Implementing Robust Simulation - Achieving Design Targets in the Automotive and Aerospace Industries

Simulation of Manufacturing Processes and Product Development
20th. of May 2003
Göteborg, Sweden
"Scatter is inherent to all physical systems"
Safety by Accident

What’s missing?
- dispersion
- realism
- robustness
- science
- knowledge
- understanding

E L R T W R T E

nominal inputs

1 solve

SOLVER

1 output

rupture load

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Scatter in a digital test – Robustness

- random variables
- deterministic solver
- realistic model

n sets of random inputs

n solves

n random outputs

rupture load
Correlation between physical and digital tests
Inadequate model, but good agreement between single test and calculation

Good physical model, but no agreement between single test and calculation
Uncertainty of these appear at each test

Stochastic simulation is deployed in order to understand and quantifying the uncertainty in any system.

Uncertainty and Scatter
Introducing Robustness Management

Model of a Complex System

Input parameters:
- $x_1$
- $x_2$
- $x_3$
- ... $x_m$

Random Sample (Monte-Carlo)

Solver

Output parameters:
- $y_1$
- $y_2$
- ... $y_n$

Deterministic Shot

Response Cloud
Uncertainty and Scatter - Forming
Introducing Robustness Management
Introducing Robust Design Improvement
Is my system (design/test/simulation) robust?
What are the dominant design parameters*?
What are the design boundaries*?
What are the sources of my variation?
How do alternative designs change robustness?
How can I guarantee a result*?
How can I improve the design*?

* When considering scatter/uncertainty
Unique Characteristics

- Scatter - uncertainty
- Correlation with test/simulation
- No pre-assumptions
- No curse of dimension
- Dependencies between variables
- Non-linear system behaviour
Application Areas

- Crashworthiness
- Occupant safety/pedestrian
- NVH
- Strength & durability
- Forming
- Engine development
- Fatigue & life-cycle prediction
Applications in the Development Process

- Model Validation
- Robustness Studies
- Robust Design Improvement
- Design Exploration
- Multidisciplinary RDI
Applications in the Development Process

Concept       Development       Verification

Model validation of components
Model validation of complete systems
Design improvement of components
Robustness studies of components
Design exploration
Multidisciplinary design improvement
Performance, Quality and Robustness

Performance (= center of gravity of result cloud)

Quality of production (= diameter of result cloud)

Robustness (= Shape of result cloud)
Adding Dimensions
Adding Dimensions
Software and Methods
**Organisation:** BMW AG, München

**Loadcase:** Allianz-Zentrum-Technik
AZT-rear crash (15 km/h)

**Method:** ST-ORM, Robust Design Improvement (RDI)

**Objective:** Reduction of damage without increase in mass

**Resources:** 3 Iterations, 15 Shots each

**SW/HW:** PAM-CRASH on SGI
Robustness Study - Example

**Organisation:**  EASi Engineering, Detroit

**Loadcase:**  Fender Stamping Analysis

**Goal:**  Robustness Study as part of provision of CAE service

**Methods:**  ST-ORM, Robustness Studies

**Resources:**  Ordinary HP WS

**Hardware:**  AutoForm on Workstation
Robustness Management - Example

Organisation: Audi AG, Ingolstadt

Goal: Integration of stochastic simulation into the complete product development process

Methods: ST-ORM, Robustness Studies, Robust Design Improvement

Resources: 2001: 128 cpu Cluster
            2002: 256 cpu Cluster

Hardware: PAM-CRASH on Linuxcluster
Robustness Study - Example

**Organisation:** CASA, Madrid

**Loadcase:** Coupled Launcher-Payload Analysis

**Method:** ST-ORM, Robustness Study

**Objective:** Robustness Study and Stochastic Normal Modes Analysis. Determine risk and dominant design parameters

**Resources:** 45 Shots

**SW/HW:** MSC.Nastran on WS-cluster
Summary

- Introduces uncertainty and scatter
- Introduces robustness and robust design improvement
- Applied from component to multidisciplinary
- Proven and scalable technology and method
- Meets requirements in lead time and economy to fit automotive and aerospace development processes
Publications:

www.easi.de/company/publications/

Events:

4th European Stochastic Experts Forum
25-28 June 2003, Bad Neuenahr, Germany

www.easi.de/company/esef2003/

Thank you for your attention!