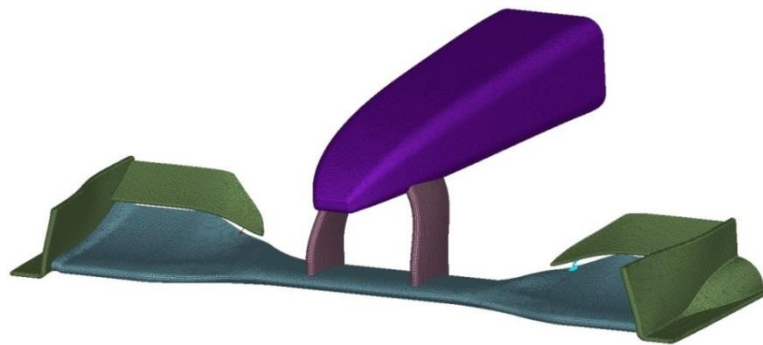


## Composite Materials Multi Objective Optimization using ANSA, META and modeFRONTIER

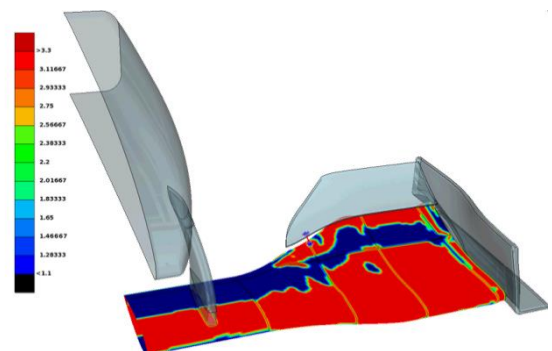
### Introduction

As the composite materials market expands and more applications appear in the automotive, aerospace and naval industry, optimization of such materials is becoming an essential step in their research, development and mass production. Due to the nature of composite materials, accurate optimization during the design process can be significantly cost and time effective. ANSA and META, the pre and post processing package of BETA CAE Systems offer the tools for creating and handling composite material models and also an also an efficient tool for setting up an optimization problem. In this paper, the capability to set up an optimization problem with ANSA will be presented and also the optimization procedure of the orientation (THETA angle) and thickness (T) of each layer of the selected component will be described, targeting mass, and angle of attack minimization (at 300km/h).



### Problem description

The model is a front wing of an F1 car according to F1 regulations (2012). The half front wing (seen in the image below) consists of 56293 shell elements (quads and trias). The highlighted part of the model (wing) which will be used for the optimization problem consists of 19583 shell elements (quads and trias) and a total of 29 layers. Two load cases are applied on the model. First is a static structural maximum displacement test, and the second load case is the static air pressure load on the wing at a

