Compositi Expo-congress
Modena ,14 Ottobre 2009

Topological optimization of the stiffener and layup of a rear wing sport car

Mauro Parodi
Exemplar srl
Corso Castelfidardo, 30/A
Torino IT
luca.fattore@exemplarsolutions.it
www.exemplarsolutions.it

Agenda

- Exemplar srl
  - composite design know-how
- Problem introduction
  - layup definition
  - spars introduction
- iDA optimization tool
  - Features description
  - Why iDA
  - Graphical interface
  - iDA method
- Wing box Results
- Questions & Answer

Exemplar and the composite design

- 12 years of experience in composite simulation
  - Aerospace, Automotive and Ship building
  - Aeroelasticity analysis
  - Static, Buckling and Dynamic analysis
  - Composite certification/verification for aeronautical industries
- R&D and founded project with innovative composite material
  - Green composite research with ALENIA
  - Nanotube application on composite on “TOP” project with ALENIA-THALES Space
- Training and technological update
  - Know-how transfer
  - Training on the job
- Software development for composite optimization
  - Dedicated interface for CAE solver

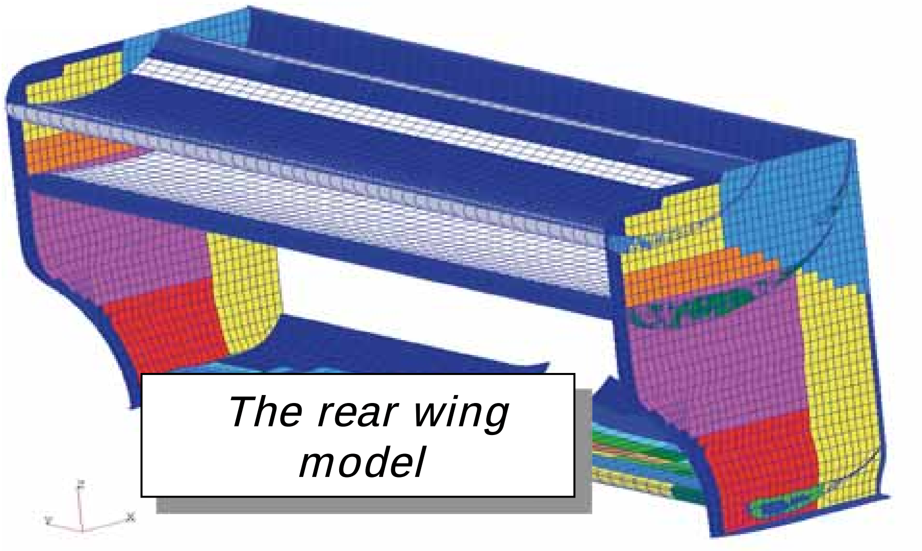
Problem introduction

- Problem description

- The iDA [*i*ntelligent *D*ecision *A*dvisor] software was been used to design a new layup for the full rear wing sport car and to investigate about the best position for the internal spar:
  - assure adequate static capability and buckling performance
  - assure the required stiffness for the auditor certification
  - assure high flexional frequency vibration
  - reduce the weight respect to the actual design
  - define the best spar number and position

Problem introduction

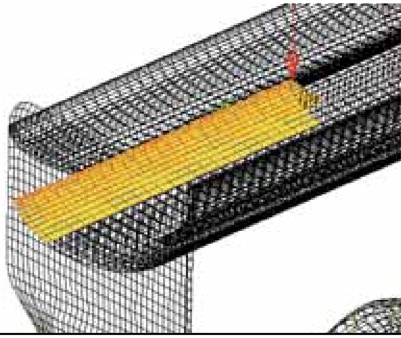
- The external shape cannot be modify
- 250 ply shapes are available
- angle ply step by 5°
- each ply can be chosen from a material list
- The problem has about 800 indipendent parameters

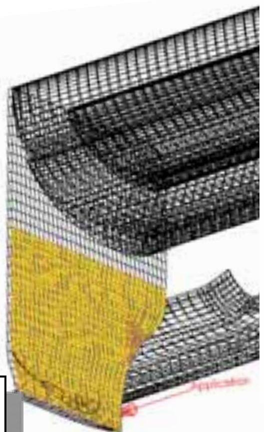


The rear wing model

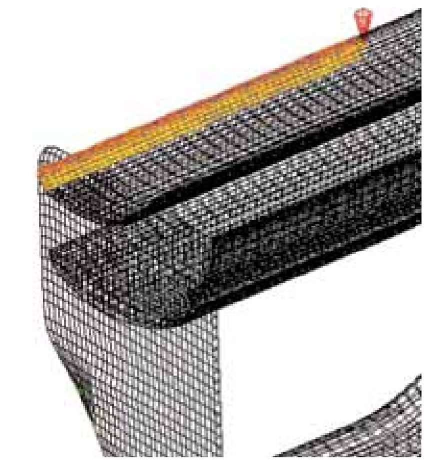
exemplar Manufacturing description in the FEM

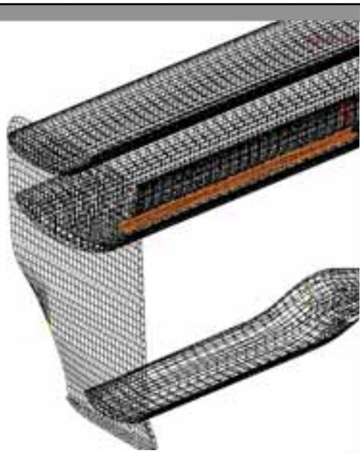
- Example of the available shapes for the plies geometry

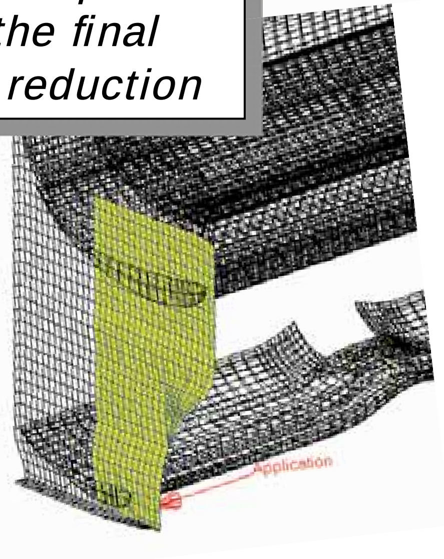


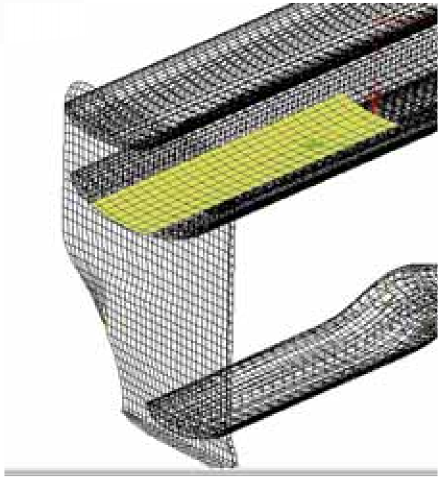


for each shape a cost estimation can be computed: iDA can handle the final manufacture cost reduction



