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Structural Design Optimization of Transformer Tanks using optiSLang and ANSYS

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Contents

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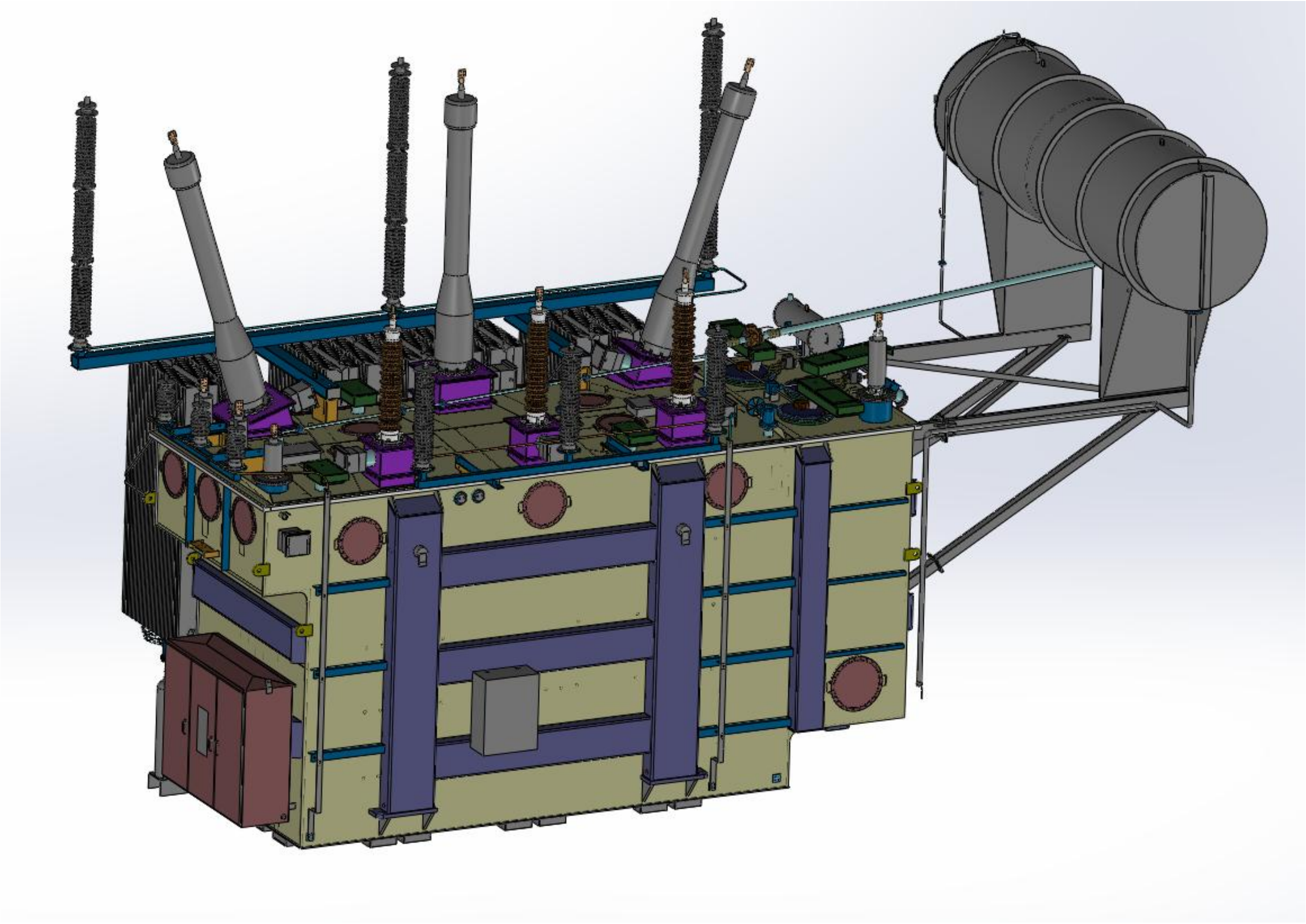
Introduction

- Power transformers



Introduction

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- The pressure and vacuum tests
- Customer's requirement - High Quality design, High performance, low cost.
- Optimization process is a complex process.
- FEA packages and optimization softwares enhanced the designer’s capabilities.
- Structural optimization and design improvements of transformer tank assembly using ANSYS11 and OptiSLang software.

Case Study 1-Problem Description

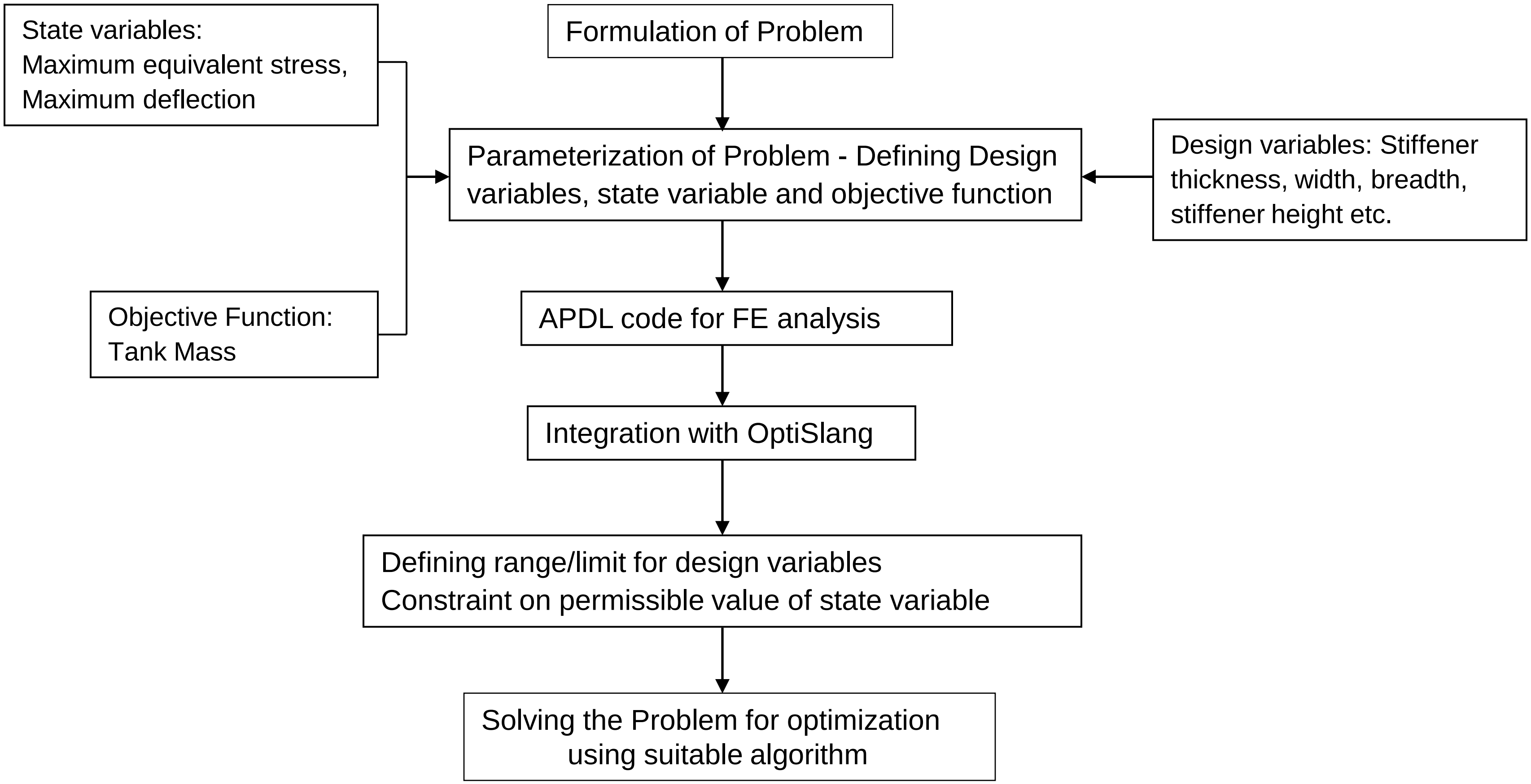
- Objective:

The objective is to minimize the weight of transformer tank keeping it Structurally safe at the same time. This has been achieved by effective usage of ANSYS and OptiSLang capabilities.

- Formulation of problem includes:

A. Parameterization
B. State variables and objective function
C. APDL macro
D. Integrated use of ANSYS & OptiSLang

Flowchart showing Automation of Optimization



A. Parameterization

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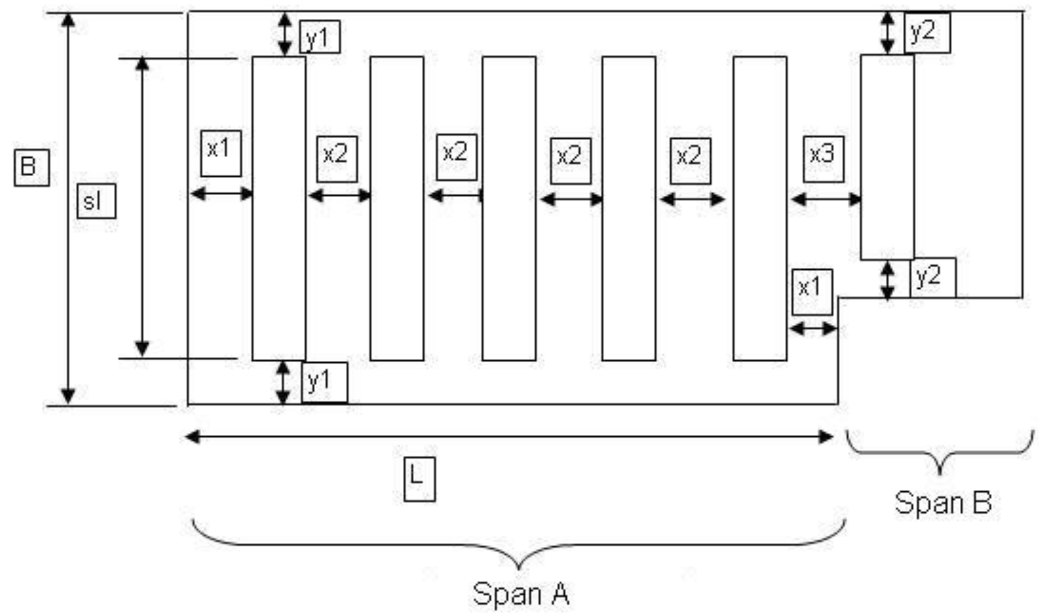
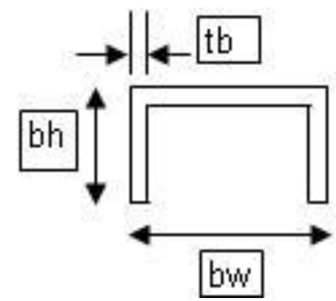
The design parameters which would be varied i.e. the driving parameters are listed below:

- tb: stiffener thickness
- bw: stiffener breadth
- bh: stiffener height
- sl: stiffener length
- n: number of stiffeners present in span A
- x1: distance of stiffener from side
- n2: number of stiffeners present in span B
- x3: distance of stiffener in span B to last stiffener in span A (as shown in figure)





B. State Variables and Objective Function

State Variable-

- The limitation on mechanical strength (stress limitation parameter)
- Instability (deflection limitation parameter)

Objective Function-

- Total mass of tank assembly

C. APDL Macro

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- APDL macro has been used for:
  - › Modeling transformer tank and stiffener arrangement in ANSYS
  - › Applying boundary conditions loads
  - › Solving for vacuum test simulation.

- APDL also writes final results-state variable and objective function values in an output text file. This is required for integration with OptiSlang.

```
WPCSYS,-1,0
CSYS,4

alls,all
vplo
vglue,all
numcmp,all
save,,db

c*** stiffeners on short side-OLTC

wpoff,1.420000000,4.32000000,0.577000000

*SET,L4,1.420
*SET,B4,2.365
!*SET,tb,.010
!*SET,bw,tb
!*SET,bh,.150
!*SET,sl4,2
*SET,n4,01
*SET,x7,x5

!*if,n4,gt,1,then
!x8=(L4-(2*x7)-(n4*bw))/(n4-1)
!*else
x8=0
!*endif


y4=y1
!y4=(B4-sl4)/2
!2*(y4)+sl4=B4
sl4=B4-(2*(y4))


k5=x8+bw

wpoff,-x7,,y4

BLC4, , ,-bw,bh,sl4,

wpoff,-tb,,tb

BLC4,,,-(bw-2*tb),(bh-tb),(sl4-(2*tb))

*get,v5,volu,,num,max

VSBV,v5-1,v5

wpoff,tb,,-tb

*get,v5,volu,,num,max
```

APDL Code

```
        0.0076
976990587.7432
     4549.8217
```

Output From APDL

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D. Integration of ANSYS with OptiSlang

