Taguchis Methoden für den robusten Entwurf

Holger Wenzel, SIMULIA SLM Europe

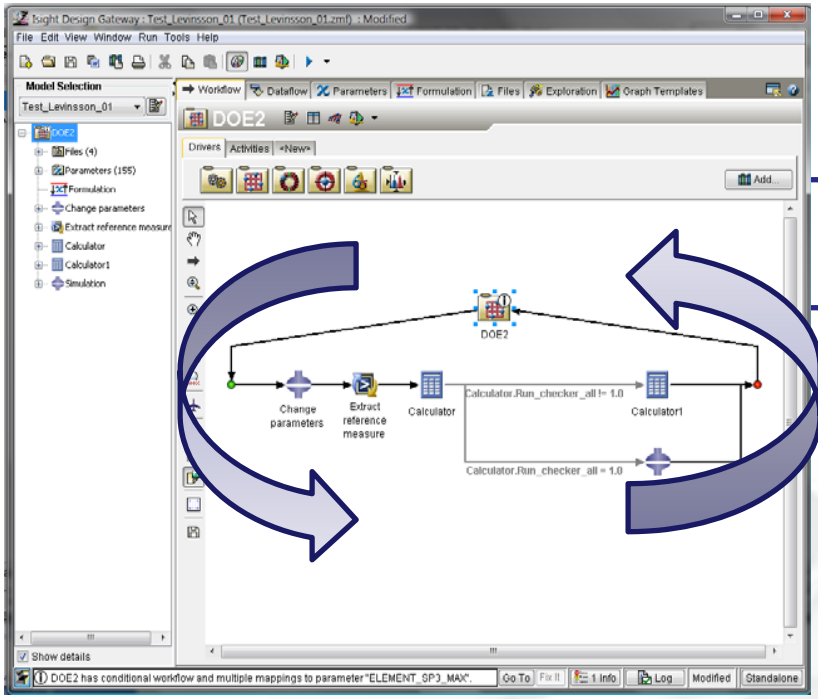
8.10.2009

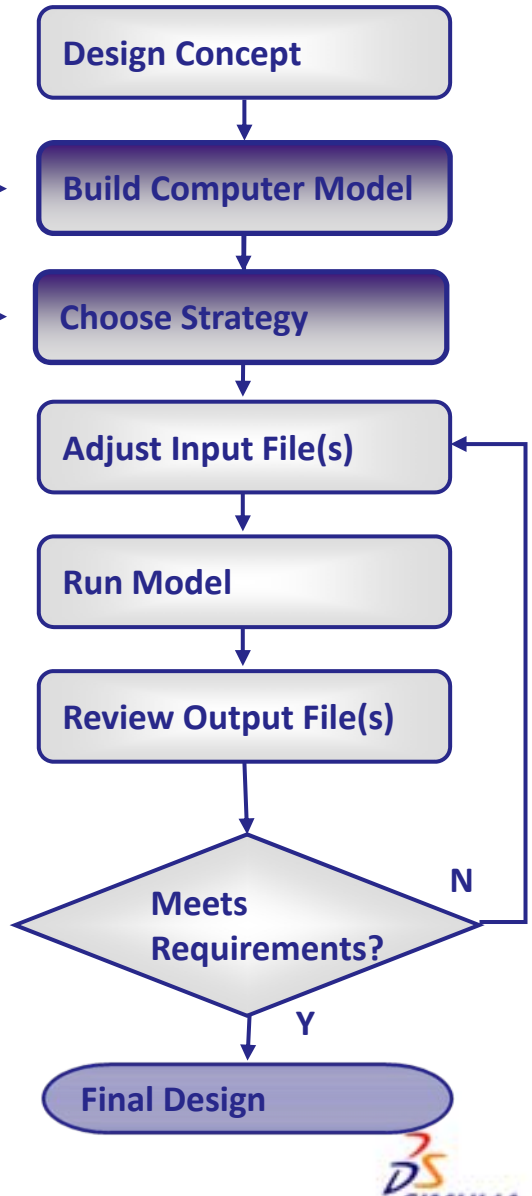
SIMULIA

Agenda

- **Introduction Isight**
- **Taguchi Method Goals and Non-Goals**
- **Static Taguchi Method**
  - Application Examples
- **Dynamic Taguchi Method**
  - Application Example
- **Conclusion**

