An alternative approach to automotive door seal design using HyperStudy

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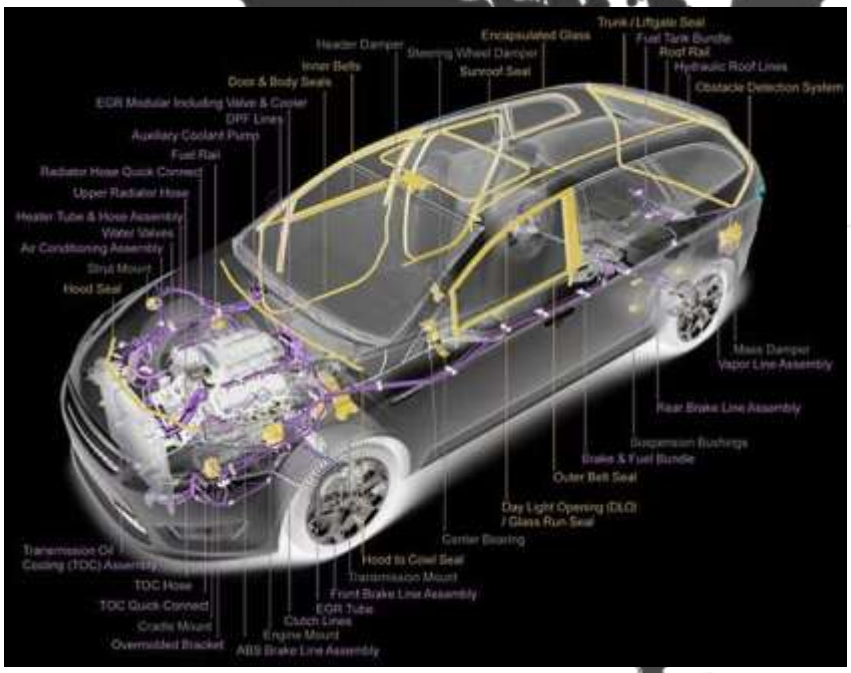
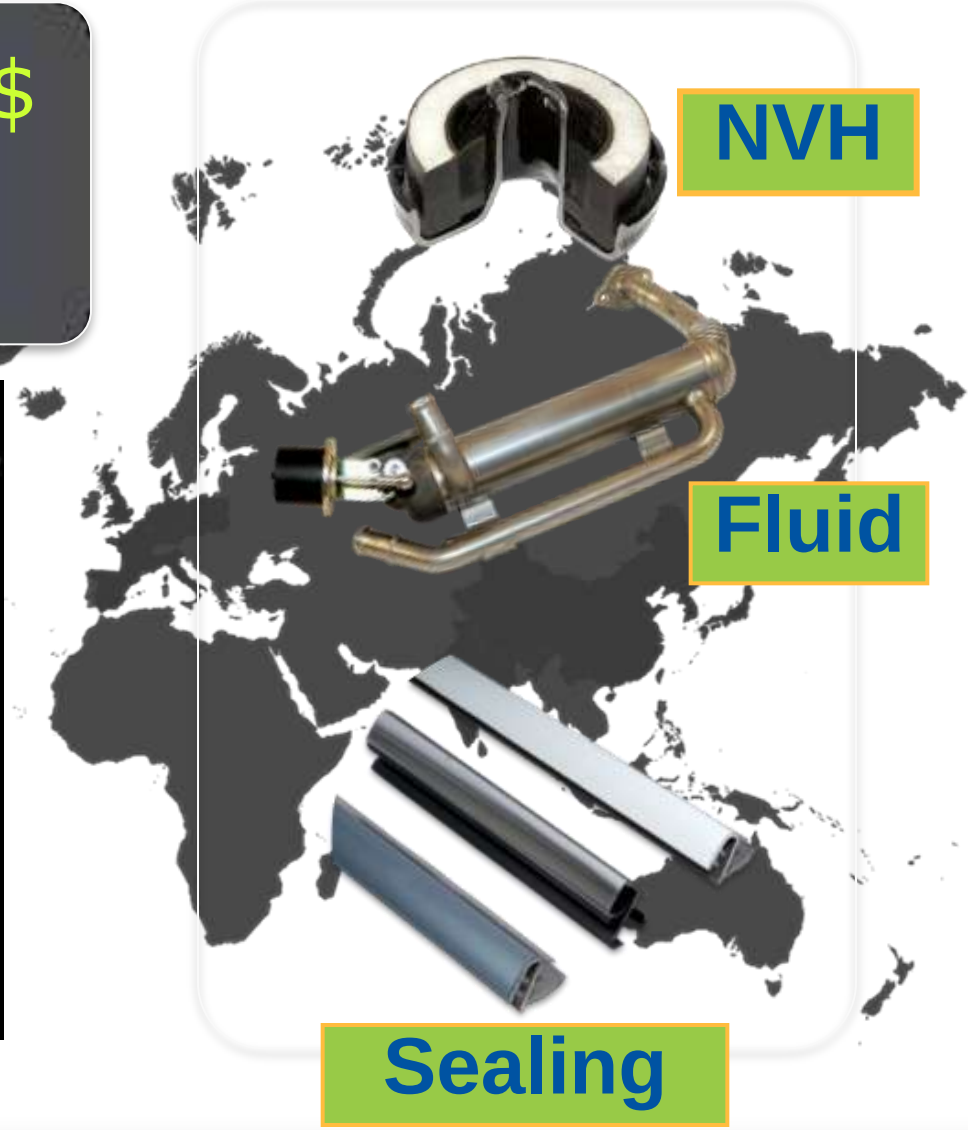
Cooper-Standard

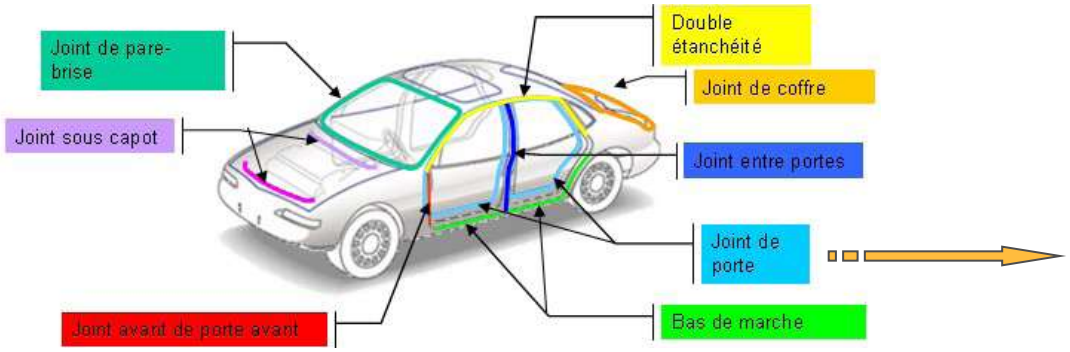
Sales : 2,5 Md$
Employees : 20 000
Locations : 55+