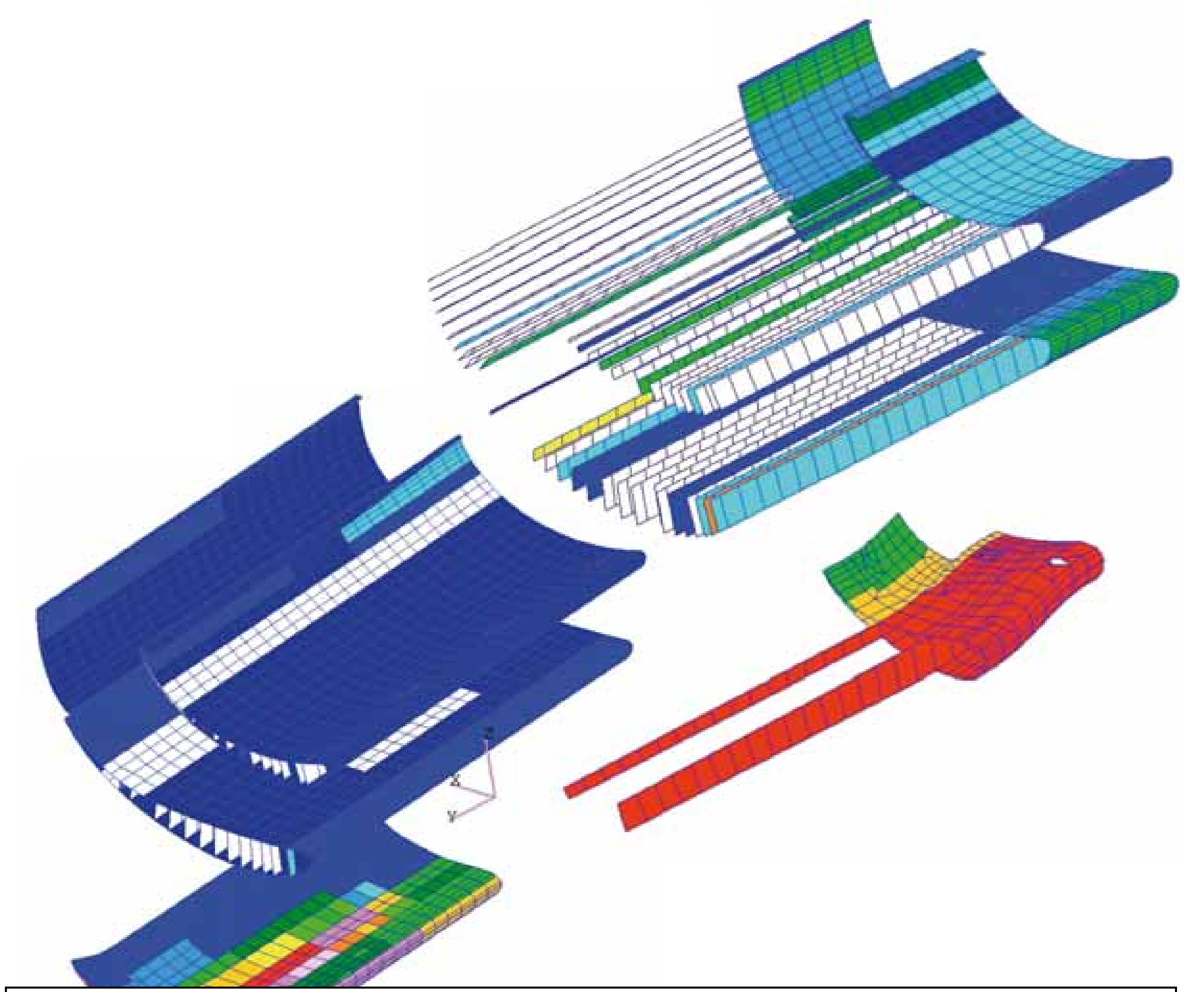






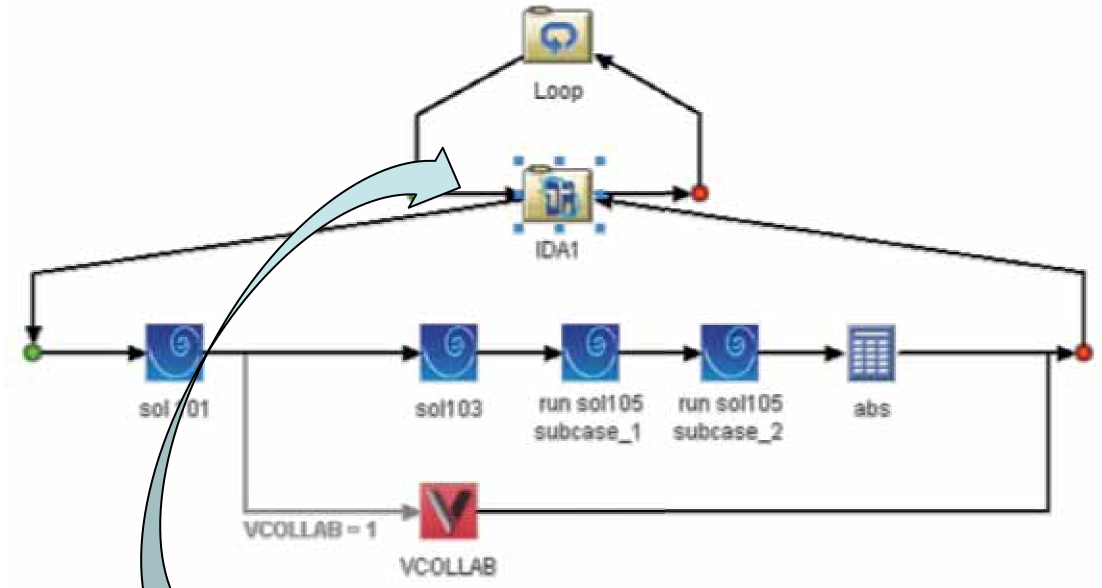
Manufacturing description in the FEM

- The internal wings have been filled with spars (50 spares)



The internal spar distribution in the wings

iDA - *intelligent Decision Advisor*



The iSight-FD workflow with iDA used to solve HT structural problem

- iDA is a algorithm able to improve the design in the real world environment (limited time, limited resources, complex problem)
- iDA has been developed by EXEMPLAR team. It collects 10 years of experience on optimization problem for the industry.
- iDA is also available as a plug-in on iSight process integration software.

Why iDA ?

- The multi-disciplinary optimization problem dramatically increase the design parameter: in the real world, the number of design parameter is huge, and only an efficient exploration of their interaction can achieve a innovation design.

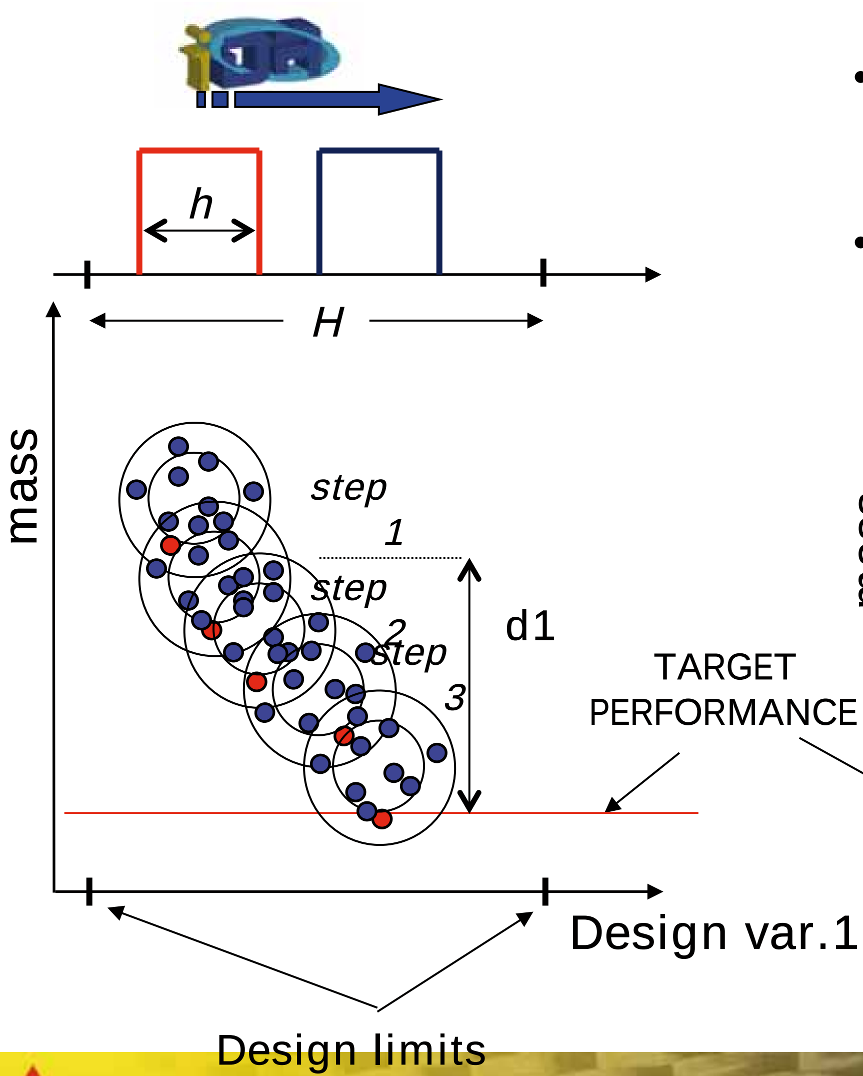
- For engineering problems many optimization method are available. EXEMPLAR experienced that all of them have a maximum number of design parameter limit, because they are "generic" method.

