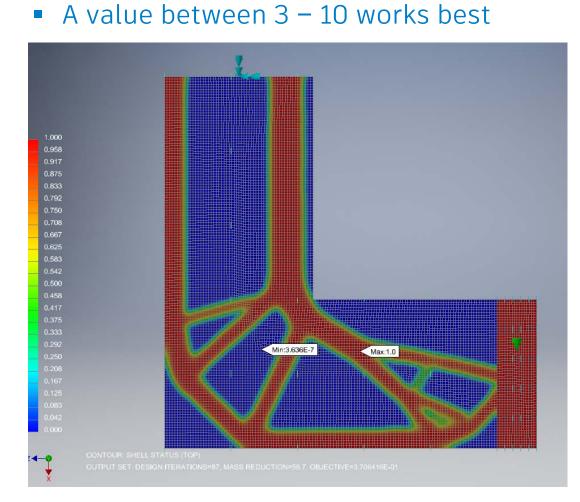
Parameters		?
File Management Directives	MAXTOPTITER	200
D Output Control Directives	NTOPTSTRESSDIV	10
Memory Management Directives	TOPTBTHRESHOLD	0.5
Program Control Directives	TOPTCOMPINDEX	1.0E+10
P Model Translator Parameters		102.10
P Geometry Processor Parameters	TOPTDATABASE	DELETE
P Solution Processor Parameters	TOPTDESIGNCONSTR	5.
P Eigenvalue Processor Parameters	TOPTDESIGNREGION	3
P Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13
P Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2
Results Processor Parameters		
Design Optimization Processor Parameters	TOPTGEN	VFSTRESS
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE -
P Frequency Response Processor Parameters	TOPTMANCORD	0
P Nonlinear Solution Processor Parameters	TOPTMANDIR	
P Results Processor Parameters		XY •
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO -
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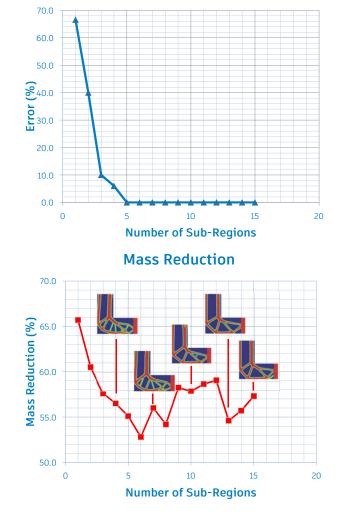
Description	Туре	Default
Topology design optimization number of stress divisions. Applicable when a stress constraint is specified. A larger value will produce a more accurate result with a reduction in performance. A value between 5 and 10 is recommended.	1 ≤ Integer ≤ 100	10

DESIGN OBJECTIVE DRESP 1	CURRENT VALUE 3.706E-01		
DESIGN CONSTRAINT DRESP 3 1	CURRENT VALUE 1.081E+00	LIMIT VALUE 1.000E+10	STATUS PASS
DRESP         2_1_1           DRESP         2_1_2           DRESP         2_1_3           DRESP         2_1_4           DRESP         2_1_6           DRESP         2_1_6           DRESP         2_1_6           DRESP         2_1_7           DRESP         2_1_6           DRESP         2_1_7           DRESP         2_1_8           DRESP         2_19           DRESP         2_1210	4.443E+00 4.030E+00 5.003E+00 5.034E+00 4.835E+00 4.595E+00 4.595E+00 4.247E+00 4.121E+00 2.583E+00	S.000E+00 S.000E+00 S.000E+00 S.000E+00 S.000E+00 S.000E+00 S.000E+00 S.000E+00 S.000E+00 S.000E+00 S.000E+00	PASS PASS PASS PASS PASS PASS PASS PASS
DESIGN ITERATION CO DENSITY MASS REDUCT ESTIMATED REMAINING ESTIMATED REMAINING	TON = 58.8 DESIGN ITERATION		

#### L-Bracket Test Case - NTOPTSTRESSDIV

Stress Error





### **In-CAD Optimization Parameters - TOPTCOMPINDEX**

Parameters		<u>?</u>
File Management Directives	MAXTOPTITER	200
Output Control Directives	NTOPTSTRESSDIV	10
Memory Management Directives	TOPTBTHRESHOLD	0.5
Program Control Directives	TOPTCOMPINDEX	1.0E+10
P Model Translator Parameters		1.02+10
P Geometry Processor Parameters	TOPTDATABASE	DELETE
P Solution Processor Parameters	TOPTDESIGNCONSTR	5.
P Eigenvalue Processor Parameters	TOPTDESIGNREGION	3
P Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13
P Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2
P Results Processor Parameters		
Design Optimization Processor Parameters	TOPTGEN	VFSTRESS
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE -
P Frequency Response Processor Parameters	TOPTMANCORD	0
P Nonlinear Solution Processor Parameters	TOPTMANDIR	XY 🔻
P Results Processor Parameters		
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO 🔻
	ΤΟΡΤΜΑΧΒΕΤΑ	AUTO
ind Advanced Settings Reset	0	K Cancel

Description	Туре	Default
Topology design optimization compliance index design constraint value. Applicable only when TOPTGEN is set to 2, 3, or 4.	Real > 1.0	1.0E+10

ESIGN OBJECTIVE RESP 1	CURRENT VALUE 3.706E-01		
DESIGN CONSTRAINT	CURRENT VALUE 1.081E+00	LIMIT VALUE 1.000E+10	STATUS PASS
DRESP 2 1 1	4.443E+00	5.000E+00	PASS
DRESP 2 1 2	4.030E+00	5.000E+00	PASS
DRESP 2_1_3	4.890E+00	5.000E+00	PASS
DRESP 214	5.003 <b>E+00</b>	5.000 <b>E+00</b>	PASS
DRESP 2_1_5	5.034 <b>E+00</b>	5.000 <b>E+00</b>	PASS
DRESP 2_1_6	4.835 <b>E+00</b>	5.000 <b>E+00</b>	PASS
DRESP 2_1_7	4.595 <b>E+00</b>	5.000 <b>E+00</b>	PASS
DRESP 2_1_8	4.247 <b>E+</b> 00	5.000 <b>E+00</b>	PASS
DRESP 2_1_9	4.121 <b>E+</b> 00	5.000 <b>E+00</b>	PASS
DRESP 2_1_10	2.583 <b>E+00</b>	5.000 <b>E+00</b>	PASS
DESIGN ITERATION CO DENSITY MASS REDUCT			
ESTIMATED REMAINING ESTIMATED REMAINING			

#### **In-CAD Optimization Parameters - TOPTDESIGNREGION**

Parameters			?
D File Management Directives	MAXTOPTITER	200	
Output Control Directives	NTOPTSTRESSDIV	10	1
Memory Management Directives	TOPTBTHRESHOLD	0.5	1
Program Control Directives	TOPTCOMPINDEX	1.0E+10	=
P Model Translator Parameters			
P Geometry Processor Parameters	TOPTDATABASE	DELETE	-
P Solution Processor Parameters	TOPTDESIGNCONSTR	5.	
P Eigenvalue Processor Parameters	TOPTDESIGNREGION	3	
P Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13	
P Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2	
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2	
P Results Processor Parameters			
Design Optimization Processor Parameters	TOPTGEN	VFSTRESS	•
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3	
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE	•
P Frequency Response Processor Parameters	TOPTMANCORD	0	7
P Nonlinear Solution Processor Parameters	TOPTMANDIR	xy	Ţ
P Results Processor Parameters			
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO	-
	TOPTMAXBETA	AUTO	
Find Advanced Settings Reset	0	K Cance	el .