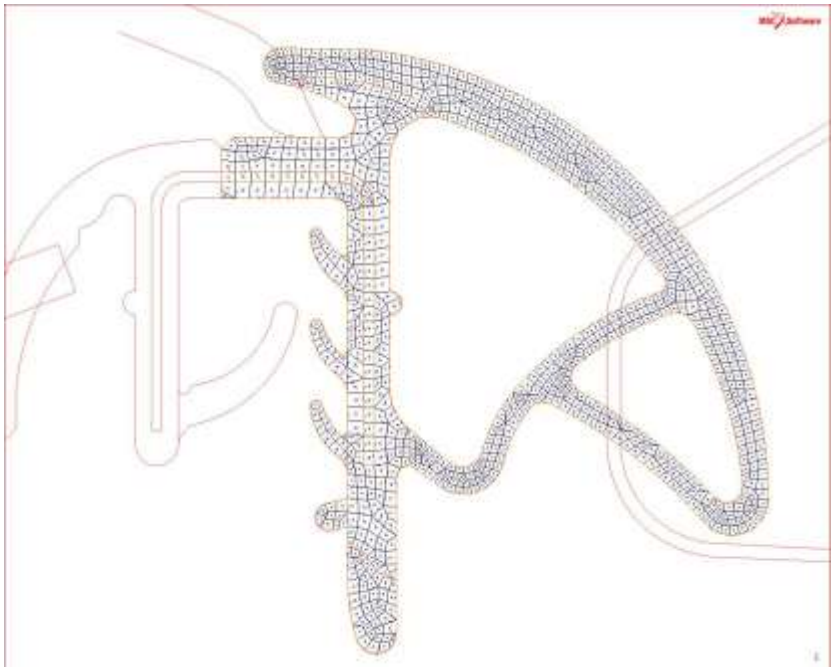




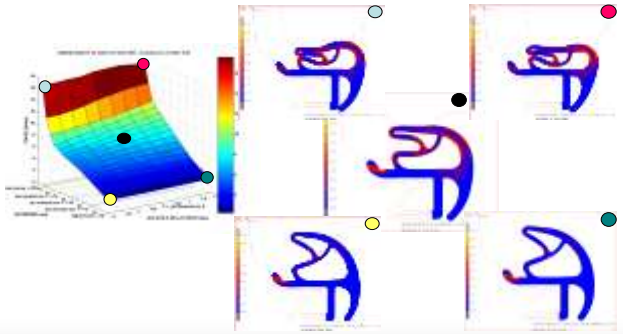
Sealing design: current approach

- Sealing systems





- Today, seal design and closing effort forces are determined using a nominal seal shape at extreme BIW tolerances.



What is the problem?

- When designing a weather-strip seal:
  - Match the OEM's requirements
  - Find the design of the seal which will better fulfill these requirements.

    » ***Shape optimization***

- When manufacturing the weather-strip seal:
  - Reduce the impact of small extrusion tolerance variation
  - Verify that a given design is less sensible to these variations

    » **Sensibility study**

  - Find the design of the product which will both satisfy the requirements and be less sensitive to small deformations

    » ***Robust design optimization***

Objectives

What :

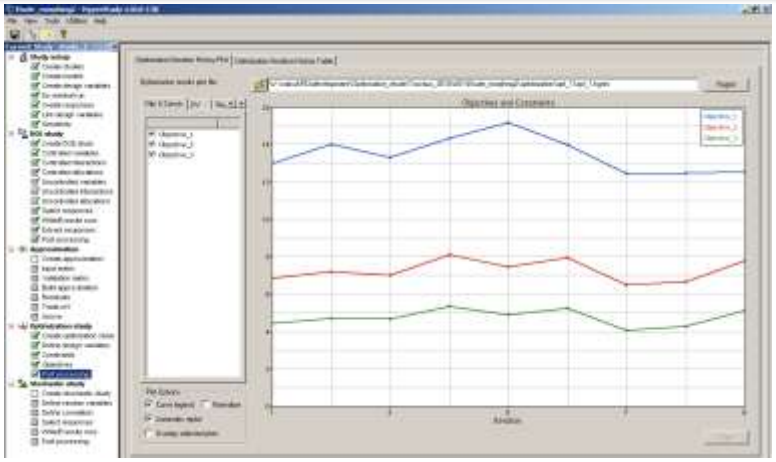
- Design process → Parametric design approach

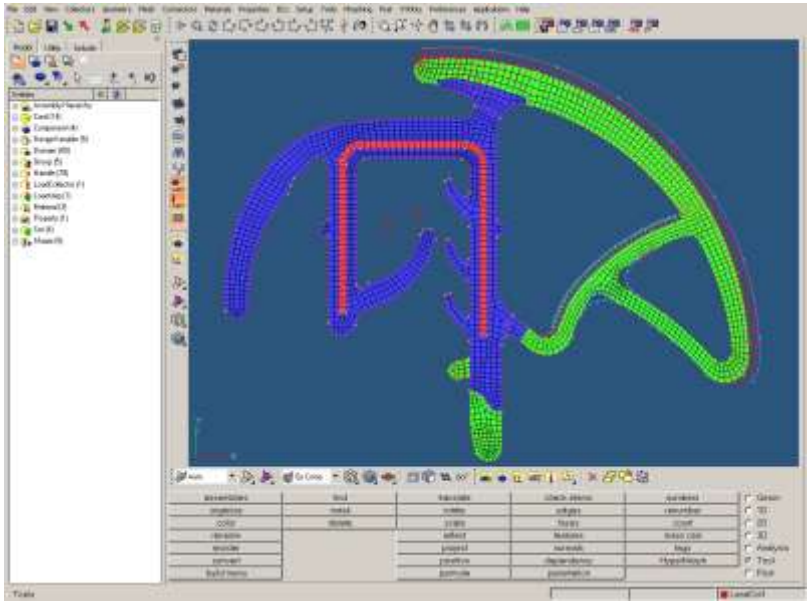
How :

- Identify the numerical tools
- Define a procedure
- Study the effect of size and shape variations in seal design

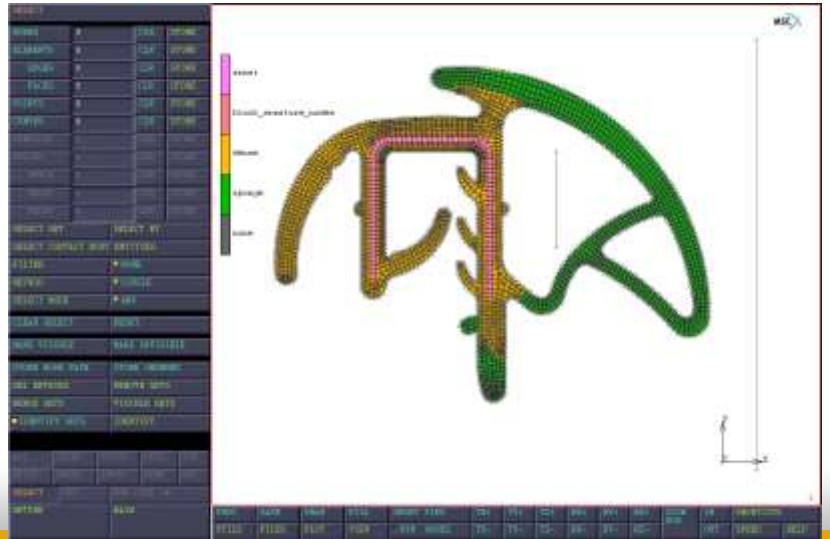
The numerical tools

HyperStudy: optimization
(*Altair Engineering)*





HyperMesh: Morphing function
(*Altair Engineering)*



Marc & Mentat:

FE solver & pre-processor
(*MSC Software)*

The procedure

- Communication not obvious between the numerical tools
- Data exchange not easy

Python routines (in house developments):
2 initialization procedures
2 analysis procedures
5 scripts

Initialisation

HyperMorph
- Parameterization of the product
- Choice of results to extract
- Creation of the model file
- First calculation

