

Reducing Weight of Non Structural Members Using Composites and Their Optimization

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ABSTRACT

Usage of fiber reinforced composite material brought about a huge revolution when industries started to design and manufacture full composite frame. Composite structures offer unmatched design potential as the laminate material properties can be tailored almost continuously throughout the structure. However, this brings new challenges for the an optimum design.

Keywords

Composite optimization, Hyperworks, Optistruct, foot rest, Tatra, Optimization methodology, Tatra, Weight reduction, structural strength improvement.

1. INTRODUCTION

Composite structures offer high design potential as the laminates thus made can have tailored properties. However, this brings new challenges for the an optimum design.

1.1 What are composites?

Composites are made out of fibers, which are embedded in a complex polymer matrix. The most common synthetic fibers consist of carbon, glass, polyamide, polyester, metal, Polymethacrylimid (Rohacell).

1.2 How are these optimized?

Need for structural optimization has increased exponentially primarily due to new materials like composites being discovered whose material properties throughout structure can be tailored according to needs.

The process consists primarily of three phases. Phase I focuses on generating ply layout concept through Free-Size optimization; Phase II further refines the number of plies for a given ply layup defined by Phase I; Then Phase III completes the final design details through Stacking sequence optimization satisfying all manufacturing and performance constraints. This optimization process is done with the help of software Altair OptiStruct

2. PROJECT AT HAND

Our aim is "Weight and structural strength optimization of a foot rest using advance composite free size, size and shuffle optimization cycles". The foot rest of a Tatra truck which was previously made of steel is now to be made out of composites and is to be optimized in order to maximize efficiency at design stage.

3. CAD MODELING

The part that is the foot rest is measured by calipers and a CAD replica is made in CATIA V5.

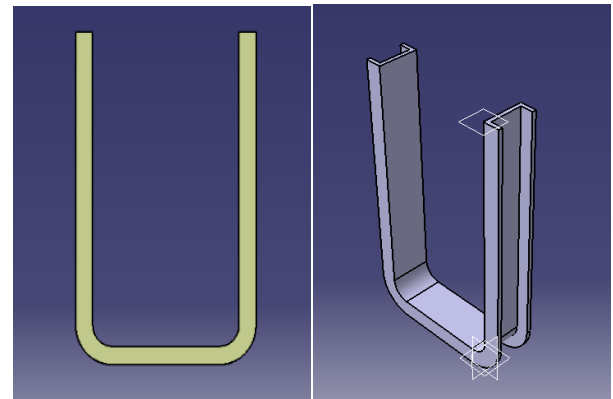


Fig 1: Front and Isometric View

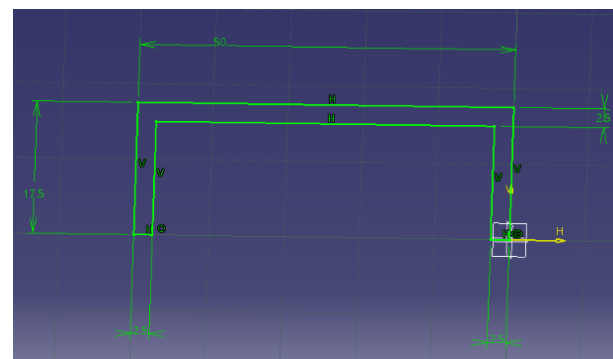


Fig 2: Cross Section

Volume = 150 cm³
Mass (Steel) = 1175.88376 grams

4. METHODOLOGY

4.1 Importing geometry and meshing

The given geometry was imported in hyper mesh and meshing was done on the mid-surface with an element size of 5.

4.2 Applying loads and constraints

Load of 1470 N was applied over the horizontal lower member and the top points were fixed.

4.3 Checking and adapting the element normals as well as material orientation

Meshing generally effects different element normal directions. While manufacturing the plies are listed upwards from the bottom surface depending on the element's normal direction. So we have to align all element normals to the same direction.

It is also necessary to define the material direction. If my material direction is along X-axis then that means the stronger fiber direction is along X-axis (0° angle).