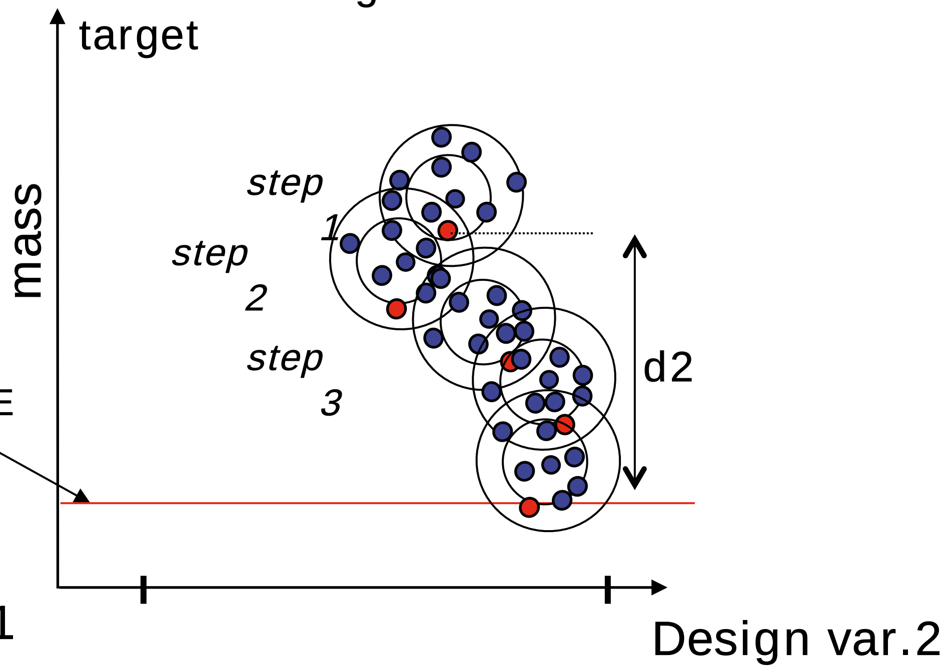
- In the classical optimization methods, the user cannot supply his knowledge about the studied system.

- The aim of iDA method is allow the expert to supply all available useful information which can help the exploration method to reach its goals.

The iDA method

- iDA can be “briefly” defined as a drove DOE
- The uniform distribution, *h*, should be such that with N steps, the design variable can reach its limits.
- iDA heads the exploration box with the user knowledge to reach the desired target





and composite

GLOBAL LAYUP SEQUENCE: the independent plies

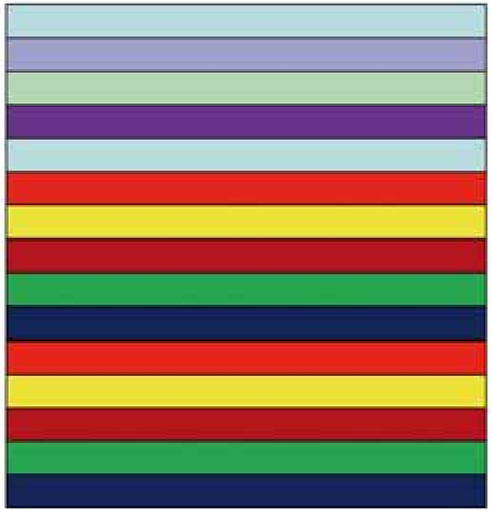
PLY NAME	ANGLE	MATERIAL
Ply_shape_#1000	angle=0°	Mat=A
Ply_shape_#1010	angle=0°	Mat=A
Ply_shape_#1012	angle=0°	Mat=A
Ply_shape_#1020	angle=0°	Mat=A
Ply_shape_#1000	angle=0°	Mat=A
Ply_shape_#2040	angle=0°	Mat=A
Ply_shape_#2045	angle=0°	Mat=A
Ply_shape_#2044	angle=0°	Mat=A
Ply_shape_#1072	angle=0°	Mat=A
Ply_shape_#1045	angle=0°	Mat=A
Ply_shape_#2040	angle=0°	Mat=A
Ply_shape_#2045	angle=0°	Mat=A
Ply_shape_#2044	angle=0°	Mat=A
Ply_shape_#1072	angle=0°	Mat=A
Ply_shape_#1045	angle=0°	Mat=A

STEP - 0 - : initial configuration

iDA and composite

- In the composite design, iDA doesn't considered the parameter like thickness, angles or materials as cardinal numbers, but it manage them as "*<u>configuration state</u>*"
- A stochastic distance is defined for each design parameter: the ply shape, the angle and the ply material;
  the list table of all these parameters is a "<u>configuration state</u>"
- The Euclid distance between the configuration state and the user desired performance is automatic computed based on the user physics consideration.
- At the step -0-, each parameter has the maximum distance to the desired target performance

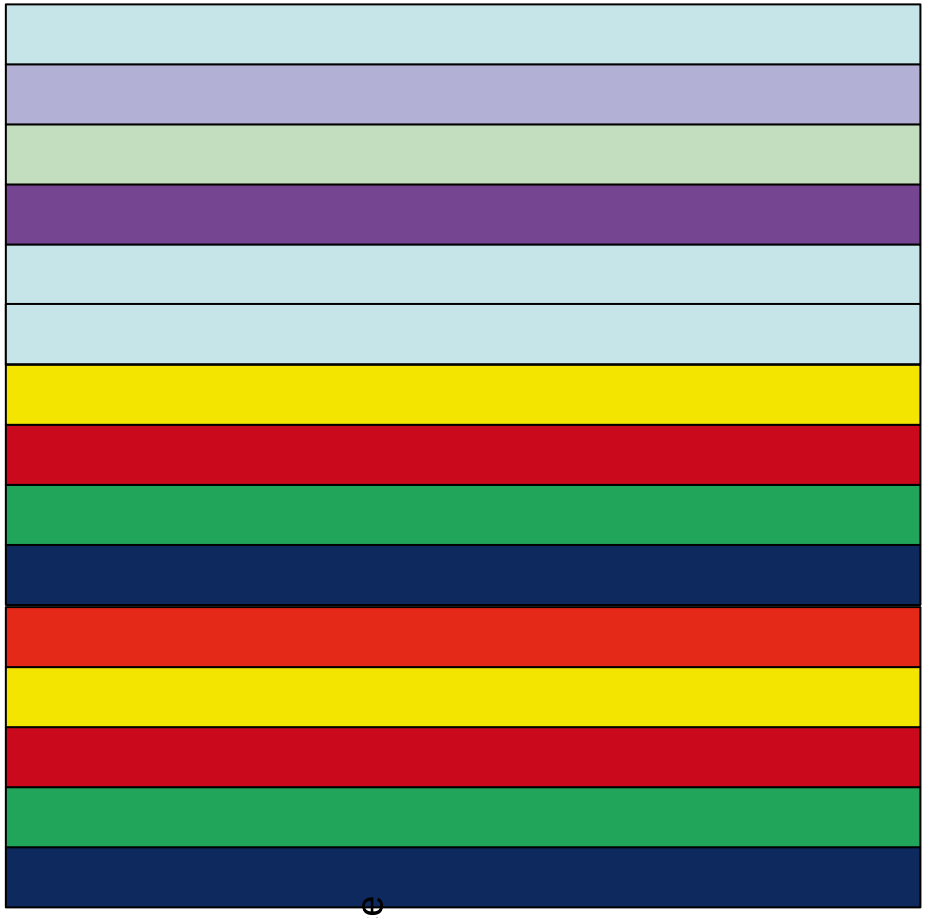
GLOBAL LAYUP SEQUENCE: the independent plies



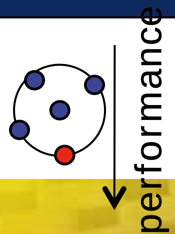
PLY NAME	ANGLE	MATERIAL
Ply_shape_#1000	angle=45°	Mat=A
Ply_shape_#1010	angle=0°	Mat=B
Ply_shape_#1012	angle=90°	Mat=A
Ply_shape_#1020	angle=0°	Mat=C
Ply_shape_#1000	angle=45°	Mat=C
Ply_shape_#2040	angle=45°	Mat=A
Ply_shape_#2045	angle=0°	Mat=B
Ply_shape_#2044	angle=0°	Mat=A
Ply_shape_#1072	angle=90°	Mat=B
Ply_shape_#1045	angle=45°	Mat=A
Ply_shape_#2040	angle=90°	Mat=A
Ply_shape_#2045	angle=45°	Mat=B
Ply_shape_#2044	angle=0°	Mat=C
Ply_shape_#1072	angle=0°	Mat=B
Ply_shape_#1045	angle=45°	Mat=A

and composite

GLOBAL LAYUP SEQUENCE: the independent plies



PLY NAME	ANGLE	MATERIAL
Ply_shape_#1000	angle=0°	Mat=A
Ply_shape_#1010	angle=0°	Mat=A
Ply_shape_#1012	angle=0°	Mat=A
Ply_shape_#1020	angle=0°	Mat=A
Ply_shape_#1000	angle=0°	Mat=A
Ply_shape_#2040	**angle=0°**	**Mat=A**
Ply_shape_#2045	angle=0°	Mat=A
Ply_shape_#2044	**angle=45°**	Mat=A
Ply_shape_#1072	angle=0°	Mat=A
Ply_shape_#1045	angle=0°	Mat=A
Ply_shape_#2040	angle=0°	Mat=A
Ply_shape_#2045	angle=0°	**Mat=C**
Ply_shape_#2044	angle=0°	Mat=A
Ply_shape_#1072	angle=0°	Mat=A
Ply_shape_#1045	angle=0°	Mat=A

