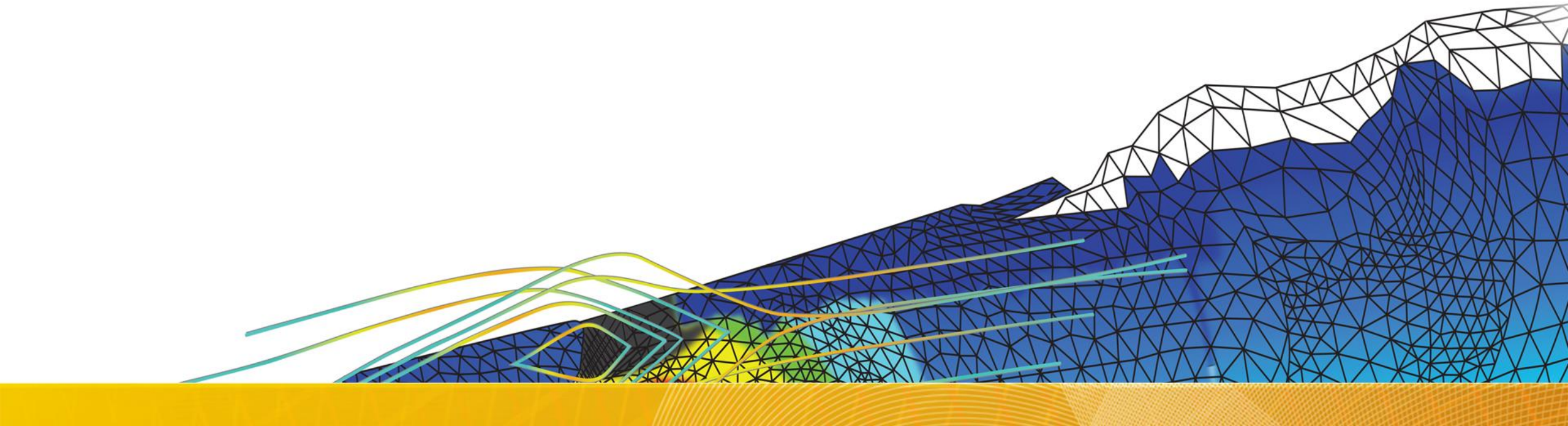
ANSYS®

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

Beginning Period (Starting Business & Development)

- 2006 – Foundation
- 2007 – Establishment Research Institute
- 2009 – **JAPAN distributing agency** of ITOCHU Techno-Solution Corporation
- 2009 – The 1st User's Conference in Korea
- 2010 – **KOREA distributing agency** of Haneul Solution
- 2010 – The 2nd User's Conference in Korea
- 2010 – Awarded form KOREA Government Ministry (Education, Science)
- 2011 – Certification R&D Services
- 2013 – Awarded form KOREA Government Institution
- 2013 – **KOREA distributing agency** of TSNE
- 2014 – **DAFUL5.0** with **MeshFree Dynamics**
- 2015 – **The 1st DAFUL Global CAE Conference in Japan**
- 2015 – The 5th User's Conference in Korea
- 2015 – Awarded form KOREA Government Ministry (Engineering Day
- 2016 – The 6th User's Conference in Korea

SW Development

- 2007 – NX-DAFUL (CAD Embedded)
- 2010 – DAFUL2.0 (1st Standalone DAFUL)
- 2011 – DAFUL3.0 (DAFUL/CAR)
- 2013 – DAFUL4.0 (MeshFree Statics)
- 2014 – DAFUL5.0 (MeshFree Dynamics)
- 2015 – DAFUL5.2 (Drivetrain NVH Toolkit)
- 2016 – DAFUL6.0 (Thermal Analysis, DOE)

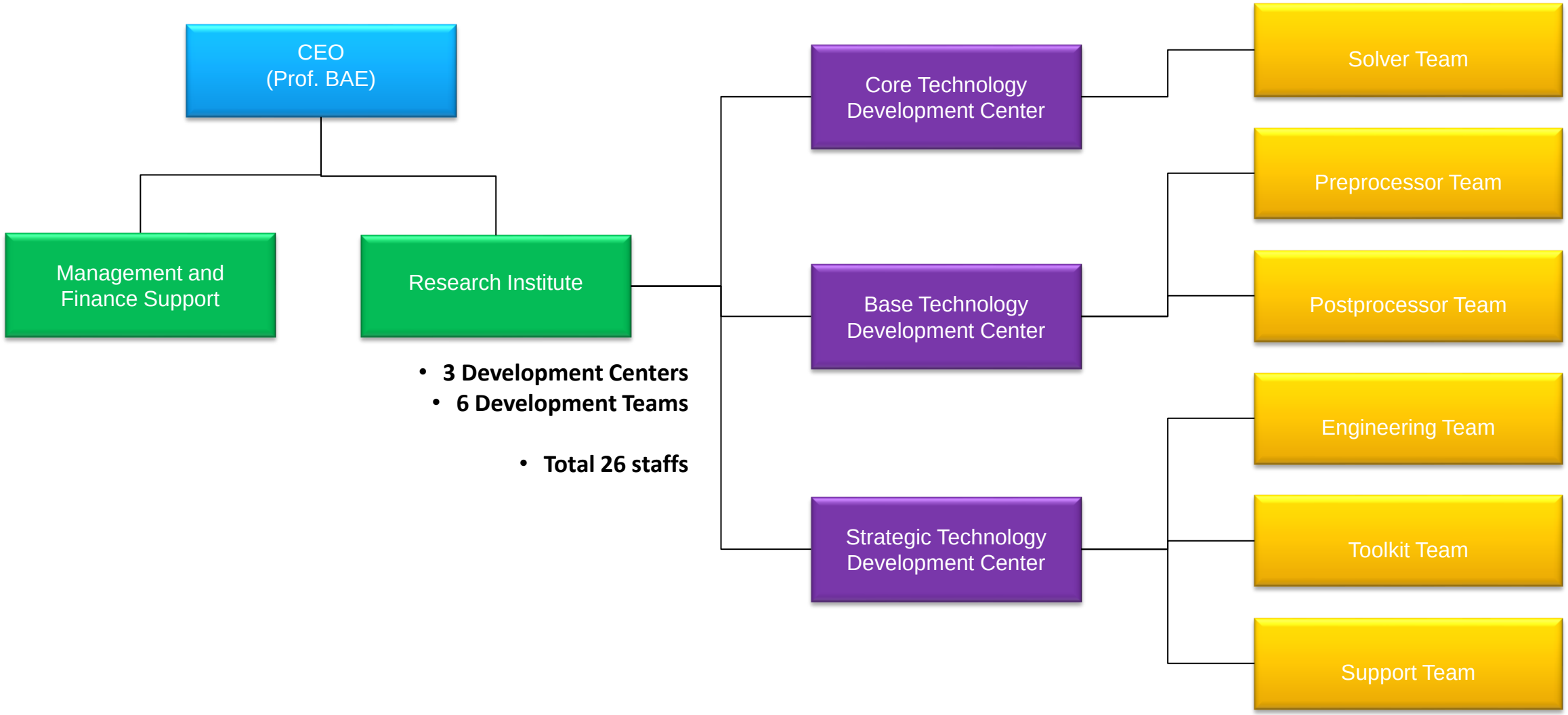
SW Donation for University

- 2013 –Kukmin Univ.
- 2014 –Hongik Univ.
- 2014 –Gunsan Univ.
- 2015 –Kyungil Univ.
- 2016 –Chunbuk Univ.
- 2016 –Hanyang Univ.
- 2016 –Hansung Univ.
- 2017 –Handong Univ.

1st Growth Period (Global Business & Development)

- 2017 - Establish Global Sales Channel
  - Global Distributing Agreement with TSNE
- 2017 DAFUL Development
  - Large scale problem Solver / EasyFlex
  - Improvement Convenience
- **2018 ANSYS MOTION development**
  - **Sales & Dev. contract with ANSYS HQ**
  - **First Releasing ANSYS Motion / Workbench**
  - **218 AE are working for**

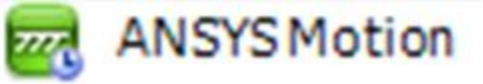
Company Organization



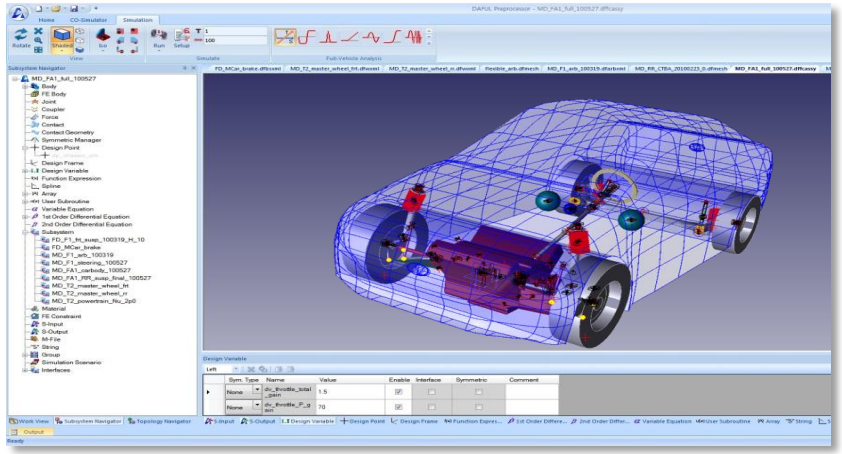
- **3 Development Centers**
- **6 Development Teams**
- **Total 26 staffs**

ANSYS Motion & its Workbench version

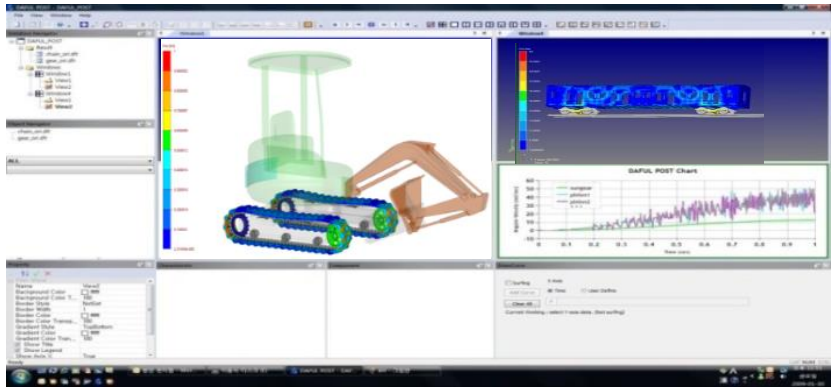
- **Development direction for DAFUL & ANSYS Motion ACT**

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

Overview of ANSYS Motion

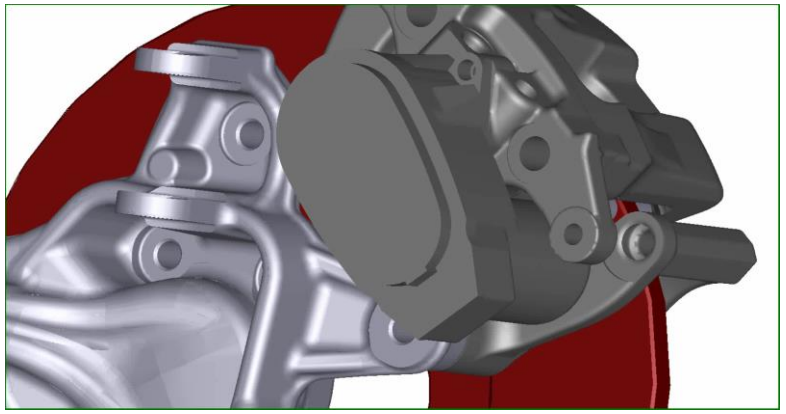


Structural Dynamics Analysis
(PRE, Solver, POST)

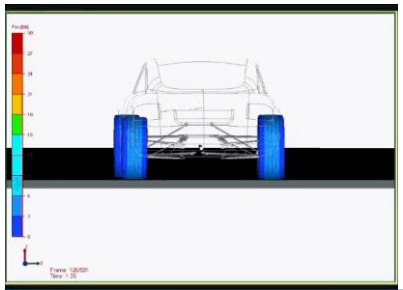


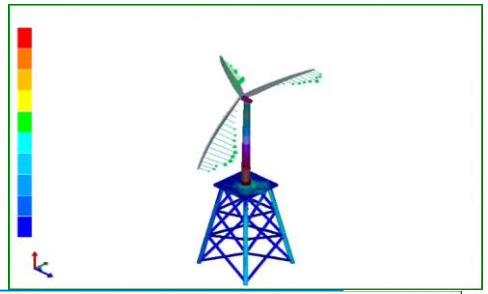
Analysis Scope

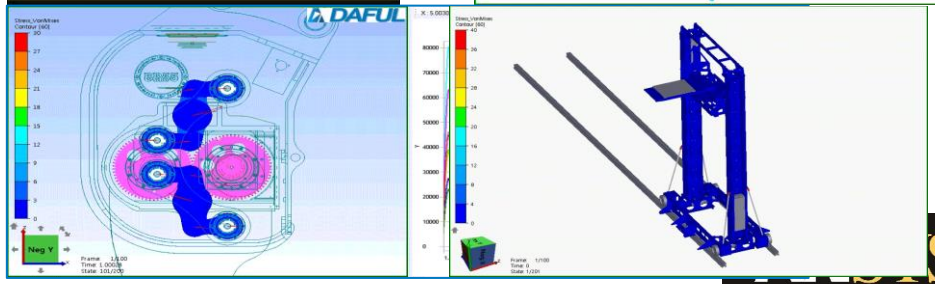
- Multi-Flexible Body Dynamics
- Strength/Fatigue
- Vibration (Linear)
- NVH (Transient)
- Heat Transfer
- DOE Design



