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CVT behavior analysis with ADAMS

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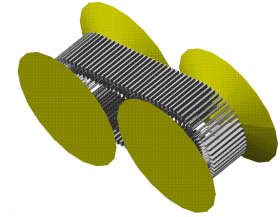
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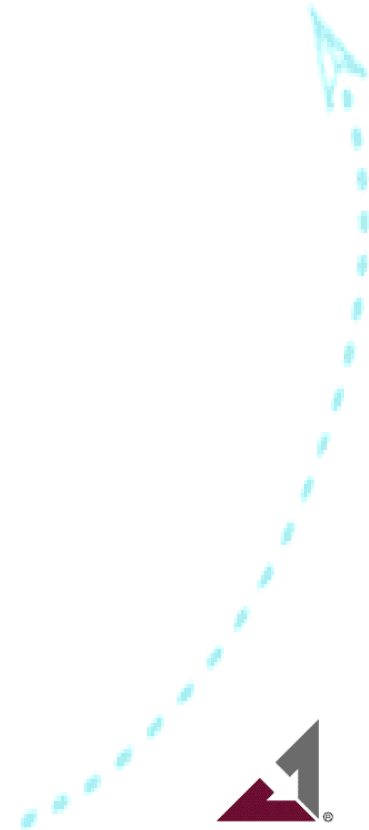


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Contributors



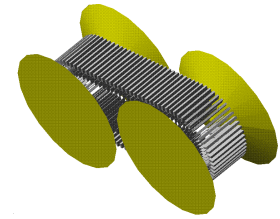
- Special thanks to those who made technical contributions to CVT projects at MDI (partial list):
 - ◆ Jungho Park
 - ◆ Judd Storrs
 - ◆ Juan Lopez De Alda
 - ◆ R. Srinivasan
 - ◆ Huihua Shen
 - ◆ Joonho Moon
 - ◆ Yeongching Lin
 - ◆ Sam McDonald
 - ◆ Ryuji Arai





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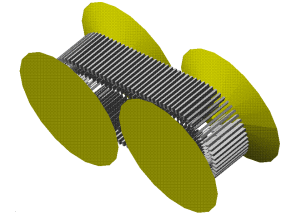


- General topics about CVT
- Description of ADAMS model
- Analysis result
- Future simulation technique for CVT behavior



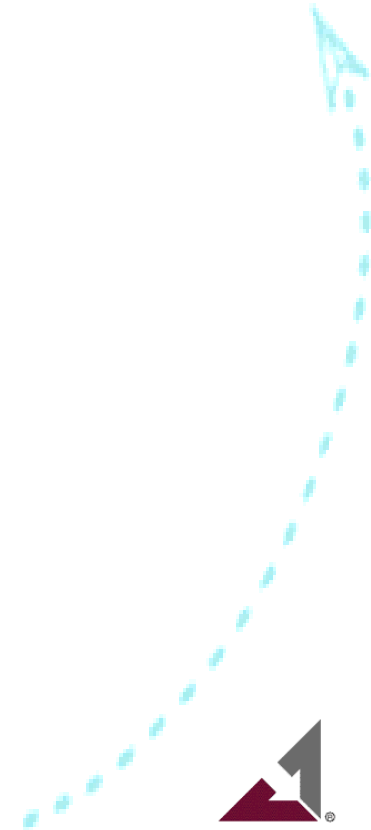
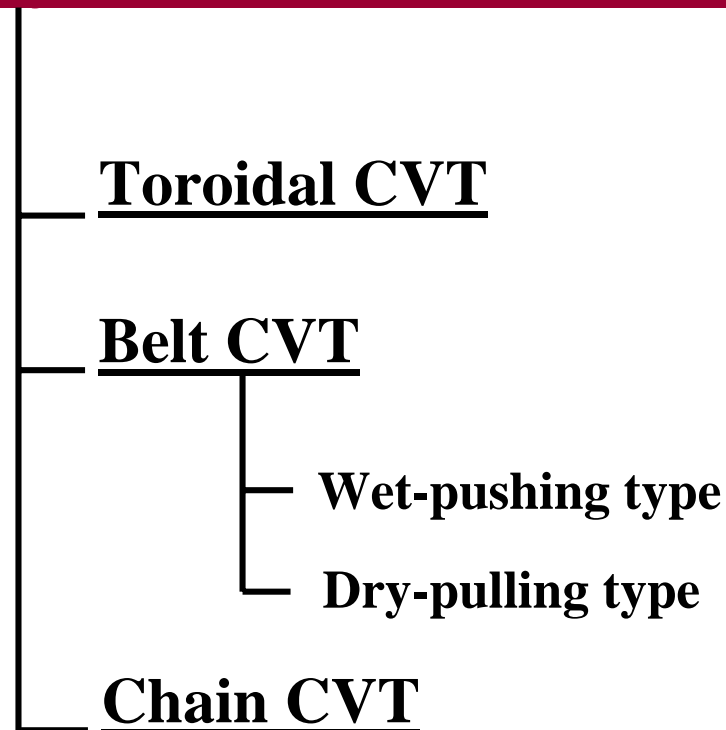