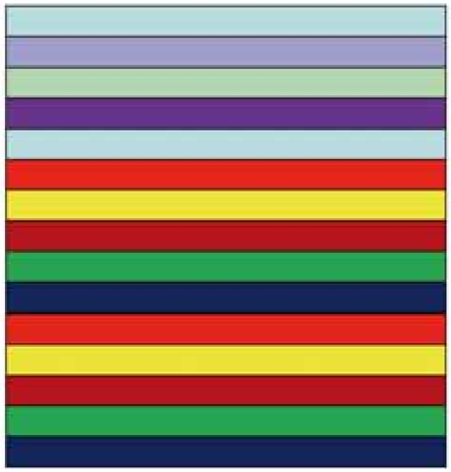


STEP -1- : first design exploration

and composite

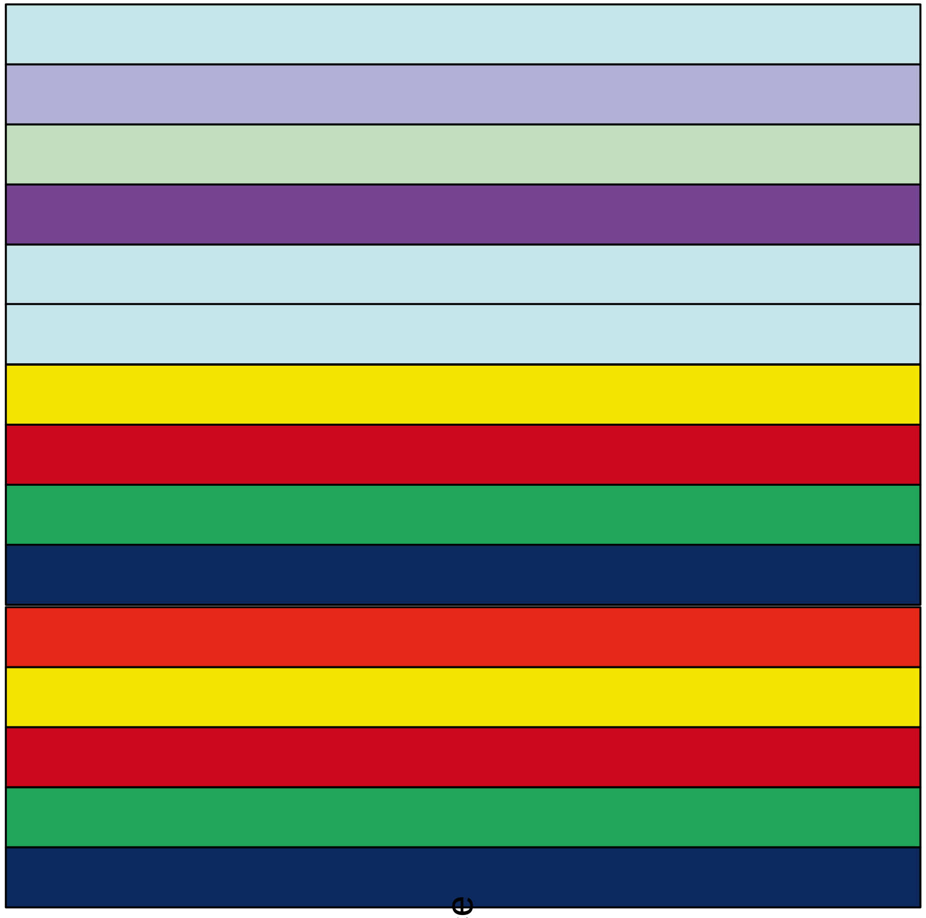
- The history of the evolution of each design parameters (shape, thick, mat, etc..) and the history of the evolution of the performance's "configuration state" are related such as a cardinal ordering in the stochastic metric is created
- The stochastic distance of the parameters is used to chose which parameter will be in the next iDA step perturbed

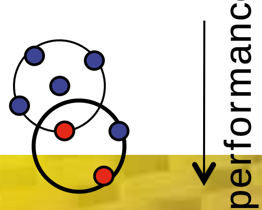
GLOBAL LAYUP SEQUENCE: *the independent plies*



PLY NAME	ANGLE	MATERIAL
Ply_shape_#1000	angle=45°	Mat=A
Ply_shape_#1010	angle=0°	Mat=B
Ply_shape_#1012	angle=90°	Mat=A
Ply_shape_#1020	angle=0°	Mat=C
Ply_shape_#1000	angle=45°	Mat=C
Ply_shape_#2040	angle=45°	Mat=A
Ply_shape_#2045	angle=0°	Mat=B
Ply_shape_#2044	angle=0°	Mat=A
Ply_shape_#1072	angle=90°	Mat=B
Ply_shape_#1045	angle=45°	Mat=A
Ply_shape_#2040	angle=90°	Mat=A
Ply_shape_#2045	angle=45°	Mat=B
Ply_shape_#2044	angle=0°	Mat=C
Ply_shape_#1072	angle=0°	Mat=B
Ply_shape_#1045	angle=45°	Mat=A

iDa and composite

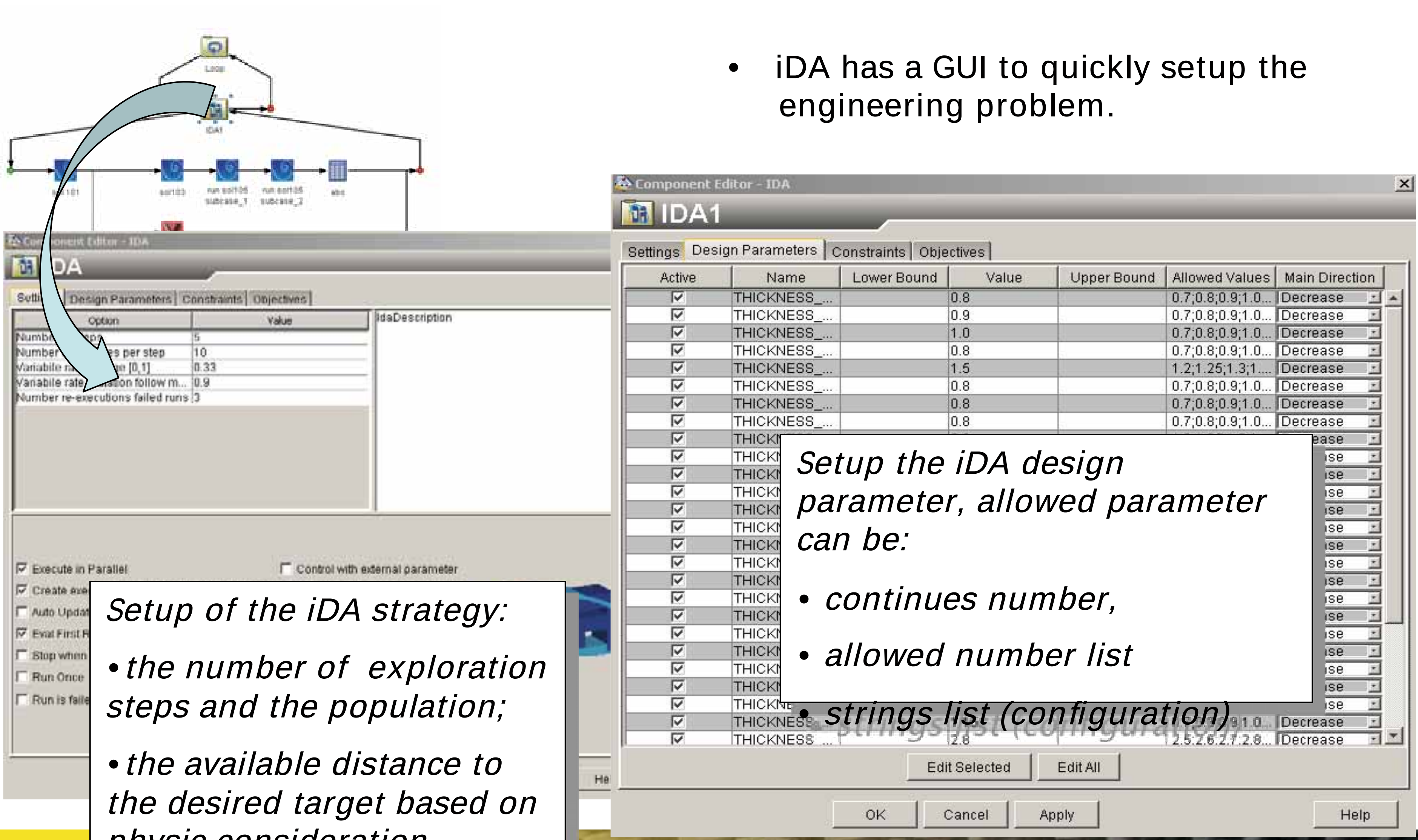
GLOBAL LAYUP SEQUENCE: the independent plies	PLY NAME	ANGLE	MATERIAL
	Ply_shape_#1000	angle=0°	Mat=A
	Ply_shape_#1010	angle=0°	Mat=A
	Ply_shape_#1012	angle=0°	Mat=A
	Ply_shape_#1020	angle=0°	Mat=A
	Ply_shape_#1000	angle=0°	Mat=A
	Ply_shape_#1000	angle=0°	Mat=A
	Ply_shape_#2045	angle=0°	Mat=A
	Ply_shape_#2044	**angle=45°**	Mat=A
	Ply_shape_#1072	angle=0°	Mat=A
	Ply_shape_#1045	**angle=90°**	Mat=A
	Ply_shape_#2040	angle=0°	Mat=A
	Ply_shape_#2045	angle=0°	**Mat=C**
	Ply_shape_#2044	angle=0°	Mat=A
	Ply_shape_#1072	angle=0°	Mat=A
	Ply_shape_#1045	angle=0°	Mat=A



STEP -2- : next step design exploration

The iDA graphical interface

- iDA has a GUI to quickly setup the engineering problem.



