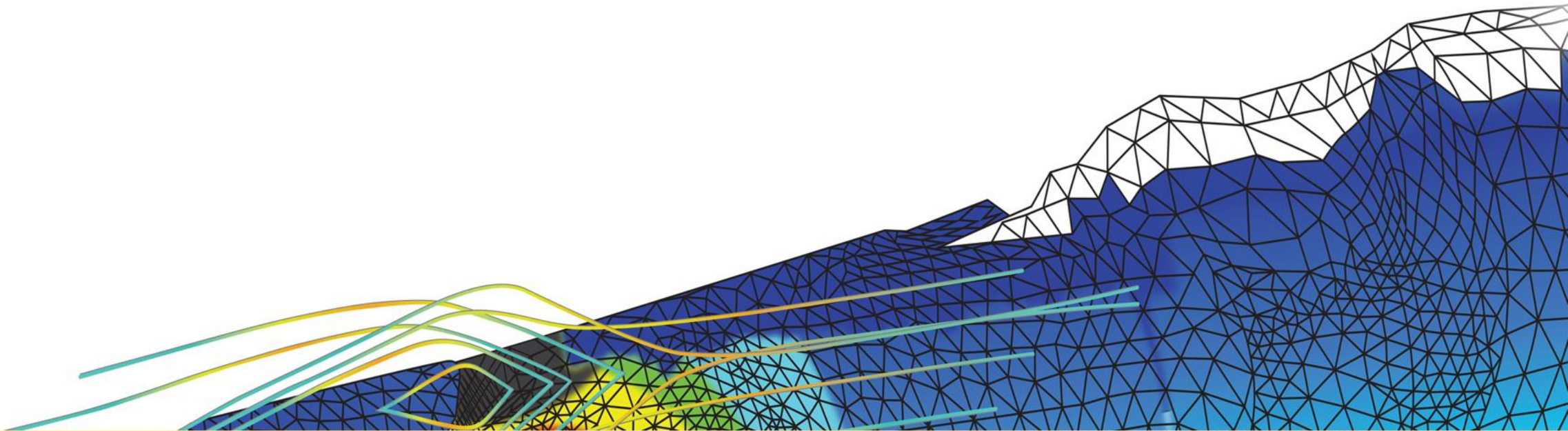




**Multi-Flexible body dynamics, ANSYS Motion.**



# Contents

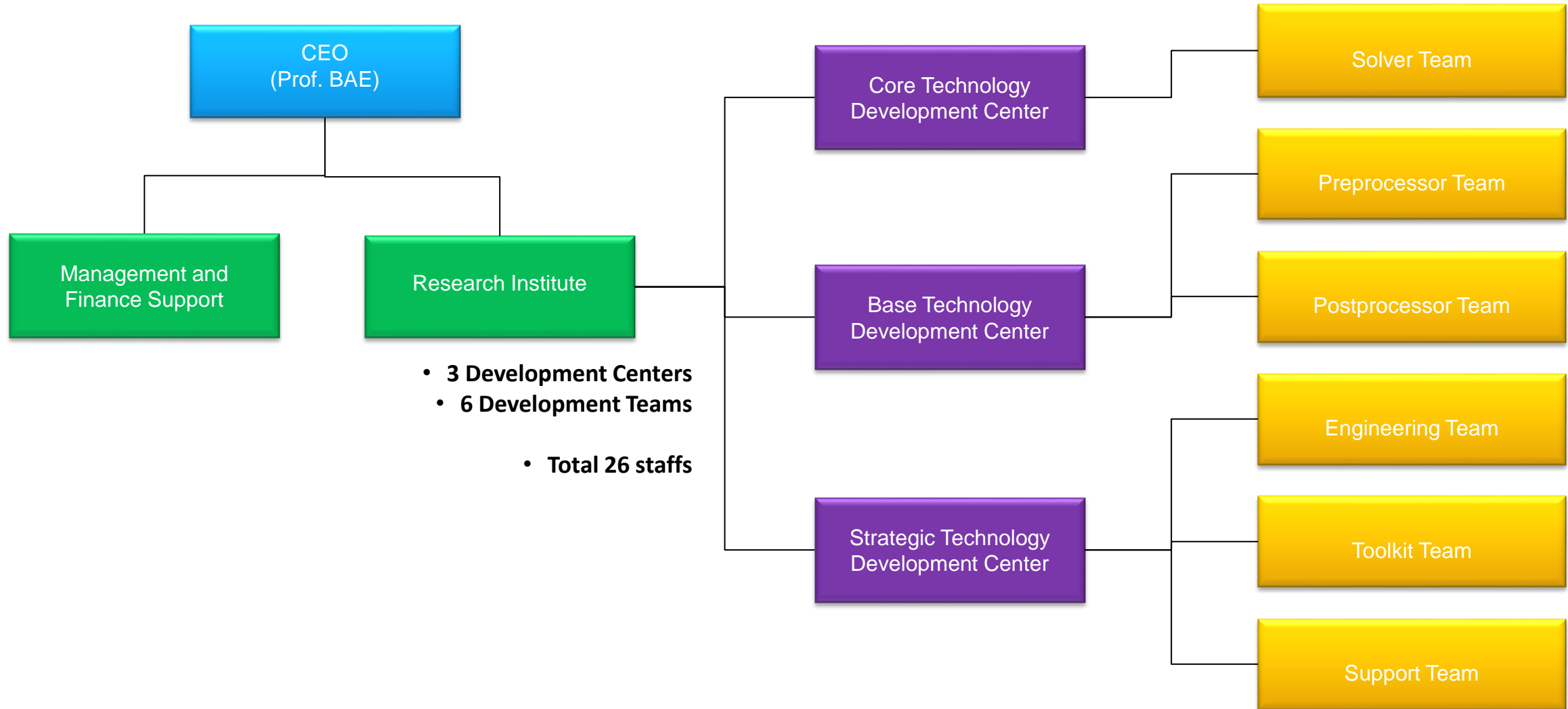
- **Overview of ANSYS Motion**
  - Basic functionalities
  - Simulation capabilities
  - Introduction of toolkits
- **ANSYS Motion Workbench 2019 R3**
  - Modeling Concept
  - Supported Entities
  - Future Plan & Demo
- **Examples**
- **Development strategy**
  - High performance solver (MPP solver)

# VirtualMotion, Inc.

- Establish: 2006. 12. 13, CEO : Prof. Bae (in Hanyang University)
- Staffs: 26, R&D Staffs: 88% (23/26)
- Product: DAFUL (General Purposed Multi-Flexible Body Dynamics and Structural Analysis Software)


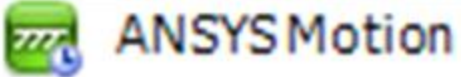
2006	.	.	.	.	2016	2017	.	2021
<b>Beginning Period (Starting Business &amp; Development)</b>						<b>1<sup>st</sup> Growth Period (Global Business &amp; Development)</b>		
<ul style="list-style-type: none"> <li>• 2006 – Foundation</li> <li>• 2007 – Establishment Research Institute</li> <li>• 2009 – <b>JAPAN distributing agency</b> of ITOCHU Techno-Solution Corporation</li> <li>• 2009 – The 1<sup>st</sup> User's Conference in Korea</li> <li>• 2010 – <b>KOREA distributing agency</b> of Haneul Solution</li> <li>• 2010 – The 2<sup>nd</sup> User's Conference in Korea</li> <li>• 2010 – Awarded form KOREA Government Ministry (Education, Science)</li> <li>• 2011 – Certification R&amp;D Services</li> <li>• 2013 – Awarded form KOREA Government Institution</li> <li>• 2013 – <b>KOREA distributing agency</b> of TSNE</li> <li>• 2014 – <b>DAFUL5.0</b> with <b>MeshFree Dynamics</b></li> <li>• <u>2015 – The 1<sup>st</sup> DAFUL Global CAE Conference in Japan</u></li> <li>• 2015 – The 5<sup>th</sup> User's Conference in Korea</li> <li>• 2015 – Awarded form KOREA Government Ministry (Engineering Day)</li> <li>• 2016 – The 6<sup>th</sup> User's Conference in Korea</li> </ul>						<ul style="list-style-type: none"> <li>• 2017 - Establish Global Sales Channel                             <ul style="list-style-type: none"> <li>• Global Distributing Agreement with TSNE</li> </ul> </li> <li>• 2017 DAFUL Development                             <ul style="list-style-type: none"> <li>• Large scale problem Solver / EasyFlex</li> <li>• Improvement Convenience</li> </ul> </li> <li>• <b>2018 ANSYS MOTION development</b> <ul style="list-style-type: none"> <li>• <b>Sales &amp; Dev. contract with ANSYS HQ</b></li> <li>• <b>First Releasing ANSYS Motion / Workbench</b></li> <li>• <b>218 AE are working for</b></li> </ul> </li> </ul>		
<b>SW Development</b> <ul style="list-style-type: none"> <li>• 2007 – NX-DAFUL (CAD Embedded)</li> <li>• 2010 – DAFUL2.0 (1<sup>st</sup> Standalone DAFUL)</li> <li>• 2011 – DAFUL3.0 (DAFUL/CAR)</li> <li>• 2013 – DAFUL4.0 (MeshFree Statics)</li> <li>• 2014 – DAFUL5.0 (MeshFree Dynamics)</li> <li>• 2015 – DAFUL5.2 (Drivetrain NVH Toolkit)</li> <li>• 2016 – DAFUL6.0 (Thermal Analysis, DOE)</li> </ul>								
<b>SW Donation for University</b> <ul style="list-style-type: none"> <li>• 2013 –Kukmin Univ.</li> <li>• 2014 –Hongik Univ.</li> <li>• 2014 –Gunsan Univ.</li> <li>• 2015 –Kyungil Univ.</li> <li>• 2016 –Chunbuk Univ.</li> <li>• 2016 –Hanyang Univ.</li> <li>• 2016 –Hansung Univ.</li> <li>• 2017 –Handong Univ.</li> </ul>								

# Company Organization



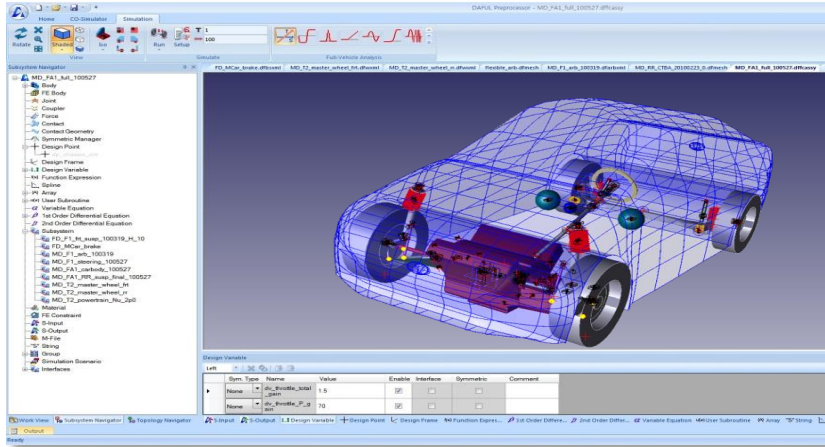
# ANSYS Motion & its Workbench version

- Development direction for DAFUL & ANSYS Motion ACT

Name	ICON	Type	Toolkit	Development
ANSYS Motion		Standalone	<ul style="list-style-type: none"><li>• Drivetrain</li><li>• Links</li><li>• Car</li><li>• EasyFlex</li></ul>	<ul style="list-style-type: none"><li>• Expanding own capabilities (solver, nvh, links, pre/post environment)</li><li>• Interfacing with other S/W (FMI, Unv, Command)</li></ul>
ANSYS Motion ACT		ANSYS environment	<ul style="list-style-type: none"><li>• None (same as above)</li></ul>	<ul style="list-style-type: none"><li>• Merge DAFUL capabilities into ANSYS environment include toolkits</li><li>• Completing as one “analysis system”</li></ul>

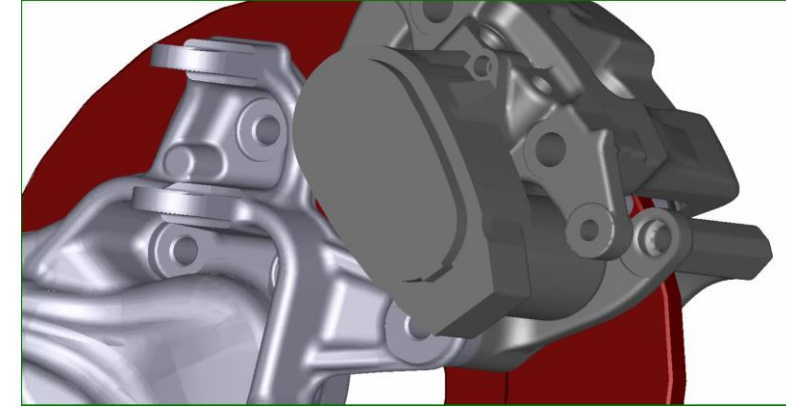


# Overview of ANSYS Motion



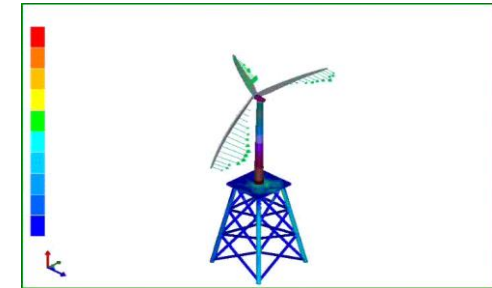
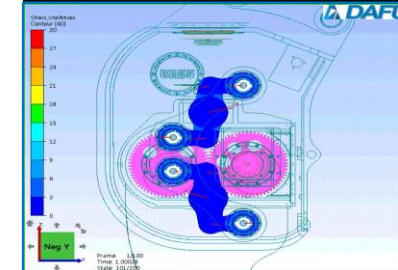
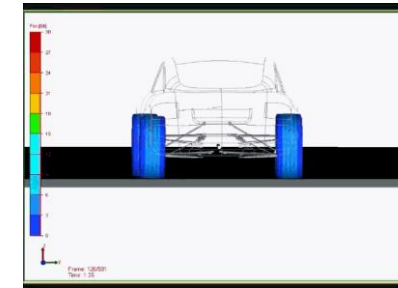
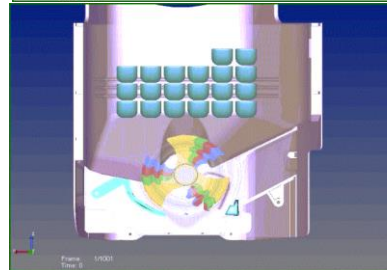
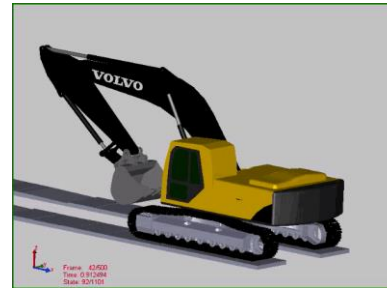
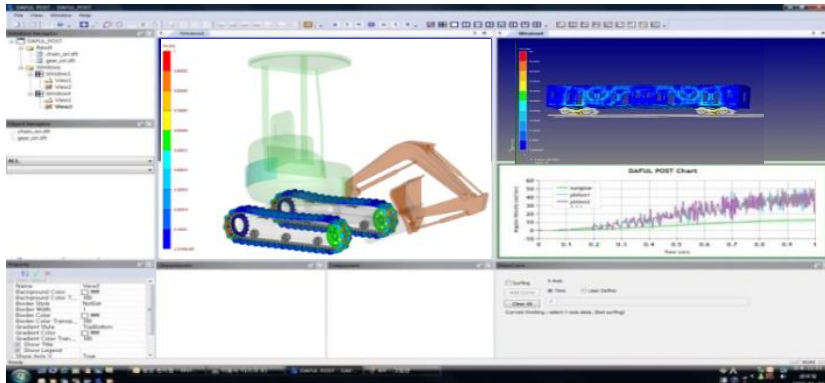
## Analysis Scope