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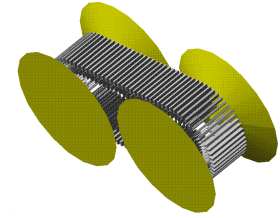
General topics about CVT

Continuously Variable Transmission (CVT)





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Current status of CVT development

■ Practical use

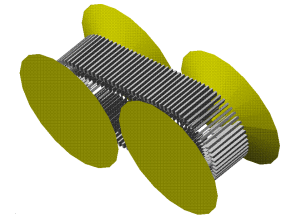
- ◆ Adopt CVT for new model car in many car manufactures
- ◆ Improve fuel consumption and driveability effectively
- ◆ Achieve both protection of earth environment and improvement of car performance

■ Subjects of CVT development

- ◆ Requirement of stable and high torque transfer
- ◆ High strength of components of CVT system
- ◆ Predict the influence of components behavior to transfer performance
- ◆ Hard to analyze the mechanism of CVT experimentally



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Requirement for belt CVT

■ Required function of CVT

- ◆ Smooth torque transfer between pulley and belt
- ◆ Smooth speed change
- ◆ High durability

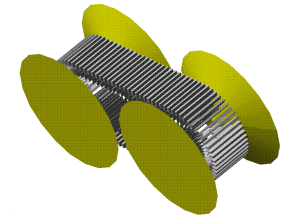
■ Required information

- ◆ Friction characteristic
- ◆ Belt behavior
- ◆ Force balance between components
- ◆ Mechanism of variable speed
- ◆ Belt, block and pulley deformation
- ◆ Influence of deformation to torque transfer

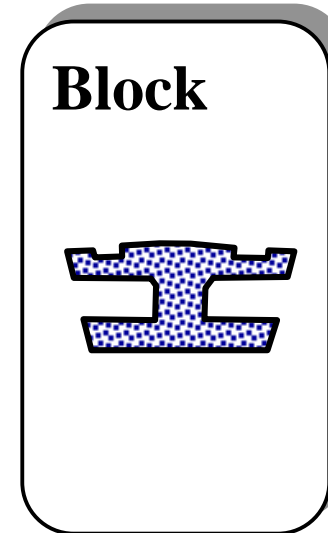
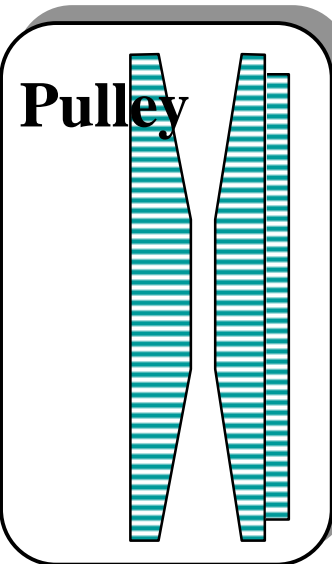
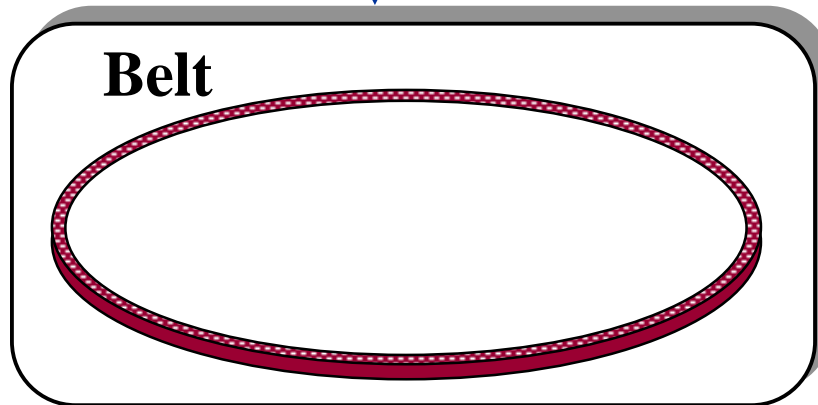
■ Evaluation items