	Description	Туре	Default
	Topology design optimization design region property identification number.	Integer > 0	1
Analysis 1 [Normal Modes] Analysis 1 [Normal Modes] I Units : CAD Model - Nodes 10435 - Veterments 10100 Part 1 B Tal Idealizations - M Top I - M Top I - M Top I - M Modal Setup 1 - M Notal - M N	Idealizations       Image: Standard         Name:       DesignRegion         D:       1         Type:       Image: Standard         Type:       Image: Im		

Note: Specifying the wrong ID may result in an 2299 or 5125 fatal error

### **In-CAD Optimization Parameters - TOPTMANCONSTR**

Parameters	?
File Management Directives	MAXTOPTITER 200
Output Control Directives	NTOPTSTRESSDIV 10
Memory Management Directives	TOPTBTHRESHOLD 0.5
Program Control Directives	TOPTCOMPINDEX 1.0E+10
P Model Translator Parameters	
Geometry Processor Parameters	TOPTDATABASE DELETE
P Solution Processor Parameters	TOPTDESIGNCONSTR 5.
P Eigenvalue Processor Parameters	TOPTDESIGNREGION 3
P Transient Response Processor Parameters	TOPTDESIGNTOL 1.0E-13
P Frequency Response Processor Parameters	TOPTELEMEXTTOL 1.0E-2
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL 1.0E-2
P Results Processor Parameters	
Design Optimization Processor Parameters	WISHLESS _
P Eigenvalue Processor Parameters	TOPTITERTOL 5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR SYM
P Frequency Response Processor Parameters	TOPTMANCORD DISABLE SYM
P Nonlinear Solution Processor Parameters	TOPTMANDIR ALM
P Results Processor Parameters	MILL
P Design Optimization Processor Parameters	TOPTMAXACTDIST AUTO
	TOPTMAXBETA AUTO
ind Advanced Settings Reset	OK Cancel

Description	Туре	Default
Defines the type of manufacturing constraint to be used in Automated Topology Optimization Generation (ATOG). There are three options:	0 ≤ Integer ≤ 3	0
0 - No manufacturing constraint is specified.	DISABLE/	
1 - Symmetry using either 1, 2, or 3 planes of symmetry is specified.	SYM/	
	EXT/	
2 - Extrude design constraint is specified.	ALM/	
3 - Additive layer manufacturing design constraint is specified.	MILL	
4 - 3-axis milling manufacturing design constraint is specified.		
The character variables: DISABLE, SYM, EXT, and ALM may be used in place of the numerical options 0 through 3. See also TOPTMANDIR and TOPTMANCORD.		

#### **In-CAD Optimization Parameters - TOPTMANCORD**

P Parameters		?
File Management Directives	MAXTOPTITER	200
Output Control Directives	NTOPTSTRESSDIV	10
Memory Management Directives	TOPTBTHRESHOLD	0.5
Program Control Directives	TOPTCOMPINDEX	1.0E+10
P Model Translator Parameters		
P Geometry Processor Parameters	TOPTDATABASE	DELETE
P Solution Processor Parameters	TOPTDESIGNCONSTR	5.
P Eigenvalue Processor Parameters	TOPTDESIGNREGION	3
P Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13
P Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2
P Results Processor Parameters		
Design Optimization Processor Parameters	TOPTGEN	VFSTRESS •
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE -
P Frequency Response Processor Parameters	TOPTMANCORD	1
P Nonlinear Solution Processor Parameters	TOTTUNDID	
P Results Processor Parameters	TOPTMANDIR	XY •
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO 🔻
	TOPTMAXBETA	AUTO
Find Advanced Settings Reset	OF	Cancel

Description		Туре	Default	
	esign optimization manufacturing constraint sponding to TOPTMANCONSTR. See also	Integer > 0	0	
	Origin       Point on XZ Plane         Defined:       Ciobal         Global       V:         Y:       47.5         Z:       0         Y:       0         Y:       0         Y:       0         Y:       0         Z:       0         Point on Z Axis		Ţ	
Constraint 1  C	☑     □       Defined:     □       □     □       X:     □       Y:     □       Z:     1   OK Cancel			
- Contour on Deformed - Criterion Contour - Criterion Contour - Parameters - Coordnate System 1 - Coordnate System 1	↓			•

### **In-CAD Optimization Parameters - TOPTMANDIR**

🦻 Parameters		? ×
D File Management Directives	TOPTDESIGNCONSTR	50.
D Output Control Directives	TOPTDESIGNREGION	5
D Memory Management Directives	TOPTDESIGNTOL	1.0E-13
Program Control Directives	TOPTELEMEXTTOL	1.0F-2
P Model Translator Parameters		
P Geometry Processor Parameters	TOPTELEMSYMTOL	0.9
P Solution Processor Parameters	TOPTGEN	VFSTRESS
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR	SYM 🔻
P Frequency Response Processor Parameters	TOPTMANCORD	1
P Nonlinear Solution Processor Parameters	TOPTMANDIR	YZ 🔻
P Results Processor Parameters	TOPTMAXACTDIST	+X
P Design Optimization Processor Parameters	TOPTMAXACTDIST	+Y +Z -X
	TOPTMAXBETA	-X -Y -7
Find Advanced Settings Reset	0	XY XZ
		ZX XYYZ
		YZZX XYZX
		XYYZZX

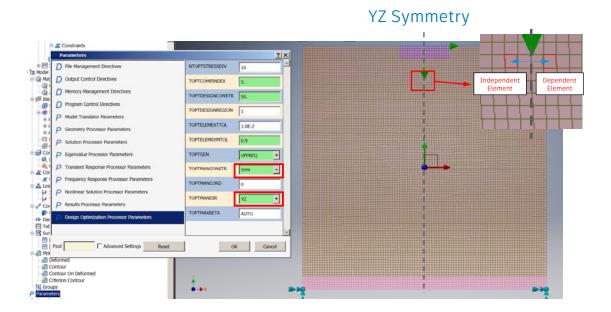
Description	Туре	Default
Specifies the topology design optimization manufacturing constraint symmetry plane(s), extrude direction, or print direction depending on the TOPTMANCONSTR value specified.	+X/+Y/+Z/	XY
	-X/-Y/-Z/	
	XY/YZ/ZX/	
	XYYZ/YZZX/	
	XYZX/	
	XYYZZX	

Keyword	TOPTMANDIR Definition
DISABLE	No manufacturing constraints specified
SYM	Symmetry plane or planes specified in the TOPTMANCORD system
EXT	Extrude direction axis specified in the TOPTMANCORD system
ALM	Print direction axis specified in the TOPTMANCORD system
MILL	Mill direction axis specified in the TOPTMANCORD system

#### **In-CAD Optimization Parameters - TOPTELEMSYMTOL**

Parameters		?
File Management Directives	MAXTOPTITER	200
Output Control Directives	NTOPTSTRESSDIV	10
Memory Management Directives	TOPTBTHRESHOLD	0.5
Program Control Directives	TOPTCOMPINDEX	1.0E+10
P Model Translator Parameters		1.02+10
P Geometry Processor Parameters	TOPTDATABASE	DELETE
P Solution Processor Parameters	TOPTDESIGNCONSTR	5.
P Eigenvalue Processor Parameters	TOPTDESIGNREGION	3
Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13
Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	
P Results Processor Parameters	TOPTELEMSTMTOL	1.0E-2
Design Optimization Processor Parameters	TOPTGEN	VFSTRESS
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE 💌
P Frequency Response Processor Parameters	TOPTMANCORD	0
P Nonlinear Solution Processor Parameters	TOPTMANDIR	
Results Processor Parameters	TOPTMANDIK	XY 💌
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO 💌
	ΤΟΡΤΜΑΧΒΕΤΑ	AUTO
ind Advanced Settings Reset	0	K Cancel

Description	Туре	Default
Near tolerance used to identify elements which are symmetric with respect to the specified TOPVAR Bulk Data entry mirror symmetry plane. The actual tolerance is derived using TOPTELEMSYMTOL and an element reference dimension.	Real	1.0E-2



#### **In-CAD Optimization Parameters - TOPTMAXACTDIST**

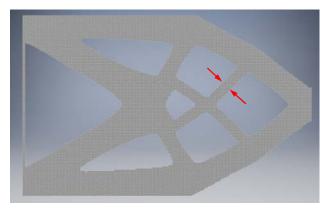
#### Use this to specify a minimum member size

P Parameters		<u>?</u> ×
File Management Directives	MAXTOPTITER	200
D Output Control Directives	NTOPTSTRESSDIV	10
Memory Management Directives	TOPTBTHRESHOLD	0.5
Program Control Directives	TOPTCOMPINDEX	1.0E+10
P Model Translator Parameters		
P Geometry Processor Parameters	TOPTDATABASE	DELETE
P Solution Processor Parameters	TOPTDESIGNCONSTR	5.
P Eigenvalue Processor Parameters	TOPTDESIGNREGION	3
P Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13
P Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2
P Results Processor Parameters	TOPTELEMISTINTOE	1.0E-2
Design Optimization Processor Parameters	TOPTGEN	VFSTRESS
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE 💌
P Frequency Response Processor Parameters	TOPTMANCORD	1
P Nonlinear Solution Processor Parameters	TOPTMANDIR	XY -
P Results Processor Parameters		
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO 🔻
	TOPTMAXBETA	AUTO
Find Advanced Settings Reset		K Cancel

Description	Туре	Default
Topology design optimization maximum distance for identifying adjacent elements. Elements within distance TOPTMAXACTDIST are used for sensitivity filtering. The default AUTO setting is recommended since large values may result in slower performance and undesired results.	Real AUTO	AUTO

TOPTMAXACTDIST is 1/2 minimum member size

• To specify a minimum member size of 1 use 0.5.



