Mercedes-Benz

Mercedes-Benz Research and Development India

Robustness Analysis in CAE

08.12.2011

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Agenda

- What is robustness ?
- Added-value
- Robustness Process in CAE
- Case studies
- Conclusions

What is Robustness ?

A system or design is said to be "**robust**" if it is capable of coping well with variations (sometimes unpredictable variations) in its operating environment with minimal damage, alteration or loss of functionality.

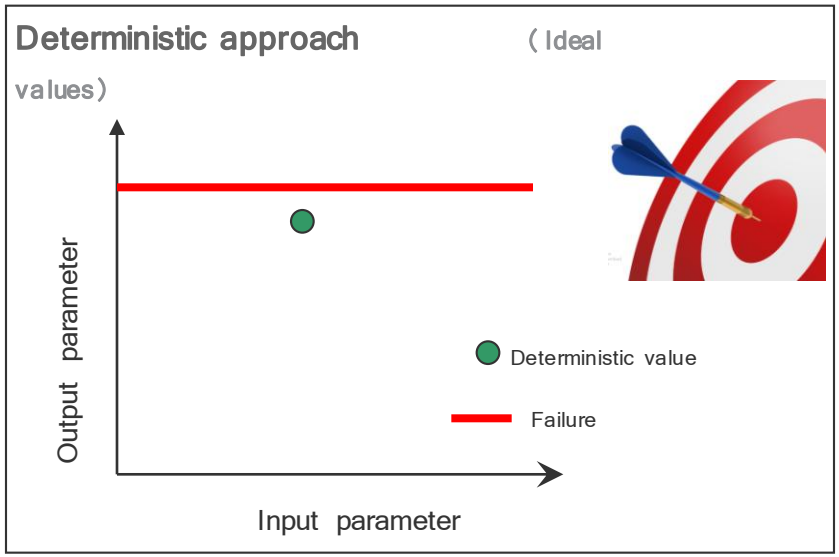
Why consider variations?

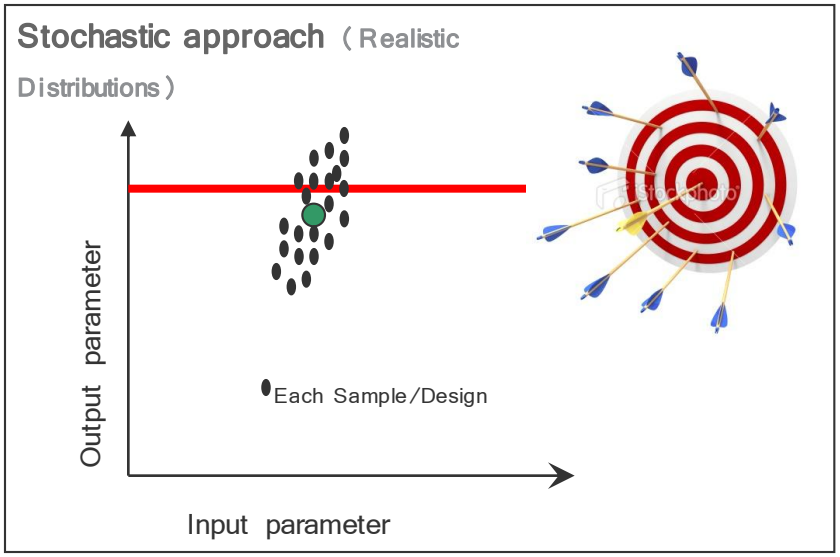
The real world is not perfect. In reality, all the components will have values that show scatter with respect to ideal values.

Examples:

Variations in sheet metal thickness, dimensions, material properties, external loads, etc.