Steps of analysis

HyperStudy
- Definition of parameters value

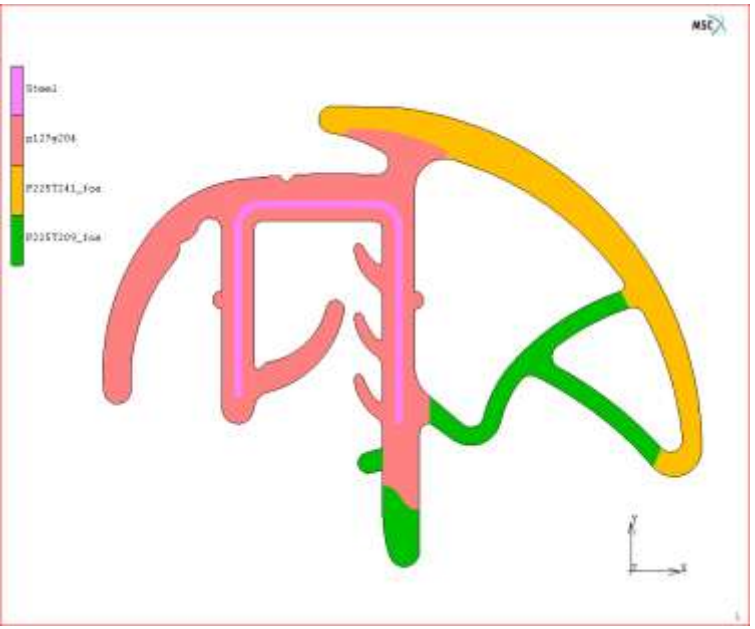
HyperStudy
- Writing of the calculation input file

Marc
- Calculation

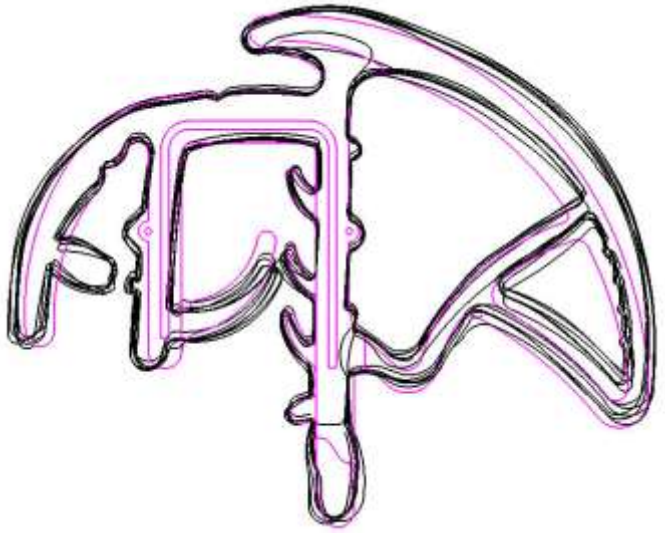
Python
- Extraction of results

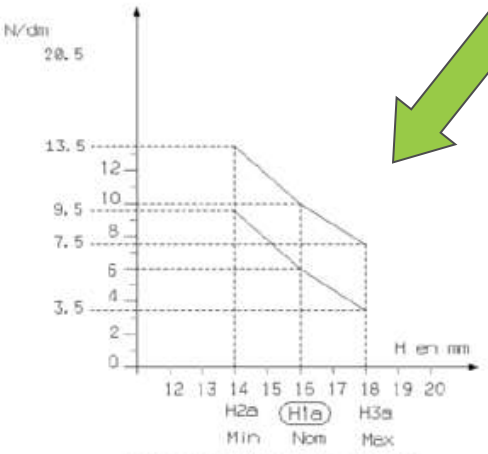
A simple typical design

Ideal (nominal design)



Reality (geometric scatter)





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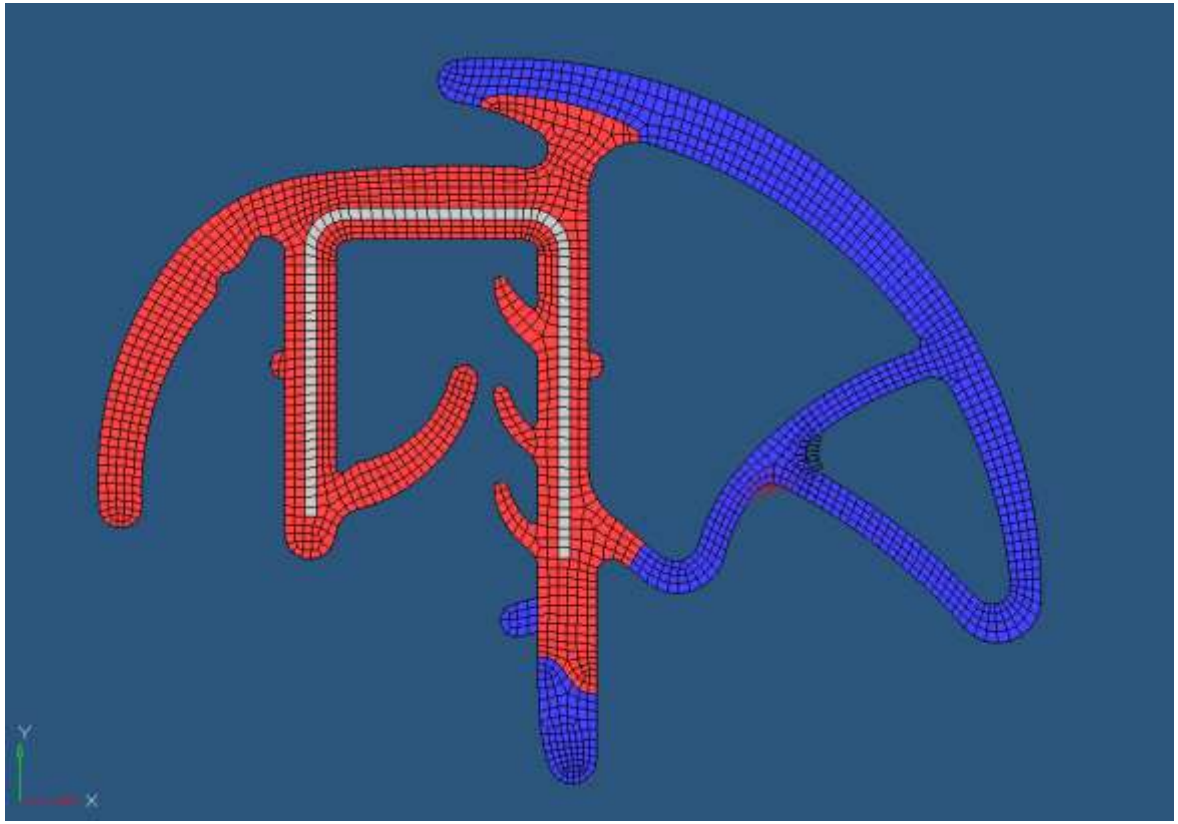
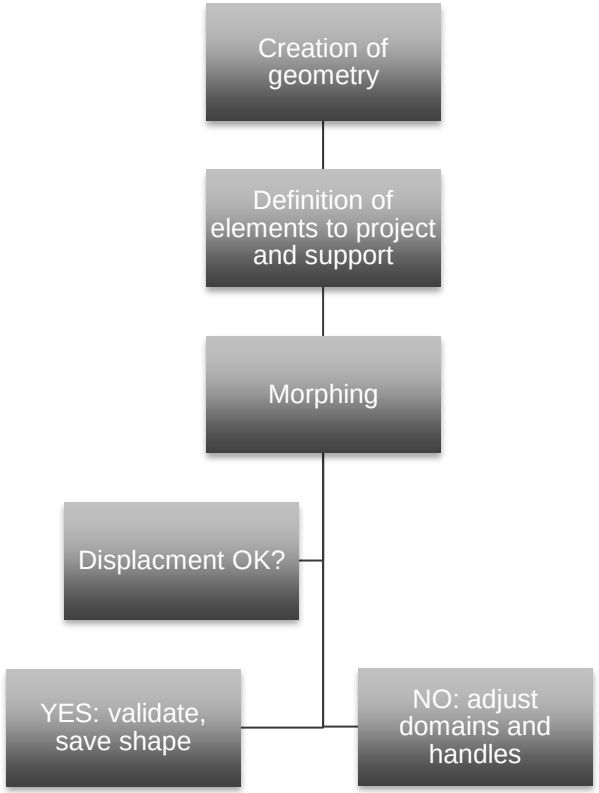
Requirements