Isight Software Robot





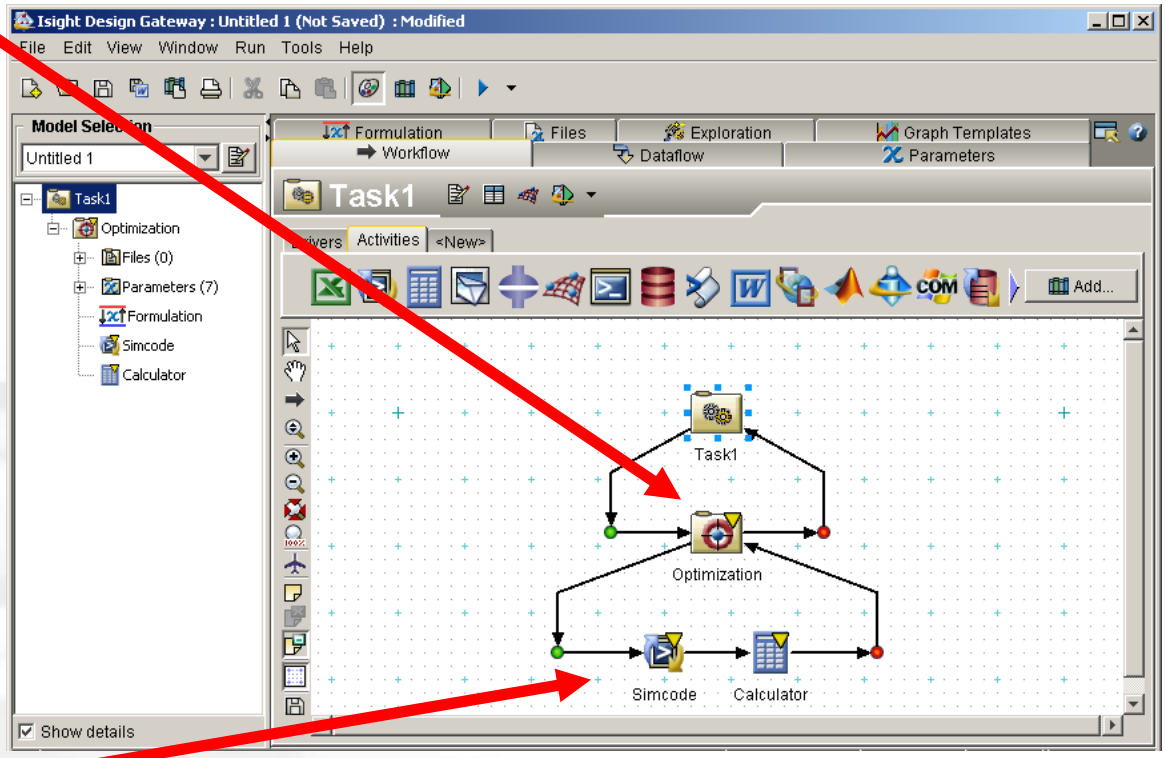
- Drag & drop analysis sim-flow creation
- Pre-built integrations with popular 3rd part CAD/CAE …no “wrapper” development required
- Shared data for software (parameters and files)
- Simulation process, Drivers/Components

SIMULIA

Simulation Process Flow Authoring

Process Components

- Task, Loop
- DOE
- Optimization
- Monte-Carlo
- Six Sigma
- Dynamic Taguchi
- SDI



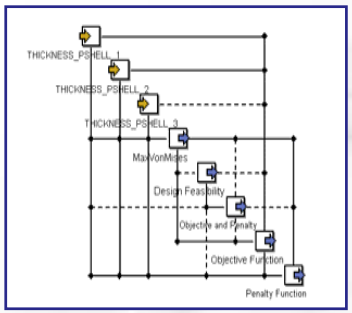
Activity Components

- Integration with in-house applications with ASCII I/O
- Integration with common commercial applications like Word & Excel
- Nested & conditional
- Parallel
  - Component (Abaqus)
  - Sim-flow execution

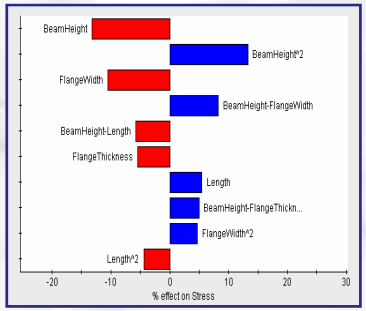
Post-Processing & Visualization

Enabling innovation and customer collaboration by allowing engineers to discover alternatives and make design tradeoffs