- Multi-Flexible Body Dynamics
- Strength/Fatigue
- Vibration (Linear)
- NVH (Transient)
- Heat Transfer
- DOE Design



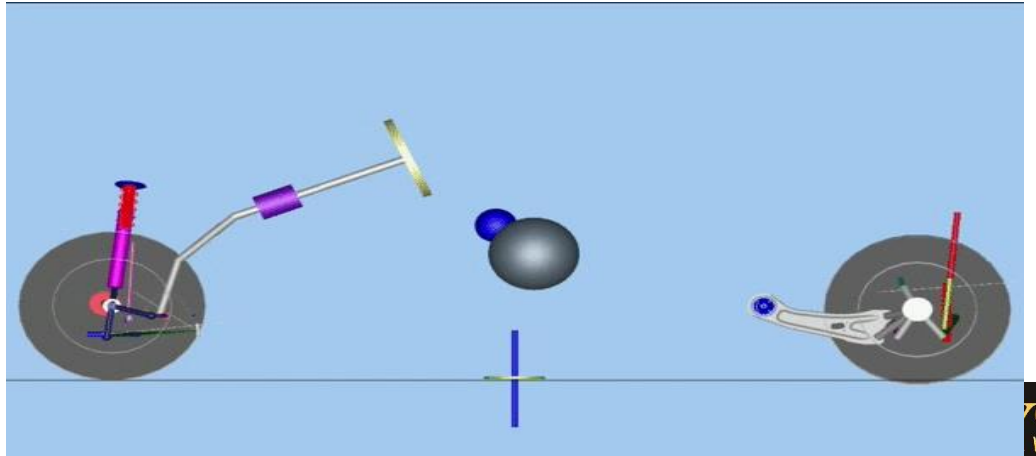
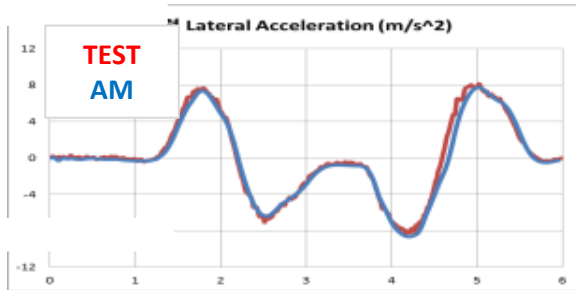
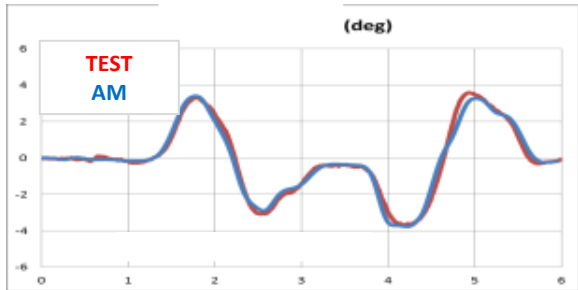
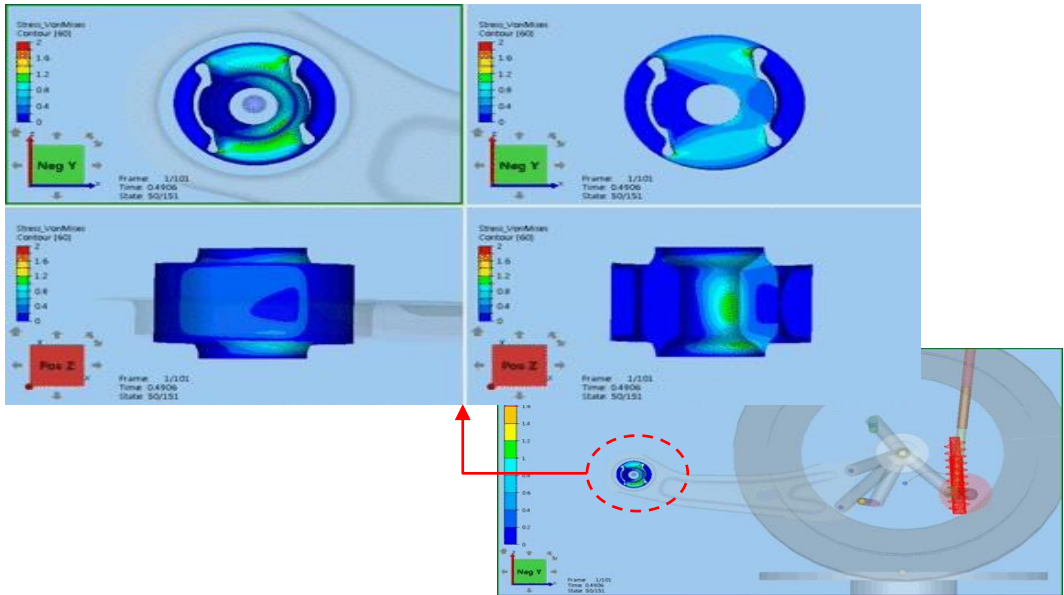
## Field of Application

### Structural Dynamics Analysis (PRE, Solver, POST)



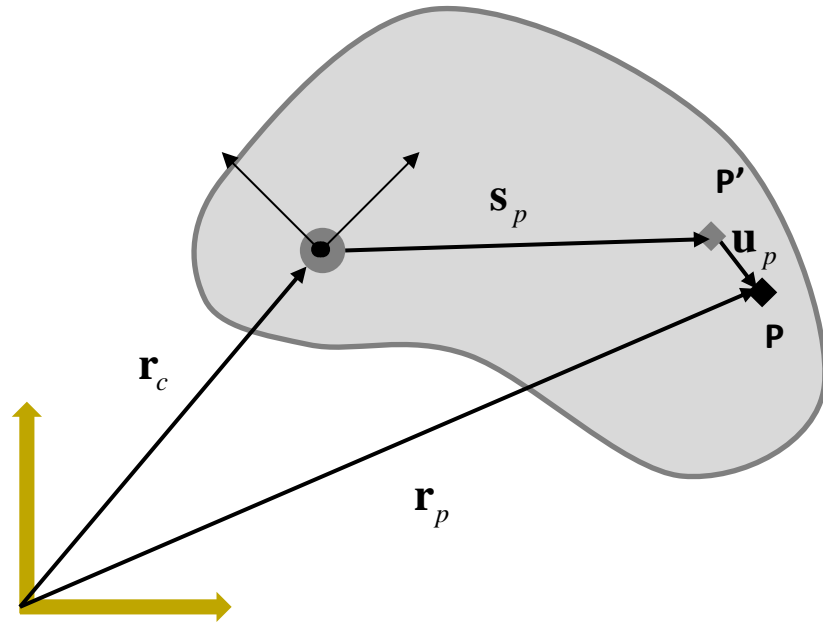
# Multi-Body Dynamics (MBD): System Analysis

## Double Lane Change



# Multi Flexible body system

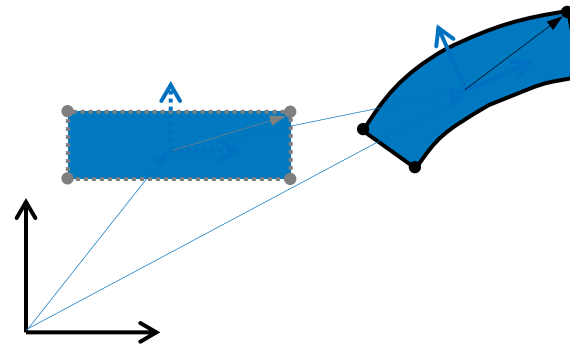
- Remove rigid body motion



- Position relationship of deformable point, P

$$\mathbf{r}_p = \mathbf{r}_p + \mathbf{A}_p (\mathbf{s}'_p + \mathbf{u}'_p)$$

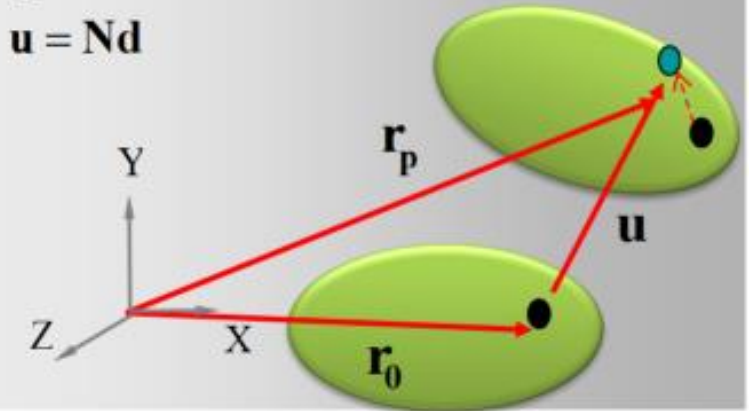
- Geometric non-linearity is caused by a rotation.
- Kinematics of flexible body can be simplified by using the orientation matrix.



## Explicit

$$\mathbf{r}_p = \mathbf{r}_0 + \mathbf{u}$$

$$\mathbf{u} = \mathbf{N}\mathbf{d}$$

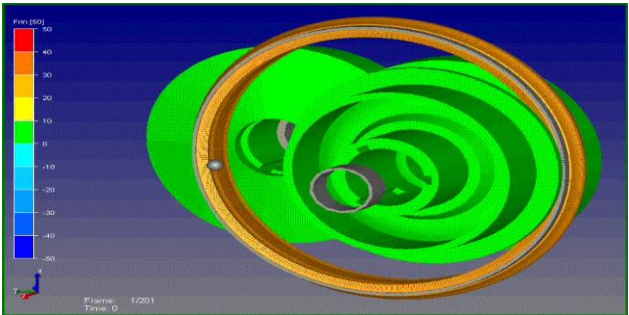
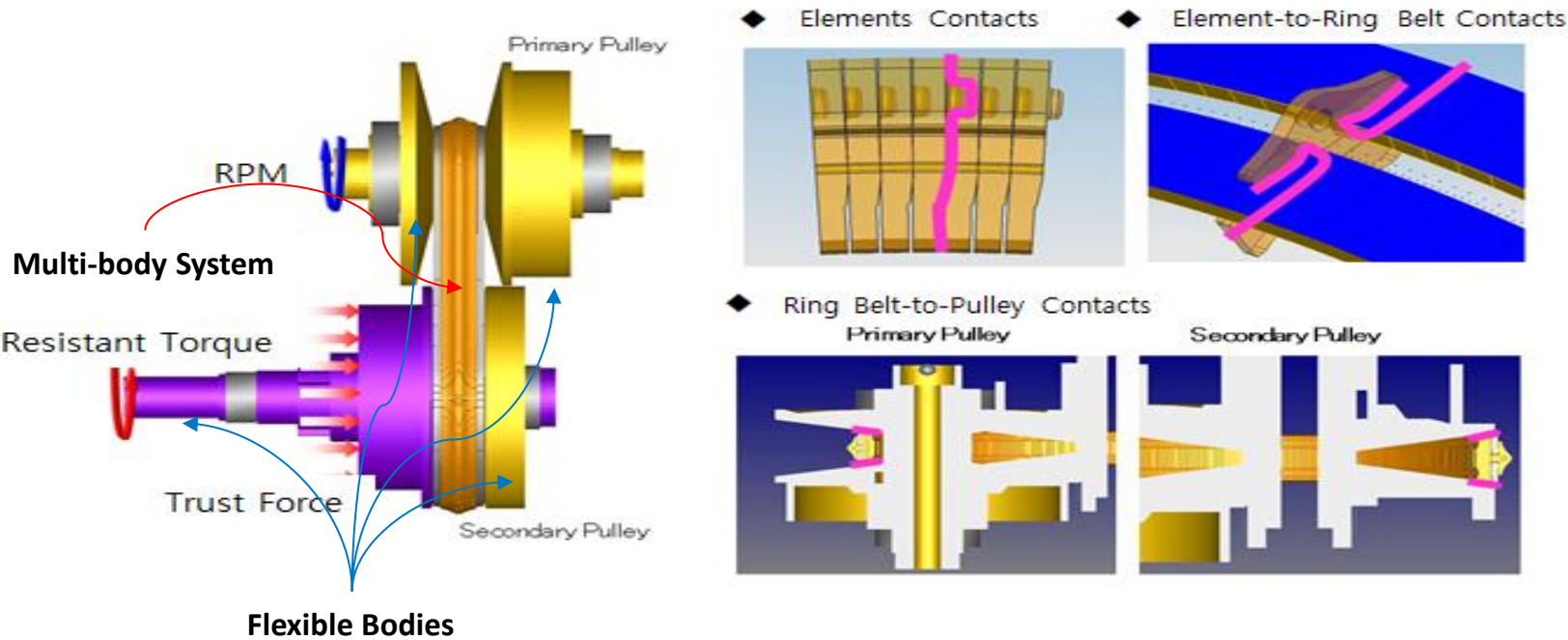


- Total Lagrangian
- Good in small deformation and small displacement
- Frequently update its pattern



# Contact on Belt type CVT system

- JATCO, HMC and FHI are partners for CVT CAE



Time	AM (MKL)	PAM
0.5s	1hr. 14min. 97x	100 hr.