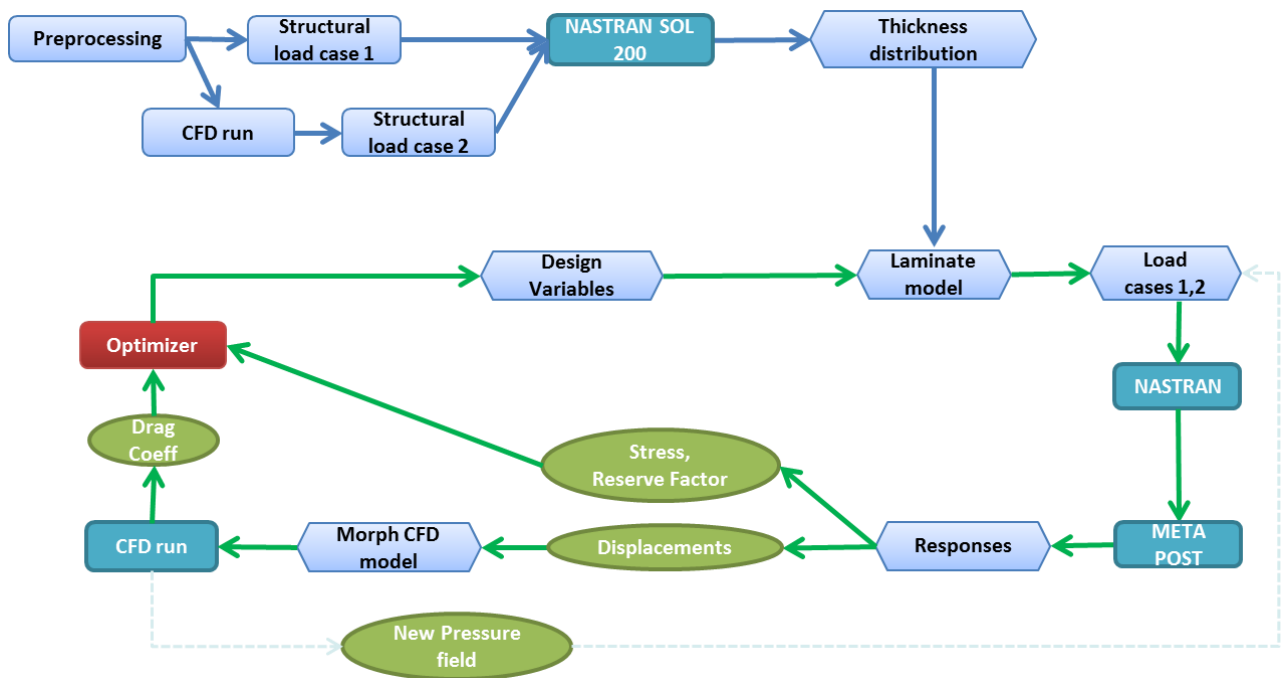




speed of 300km/h (acquired from CFD analysis). The two loading conditions were applied in a thickness optimization case, to provide a first view of the critical areas, helping with the design of the laminate model.

The model was already designed for reduced mass and angle of attack change at high speeds. The objective of the main optimization problem is to further minimize the mass of the selected component by optimizing layer thickness and area, and also due to layer orientation, to minimize the angle of attack of the front wing under the air pressure load. Minimizing the angle of attack at high speeds, aims to achieve reduction of the drag coefficient, thus higher top speed. The constraints of this problem are the maximum displacement of the front wing under a specific static load (F1 rules) and maximum stress limit for all the layers of the part (Reserve Factor).

The main optimization process starts where the laminate model is used for a static analysis with the two loadcases (Structural and pressure field). Responses regarding displacement and Reserve factor are acquired to and used as design constraints. Also displacements resulting from the pressure loading are mapped to the initial CFD model, simulating the bending of the wing at 300km/h and the CFD analysis takes place for the updated CFD model. After post processing, the result from the CFD model is the drag coefficient that is used as a design objective and also a new pressure field that is transferred to the structural model of the next iteration. Response values for model weight, drag coefficient, displacement, stress, angle of attack and stress factor.

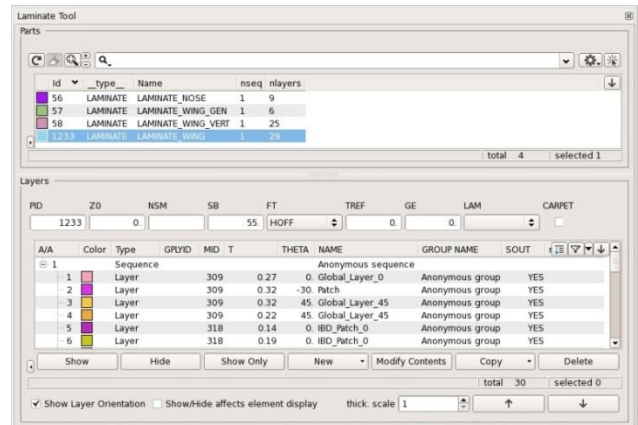
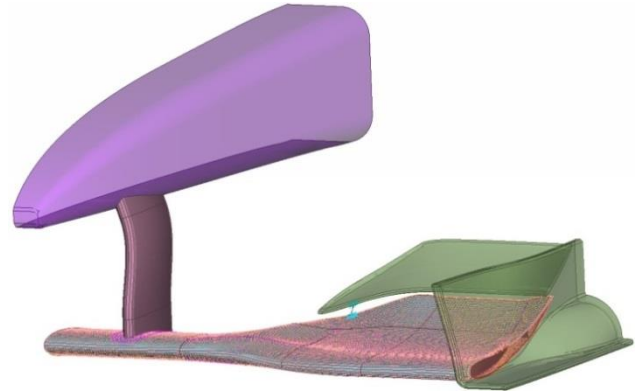




## Laminate tool of ANSA

Laminate tool is ANSA's tool for handling composite material (layered) models. Any action, from creating new laminates and layers, to editing (orientation, thickness, adding/removing elements), positioning, adding or removing layers can be performed with ease within the laminate tool and also a preview of the output format can be viewed in the ANSA info window. Visualization of layers, layer orientation and thickness is also possible and all information regarding laminates and layers can be obtained. Also a comprehensive laminate report can be automatically produced and layer curves can be created in CAD format within the laminate tool.