#### **In-CAD Optimization Parameters - TOPTMAXBETA**

Parameters		<u>?</u> ×
File Management Directives	MAXTOPTITER	200
Output Control Directives	NTOPTSTRESSDIV	10
Memory Management Directives	TOPTBTHRESHOLD	0.5
Program Control Directives	TOPTCOMPINDEX	1.0E+10
Model Translator Parameters		1.02+10
P Geometry Processor Parameters	TOPTDATABASE	DELETE
P Solution Processor Parameters	TOPTDESIGNCONSTR	5.
P Eigenvalue Processor Parameters	TOPTDESIGNREGION	3
Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13
Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2
P Results Processor Parameters		
Design Optimization Processor Parameters	TOPTGEN	VFSTRESS
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE -
P Frequency Response Processor Parameters	TOPTMANCORD	1
P Nonlinear Solution Processor Parameters	TOPTMANDIR	
P Results Processor Parameters	TOPTMANDIK	XY •
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO 🔽
	ΤΟΡΤΜΑΧΒΕΤΑ	AUTO
ind Advanced Settings Reset		OK Cancel

Description	Туре	Default
Specifies the penalty value for enforcing minimum member size manufacturing constraints. A value between 1.0 and 16.0 is recommended. The default AUTO value selects the best value depending on what other constraints are specified.	Real AUTO	AUTO

### **In-CAD Optimization Parameters - MAXTOPTITER**

Parameters           File Management Directives	MAXTOPTITER	[	?
D File Management Directives	MAXTOPTITER	200	
Output Control Directives	NTOPTSTRESSDIV	10	
Memory Management Directives	TOPTBTHRESHOLD	0.5	_
Program Control Directives	TOPTCOMPINDEX	1.0E+10	_
P Model Translator Parameters	TOT TEOPIL INDEX	1.0E+10	
P Geometry Processor Parameters	TOPTDATABASE	DELETE	•
P Solution Processor Parameters	TOPTDESIGNCONSTR	5.	
P Eigenvalue Processor Parameters	TOPTDESIGNREGION	3	
P Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13	
P Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2	_
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2	_
P Results Processor Parameters		1.02 2	
Design Optimization Processor Parameters	TOPTGEN	VFSTRESS	•
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3	
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE	•
P Frequency Response Processor Parameters	TOPTMANCORD	0	
P Nonlinear Solution Processor Parameters	TOPTMANDIR	xy	
P Results Processor Parameters			
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO	•
	TOPTMAXBETA	AUTO	
ind V Advanced Settlings Reset	O		ncel

Description	Туре	Default
Topology design optimization maximum number of convergence iterations permitted. The solver will iterate until the convergence factor set by TOPTITERTOL is reached or MAXOPTITER iterations have been performed. A zero setting will result in iteration until convergence is reached.	Integer ≥ 0	200

DESIGN OBJECTIVE DRESP 1	CURRENT VALUE 3.706E-01		
DESIGN CONSTRAINT DRESP 3_1 DRESP 2_1_1 DRESP 2_1_2 DRESP 2_1_3 DRESP 2_1_4 DRESP 2_1_5 DRESP 2_1_5 DRESP 2_1_6 DRESP 2_1_6 DRESP 2_1_7 DRESP 2_1_9 DRESP 2_1_10	CURRENT VALUE 1.081E+00 4.443E+00 4.030E+00 5.032E+00 5.032E+00 4.835E+00 4.835E+00 4.595E+00 4.121E+00 2.583E+00	LIMIT VALUE 1.000E+10 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00	STATUS PASS PASS PASS PASS PASS PASS PASS PA
DESIGN ITERATION CO DENSITY MASS REDUCT ESTIMATED REMAINING ESTIMATED REMAINING	ION = 58.8 DESIGN ITERATION	5 = 0 = 0.0 SECONDS	

### **In-CAD Optimization Parameters - TOPTITERTOL**

Parameters     File Management Directives	MAXTOPTITER	200
Output Control Directives	NTOPTSTRESSDIV	10
Memory Management Directives	TOPTBTHRESHOLD	0.5
Program Control Directives	TOPTCOMPINDEX	1.0E+10
P Model Translator Parameters		1.02.10
P Geometry Processor Parameters	TOPTDATABASE	DELETE
Solution Processor Parameters	TOPTDESIGNCONSTR	5.
Eigenvalue Processor Parameters	TOPTDESIGNREGION	3
Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13
Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2
Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2
Results Processor Parameters     Design Optimization Processor Parameters	TOPTGEN	VFSTRESS -
Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE 🔻
P Frequency Response Processor Parameters	TOPTMANCORD	0
P Nonlinear Solution Processor Parameters	TOPTMANDIR	XY -
P Results Processor Parameters		
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO 💌
	ΤΟΡΤΜΑΧΒΕΤΑ	AUTO
ind Advanced Settings Reset		OK Cancel

Description	Туре	Default
Topology design optimization Iterative solver convergence factor. The topology optimization solver will iterate until the convergence factor set by TOPTITERTOL is reached or MAXTOPTITER iterations have been performed.	Real	5.0E-3

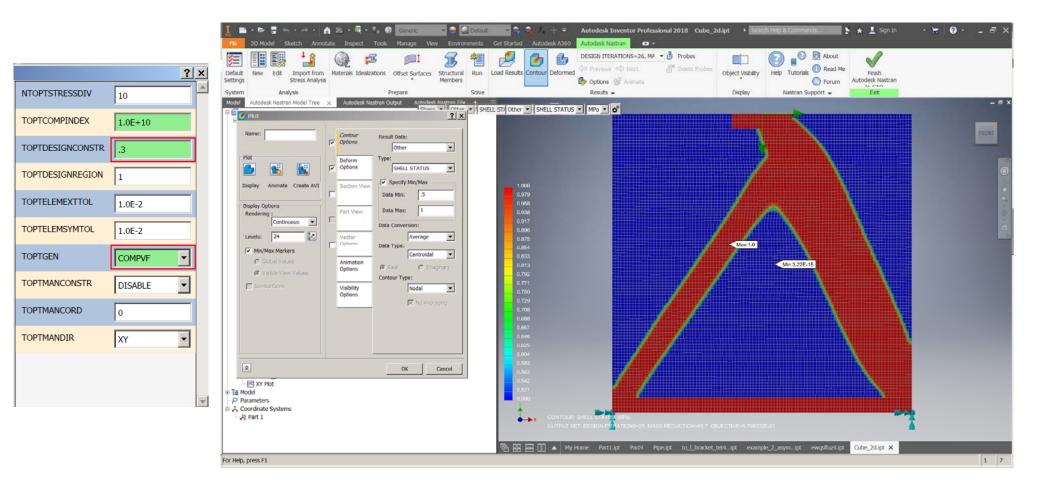
DESIGN OBJECTIVE DRESP 1	CURRENT VALUE 3.706E-01		
DESIGN CONSTRAINT DRESP 3_1 DRESP 2_1_1 DRESP 2_1_2 DRESP 2_1_3 DRESP 2_1_4 DRESP 2_1_5 DRESP 2_1_6 DRESP 2_1_6 DRESP 2_1_7 DRESP 2_1_8 DRESP 2_1_9 DRESP 2_1_10	CURRENT VALUE 1.081E+00 4.43E+00 4.030E+00 5.03E+00 5.034E+00 4.835E+00 4.595E+00 4.247E+00 4.121E+00 2.583E+00	LIMIT VALUE 1.000E+10 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00 5.000E+00	STATUS PASS PASS PASS PASS PASS PASS PASS PA
DRESP 2_1_10 DESIGN ITERATION CO DENSITY MASS REDUCT	NVERGENCE = 100.0		PASS

