第三届LS-DYNA中国论坛

2018年10月26日　　上海

Livermore Software Technology Corporation　　上海仿坤软件科技有限公司（**LS-DYNA** 中国）

Application of LS-DYNA in safety product developing

Autoliv CTC in Sep 19th,2018

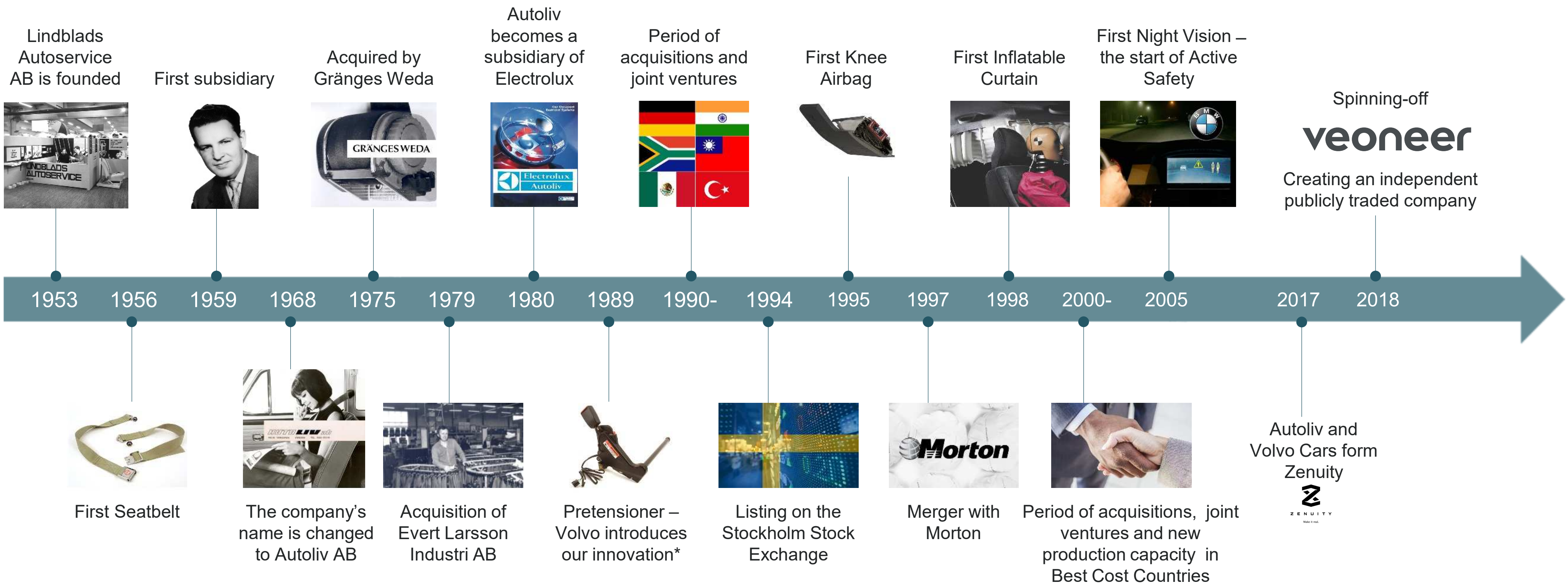
v 1.0

Autoliv

Contents

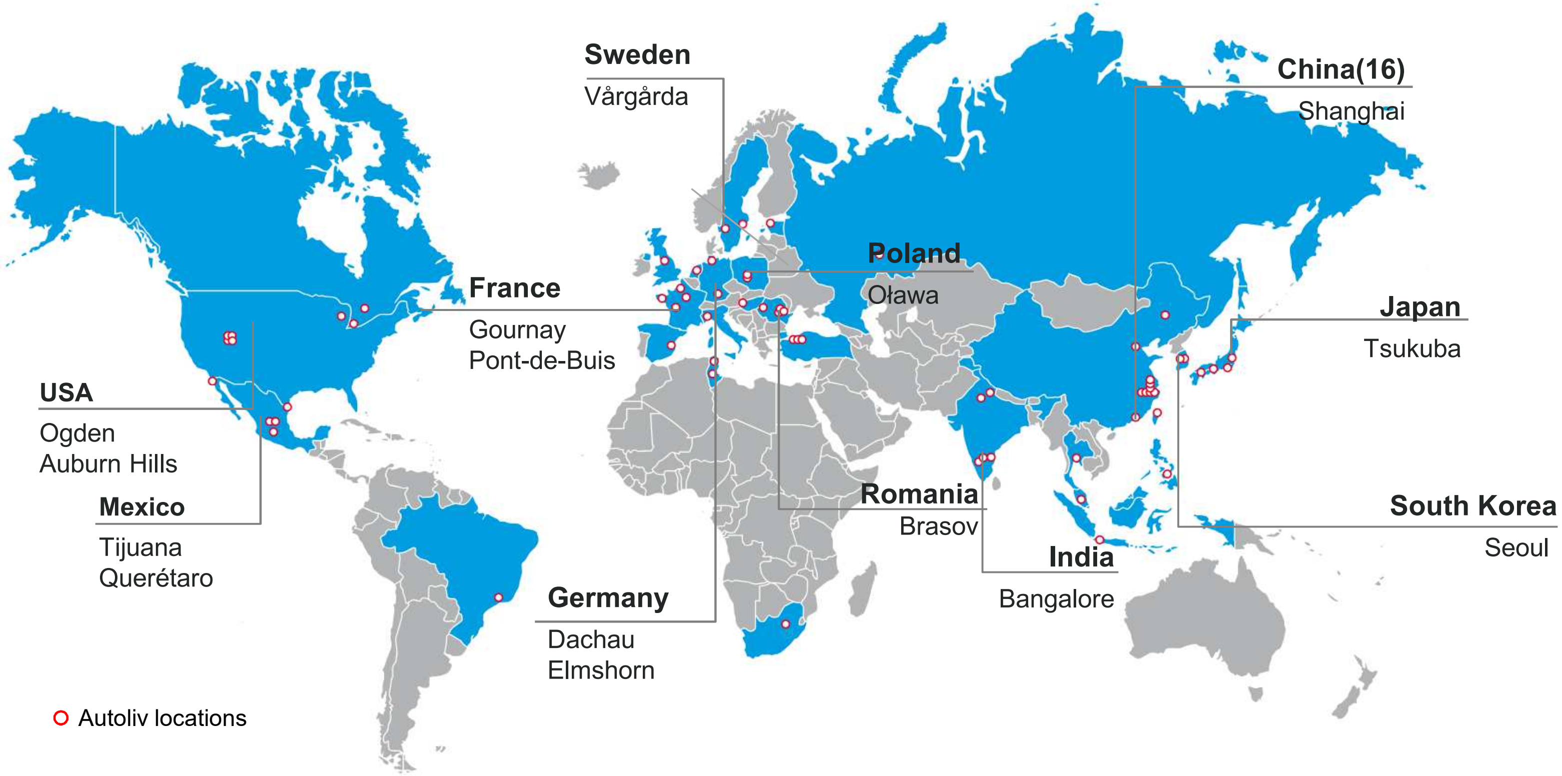
- Autoliv
- Safety product
- Strength
- Airbag deployment
- Fatigue
- Acoustic

Autoliv – 65 years of Dedication to Saving Lives



Autoliv

Autoliv's Research, Development & Engineering



27 Countries
Across All Key Automotive Regions

64 Facilities
In Close Proximity to OEMs

12 Tech Centers
With 5,300 Engineers, Close to OEMs' Engineering Hubs

19 Crash Test Tracks
Enabling Crash Simulations Globally

Safety Technologies

Airbags

In frontal crashes, driver airbags reduce fatalities by appr 25%, and front-seat airbags by appr 20%. Side-curtain airbags reduce life-threatening head injuries in side impacts by appr 50% for passengers sitting on the side of the vehicle that is struck. Side airbags, rear side airbags, knee airbags and far-side airbags also help save lives and reduce serious injuries.

Seatbelts prevent fatalities

The combination of seatbelt, seatbelt pretensioners, load limiters, lap pretensioners and frontal airbags reduces the risk of life-threatening head or chest injuries in frontal crashes by 75%.

Protecting Pedestrians

Thanks to a pyrotechnic hood-lifter and/or an outside pedestrian protection airbag, a pedestrian who is hit can avoid head injury caused by the hard area between the hood and the windscreen or one of the windshield pillars.

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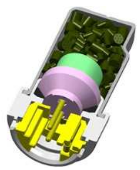
Safety Product

Airbags – Snapshot

Product Portfolio Overview

Airbags		✓ Driver and passenger ✓ Knee ✓ Side and curtain ✓ Far-Side ✓ Pedestrian protection
Inflators		✓ Pyrotechnic ✓ Stored gas ✓ Hybrid
Initiators and Micro Gas Generators		✓ Initiators ✓ Micro gas generators
Textiles		✓ Weaving of one-piece cushions ✓ Cut & sew operations

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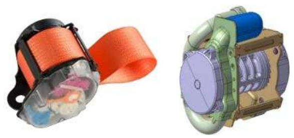
Safety Product

Seatbelts – Snapshot

Product Portfolio Overview

Retractors/ Pretensioners		✓ Tightens seatbelt in case of accident ✓ Stops spool that retains seatbelt webbing from rotating
Pre-Pretensioners		✓ Tightens seatbelt prior to crash or during aggressive driving manoeuvres ✓ Soft tightening as warning for ADAS functions
Buckles		✓ Can provide tightening of seatbelt during crash ✓ Illuminated and buckle presenters
Height Adjusters, Pillar Loops & Tongues, Webbing		✓ Accommodate diverse vehicle interior layouts and safety needs

Safety Product

Steering Wheels – Snapshot

Product Portfolio Overview

Steering Wheel Products

- ✓ Leather wrap and polyurethane wheels
- ✓ Magnesium & aluminum die cast structures

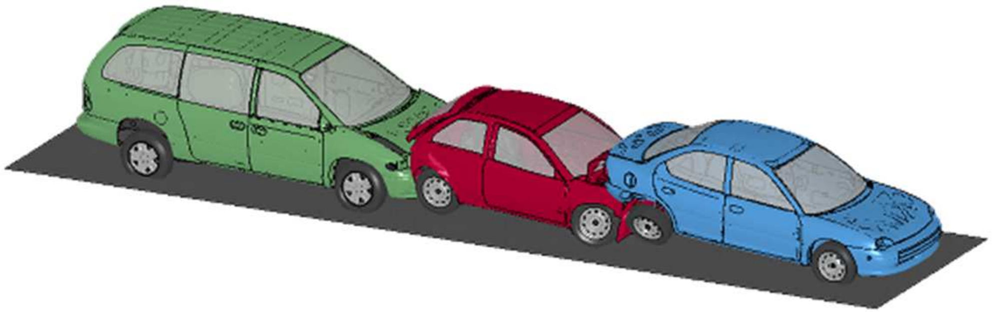
Steering Wheel Electrical Device

- ✓ Heated rim, horn and touch switches
- ✓ Gesture controls
- ✓ Steering wheel ECUs (HOD, heat and alert)

Human Machine Interface (HMI) Features

- ✓ HMI platform, enabling ADAS features
- ✓ Optical sensor
- ✓ Hands on/ off detection (HOD)
- ✓ Driver alert (optical and haptic)

Solve all problems in LS-Dyna



One code strategy

- In automotive, one model for crash, durability, NVH shared and maintained across analysis groups.
- Manufacturing simulation results from LS-DYNA used in crash, durability, and NVH modeling.

"All-in-one" package

Structure

Crashworthiness

Occupant Safety

NVH

Durability

Acoustic

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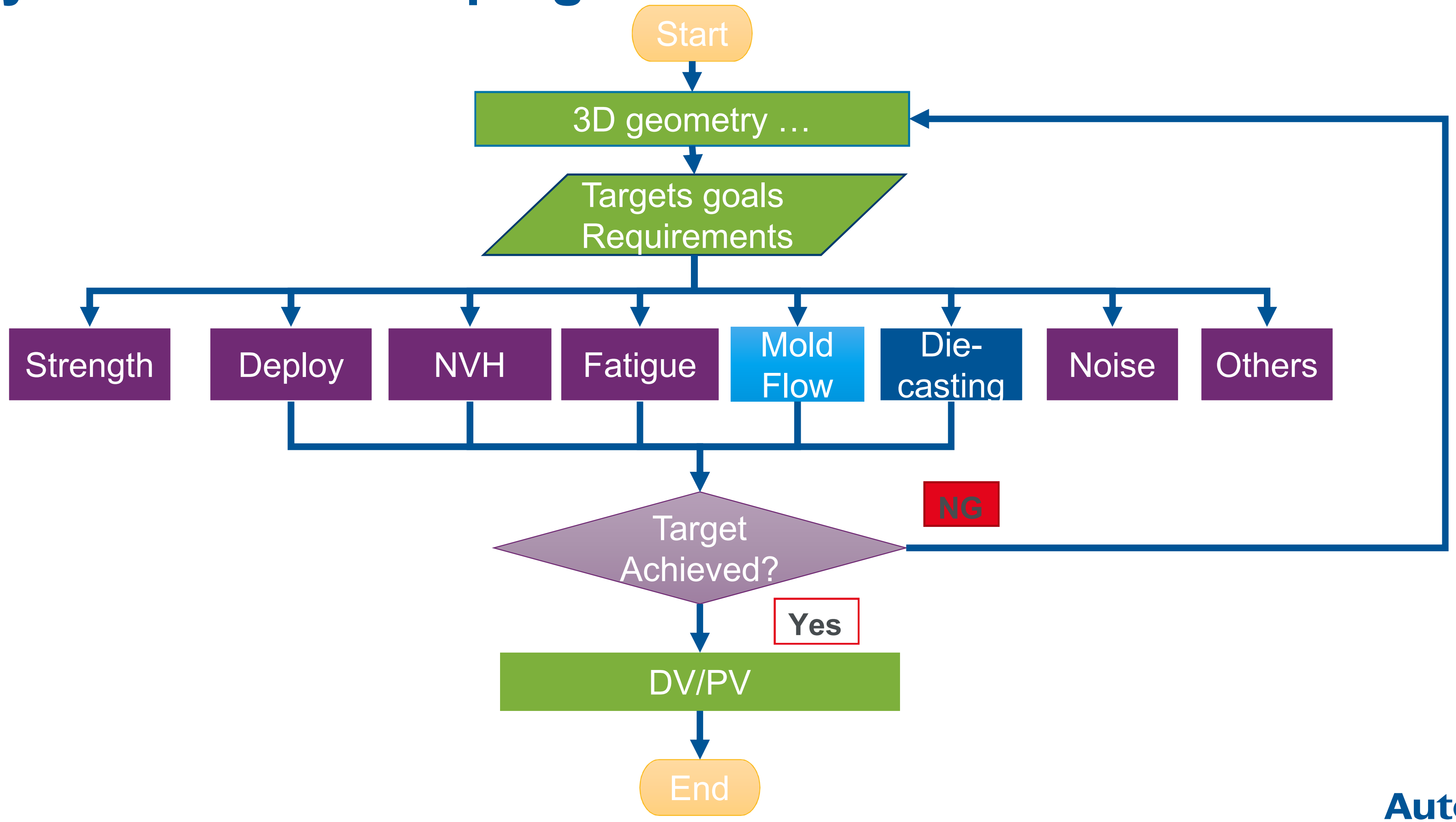
Safety Product Developing