Field of Application

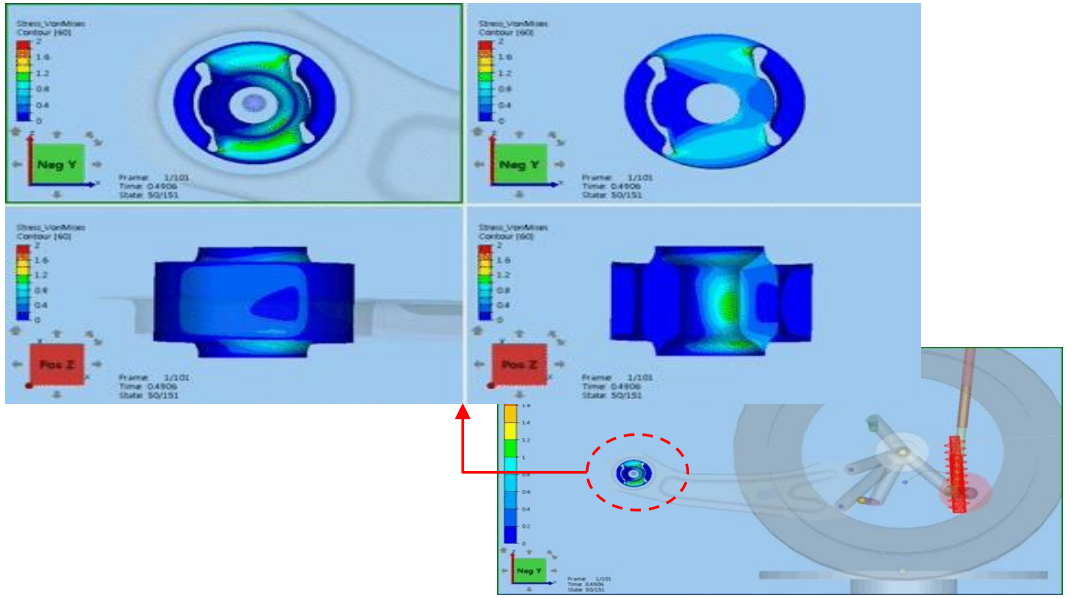


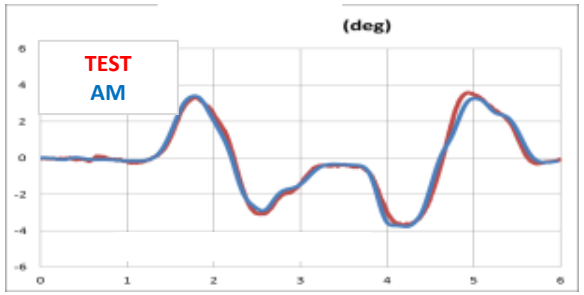


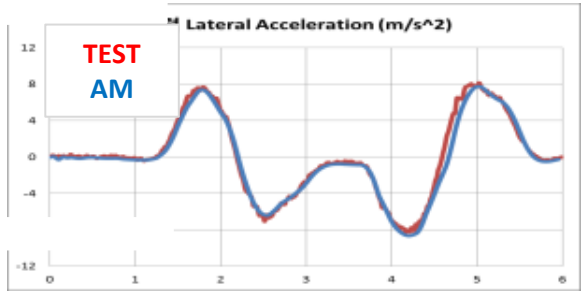


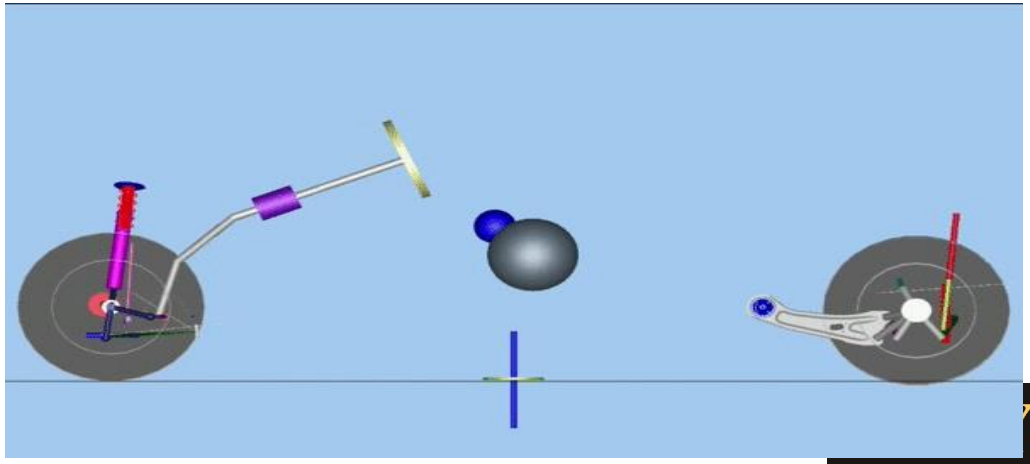
Multi-Body Dynamics (MBD): System Analysis

Double Lane Change



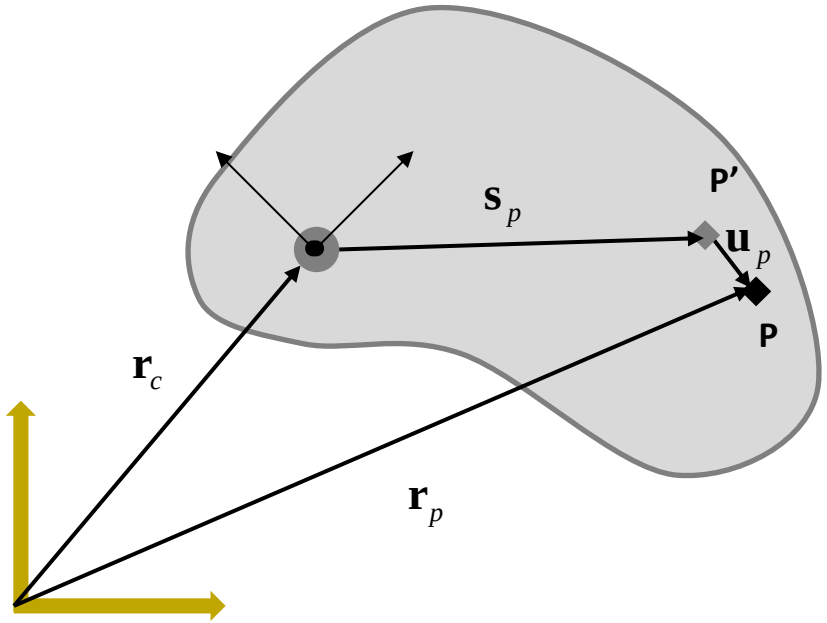






Multi Flexible body system

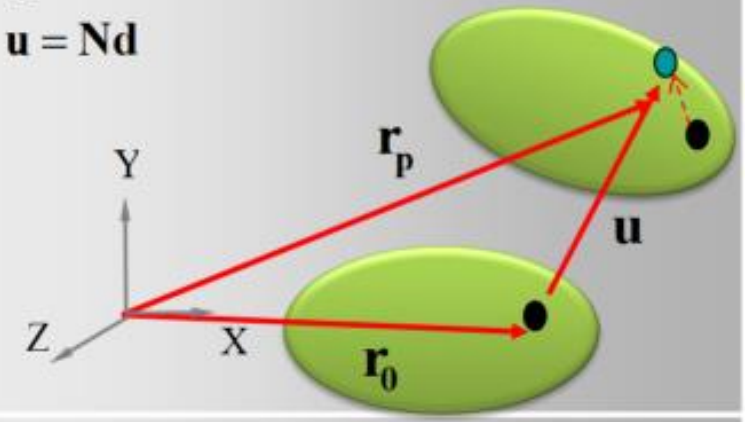
- **Remove rigid body motion**



Explicit

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

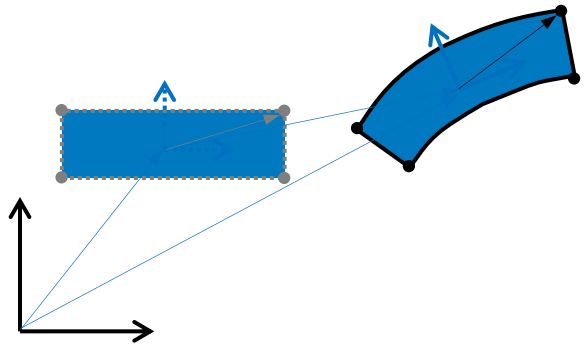
$\mathbf{u} = \mathbf{N}\mathbf{d}$



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

- **Position relationship of deformable point, P**

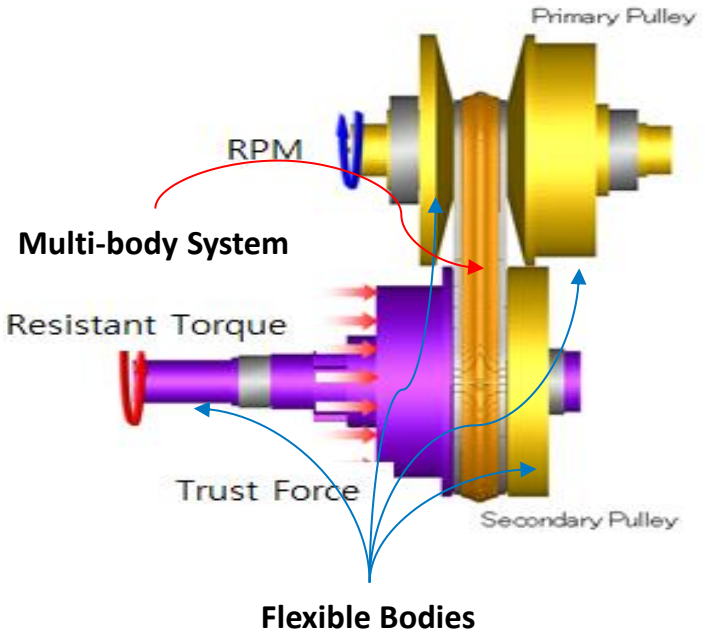
$$\mathbf{r}_p = \mathbf{r}_p + \mathbf{A}_p\left(\mathbf{s}'_p + \mathbf{u}'_p\right)$$

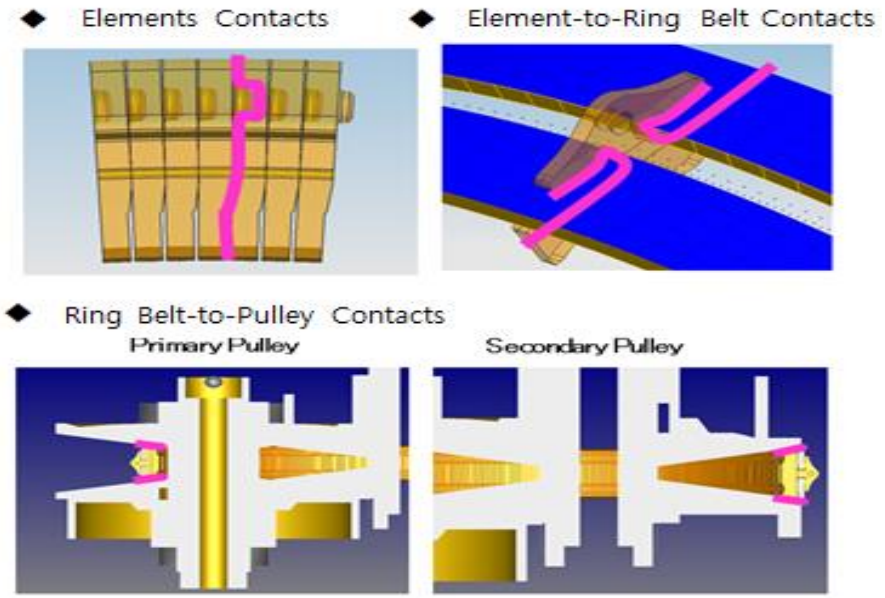


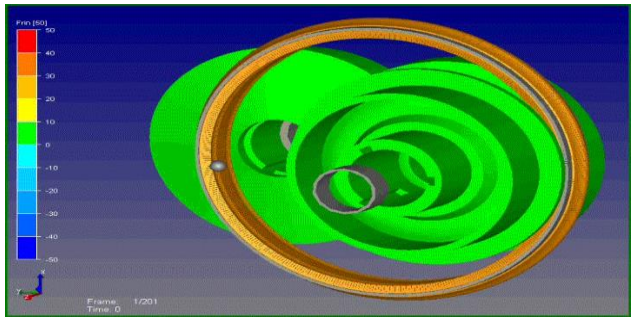
- Geometric non-linearity is caused by a rotation.
- Kinematics of flexible body can be simplified by using the orientation matrix.