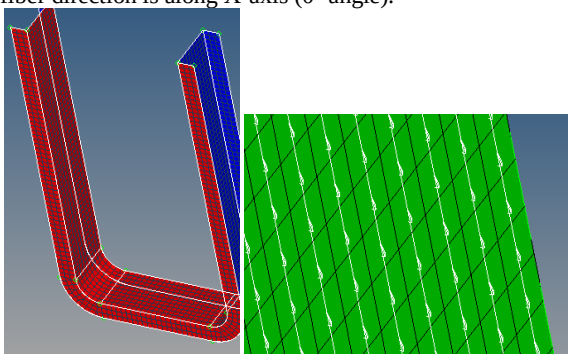


Fig 3: Element normals and material orientation

4.4 Specifying the material

A large number of materials are being used nowadays in their composite structure. We are using Carbon fiber K

E1	E2	[NU12]	[G12]	[G13]	[G23]	[RHO]
1.1e+05	8500.00	0.300	4000.00			1.7e-03
[A2]	[TREF]	[Xc]	[Yc]	[Zc]	[S]	
		1500.00	900.000	50.000	170.000	80.000
[F12]	[STRN]					

Fig 4: Material Properties

4.5 Building a laminate with PCOMPP-property

A composite laminate is a stack combination of different number of plies having different properties, material orientation and thickness.

Type:

Ply laminate

Name:

Laminate1

☐ Same as:

Laminate1

Card image:

STACK

☒ Update color:

Laminate option:

Total

Define laminate:

Name	Id	Color	Material	Thickness	Orientation	IP	Result
Ply1	1		Carbon	0.50000	0.0	3	yes
Ply2	2		Carbon	0.50000	45.0	3	yes
Ply3	3		Carbon	0.50000	90.0	3	yes
Ply4	4		Carbon	0.50000	-45.0	3	yes
Ply5	5		Carbon	0.50000	0.0	3	yes

Fig 5: Laminate of 5 CFK plies

In this software there is a provision of a property specifically for composites ie PCOMPP. This combines information pertaining to ply, sequence and laminates.

4.6 Define load cases and constraints and analyze the un optimized model

The load collectors including the force and the single point constraints have been applied and analysis carried out.

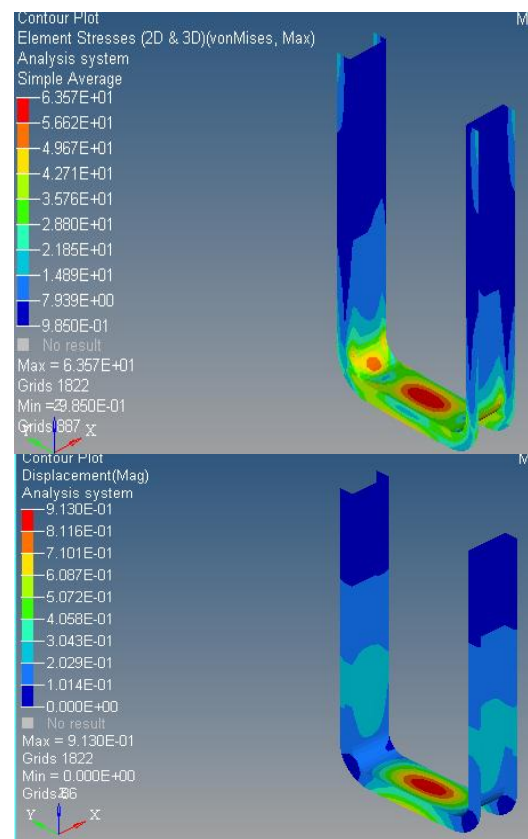


Fig 6: Analysis results of an un optimized part

4.7 Free size-optimization

This step takes the same initial ply thickness provided by us to run the optimization. After generating the design variable which limits the upper and lower bound of laminate as well as their orientation according to manufacturing constraints, we

create static displacement and mass response for constraint and objective parameter.

Specifying min and max thickness as 1mm and 2.5 mm. and lower bound of constraint to be -2mm

ITERATION 0

(Scratch disk space usage for starting iteration = 50 MB)
(Running in-core solution)

Objective Function (Minimize MASS) = 2.28592E+02
No active constraints
Design Volume Fraction = 9.00000E-01 Mass = 2.28592E+02

Fig 7: Initial Mass 228.592g

ITERATION 1

Objective Function (Minimize MASS) = 1.52394E+02 | % change = -33.33
No active constraints
Design Volume Fraction = 6.00000E-01 Mass = 1.52394E+02

Fig 8: Mass after iteration (1) 152.934g

ITERATION 2

Objective Function (Minimize MASS) = 1.01596E+02 % change = -33.33
No active constraints
Design Volume Fraction = 4.00000E-01 Mass = 1.01596E+02