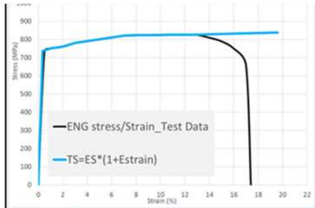


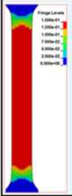
Application of LS-DYAN

Strength in Implicit and explicit of Ls-Dyna

- Material property
- Seatbelt
- Airbag
- Steering wheel

Strength Analysis
-Material property

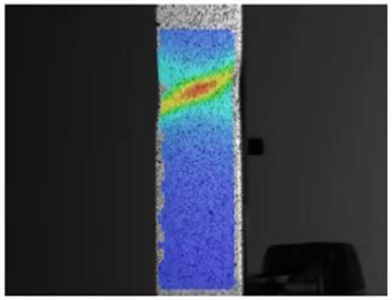


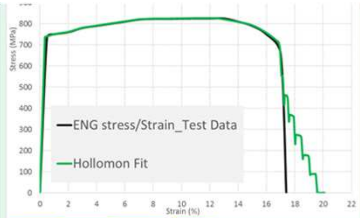


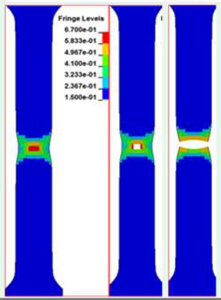
→ Uniform Elongation

→ No Necking

→ No Force Reduction



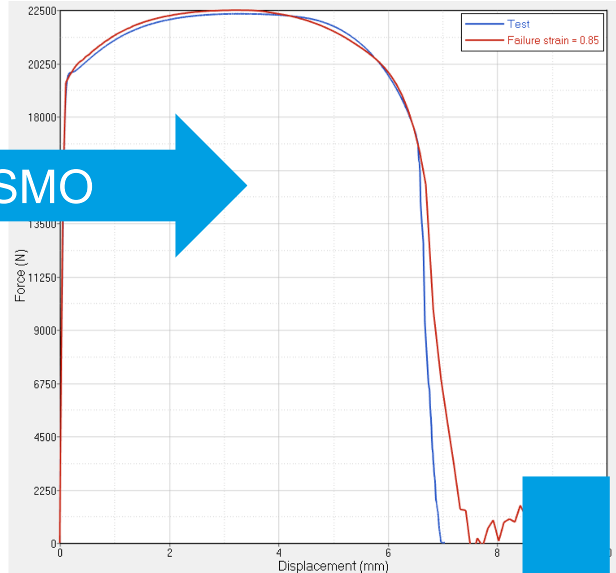


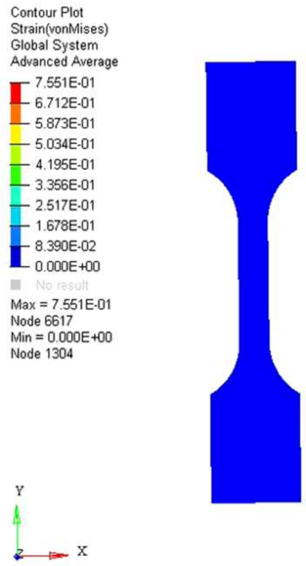


→ necking achieved
→ local strain (68%)
→ close match with eng. stress-strain curve
→ failure: inside-out

ARAMIS TEST
→ 68% failure strain

GISSMO





Validated GISSMO Material Card for strength analysis

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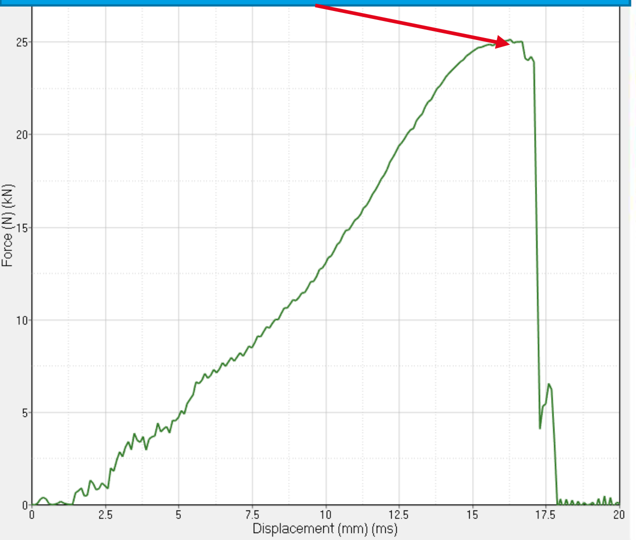
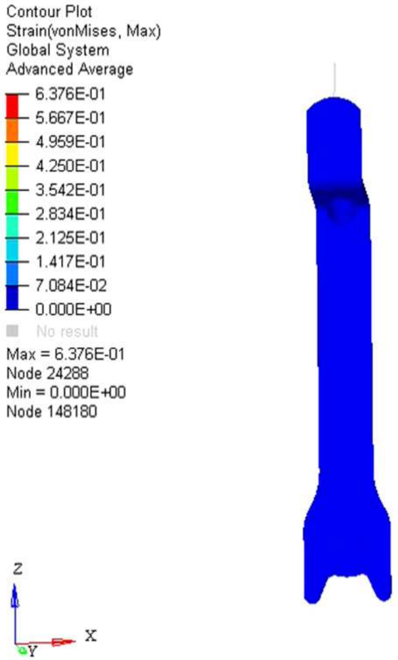
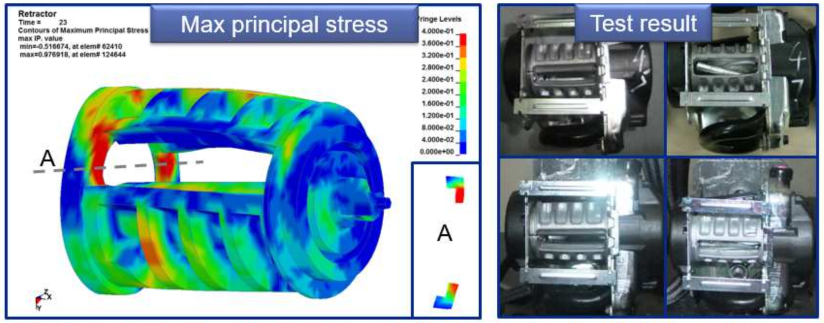
Strength Analysis -Seatbelt

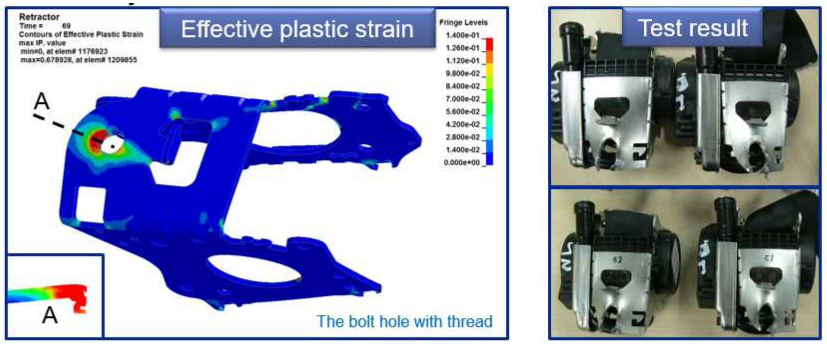
25kN is close to test (24.95 ~26.06)







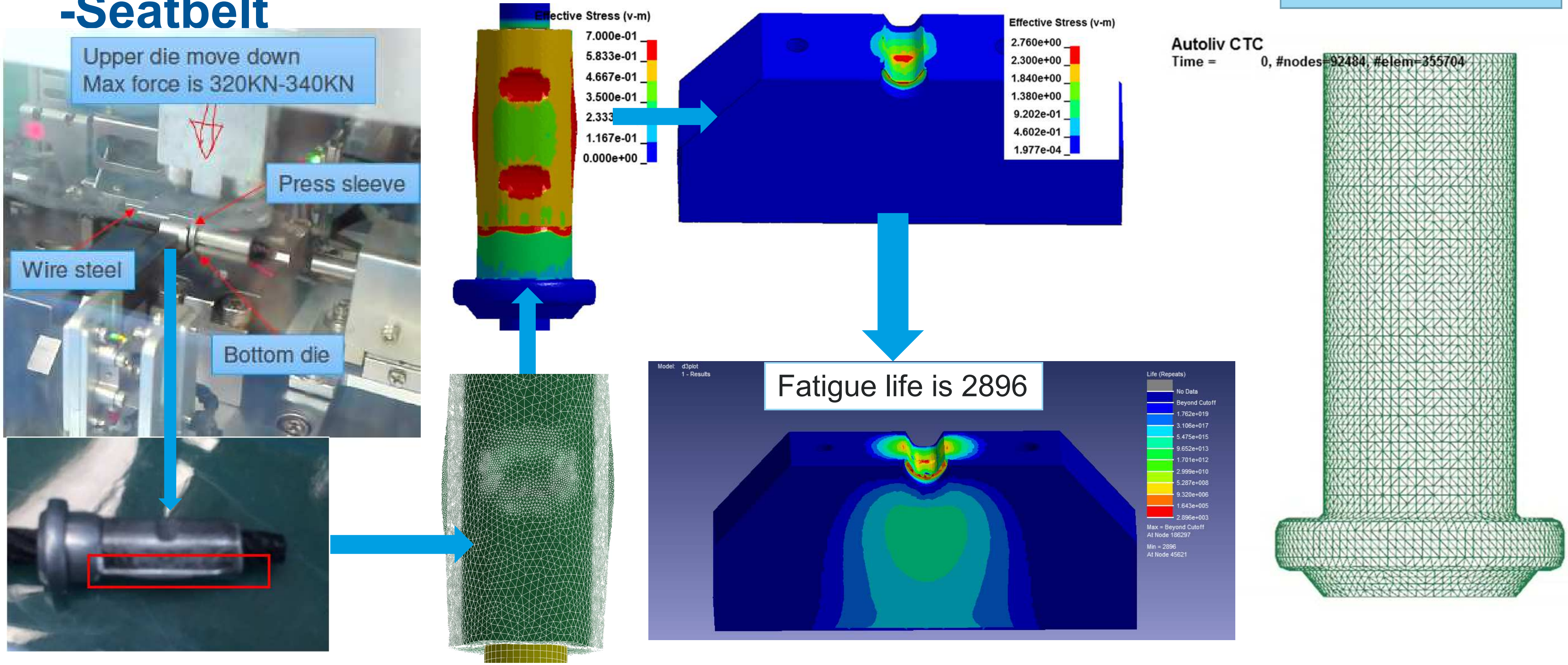
The frame took place fracture when pulling force reached 20KN as similar test result of 17-19KN.



The frame took place fracture when pulling force reached 16KN as similar test result of 16-18KN.

Strength Analysis -Seatbelt

EFG method



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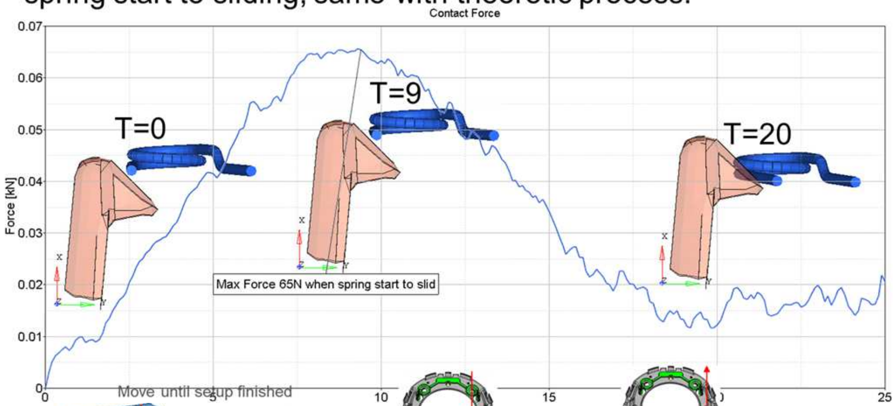
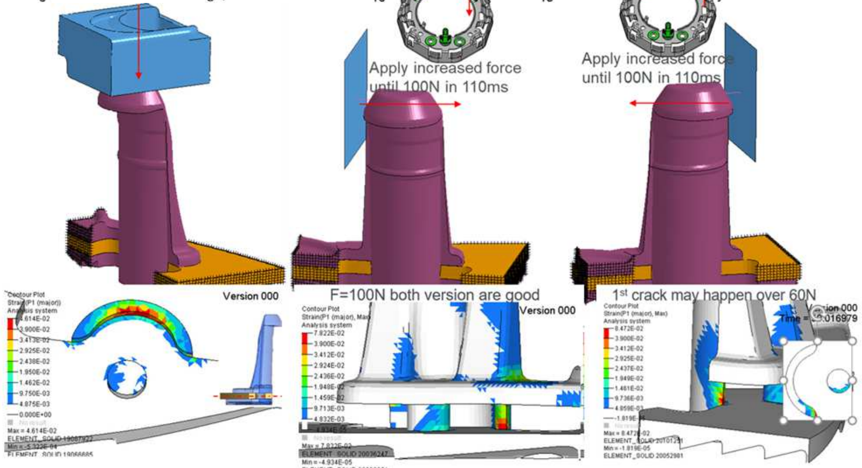
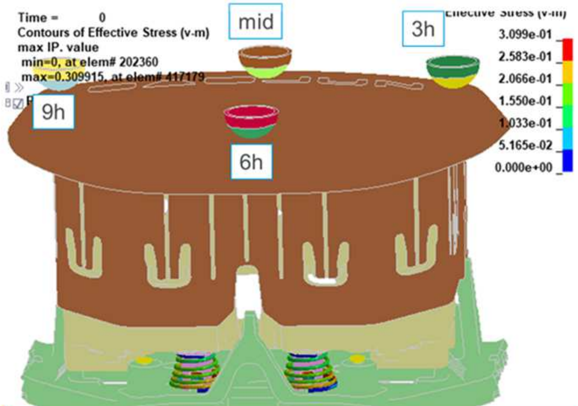
Strength Analysis -Airbag

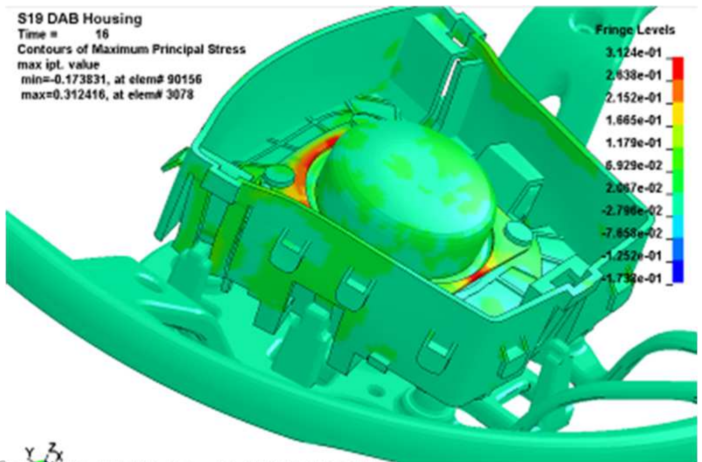
DAB maximum setup force is about 65N when omega spring start to sliding, same with theoretic process.