Contact on Belt type CVT system

- JATCO, HMC and FHI are partners for CVT CAE







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

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

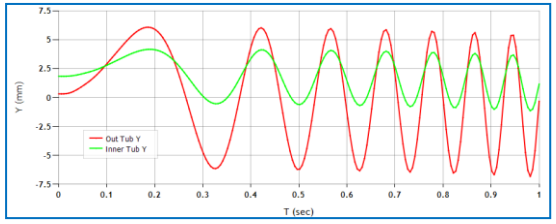
Simulation capability – Dynamics(NVH) and Fatigue

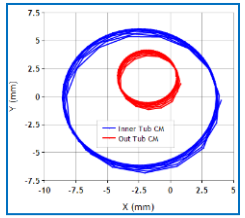
Dynamics Analysis

Confidential

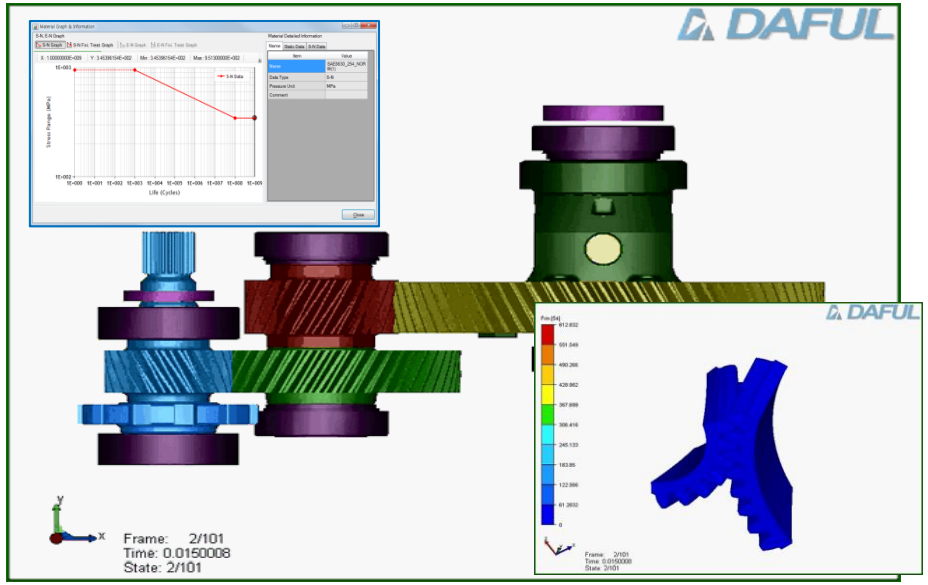
- ✓ Dynamics Behavior
- ✓ Small/Large Deformation
- ✓ Contact Analysis
- ✓ Vibration Analysis

Confidential

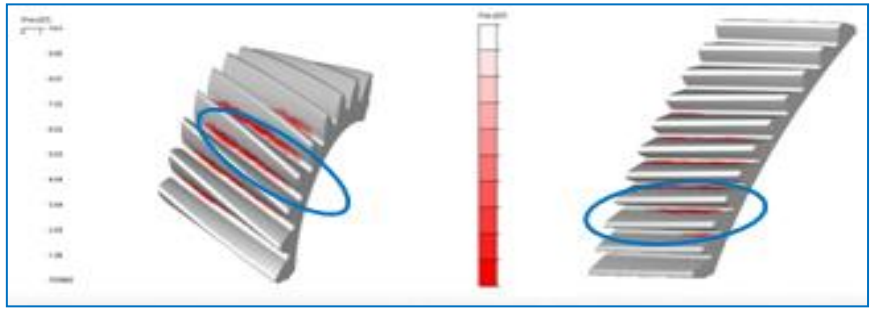




Fatigue and Damage Analysis



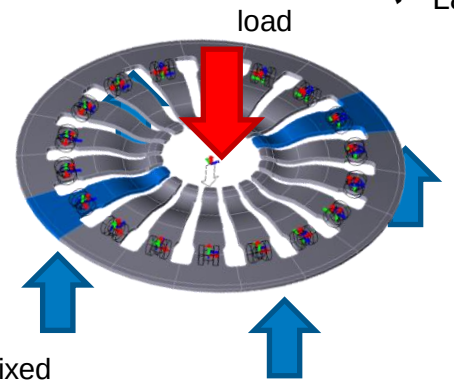
- ✓ Design Stress
- ✓ S/N Curve

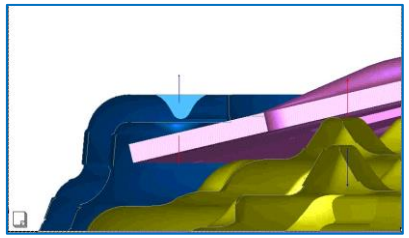


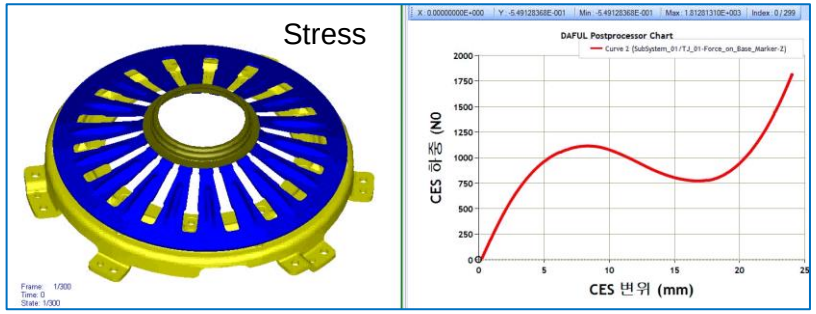
Simulation capability – Static & Eigenvalue

Static and Compliance Analysis : Non-Linear

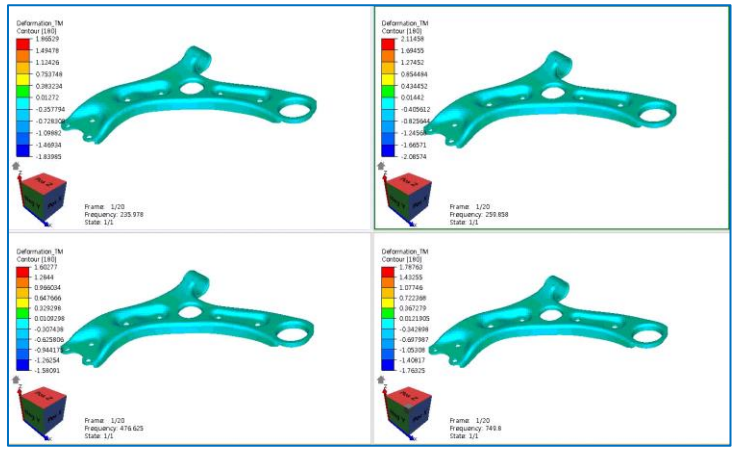
✓ Large Deformation





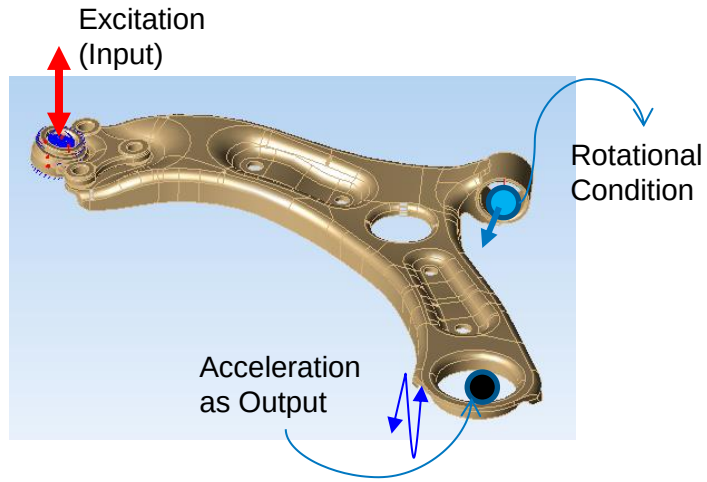


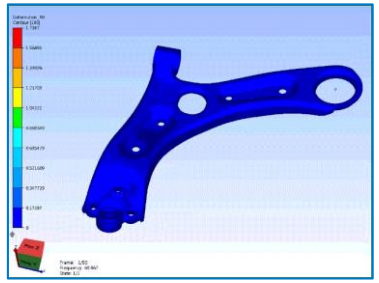
Mode and Natural Frequency Analysis



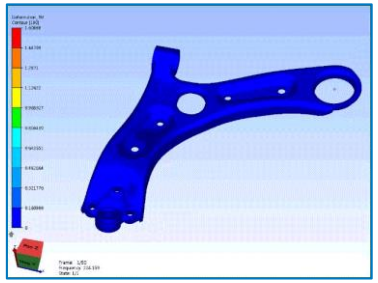
Mode	Natural Frequency (Hz)
1	2.28E+02
2	2.48E+02
3	4.55E+02
4	6.88E+02
5	7.23E+02
6	1.25E+03
7	1.27E+03
8	1.49E+03
9	1.60E+03
10	1.77E+03