Model information	Number of
Bodies	1,220
Nodes	32,290
Elements	26,700
RigidToRigid	98,154
FlexToRigid	1,599
D.O.F	116,740

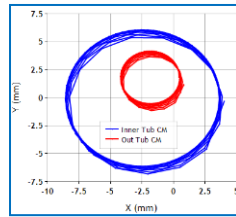
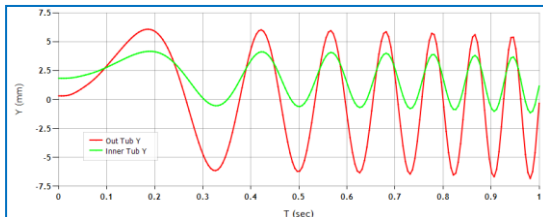
# Simulation capability – Dynamics(NVH) and Fatigue

## Dynamics Analysis

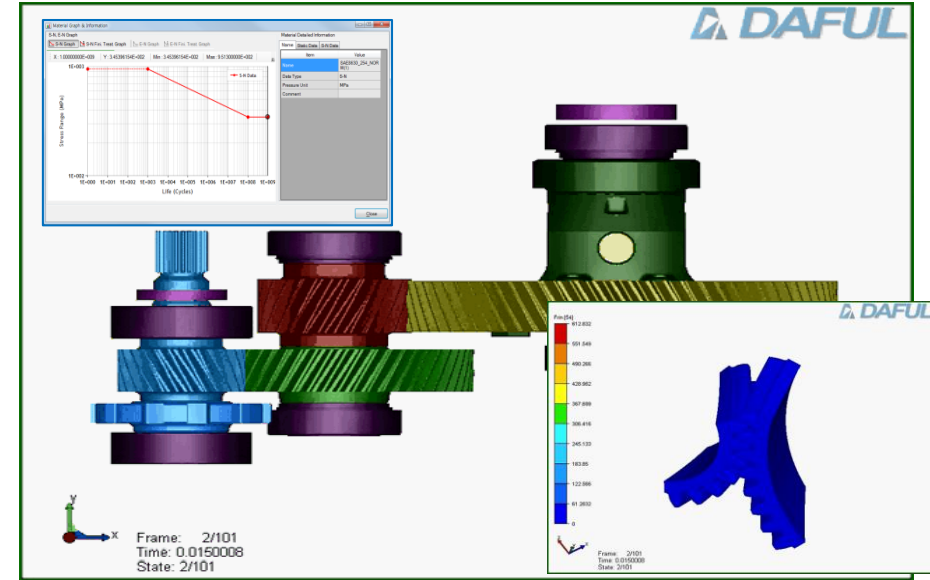
- ✓ Dynamics Behavior
- ✓ Small/Large Deformation
- ✓ Contact Analysis
- ✓ Vibration Analysis

Confidential

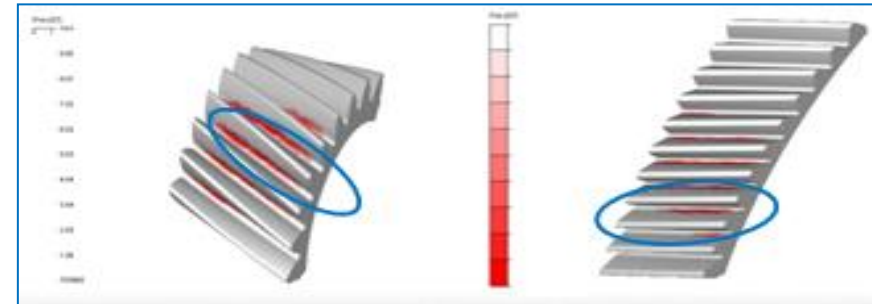
Confidential



## Fatigue and Damage Analysis

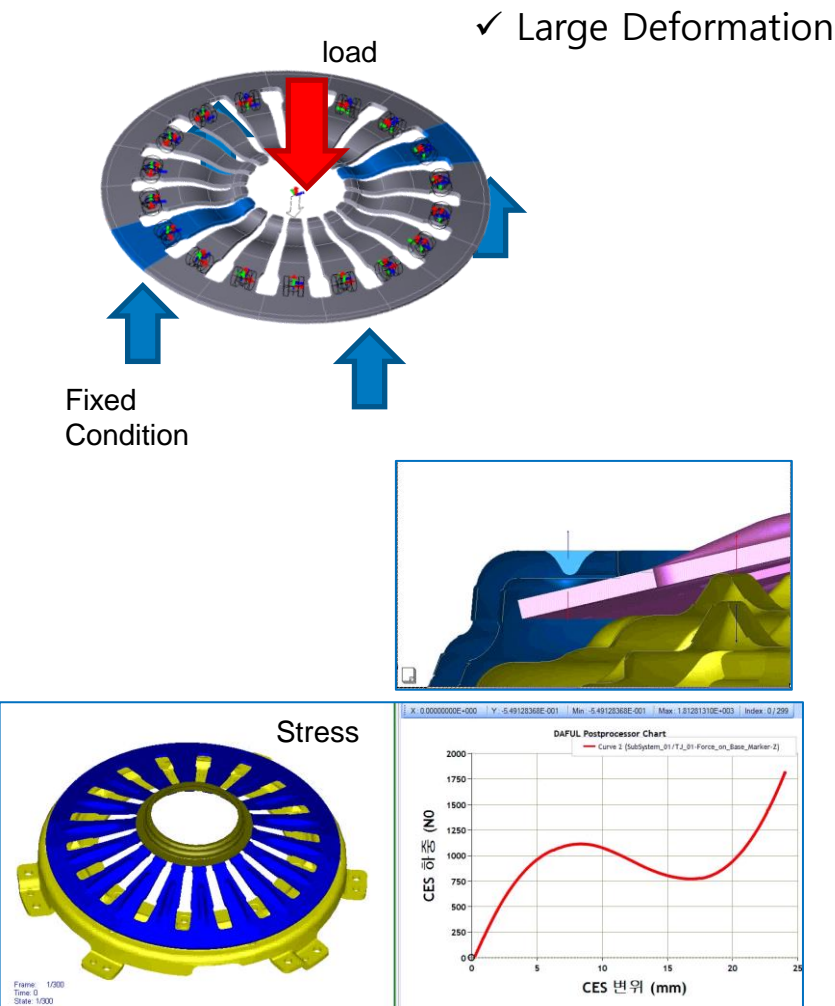


- ✓ Design Stress
- ✓ S/N Curve

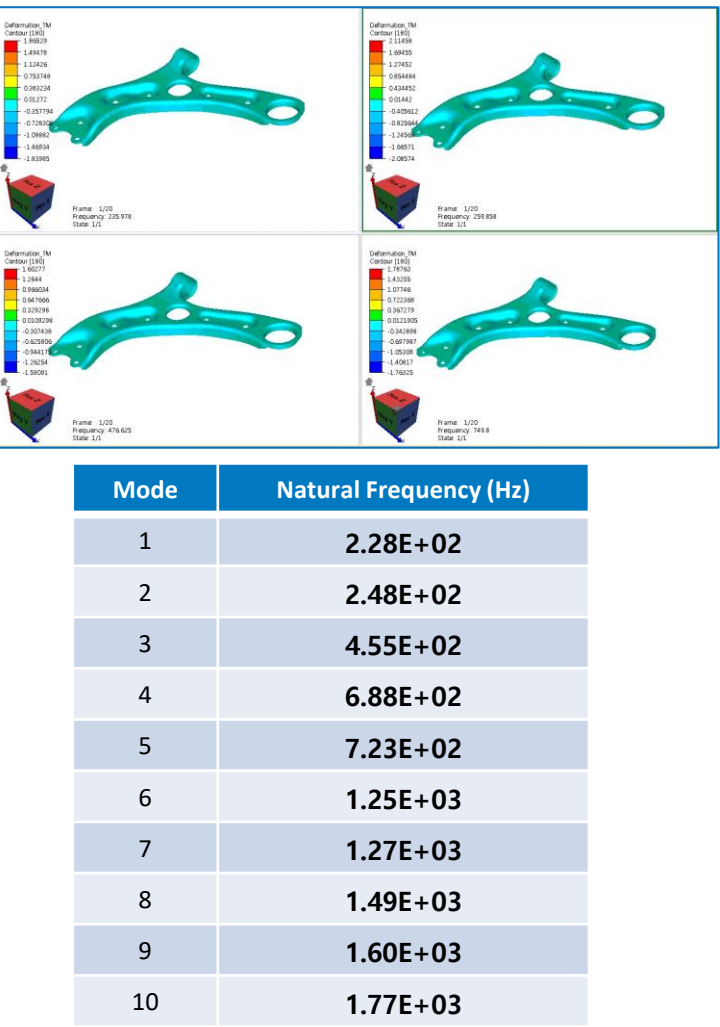


# Simulation capability – Static & Eigenvalue

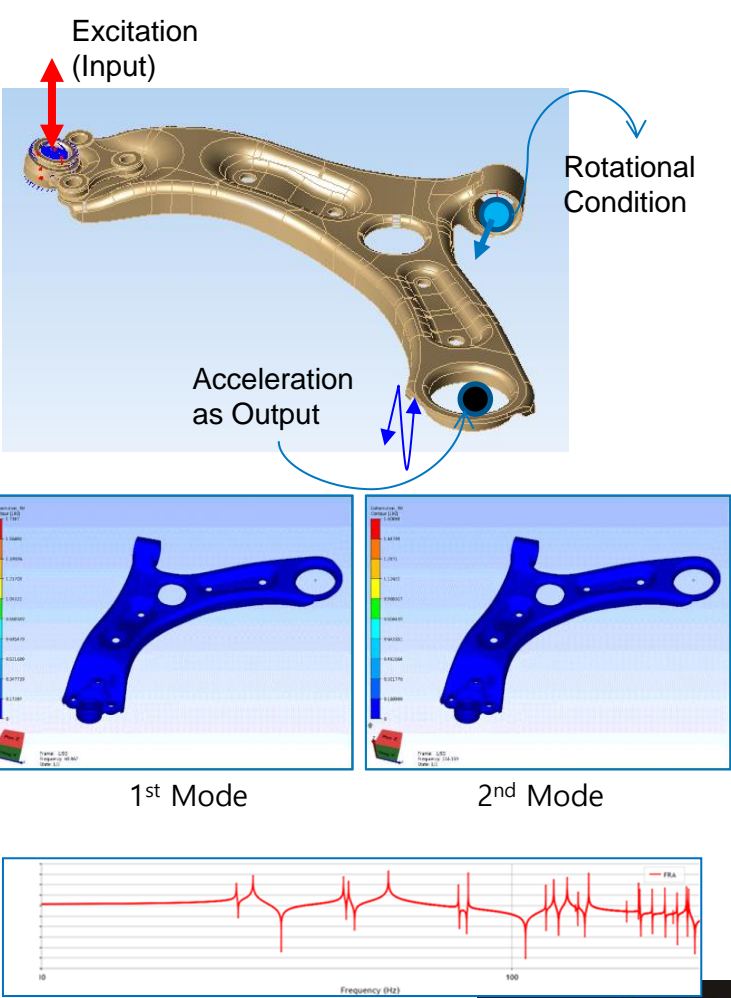
## Static and Compliance Analysis : Non-Linear