Horn force are 20N~25N



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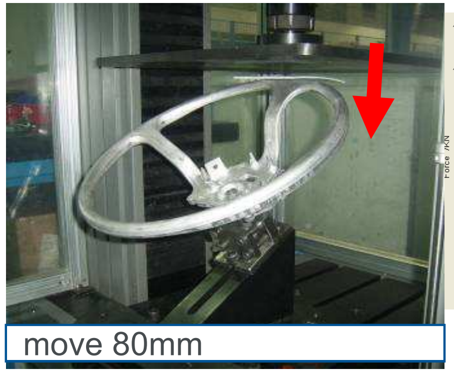
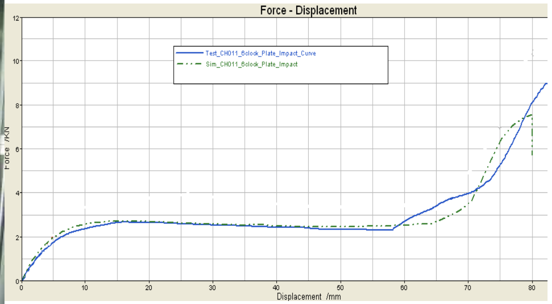
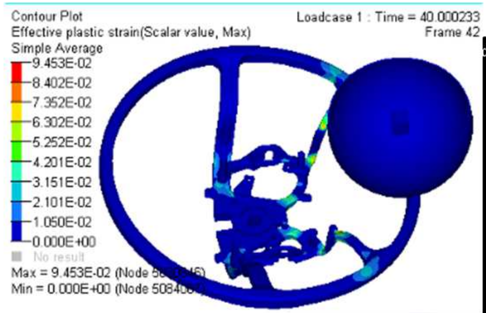
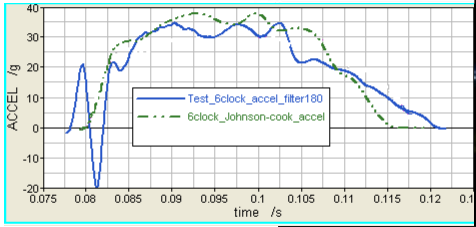
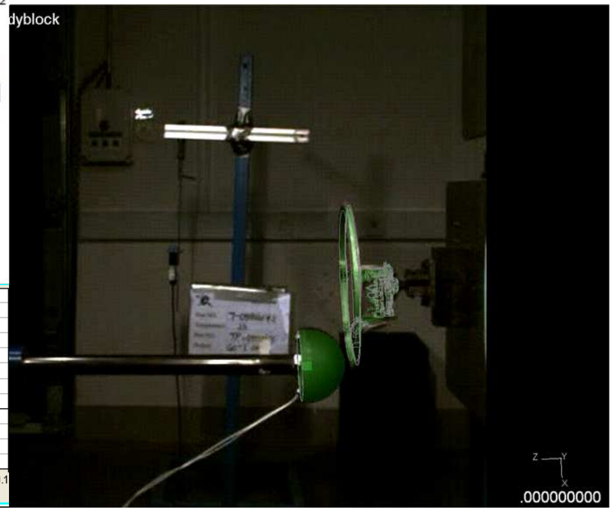
Strength Analysis -SW



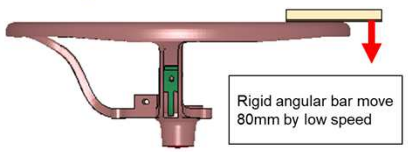


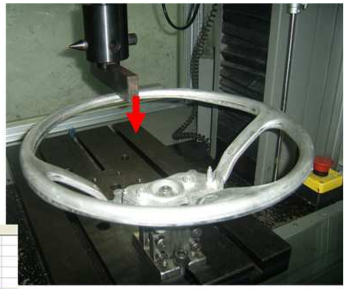


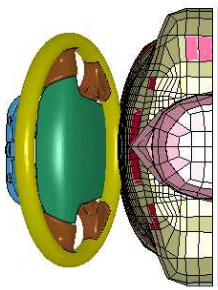


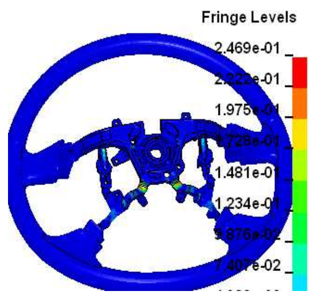


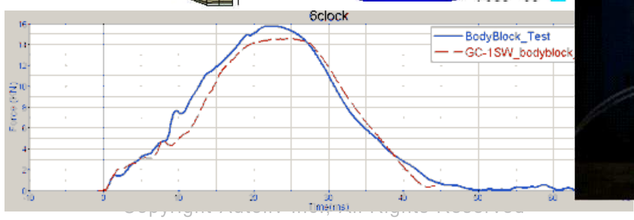
Pressing Stiffness 0º / 12' clock

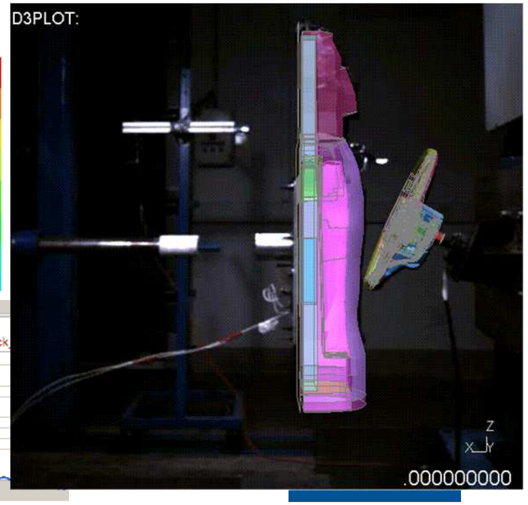










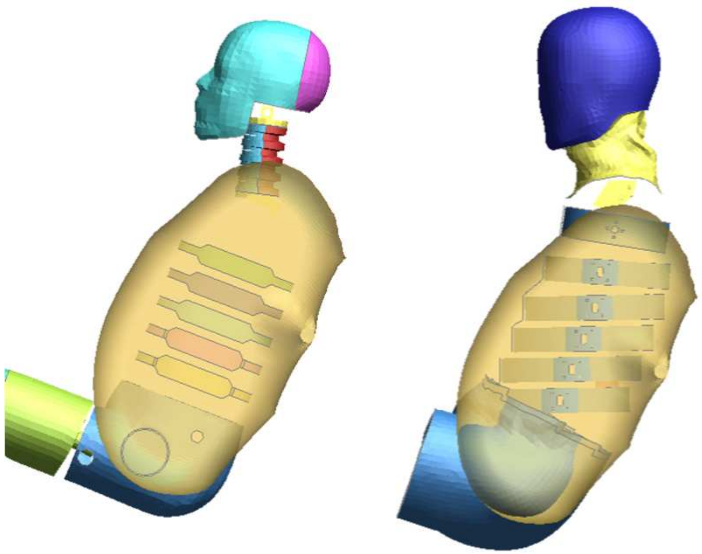


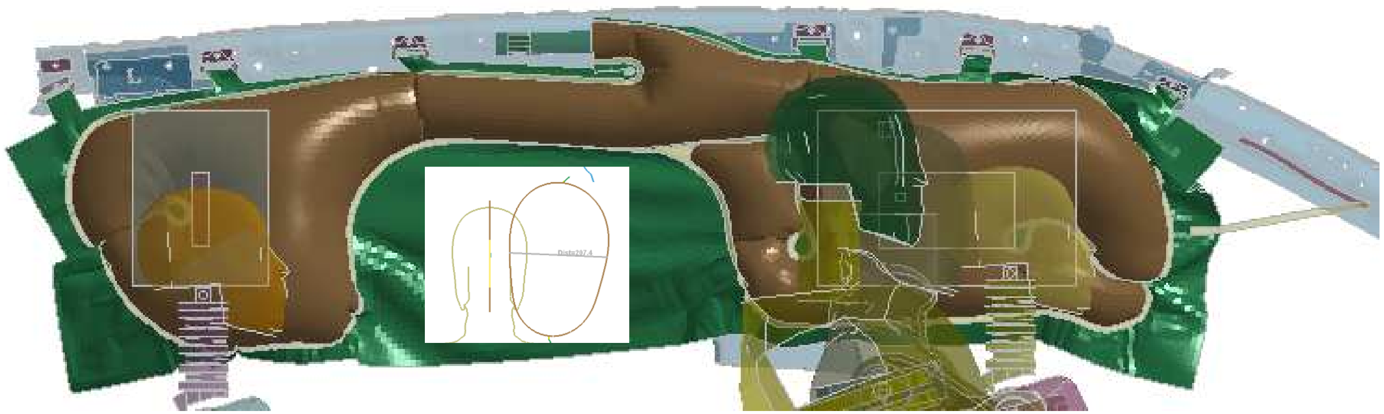
Application of LS-DYAN

Airbag deployment in Ls-Dyna

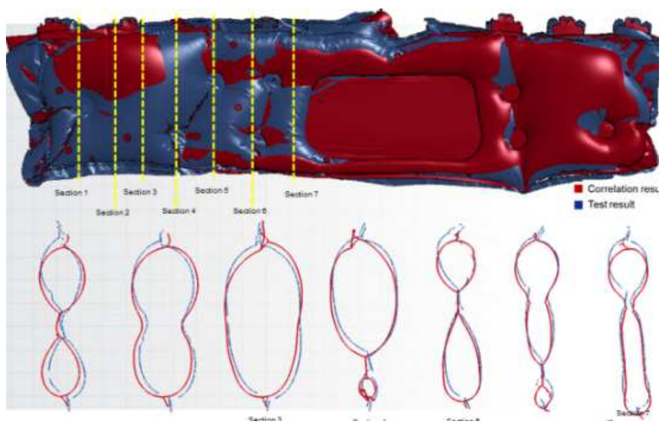
- Coverage area
- Bag deployment
- Airbag subsystem model

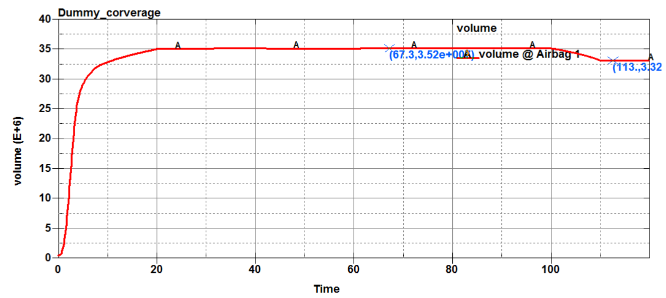
Airbag deployment
Coverage area





Airbag volume	15.3L





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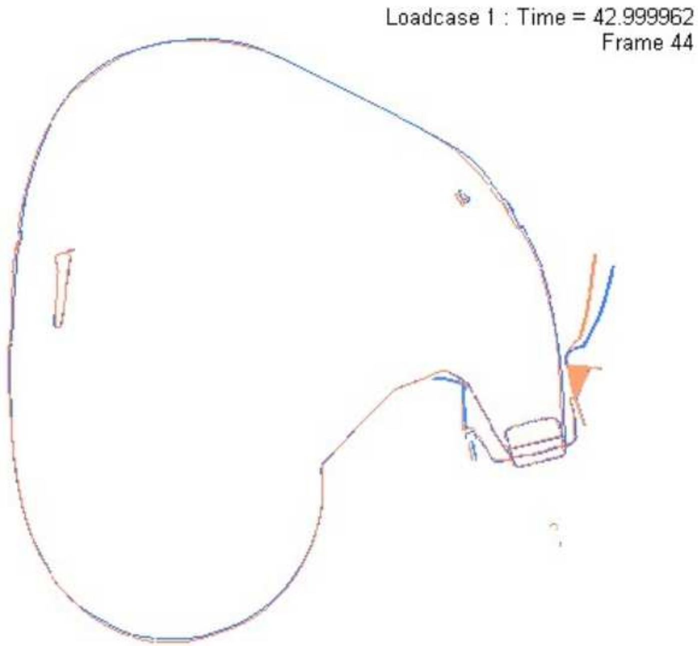
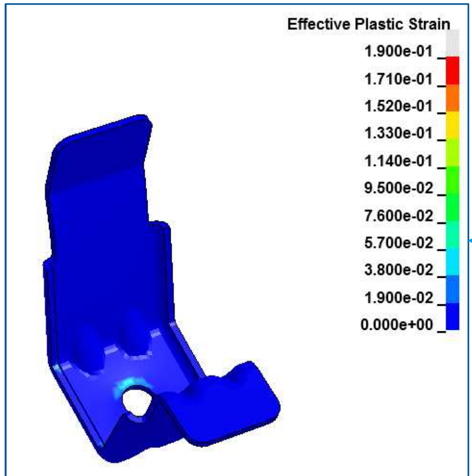
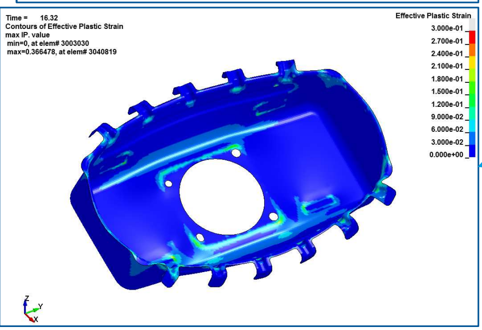
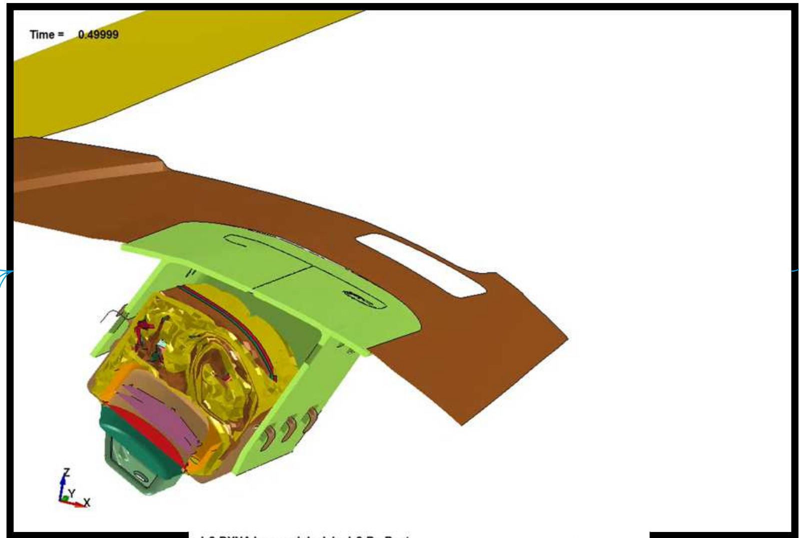
Airbag deployment
Coverage area

