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

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Agenda

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





Semplar 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

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- 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





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 **ModenaFiere**

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



- 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.







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- The multi-disciplinary optimization problem dramatically increase the design parameter: in the real world, the <u>number of design parameter is huge</u>, 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 <u>iDA</u> method is allow the expert to supply all available useful information which can help the exploration method to reach its goals.

exemplar The ISB method



GLOBAL LAYUP SEQUENCE: the independent plie	s 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



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- 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 "configuration state"

- 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



PLY NAME ANGLE



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 Mat=A angle=45° 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 Mat=B angle=0* Ply shape #1045 angle=45° Mat=A

MATERIAL



GLOBAL LAYUP SEQUENCE: the independent plies	s 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_#2000	amgle=0°	Maatt=A	
	Ply_shape_#2045	angle=0°	Mat=A	
	Ply_shape_#2044	amgle=0 5°	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=£	
	Ply_shape_#2044	angle=0°	Mat=A	
	Ply_shape_#1072	angle=0°	Mat=A	
1)	Ply_shape_#1045	angle=0°	Mat=A	
STEP -1- : first design exploration				
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- 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	PLYNAME	ANGLE	MATERIAL
	Ply_shape_#1000	angle=45*	Mat=A
	Ply_shape_#1010	angle=0*	Mat=B
	Ply_shape_#1012	angle=90*	Mat=A
1	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
5	Ply_shape_#1072	angle=90°	Mat=B
	Ply_shape_#1045	angle=45°	Mat=A
5	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



GLOBAL LAYUP SEQUENCE: the independent plie	es 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	amgle=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			
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iDA has a GUI to quickly setup the ٠ engineering problem. 🔁 Component Editor - IDA 10.0 subcase 1 subcase 2 IDA1 Settings Design Parameters Constraints Objectives Upper Bound Allowed Values Main Direction Lower Bound Value Active Name Design Parameters Constraints Objectives V THICKNESS 0.8 0.7;0.8;0.9;1.0... Decrease V THICKNESS 0.9 0.7:0.8:0.9:1.0... Decrease IdaDescription Value V 1.0 THICKNESS 0.7;0.8;0.9;1.0.. Decrease V THICKNESS 0.8 es per step 10 0.7;0.8;0.9;1.0... Decrease pe [0,1] 0.33 V 1.5 Variabile THICKNESS_ 1.2;1.25;1.3;1.. Decrease Variabile rate son follow m... 10.9 V 0.8 THICKNESS 0.7:0.8:0.9:1.0... Decrease Number re-executions failed runs 3 V THICKNESS 0.8 0.7;0.8;0.9;1.0... Decrease V 0.8 THICKNESS 0.7;0.8;0.9;1.0... Decrease V THICK ase V THICK Setup the iDA design * ise V THICK . ise 2 THICK parameter, allowed parameter ise V THICK ise V THICK ise can be: V THICK * ise 2 THICK * ise Execute in Parallel Control with external parameter V THICK . ISE Create en • continues number, 2 THICK ise . Setup of the iDA strategy: T Auto Upd V THICK ise 2 P Eval First THICK ise 1 V THICK allowed number list ise F Stop when • the number of exploration 2 THICK ise * Run Once V THICK ise F Run is faile steps and the population; 2 THICKI ise THICKNES strings list (configuration) V Decrease V THICKNESS 2.5.2.6.2.7.2.8. Decrease - -78 • the available distance to Edit Selected Edit All He the desired target based on OK Cancel Apply Help physic consideration Modenamere





	 Constrains and target can be defined using engineering sense.
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Ings Design Parameters Constraints Objectives Ive Name Lower Bound Upper Bound Weight Soft Cycle_1_sub120 17.3 1	Setup the desired system target: do not use the minimize or maximize concept, but define the engineer desired system
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Exemp 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

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IVAL AND STOLEN SAS

 ExeComponent4Abaqus and ExeComponent4Ansys are also available.

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exempThe final recipe: Local layup rules 9 symmetric and balanced Ş Loop Ş external wrapper δ sandwich behaviour, etc **Global layup rules** Ş Defined by the shape of the subcase_1 subcase 2 manufacture 🍄 Component Editor - ExeComponent4Nastra X VCOLLAB = 1 ExeComponent4Nastran1 VCOLLAB Comp Options Parameters Running Results Grid Composites Symmetry Exe Monent4Nastran1 Activate Rule Index GPlyId 1 GPIvId 2 Target ID 1 Target ID 2 Angle Rotation V 2000 0 1000 Symmetric unning Results Grid Composites Symmetry Options Pa 1011 2010 Anti Simme ... V Selected GPlyId Name MatID Deletable Symmetric Ba 1005 3005 2 1001 V 3 1030 1060 3030 1 1002 external ply skin 1 1003 2 external ply skin 1 Another special table 4 1004 external ply skin 2 5 1017 external ply skin 2 6 1018 external ply skin define the structure 1021 8 HC SPAR3 1022 rules for the symmetry 9 HC SPAR2 1025 10 1026 HC SPAR1 of the structure, from a For each ply, special point of view of the rules can be defined. properties and of the like the allowed material global geometry list, or if the ply can be removed and/or moved Add Rule Import Rules **Delete Selected** Activate all Invert Activation Export Rules Mirror half FEM model in the stack sequence, 0 • XY F Mirror the loads O XZ O YZ Coord ID or if it has to be imple File balanced and 0K Cancel Apply Help symmetrical defined



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%







First buckling eigenvector Static deformation under pressure load 3.08+01 Margin of Safety plot 2 X Mex 3.08+0 Min 0.@No





• Questions?