## Mode and Natural Frequency Analysis

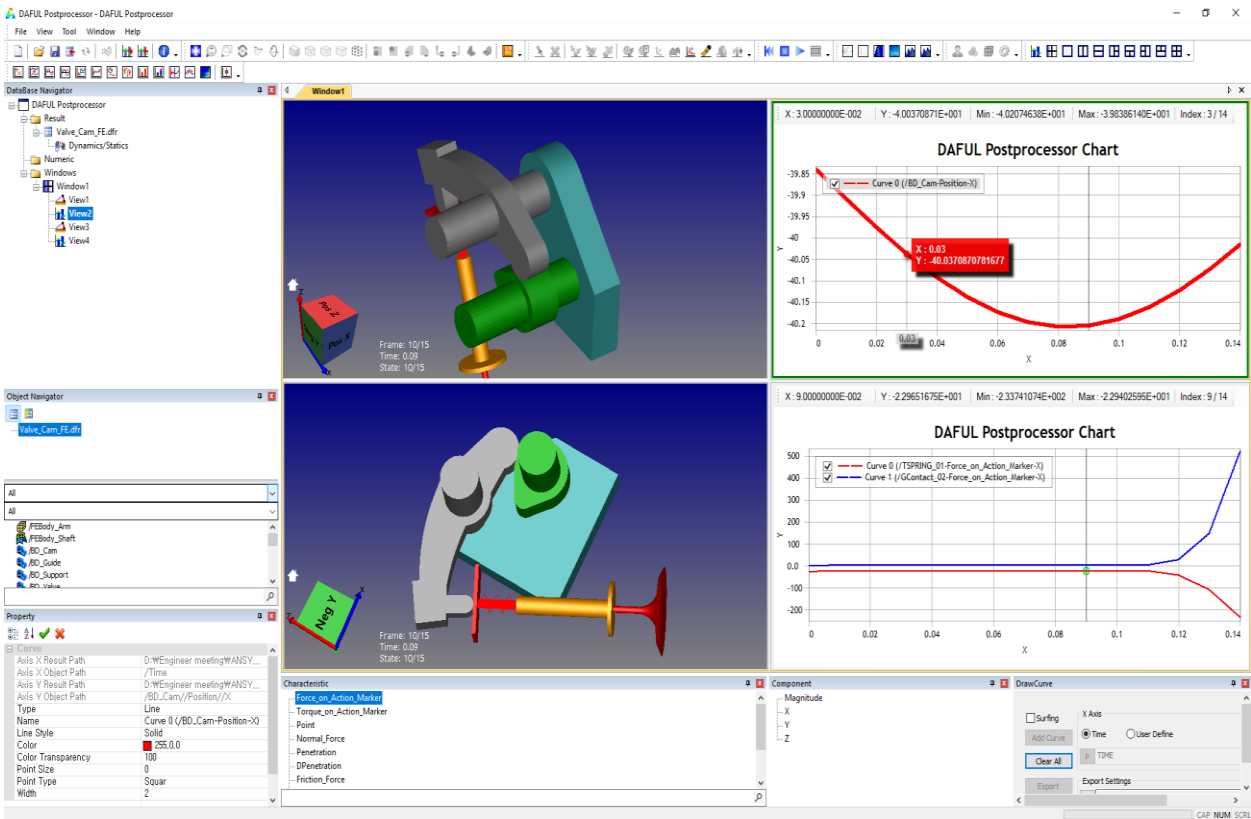
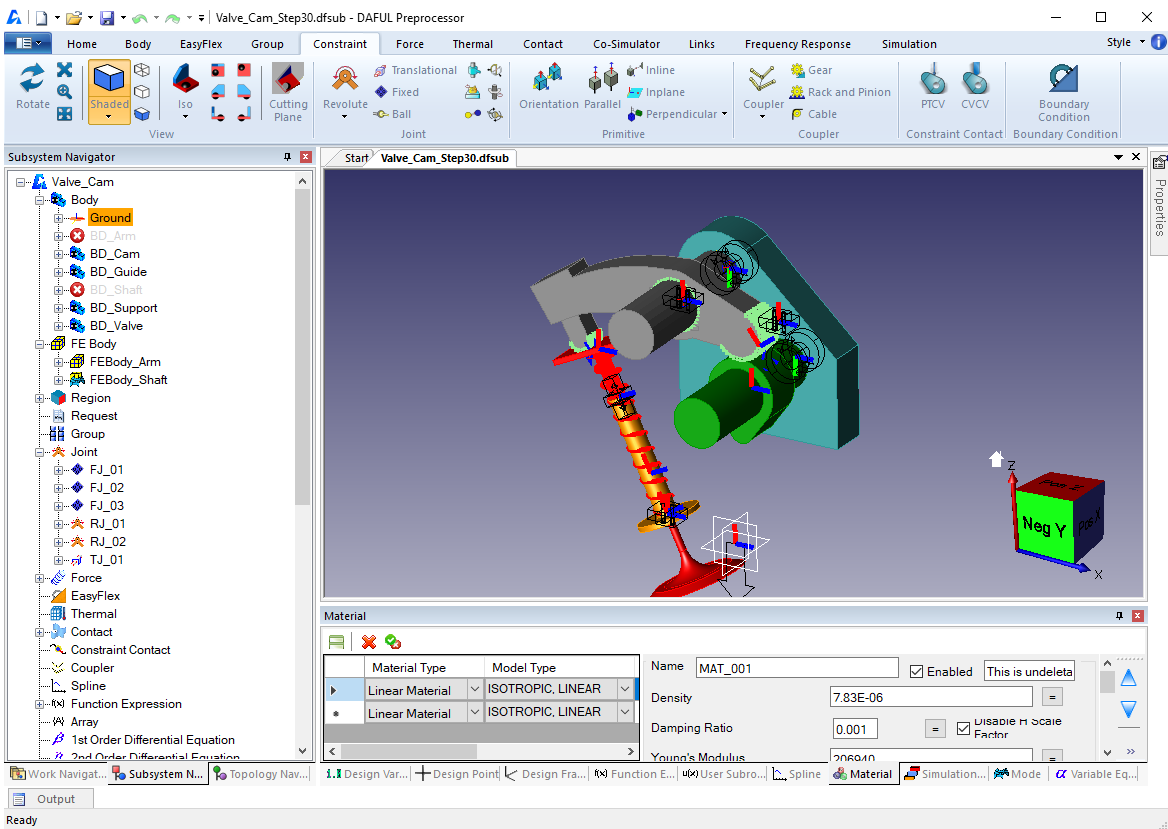


## Frequency Response Analysis





# Preprocessor & Postprocessor





# System interface – Various combinations

## System Model

- MATLAB
- FMI Slave

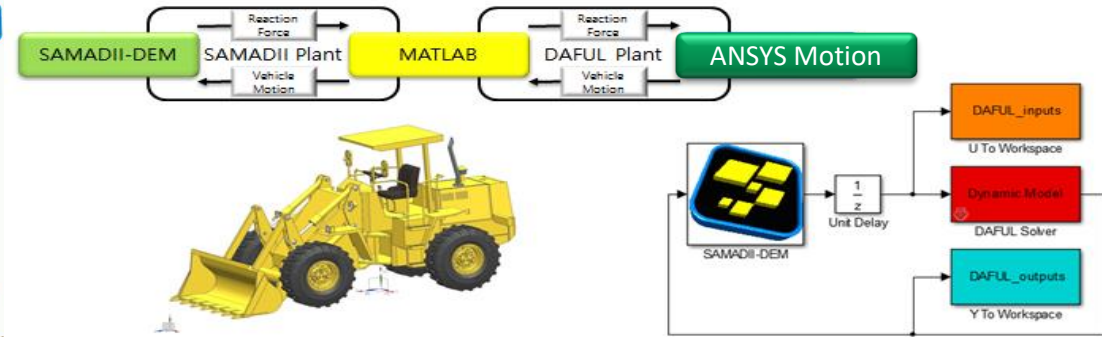
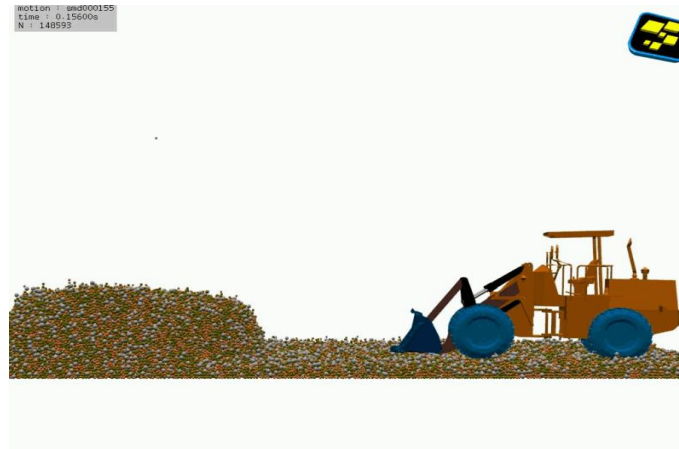
## POST Processing

- FEMFAT (Fatigue)
- EnSight

## CFD Co-Simulation

- CFX
- Phoenix

## Interface with Particle Dynamics - Bucket Loader



## Interface with CFD - Circuit Breaker Mechanism

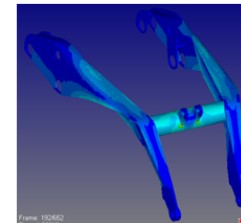
Confidential

## FMI Interface with Hydraulic(1D) – Mini Loader

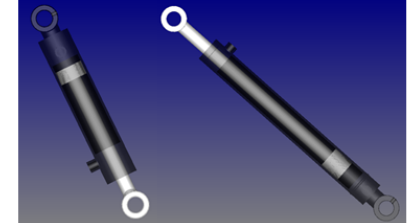
### > Multi-body Dynamics



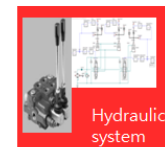
### > Structure



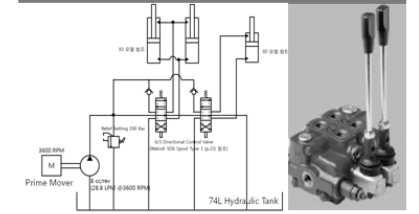
### > Hydraulic System



### > Data Interface



Load  
Displacement



# ANSYS Motion Toolkits

- **DRIVETRAIN**

- Focusing on the dynamic NVH
- Powertrain components
- Special algorithm for Gear, Bearing
- Outputs for a NVH

- Traveling on normal soil
- Slope Up and Down
- Spin and Pivoting turning
- Swing and Lifting
- Rough road NVH test
- Digging, Hammering, Scratching

► **Track (for Tracked Vehicle)**  
**Joint with Volvo Construction**

- **LINKS**

- Build a continuous system
- Easy way to assemble & manage
- Special component for Tracked Vehicle

- **Test Validation for S/W Reliability**
- **Toolkit and Customization**



- **CAR**

- Template based vehicle dynamics
- Predefined simulation scenario & outputs
- Vehicle characteristics

► **Car (for Automotive)**  
**Joint with Hyundai Automotive**

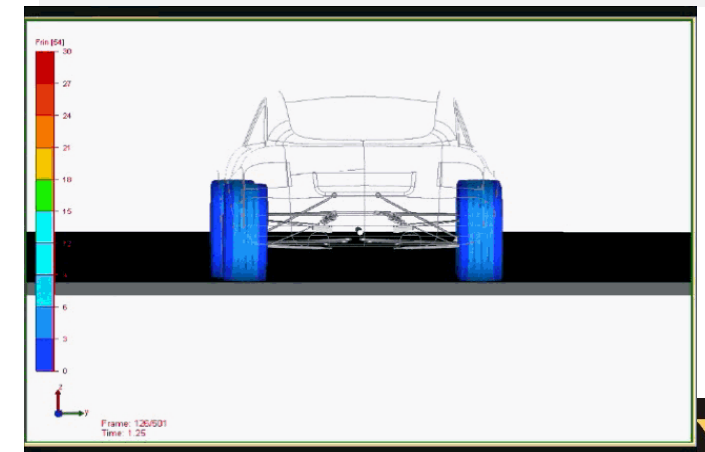
- **EasyFlex**

- Meshfree technique

- Hydraulic forces
- Buoyancy design
- Steering analysis
- Soft soil interaction

Confidential

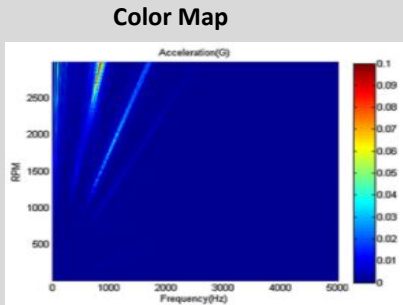
- K & C analysis
- R & H analysis
- FEM Tire verification
- T/M NVH analysis
- Part Compliance verification



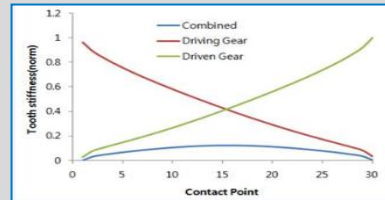
# Toolkit : Drivetrain

- A drivetrain toolkit has been used to analysis NVH of driveline system which consists of gear pairs, shaft, bearings, and housing.
- Gear supports the involute, cycloid, and rack types for tooth shape. Mesh stiffness is automatically calculated with considering a misalignment.
- Bearing supports the catalog of bearing makers. Stiffness of bearing is automatically calculated for loading conditions.