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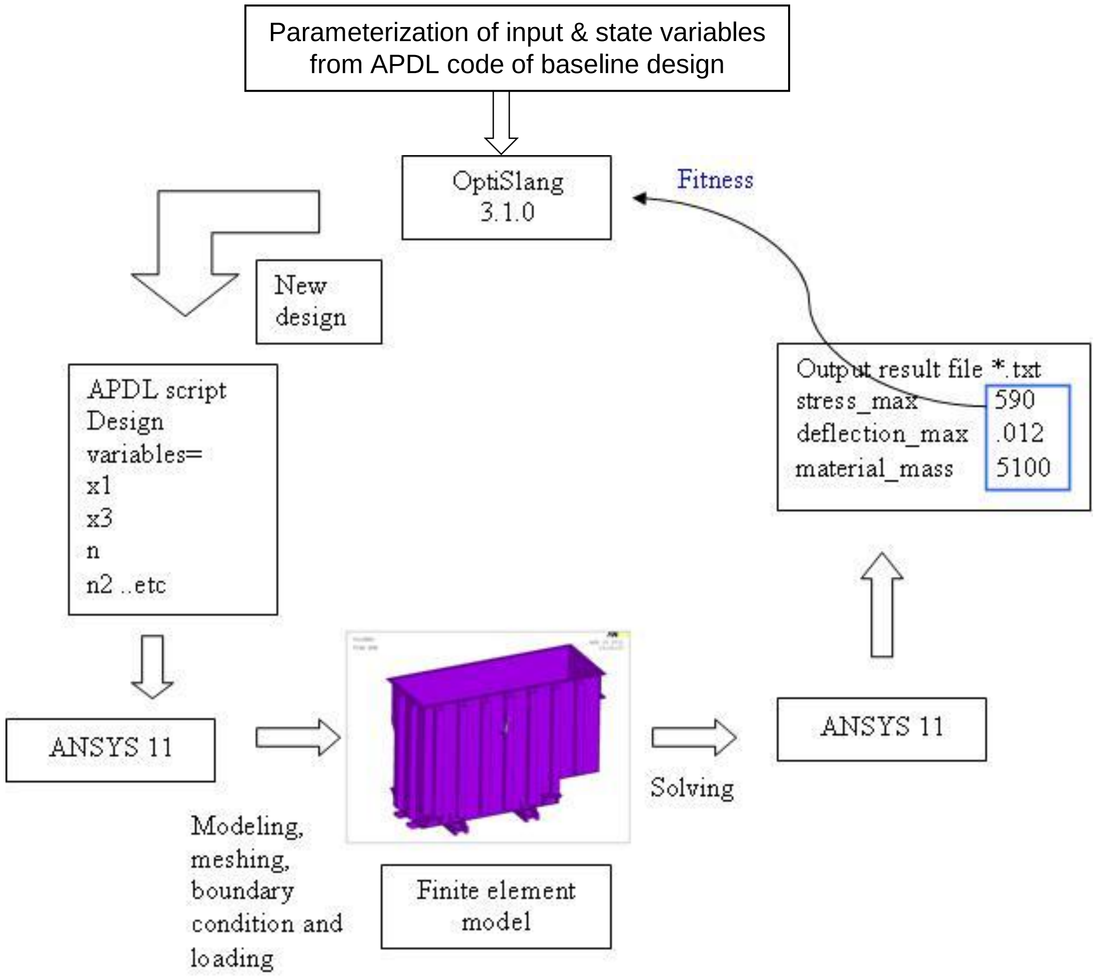
Input and state variables are needed to be re-defined in OptiSlang.

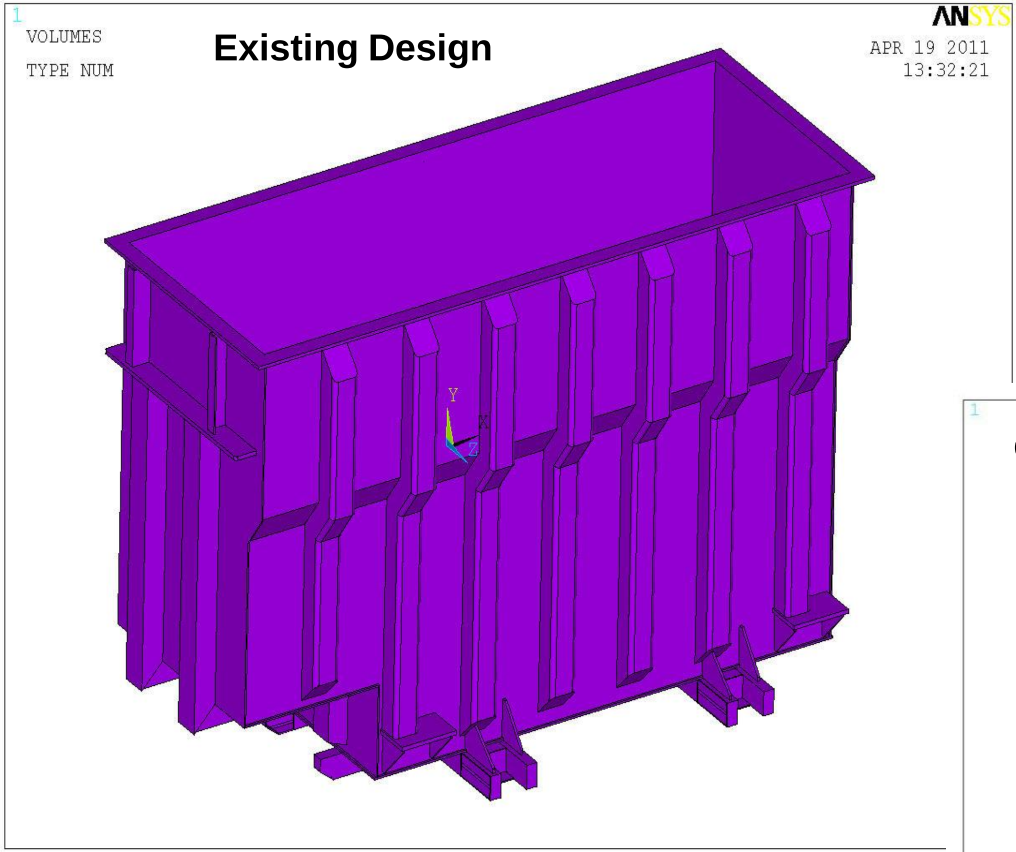
1. The range/limit in which the input design variables can vary are defined.
2. Constraint on permissible value of state variables:
   - Maximum equivalent deflection
   - Maximum equivalent stress
   - bw (stiffener width) => bh (stiffener height)

3. Evolutionary Algorithm method has been used for calculating global optimum solutions with specified constraint functions and combination of existing finite element analysis.