Frequency Response Analysis

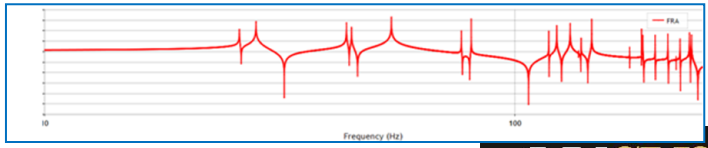




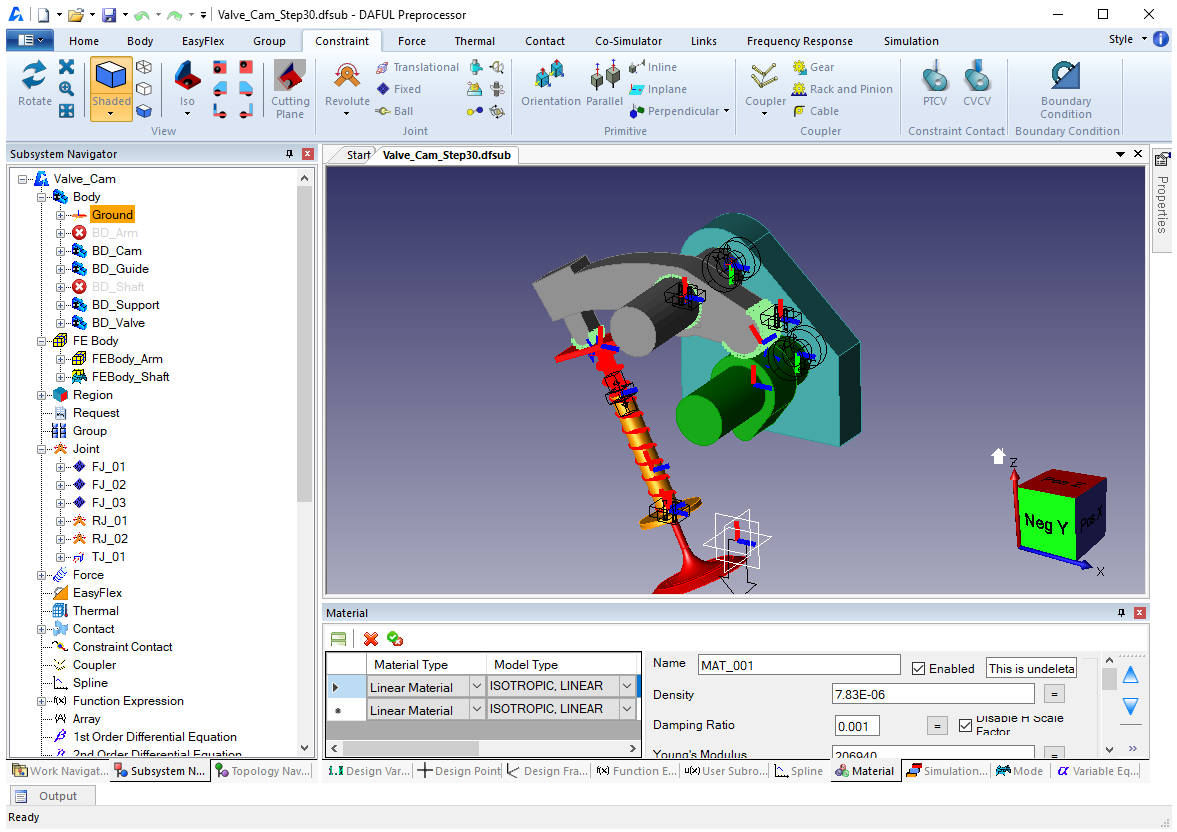
1st Mode

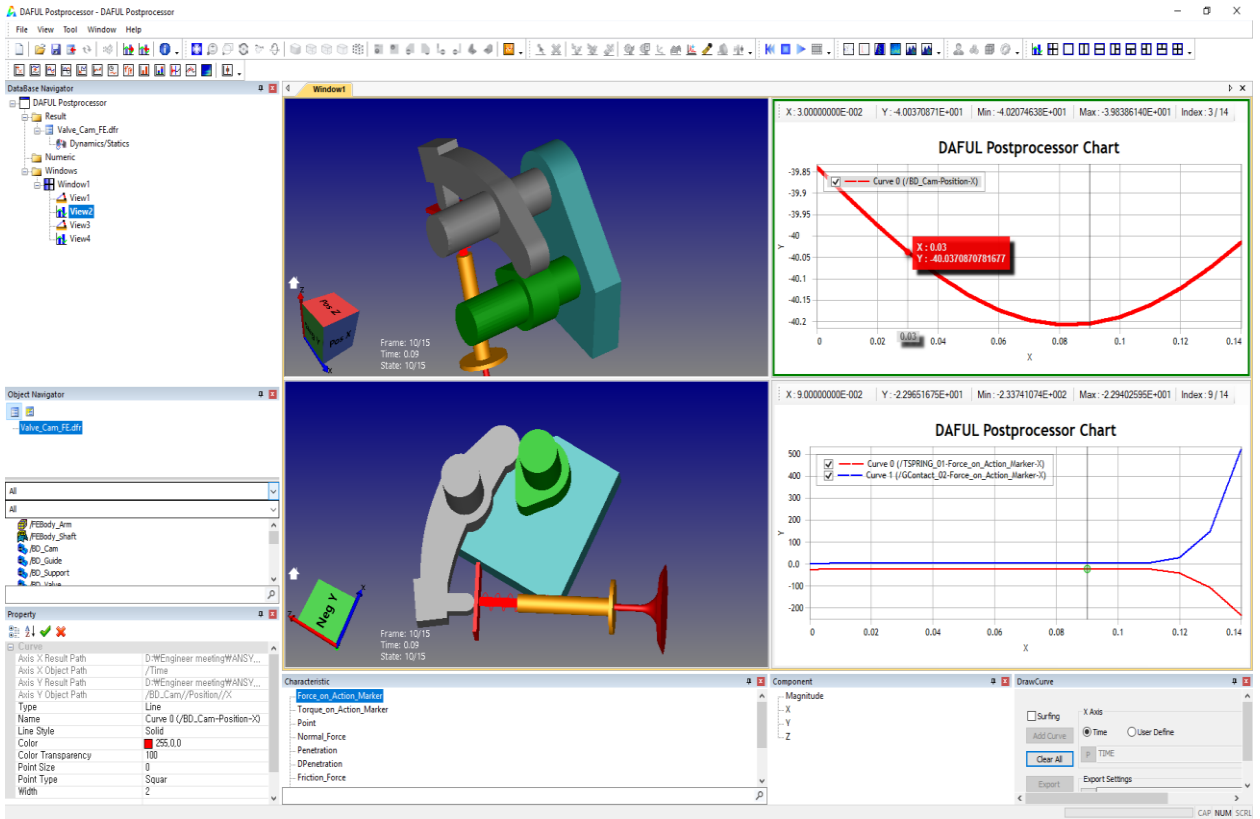


2nd Mode



Preprocessor & Postprocessor





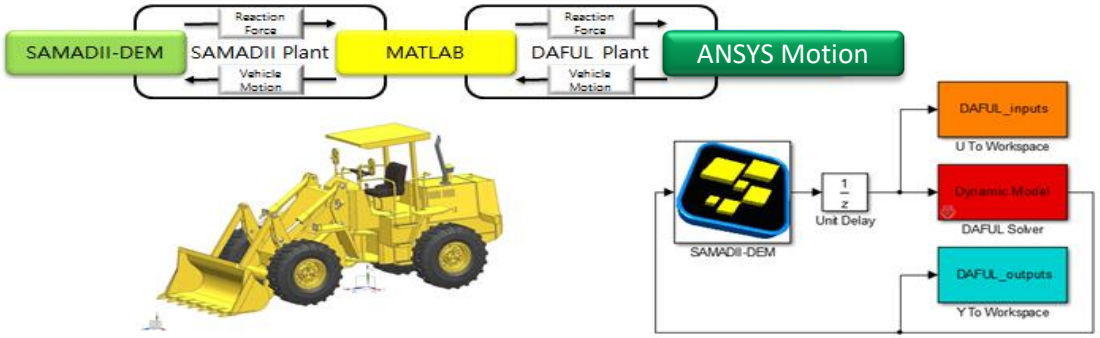
System interface – Various combinations

System Model
- MATLAB
- FMI Slave

POST Processing
- FEMFAT (Fatigue)
- EnSight

CFD Co-Simulation
- CFX
- Phoenix

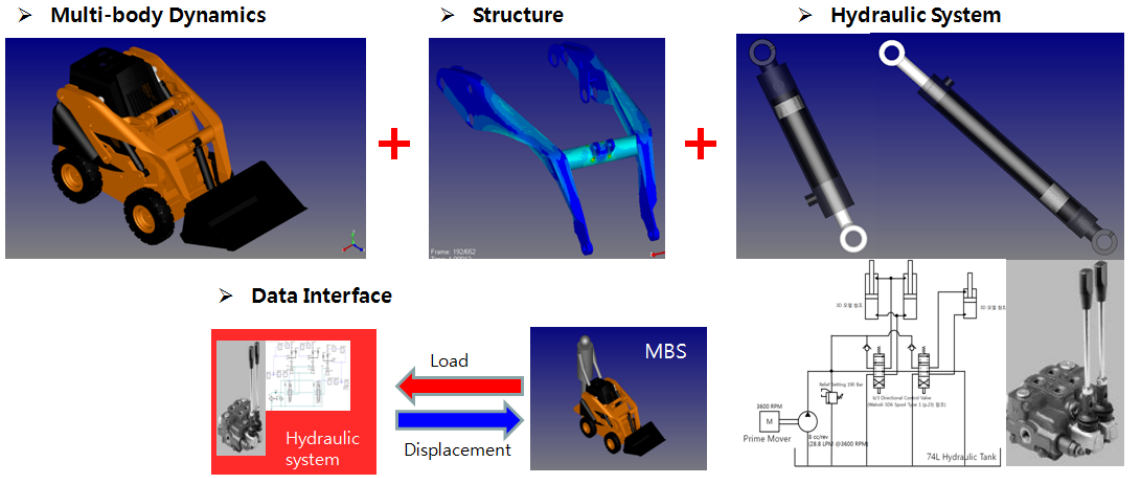
Interface with Particle Dynamics - Bucket Loader



Interface with CFD - Circuit Breaker Mechanism

Confidential

FMI Interface with Hydraulic(1D) – Mini Loader



ANSYS Motion Toolkits

- ***DRIVETRAIN***
  - Focusing on the dynamic NVH
  - Powertrain components
  - Special algorithm for Gear, Bearing
  - Outputs for a NVH
- ***LINKS***
  - Build a continuous system
  - Easy way to assemble & manage
  - Special component for Tracked Vehicle
- ***CAR***
  - Template based vehicle dynamics
  - Predefined simulation scenario & outputs
  - Vehicle characteristics
- ***EasyFlex***
  - Meshfree technique

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

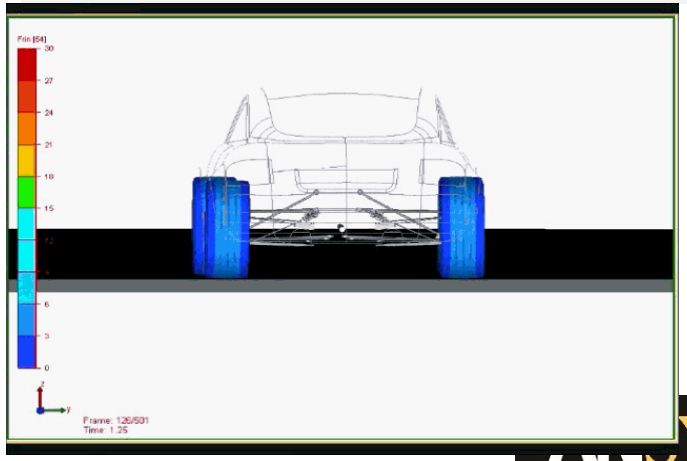
Track (for Tracked Vehicle)
Joint with Volvo Construction

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

Car (for Automotive)
Joint with Hyundai Automotive

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

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

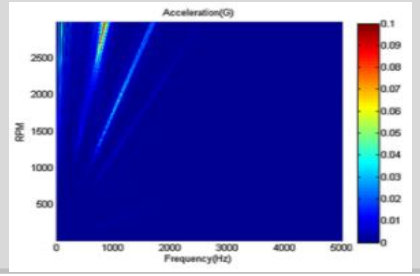


Toolkit : Drivetrain

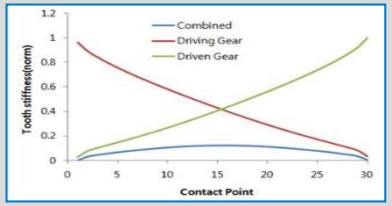
- A drivetrain toolkit has been used to analysis NVH of driveline system which consists of gear pairs, shaft, bearings, and housing.
- Gear supports the involute, cycloid, and rack types for tooth shape. Mesh stiffness is automatically calculated with considering a misalignment.
- Bearing supports the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