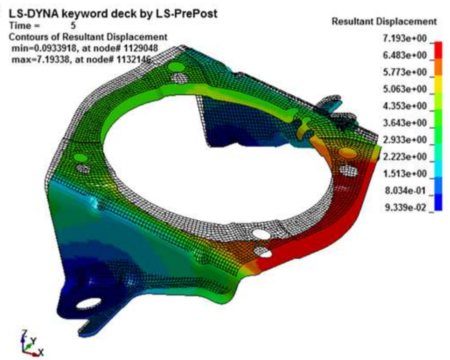


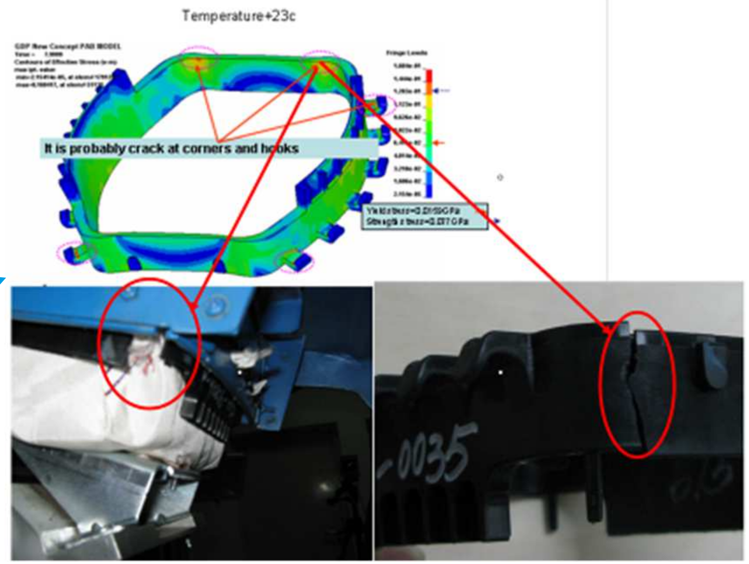
Airbag deployment
PAB

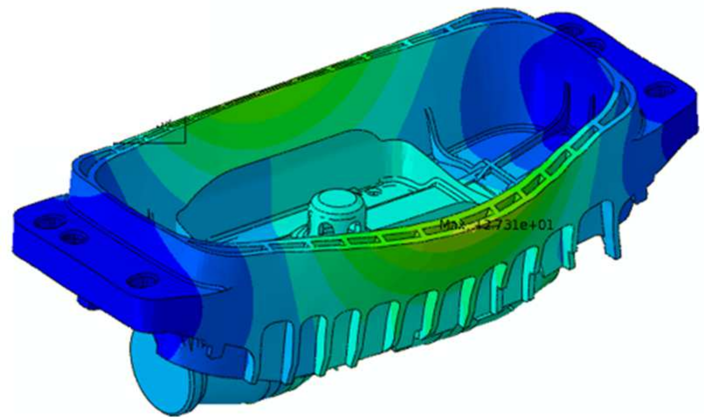




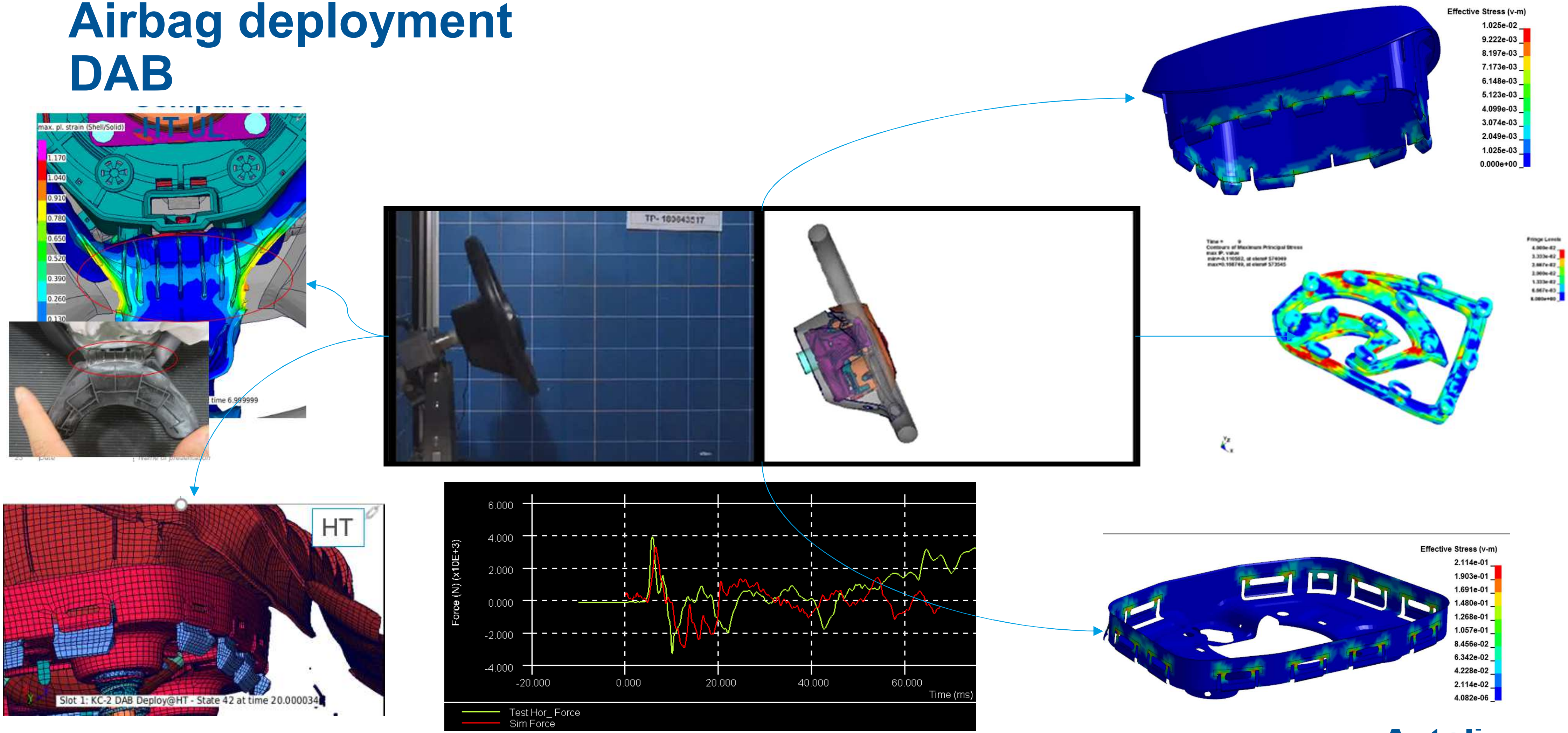








Airbag deployment DAB



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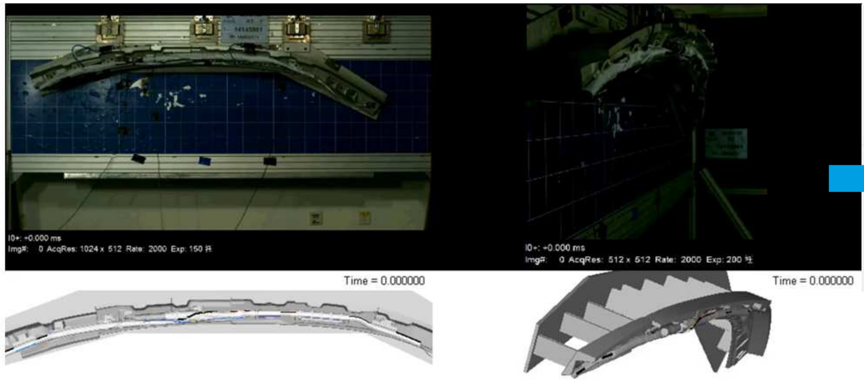
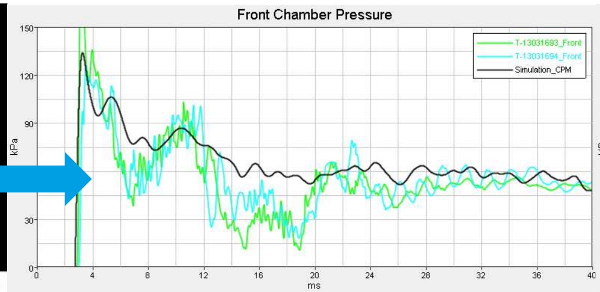
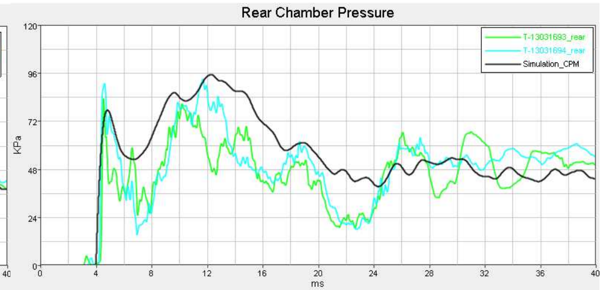
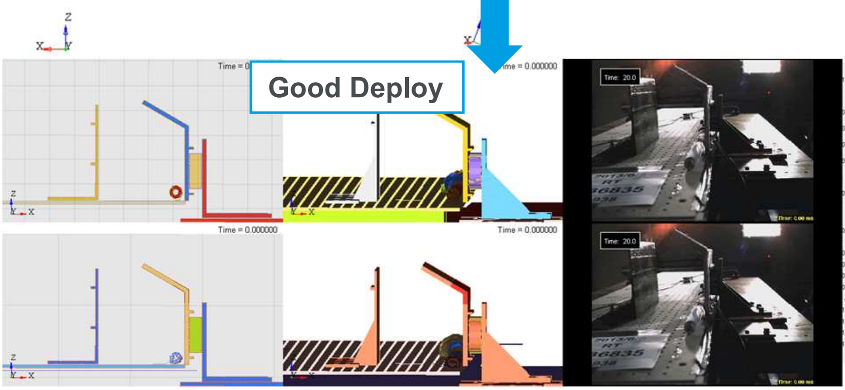
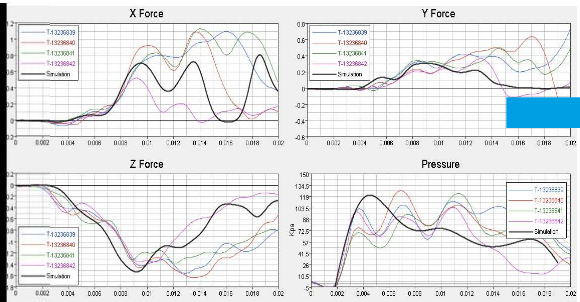
Airbag deployment
IC