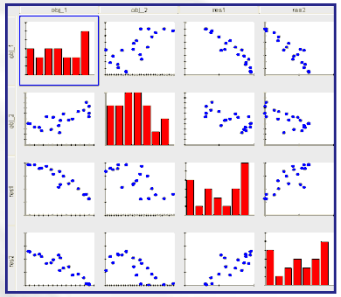
- Plots with one-click virtual prototype visualization in Abaqus/Viewer
- Correlation maps show the impact of model parameters on target
- Interactive engineering data mining
- Design Space Visualization for real-time attribute tradeoffs
- Statistical post processing
- Robustness/reliability graphs
- Real-time history plots



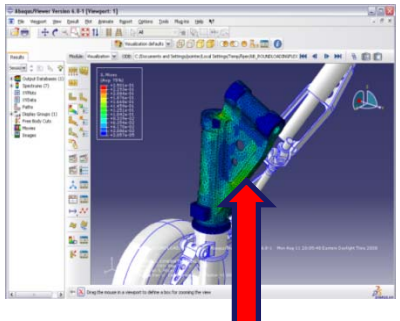
Design Parameter Correlation

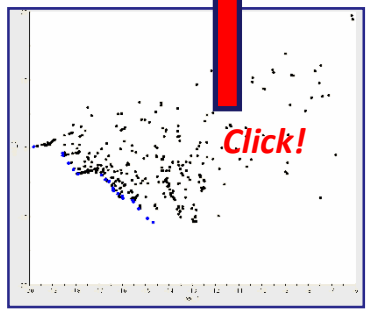


Statistical Processing



Data Mining





Interactive Real-time Plots

SIMULIA

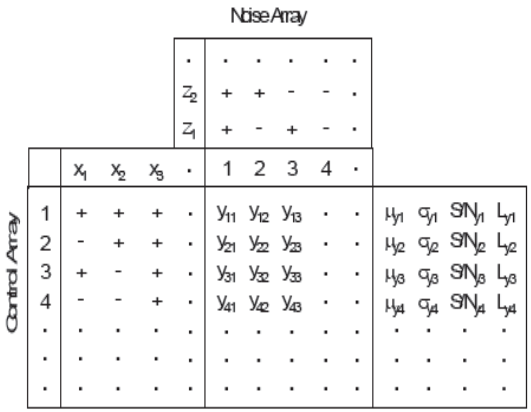
Taguchi Method Goals and Non-Goals

- **Goals**
  - Taguchi methods strive for a robust design while still taking performance into account
  - Taguchi methods for parameter selection are embedded in a design process
- **Non Goals**
  - Taguchi methods try to improve the design. They are no (robust/reliability) opimization methods
  - Taguchi methods try to improve the robustness of a design. The reliability is not taken into account at all.

Static Taguchi Method

- **In the Taguchi method there is a strict differentiation between noise factors (random variables) and control factors (design variables).**
- **The Taguchi Method works through a nested Design of Experiments approach.**
  - A DOE matrix is constructed individually for the noise and control factors. For each experiment in the control factor matrix the complete DOE matrix for the noise factors is executed. The
    - mean μ
    - standard deviation σ
    - signal to noise ratio S/N
    - Loss function $L = \sum k(y_i - T)2$
  - are recorded