Part/System Modes

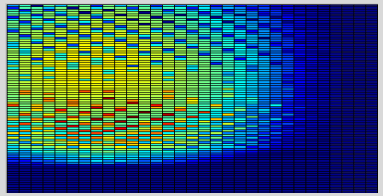
Color Map



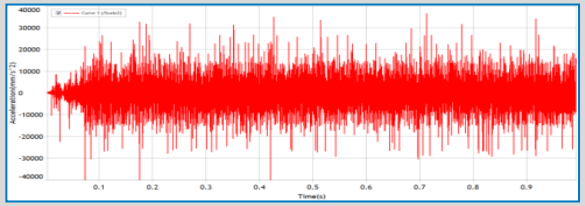
Gear/Bearing/Web Stiffness



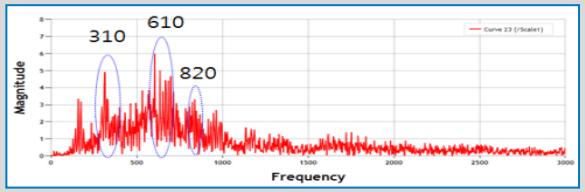
Tooth Contact Pressure



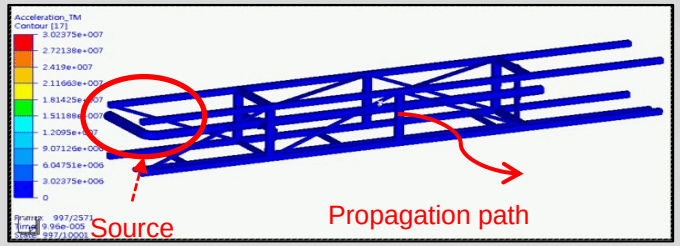
Results in Time Domain



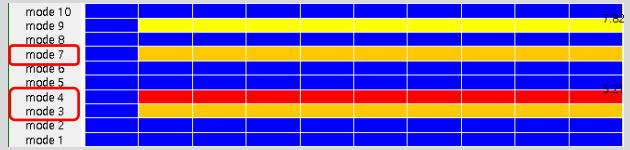
Results in Frequency Domain



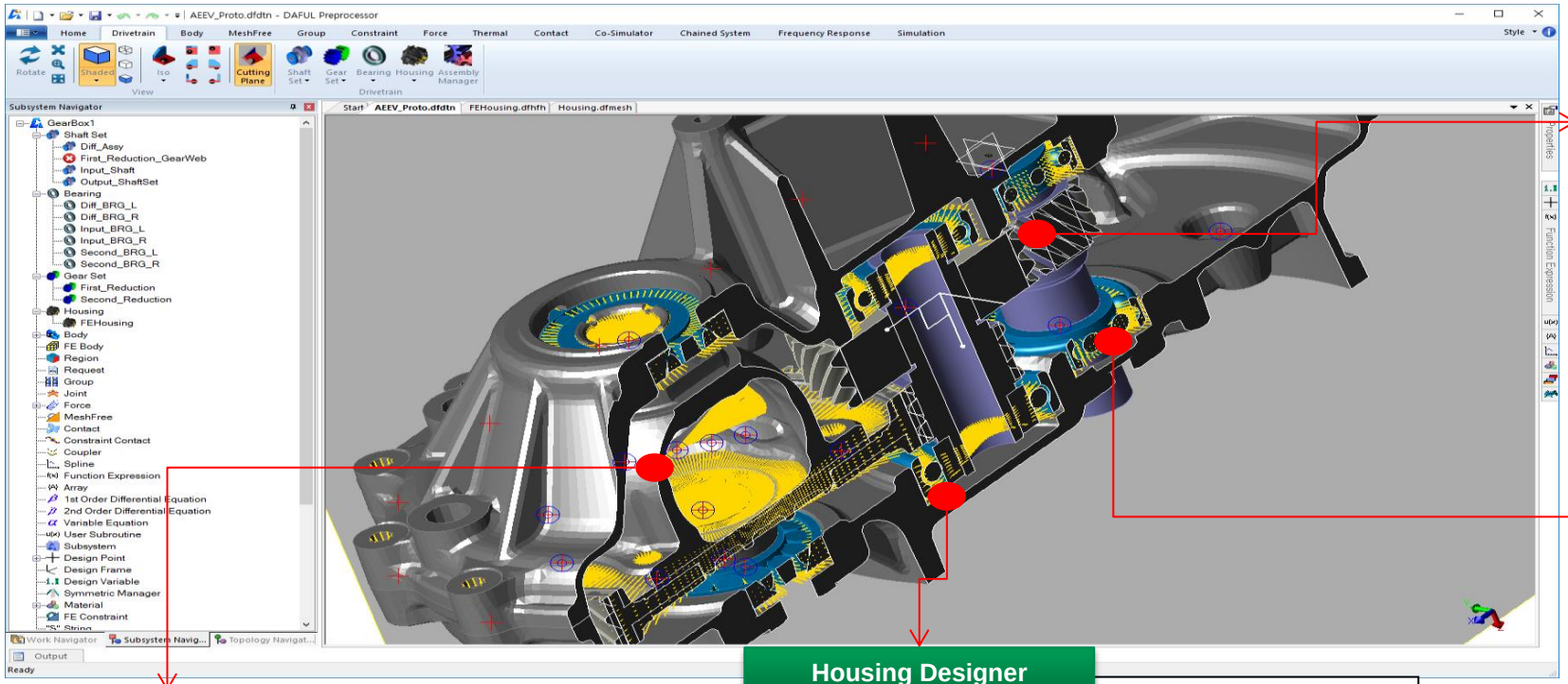
Acceleration Contour for Path



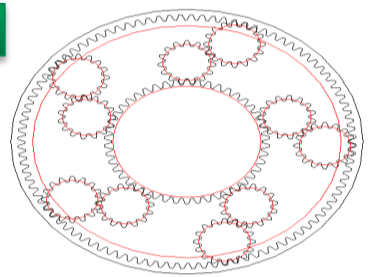
Contribution Analysis

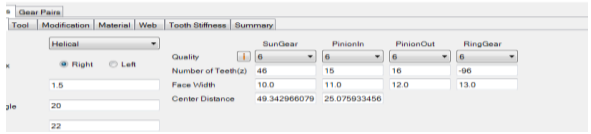


Overview of Drivetrain

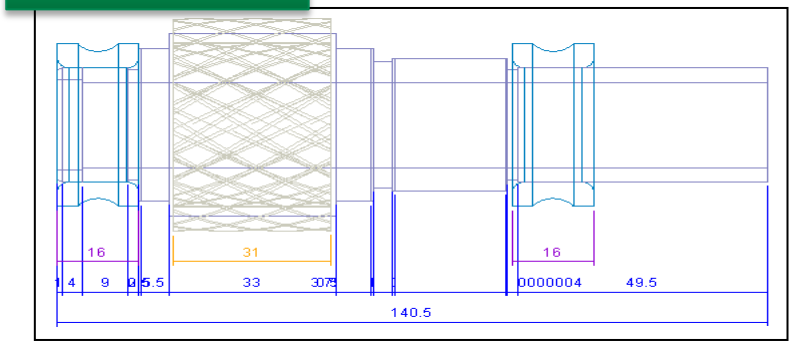


Gear Designer

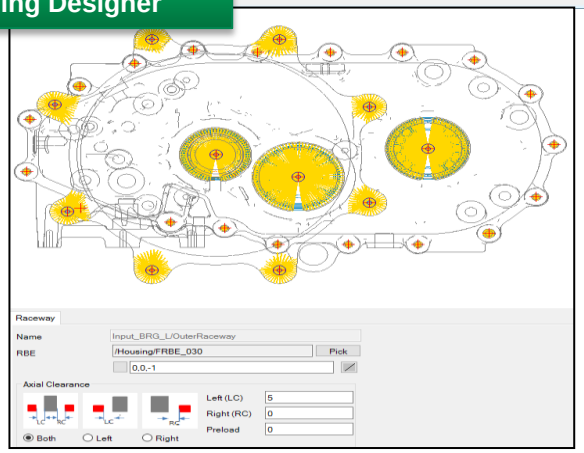




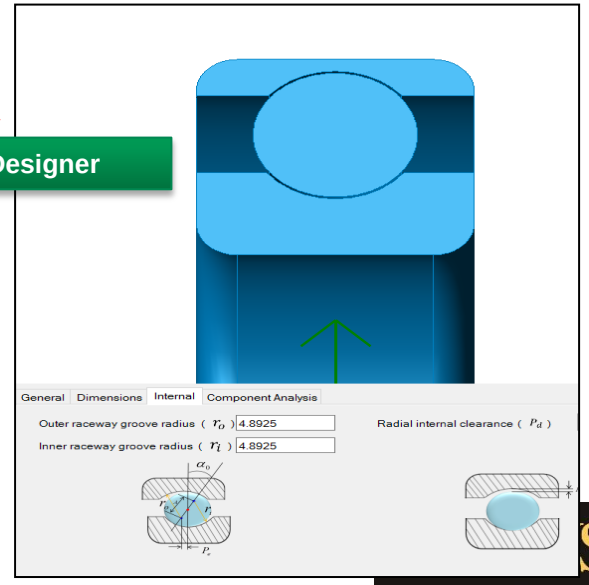
Shaft Designer



Housing Designer



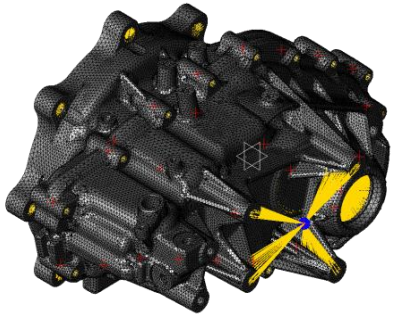
Bearing Designer

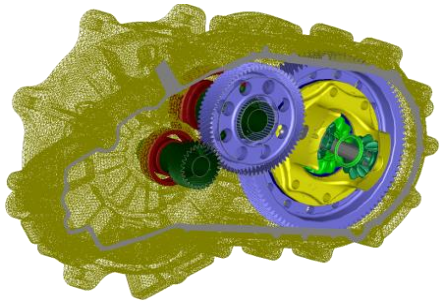


Drivetrain in EV Car

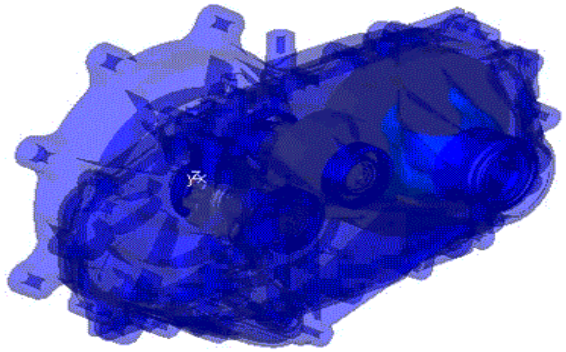
- Verified model development and improve the whine noise

Gearbox Model

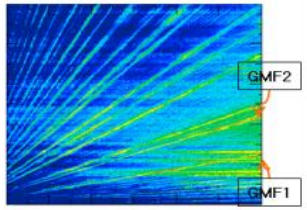
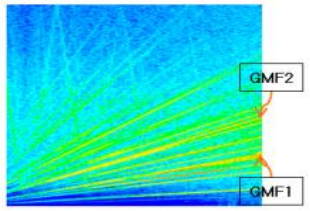
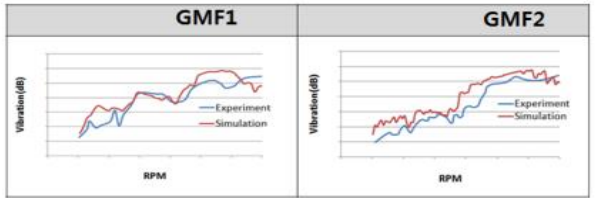




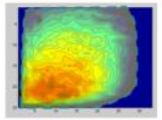
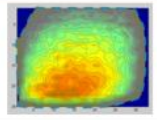
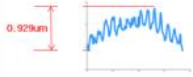
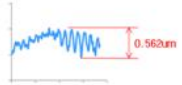
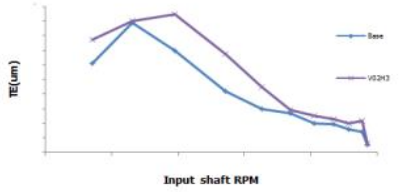
Characteristics of System
➢ 2 stage Helical gear reduction
➢ 2 ball bearing on each shaft
➢ Accelerate speed and increase applied load



Verification

	Experiment	Analysis	Opinion
Waterfall			Each order components and its frequency is similar with experimental one
Order Tracking			Overall pattern and peak value is very similar

Design Change of Gear Tooth

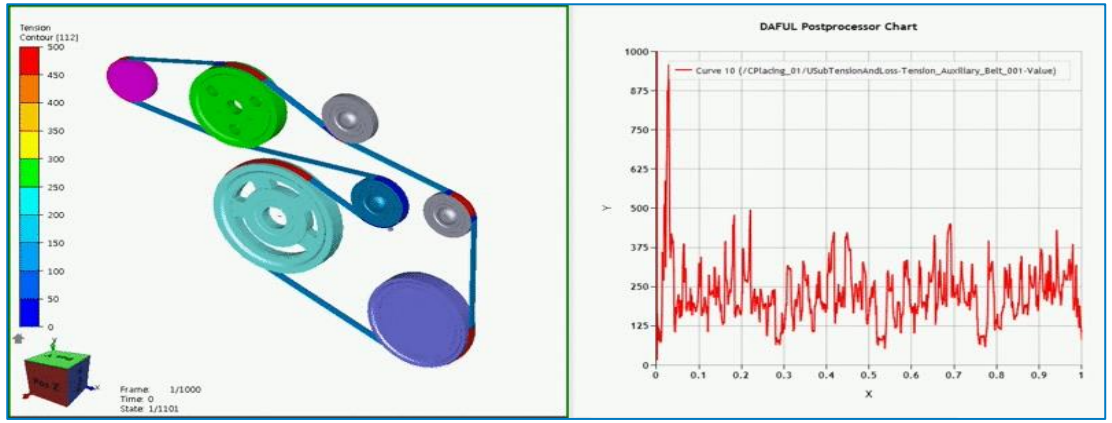
	Proto	Modified	Remarks
Tooth Contact Area			Modify tooth profile to maximize contact area
PPTE			Modify tooth profile to reduce PPTE
DPPTE			DPPTE is determined by gear characteristics and system characteristics

Toolkit : LINKS

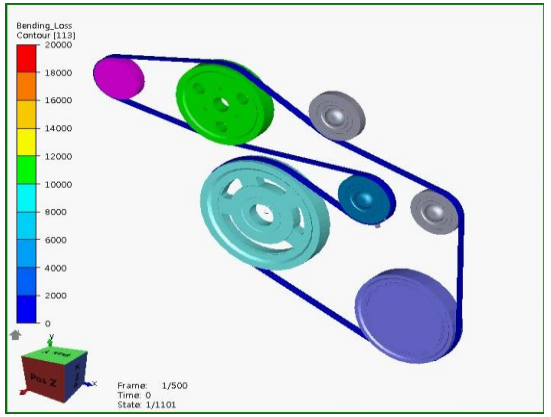
- A Links System is the modeling tool of the open or closed loop chained system.

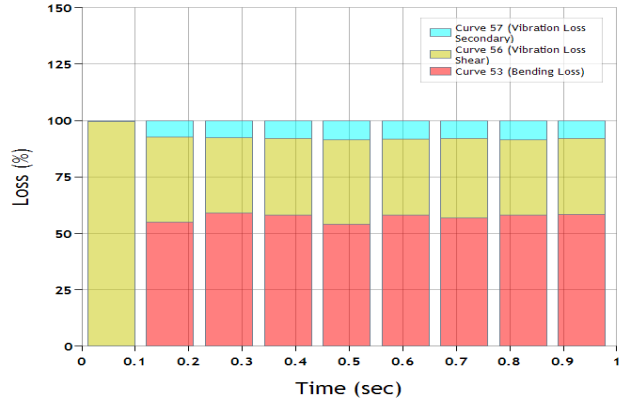
- Concept of Segment and Path has been used to build a winding system. Especially, connector between segments and contact modeling are very easy.