D. Integration of ANSYS with OptiSlang



Results and Discussion



Results and Discussion

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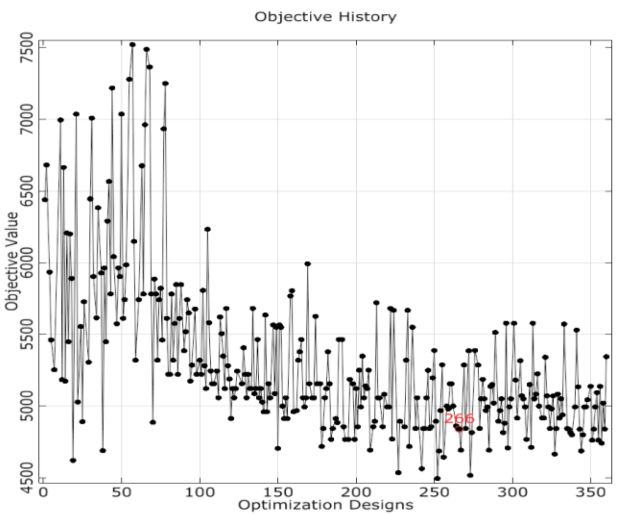
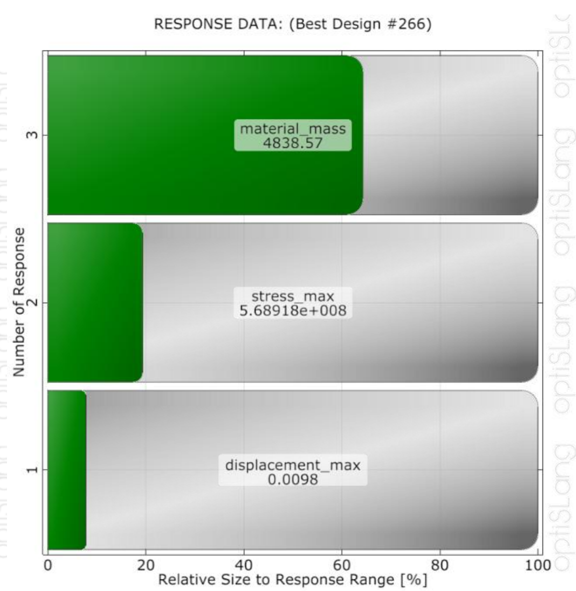
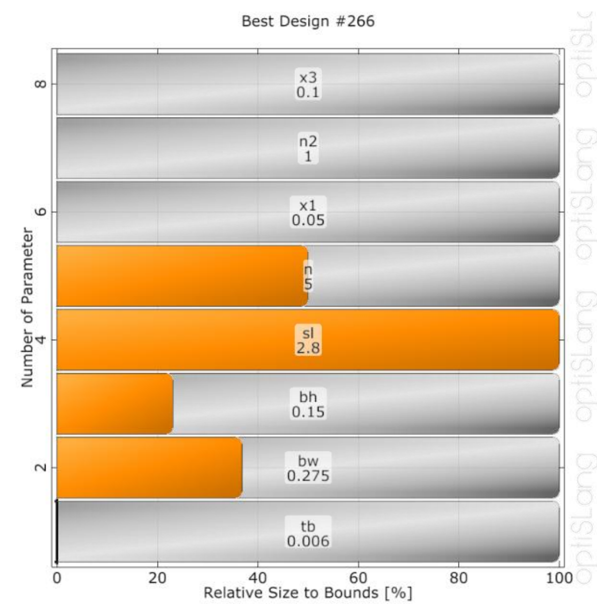
Evolutionary Algorithm method used for calculating optimized tank design parameters. Result of optimized design set:



Objective History



State Variables for best design



Input Variables for best design

FEA Simulation Results: Maximum deflection plot

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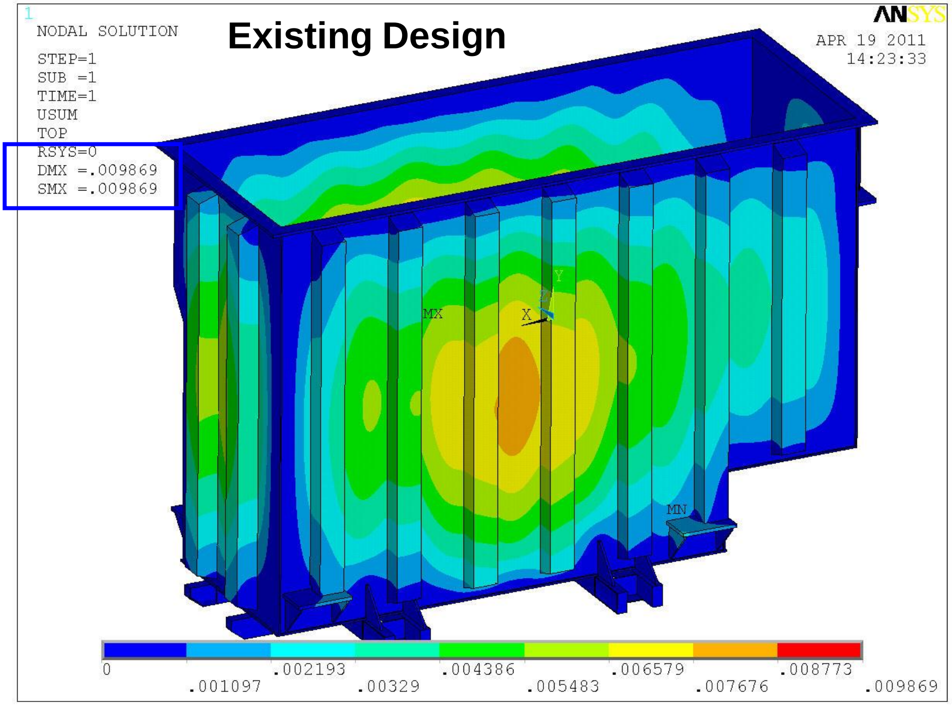
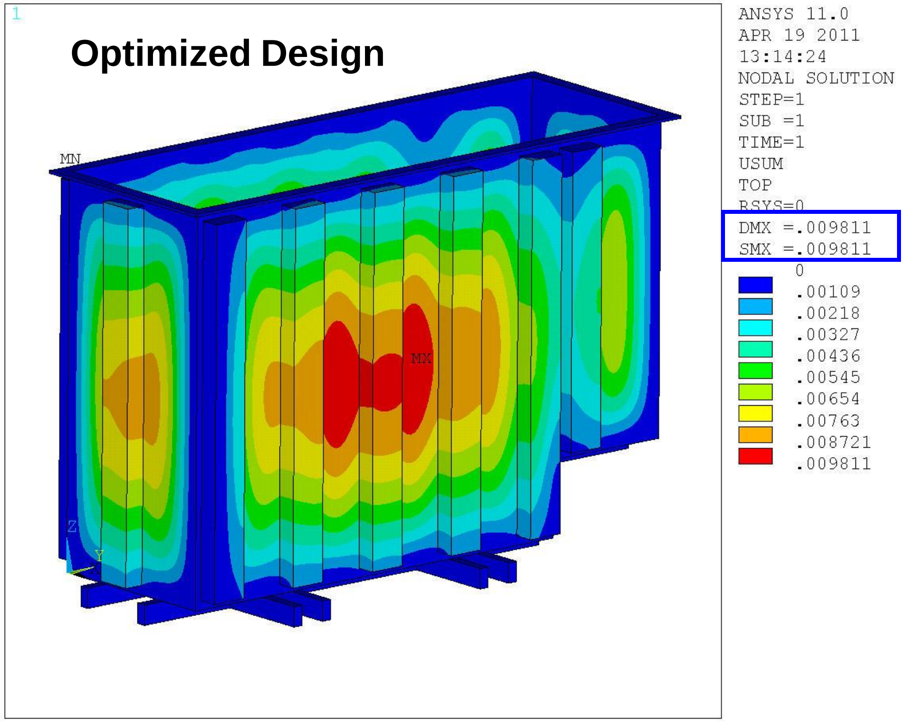