### **In-CAD Optimization Parameters - TOPTDATABASE**

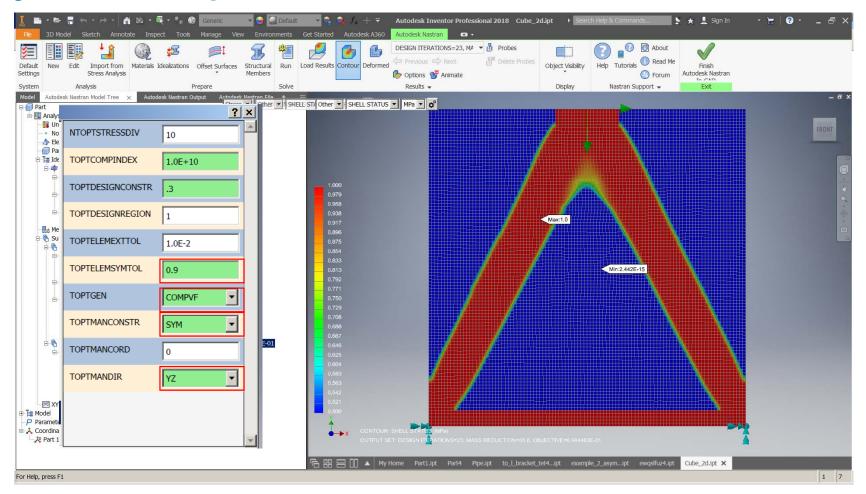
Parameters		?
File Management Directives	MAXTOPTITER	200
Output Control Directives	NTOPTSTRESSDIV	10
Memory Management Directives	TOPTBTHRESHOLD	0.5
Program Control Directives	TOPTCOMPINDEX	1.0E+10
P Model Translator Parameters		1.02.10
Geometry Processor Parameters	TOPTDATABASE	DELETE
Solution Processor Parameters	TOPTDESIGNCONSTR	5.
Eigenvalue Processor Parameters	TOPTDESIGNREGION	3
Transient Response Processor Parameters	TOPTDESIGNTOL	1.0E-13
Frequency Response Processor Parameters	TOPTELEMEXTTOL	1.0E-2
P Nonlinear Solution Processor Parameters	TOPTELEMSYMTOL	1.0E-2
Results Processor Parameters		
Design Optimization Processor Parameters	TOPTGEN	VFSTRESS
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE -
P Frequency Response Processor Parameters	TOPTMANCORD	0
P Nonlinear Solution Processor Parameters	TOPTMANDIR	
P Results Processor Parameters	TOPTMANDIK	XY •
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO 🔻
	ΤΟΡΤΜΑΧΒΕΤΑ	AUTO
ind Advanced Settings Reset	0	K Cancel

Description	Туре	Default
Controls the storage and retrieval of topology design optimization density data. The default value DELETE purges all element density data	DELETE	DELETE
when the program terminates normally. When set to STORE, the converged optimized design is stored in a single file with the same base name as the Madel Baselts Output File and a COR file extension. When	FETCH	
name as the Model Results Output File and a <i>.ODB</i> file extension. When set to FETCH, the optimized design specified by the TOPTDATFILE directive is retrieved and used as the starting point for the subsequent	STORE	
topology design optimization solution sequence. When set to UPDATE, the optimized design data will be retrieved and stored.	UPDATE	

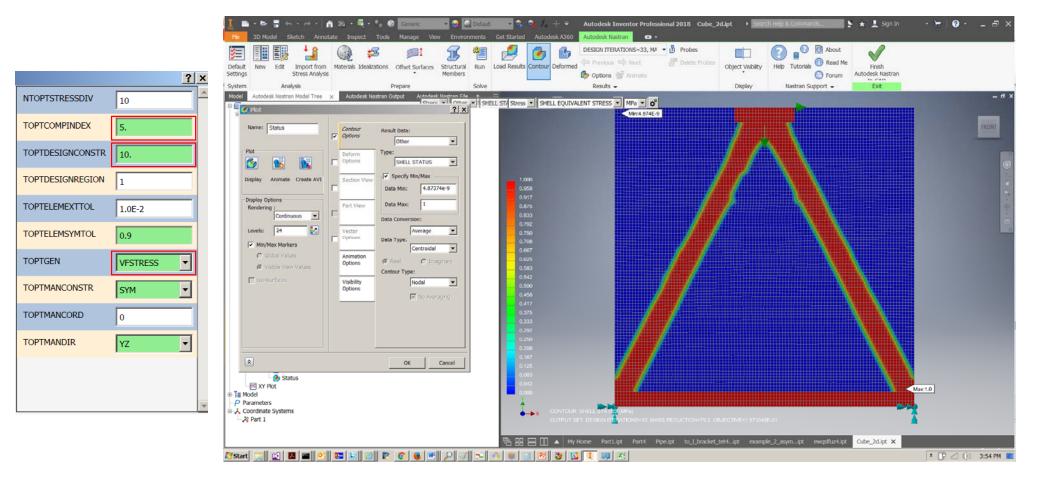
#### **Obj: Min. Compliance, Constraint: Desired VF, no Sym**



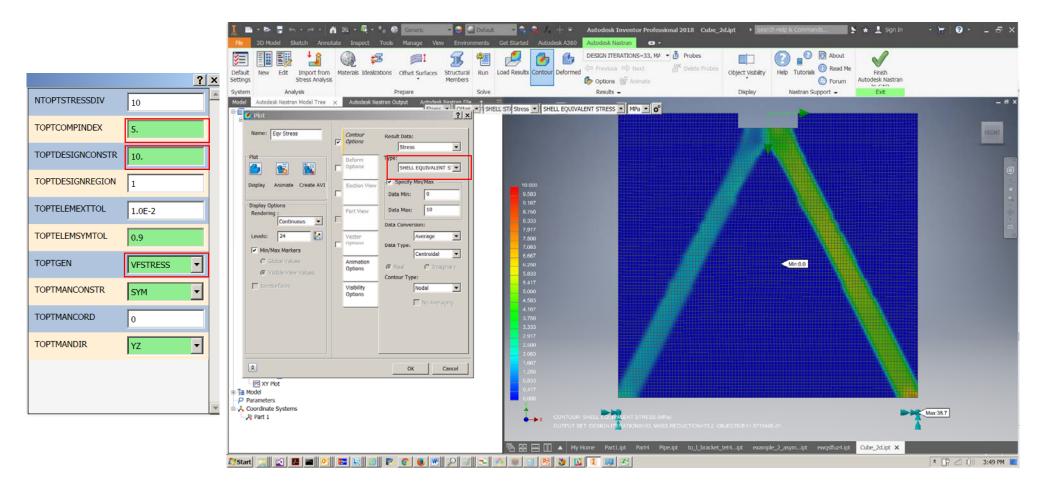
#### **Obj: Min. Compliance, Constraint: Desired VF, with Sym**



#### **Obj: Min. VF (mass), Constraint: Stress & Comp. Index**



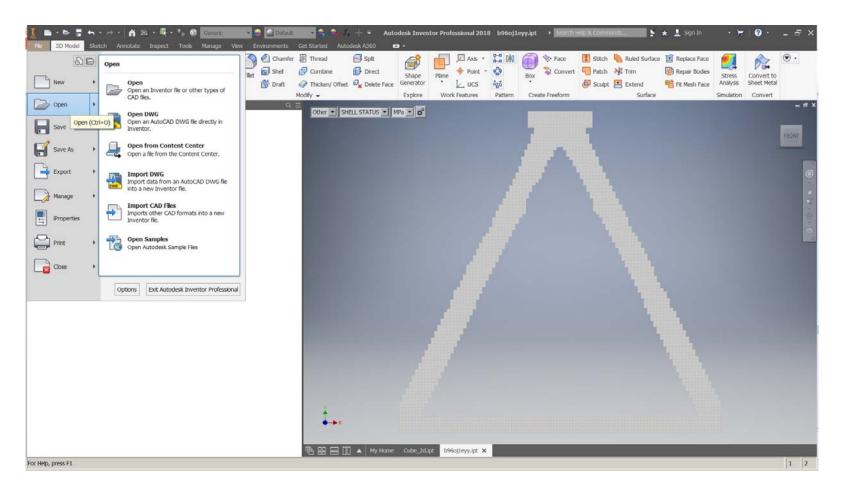
### **Verify Stress Constraint Using Equivalent Stress**



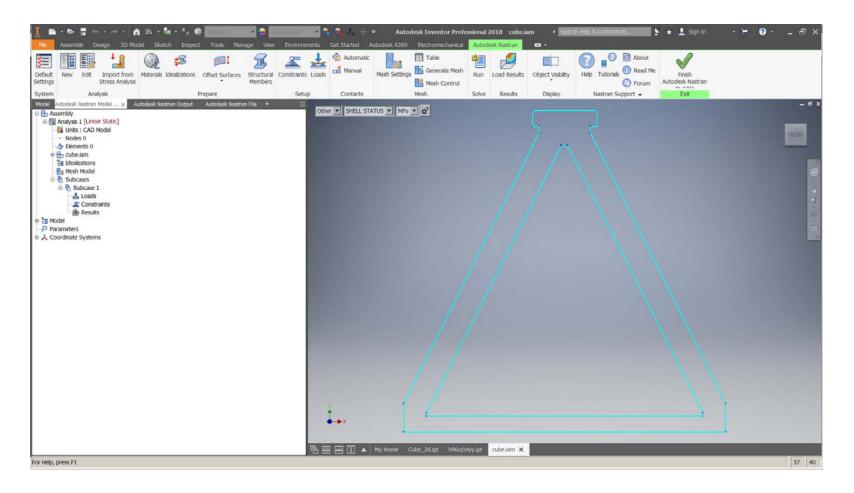
### Verify Stress Constraint Using Equivalent Stress