- **Tension Contour Display**

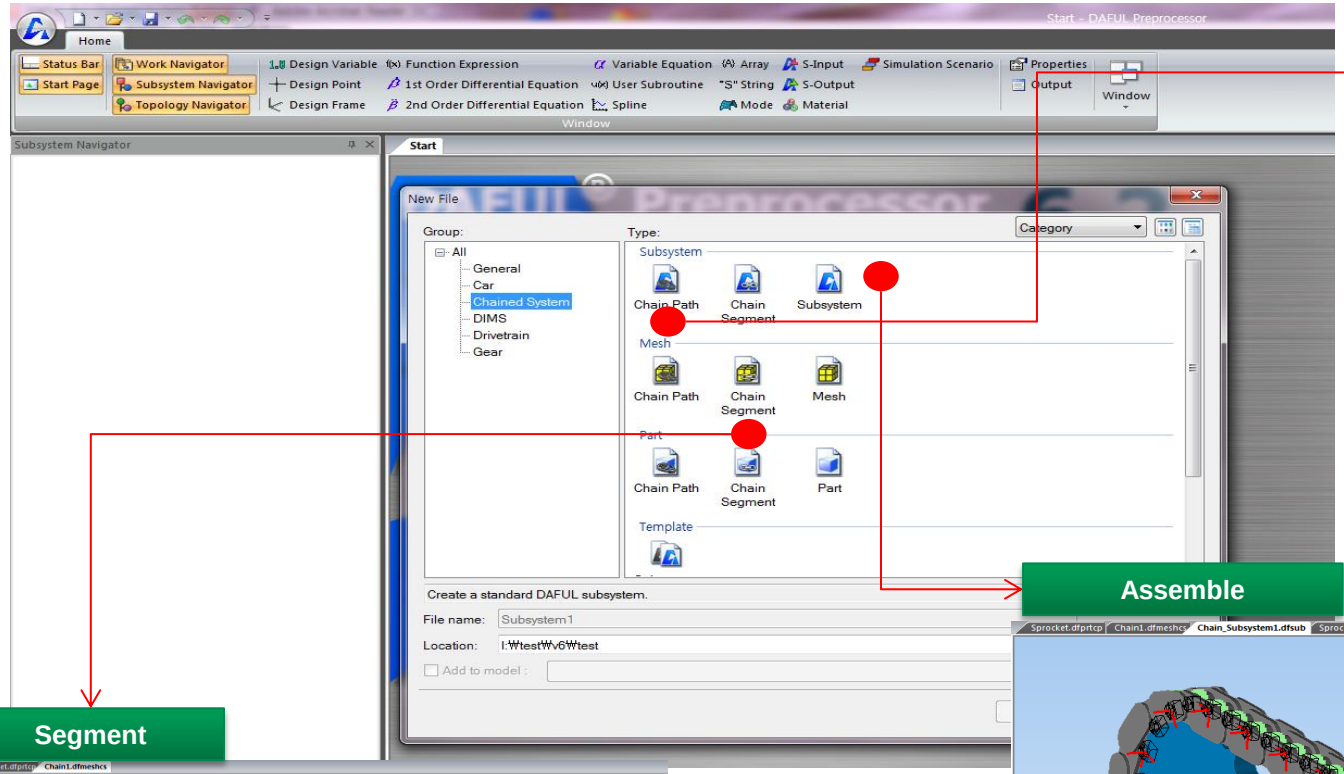


- **Loss Contour Display and Chart**

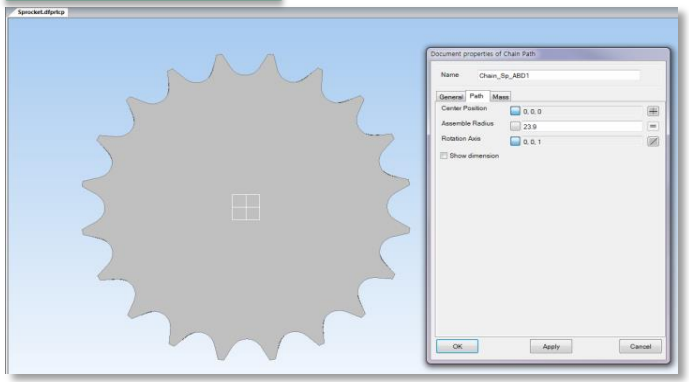




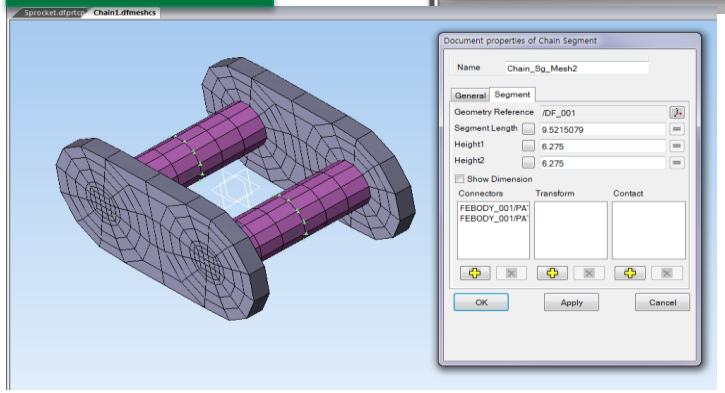
Overview of Links toolkit



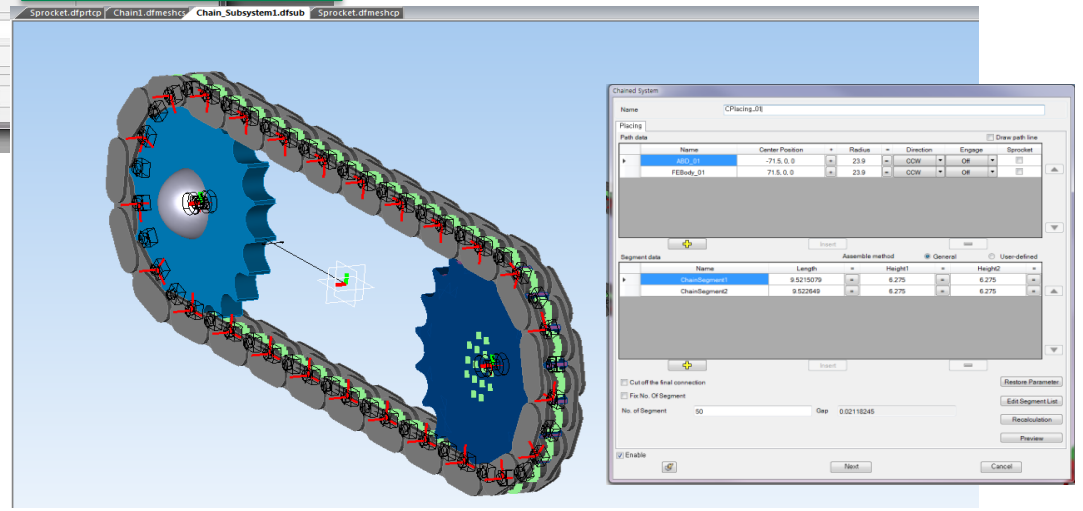
Path



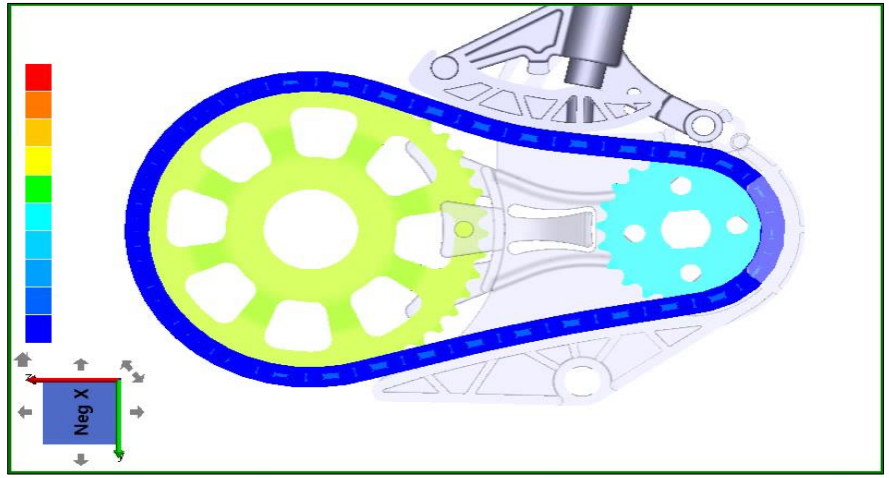
Segment



Assemble



Various Timing Chain System with Links

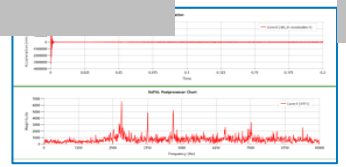


No. of Node
= 2.7M

Content	GMS
Speed	**22.7 hr.**
Memory	**45 GB**

Flexible timing belt

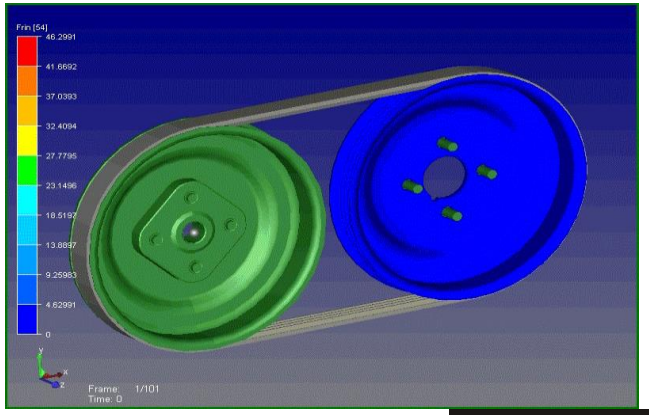
Confidential



Multi-body timing belt

Confidential

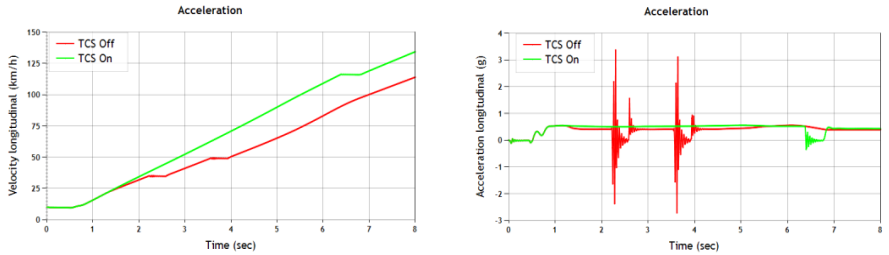
Rib belt



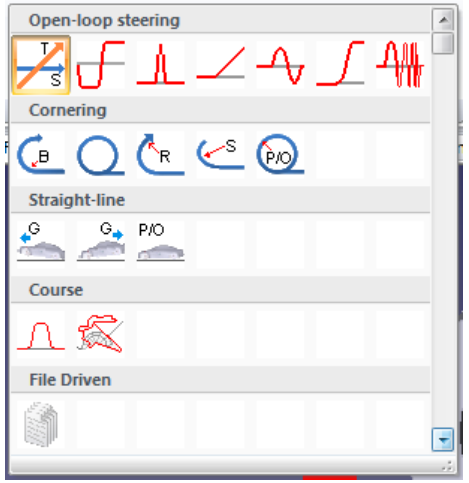
Toolkit : CAR

- 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 >



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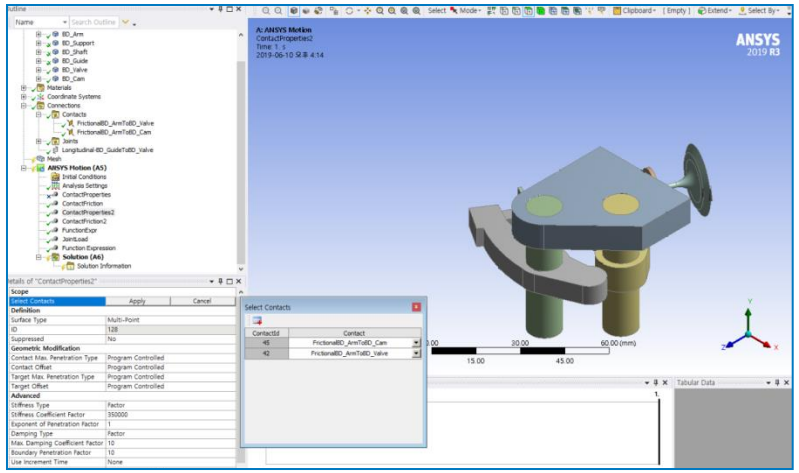
- Overview of ANSYS Motion
  - Basic functionalities
  - Simulation capabilities
  - Introduction of toolkits
- **ANSYS Motion Workbench 2019 R3**
  - **Modeling Concept**
  - **Supported Entities**
  - **Future Plan & Demo**
- Examples
- Development strategy
  - High performance solver (MPP solver)

What’s ANSYS Motion

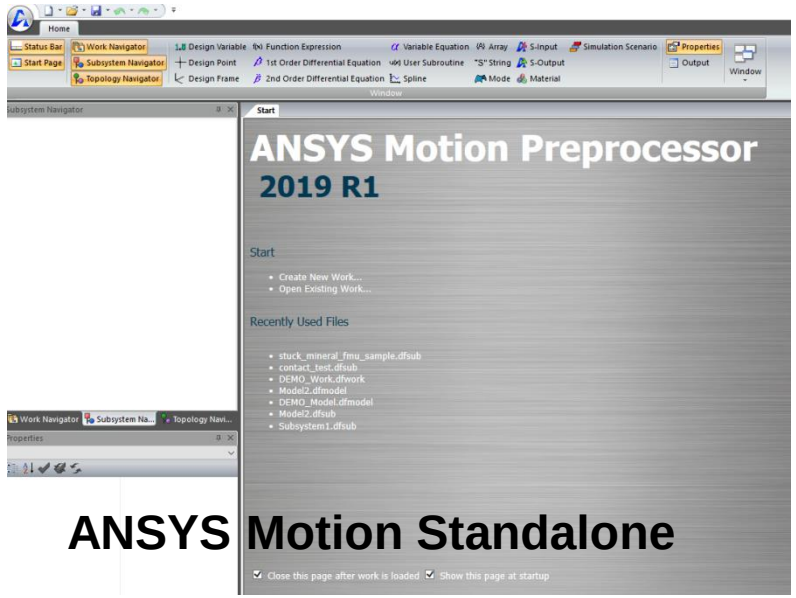
- Integrate Motion solver technology into Ansys Mechanical for the complete workflow.

  - 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 MFBD.