Added Value

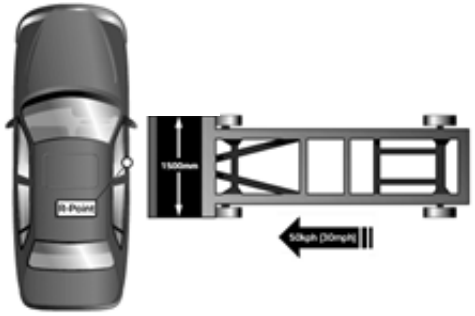




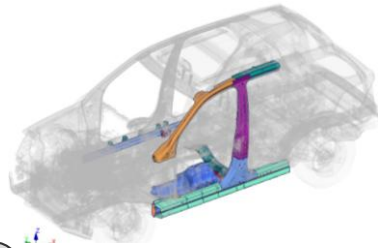
Added values :

- Checks if variations in components result in the loss of functionality.
- Identifies the crucial components that influence the functionality of a design.
- Helps identify worst case scenarios for counter measures.
- Leads towards optimisation.

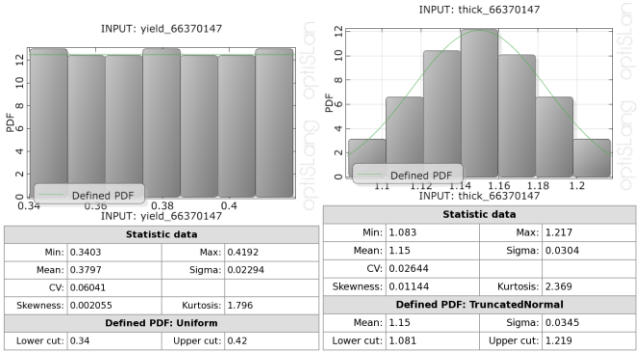
Robustness Process in CAE



1 Ideal CAE Model



2 Identification of input parameters

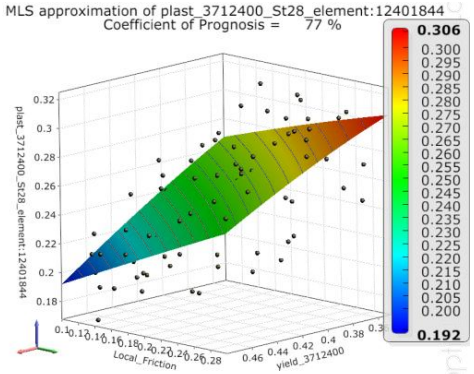


Statistic data			
Min:	0.3403	Max:	0.4192
Mean:	0.3797	Sigma:	0.02294
CV:	0.06041		
Skewness:	0.002055	Kurtosis:	1.796
Defined PDF: Uniform			
Lower cut:	0.34	Upper cut:	0.42

Statistic data			
Min:	1.083	Max:	1.217
Mean:	1.15	Sigma:	0.0304
CV:	0.02644		
Skewness:	0.01144	Kurtosis:	2.369
Defined PDF: TruncatedNormal			
Mean:	1.15	Sigma:	0.0345
Lower cut:	1.081	Upper cut:	1.219