Parameterization of geometric scatter



Process



Parameters

- Height
- Thicknesses
- Radiuses

Initialization of study – export of parameters

- Accessible from *optimization* panel of HyperMesh
- Associates to each deformation a variable (initial value and definition interval)
- Export two files:
  - *.shp* : contains the definition of all deformations as a list of Δx, Δy,Δz associated to the nodes coordinates.
  - *.marc.node.tpl* : definition of parameters et list of nodes coordinates in *Marc* format; the nodes affected by a deformation are indicated by a tag and point to the matching line in the *shp* file.

```
1   {parameter(epaisseur_3,"epaisseur_3", 0.00000000e+000, 0.00000000e+000, 1.00000000e+000)}
15  {coeff1 = read ("model_0_7.shp",0,0,1 )}
30  {I1 = I1 + epaisseur_3 * coeff1 }
```

```
590     548  1.0457214282e+001  8.7576297549e+000  0.0000000000e+000
591     549{ getvalueatindex("I1", 3),%20.10e}{ getvalueatindex("I1", 4),%20.10e}{ getvalu
```

Initialization of study – creation of model file

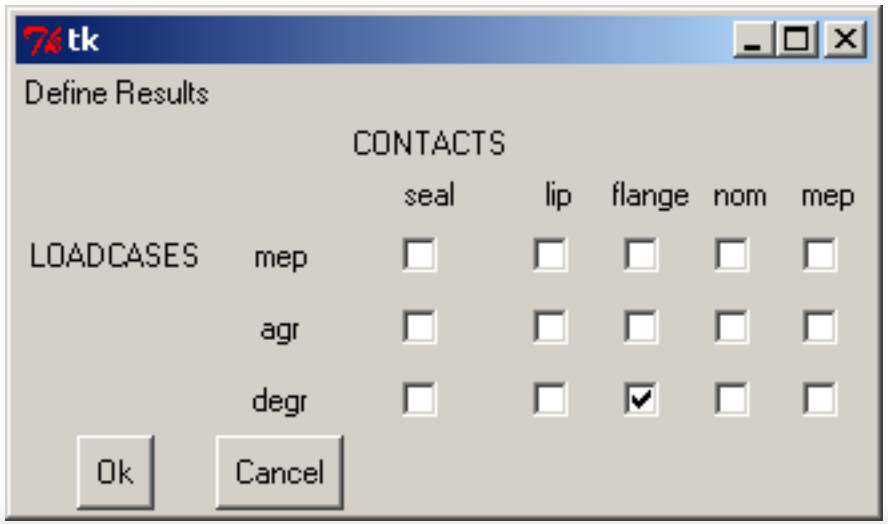
- Procedure accessible in HyperStudy
- Ask the user for the location of the *Marc* input file on which the morphing were based, and for the location of the *.marc.node.tpl* file
- Delete the list of nodes coordinates in the input file and replace it by an inclusion of the *.marc.node.tpl* file

```
1391  coordinates
1392      3     1636     0     1
1393  {include "W:/calcul/Stagiaires/Maxime_LeMoine/Etude_T9/model_0_7.marc.node.tpl"}
1394  define          node          set          fx-y_nodes
1395      22          63
1396  define          node          set          fx-x_nodes
1397      22          63
1398  define          element       set          gde-levre
1399      398         to      735
1400  mooney
1401
```

- The file created will be used as model (*template*) to HyperStudy

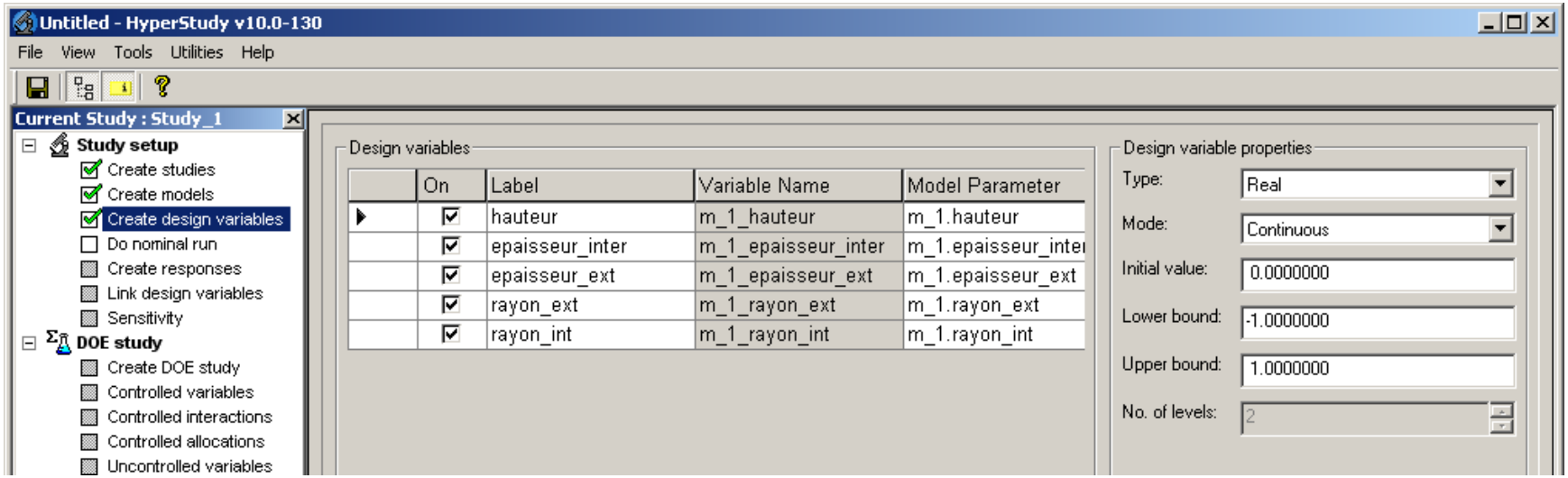
Initialization of study – Definition of output results

- Procedure accessible from HyperStudy
- Analyses of the *Marc* input file used for the study
  - Lists all the contacts and loadcases
- Opens a Python/Tk window where the user chooses the couples *Contacts / Load cases* to be studied



Start of nominal run

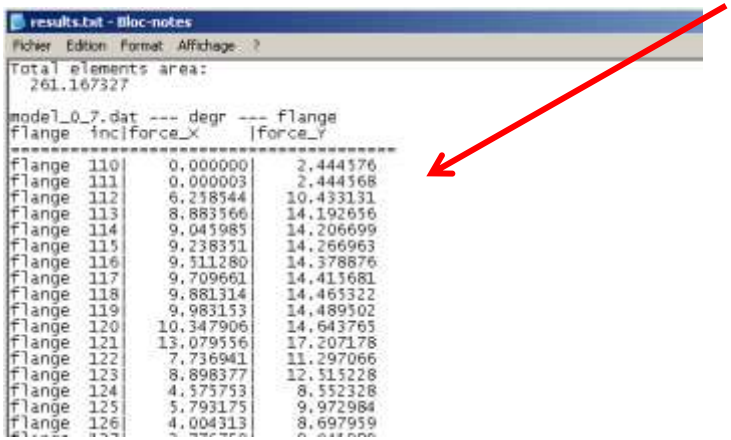
- The model can now be imported in HyperStudy; the parameters will be recognized automatically.