- ◆ Belt tension force
- ◆ Block compression force
- ◆ Forces between block & pulley
- ◆ Pulley deformation
- ◆ Speed ratio
- ◆ Torque ratio
- ◆ Slip ratio
- ◆ Friction force etc.

Approach of CVT behavior analysis



MDI own elastic belt analysis technology



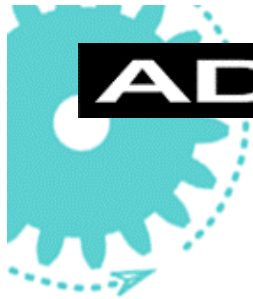
Beam theory (Adopted in ADAMS/Belt analysis technology)

Rigid or flexible body (FE model for flexible body)

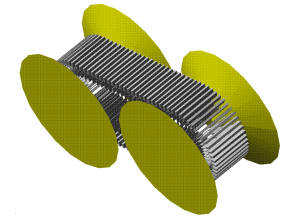
Connection with contact element of ADAMS

Analysis conditions (Operating conditions)

Evaluation items

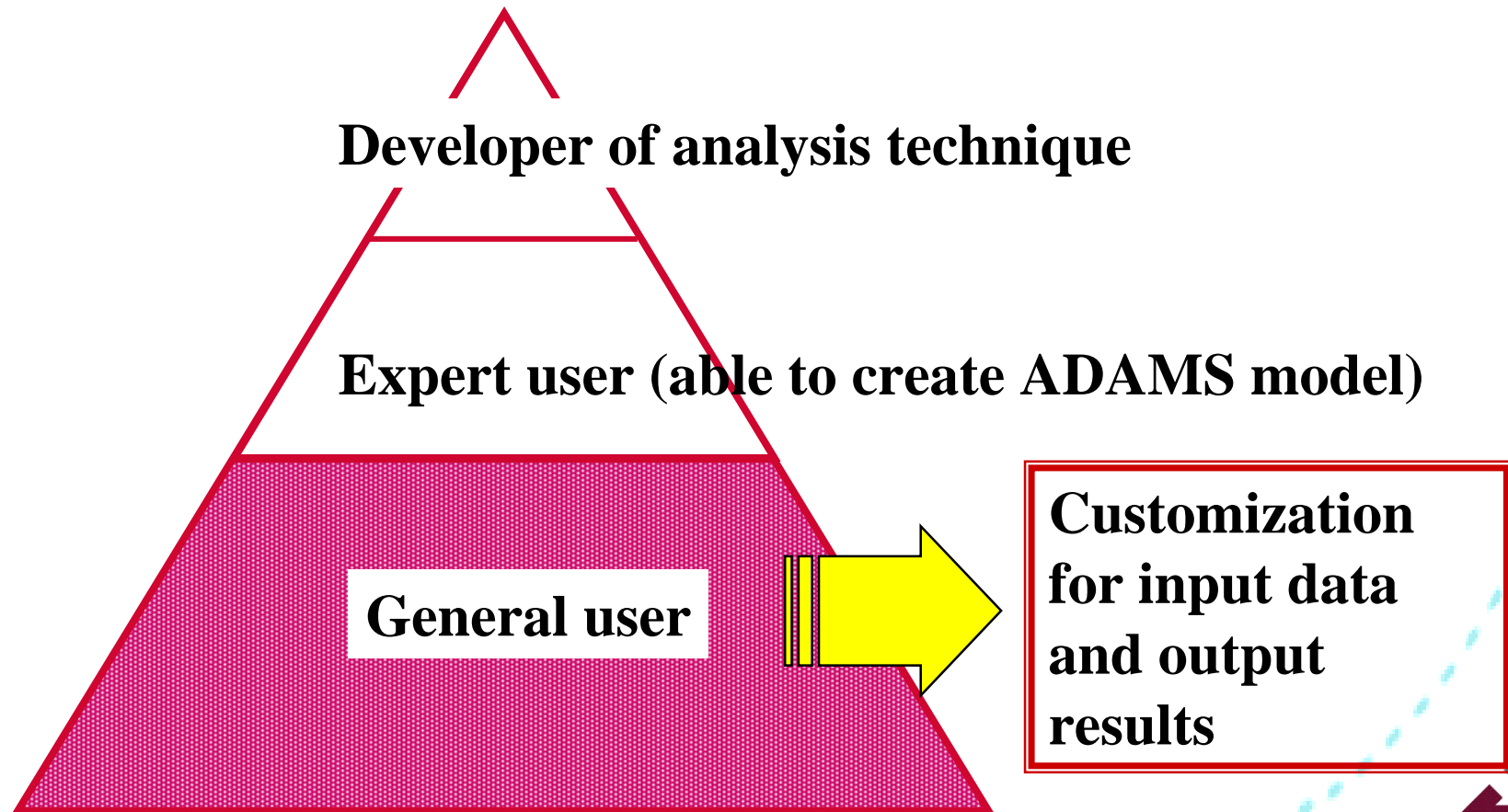


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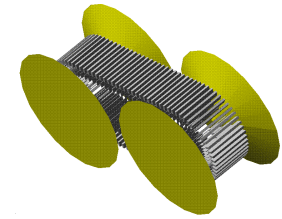
Customization of pre / post processor

- Easy system to use for CVT developers, general users, for model creation and parametric study