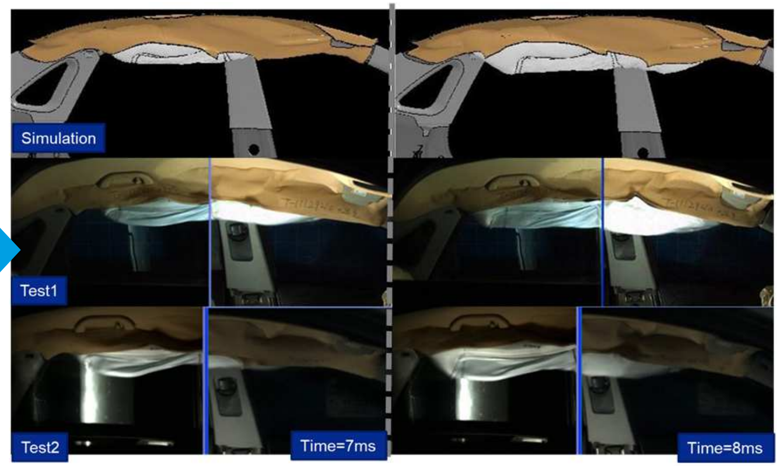




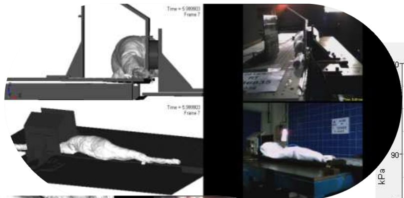


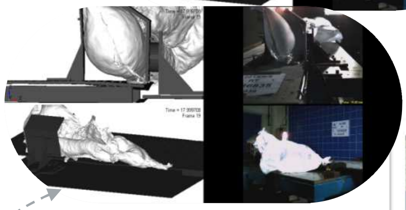






Airbag deployment IC

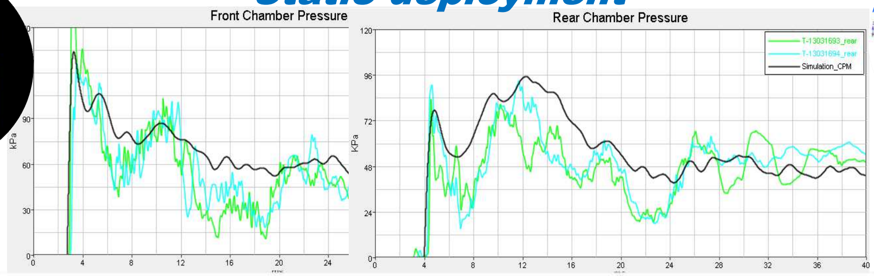


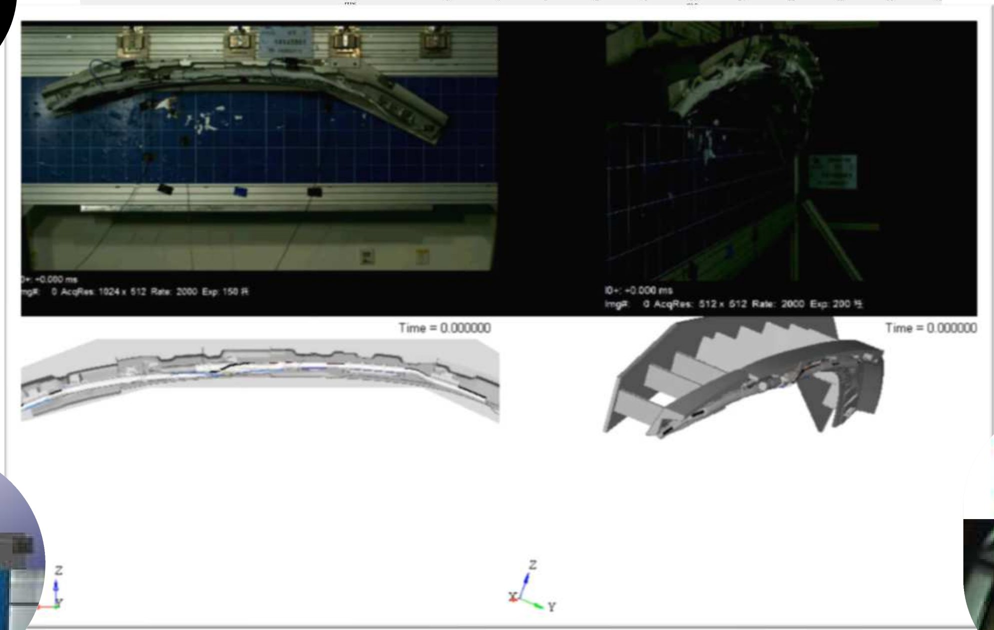


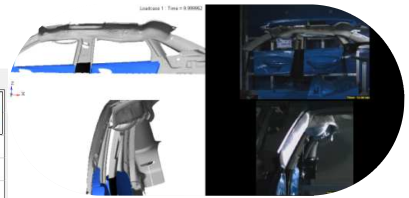
impact force from IC deploying

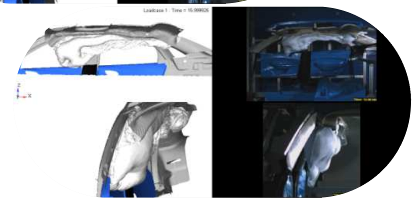
Acceleration when IC deploying

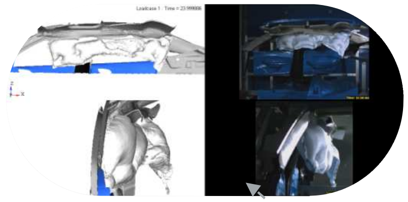
Static deployment





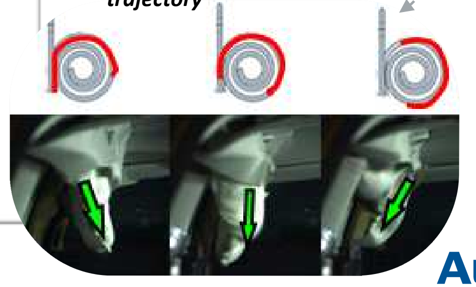




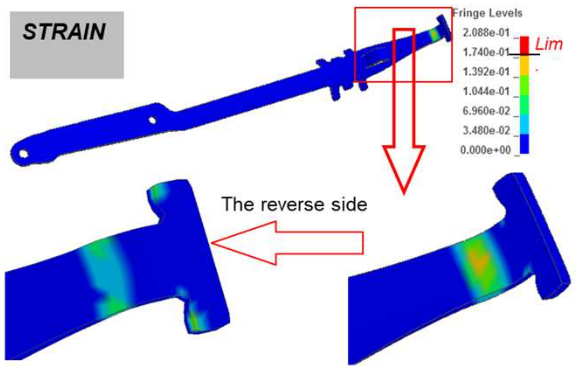


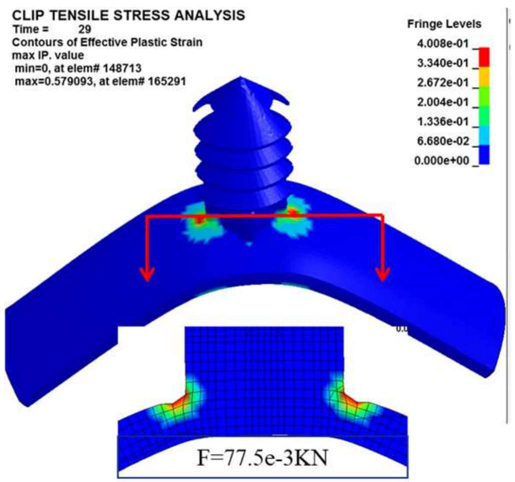
IC deployment with trim

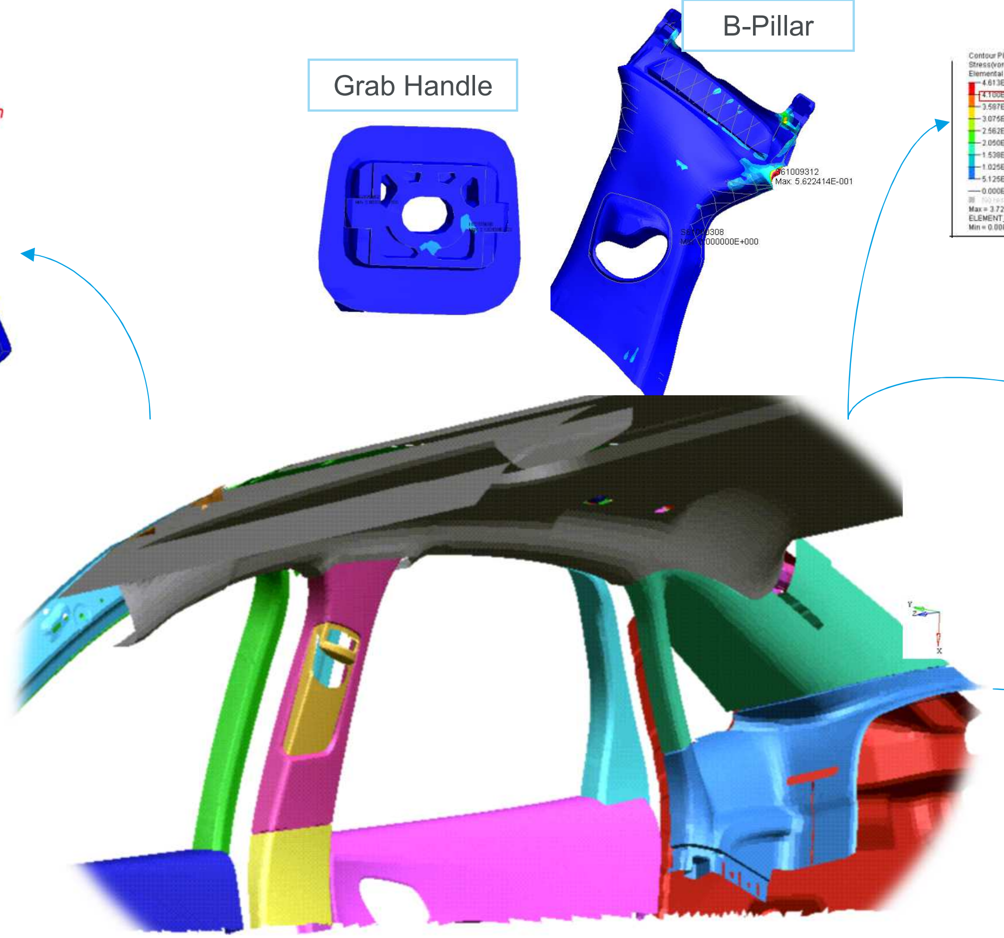
IC folding influent deployment trajectory

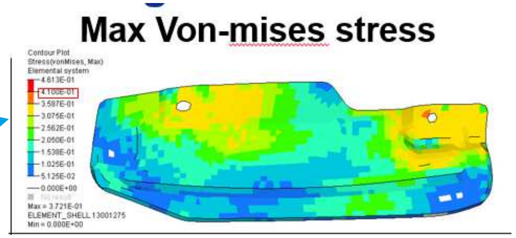


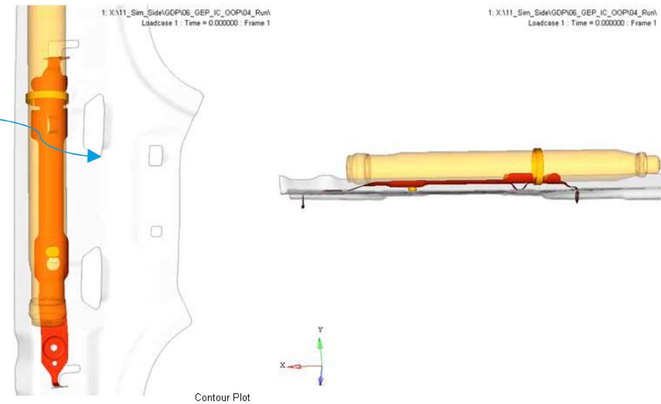
Airbag deployment IC

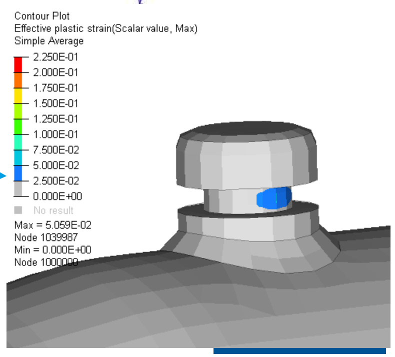




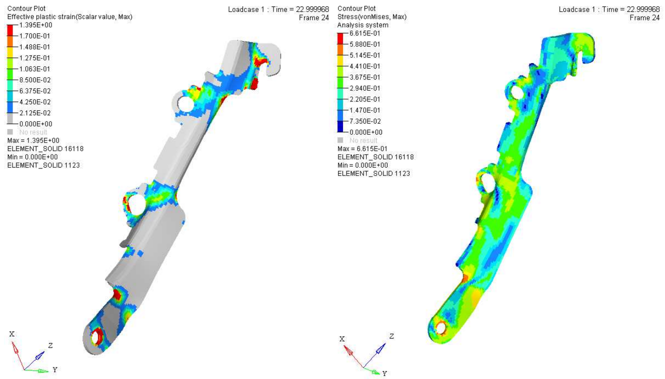


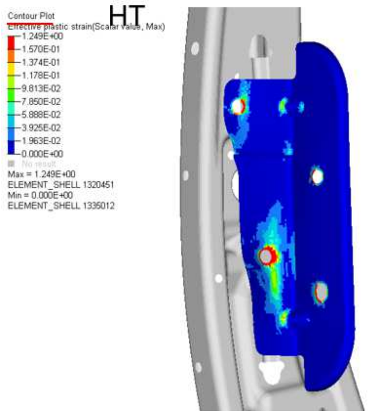


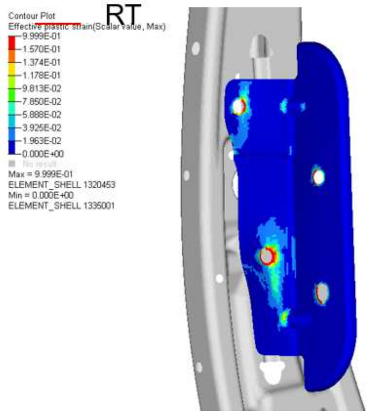


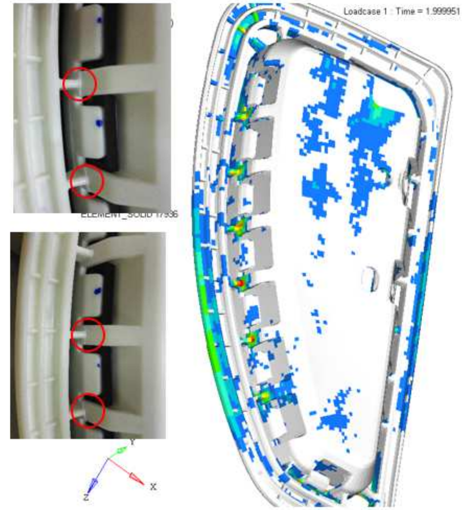


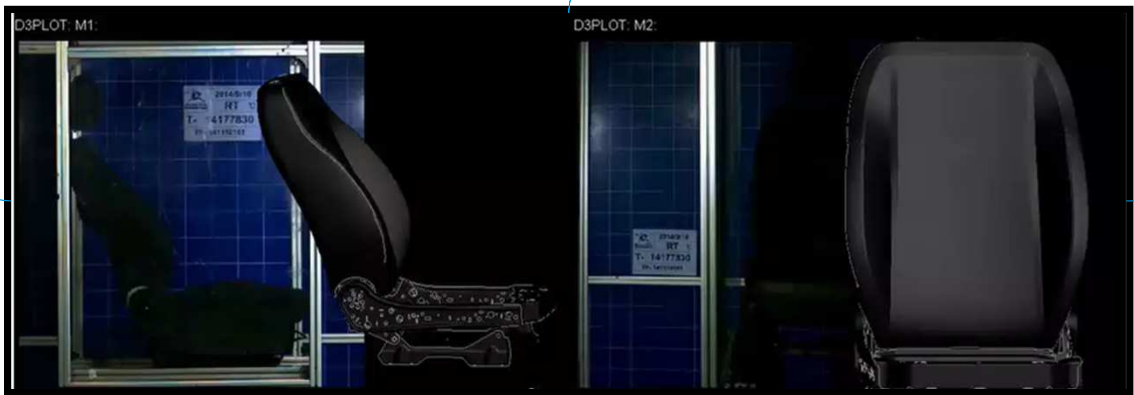
Airbag deployment
SAB



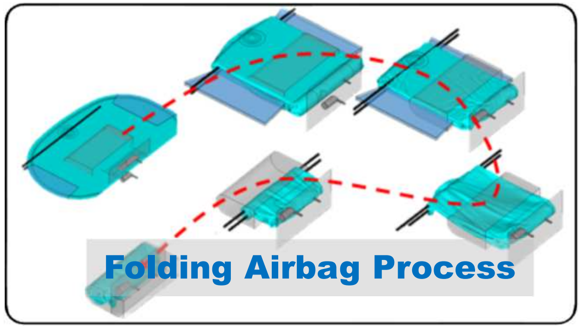


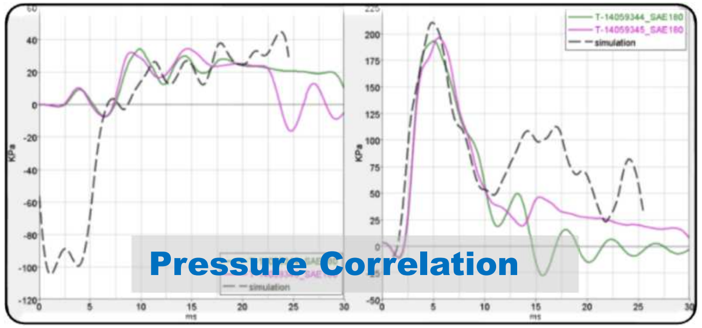


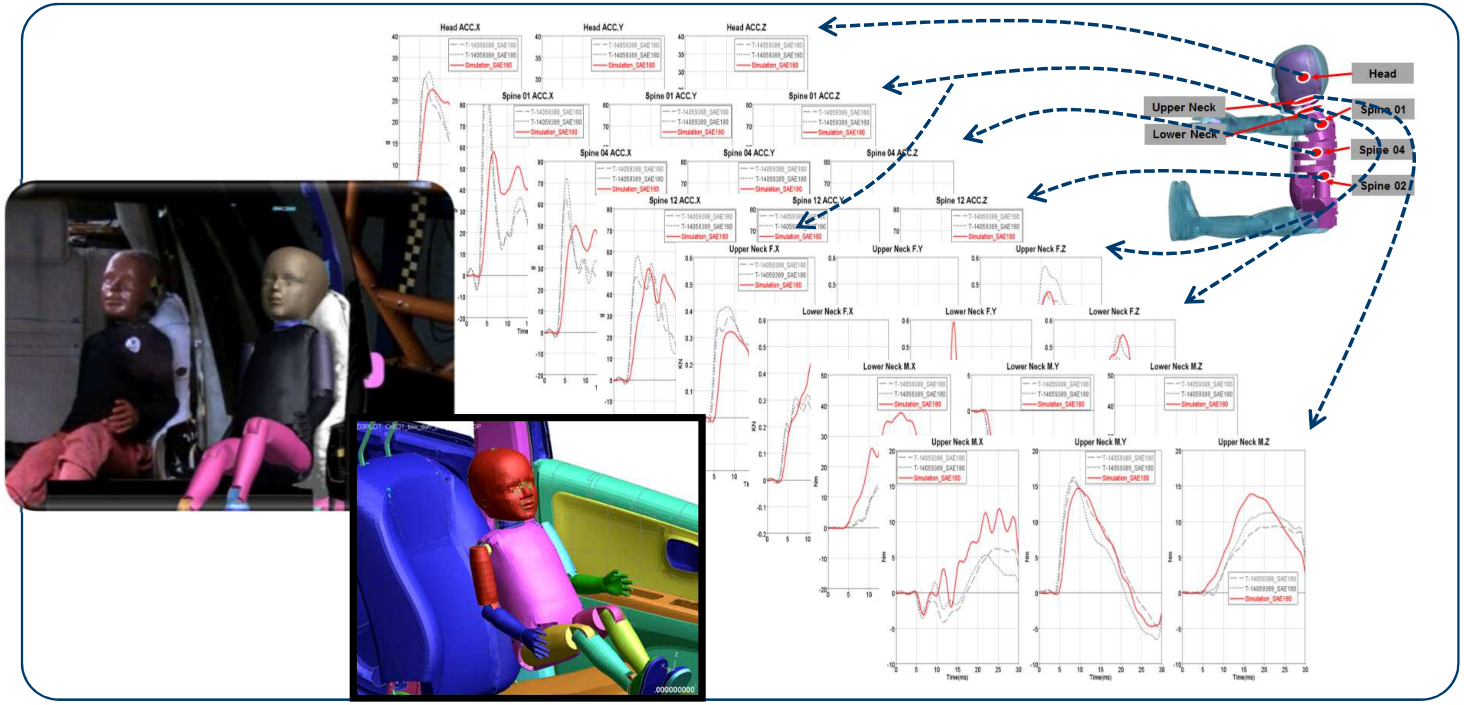




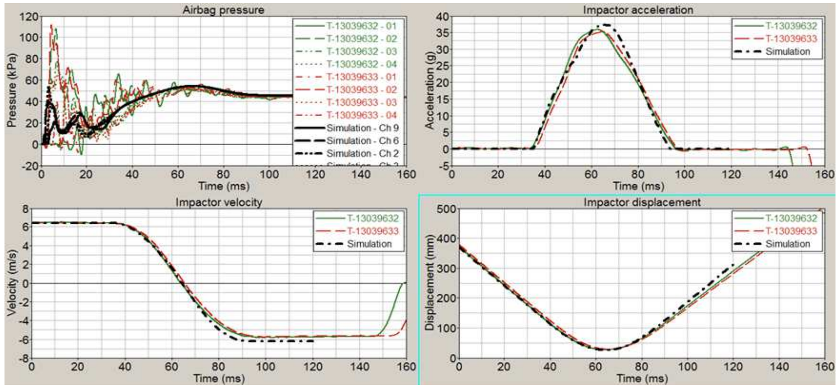
Airbag subsystem model OOP



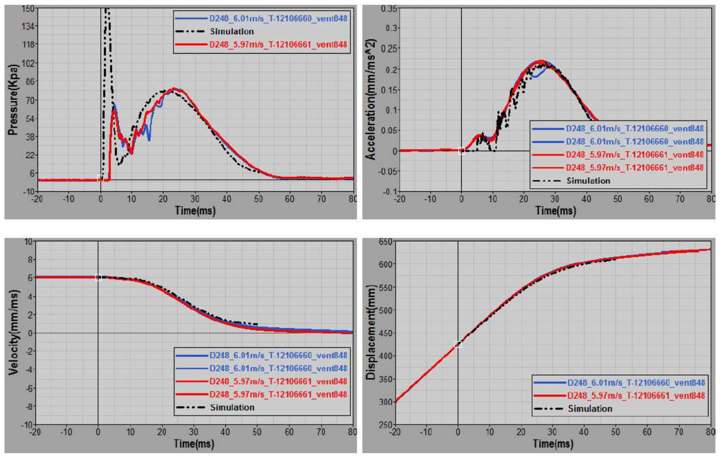


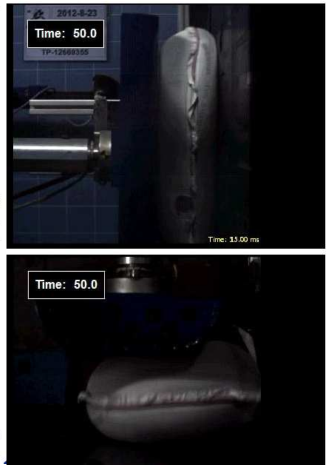


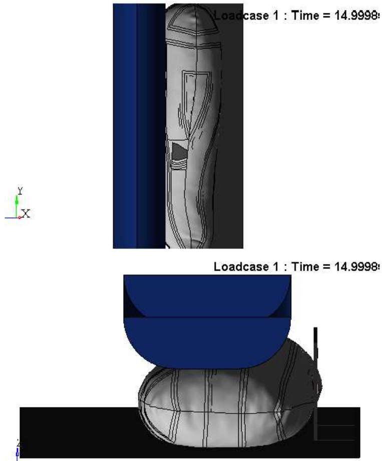
Airbag subsystem model Validated for system