Maximum deflection observed is 9.86 mm



Maximum deflection observed is 9.81 mm

FEA Simulation Results: Equivalent Stress plot

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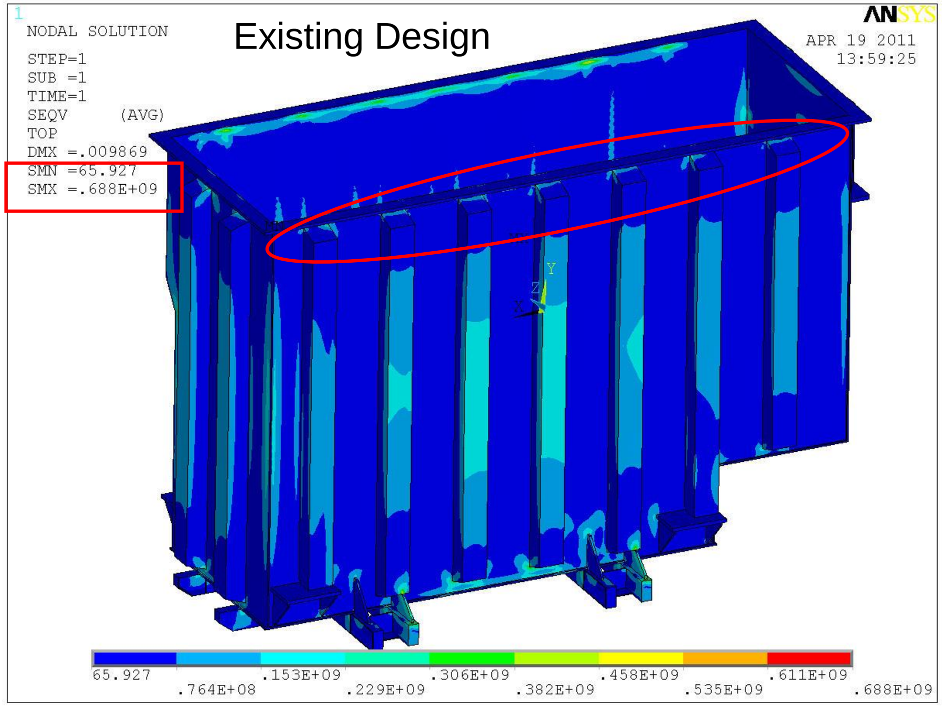

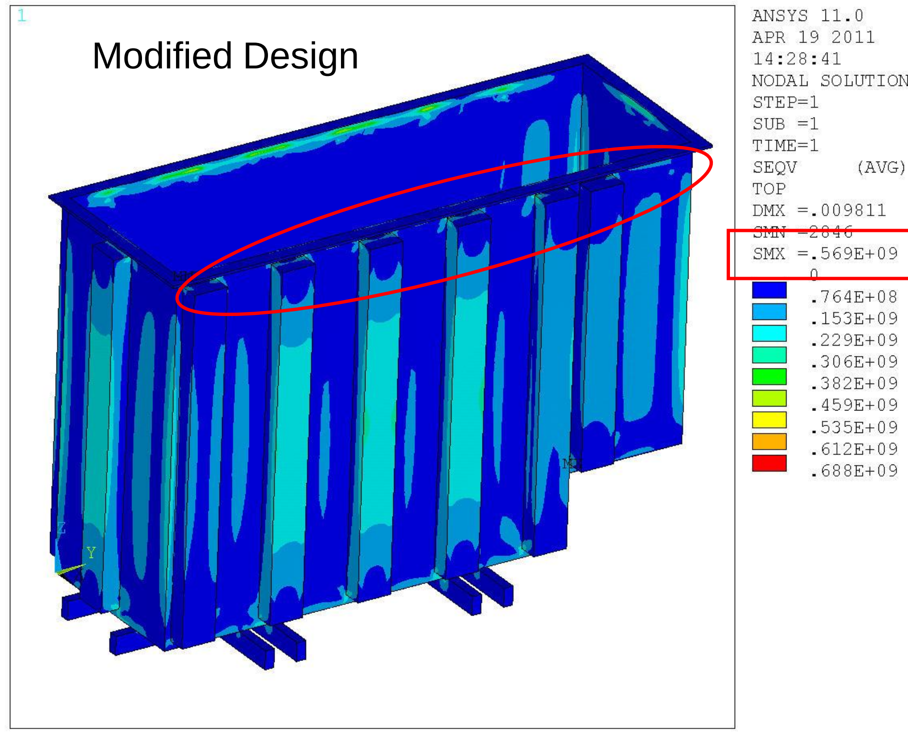

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Conclusion

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Properties	Improvement
Equivalent stress (MPa)	17.31 %
Equivalent deflection (mm)	0.5 %
Tank mass (kg)	9.91 %

- Tank was further optimized by changing the profile used on short sides and inputs from electrostatic and electromagnetic optimization.
- Optimized transformer tank and cover design has been validated under all mandatory loading conditions.
- Recommended optimized design achieved an overall weight reduction of 15.6 % of existing tank weight or 1037 kg. It also resulted in saving 2706 liters of oil.
- Fully automated optimization process for transformer tank is established.
- This methodology can be used for other products also with proper parameterization of problem.

Case Study 2-Problem Description

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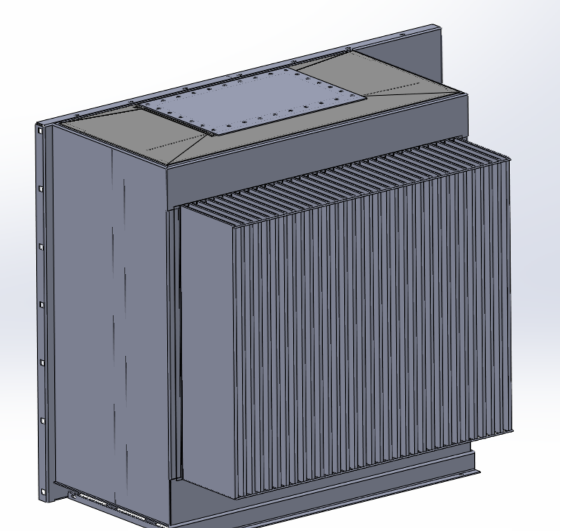
- Objective

Design validation of DT tank assembly under pressure load and modifications for radiator wall to reduce stress and deformation.