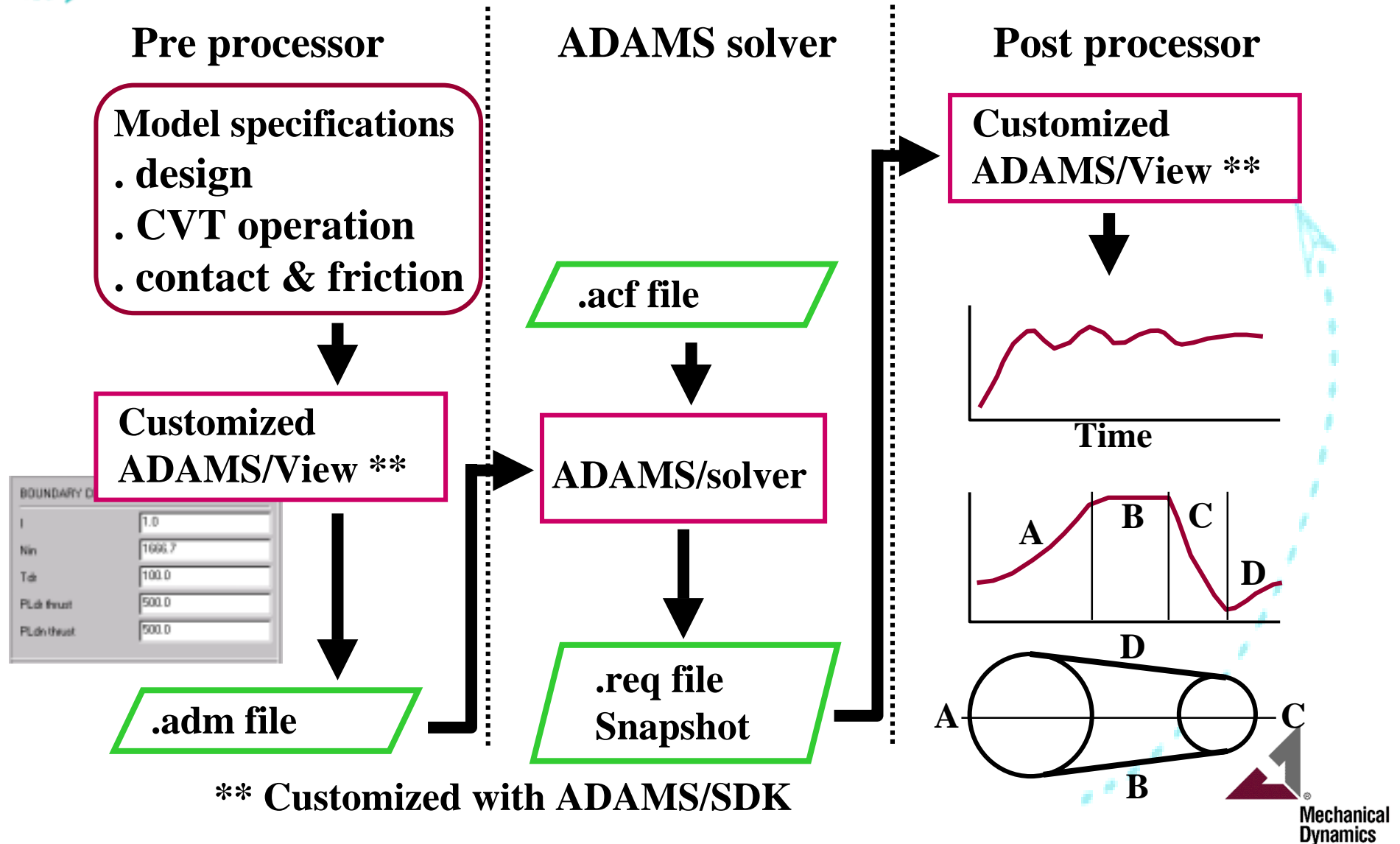




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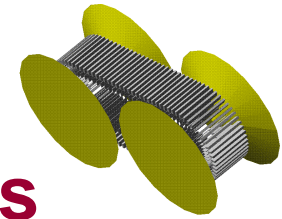


Outline of CVT/ADAMS system





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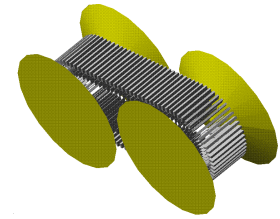
Differences of pull and push-type CVTs

	Dry-pulling type	Wet-pushing type
Torque transfer path	Driving pulley -> Belt -> Driven pulley	Driving pulley -> Block -> Belt -> Block -> Driven pulley
Function of block	Reinforcement of belt	Torque transfer (Also between blocks)
Belt friction coefficient	Two times of wet type	Less than dry type
Adoption	Light passenger car	Ordinary passenger car