In this case, the wing part that is optimized has a single laminate property separated in areas, "patches" of different number of layers according to the design needs. Several numbers of sequences of layers can also be created for a single laminate property with the laminate tool. Additionally, FiberSim, Simulayt and PamStamp laminate mapped data are supported by ANSA.



## META Composite Post Toolbar

Post processing of composite material models can be performed with the use of the unique META Composite Post Toolbar that offers calculation of Failure Criteria, Reserve Factor and Effort (Tsai-Wu, Hill, etc). Identification of max failure layer, isolation of failed elements, re-evaluation of failure criteria after modifying material properties and also plot of stress tensor results across each element thickness.

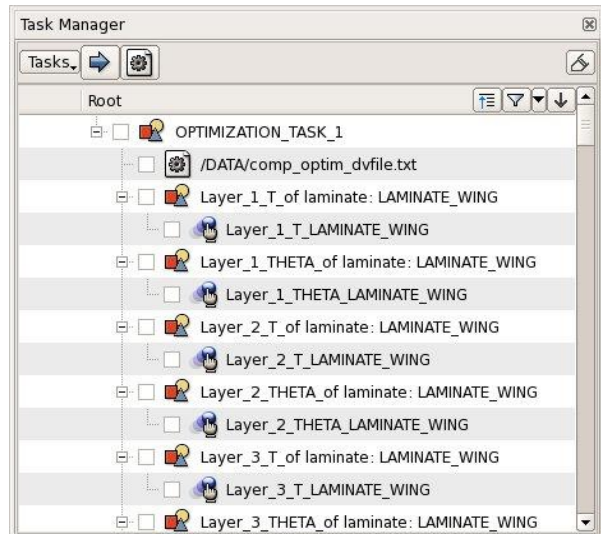
## Optimization Task

Coupling of ANSA with optimizers is possible with the Optimization Task of ANSA's Task Manager tool. This task describes a series of actions that ANSA will execute during each cycle of the optimization procedure. In this case, at each run of the task, orientation (THETA angle), layer area and thickness (T) of each layer of the component are defined as Design Variables and are connected to the optimization task. User defined items can also be added such as user scripts and session commands. For this paper's purpose, a session command is added in the optimization task in order to extract the model



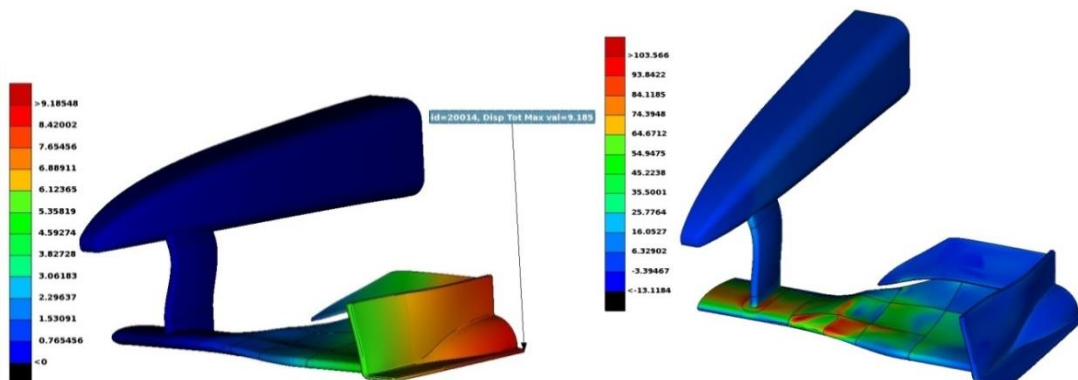
mass at each iteration and is used as a design objective for the optimizer in order to minimize it. Finally at each iteration, the new model is output with a specific format for a selected solver.