D3PLOT: LS-DYNA keyword deck by LS-PrePost







Application of LS-DYAN

Fatigue Analysis in Ls-Dyna

- Fatigue Simulation method
- Calibration Fatigue method
- Fatigue material properties
- Fatigue examples

Fatigue Analysis

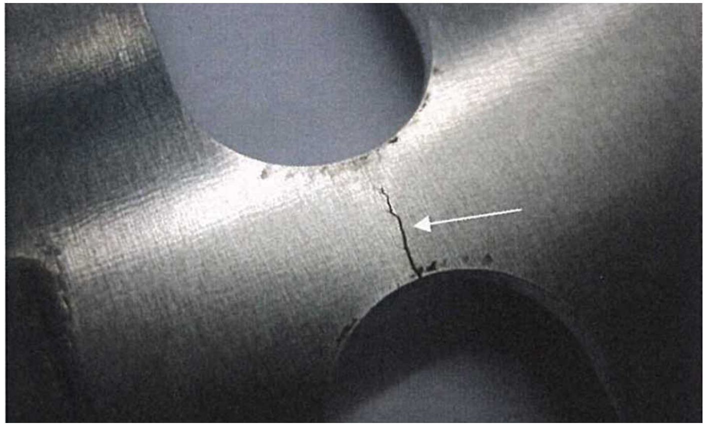
What is fatigue?

- Fatigue is a process in which damage accumulates due to the repetitive application of loads that may be well below the yield point.
- Fatigue is a complex process involving many steps but it can be broken down into initiation and propagation of fatigue cracks.
- It is estimated that fatigue failures are responsible for 90% of all metallic failures.
- For many years, fatigue has been a significant and challenging problem for engineers, especially for those who design structures such as aircrafts, railroad vehicles, automotives, bridges, pressure vessels, and cranes.

Fatigue Analysis

How to run fatigue analysis?

- Fatigue analysis can be performed in time domain and frequency domain.
- Two frequency domain approaches based on **random vibration theory and harmonic vibration (SSD) theory** have been implemented in LS-DYNA for fatigue and durability analysis.
- Recently we implemented time domain fatigue, including **one based on stress** and **the other based on strain** (further testing and validation needed)



Fatigue Analysis

S-N curve *(high cycle, low stress)*

***MAT_ADD_FATIGUE**

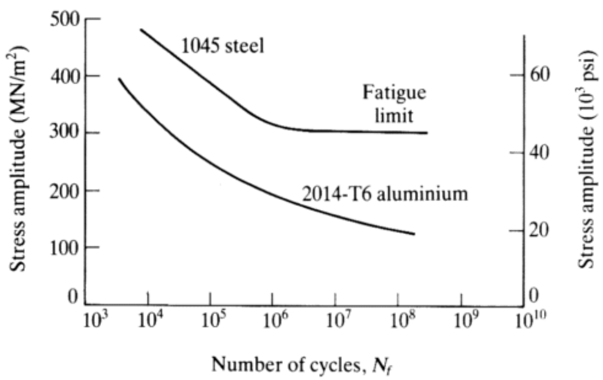
Card 1	1	2	3	4	5	6	7	8
Variable	MID	LCID	LTYPE	A	B	STHRES	SNLIMT	SNTYPE
Type	I	I	I	F	F	F	I	I
Default	none	-1	0	0.0	0.0	none	0	0

- By ***DEFINE_CURVE**
- By equation

$$\boxed{N \cdot S^m = a}$$

$$\boxed{\log(S) = a - b \cdot \log(N)}$$

N: number of cycles for fatigue failure
S: stress



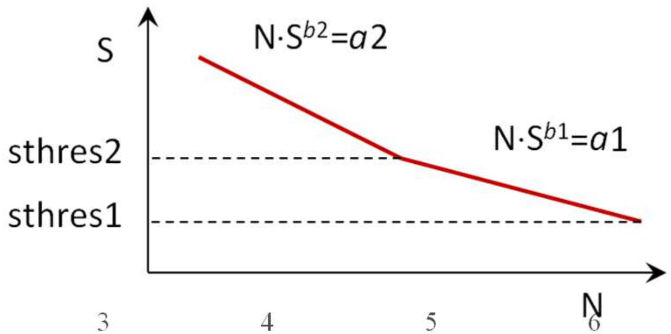
Source of information: http://www.efunda.com

- Fatigue life of stress below fatigue threshold

SNLIMT *Fatigue life for stress lower than the lowest stress on S-N curve.*
EQ.0: use the life at the last point on S-N curve
EQ.1: extrapolation from the last two points on S-N curve
EQ.2: infinity.

Fatigue Analysis

S-N curve *(high cycle, low stress)*



*MAT_ADD_FATIGUE

Card 1	1	2	3	4	5	6	7	8
Variable	MID	LCID	LTYPE	A	B	STHRES	SNLIMT	SNTYPE
Type	I	I	I	F	F	F	I	I
Default	none		0	0.0	0.0	none	0	0

Card 2	1	2	3	4	5	6	7	8
Variable				Ai	Bi	STHRESi		
Type				F	F	F		
Default				0.0	0.0	none		

To define S-N curve with multiple slopes, the S-N curve can be split into multiple segments and each segment is defined by a set of parameters Ai, Bi and STHRESi. Up to 8 sets of the parameters (Ai, Bi and STHRESi) can be defined. The lower limit of the *i*-th segment is represented by the threshold stress STHRESi.

Fatigue Analysis

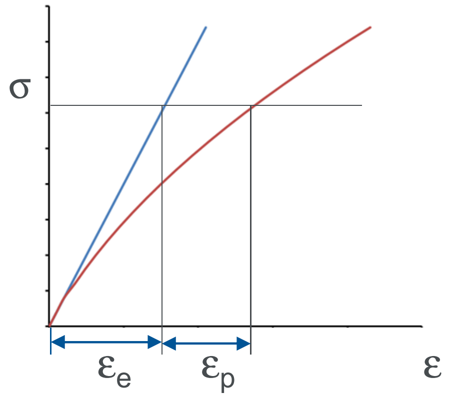
E-N curve *(low cycle, high stress)*

***MAT_ADD_FATIGUE_EN**

Card 1	1	2	3	4	5	6	7	8
Variable	MID	KP	NP	SIGMAP	EPSP	B	C	
Type	I	F	F	F	F	F	F	
Default	none	none	none	none	none	none	none	

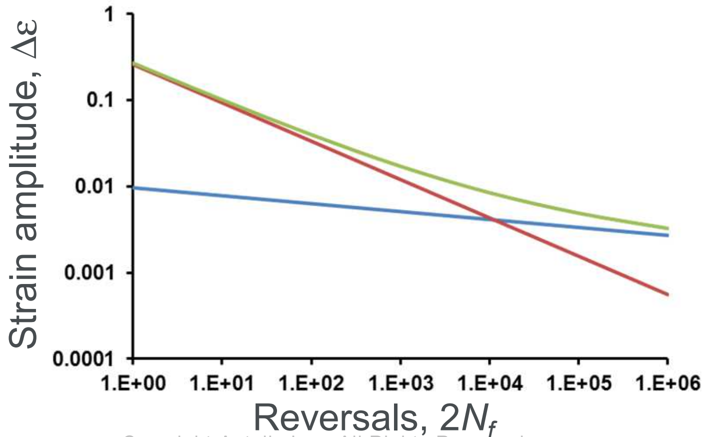
Cyclic stress strain curve

$$\varepsilon = \frac{\sigma}{E} + \left(\frac{\sigma}{K'}\right)^{1/n'}$$



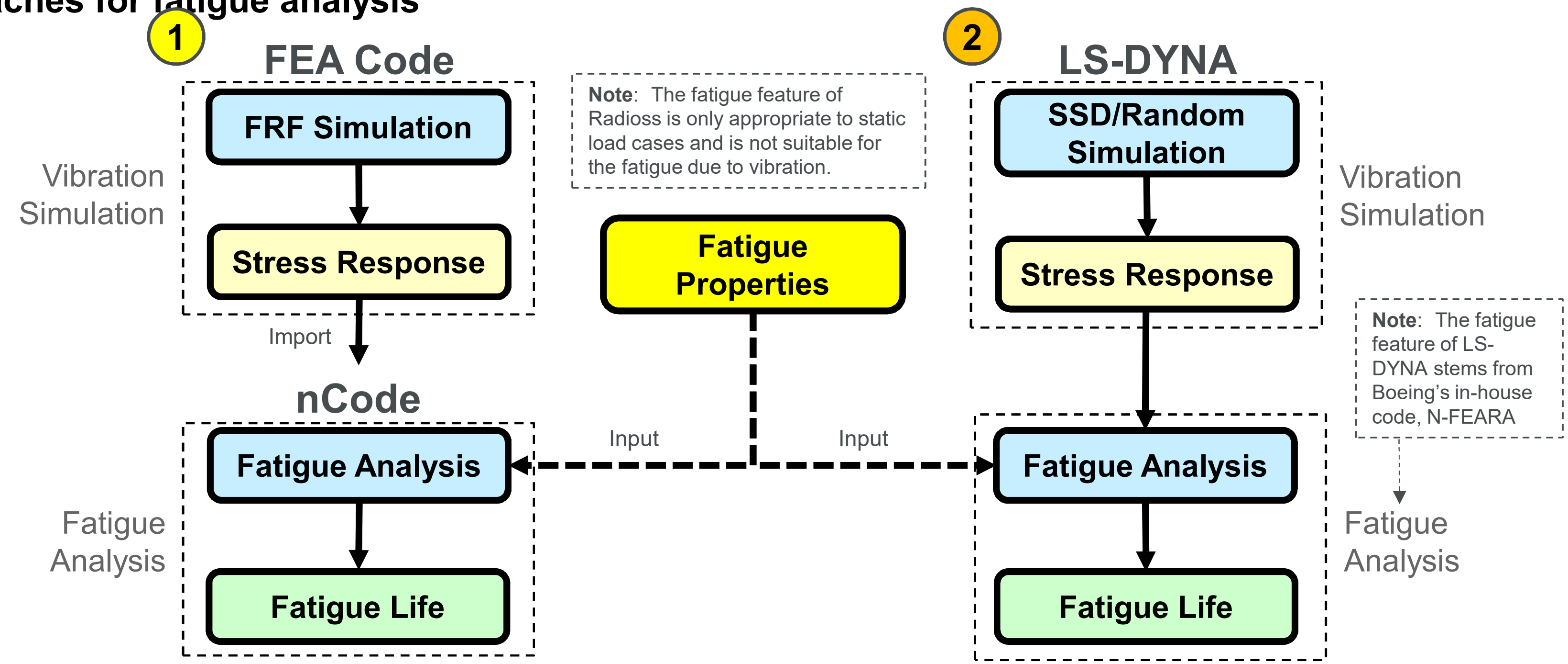
Local strain−life relationship

$$\frac{\Delta\varepsilon}{2} = \frac{\sigma'_f}{E}\left(2N_f\right)^b + \varepsilon'_f\left(2N_f\right)^c$$



Fatigue Analysis

Two approaches for fatigue analysis



Advantage:
- We are familiar with Radioss and nCode and have a lot of experiences on this type of simulation.

Disadvantage:
- Solve one problem in two different codes.

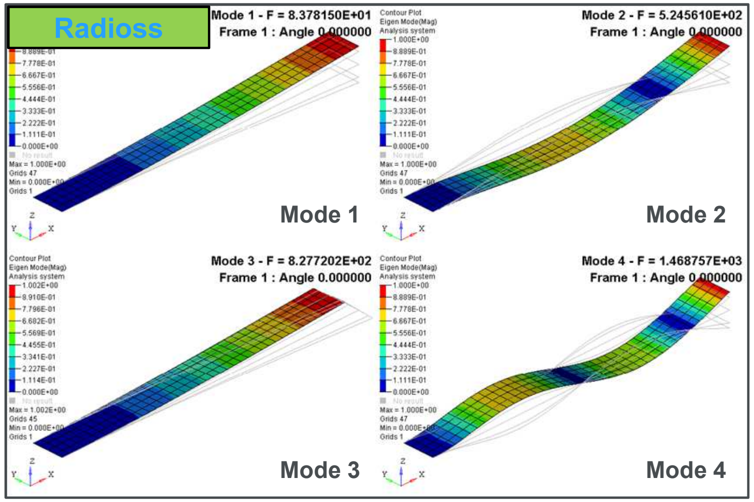
Advantage:
- Solve all problems in one code.

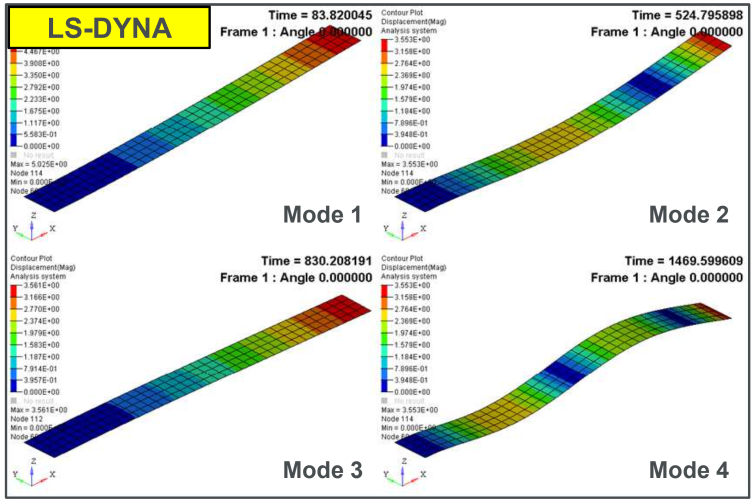
Disadvantage:
- Fatigue simulation, as well as frequency domain simulation, is a new feature of LS-DYNA. So we have to check the accuracy of its results.