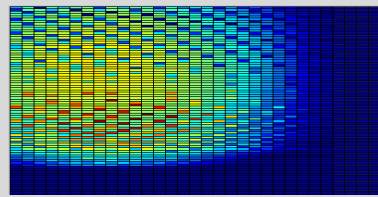
Part/System Modes



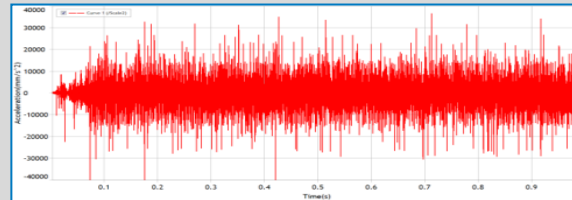
Gear/Bearing/Web Stiffness



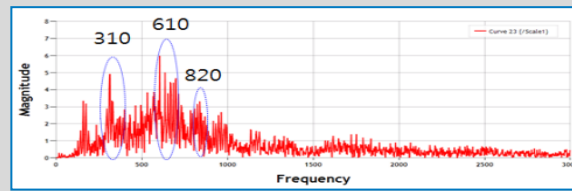
Tooth Contact Pressure



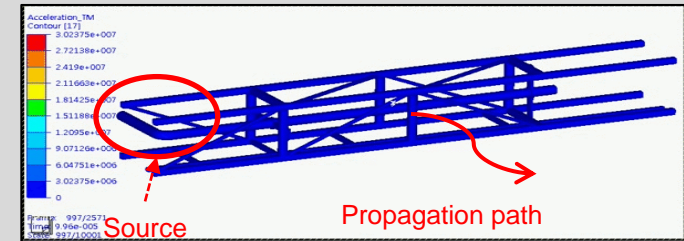
Results in Time Domain



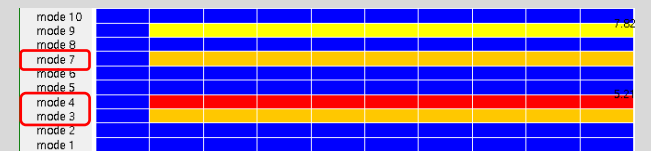
Results in Frequency Domain



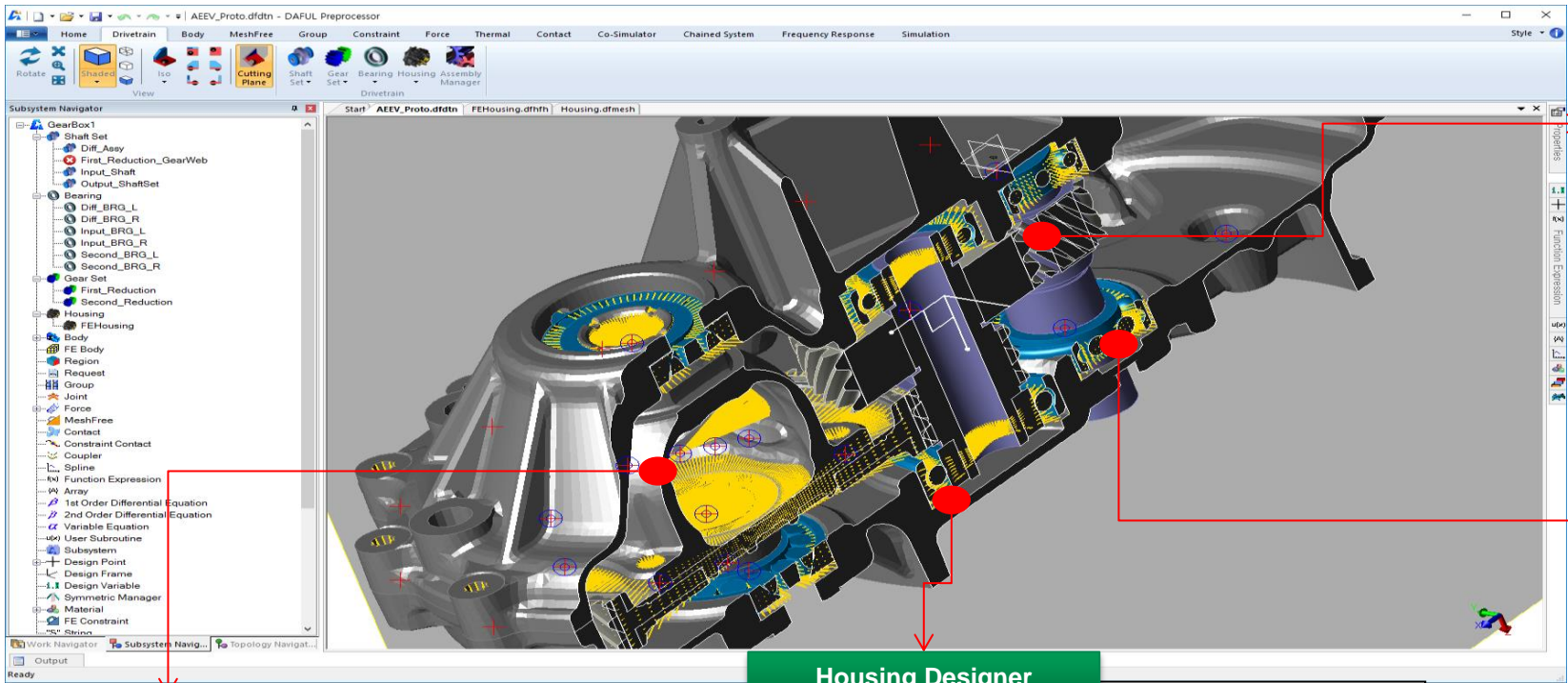
Acceleration Contour for Path



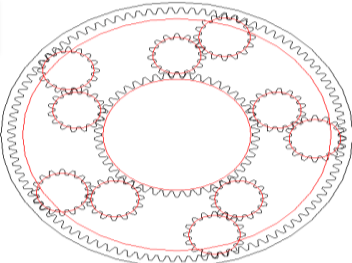
Contribution Analysis



# Overview of Drivetrain

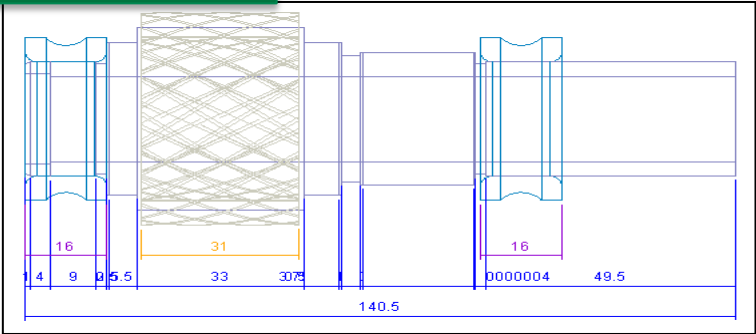


Gear Designer

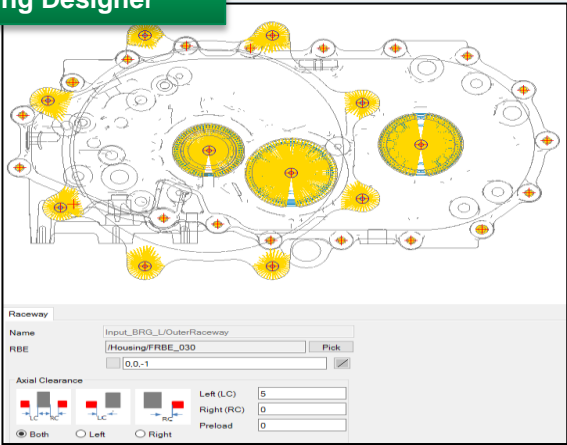


Gear Pairs									
Tool   Modification   Material   Web   Tooth Stiffness   Summary									
Helical		Quality	1	6	SunGear	6	PinionIn	6	PinionOut
Right		Number of Teeth(z)	46	15	16	96			
1.5		Face Width	10.0	11.0	12.0	13.0			
20		Center Distance	49.342966079	25.075933456					
22									

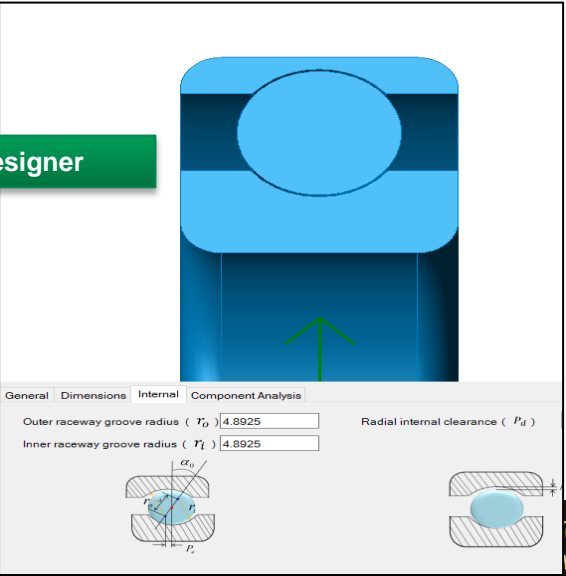
Shaft Designer



Housing Designer



Bearing Designer

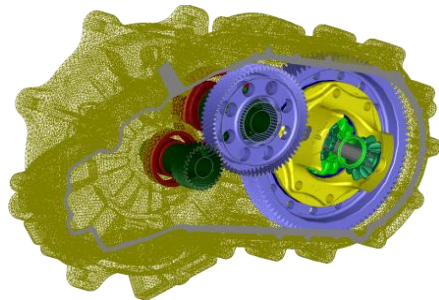
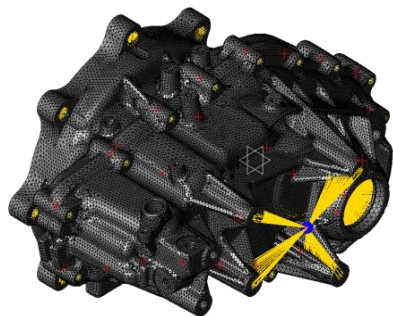




# Drivetrain in EV Car

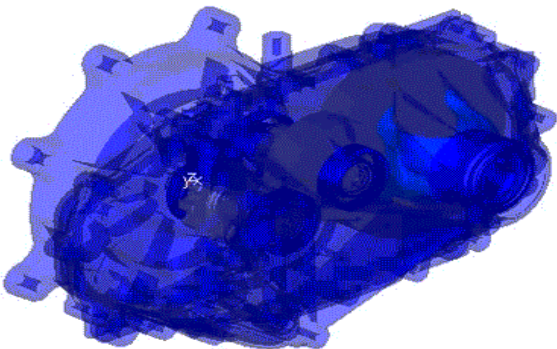
- Verified model development and improve the whine noise

Gearbox Model

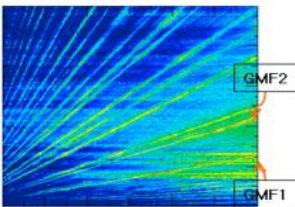
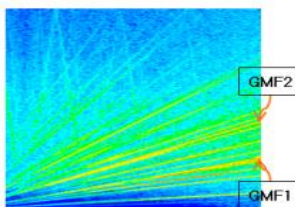
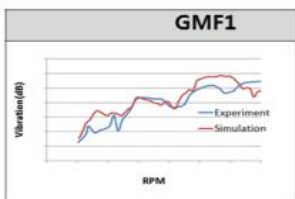
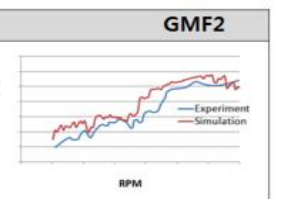


### Characteristics of System

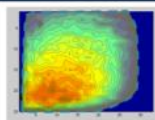
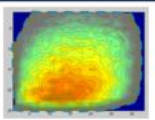
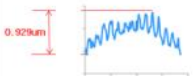

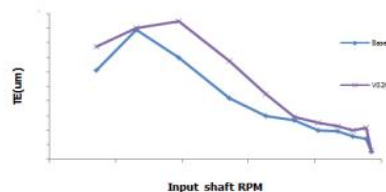
- 2 stage Helical gear reduction
- 2 ball bearing on each shaft
- Accelerate speed and increase applied load



### Verification

	Experiment	Analysis	Opinion
Waterfall			Each order components and its frequency is similar with experimental one
Order Tracking	<div><div>GMF1</div></div> <div><div>GMF2</div></div>		Overall pattern and peak value is very similar

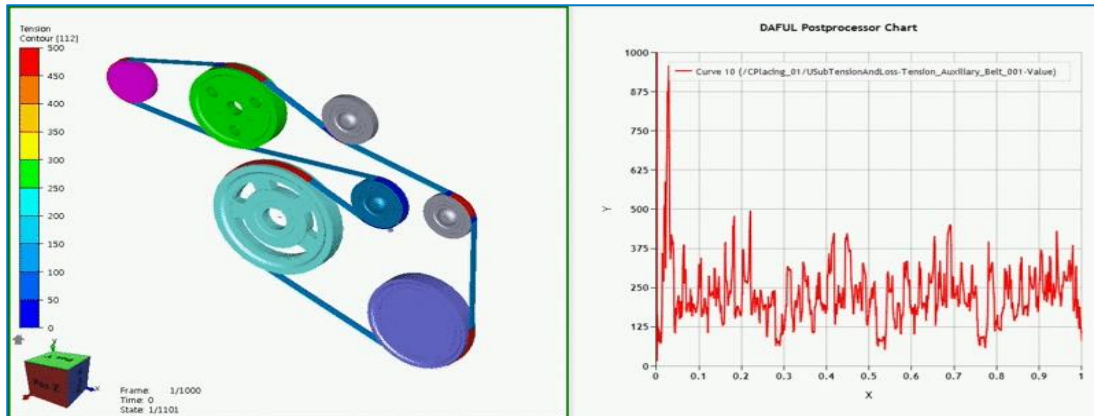
### Design Change of Gear Tooth

	Proto	Modified	Remarks
Tooth Contact Area			Modify tooth profile to maximize contact area
PPTE			Modify tooth profile to reduce PPTE
DPSTE			DPSTE is determined by gear characteristics and by system

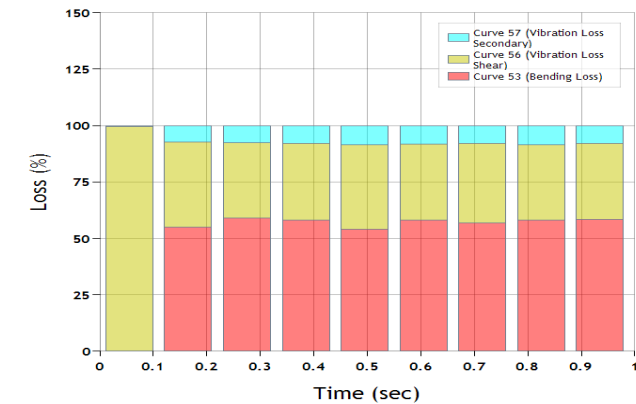
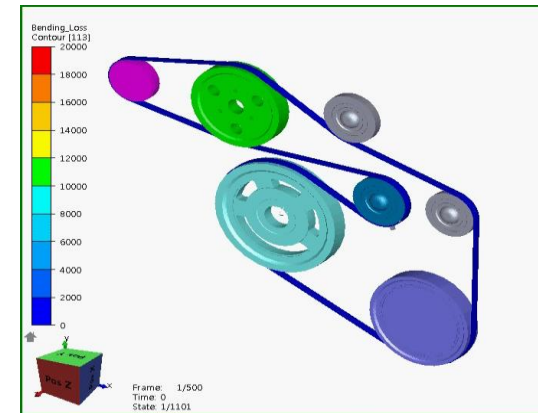
# Toolkit : LINKS

- A Links System is the modeling tool of the open or closed loop chained system.
- Concept of Segment and Path has been used to build a winding system. Especially, connector between segments and contact modeling are very easy.

- Tension Contour Display



- Loss Contour Display and Chart



# Overview of Links toolkit

The main screenshot shows the ANSYS DAFUL Preprocessor interface. The 'New File' dialog is open, displaying a tree view of file types. Red dots and arrows highlight specific options: 'Chain Path' in the 'Subsystem' category, 'Chain Segment' in the 'Mesh' category, and 'Chain Path' in the 'Part' category. Below the dialog, a green box labeled 'Segment' points to a 3D model of a chain segment and its properties dialog. Another green box labeled 'Path' points to a 2D gear mesh and its properties dialog. A third green box labeled 'Assemble' points to a 3D assembly of a chain drive and its properties dialog.