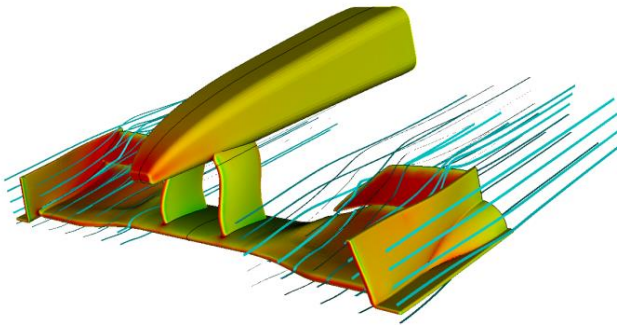
Due to the large number of layers (and evidently large number of design variables) used in composite material components, the setup of such an optimization problem can be time consuming. In ANSA, this procedure was entirely automated with the help of a **User Script**. An optimization task is created in the Task manager as well as design variables (one for THETA angle, one for layer area and one for T for each layer) with initial layer orientation and thickness values within a few seconds. The design variables are connected to the values of the laminate layers and are able to obtain different values during the optimization procedure (by the optimizer), thus creating a different design of the model at every cycle.



### Extract responses through META

Responses are extracted at each iteration in order to be evaluated by the optimizer. META offers an effective and user friendly way of extracting any type of response (scalar, vector, real, complex), making use of the Annotation Tool and the Optimizer set-up toolbar. The result files from the solvers (structural and CFD) are viewed in META and the process of extracting the responses is recorded once in a session file. modeFRONTIER, being compatible with META, can use this session file for every iteration, call META and extract the same responses for each design of the optimization procedure. The extracted responses are written in an ASCII file from where modeFRONTIER can obtain them, completing an optimization cycle.





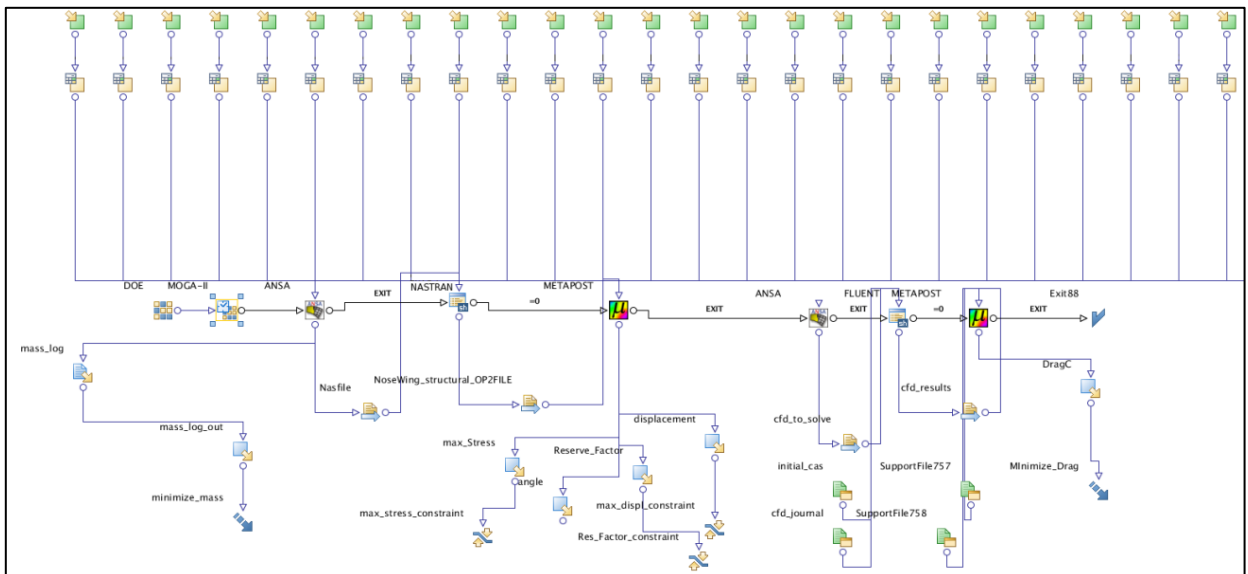
- The first response that is extracted is the maximum total displacement of the wing when subjected to a static load of 1000N that is applied at the narrow top area of the vertical end plate of the wing (loadcase 1)

- The second response is the maximum stress of all the layers of the composite component when subjected to an air pressure load simulating speed of 300km/h ( loadcase 2). These two responses are used as design constraints for this optimization problems

- A third response that is extracted from META is the drag coefficient result from the cfd analysis . This response is used as the second design objective aiming to reduce drag.