Fatigue Analysis

Comparison of Radioss (bulk data)/nCode and LS DYNA (implicit)

Natural Frequencies: simulation results





		Mode 1		Mode 2		Mode 3		Mode 4	
	Analytical Solution	83.28		521.93		832.78		1461.6	
	Radioss	83.78	100%	524.56	100%	827.72	100%	1468.76	100%
Poor	LS DYNA (ELFORM=2)	83.74	99.95%	524.54	99.99%	801.28	96.80%	1469.59	100.06%
	LS DYNA(ELFORM=18)	83.82	100.05%	524.80	100.05%	830.21	100.30%	1469.60	100.06%
Good	LS DYNA(ELFORM=20)	83.75	99.96%	524.27	99.94%	827.60	99.98%	1467.33	99.90%

Note: ELFORM=2: Belytschko-Tsay (default)
ELFORM=18: Fully Integrated linear DK quadrilateral or triangular shell
ELFORM=20: Fully integrated linear enhanced shell → CQUAD4

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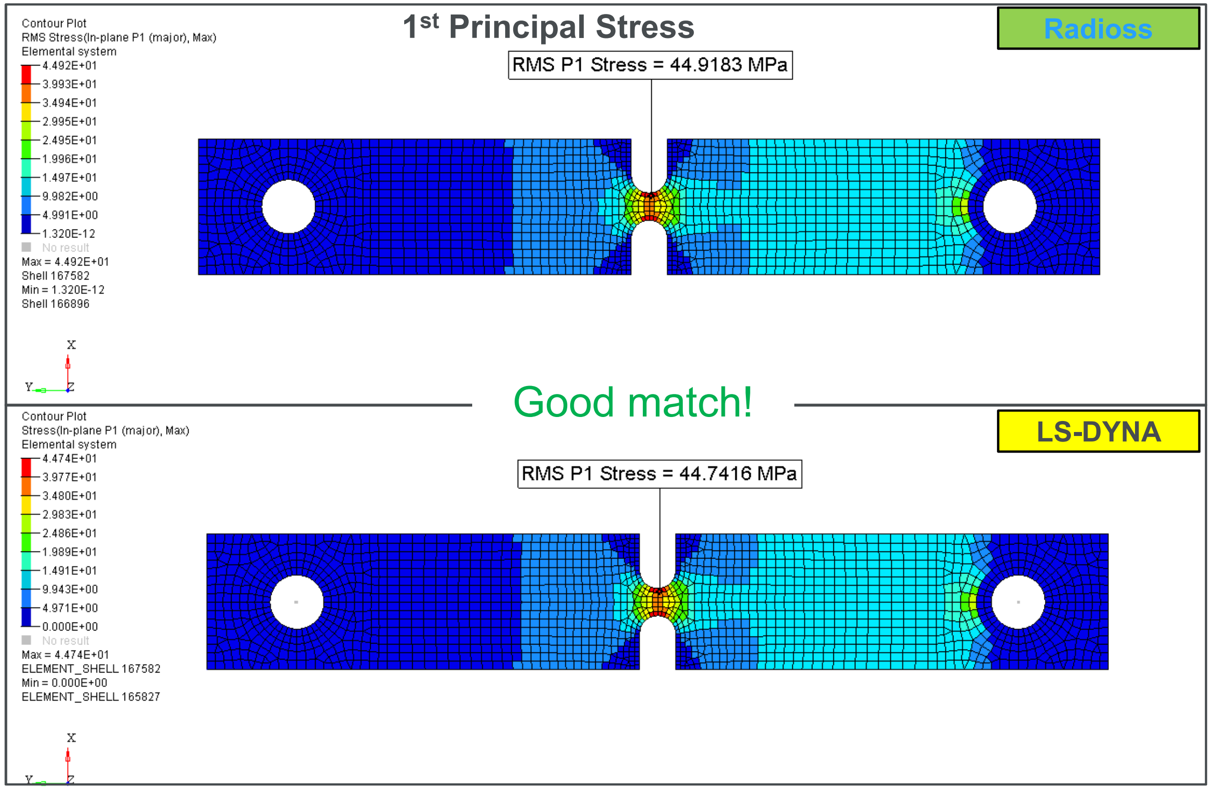
Fatigue Analysis

Comparison of Radioss (bulk data)/nCode and LS DYNA (implicit)

Random Vibration: simulation results

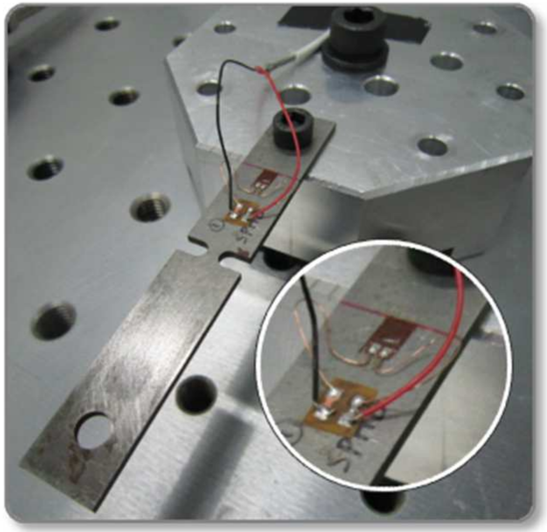
- The **R**oot **M**ean **S**quare (RMS) stress of the specimen is calculated by *Radioss* and *LS-DYNA*, respectively.



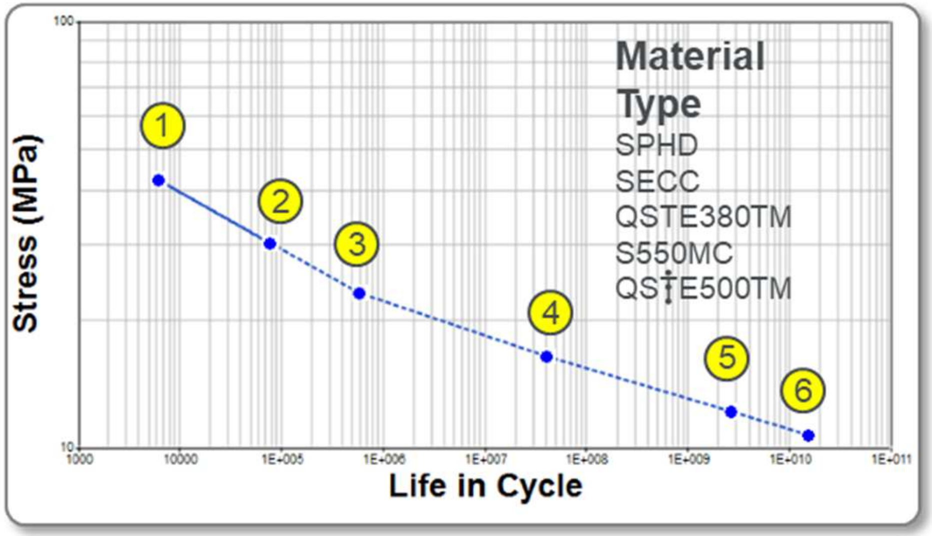
Fatigue Analysis

Measure the fatigue material property

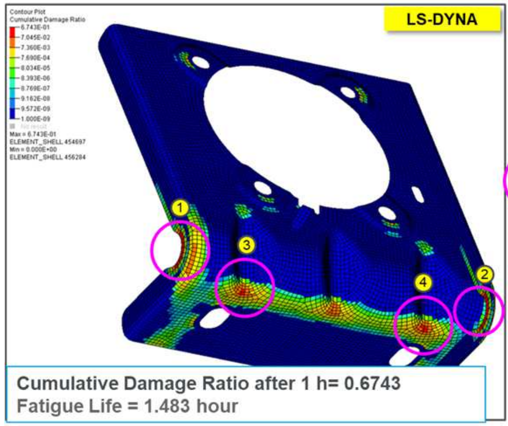
Shaker-based fatigue test

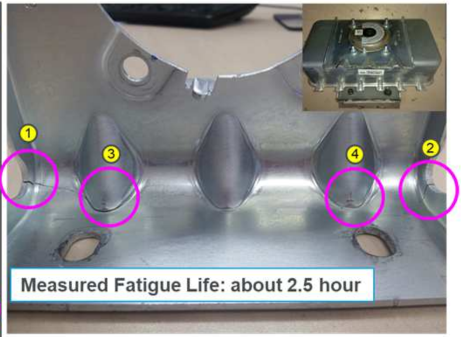


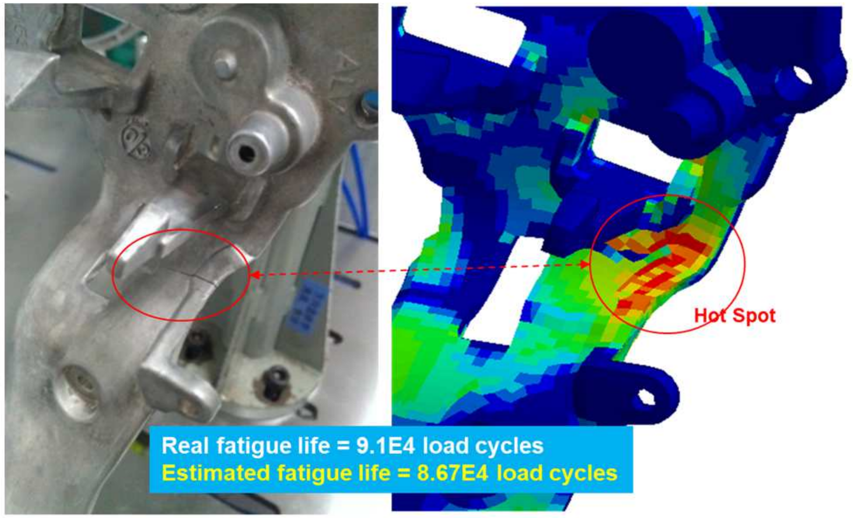
Fatigue material property data base

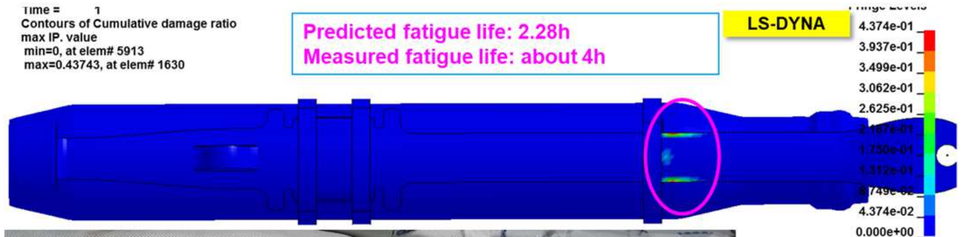


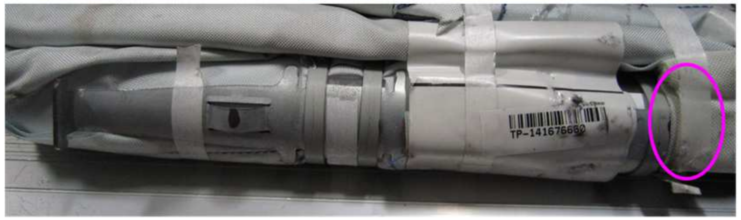
Fatigue Analysis



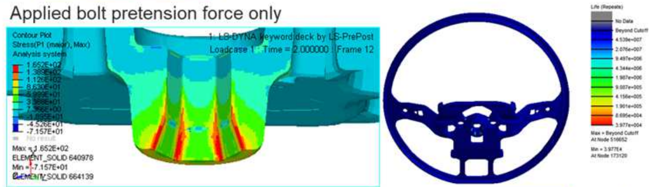




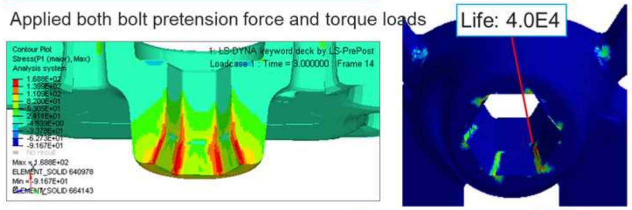




Applied bolt pretension force only



Applied both bolt pretension force and torque loads



Min. Fatigue Life = 40'000 cycles < 100'000 cycles Fail!

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Application of LS-DYAN

Acoustic Simulation in Ls-Dyna

- Introduce
- Application
- Steering wheel

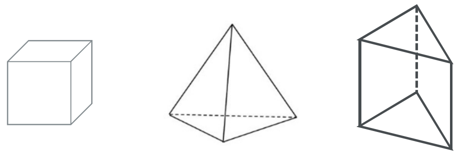
Acoustic Simulation introduce

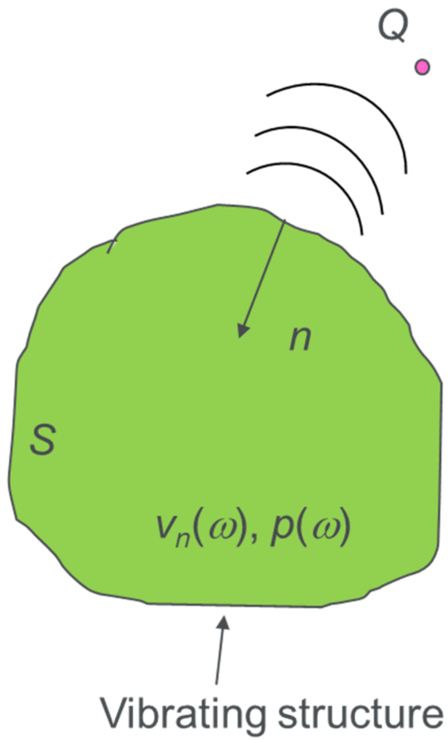
Time domain acoustic solver in LS-DYNA

- ✓ MAT_ACOUSTIC with solid element 8 or 14

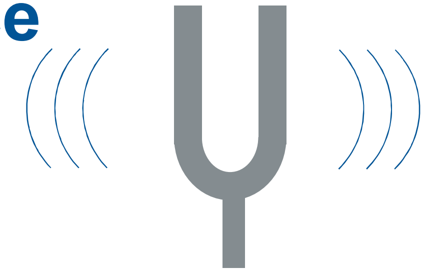
Frequency domain acoustic solver in LS-DYNA

- ✓ FREQUENCY_DOMAIN_ACOUSTIC_BEM
  - Rayleigh method
  - Kirchhoff method
  - Collocation BEM
  - Variational indirect BEM
- ✓ FREQUENCY_DOMAIN_ACOUSTIC_FEM
  - Hexahedron
  - Tetrahedron
  - Pentahedron
- ✓ SEA *(ongoing development)*

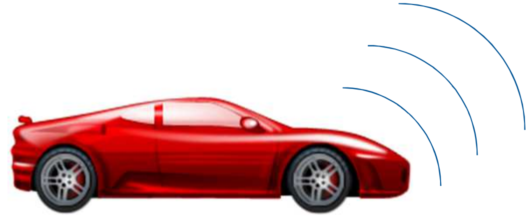




Acoustic Simulation introduce



Vibro-acoustics



Loading on structures

FEM transient analysis

SSD

V (P) in time domain

User data

FFT

V (P) in frequency domain

FEM / BEM acoustic analysis

Acoustic pressure and SPL (dB) at field points

National Taipei University of Technology, Taiwan: Guo-Ding Huang, Hsiu-Ying Hwang, Xijun Wang, "*Vibration Testing and Analysis for a Midsize Electric Bus*", Proceedings of the 19th National Conference on Vehicle Engineering, Nov. 14, 2014, TIIT, Jhongli, Taiwan.