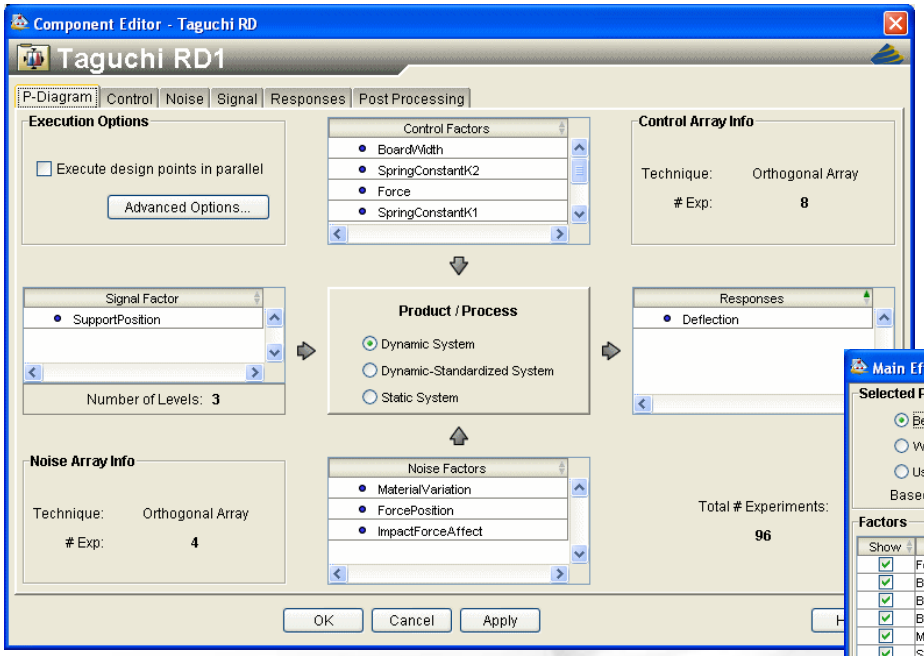
$$10\log_{10}\frac{\mu^2}{\sigma^2}$$



SIMULIA

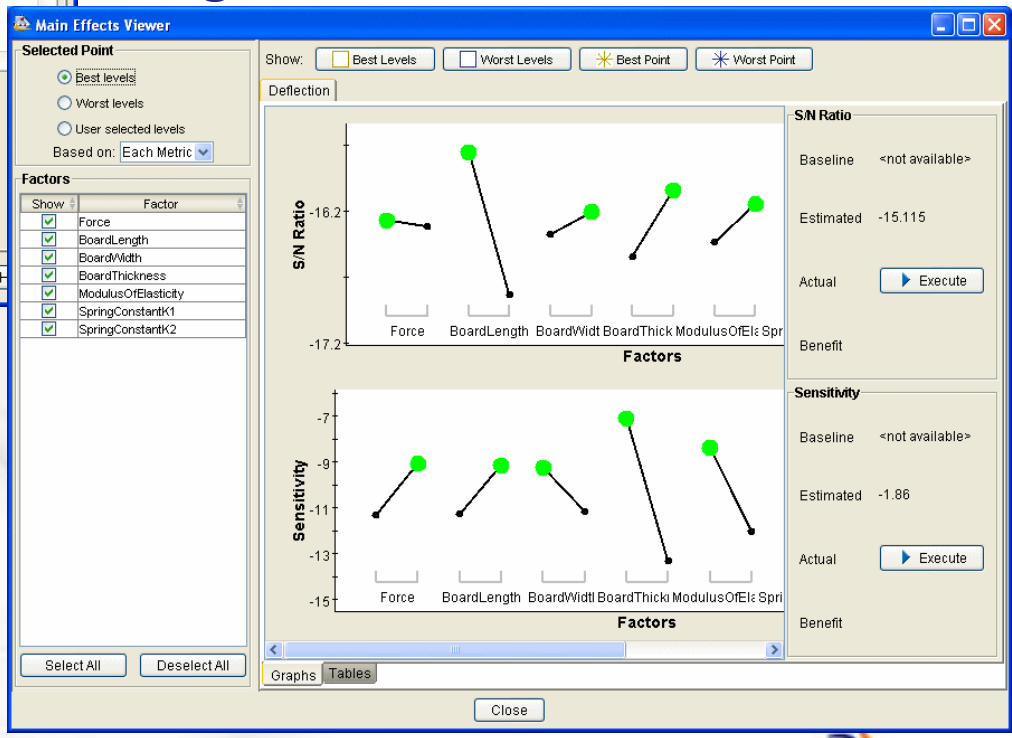
Static Taguchi Method

Configuring and using Taguchi methods in Isight



Configuration using the P-Diagram

Taguchi Main Effects Viewer

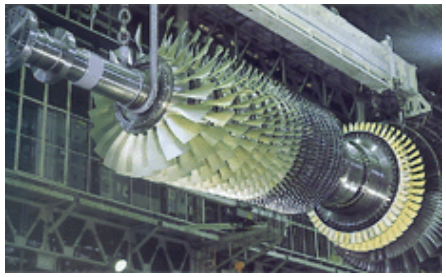


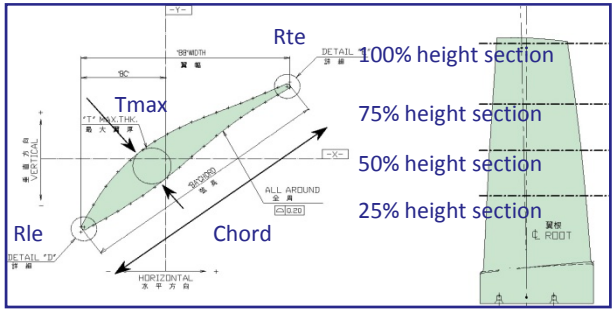
SIMULIA

Robust design of dynamic rotor blade of gas turbine

Taguchi Methods in iSIGHT automatically generates and executes simulations

- **Issues**
  - Dynamic rotor blade is designed to its eigenvalues are within specified values to avoid resonance
  - Eigenvalues vary dues to tolerance of blade shape in manufacturing
  - Robust design parameters must be defined by Taguchi method
- **Problem description**
  - Design factors
    - Shape parameters Tmax, Chord, Rle, Rte of each section） :13 factors x 3 levels