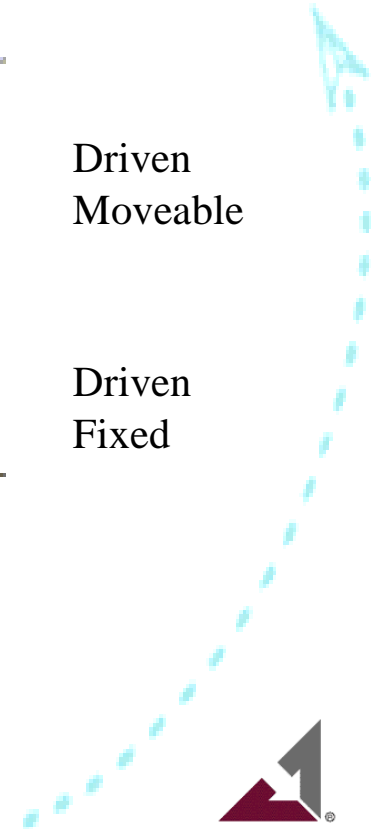
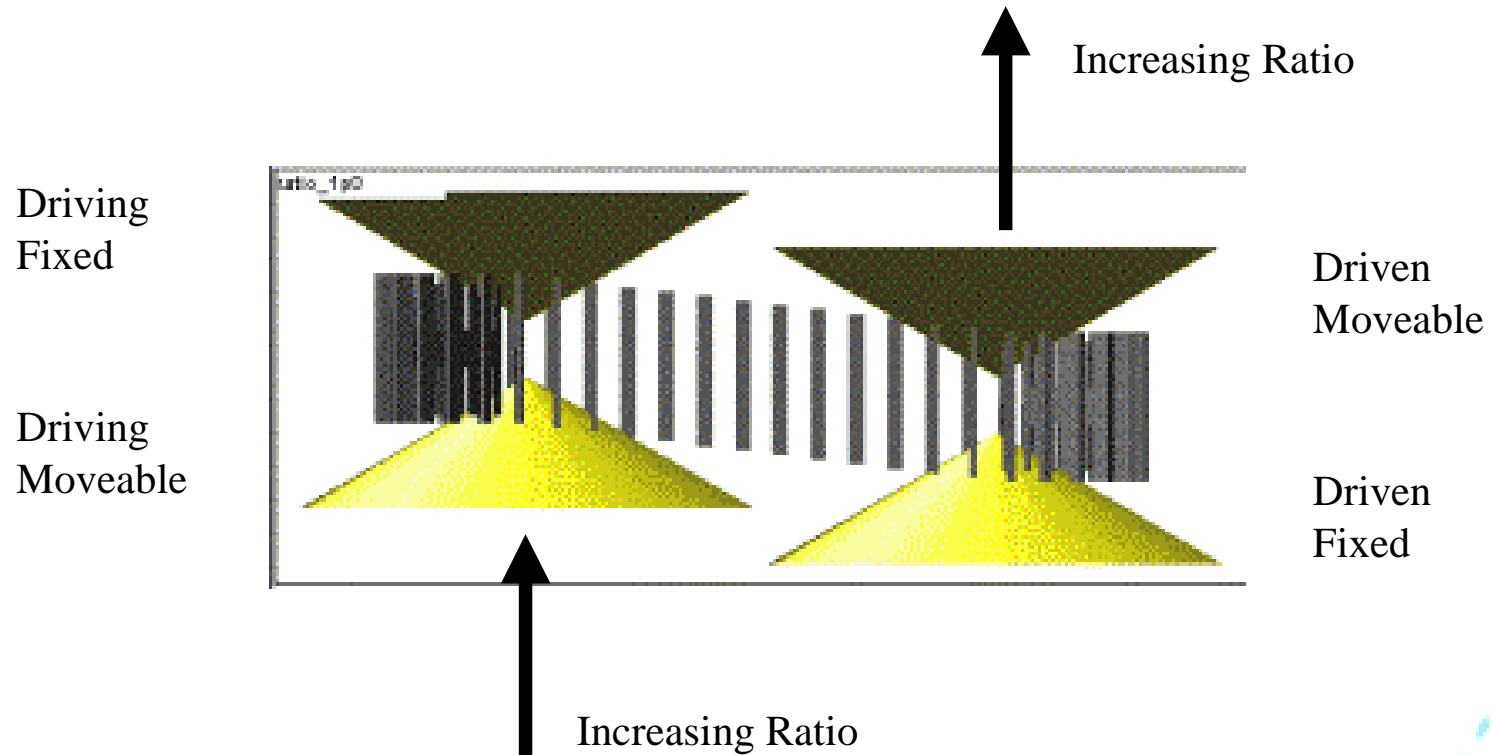