Fig 9: Mass after iteration (1) 101.596g

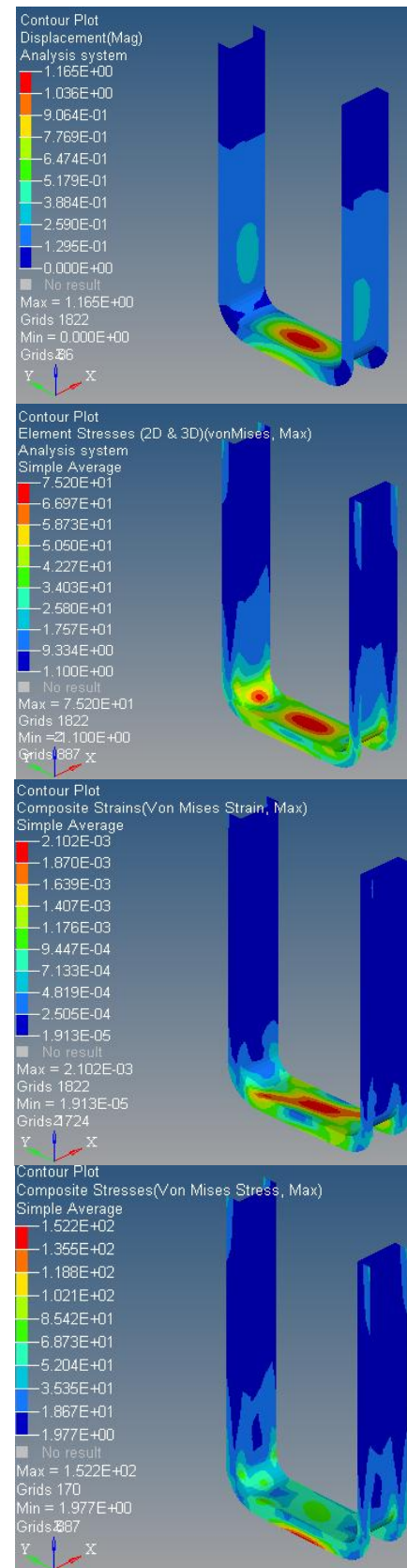
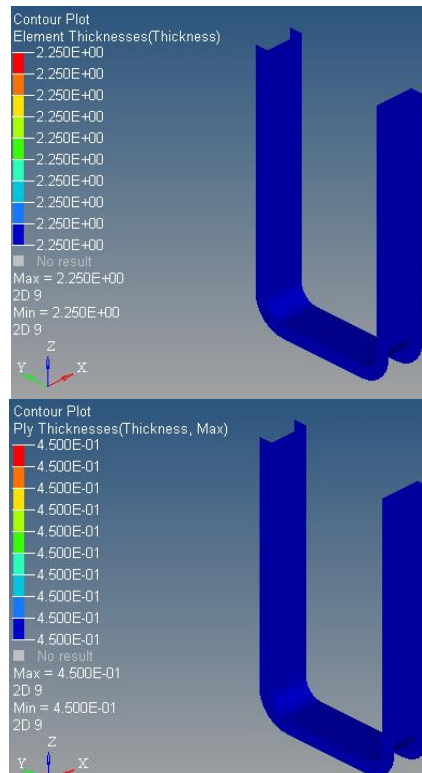


Fig 10: Stress, thickness and Displacement results after Free Size optimization

4.8 Size-optimization

This Part attends to the Ply-Bundle Size Optimization. The approach of this method is to tare the best thickness for each **ply-bundle** considering manufacturing constraints. You see the plies from free size are not manufacturable. The aim is to obtain feasible thicknesses which can be produced within usual standards.

ITERATION 1

Soft convergence criterion satisfied;
the design did not change during the last iteration.

Objective Function (Minimize MASS) = 1.01596E+02 % change = 0.00
Maximum Constraint Violation % = 0.00000E+00
Volume = 5.97625E+04 Mass = 1.01596E+02