Setup of the iDA strategy:

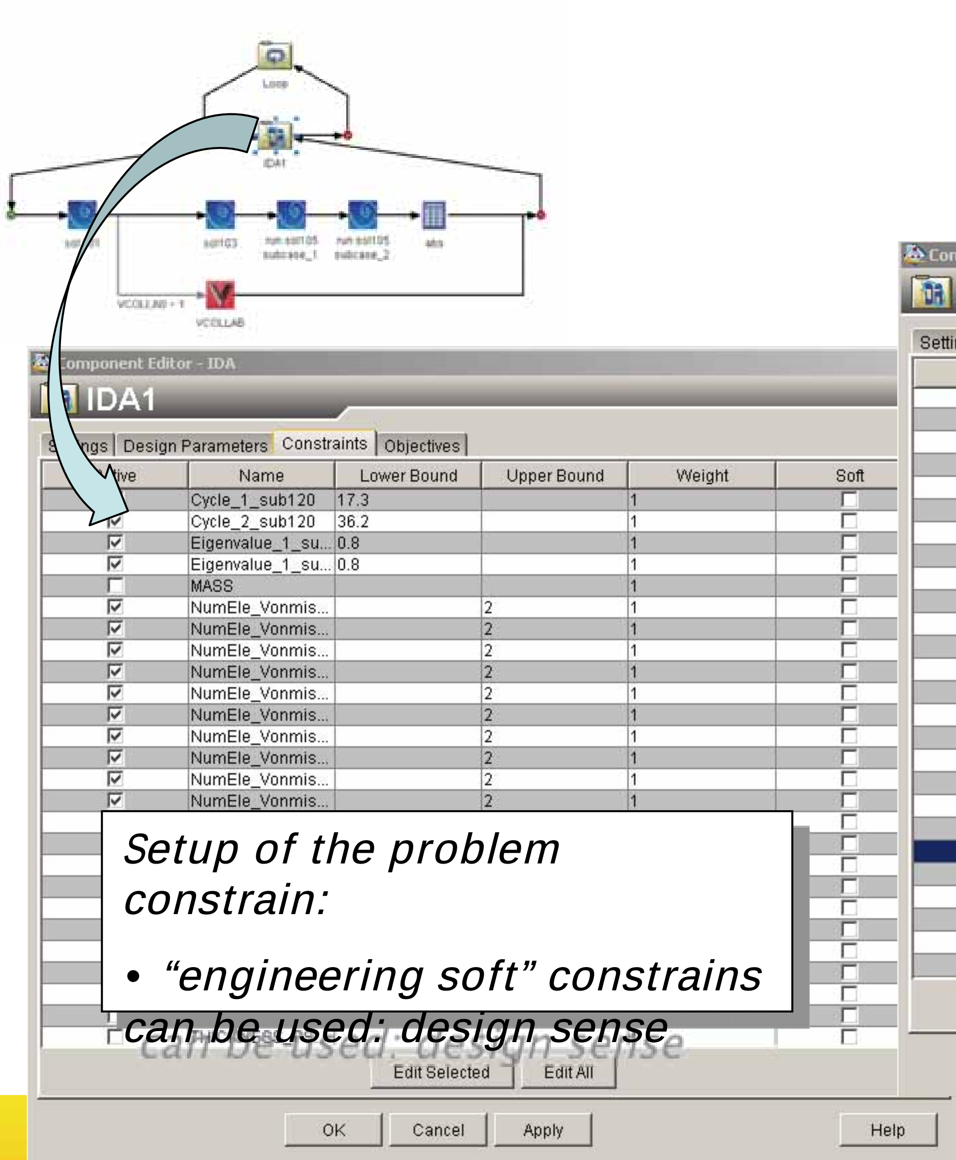
- *the number of exploration steps and the population;*
- *the available distance to the desired target based on physic consideration*

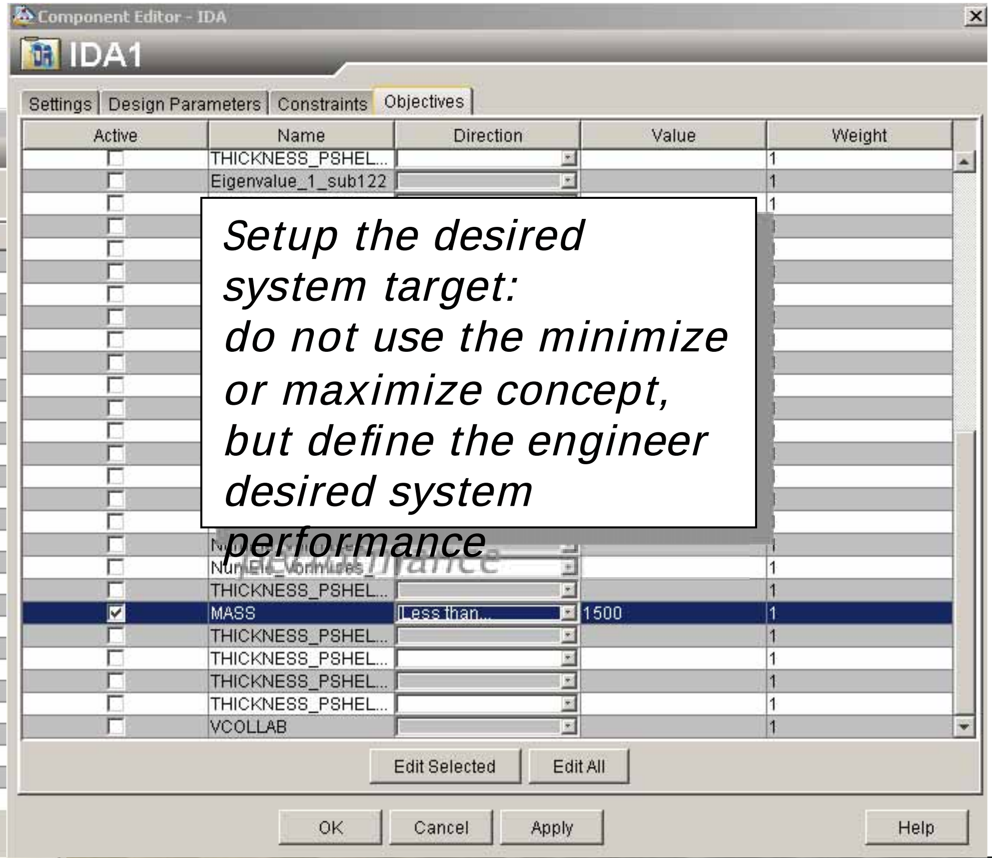
Setup the iDA design parameter, allowed parameter can be:

- *continues number,*
- *allowed number list*
- *strings list (configuration)*

The iDA GUI

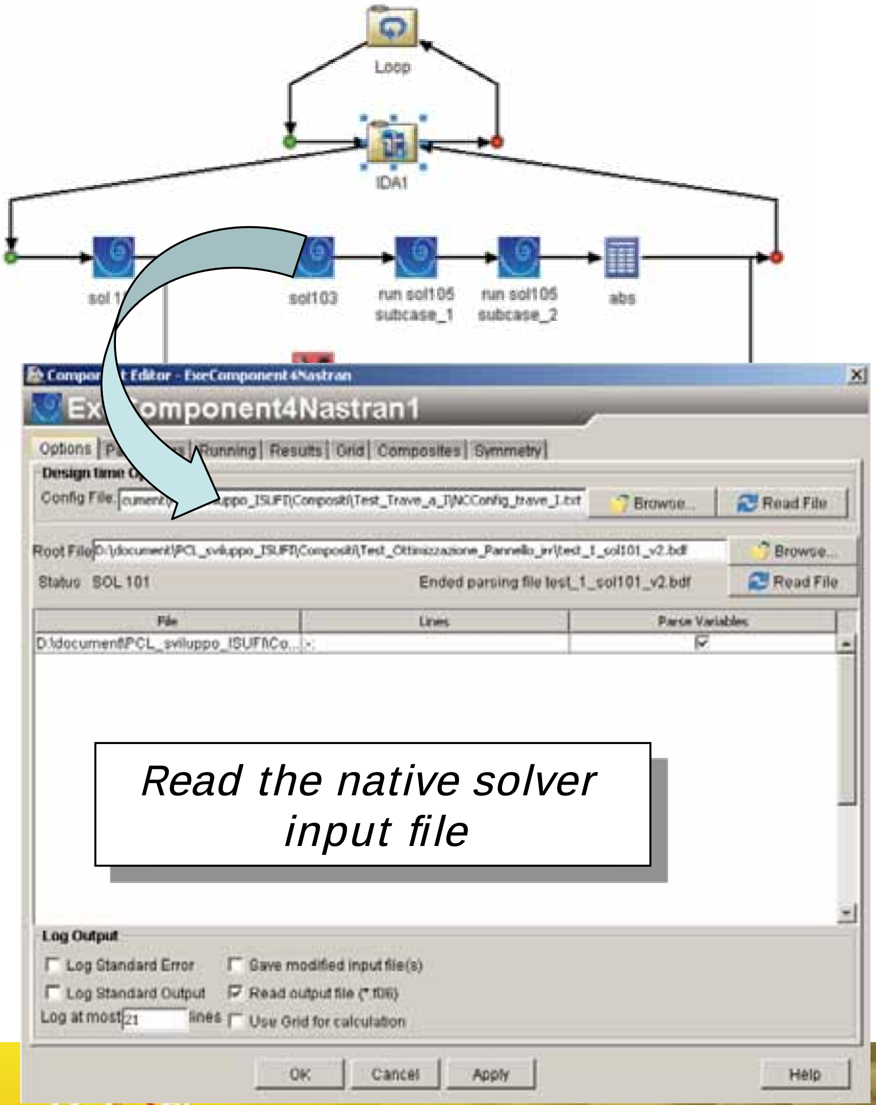
- Constrains and target can be defined using engineering sense.



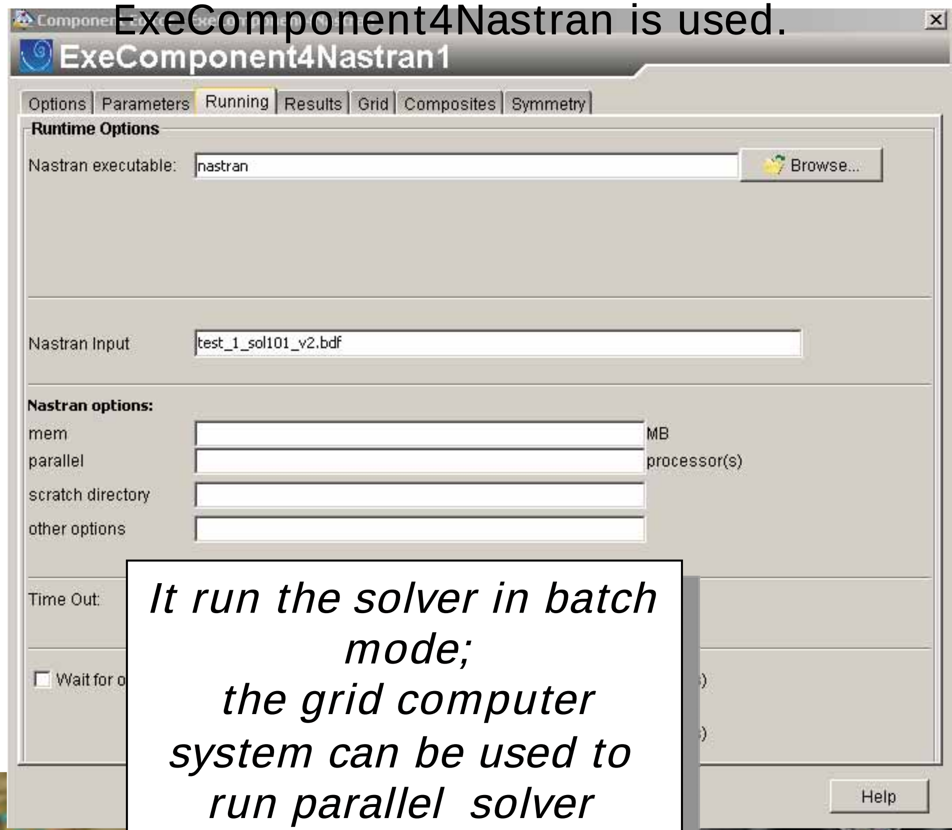


The final recipe: &

- The iDA generic interface can handle all kind of optimization problem
- But a dedicated interface has been developed for a quick composite complex problem setup, based on rules design.
- In the current example the ExeComponent4Nastran is used.