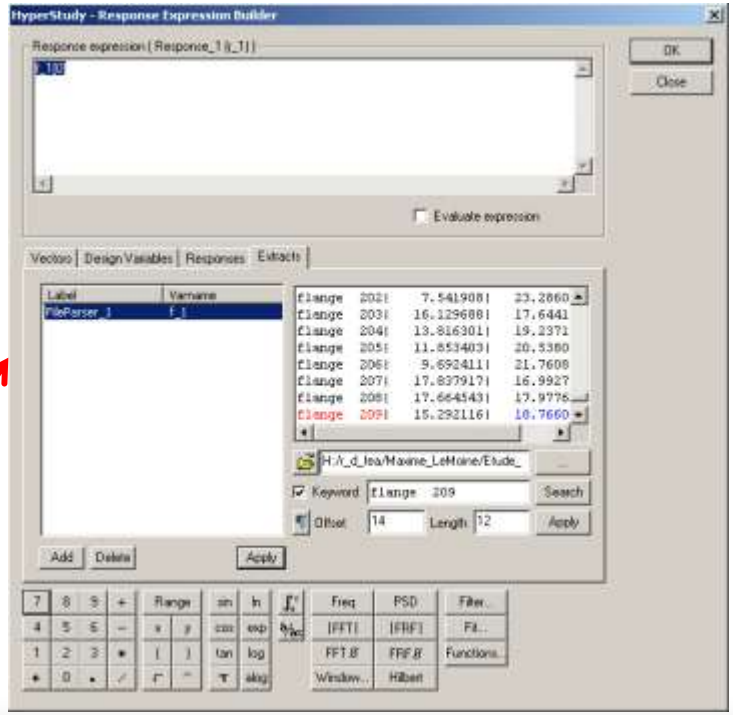
- A first calculation (nominal run) must be performed in order to define the responses (numerical values) to study.

Initialization of study – Definition of response

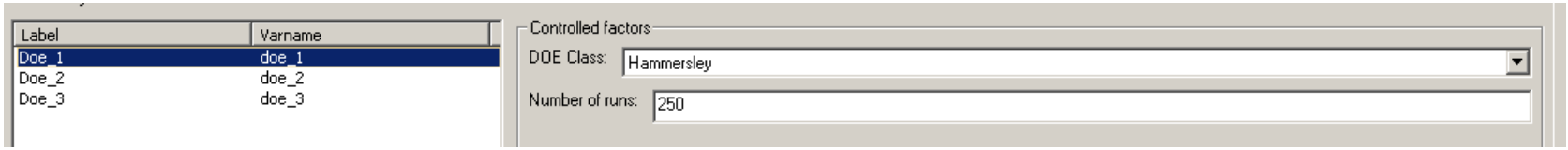
- During initialization: choice of couples *contacts/loadcases* to study
- During a calculation: writing of a text file containing the forces applied to a contact during the associated loadcase, for each increment and both X- and Y- axis



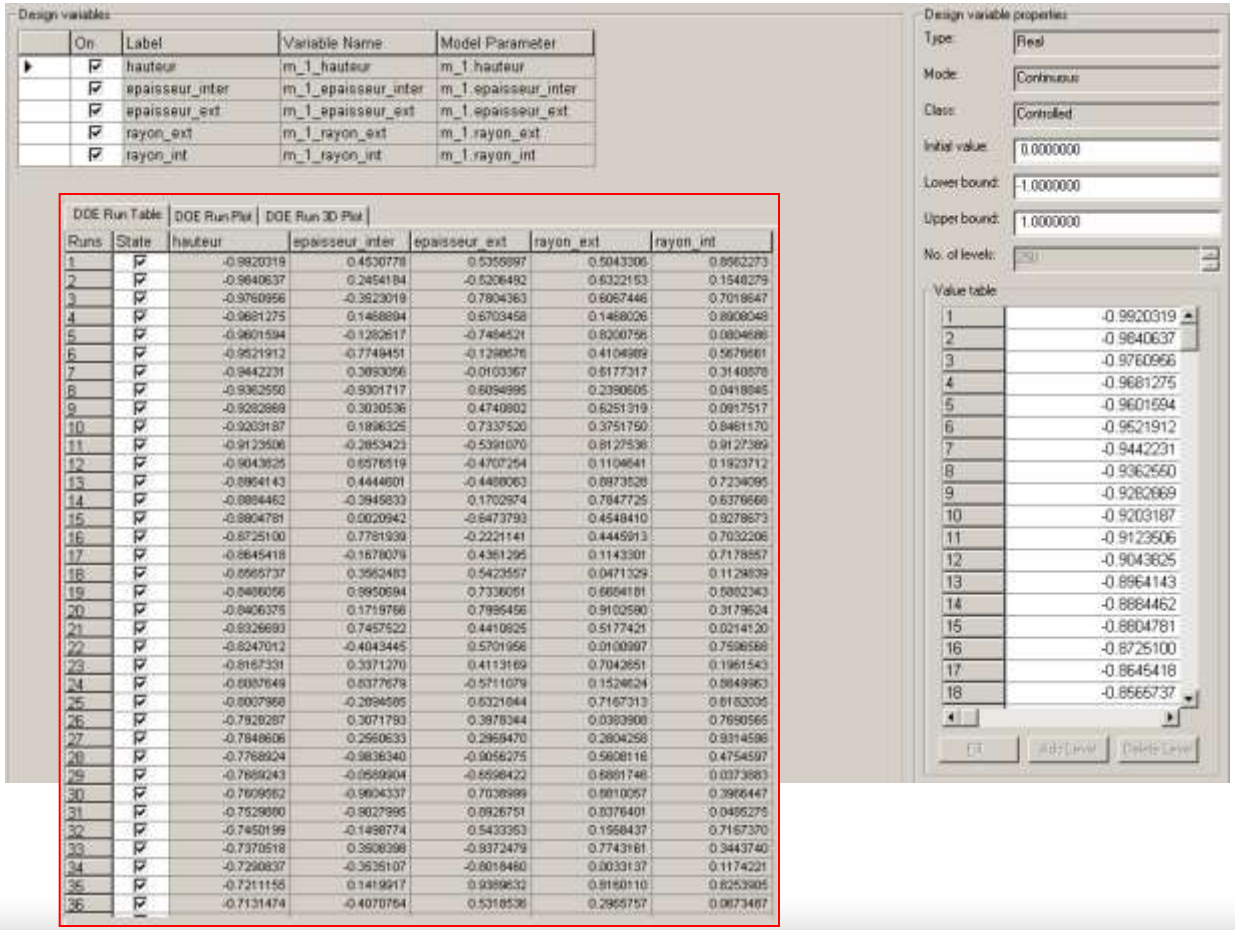
- After the nominal run, choice of particular values by a tool in HyperStudy



DOE



- Type of DOE
- Number of runs
- Set of possible values for each parameter
- Set of combinations for all parameters



DOE: results

Extract

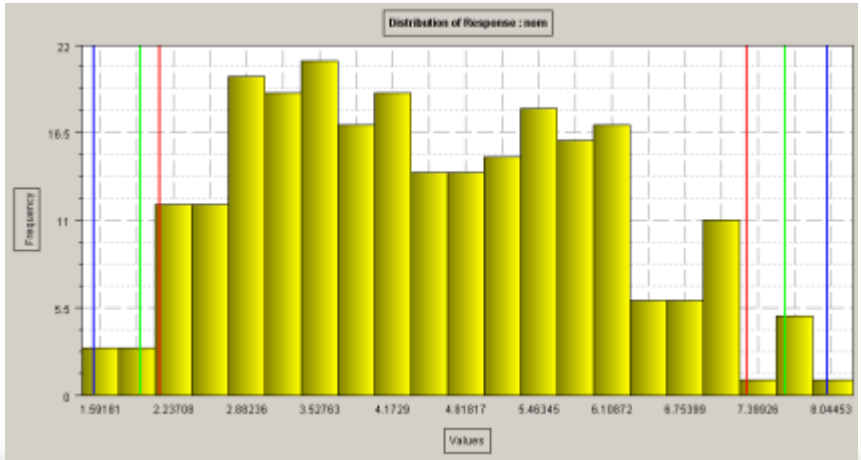
Run	State
1	☑
2	☑
3	☑
4	☑
5	☑
6	☑
7	☑
8	☑
9	☑
10	☑
11	☑
12	☑
13	☑
14	☑
15	☑
16	☑
17	☑
18	☑
19	☑
20	☑
21	☑
22	☑
23	☑
24	☑
25	☑
26	☑
27	☑
28	☑
29	☑
30	☑
31	☑
32	☑
33	☑
34	☑
35	☑
36	☑
37	☑