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Moveable Pulley Motion



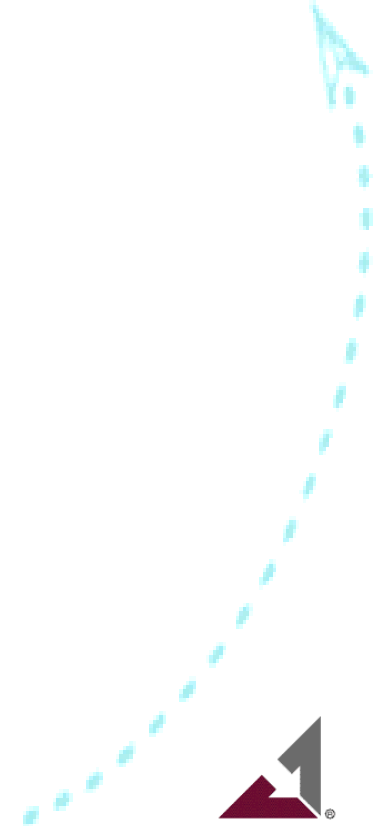
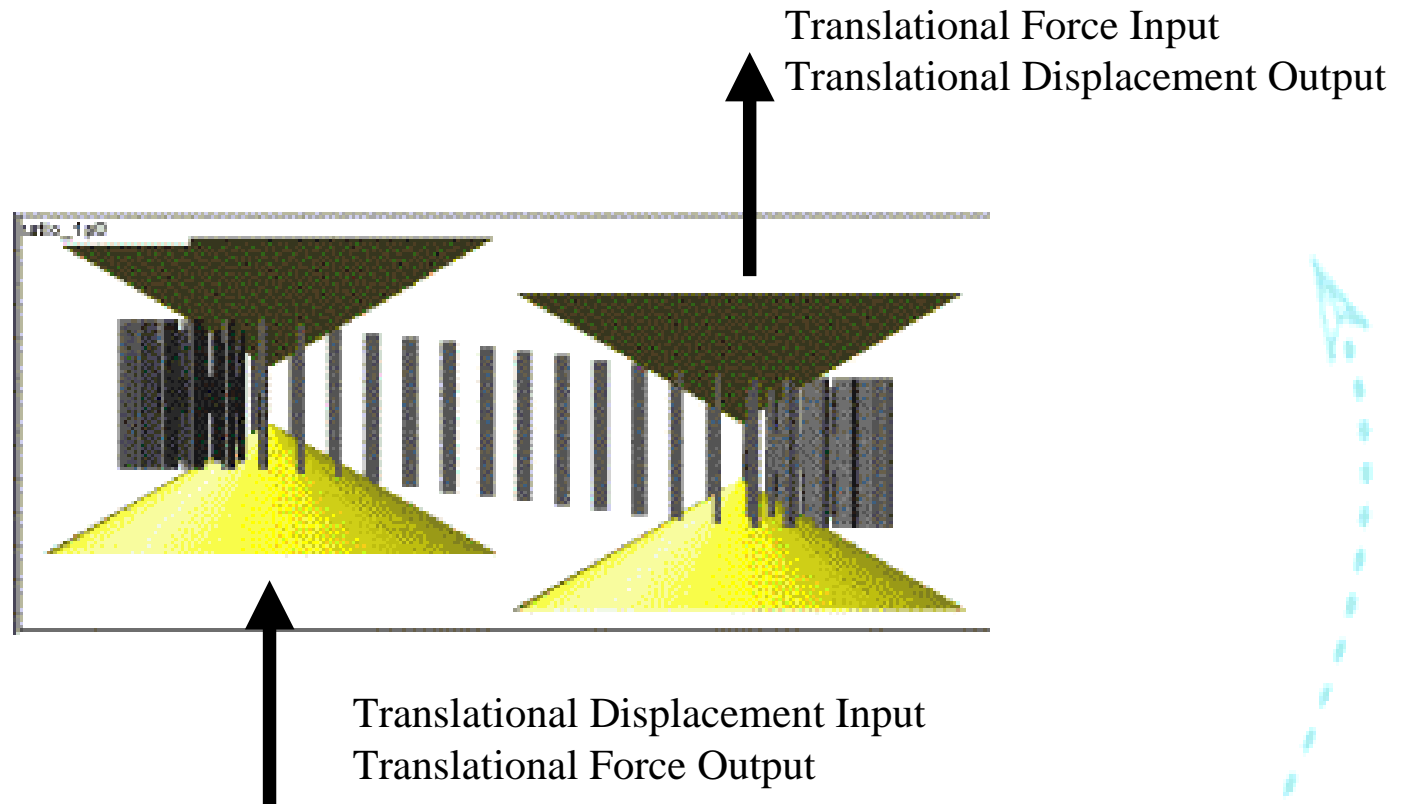