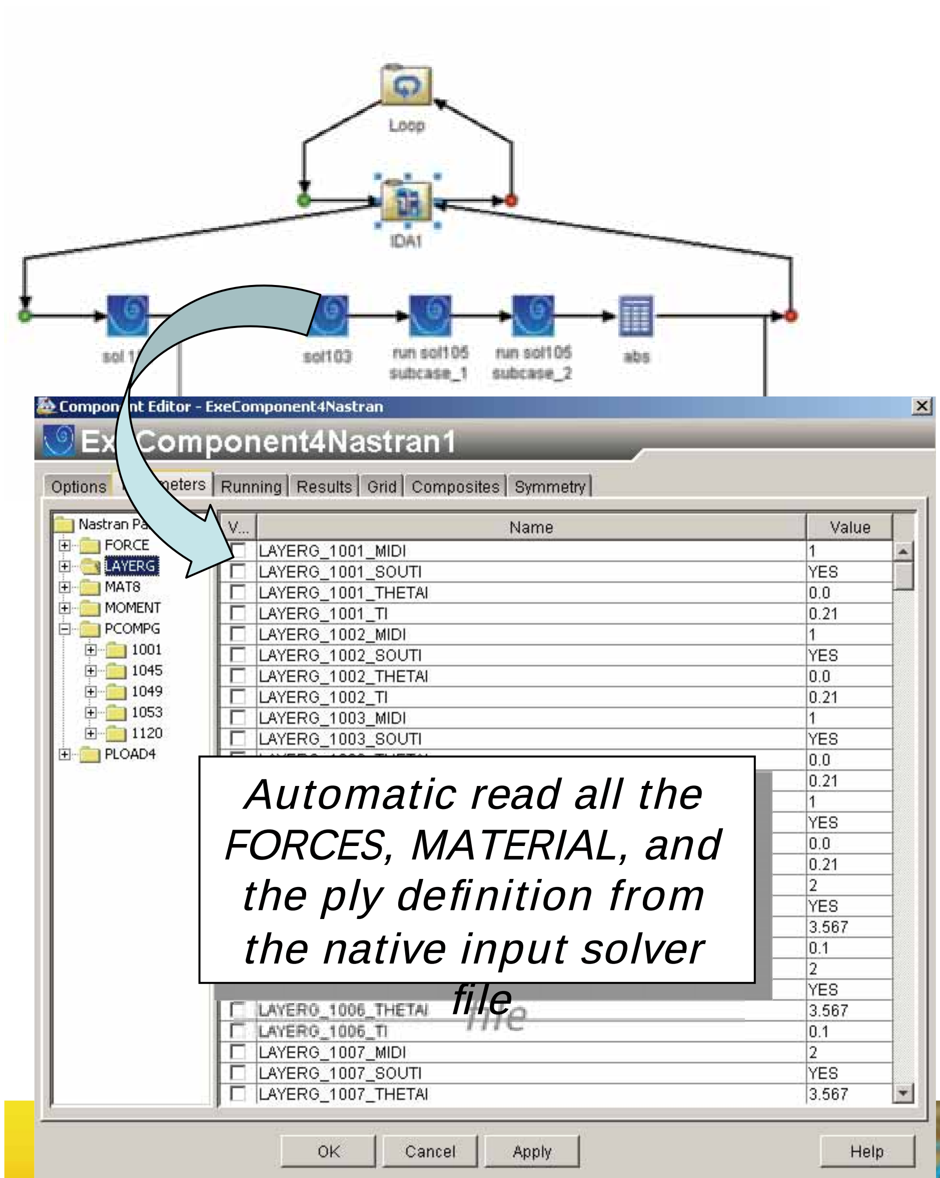
Read the native solver input file



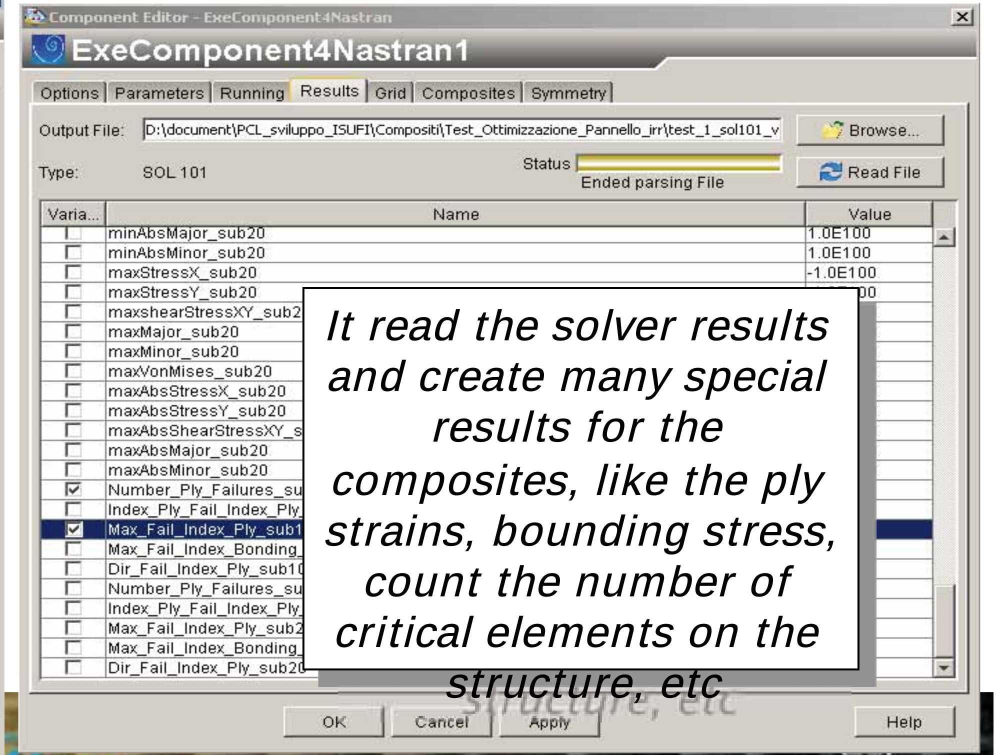
It run the solver in batch mode;
the grid computer system can be used to run parallel solver session

The final recipe: &

- ExeComponent4Abaqus and ExeComponent4Ansys are also available.



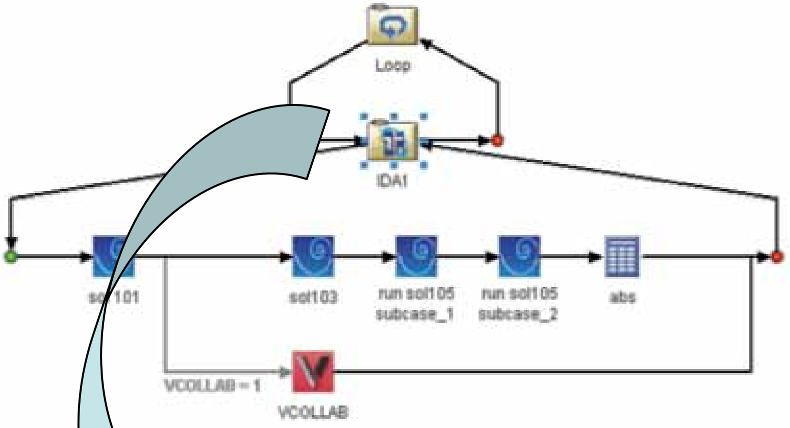
Automatic read all the FORCES, MATERIAL, and the ply definition from the native input solver file

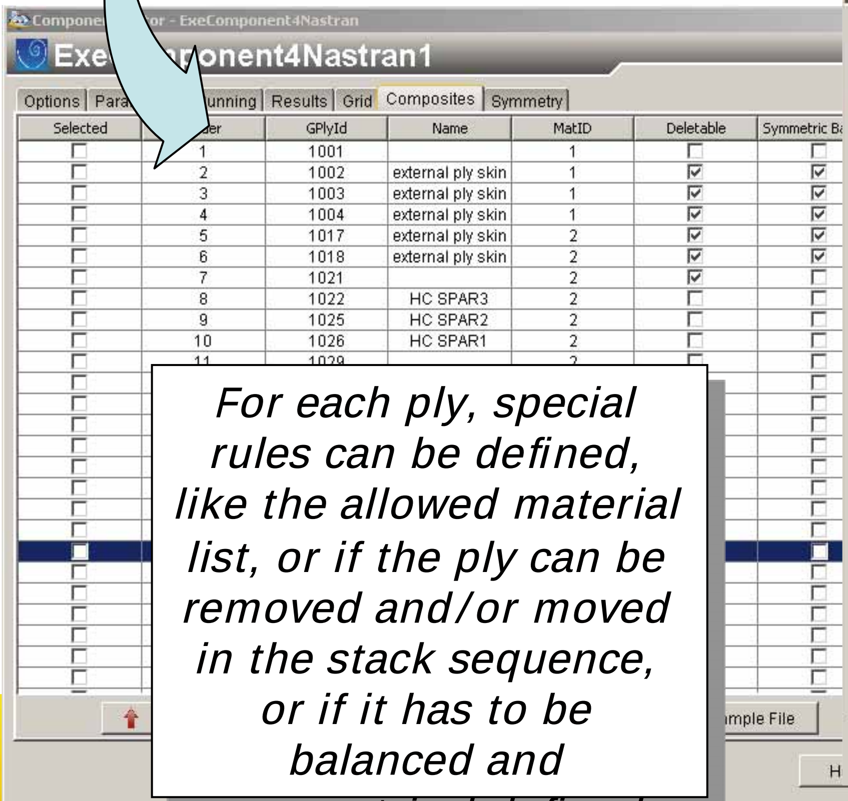


It read the solver results and create many special results for the composites, like the ply strains, bounding stress, count the number of critical elements on the structure, etc

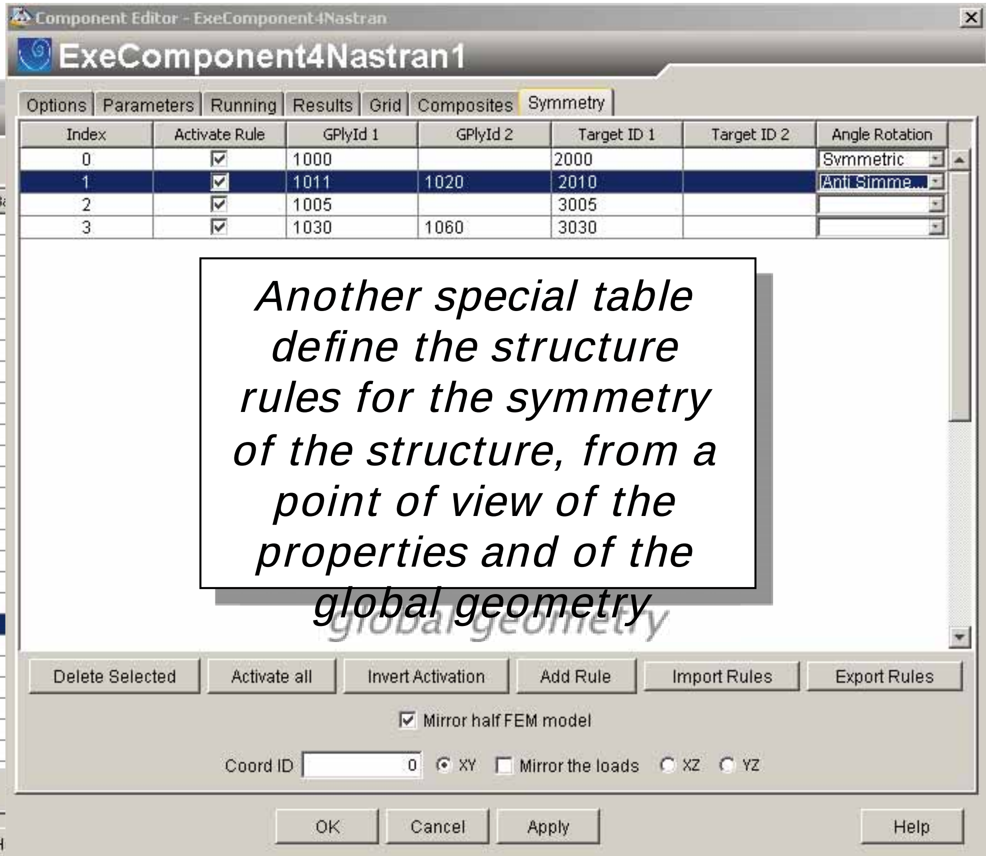
The final recipe: &

- Local layup rules
  - symmetric and balanced
  - external wrapper
  - sandwich behaviour, etc
- Global layup rules
  - Defined by the shape of the manufacture