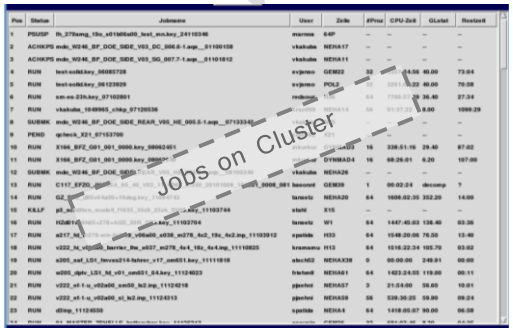
3 Defining Variation in Parameters

Robustness Process

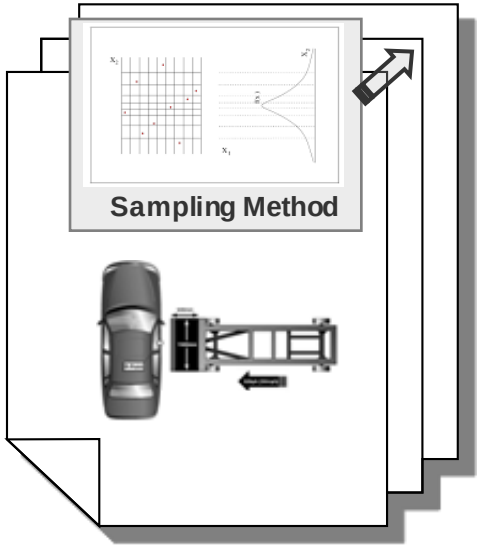


3D Anthill Plot

6 Post processing & Analysis

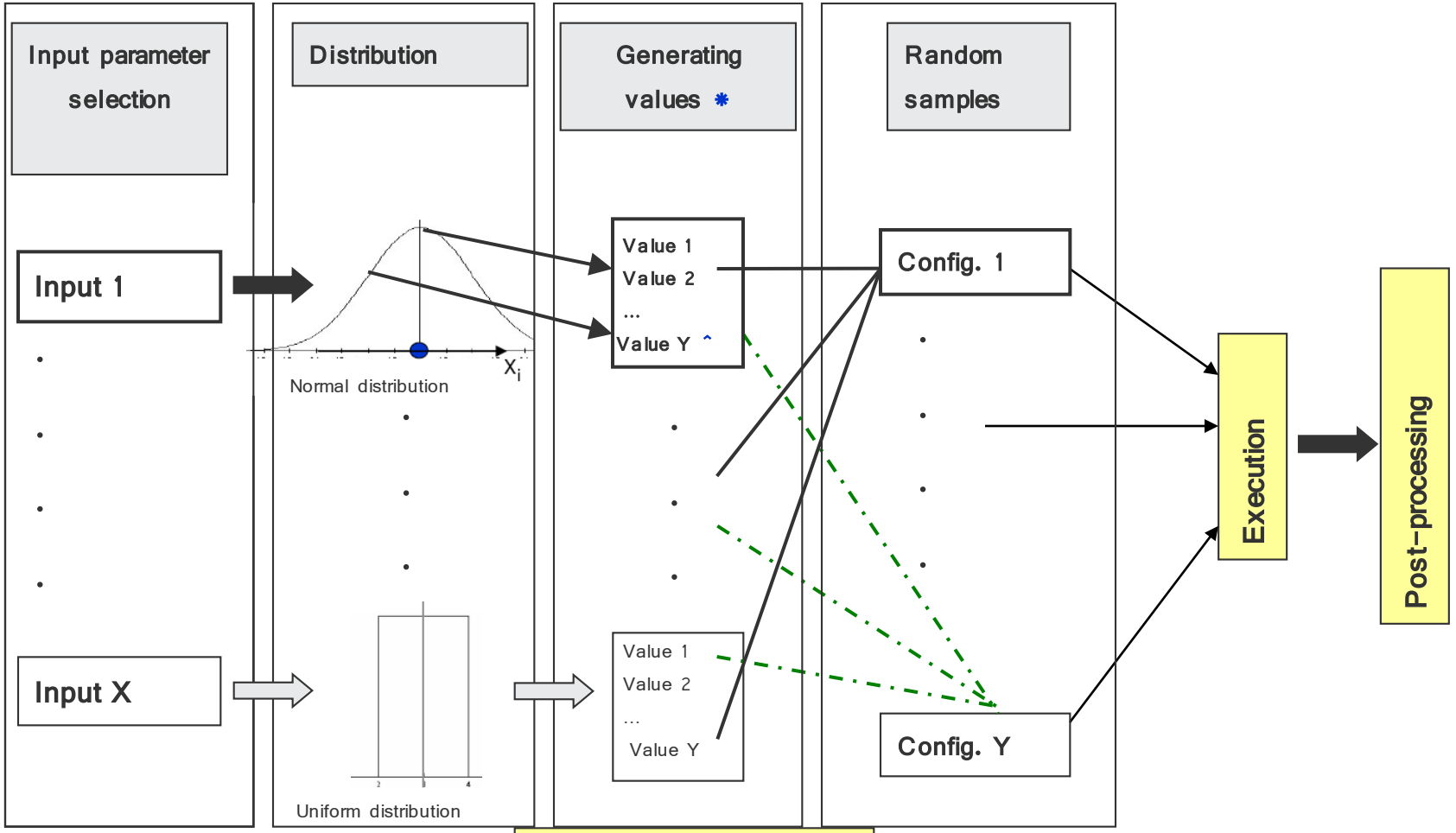


5 Computation of Samples



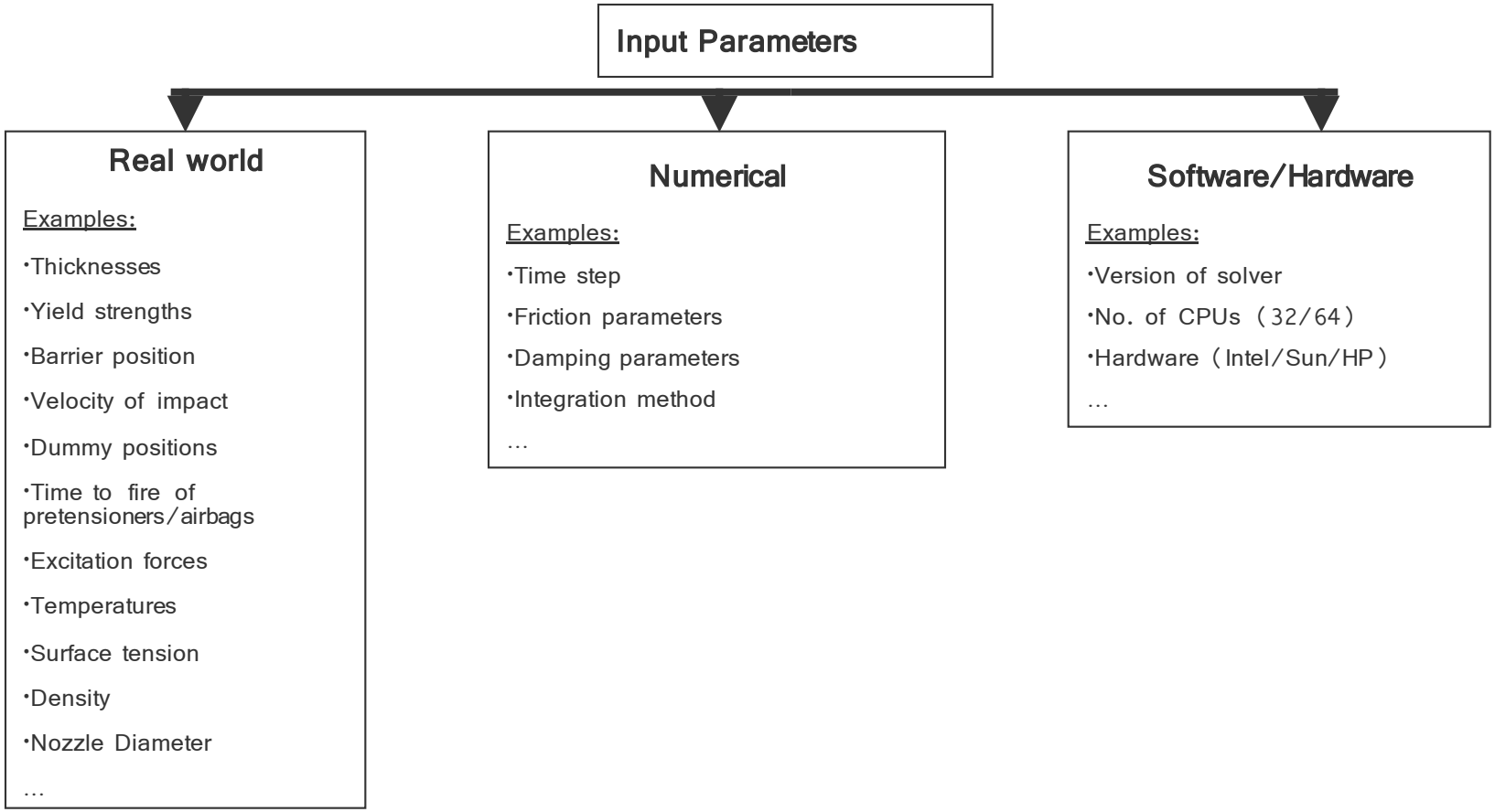
4 Generation of Samples

Flow chart



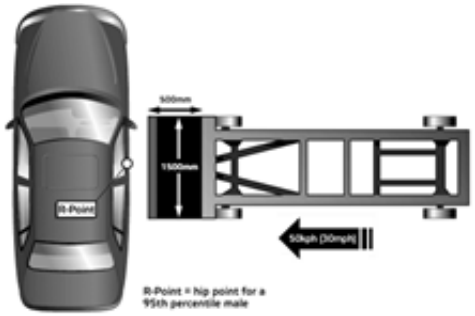
*Input values generated based on the distribution defined
** Input values are selected at random and each combination of all these inputs is a configuration.
^ Y should be atleast X+1