Settings Stress Analysis • Members System Analysis Prepare Solve	Design Trerations-33, MA     Dip Probes       contour     Deformed       Previous     Previous       Options     Animate       Results     Diskin       Deformed     Previous       Results     Diskin       Deformed     Previous       Deformed     Previous       Previous     Previous       Deformed     Previous       Results     Diskin       Diskin     Diskin       Diskin     Diskin       Diskin     Diskin
Model Autodesk Nastron Model Tree Autodesk Nastron Output × Autodesk Nastron File + ReSultTS PROCESSOR MODULE CALCULATING RESULTS FOR SUBCASE 1 WRITING GRID POINT DISPLACEMENTS FOR SUBCASE 1 TO FILE: b96ojleyy.DIS WRITING GRID POINT DISPLACEMENTS FOR SUBCASE 1 TO FILE: b96ojleyy.GPF GENERATING RESULTS NEUTRAL FILE PERCENT COMPLETE: 100 WRITING RESULTS NEUTRAL FILE TO: b96ojleyy0030.FNO GENERATING TOPOLOGICAL DESIGN PERCENT COMPLETE: 100 SOLUTION TIME FOR 4750 DESIGN VARIABLES - 3.4 SECONDS NUMBER OF CONVERGENCE ITERATIONS - 597 FINAL CONVERGENCE TERATIONS - 597 FINAL CONVERGENCE - 37.9 DESIGN OBJECTIVE CURRENT VALUE DESIGN OBJECTIVE CURRENT VALUE DESIGN OBJECTIVE CURRENT VALUE DESIGN OBJECTIVE CURRENT VALUE DESIGN CONSTRAINT CURRENT VALUE DESIGN CONSTRAINT CURRENT VALUE DESIGN 005001 1.0000F+01 PASS DESESP 2.1_2 5.932E+00 1.000F+01 PASS DESESP 2.1_3 5.345E+00 1.000F+01 PASS DESESP 2.1_4 5.380E+00 1.000F+01 PASS DESESP 2.1_5 5.338E+00 1.000F+01 PASS DESESP 2.1_5 5.338E+	Stress SHELL EQUIVALENT STRESS MPa C
DRESP 2_1_6 5.2238+00 1.000E+01 PASS DRESP 2_1 7 4.717E+00 1.000E+01 PASS DRESP 2_1 8 2.901E+00 1.000E+01 PASS DRESP 2_1 9 1.629E+00 1.000E+01 PASS DRESP 2_1_9 0.471E-01 1.000E+01 PASS DRESP 2_1_10 0.471E-01 1.000E+01 PASS DESIGN OPTIMIZATION ITERATION 31 TOPOLOGY DESIGN OPTIMIZATION ASSEMBLY PROCESSOR MODULE ↓ ↓ ↓ ↓	1.667 1.200 0.033 0.417 0.000 ↓ CONTOUR SHELL BOUNDAENT STRESS (MPA) OUTPUT SET DESIGN IT ATIONS-33, MASS REDUCTION-78.2, OBJECTIVE-1 872329E-01 ↓ My Home Cube_2d.jpt × b960jLeyy.jpt cube.lsm 1 40

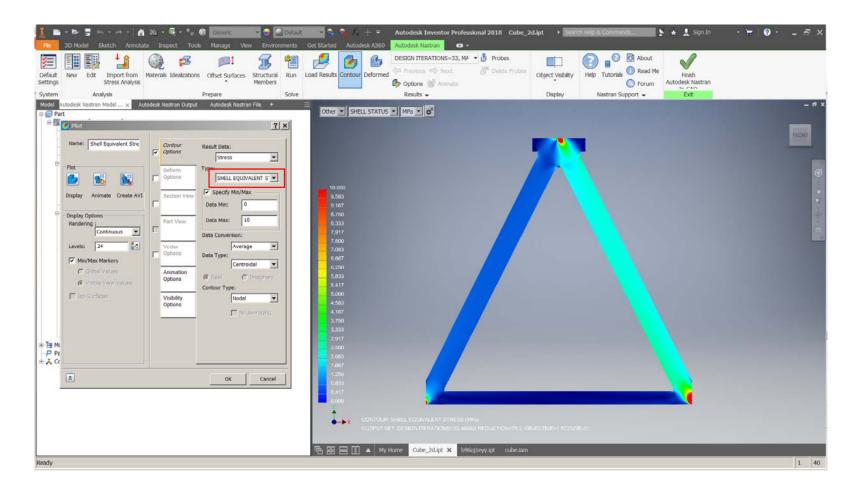
#### **Import Generated Geometry to Build New Design**



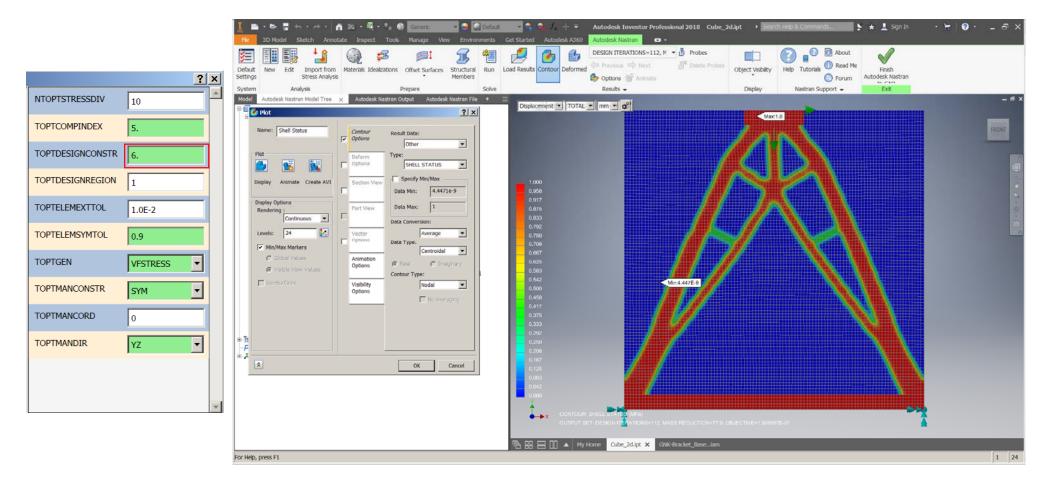
#### **Import Generated Geometry to Build New Design**



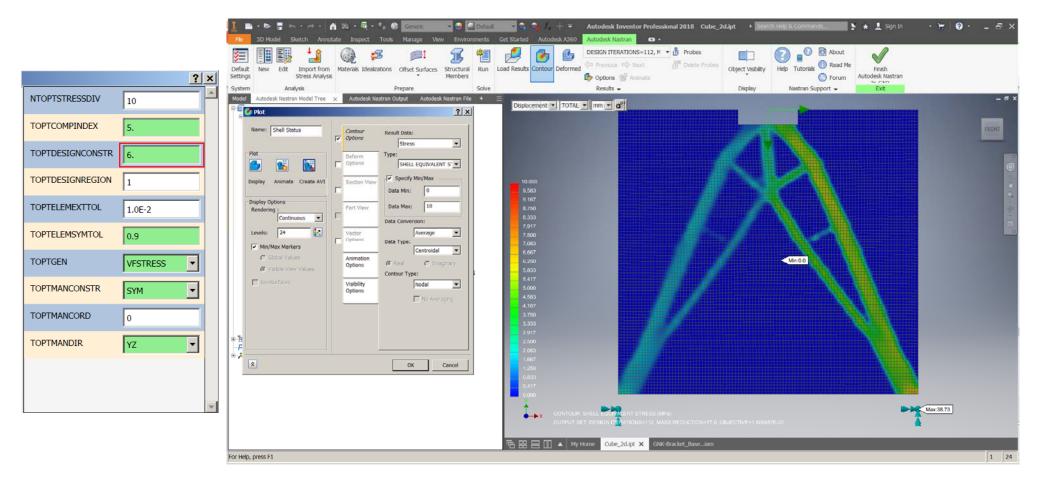
#### **Import Generated Geometry to Build New Design**