### Direct coupling of ANSA and META with modeFRONTIER

ANSA and META CAE nodes are available in modeFRONTIER and no scripts are needed to connect them. The ANSA node is used to handle models and to set and extract data from the ANSA optimization task. Defined design variables in the optimization task are automatically recognized and created in modeFRONTIER which looks for the best values for them in order to obtain the optimal solution. META node is used to feed in the optimizer the extracted responses (scalar, vector, real, complex) that can be defined as design objectives or design constraints within modeFRONTIER.





modeFRONTIER automatically recognizes and creates all the design variables for optimization. The extracted responses are auto-recognized as well. Initially, the algorithm chosen for this optimization problem was the Multi Objective Game Theory algorithm (MOGT). This algorithm is very efficient in finding solutions between multiple objectives and among a large number of designs (many design variables).

After the first optimization run, the design variables that had a significant influence on the designs were detected via the correlation matrix charts of modeFRONTIER. These design variables were then used for a second optimization run enabling the use of more iterations and saving time.

The algorithm used in the second run is MOGA II (Multi Objective Genetic Algorithm) which is a robust and highly used genetic algorithm designed for fast Pareto convergence. MOGA II algorithm uses directional crossover (also mutation, selection and simple crossover operators) operator for fast convergence and elitism to ensure that the best solutions are preserved during the evolution.

## Results

ANSA and META offer a time efficient and user friendly tool for this type of optimization process due to the fully automated functionality and seamless connection between the pre and post processor and the optimizer. Concluding, this coupling of ANSA, META and modeFRONTIER is a powerful combination for automated and fast CAE processes.

### Indicative time of operations completion

ANSA Optimization Task creation using script: 1.2sec

Optimization Task run: 1.1 sec

META session file manual creation: 3.5min

modeFRONTIER Optimization loop in batch mode (ANSA, NASTRAN, META): 3min

The acquired results showed that this type of optimization is possible and viable solutions can be obtained. Mass reduction reached 32% for the optimized part and drag coefficient was reduced by 2.5% at 300km/h

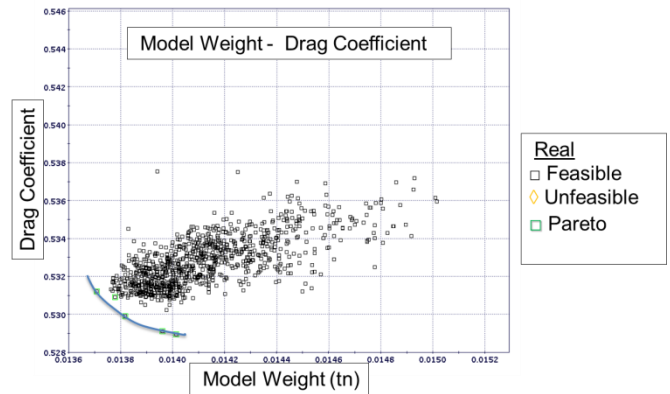
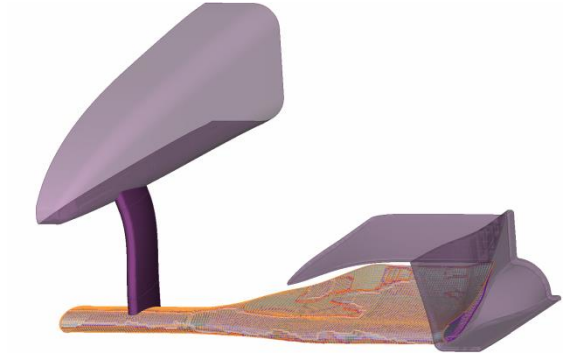


### Initial design

Wing Mass: 3.323kg (Total: 14.860kg)  
Max displacement (loadcase 1): 8.07mm  
Max stress (wing only, loadcase): 237.12 MPa  
Reserve factor: 10  
Angle of attack (loadcase 2): 12.3°

### Optimized design: id 1952

Wing Mass: 2.235kg (Total: 13.772kg)  
Max displacement (loadcase 1): 9.92mm  
Max Stress (wing only, loadcase 2): 177.6MPa  
Reserve factor: 15.8  
Angle of attack (loadcase 2): 12.0°



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