First release in 2019 R3, Installed with ANSYS Motion



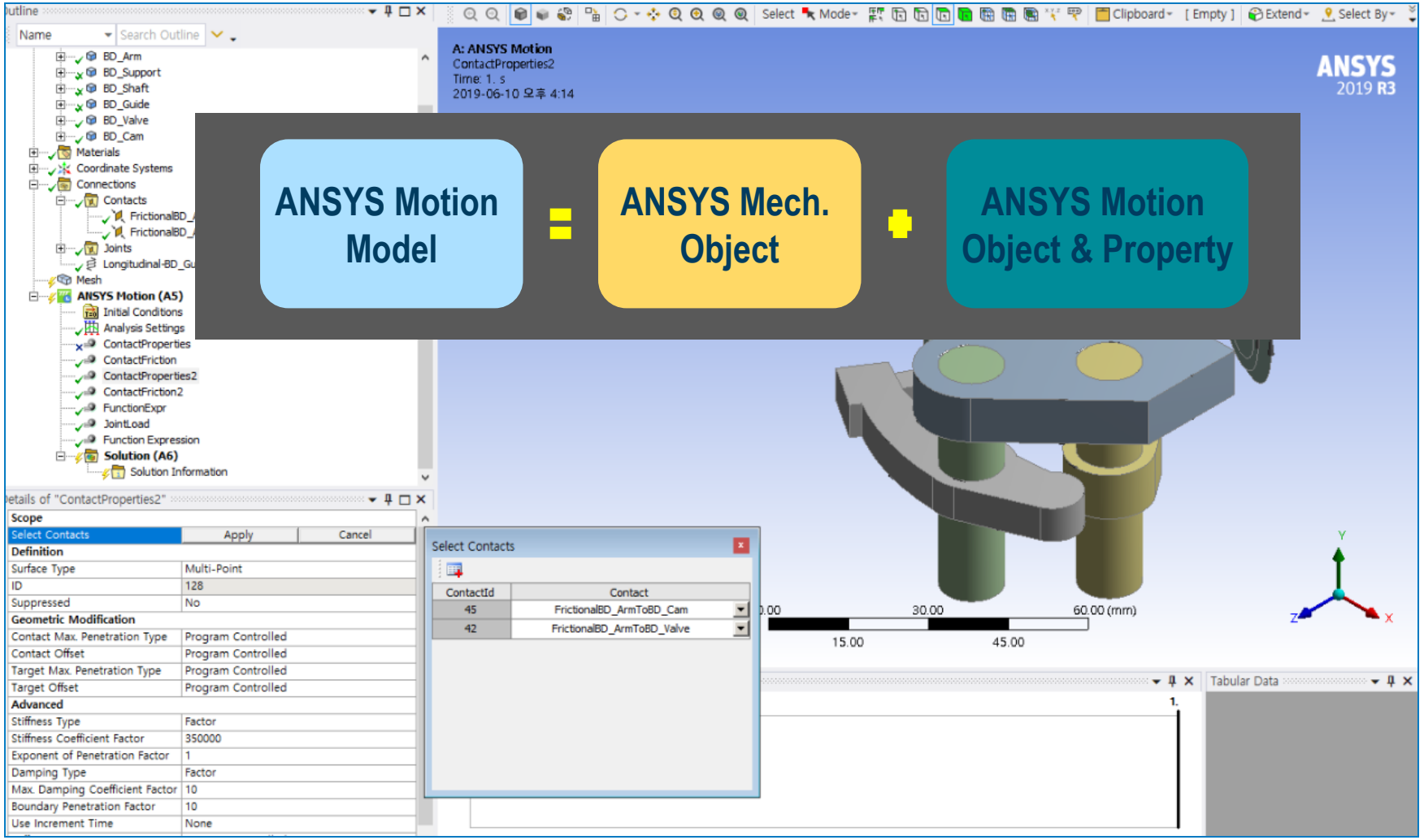
ANSYS Motion Workbench



ANSYS Motion Standalone

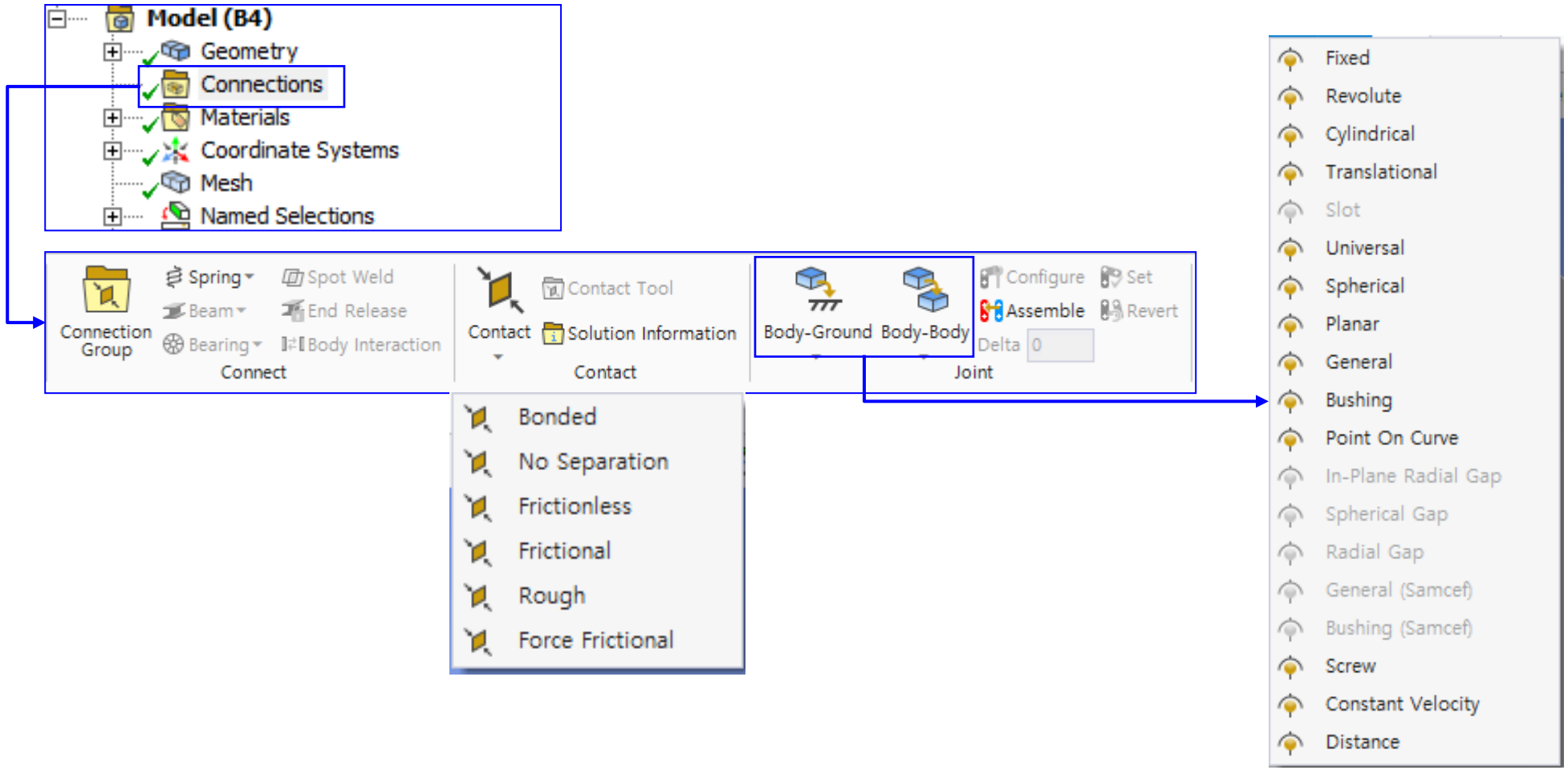
ANSYS Motion ACT – Modeling Concept

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



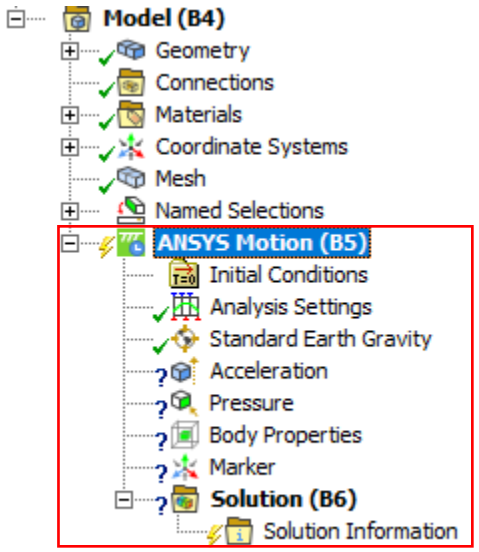
ANSYS Motion ACT – Available ANSYS Objects

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

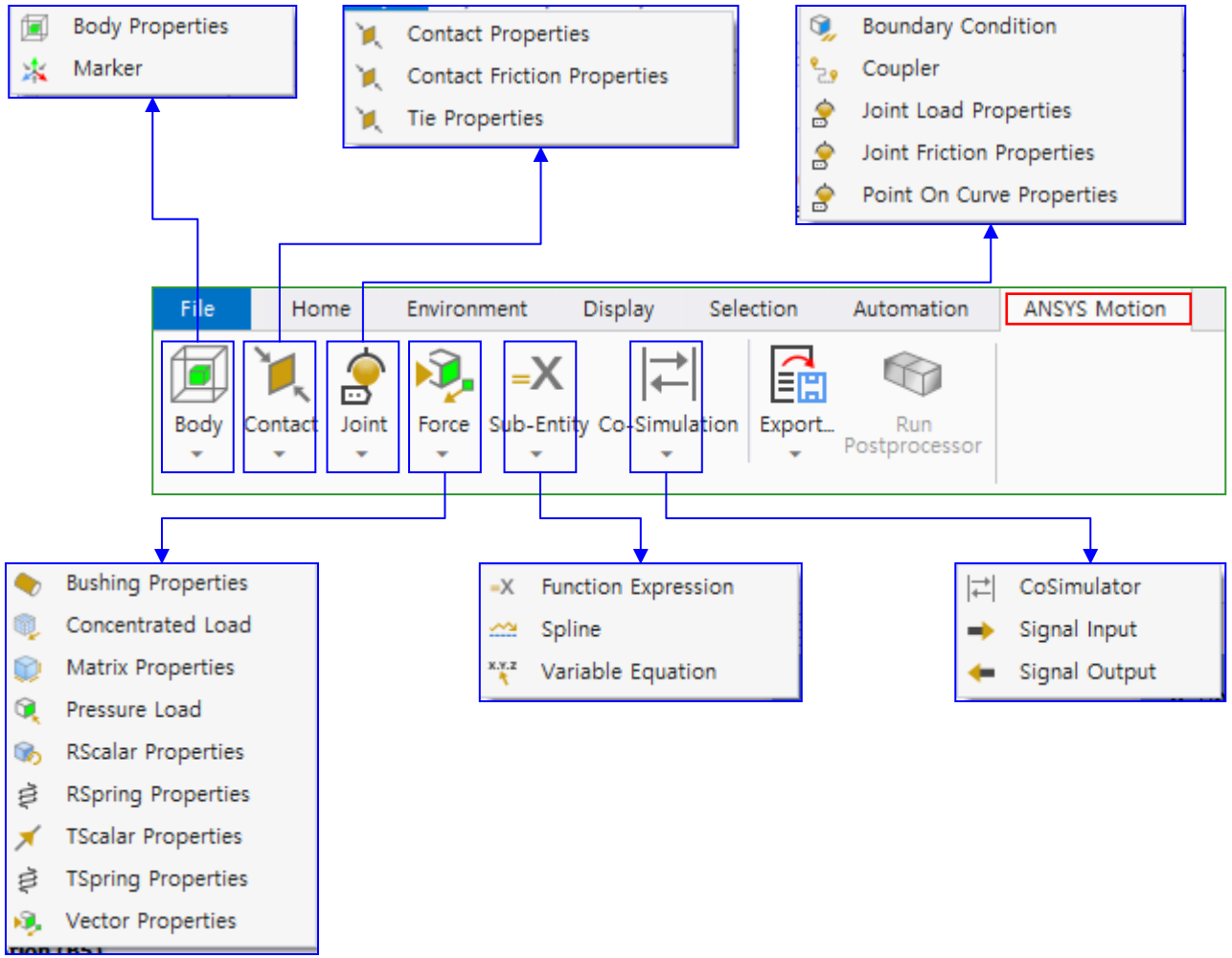


ANSYS Motion ACT – Available AM Objects and Properties

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

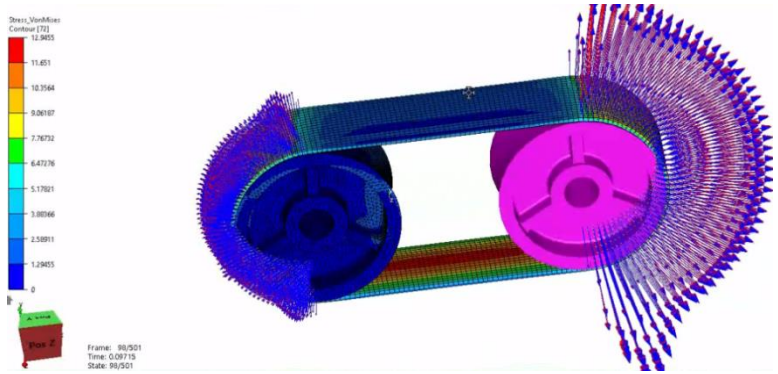


ANSYS Motion Objects and Properties



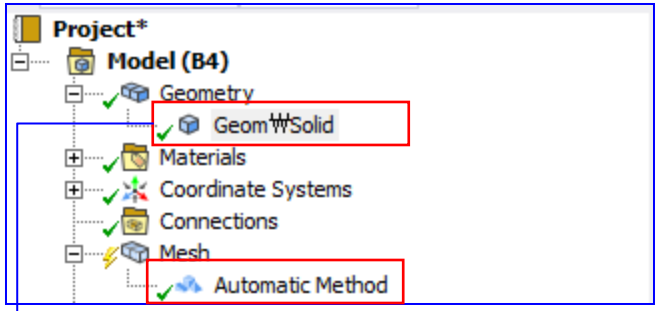
ANSYS Motion ACT – Various Body Types

- **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

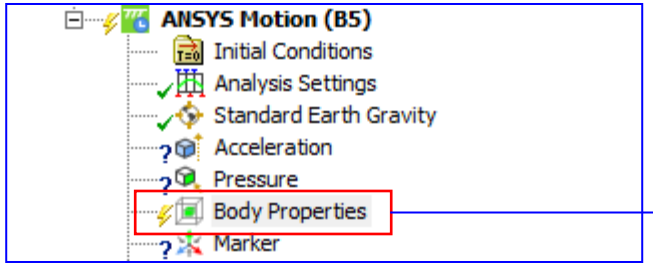
Nodal Body of ANSYS Motion



Details of "Geom₩Solid"

Graphics Properties	
Definition	
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

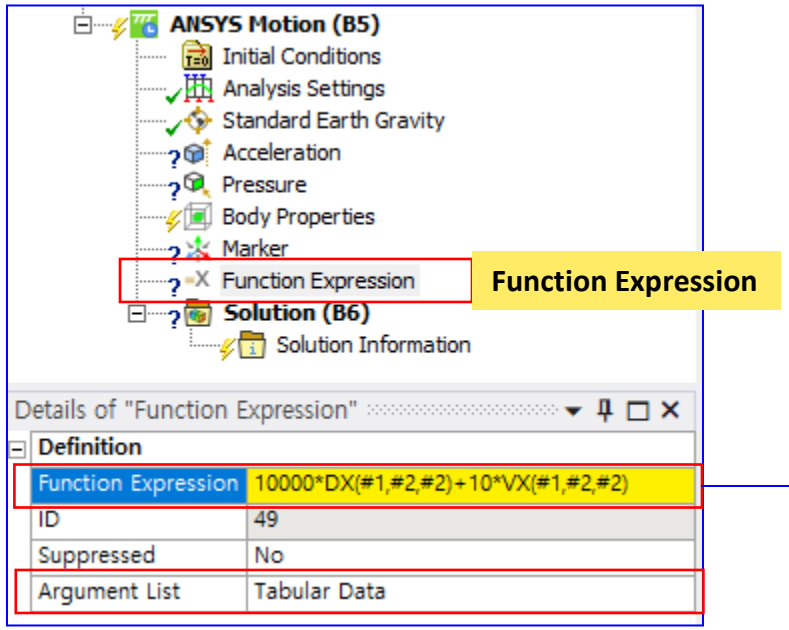


Details of "Body Properties"

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

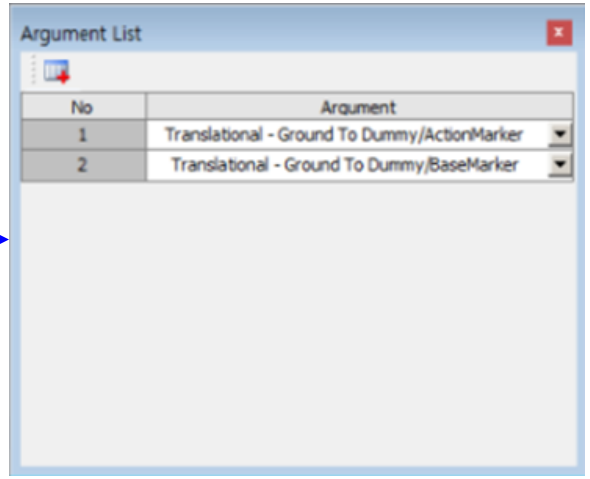
ANSYS Motion ACT – Complex Function Expression