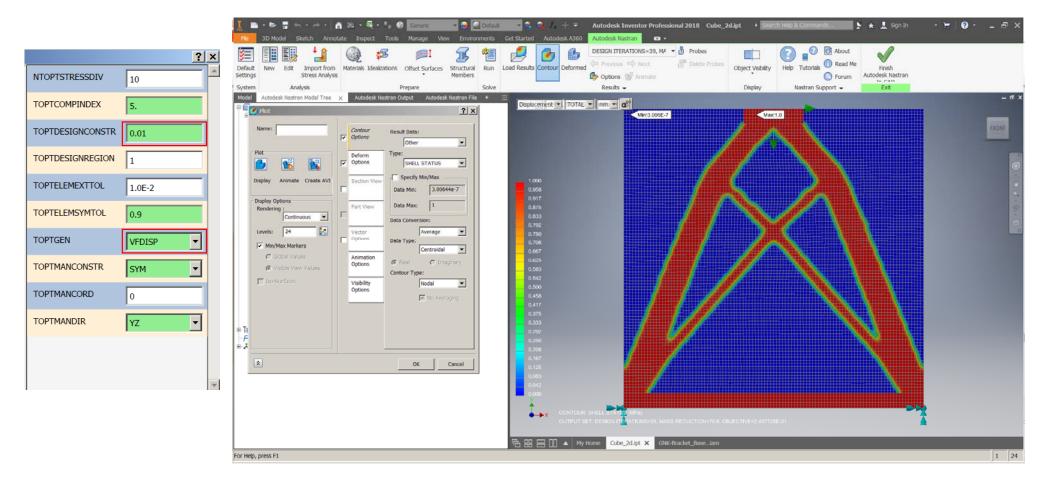
#### **Obj: Min. VF (mass), Constraint: Stress & Comp. Index**



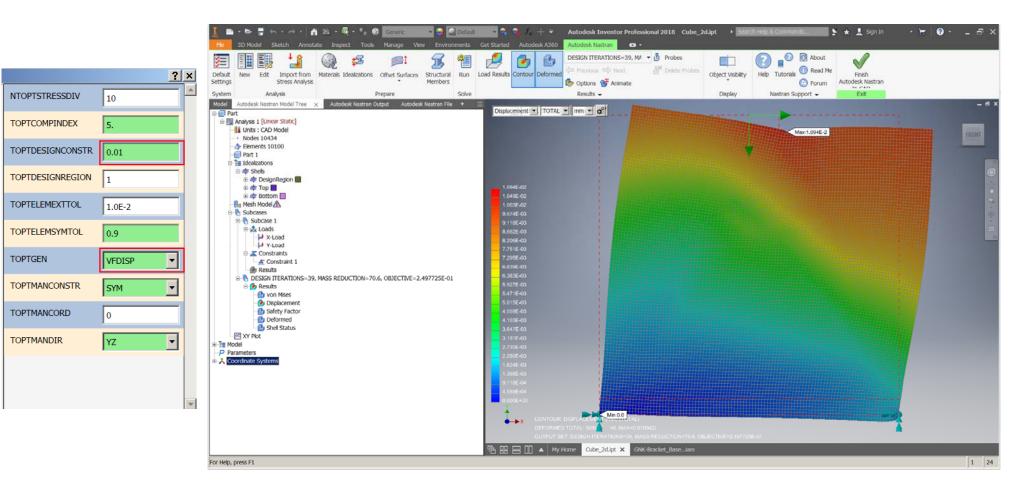
### **Obj: Min. VF (mass), Constraint: Stress & Comp. Index**



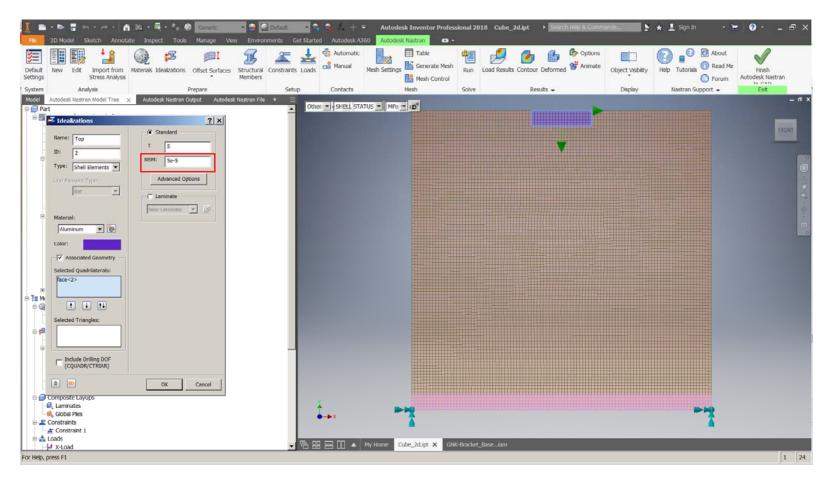
#### Obj: Min. VF (mass), Constraint: Disp. & Comp. Index



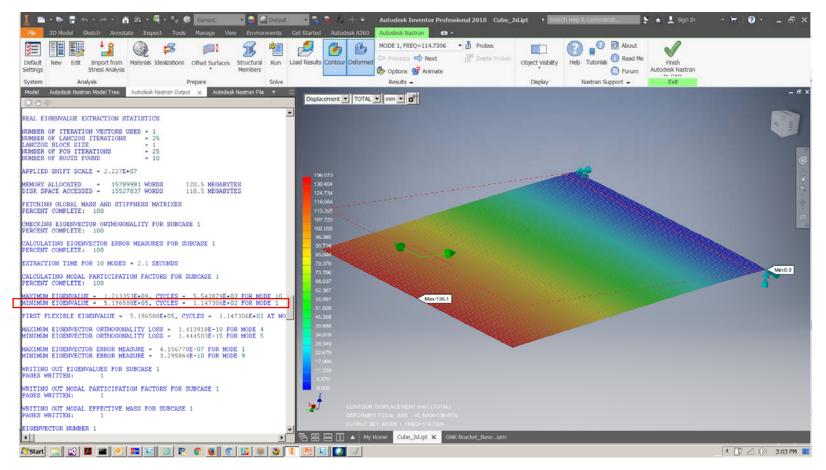
#### Obj: Min. VF (mass), Constraint: Disp. & Comp. Index



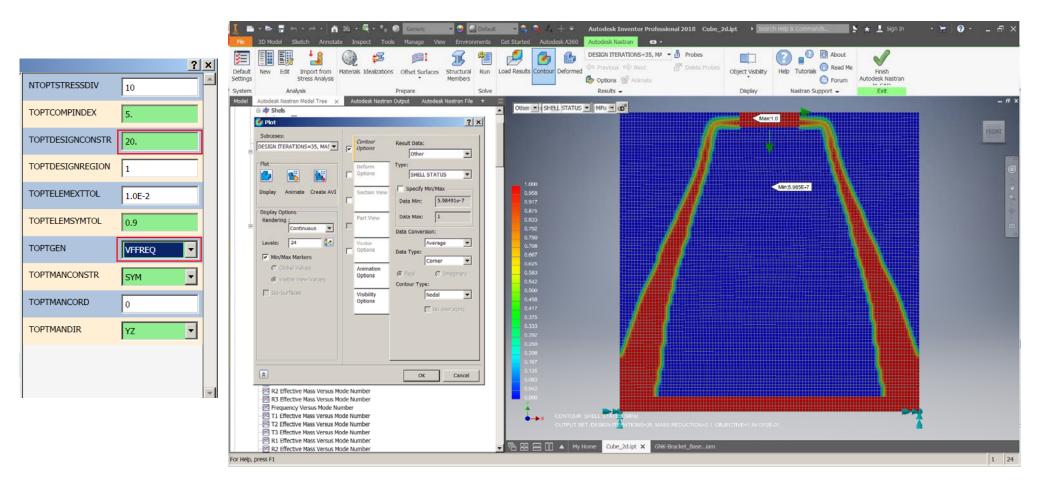
### Obj: Min. VF (mass), Constraint: Frequency