  - Error factors
    - Tolerance : 3 factors x 2 levels
- **Results**
  - Variance of frequency（Standard deviation） reduced by 53%





① Define parameters

② Generate orthogonal arrays

③ Execute simulations

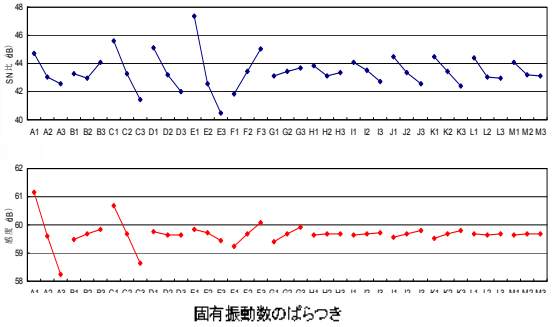
L27

④ Calculate SN ration and select best combination

⑤ Confirmation simulation

NASTRAN

			①Initial	②Best
A	100% section	Tmax	100 %	←
B		Chord	100 %	←
C		Rle	100 %	110 %
D		Rte	100 %	90 %
E	75% section	Tmax	100 %	90 %
F		Chord	100 %	110 %
G		Rle	100 %	←
H		Rte	100 %	←
I	50% section	Tmax	100 %	←
J		Chord	100 %	←
K		Rle	100 %	←
L		Rte	100 %	←
M	25%	Tmax	100 %	←



53% reduction of standard deviation

SIMULIA

Robust Design of Side Impact Simulation

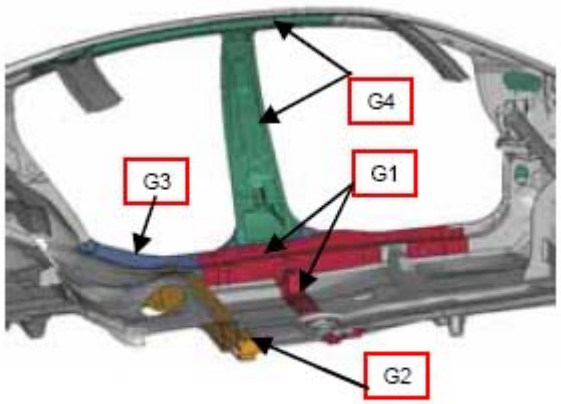


Fig. 6 Groups of Design Variables

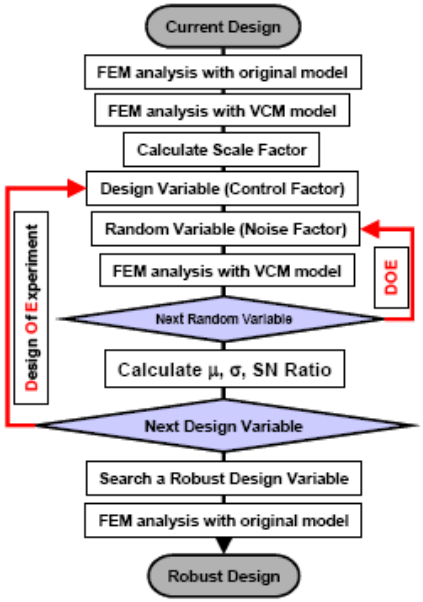
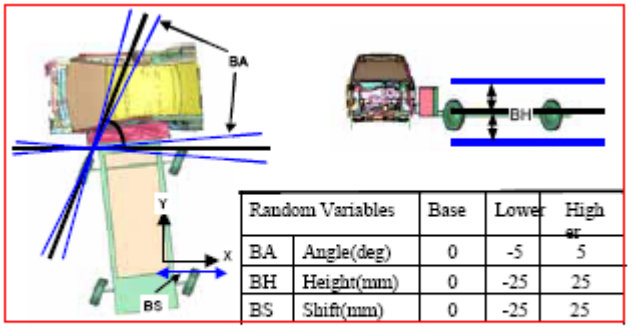