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



Function Expression

Argument List



ANSYS Motion ACT – Supported Entities in 2019 R3

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

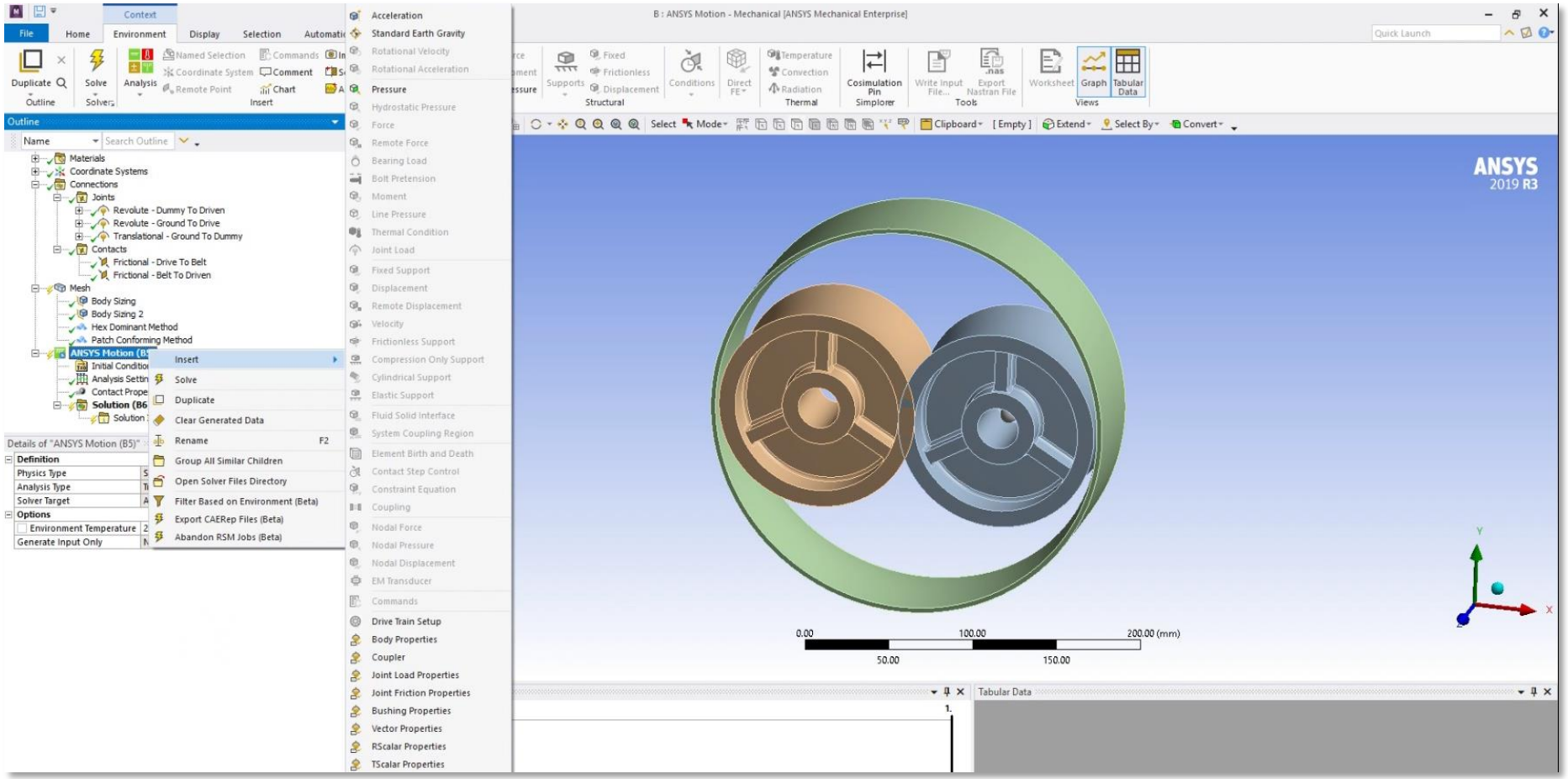
ANSYS Motion ACT – Future Development Plan

Contents	Planed 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!**

AM ACT Demo



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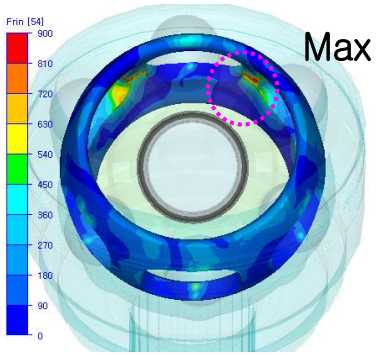
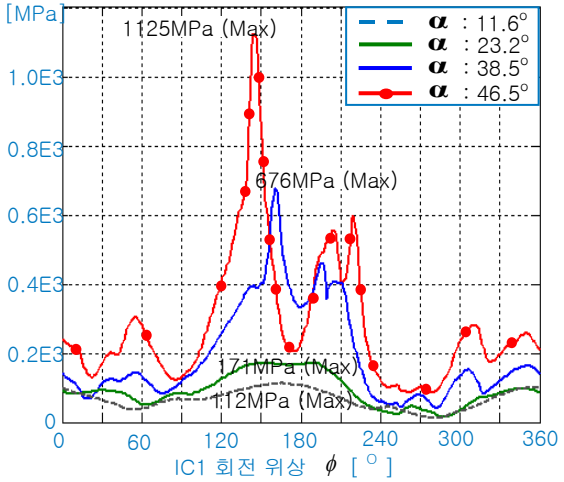
- Development strategy
  - High performance solver (MPP solver)

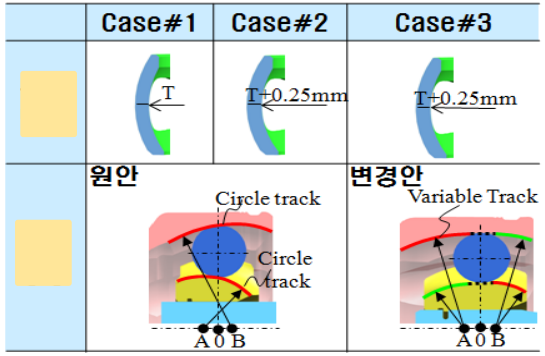
Constant Velocity Joint - Cage broken issue

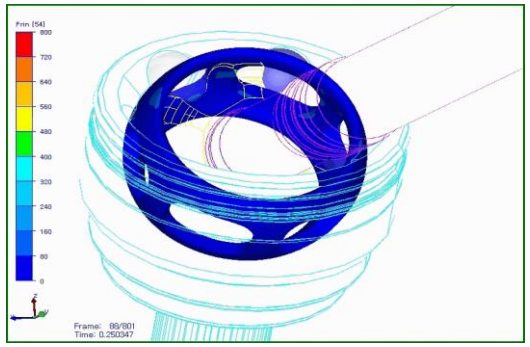
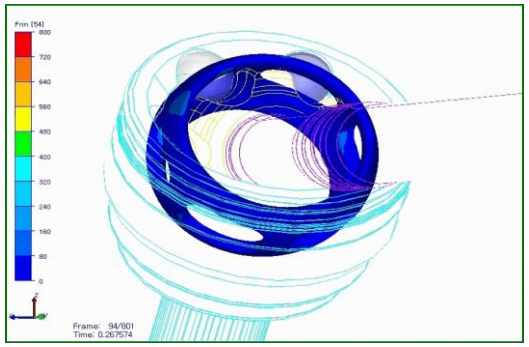
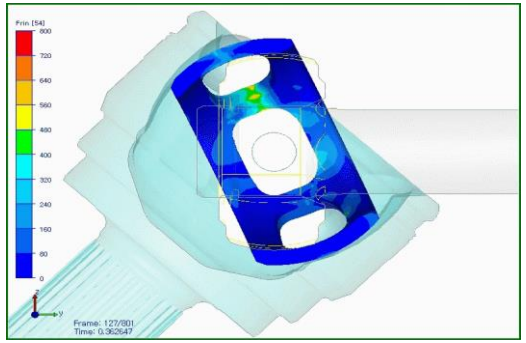
Reproduction



Define a problem and improve a design
– High rotation and asymmetricity

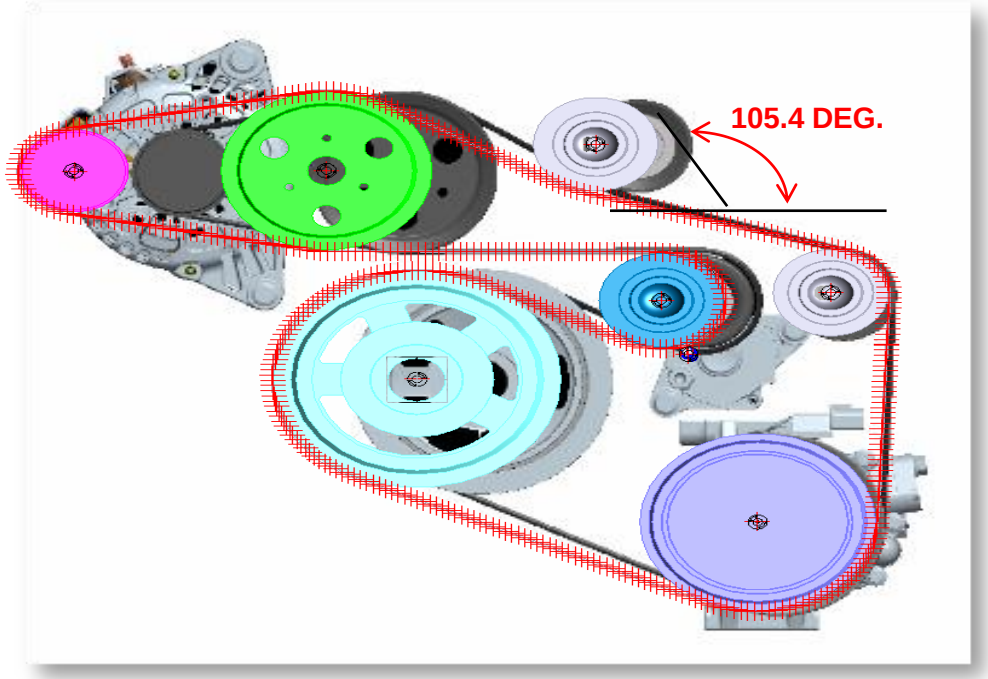


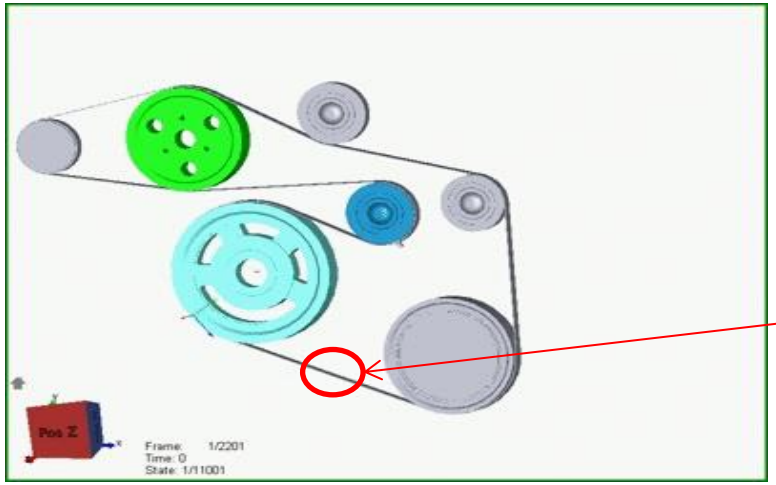


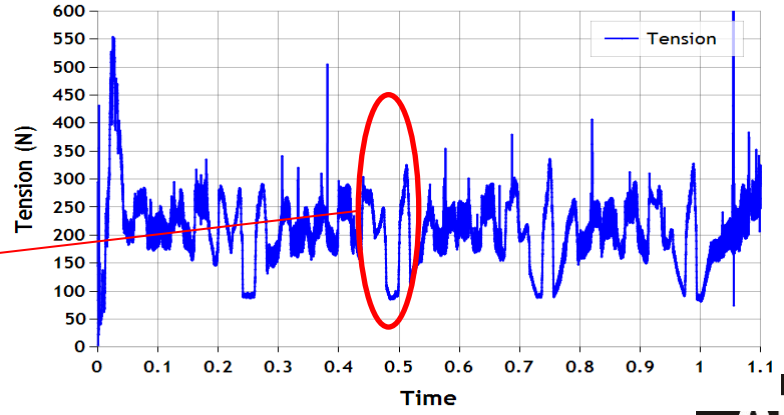
Original Design(Case#2)	Modified Track(Case#3)
	
	

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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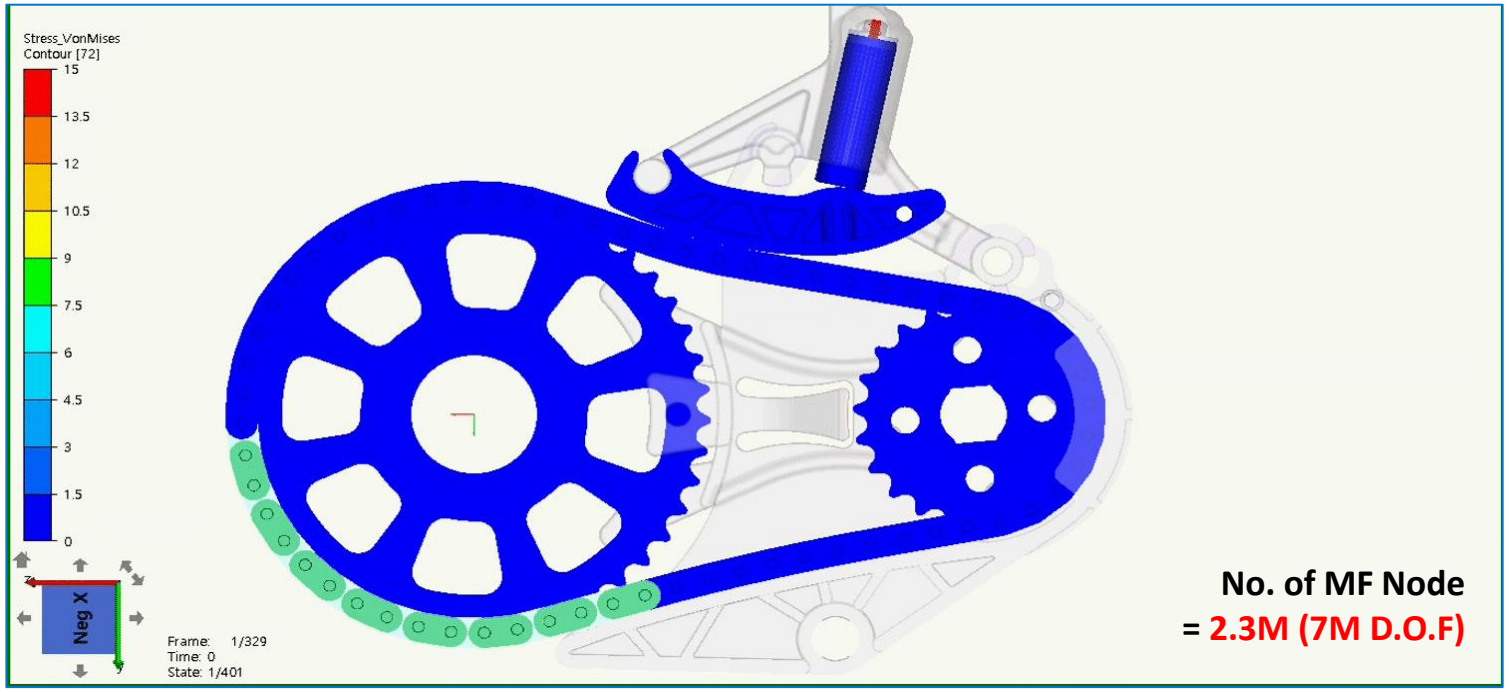
- **Development strategy**
  - **High performance solver (MPP solver)**

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	**32 hr**
Memory (GB)	**235** → 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!