- Description

› Baseline tank design should be able to withstand specified pressure load.
› Modify the design to reduce permanent deformation of radiator wall.
› Optimize the final design to minimize cost and weight of complete assembly (with focus on radiator wall).



DT Tank Assembly

A. Parameterization

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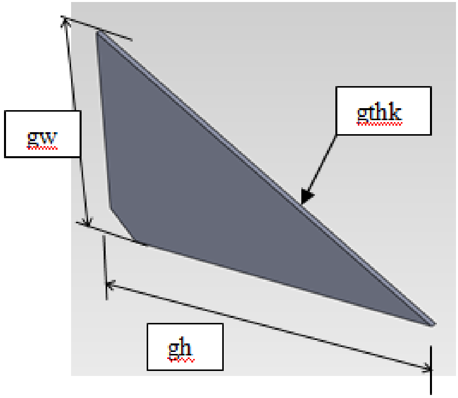
- Design variables shown in Table no. 1 have been considered for optimization of tank assembly.
- A range of design concepts have been obtain as a result of various combinations of design variables which satisfies the constraints of equivalent stress and maximum deformation.
- Detail analysis has been repeated for the best design

Variable Name	Design Variable	Values
gh	Gusset Height	a1,a2,a3
gw	Gusset width	b1,b2,b3
gthk	Gusset Thickness	c1,c2
Critical_thk	Thickness of Section A	d1,d2
N	Number of Gussets	e1,e2,e3



Note:

- Design validation of baseline design has been carried out under specified loading conditions.
- These results have been considered as benchmark for further design optimization.

B. State Variables and Objective Function

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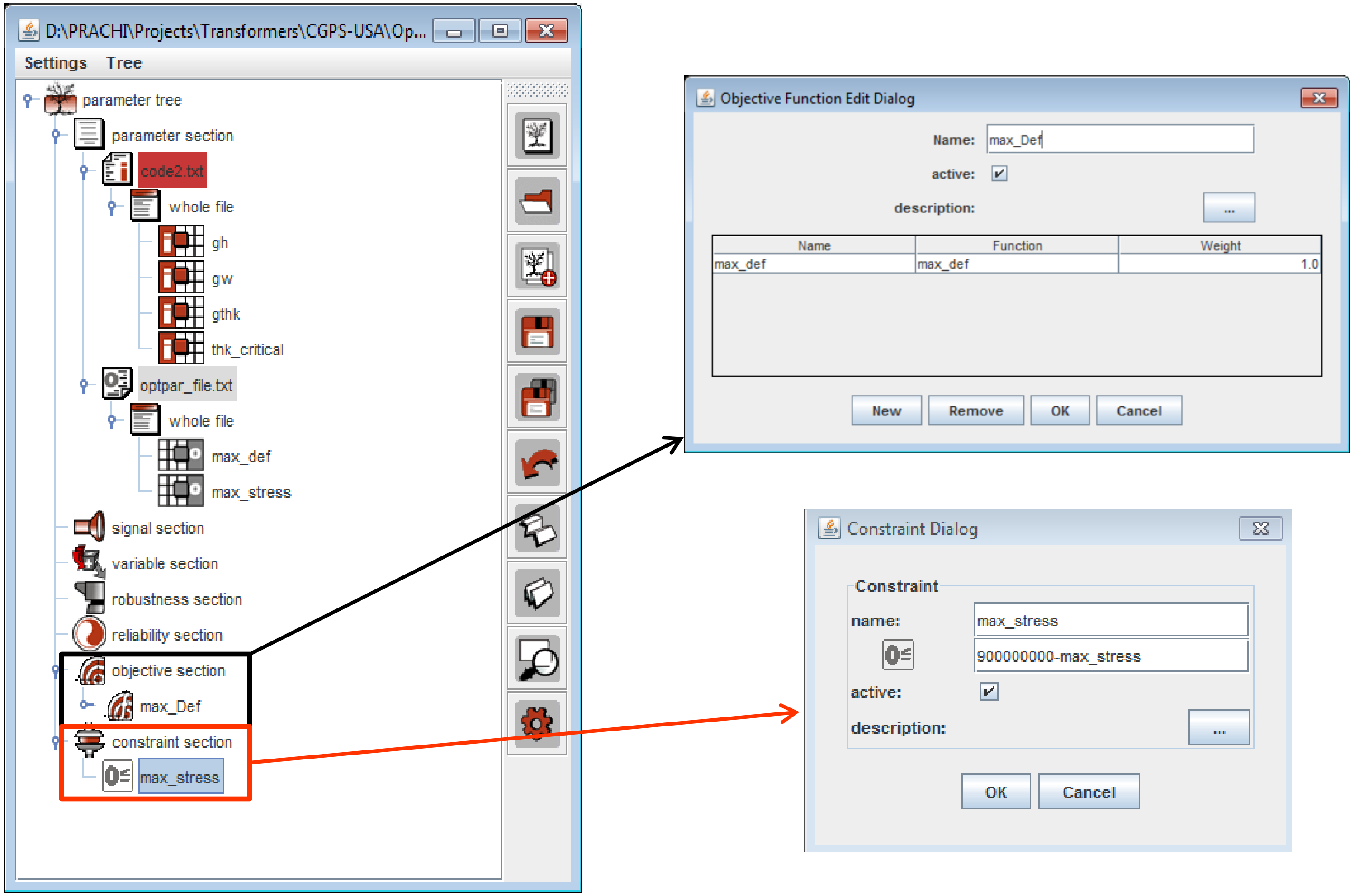

Results and Discussion

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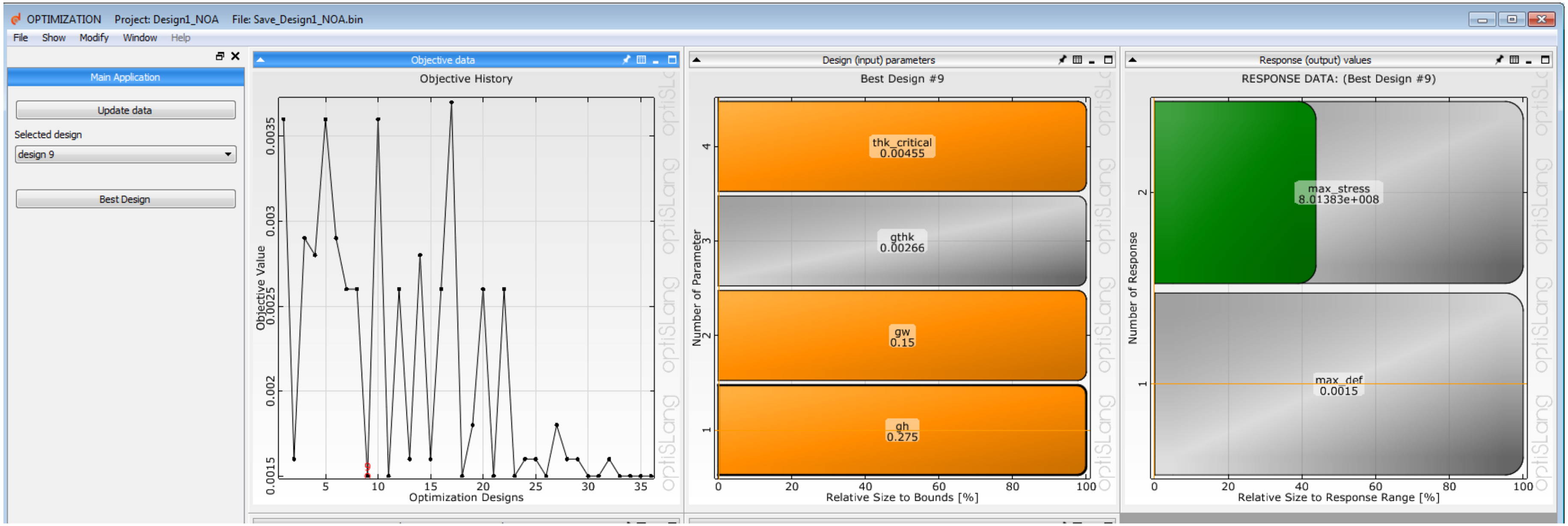