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Acoustic Simulation introduce

BEM (accurate)

- Indirect variational boundary element method
- Collocation boundary element method
  - Burton-Miller formulation
  - Sound power and radiation efficiency are computed

They used to be time consuming

A fast solver based on domain decomposition

MPP version

Approximate (simplified) methods

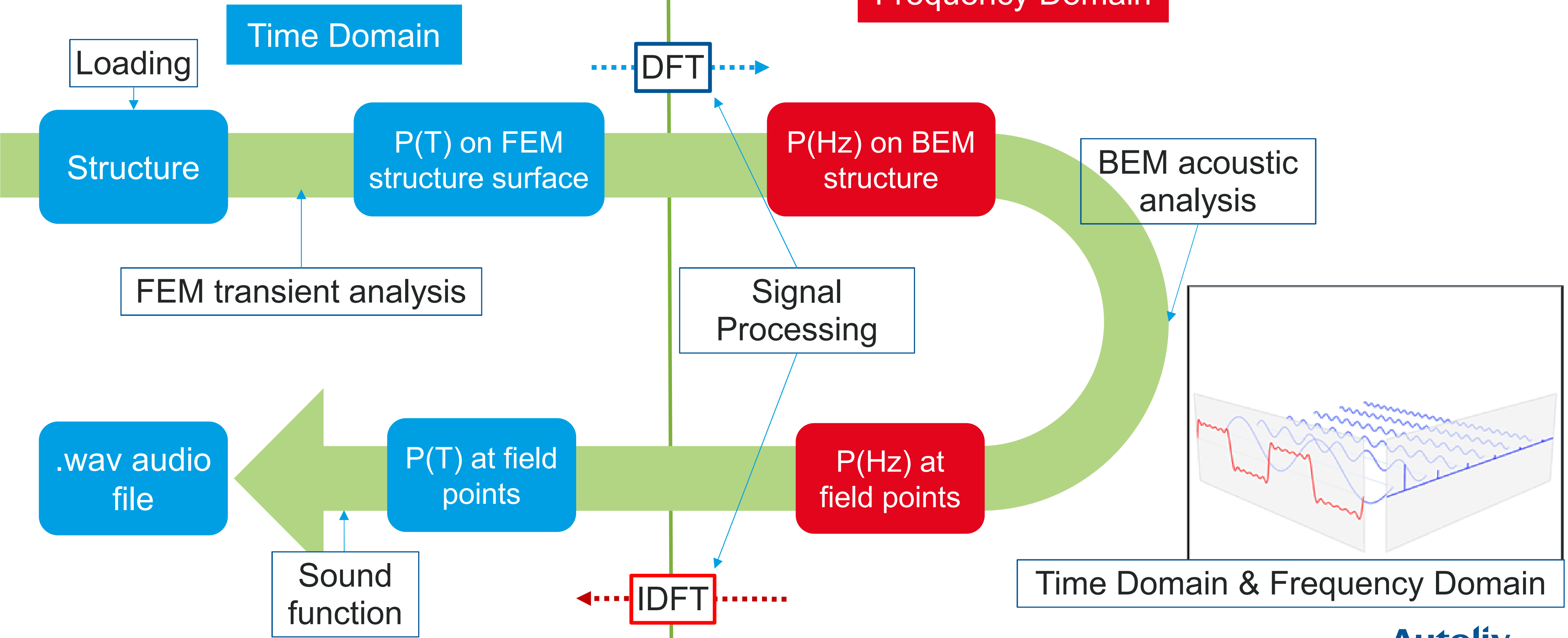
- Rayleigh method
- Kirchhoff method

Assumptions and simplification in formulation

Very fast since no equation system to solve

Acoustic Simulation introduce

Technical Route



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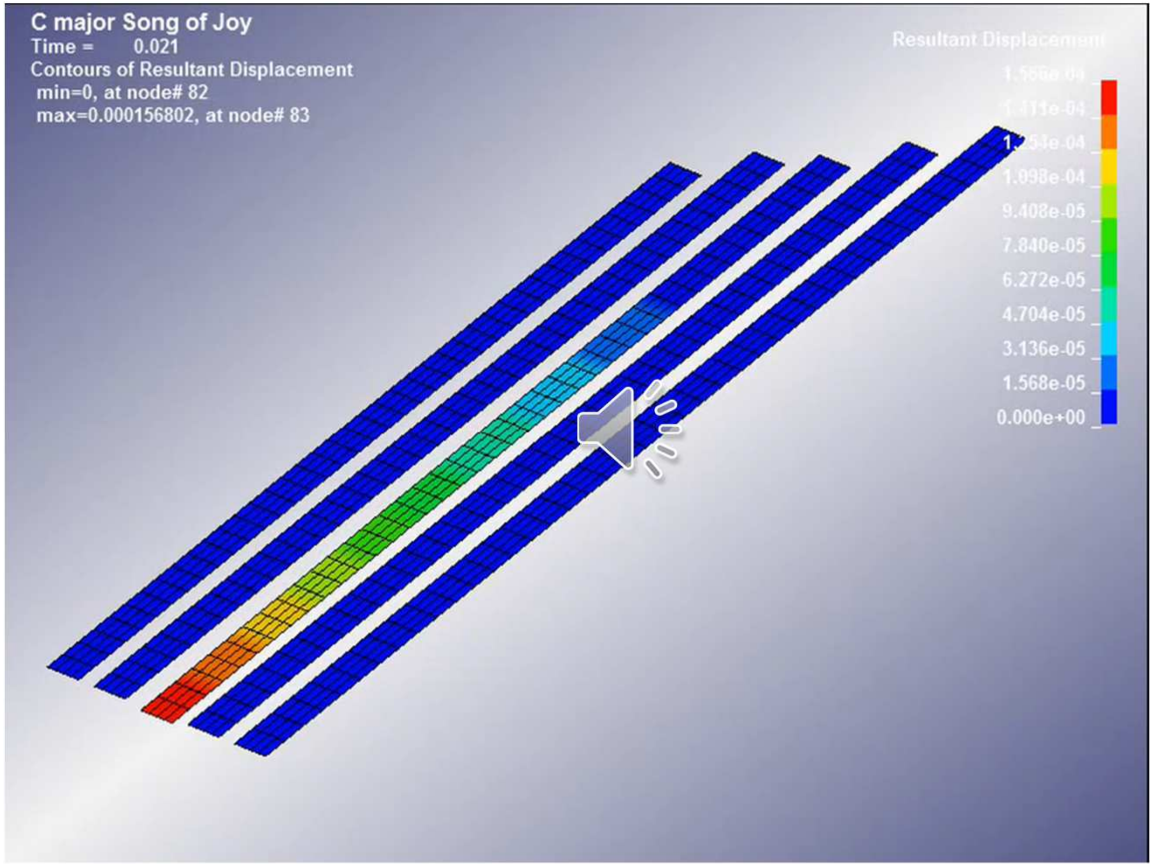
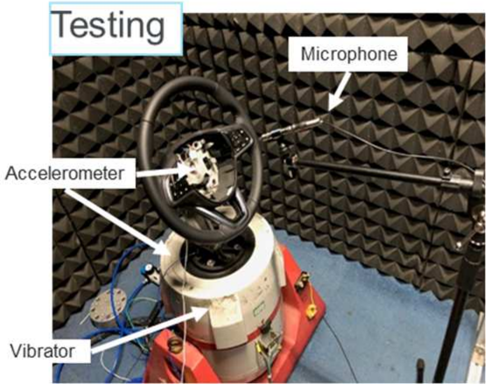
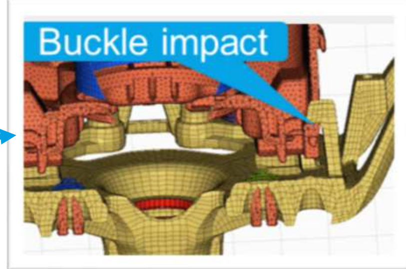
Acoustic Simulation
Music Box (minimalism version)

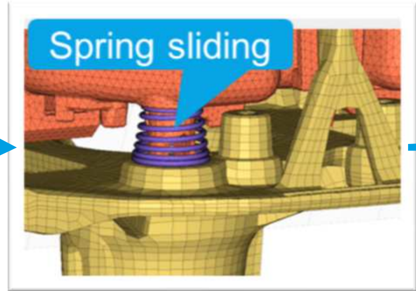


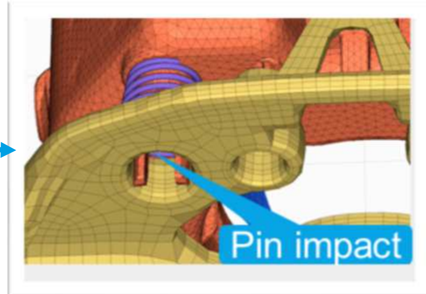
Acoustic Simulation

Dynamic analysis for noise source identification

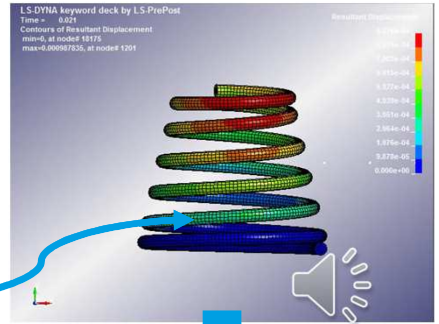


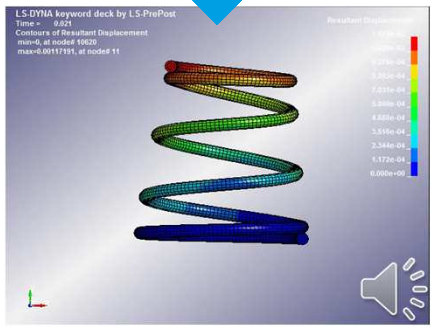




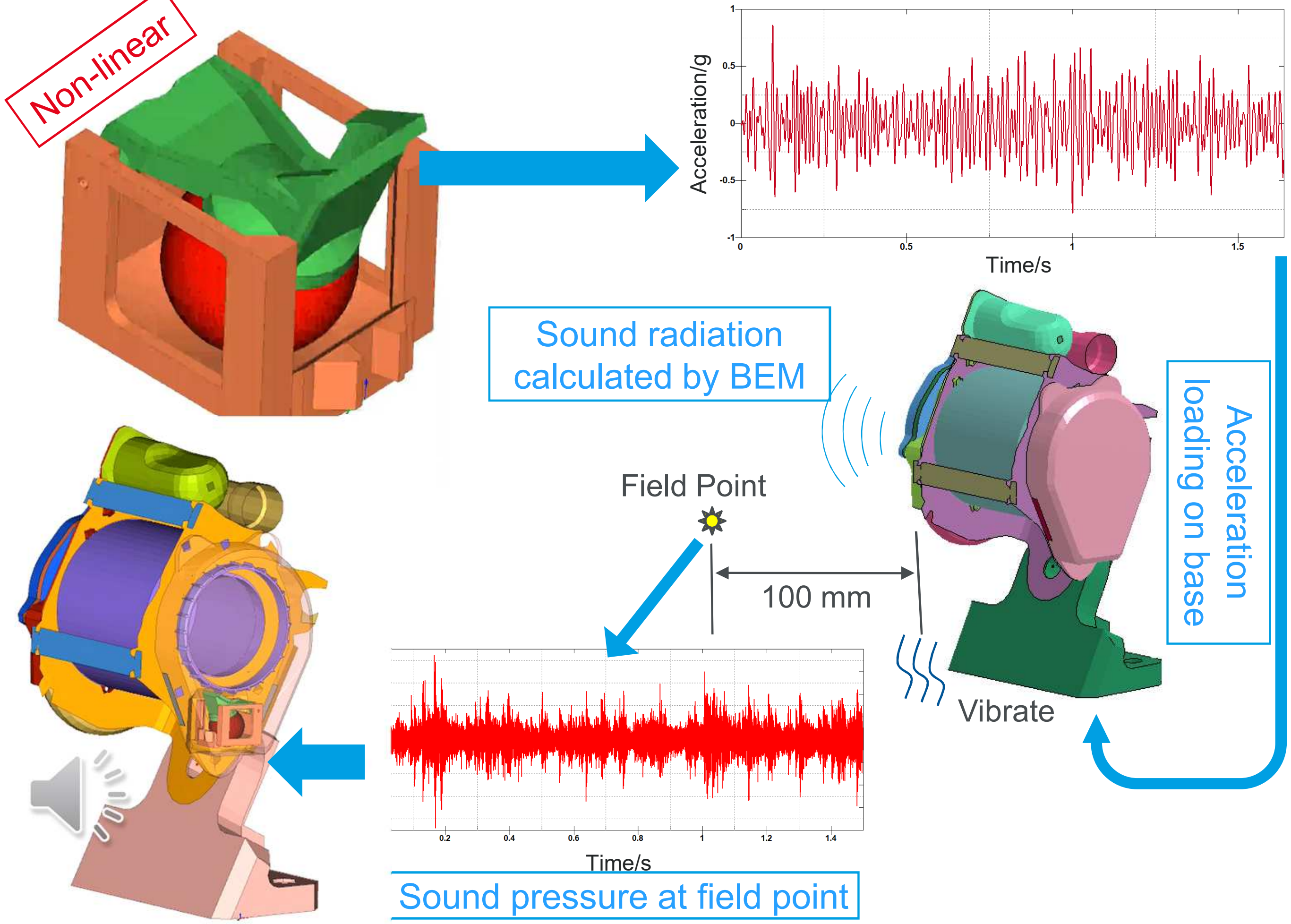


- Transient analysis for sound simulation

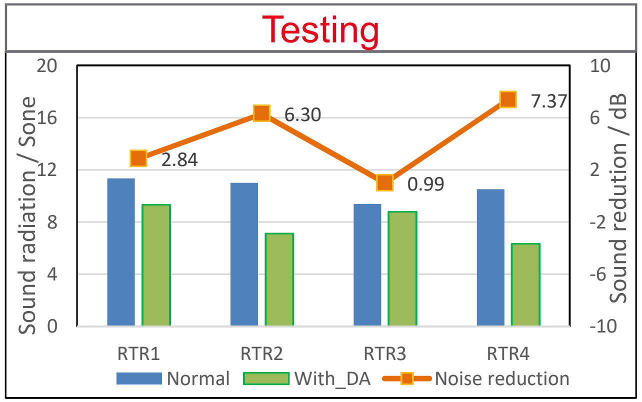




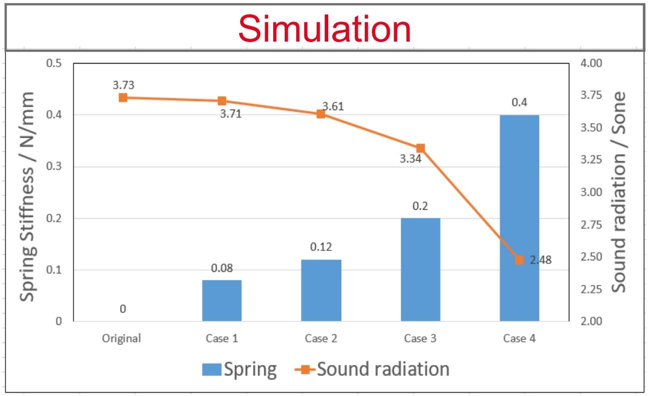
Acoustic Simulation



CS Rattle noise is caused by highly non-linear, can only be simulated by transient dynamic analysis.



Noise reduction: 4.37 dB (4 averaged)



Noise reduction: 5.89 dB

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