Fig 11: Mass after iteration (1) 101.596g

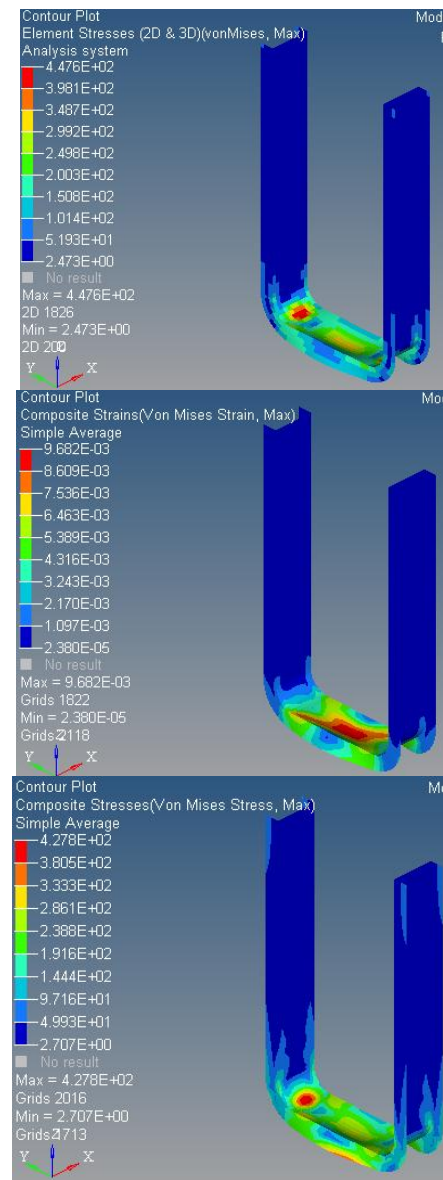
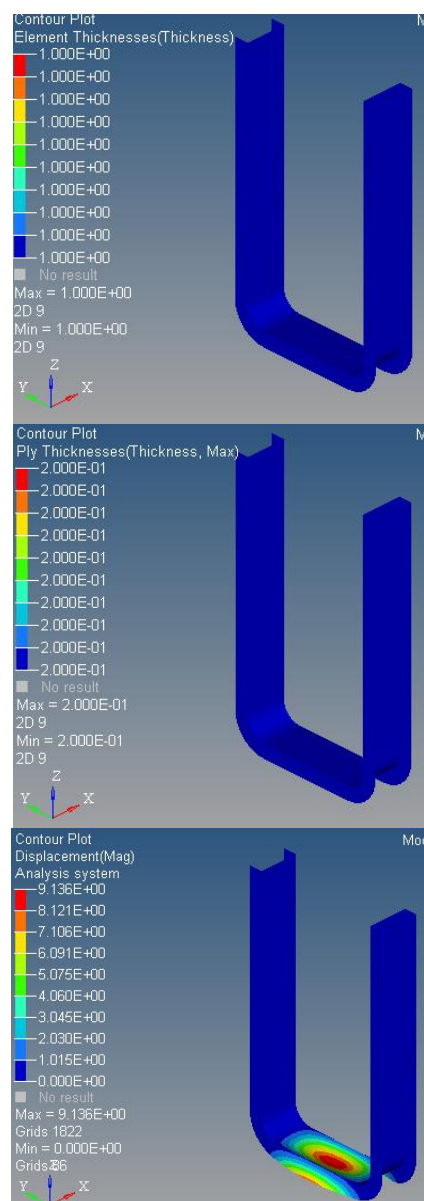


Fig 12: Stress, thickness and Displacement results after Size optimization

4.9 Shuffle-optimization

In this phase, an optimal shuffling sequence is generated for the loads and BCs' applied, that is which ply should go where in the laminate. MAXsucc feature controls number of similarly oriented plies to go on one another.

ITERATION 2

Objective Function (Minimize MASS) = 1.01596E+02 % change = 0.00
No active constraints
Volume = 5.97625E+04 Mass = 1.01596E+02

Fig 13: Mass after iteration (2) 101.596g

Stacking sequence for STACK 1

Iteration 0	Iteration 1	Iteration 2	Legend
11101	11101	11101	90.0 degrees
12101	12101	12101	45.0 degrees
13101	14101	14101	0.0 degrees
14101	15101	15101	-45.0 degrees
15101	13101	13101	

Fig 14: Stacking Sequence of Plies

5. RESULTS

Reduction of mass from 1175.8838g when in steel form to 223.6g when in composite form and 101.1596g after optimization.

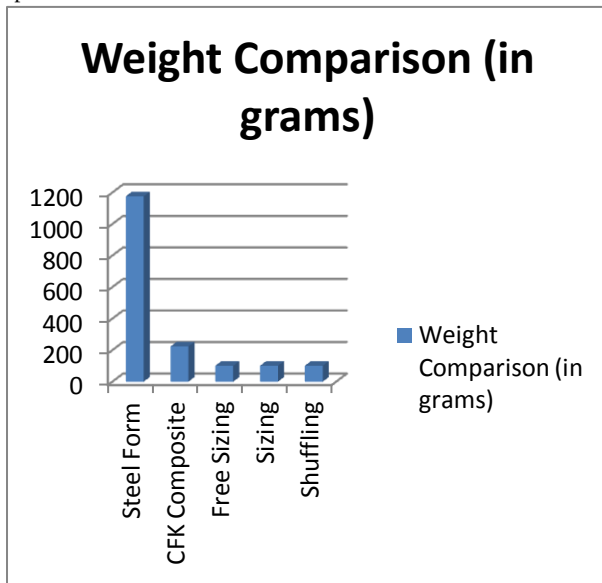


Fig 15: Weight Comparison

6. ACKNOWLEDGMENTS

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7. REFERENCE

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