>> Extract >>

Post process

Run	State	mini	nom	maxi
1	☑	1.0450980	1.9584940	3.7718900
2	☑	2.7627400	5.1002810	8.8145690
3	☑	2.3157120	4.4913510	7.8961890
4	☑	1.3643910	2.8765670	5.8128030
5	☑	0.8497170	1.6935980	3.5082760
6	☑	0.8562270	1.7538960	3.6492560
7	☑	2.1665510	4.2418960	7.9212790
8	☑	2.2508740	4.2838920	8.2077420
9	☑	1.6322850	3.3979580	6.4889000
10	☑	0.8175650	1.7303670	3.6332400
11	☑	2.3978070	4.6849270	8.2681790
12	☑	1.4055130	2.9954320	5.7196890
13	☑	2.3412960	4.5739770	8.0819230
14	☑	2.9048180	5.4012630	9.1522780
15	☑	1.0048130	2.1831770	4.4340620
16	☑	2.1296780	4.1669670	8.0469340
17	☑	1.5451010	3.2656260	6.2678010
18	☑	0.9412210	2.0798830	4.2336840
19	☑	2.2654120	4.4870000	8.2043110
20	☑	2.4063590	4.5591020	7.7964580
21	☑	1.8311530	3.7364480	7.0539880
22	☑	1.7632060	3.6653630	6.7267680
23	☑	1.3473890	2.9020150	5.5002180
24	☑	2.6077080	4.7514280	8.0238110
25	☑	1.2056800	2.6126970	5.0097010
26	☑	1.4687310	2.7418720	5.0353620
27	☑	1.7564860	3.3864800	6.1336110
28	☑	1.4343290	2.8475530	5.1938350
29	☑	2.7343300	5.2090980	8.8973620
30	☑	1.9120870	3.8826430	6.8884200
31	☑	2.9444750	5.4809000	9.0764830
32	☑	2.9363880	5.4425380	9.0654030
33	☑	2.4647590	4.7666680	8.1618700
34	☑	1.8791070	3.8912800	7.0584180
35	☑	1.5053830	3.0267690	5.4639470
36	☑	2.2803370	4.3666720	7.5243160
37	☑	1.6132580	3.3884080	6.1103030

		min	nom	max	hauteur	epaisseur_i~	epaisseur_e~	rayon_ext	rayon_int
Forces	mini	1	0.99	0.95	0.43	-0.07	-0.2	-0.055	-0.022
	nom	0.99	1	0.99	0.32	-0.094	-0.19	-0.048	-0.02
	maxi	0.95	0.99	1	0.2	-0.099	-0.18	-0.044	-0.024
Variables	hauteur	0.43	0.32	0.2	1	0.045	-0.12	0.015	0.027
	epaisseur_i~	-0.07	-0.094	-0.099	0.045	1	-0.033	-0.15	0.048
	epaisseur_e~	-0.2	-0.19	-0.18	-0.12	-0.033	1	0.048	0.001
	rayon_ext	-0.055	-0.048	-0.044	0.015	-0.15	0.048	1	0.067
	rayon_int	-0.022	-0.02	-0.024	0.027	0.048	0.001	0.067	1



- Extraction of results
- Main and secondary effects
- Distribution of responses

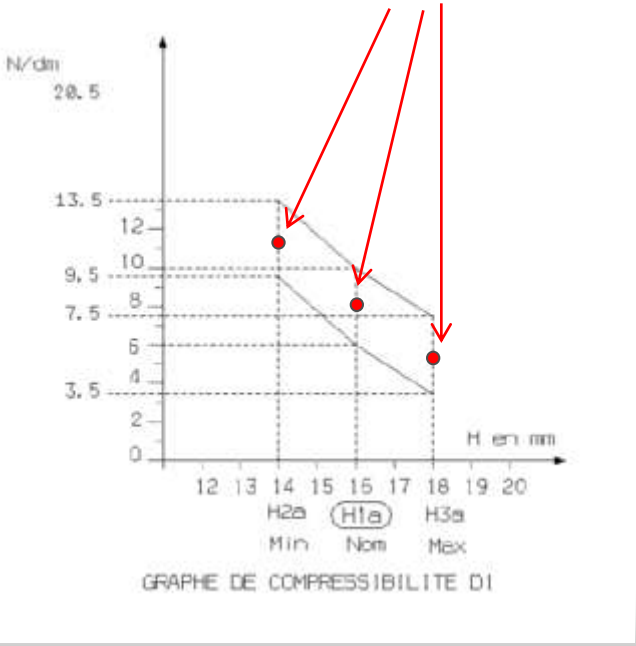
Optimization

Optimization:

Label	Varname
Optimization_1	opt_1
Optimization_2	opt_2
Optimization_3	opt_3

Optimization Engine: (ARSM) - Adaptive Response Surface Method

- Choice of the optimization algorithm: ARSM for a shape optimization
- Choice of the objectives: get as close as possible to the requirements



Define objective

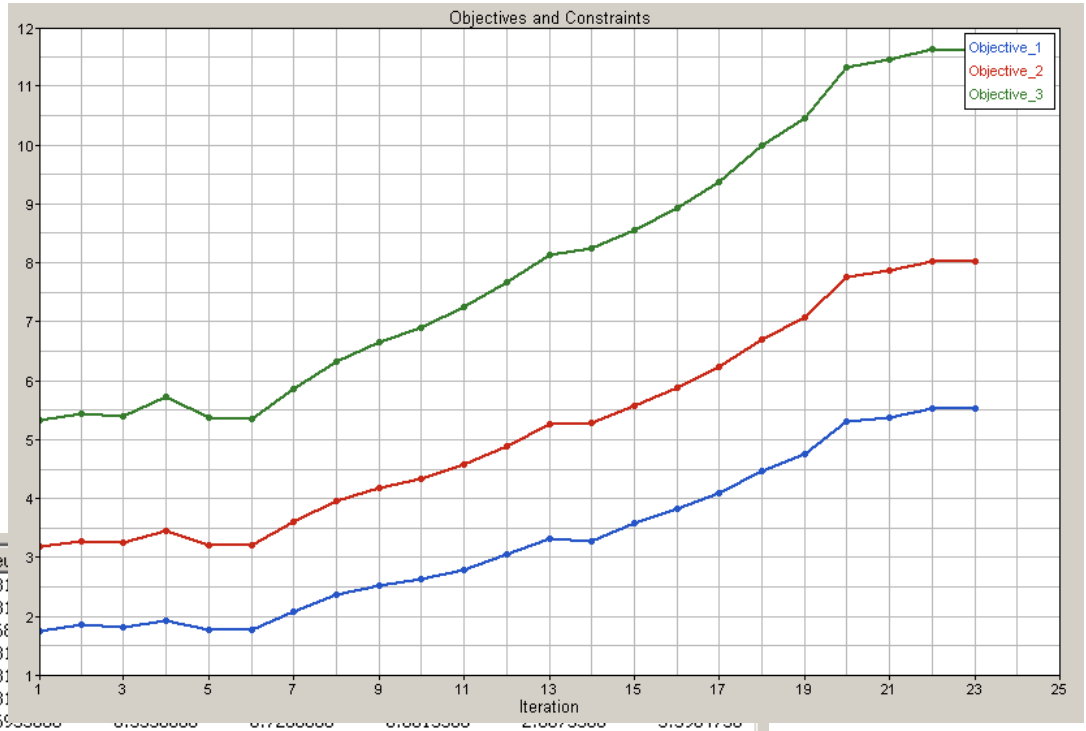
Goal: System Identification

	On	Label	Varname	Apply On	Evaluate from	Target Value
▶	☑	Objective_1	obj_1	mini	SOLVER	5.5000000
	☑	Objective_2	obj_2	nom	SOLVER	8.0000000
	☑	Objective_3	obj_3	maxi	SOLVER	11.500000