Fig. 5 Process of Robust Design Using VCM Model



Random Variables		Base	Lower	High er
BA	Angle(deg)	0	-5	5
BH	Height(mm)	0	-25	25
BS	Shift(mm)	0	-25	25

Fig. 7 Random Variables on MDB

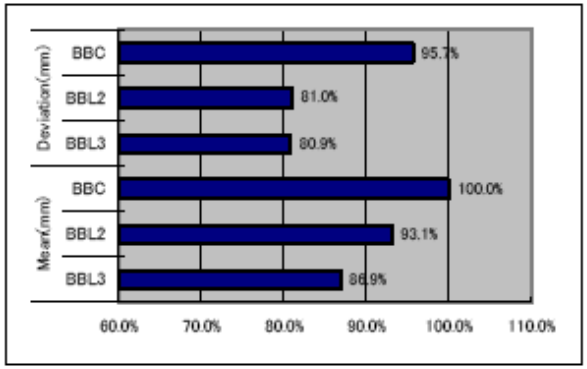
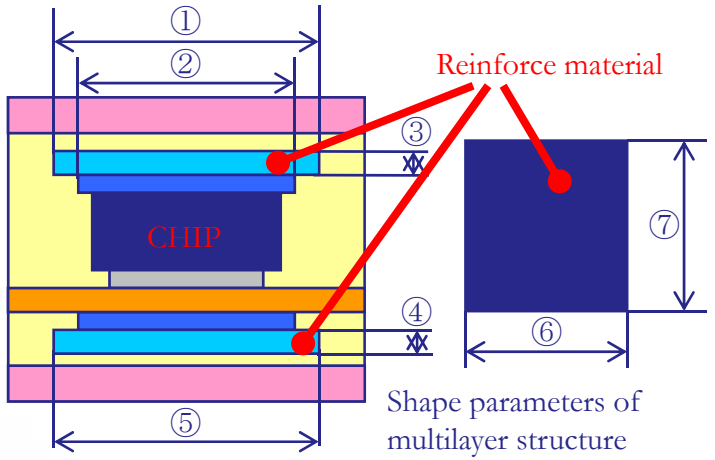


Fig. 12 Comparison of Deviation and Mean Value of Intrusion (Ratio=Robust/Initial)

Robust design of multilayer structure package

Stable and strong semi-conductor package design in short time

- **Issues**
  - Optimize shape parameters of reinforce materials by which give semi-conductor chip minimum damage by bending
- **Result**
  - Package design finished in four days
  - Physical testing drastically reduced
  - Available to compare good and bad design virtually
  - Many engineers became to learn quality engineering



Shape parameters of multilayer structure

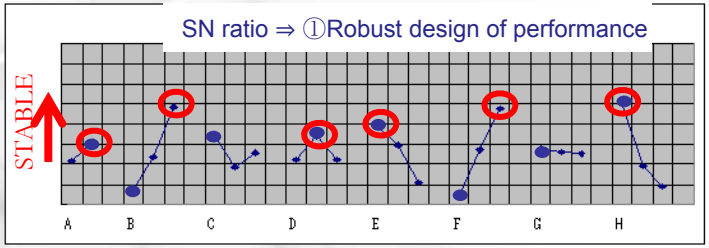
Control factor L_{18} (8

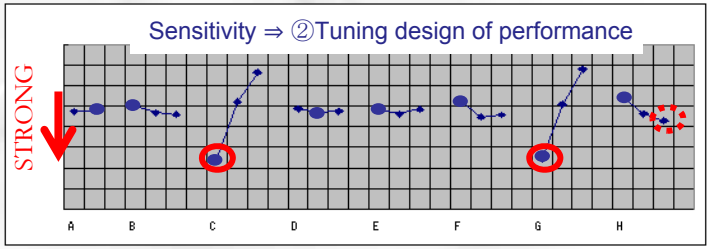
	Factor	level1	level2	level3
1	width A	4.4	5.5	
2	thickness B	0.075	0.08	0.085
3	width C	5.5	7.7	9.9
4	width D	4.4	5.5	6.6
5	thickness E	0.075	0.08	0.085
6	width F	5.5	7.7	9.9
7	width G	5.5	7.7	9.9
8	width H	5.5	7.7	9.9