**Path**

Document properties of Chain Path

General	Path	Mesh
Name	Chain_Path_ASD1	
Center Position	0, 0, 0	
Assembly Radius	23.9	
Rotation Axis	0, 0, 1	
<input type="checkbox"/> Show dimension		

**Segment**

Document properties of Chain Segment

General	Segment
Name	Chain_Sg_Mesh2
Geometry Reference	/DEF_001
Segment Length	9.5215079
Height1	6.275
Height2	6.275
<input type="checkbox"/> Show Dimension	
Connectors	Transform
FEBODY_001/PA FEBODY_001/PA	

**Assemble**

Chained System

Name	Center Position	Radius	Direction	Engage	Sprocket
ChainSegment1	-71.5, 0, 0	23.9	CCW	OK	
ChainSegment2	71.5, 0, 0	23.9	CCW	OK	

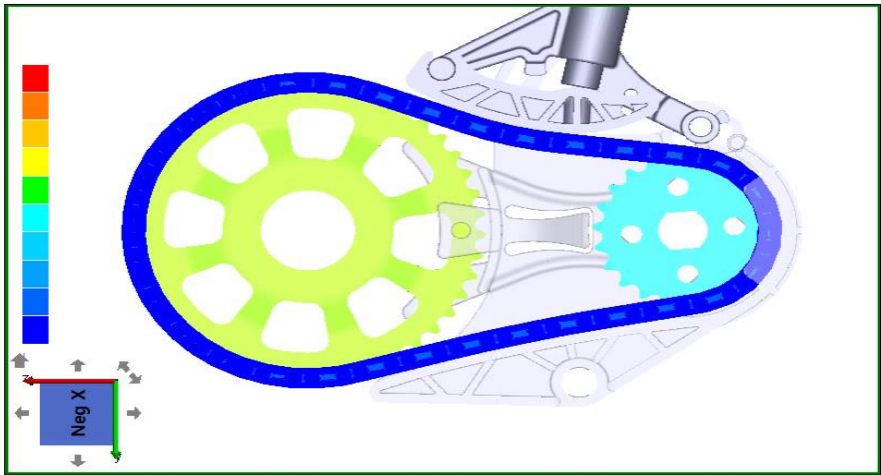
Segment data	Name	Length	Height1	Height2
ChainSegment1	9.5215079	6.275	6.275	
ChainSegment2	9.5215079	6.275	6.275	

☐ Cut off the first command  
☐ For No. Of Segment  
No. of Segment: 50  
Gap: 0.02116245

☐ Enable



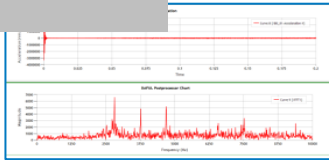
# Various Timing Chain System with Links



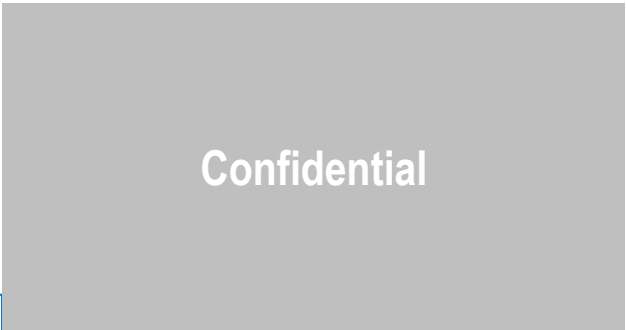
No. of Node  
= **2.7M**

Content	GMS
Speed	<b>22.7 hr.</b>
Memory	<b>45 GB</b>

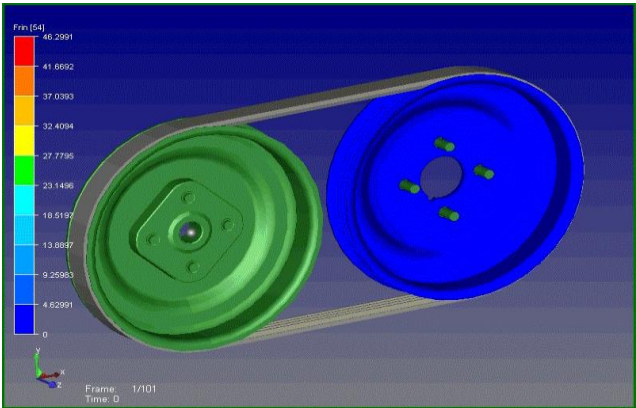
Flexible timing belt



Multi-body timing belt



Rib belt

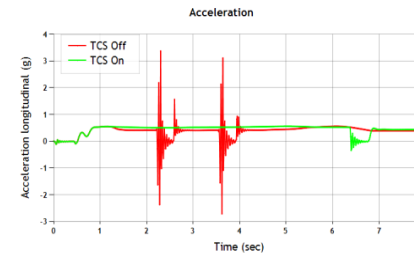
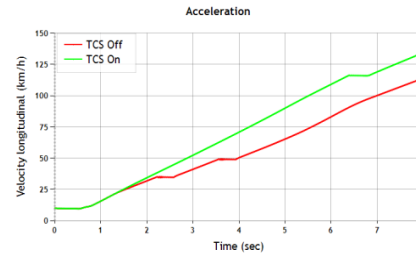




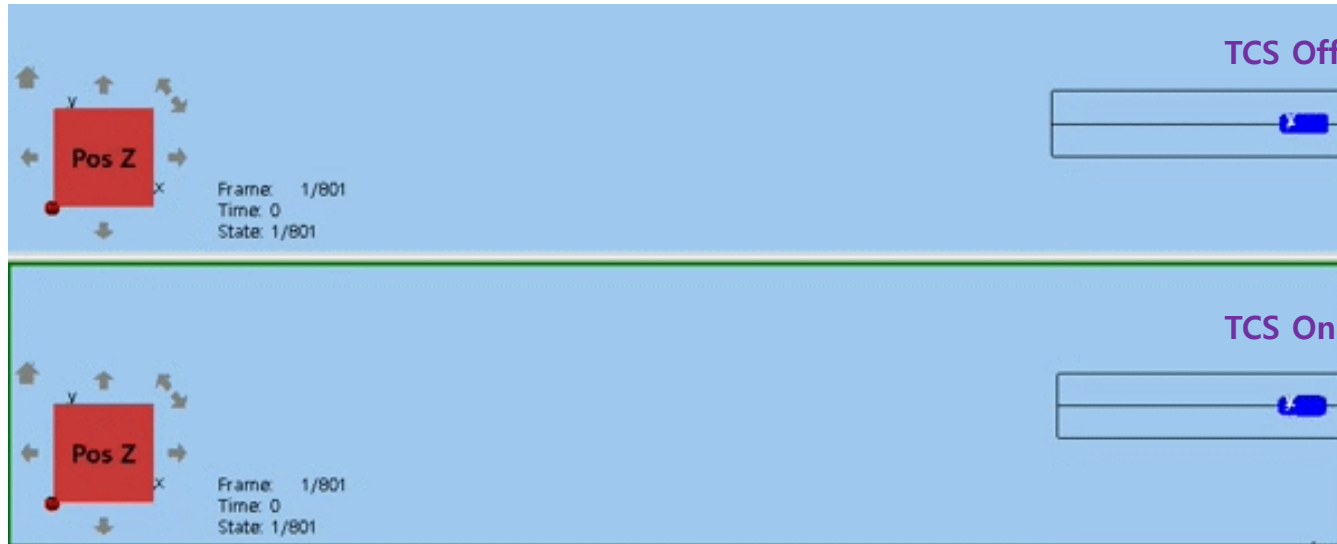
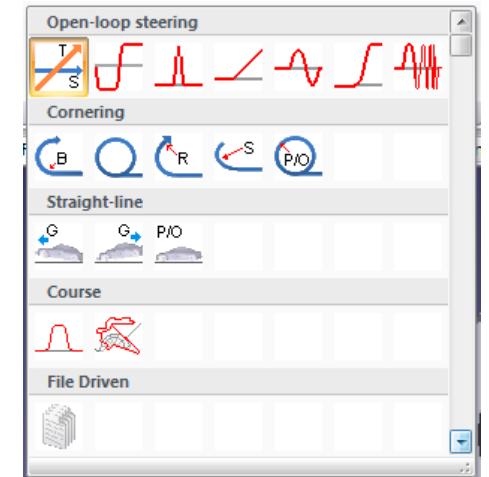
# Toolkit : CAR

- Car for automotive area based on the vehicle dynamics
  - CAR has been used to analysis K&C and R&H performances of automotive system.
  - Various templates for the chassis system are provided.
  - Various loading conditions are pre-defined.

Acceleration	
Initial Velocity	10km/h
Start Time	0sec
Final Throttle Ratio	80%



## < Simulation Scenario >



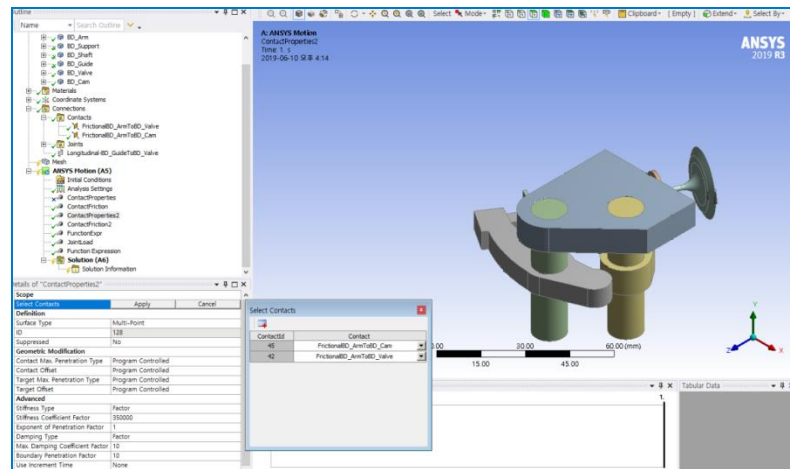
# Contents

- Overview of ANSYS Motion
  - Basic functionalities
  - Simulation capabilities
  - Introduction of toolkits
- **ANSYS Motion Workbench 2019 R3**
  - Modeling Concept
  - Supported Entities
  - Future Plan & Demo
- Examples
- Development strategy
  - High performance solver (MPP solver)

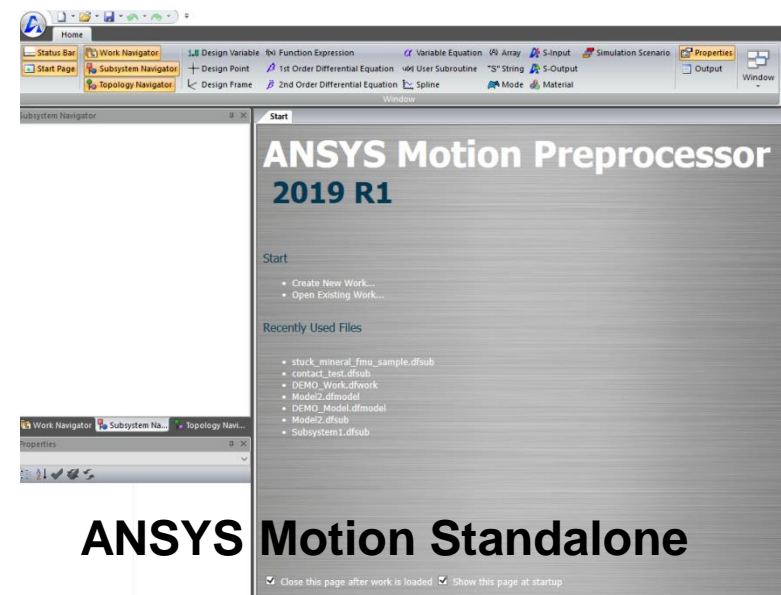
# What's ANSYS Motion

- Integrate Motion solver technology into Ansys Mechanical for the complete workflow.
  - ANSYS Motion Workbench and ANSYS Motion Standalone with one license.
  - ANSYS Motion Workbench is very friendly for ANSYS users
  - ANSYS Motion Standalone with various functionalities for MFBDD.

*First release in 2019 R3, Installed with ANSYS Motion*



**ANSYS Motion Workbench**



**ANSYS Motion Standalone**

# ANSYS Motion ACT – Modeling Concept

- ANSYS Motion model can be build with **native MECH objects**, **AM objects** and **properties**.

The screenshot displays the ANSYS Motion 2019 R3 software interface. On the left, the Outline pane shows a hierarchical tree of model components including BD\_Arm, BD\_Support, BD\_Shift, BD\_Guide, BD\_Valve, BD\_Cam, Materials, Coordinate Systems, Connections, Contacts, Joints, Mesh, and ANSYS Motion (A5). The central workspace shows a 3D mechanical assembly with a coordinate system (X, Y, Z) and a scale bar ranging from 0.00 to 60.00 (mm). A large, semi-transparent diagram is overlaid on the workspace, illustrating the modeling concept: **ANSYS Motion Model = ANSYS Mech. Object + ANSYS Motion Object & Property**. Below this diagram, the 'Details of "ContactProperties2"' pane is visible, showing various settings for a contact property, including Scope, Definition, Geometric Modification, and Advanced options. A 'Select Contacts' dialog box is also open, showing a list of contact IDs and names.

**ANSYS Motion Model = ANSYS Mech. Object + ANSYS Motion Object & Property**

**Details of "ContactProperties2"**

Scope	
Select Contacts	Apply Cancel
Definition	
Surface Type	Multi-Point
ID	128
Suppressed	No
Geometric Modification	
Contact Max. Penetration Type	Program Controlled
Contact Offset	Program Controlled
Target Max. Penetration Type	Program Controlled
Target Offset	Program Controlled
Advanced	
Stiffness Type	Factor
Stiffness Coefficient Factor	350000
Exponent of Penetration Factor	1
Damping Type	Factor
Max. Damping Coefficient Factor	10
Boundary Penetration Factor	10
Use Increment Time	None