Optimization: results

- Convergence in 23 iterations

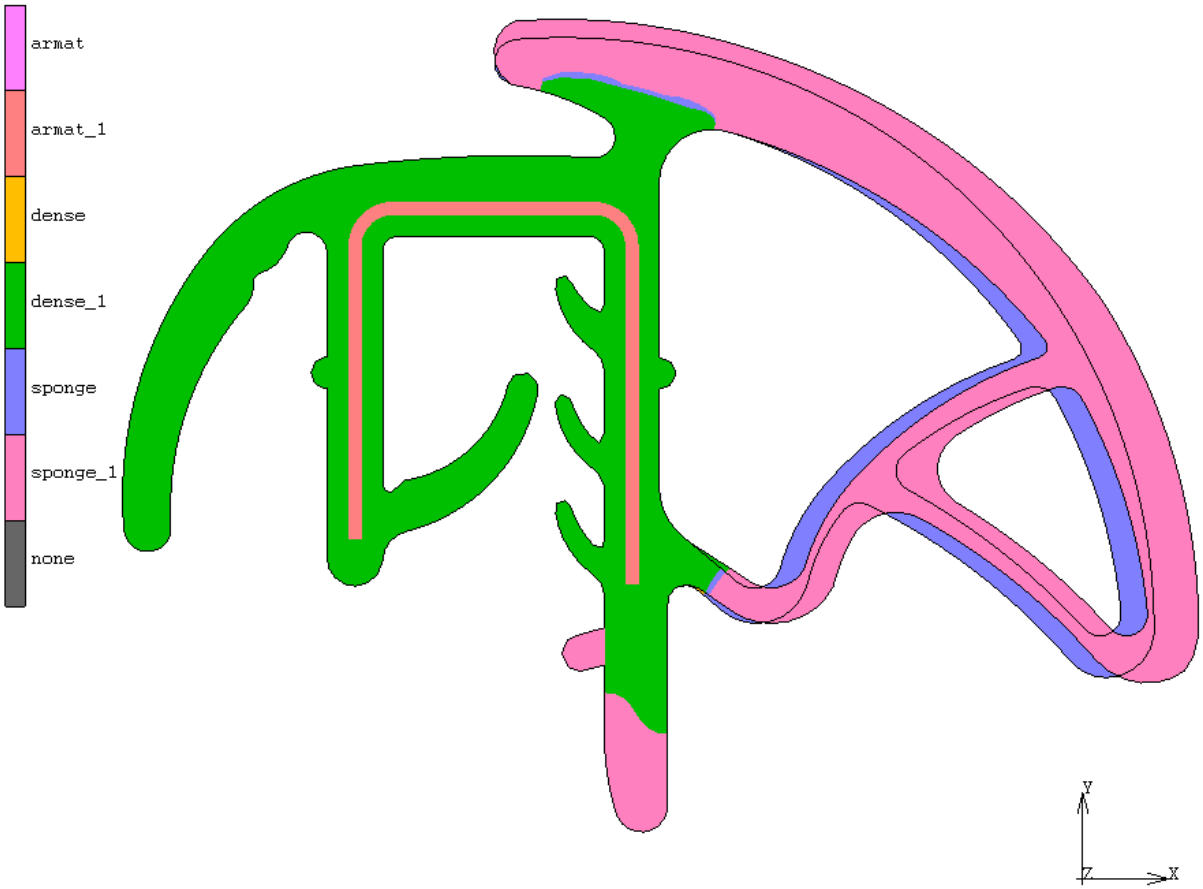
	Optimized design	Requirements
Force mini	5.52	5.5
Force nominal	8.01	8.0
Force maxi	11.60	11.5



Iteration	Objective_1	Objective_2	Objective_3	hauteur	epaisseu					
1	1.7548590	3.1856950	5.3329180	0.8200000	-0.81					
2	1.8608490	3.2841180	5.4390250	0.9553000	-0.81					
3	1.8184810	3.2570870	5.4018500	0.8200000	-0.68					
4	1.9213130	3.4410200	5.7186250	0.8200000	-0.81					
5	1.7827910	3.2164930	5.3630400	0.8200000	-0.81					
6	1.7672500	3.2042940	5.3560190	0.8200000	-0.81					
7	2.0873300	3.5964750	5.8583790	0.9430000	-0.69					
8	2.3678460	3.9506650	6.3150310	1.0000000	-0.5910050	-0.4550000	0.8349000	0.9905525	2.3678460	3.9506650
9	2.5225420	4.1768660	6.6601800	1.0000000	-0.6969629	-0.3550000	0.9845845	1.0000000	2.5225420	4.1768660
10	2.6403190	4.3430700	6.9024830	1.0000000	-0.7052751	-0.2869479	0.9950751	1.0000000	2.6403190	4.3430700
11	2.7857680	4.5709150	7.2566520	1.0000000	-0.7109561	-0.1869479	0.7402443	1.0000000	2.7857680	4.5709150
12	3.0444790	4.8961560	7.6731830	1.0000000	-0.6108504	-0.0869479	0.8729585	0.8745010	3.0444790	4.8961560
13	3.3290180	5.2579190	8.1325590	1.0000000	-0.5108504	0.0130521	0.9825139	0.8714408	3.3290180	5.2579190
14	3.2649290	5.2951730	8.2487290	0.8207157	-0.6108504	0.1130521	1.0000000	1.0000000	3.2649290	5.2951730
15	3.5793150	5.5791030	8.5487080	1.0000000	-0.4108504	0.1130521	0.9489659	0.9714408	3.5793150	5.5791030
16	3.8228340	5.8812700	8.9328620	1.0000000	-0.3108504	0.2130521	1.0000000	0.9161345	3.8228340	5.8812700
17	4.0920400	6.2281040	9.3797400	1.0000000	-0.2108504	0.3195781	0.9000000	0.8881089	4.0920400	6.2281040
18	4.4671130	6.7050850	9.9973990	1.0000000	-0.1108504	0.4793672	0.8000000	0.9157960	4.4671130	6.7050850
19	4.7656560	7.0783960	10.460629	1.0000000	-0.0450885	0.5887693	0.8578537	0.9158438	4.7656560	7.0783960
20	5.3059130	7.7559700	11.308955	1.0000000	0.0549115	0.8020596	0.8535950	0.8323079	5.3059130	7.7559700
21	5.3823700	7.8592270	11.445607	0.9961363	0.0359115	0.8396682	0.8345950	0.8333079	5.3823700	7.8592270
22	5.5289070	8.0260790	11.625439	1.0000000	0.1359115	0.8665664	0.9345950	0.8734992	5.5289070	8.0260790
23	5.5220340	8.0137000	11.603008	1.0000000	0.1517210	0.8563145	0.9589062	0.9734992	5.5220340	8.0137000

Optimization: optimized section

- Comparison *Initial CAD section / optimized section*



Geometric differences:

Height : +1mm

Thickness_ext : +0.86mm

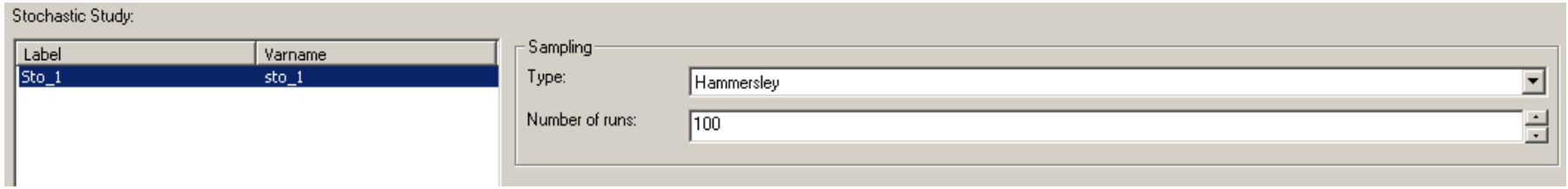
Thickness_int : +0.15mm

Radius_ext : +0.96mm

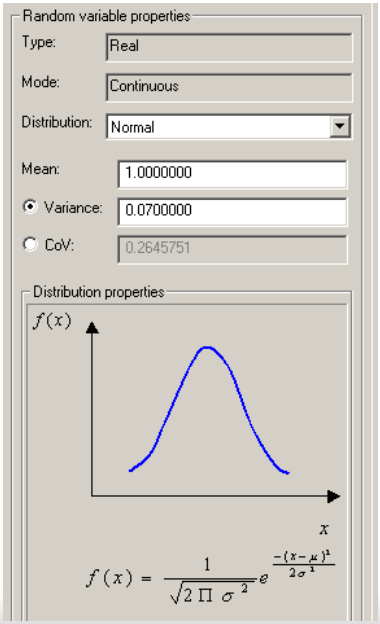
Radius_int : +0.97mm

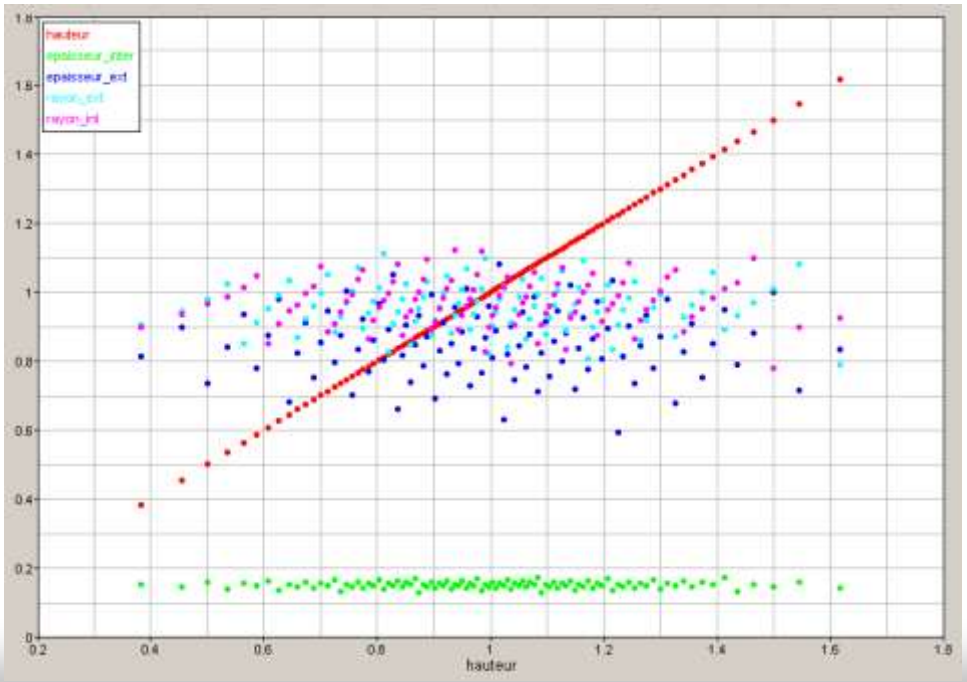
Stochastic study

- Check for robusteness of the optimized design
- Choice of type of study



- Distribution of input variables





Stochastic study: results

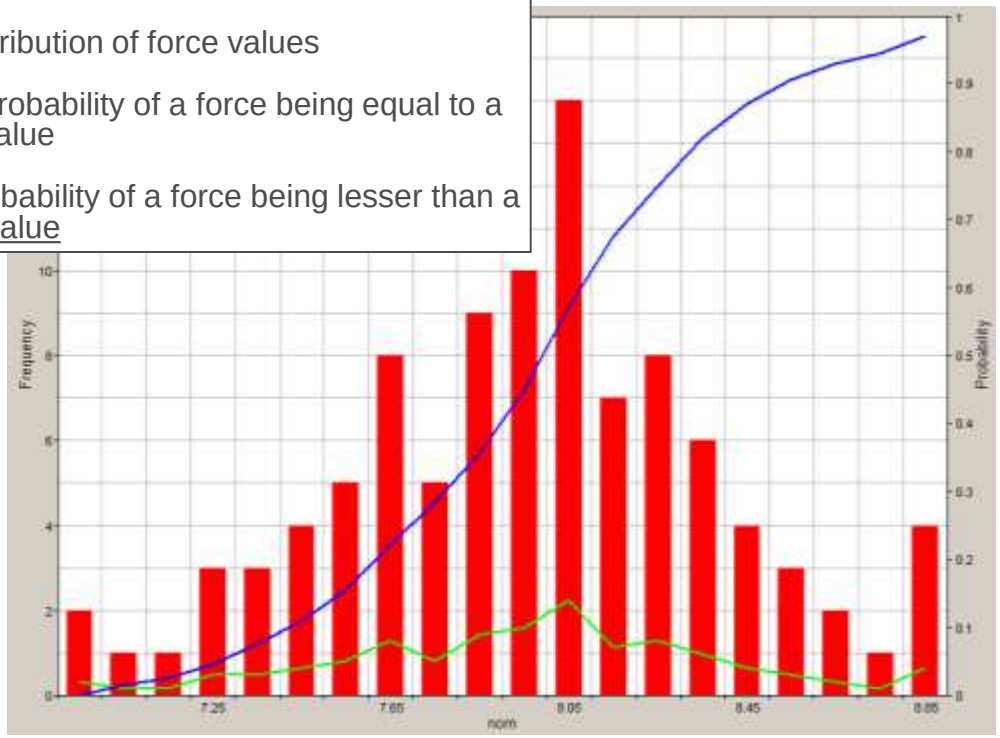
- Probability bar chart
- Statistic indicator

Nominal force

Red : distribution of force values

Green : probability of a force being equal to a specific value

Blue : probability of a force being lesser than a Specific value



	mini	nom	maxi
Mean	5.4662116	7.9635887	11.545768
Avg. Dev.	0.3468417	0.3344647	0.4010990
Std. Dev.	0.4348599	0.4210807	0.5110038
Variance	0.1891031	0.1773089	0.2611249
CoV	0.0795542	0.0528757	0.0442590
Skewness	-0.0800649	-0.0689962	-0.0185944
Median	5.4683095	7.9502505	11.572595
RMS	5.4833093	7.9746022	11.556957
Min	4.3875740	6.9787310	10.346871
Max	6.4297900	8.8894300	12.789698
Range	2.0422160	1.9106990	2.4428270

- Robustness indicator:
- Solution is robust

	Response	Bound Type	Bound Value	Reliability	Probability of Failure
▶	mini	<=	6.2162870	0.9500000	0.0500000
	nom	<=	8.6524290	0.9500000	0.0500000
	maxi	<=	12.359195	0.9500000	0.0500000

Conclusions

- New design approach
- Effect of extrusion tolerance on the design response investigated

- Optimal response predicted using numerical model
- Design of optimal solution is robust

- The approach used is valid for shape definition that meets specified design requirements.
- Can be extended to define manufacturing tolerances of the design

Merci
Thank you