Objective History

Input Variables for best design

State Variables for best design

Results and Discussion (FE Model)

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Boundary Conditions:

- Specified uniform pressure applied on walls of the tank and top cover.
- Bottom support plates constrained in all directions.

Existing Design

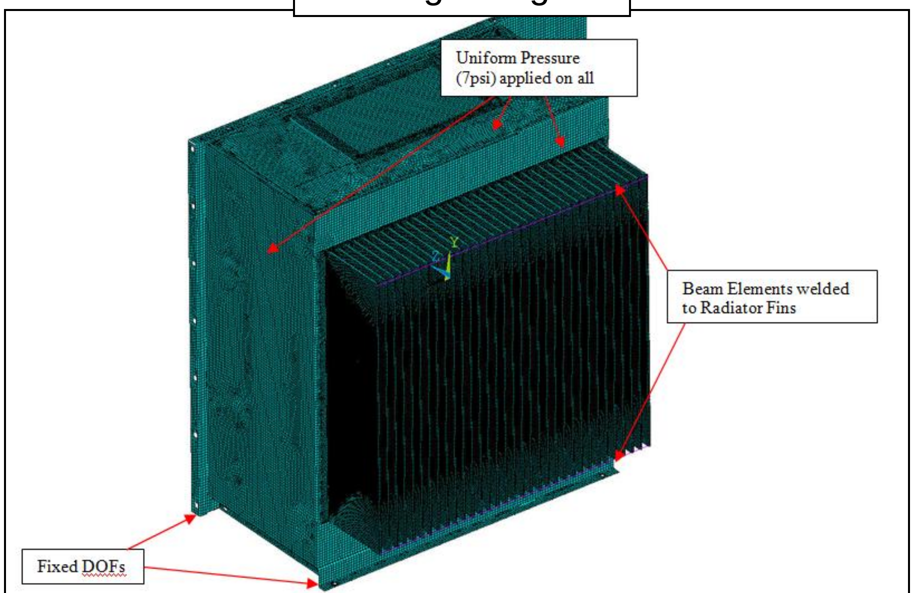
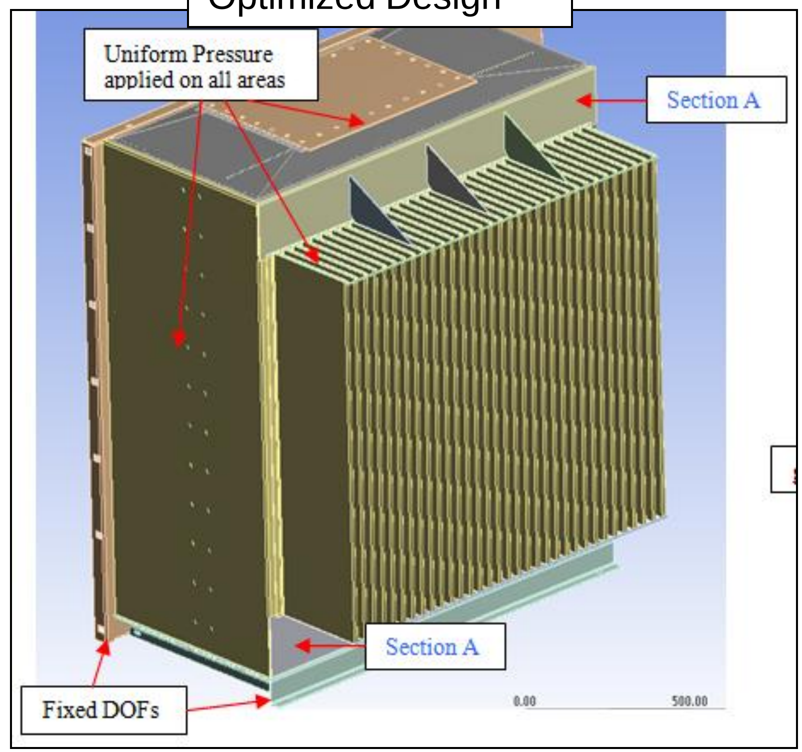