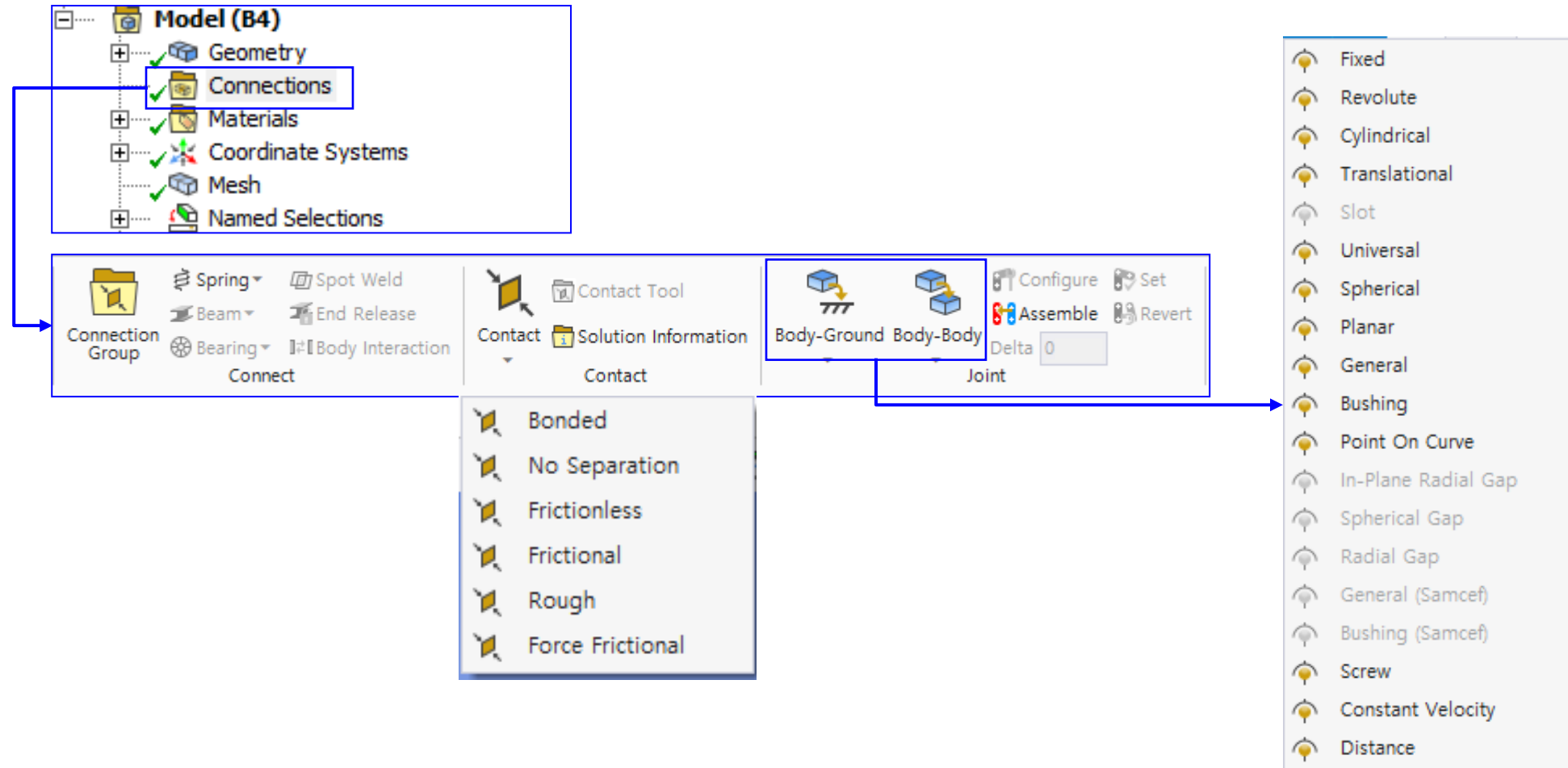
**Select Contacts**

ContactId	Contact
45	FrictionalBD_ArmToBD_Cam
42	FrictionalBD_ArmToBD_Valve



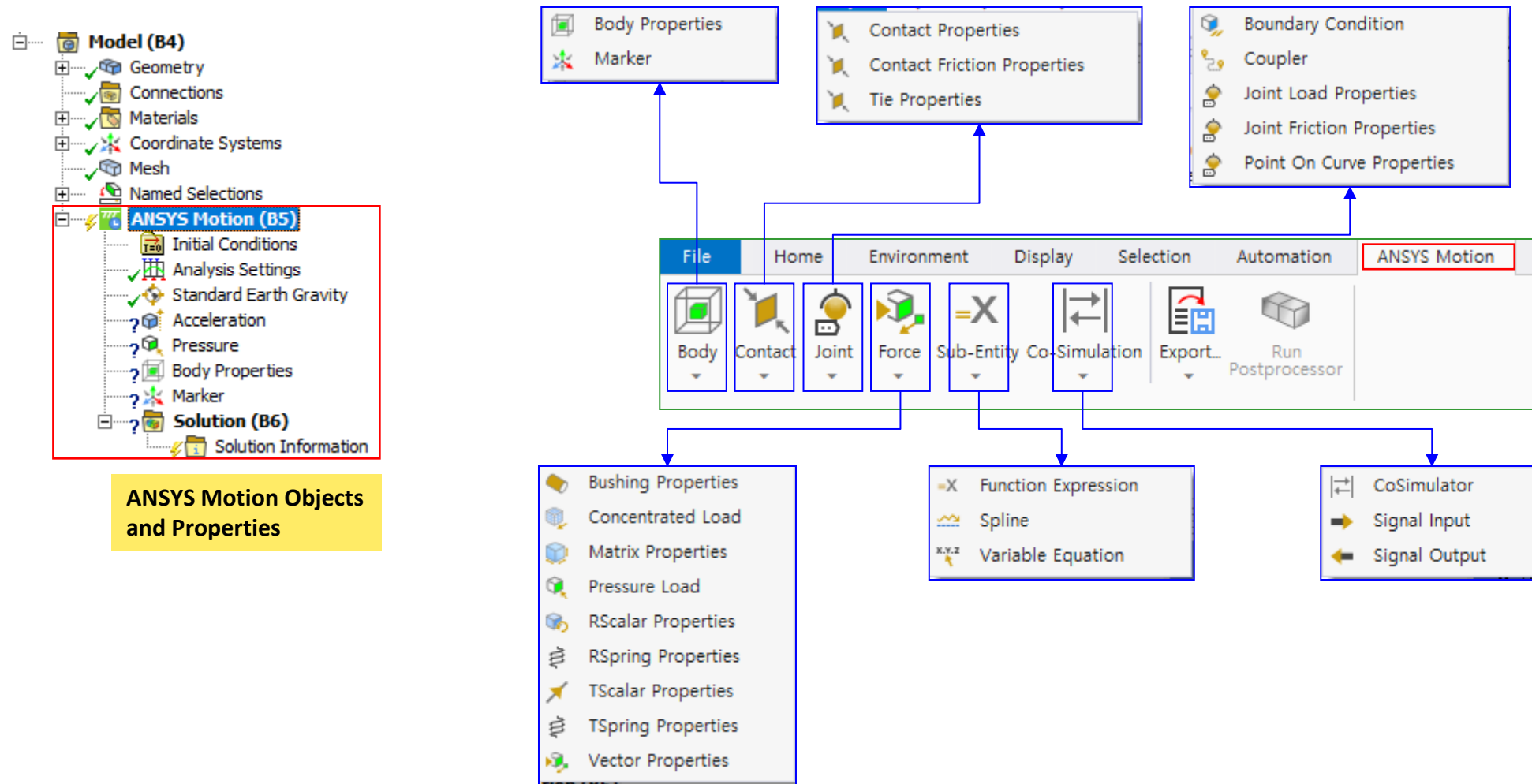
# ANSYS Motion ACT – Available ANSYS Objects

- ANSYS objects on Geometry, Connections, Materials, Coordinate Systems, Mesh, and Named Selection are available in ANSYS Motion.



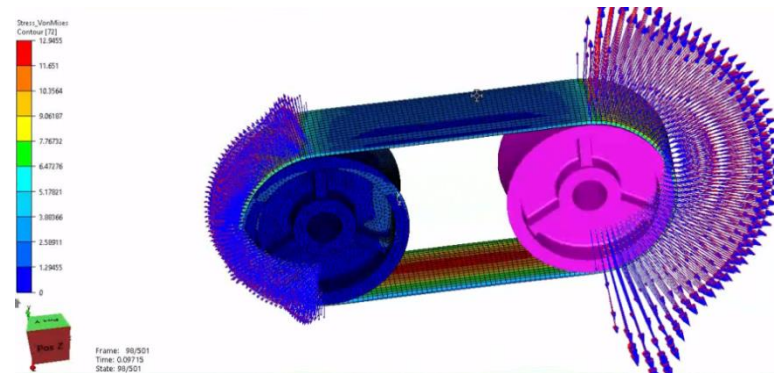
# ANSYS Motion ACT – Available AM Objects and Properties

- **ANSYS Motion objects and properties** are defined from the content and ribbon menu of ANSYS Motion.



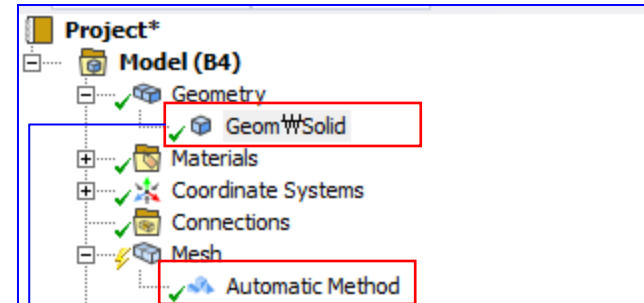
# ANSYS Motion ACT – Various Body Types

- Various body types such as nodal, modal and rigid bodies can be built together in a model.



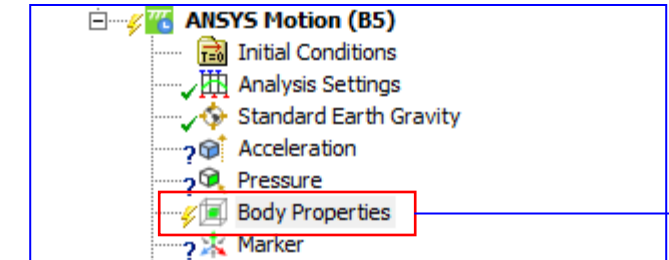
Dynamics system with Nodal, modal, and rigid bodies

## Nodal Body of ANSYS Motion



Details of "GeomWSolid"	
+ Graphics Properties	
- Definition	
<input type="checkbox"/> Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Treatment	None
- Material	
Assignment	Structural Steel
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
+ Bounding Box	
+ Properties	
+ Statistics	
- CAD Attributes	
PartTolerance:	0.00000001
Color:143.175.143	

## Modal Body of ANSYS Motion



Details of "Body Properties"	
- Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
- Definition	
Type	Generate modal data file
Type of Mode Analysis	Static Correction Mode
Analysis Settings	Program Controlled
Suppressed	No

# ANSYS Motion ACT – Complex Function Expression

- Function expression on motion or force can be dependent on the position, velocity, acceleration, other forces, or state variables.

The screenshot displays the ANSYS Motion (B5) interface. The 'Details of "Function Expression"' panel is open, showing the following information:

Definition	
Function Expression	10000*DX(#1,#2,#2)+10*VX(#1,#2,#2)
ID	49
Suppressed	No
Argument List	Tabular Data

A yellow box labeled 'Function Expression' points to the 'Function Expression' row in the table. A yellow box labeled 'Argument List' points to the 'Argument List' row in the table. The 'Argument List' panel is also visible, showing a table with two arguments:

No	Argument
1	Translational - Ground To Dummy/ActionMarker
2	Translational - Ground To Dummy/BaseMarker



# ANSYS Motion ACT – Supported Entities in 2019 R3

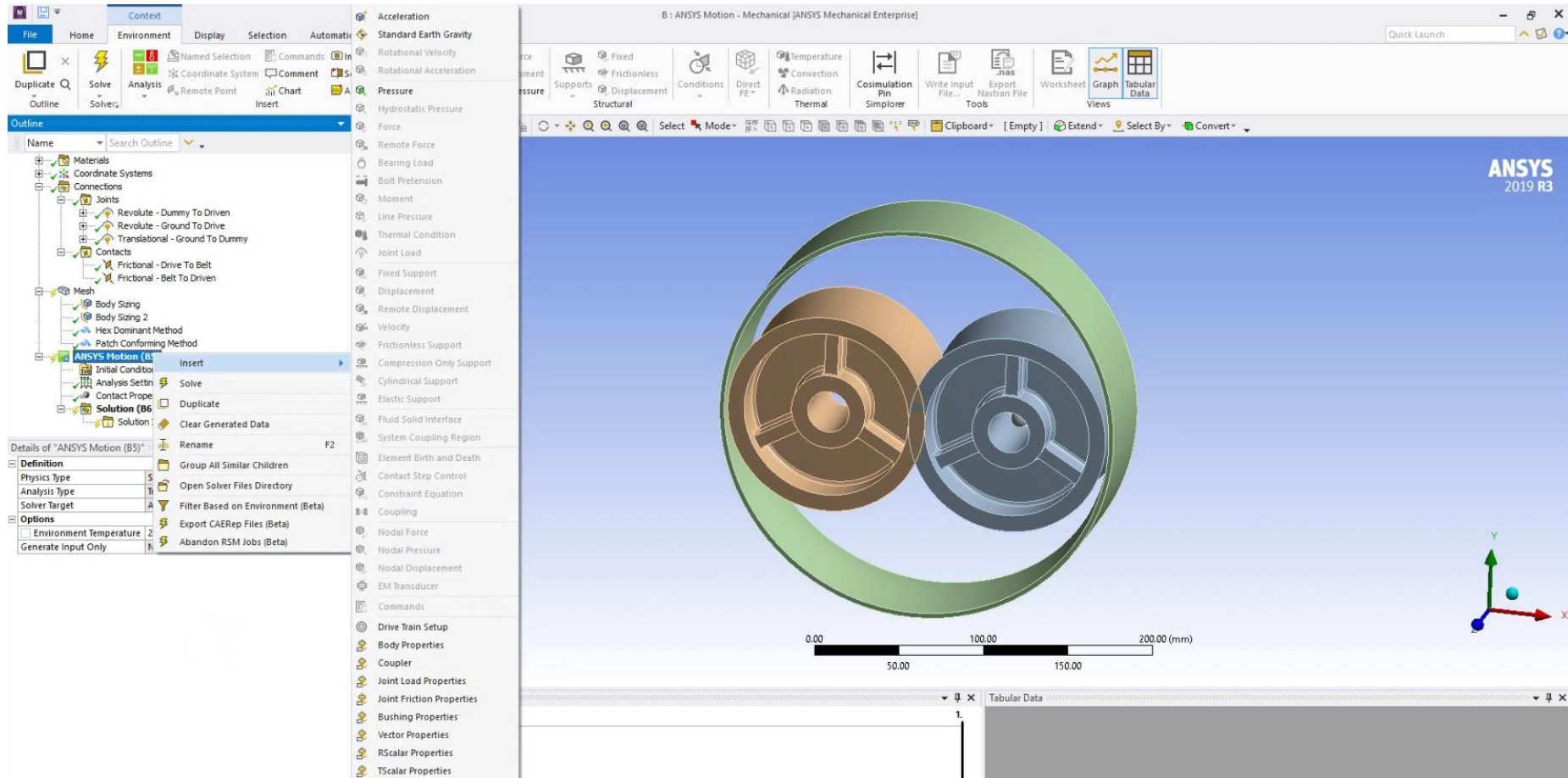
Contents		Target Version
Body	<b>Rigid, FE Nodal, FE Modal, Marker</b>	<b>2019 R3</b>
	EasyFlex Nodal & Modal	2020 R2
Constraint	<b>FIX, REV, TRA, CYL, UNI, SPH, PLA, SCR, DIS, COV, PTCV, Coupler, BC</b>	<b>2019 R3</b>
	<b>Friction (REV, PTCV), Motion (REV, TRA, CYL)</b>	<b>2019 R3</b>
	Joint Primitives, CVCV	2020 R2
Force	<b>Spring (T/R), Scalar (T/R), Vector, Bushing, Matrix, CLOAD, PLOAD</b>	<b>2019 R3</b>
	Tire, G-Bearing	2020 R2
Contact	<b>General3D(RTR3D, FTR3D, FTF3D), TIE</b>	<b>2019 R3</b>
	Contacts with CurveSet	2020 R2
Sub Entity	<b>Function Expression, Spline, S-Input, S-Output, Materials</b>	<b>2019 R3</b>
	Function USUB, String, Array, Equations, Simulation Scenario	2020 R2
Co-Sim	<b>Matlab Interface, FMI Slave</b>	<b>2019 R3</b>

# ANSYS Motion ACT – Future Development Plan

Contents	Planned Version
Drivetrain	2020 R1 (Jan. 2020)
Links	2020 R1
EasyFlex	2020 R2 (May. 2020)
Missing Entities	2020 R2
Car	2020 R3 (Sep. 2020 - Depend on Market)
Upgrade Toolkits	2020 R3

# ANSYS Motion ACT – Demonstration with Movie

- Modeling of FE Belt system and dynamics analysis are presented!