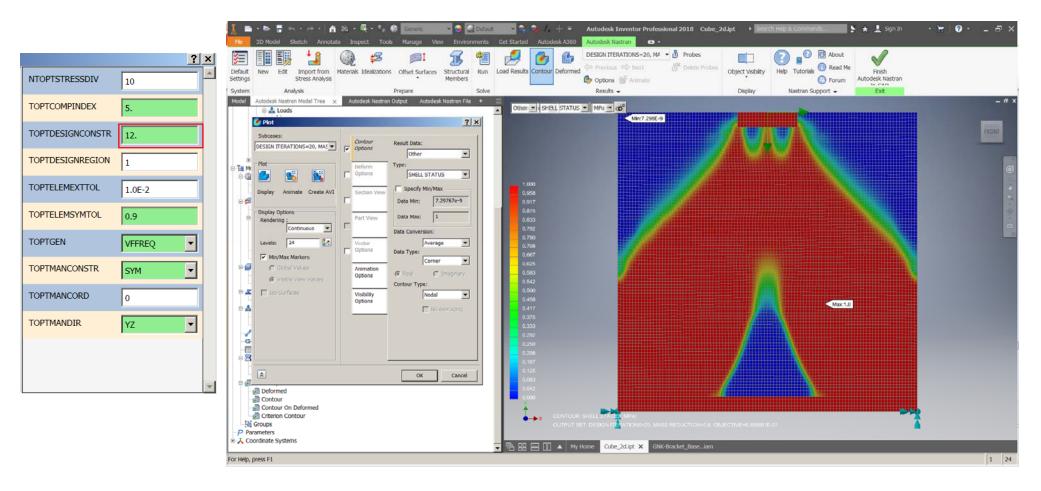
## Obj: Min. VF (mass), Constraint: Frequency



### Obj: Min. VF (mass), Constraint: Frequency > 10Hz

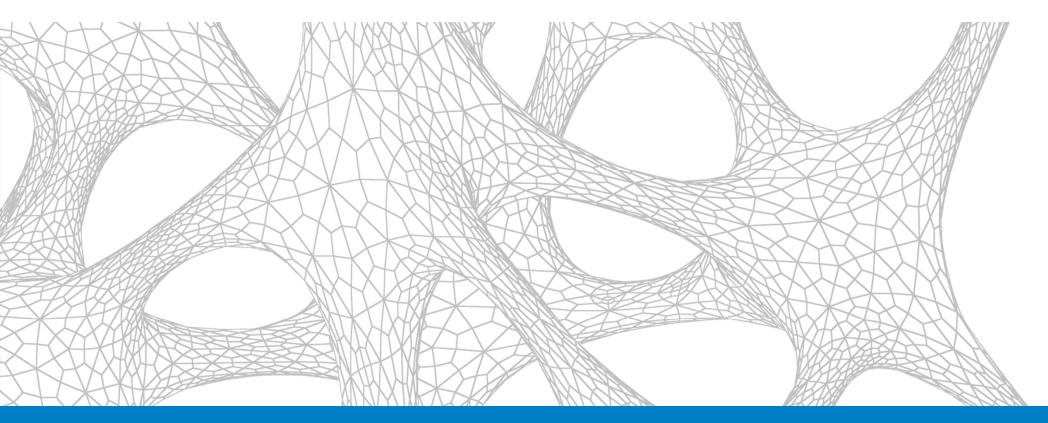


### Obj: Min. VF (mass), Constraint: Frequency > 12Hz



### **Commonly Used Topology Optimization Parameters**

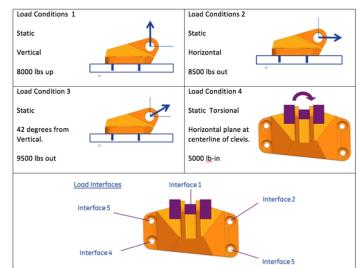
Parameter	Description	Default	Suggested Range	Remarks
MAXTOPTITER	Limits the number of design iterations	200	100 - 300	Increase when iteration limit exceeded
NTOPTSTRESSDIV	Number of stress sub-divisions	10	3 - 10	Reduce for better performance/increase for better accuracy
TOPTELEMEXTTOL	Tolerance for extrusion manufacturing constraint	1.0E-02	< 1.0	Increase if elements are not linked
TOPTELEMSYMTOL	Tolerance for symmetry manufacturing constraint	1.0E-02	< 1.0	Increase if elements are not linked
TOPTITERTOL	Tolerance for overall design iteration tolerance	5.0E-03	< 1.0E-02	Reduce for better accuracy/increase for better performance

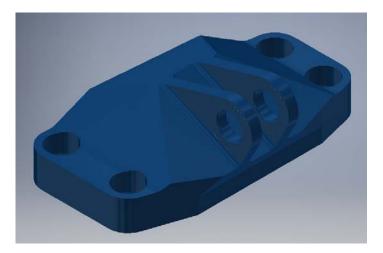


## GE Bracket Challenge Problem

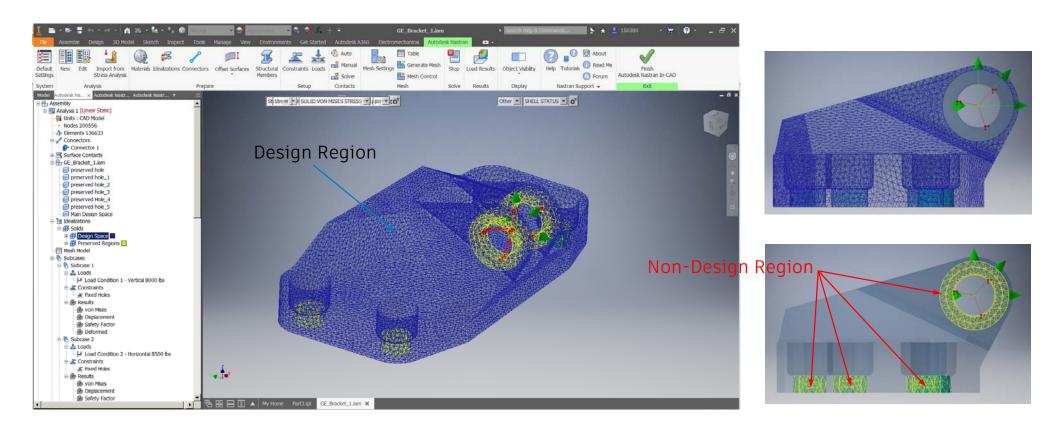
## **GE Bracket Challenge Problem**

- Material: Titanium Ti-6Al-4V
- BC constraints: At inside of bolt holes
- Load conditions
  - Vertical 8000 lbs
  - Horizontal 8500 lbs
  - 42 deg 9500 lbs
  - 5000 in-lbs torque about horizontal plane
- Design constraint: Factor of Safety (FOS) = 1.2
- Manufacturing constraint: AM
- Objective: minimize mass
- Original volume: 27.58 in<sup>3</sup>
- Mesh density: 133k tet10 elements
- Run on a Dell M4800 laptop with 32GB of RAM
- Geometry generated automatically as a smoothed STL and then a BREP





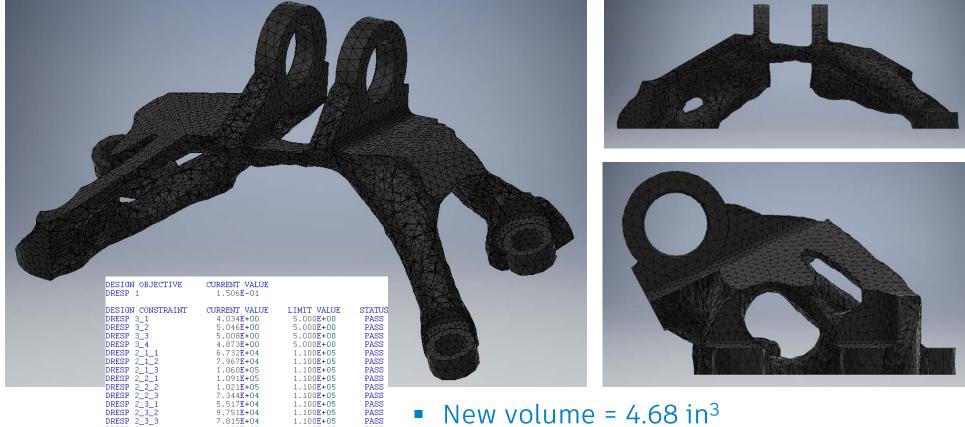
### **GE Demo Bracket Model**



## **GE Demo Bracket With Stress Constraints Only**

P Parameters		<u>? ×</u>	
File Management Directives	MAXTOPTITER	200	1
D Output Control Directives	NTOPTSTRESSDIV	3	I
Memory Management Directives	TOPTBTHRESHOLD	0.5	t
Program Control Directives	TOPTCOMPINDEX	5.	t
P Model Translator Parameters			Ļ
P Geometry Processor Parameters	TOPTDATABASE	DELETE	Ļ
P Solution Processor Parameters	TOPTDESIGNCONSTR	1.1e+5	l
Output Control Directives	TOPTDESIGNREGION	1	T
Memory Management Directives	TOPTDESIGNTOL	1.0E-13	l
D Program Control Directives	TOPTELEMEXTTOL		l
P Model Translator Parameters	TOPTELEMENTIOE	1.0E-2	l
P Geometry Processor Parameters	TOPTELEMSYMTOL	1.0E-2	
P Solution Processor Parameters	TOPTGEN	VFSTRESS	l
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3	t
P Transient Response Processor Parameters	TOPTMANCONSTR	DISABLE -	l
P Frequency Response Processor Parameters	TOPTMANCORD	d	l
P Nonlinear Solution Processor Parameters	TOPTMANDIR	XY -	l
P Results Processor Parameters			┢
P Design Optimization Processor Parameters	TOPTMAXACTDIST	0.2 💌	
	TOPTMAXBETA	AUTO	·
Find Advanced Settings Reset	OF	Cancel	