Fig.1- FE Model of transformer Tank

Optimized Design



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Maximum Deformation Plot

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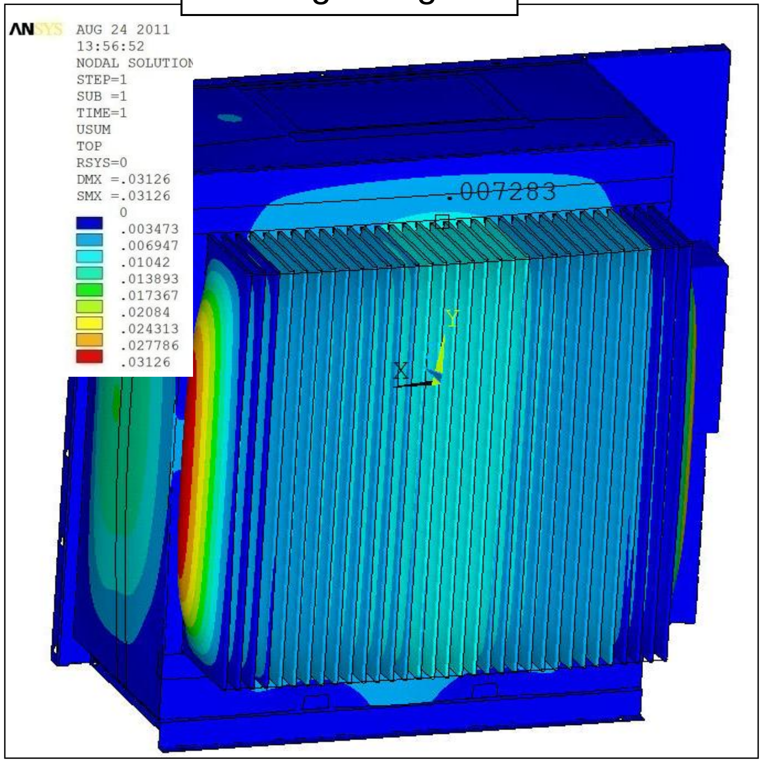
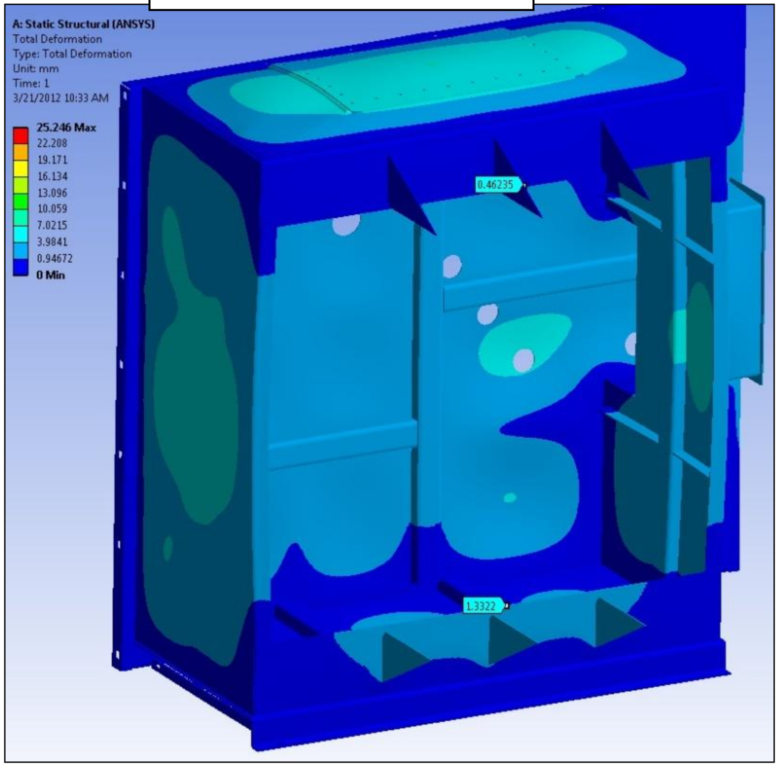
Existing Design



Optimized Design

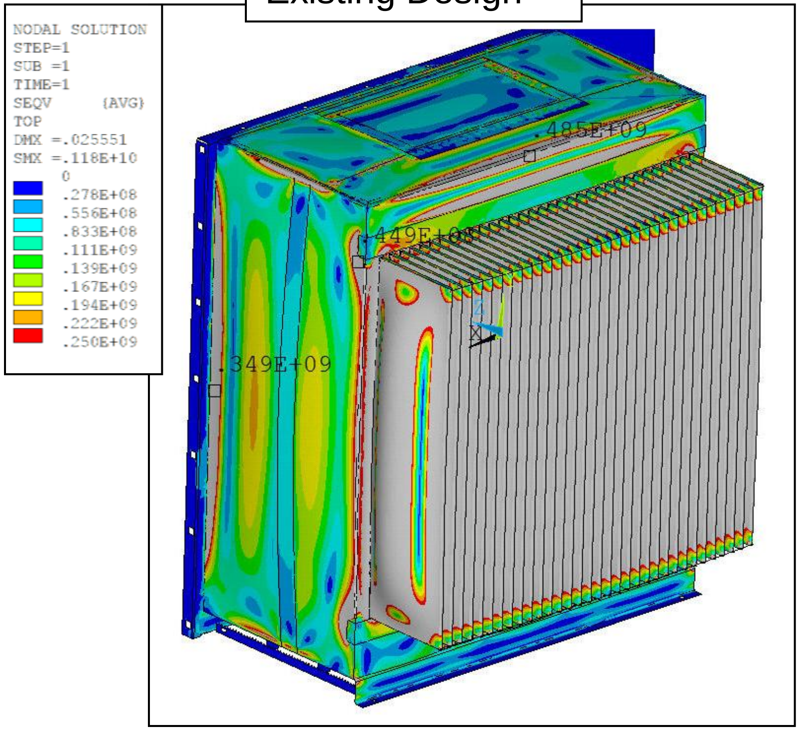


Maximum deflection observed is 7.2 mm

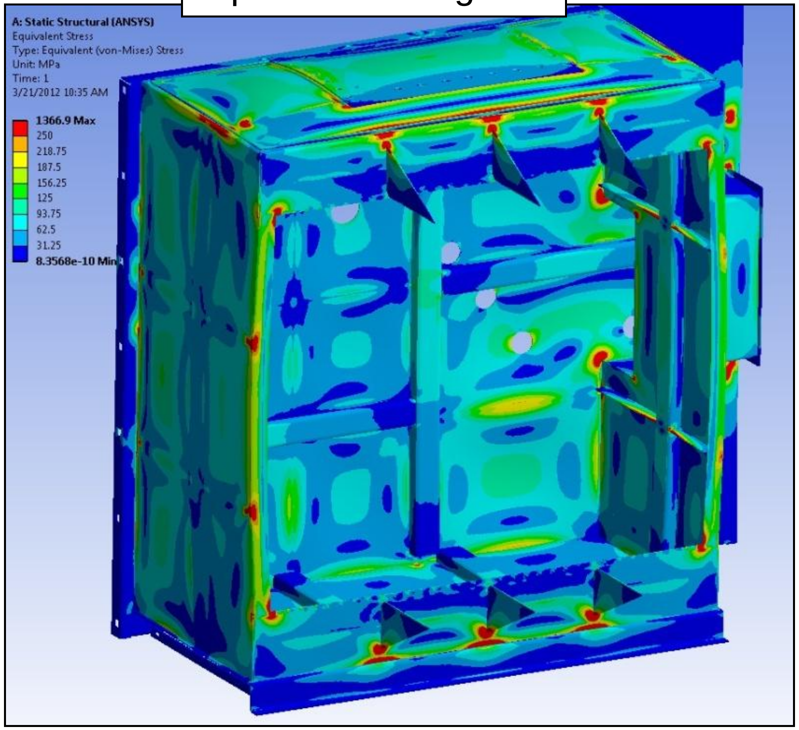
Maximum deflection observed is 1.3 mm

Equivalent Stress Plot

Existing Design



Optimized Design



Conclusion

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- Deformation has significantly reduced with addition of optimum number of gussets on section-A.
- Equivalent stresses are also observed to be within allowable limit near section A, except few locations which are showing local high stresses near gussets.
- This exercise has been repeated for various similar tank assemblies (of different ratings) where complete automated procedure of optimization using optiSLang and ANSYS has been used.

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Thank you