For each ply, special rules can be defined, like the allowed material list, or if the ply can be removed and/or moved in the stack sequence, or if it has to be balanced and symmetrical defined



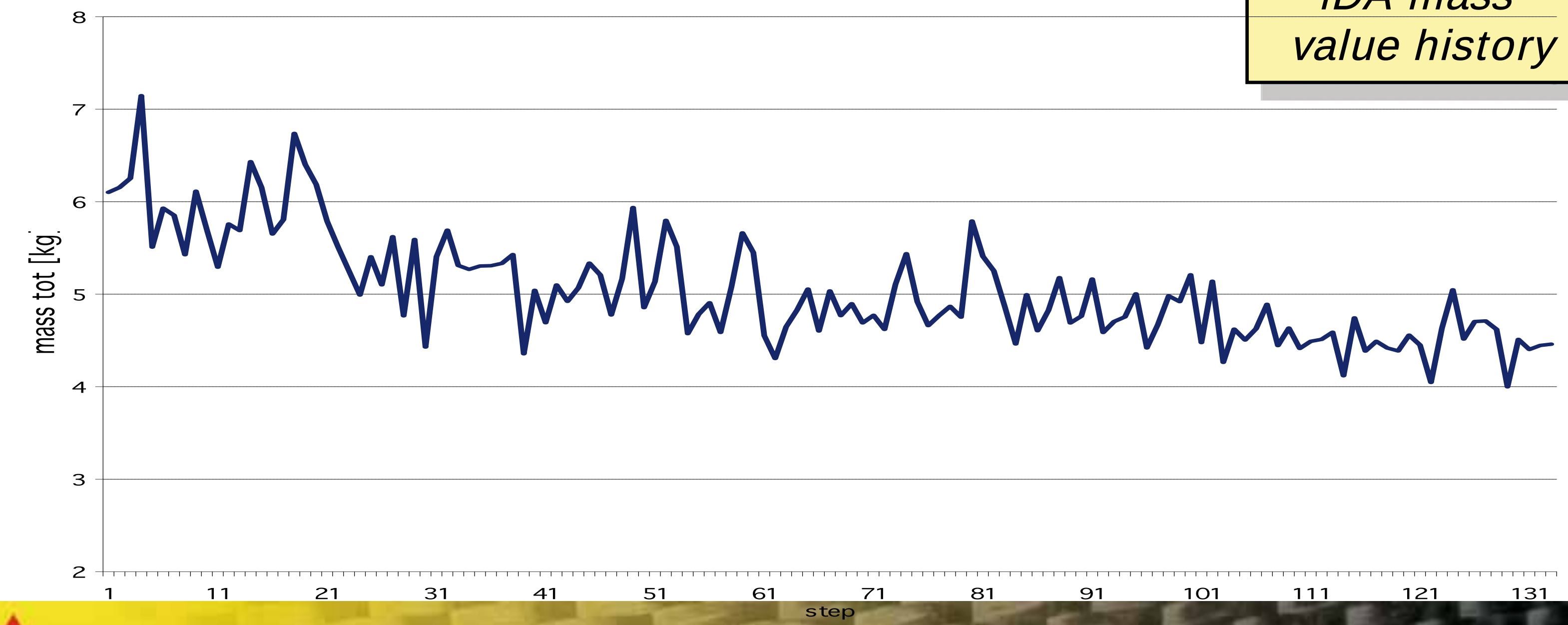
Another special table define the structure rules for the symmetry of the structure, from a point of view of the properties and of the global geometry

Results

- 131 function evaluations have been used to reduce weight and achieve the desired performance
- 15.0% weight reduction on the initial design

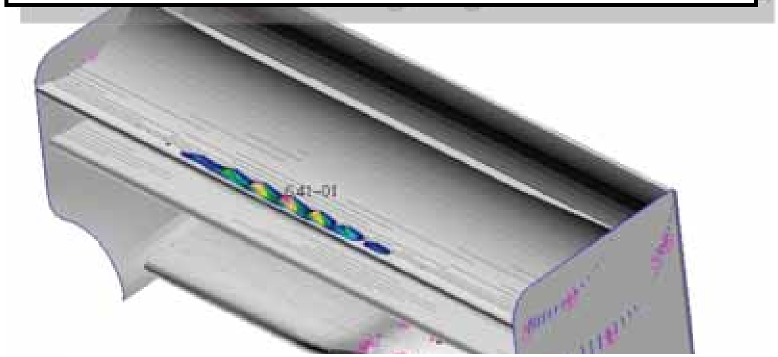
	Initial Design	iDA Result	Variation
Mass of the component	1	0,847	**-15.3%**
Requirement stiffness	0,893	0,952	**+6%**
Flexional freq.	21,17	24,5	**+14%**

iDA mass value history

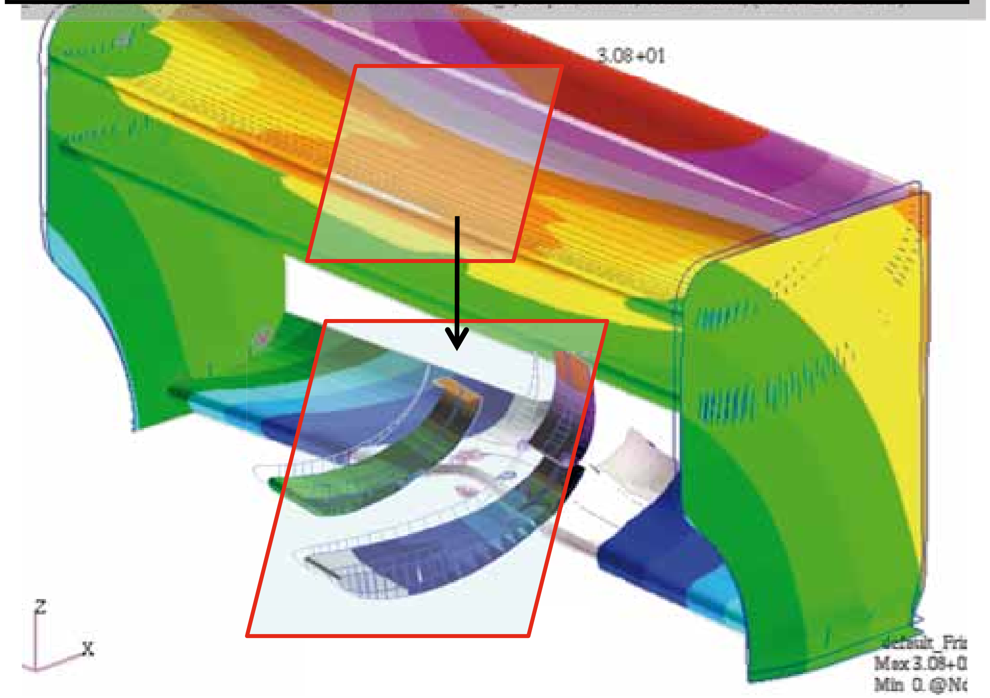


Results

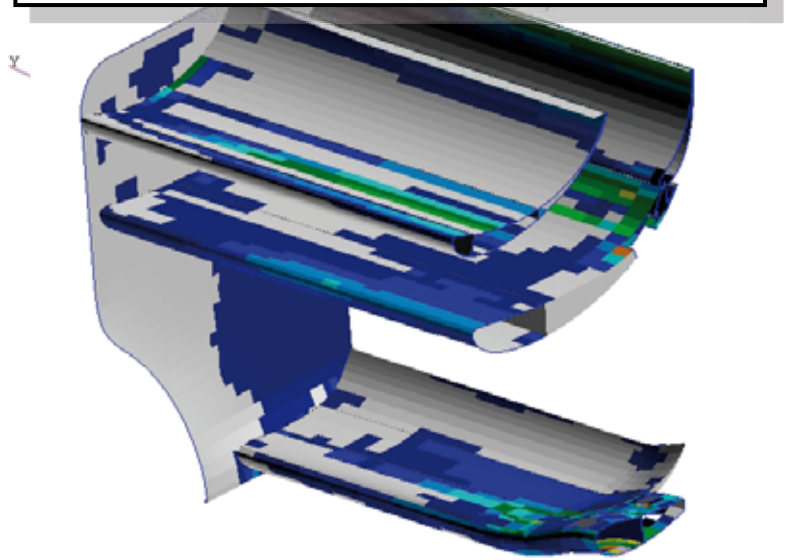
First buckling eigenvector



Static deformation under pressure load



Margin of Safety plot



- Questions?