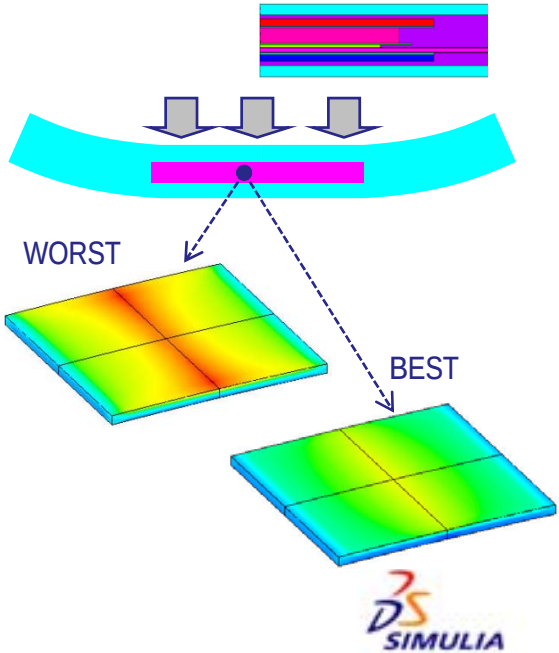
Noise factor L_{12} (11 factors)

	Factor	level1	level2
1	width A	-3%	+3%
2	thickness B	-3%	+3%
3	width C	-3%	+3%
4	width D	-3%	+3%
5	thickness E	-3%	+3%
6	width F	-3%	+3%
7	width G	-3%	+3%
8	width H	-3%	+3%
9	Direction of Bending	Up	Down
10	Material Property J	-3%	+3%
11	Material Property K	-3%	+3%

$L_{18} \times L_{12} = 216$ calculations

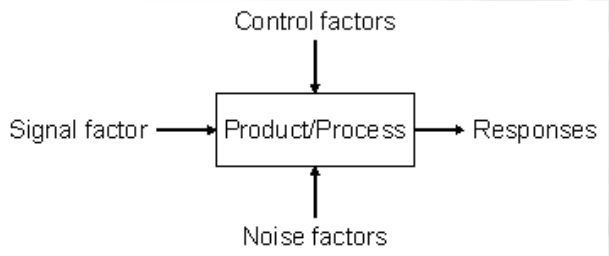


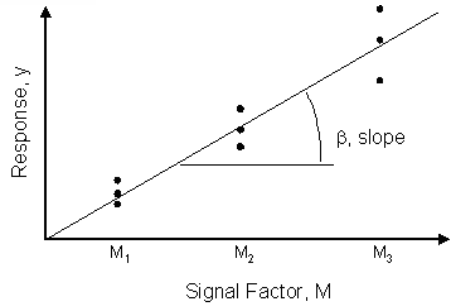




Dynamic Taguchi Methods

- **Dynamic Taguchi Methods are used, when the design should react in a given manner to the change of specific parameters called signal factors.**
  - Examples for signal factors are thermostats, gas pedal position, ...
- **Typical Goals are**
  - Linear response
  - Decrease variation in slope and offset



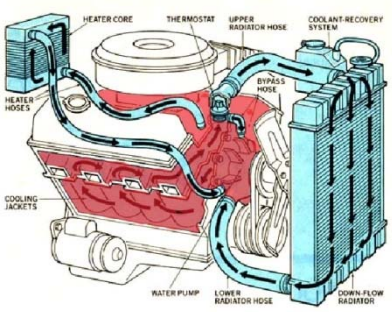


- **Dynamic Taguchi Methods add a third DOE matrix**
  - Each static Taguchi product matrix is execute for each experiment in the signal factors DOE