Types of Input Parameters



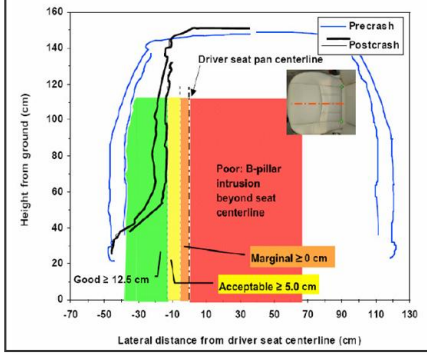
Case Study: Robustness of Design (IIHS) 1/2

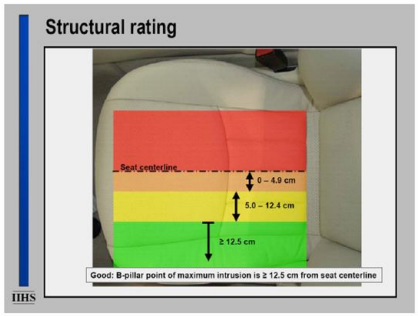
IIHS Load case configuration



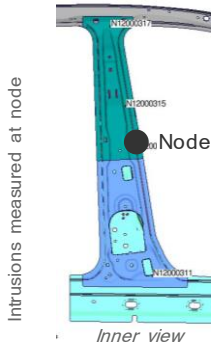
Structure Rating (IIHS)

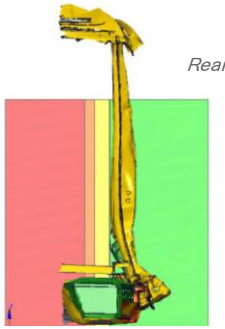
Boundary line	Good	Acceptable	Marginal	Poor
B-pillar to driver seat centerline distance (cm)		12.5	5.0	0.0
Structural failures	Downgrade structural rating by one category			



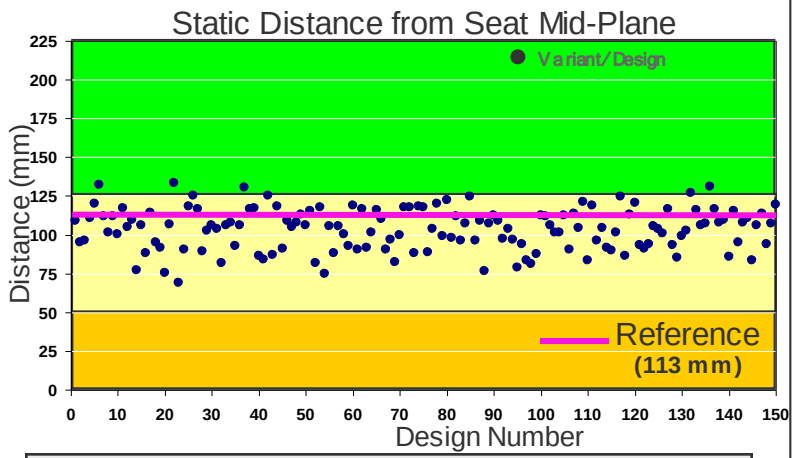


Evaluation





Sample B-Pillar deformation

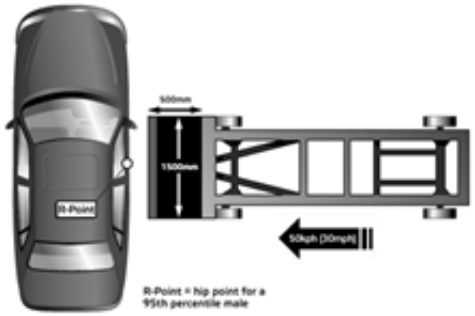


No risk of B-Pillar intrusions into the marginal zone.