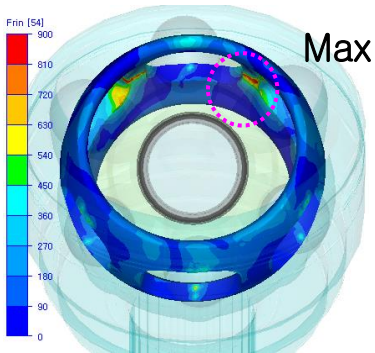
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  - High performance solver (MPP solver)



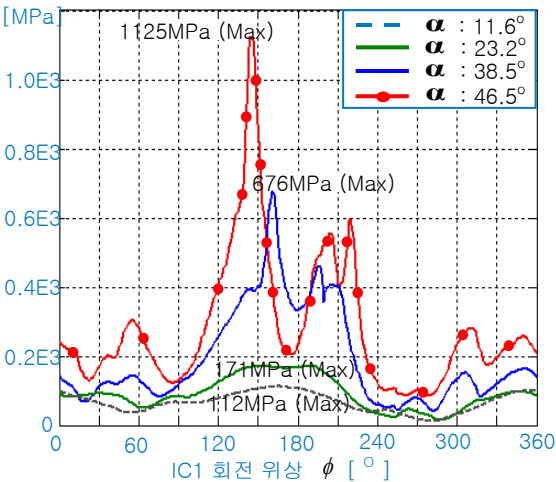
# Constant Velocity Joint - Cage broken issue

## Reproduction

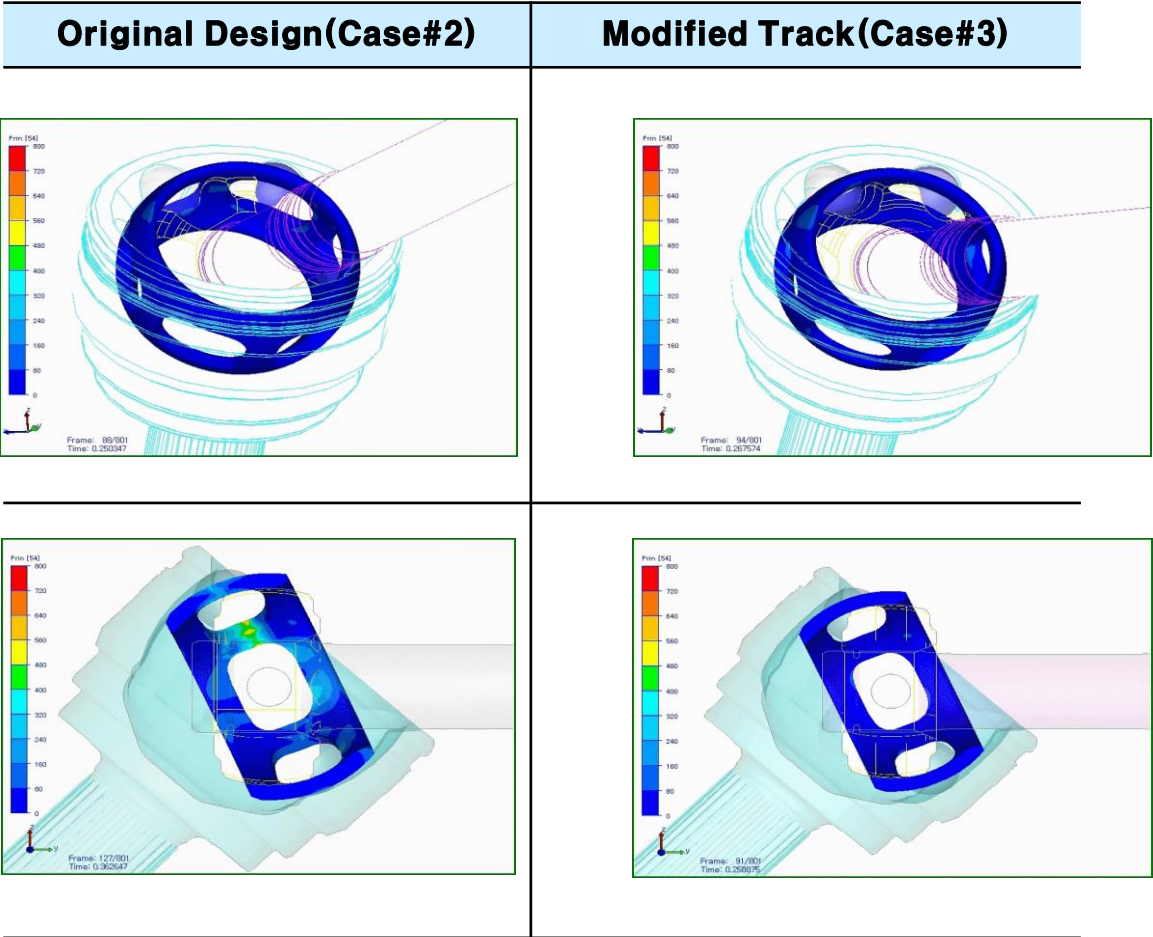


## Define a problem and improve a design

– High rotation and asymmetry

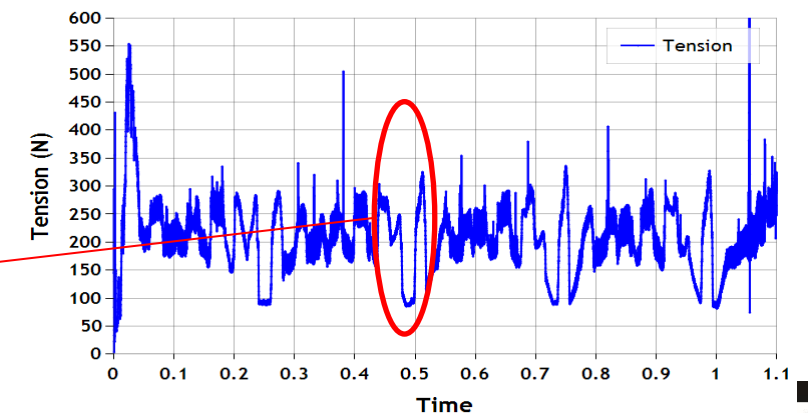
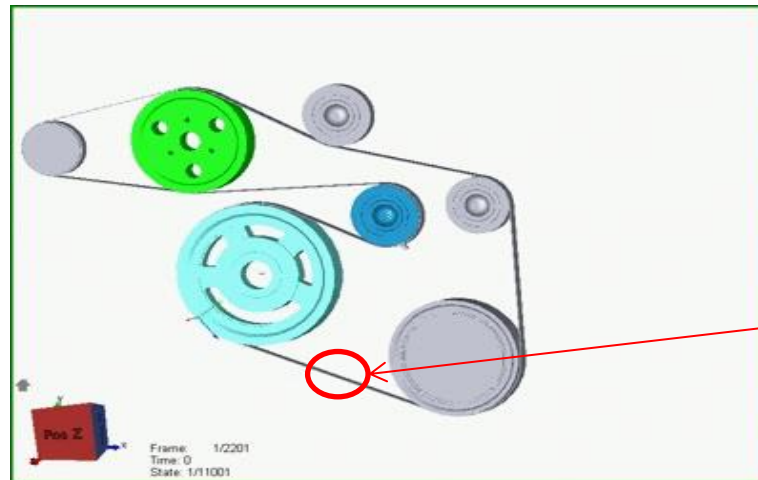
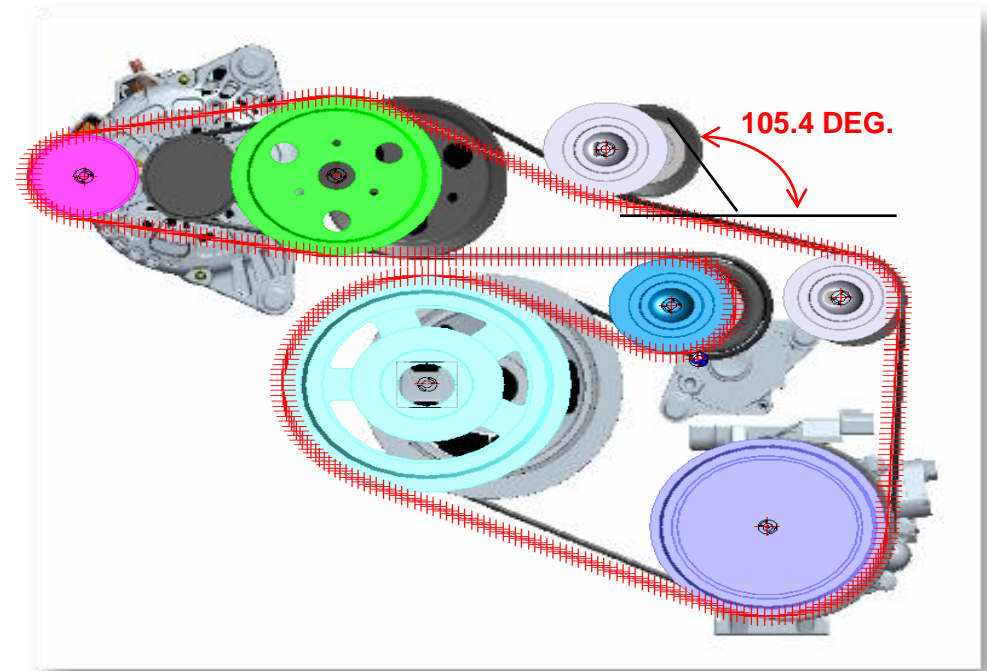


	Case#1	Case#2	Case#3
	원안		변경안
	Circle track	Circle track	Variable Track
	A O B	A O B	A O B



# Engine Auxiliary BELT system

- Goal
  - Belt system BMT for engine system analysis
- Contents
  - Belt analysis specialized tool has limitation to include neighboring system components like as chain, engine in detail
  - Requirement : solving within 15 min
  - Operating condition : Max 4000 RPM, include tensioner preload.
  - Target : Monitoring vibration & slip ratio
  - Available → Belt tension / Loss / Stiction contour

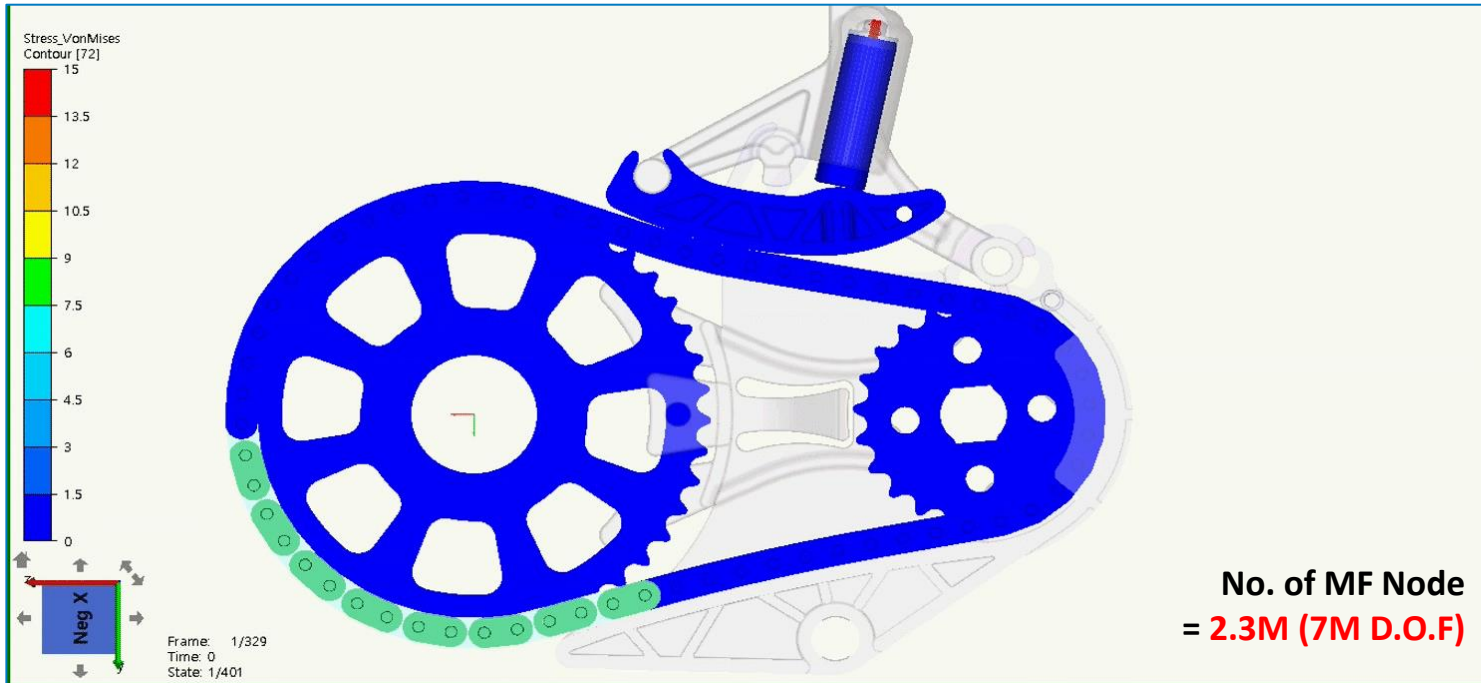


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# 2nd ANSYS Motion solver Revolution

- ✓ Chain model – MF guide, MF piston, MF chain links(48) (**0.4sec 400 frame**)



Version 6.2

Content	V6.2
Speed	<b>32 hr</b>
Memory (GB)	<b>235</b> → Can be more improved!

- ❖ **GMS** solver can solve the giant model with **6.2M D.O.F. in 32GB RAM**.
- ❖ **GMS MPP** solver is possible to solve more D.O.F. and speed up in **N order**.



# ANSYS Motion 2019 R3 – PCG solver on MPP computer (Beta)

- Massively Parallel Processing(MPP) solver with PCG method
- About 3 times fast with using 4 nodes.

Intel® Core™ i7 CPU 950 @ 3.07GHz

Model Name	Model Information	CPU Time (sec)			Target
		1 node	4 node	x Times	4 node
Swing Door	29,500 DOF, Solid Element	337	183	x 1.8	x 2.5
Bearing	132,000 DOF, Solid Element	584	318	x 1.8	x 2.7
CVT Pulley	200,000 DOF, Solid Element	9,414	3,147	x 3.0	x 3.5

# Thank you!