### **GE Demo Bracket With Stress Constraints Only**



1.100E+05

1.100E+05

1.100E+05

1.100E+05

PASS PASS

PASS

7.815E+04

1.058E+05

8.080E+04

4.139E+04

= 82.9

DESIGN ITERATION CONVERGENCE = 100.0

DRESP

DRESP

DRESP 2\_4\_1

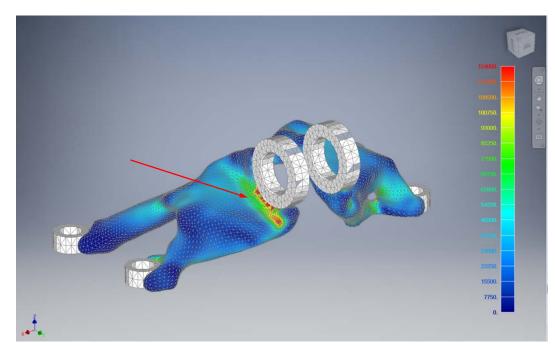
DRESP 2 4 3

242

DENSITY MASS REDUCTION

- New volume = 4.68 in<sup>3</sup>
- Design space weight reduction = 83%
- Total weight reduction = 80.5%

### **Verification Analysis**



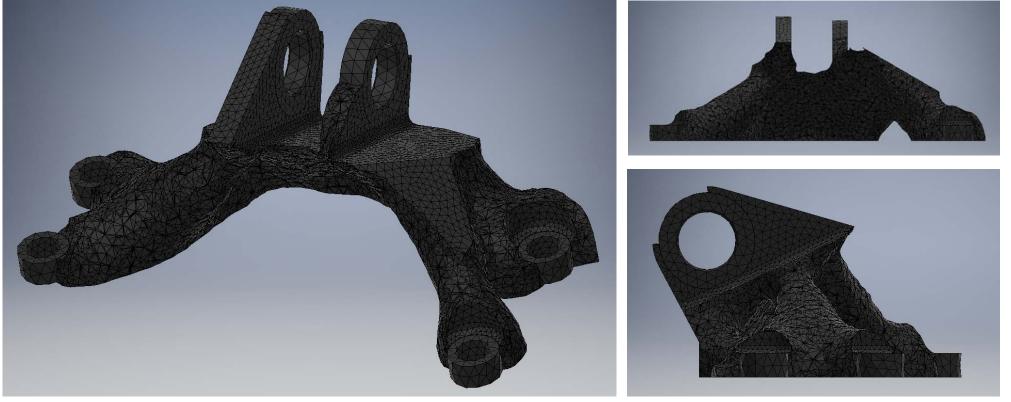
	Original Model		Stress Only	
Load				
Case	von Mises Stress (ksi)	FOS	von Mises Stress (ksi)	FOS
1	96.0	1.15	124.0	0.89
2	76.8	1.43	95.8	1.15
3	62.0	1.77	95.6	1.15
4	47.5	2.32	106.5	1.03

- TO models do not use corner stress data unlike the verification model shown
- Using a 20% higher stress limit is recommended to account for center stresses and variations in smoothed geometry

# **GE Demo Bracket With Stress & AM Constraints**

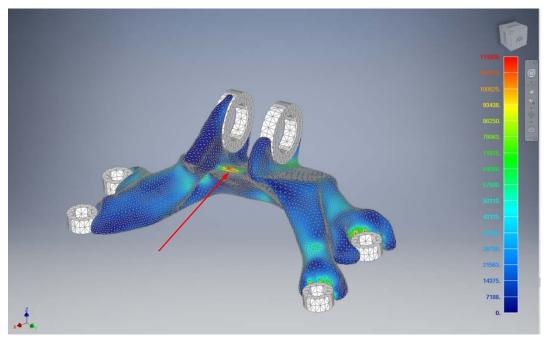
P Parameters		? X
D File Management Directives	MAXTOPTITER	300
D Output Control Directives	NTOPTSTRESSDIV	3
D Memory Management Directives	TOPTBTHRESHOLD	0.5
Program Control Directives	TOPTCOMPINDEX	5.
P Model Translator Parameters		5.
P Geometry Processor Parameters	TOPTDATABASE	DELETE
P Solution Processor Parameters	TOPTDESIGNCONSTR	1.1e+5
D Output Control Directives	TOPTDESIGNREGION	1
Memory Management Directives	TOPTDESIGNTOL	1.0E-13
Program Control Directives	TOPTELEMEXTTOL	1.0E-2
P Model Translator Parameters		
P Geometry Processor Parameters	TOPTELEMSYMTOL	1.0E-2
P Solution Processor Parameters	TOPTGEN	VFSTRESS
P Eigenvalue Processor Parameters	TOPTITERTOL	5.0E-3
P Transient Response Processor Parameters	TOPTMANCONSTR	ALM
P Frequency Response Processor Parameters	TOPTMANCORD	d
P Nonlinear Solution Processor Parameters	TOPTMANDIR	+Z 💌
P Results Processor Parameters		
P Design Optimization Processor Parameters	TOPTMAXACTDIST	AUTO 🔻
	TOPTMAXBETA	AUTO
Find Advanced Settings Reset	Ok	Cancel

## **GE Demo Bracket With Stress & AM Constraints**



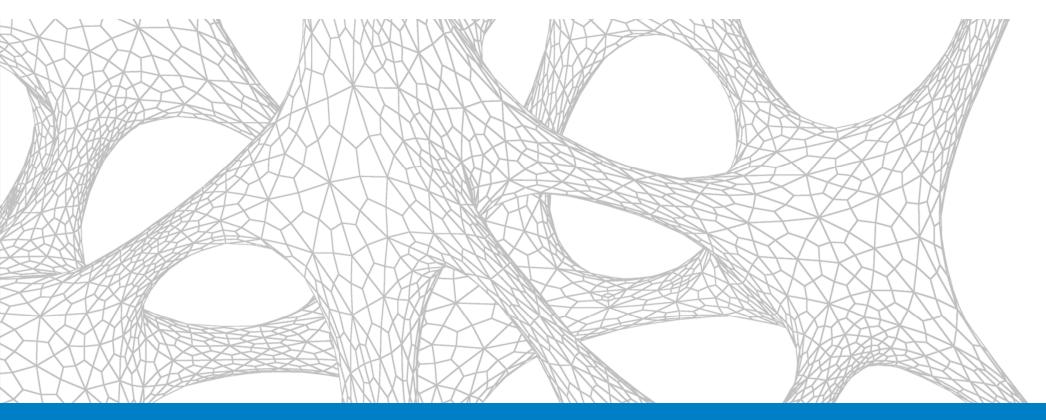
- New volume = 4.68 in<sup>3</sup>
- Design space weight reduction = 72%
- Total weight reduction = 68.1%

### **Verification Analysis**



	Original Model		Stress Only	
Load				
Case	von Mises Stress (ksi)	FOS	von Mises Stress (ksi)	FOS
1	96.0	1.15	115.7	0.95
2	76.8	1.43	71.5	1.54
3	62.0	1.77	80.2	1.37
4	47.5	2.32	77.5	1.42

- TO models do not use corner stress data unlike the verification model shown
- Using a 20% higher stress limit is recommended to account for center stresses and variations in smoothed geometry



## Live Demo Problems

### **Questions?**





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