Info: Typical number of parametric combinations: 100 to 150

Case Study: Robustness of Design 2/2

IIHS Load case configuration



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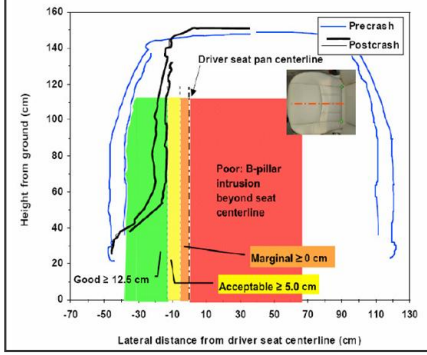
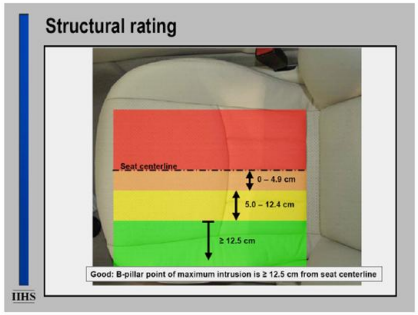
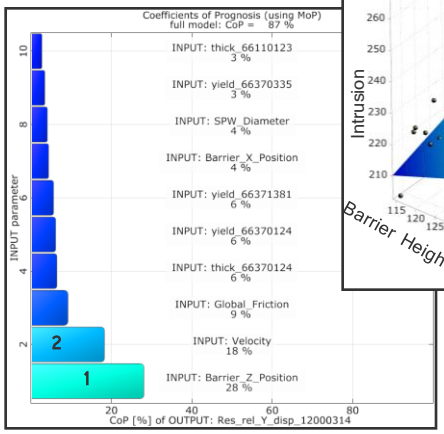


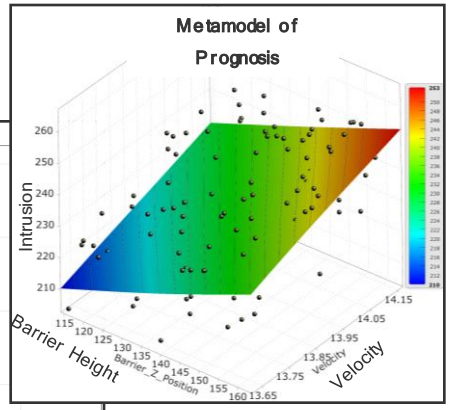


Results Analysis

Coefficient of Importance



Metamodel of Prognosis



In the scope of variations considered in this study

- The most influential parameters are:
  - Barrier height (1 shown above)
  - Velocity of impact (2 shown above)
  - Thickness and yield strength of B-Pillar reinforcement

Added Values (1/3)

A Prediction

Deterministic Model

- In the deterministic model there are phenomena which are evident.
- These could be material separations, B-Pillar deformations etc.
- Confidence level of these are purely relevant to modeling assumptions.

Robustness Analysis

- In the stochastic model there are phenomena which are non-evident (just like test to test variations).
- Deformation patterns vary with parameters.
- This was also predicted in a case study.
- Some patterns seen from the robustness analyses were captured clearly in the test.

Added Values (2/3)

B Confirmation

Deterministic Model

- Design features necessary to improve performances (eg. Notches, beads, darts) are evaluated.
- Functionality of these features can vary in tests.

Robustness Analysis

- From Robustness Analysis, we can confirm the functionality of the design features by varying input parameters.
- This helps in improving confidence in the design.
- This can also help in test avoidance.

Added Values (3/3)

C Counter Measures

Deterministic Model

- Deterministic models do not always provide us with worst case scenarios.
- During design development some critical areas might go un-noticed with ideal scenarios.

Robustness Analysis

- Robustness analysis can provide with worst case scenarios, there by identifying potential critical problems.
- These critical areas of concern, can be addressed with new design proposals/reinforcements.

Conclusions

- Robustness analysis significantly enhances the information out of a CAE model :
  - Evaluation of the robustness of a design
  - Evaluation of the numerical robustness of CAE models
  - Prediction/Interpretation of hardware test
  - Identification of worst-case scenarios
  - Derivation of countermeasures
  - …

Questions ?