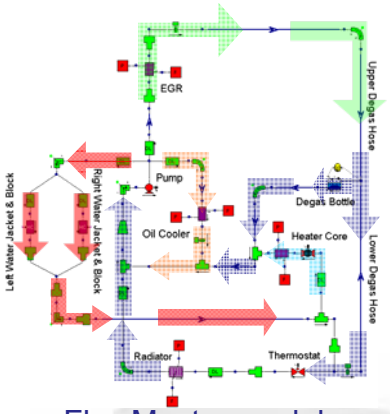
SIMULIA

Robust design of automotive engine cooling system

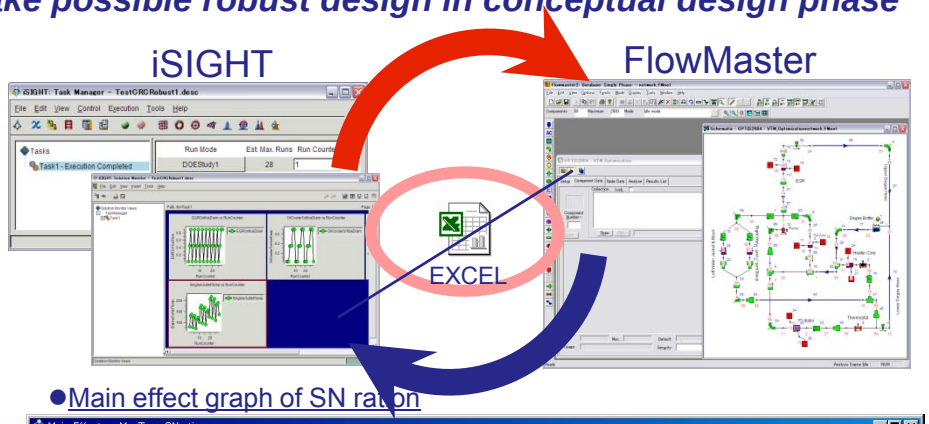
1D cooling simulation and Taguchi method make possible robust design in conceptual design phase



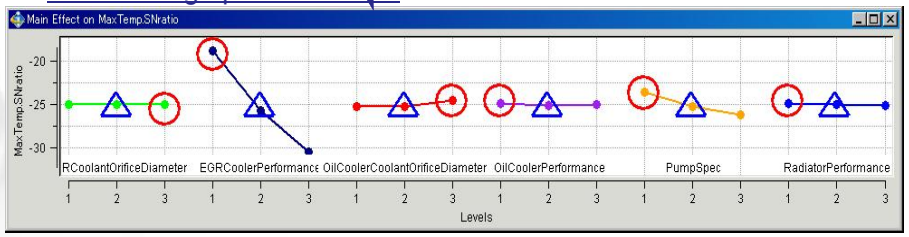
Engine Cooling system



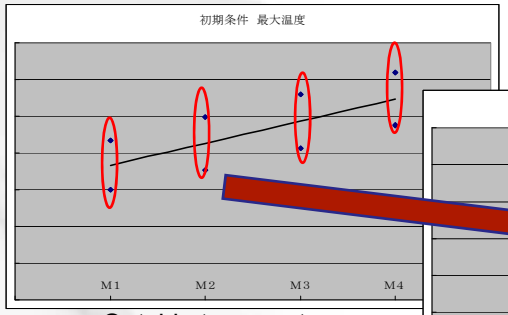
FlowMaster model



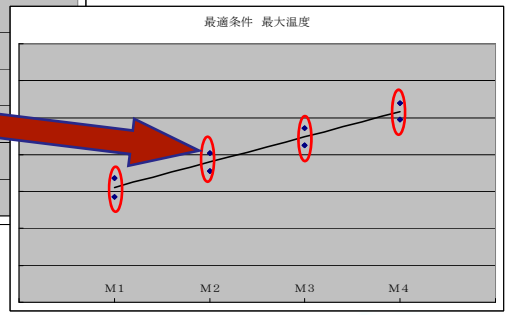
●Main effect graph of SN ration



●Initial variance of water temperature



●Robust variance of water temperature



Condition (Dynamic Taguchi)

Control factors

Design variable

Flow rate
Heat-exchange efficiency

L27

Signal factors

Outside temperature

4 levels

Cooling System

Response

Water temperature

432 calc by iSIGHT

RPM Tolerance

L4

uncontrol able

Noise factor

Water tempereture become stable under given outside temperature conditions

SIMULIA

Conclusion

- **Taguchi methods are a simple and proven approach to robust design**
- **They build on some strong assumptions**
  - DOE plans for robustness assessment and selection of best design
  - No reliability is taken into account
- **Like almost all robust design methods they can become very expensive**
  - Approximation methods might be necessary
- **No need to collect information on input parameter distributions**
- **Taguchi Methods provide a good first step for robust design**
  - Isight provides the environment to facilitate a more detailed analysis/optimization