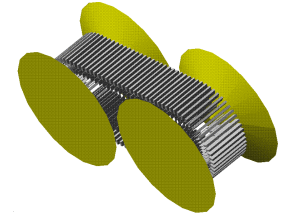
Moveable Pulleys Move Together





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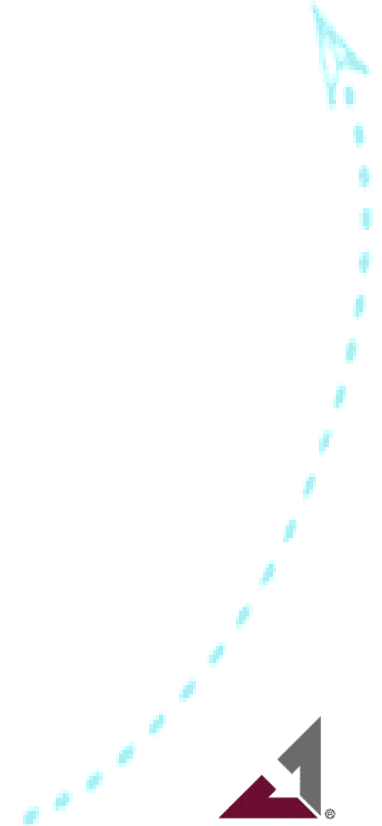
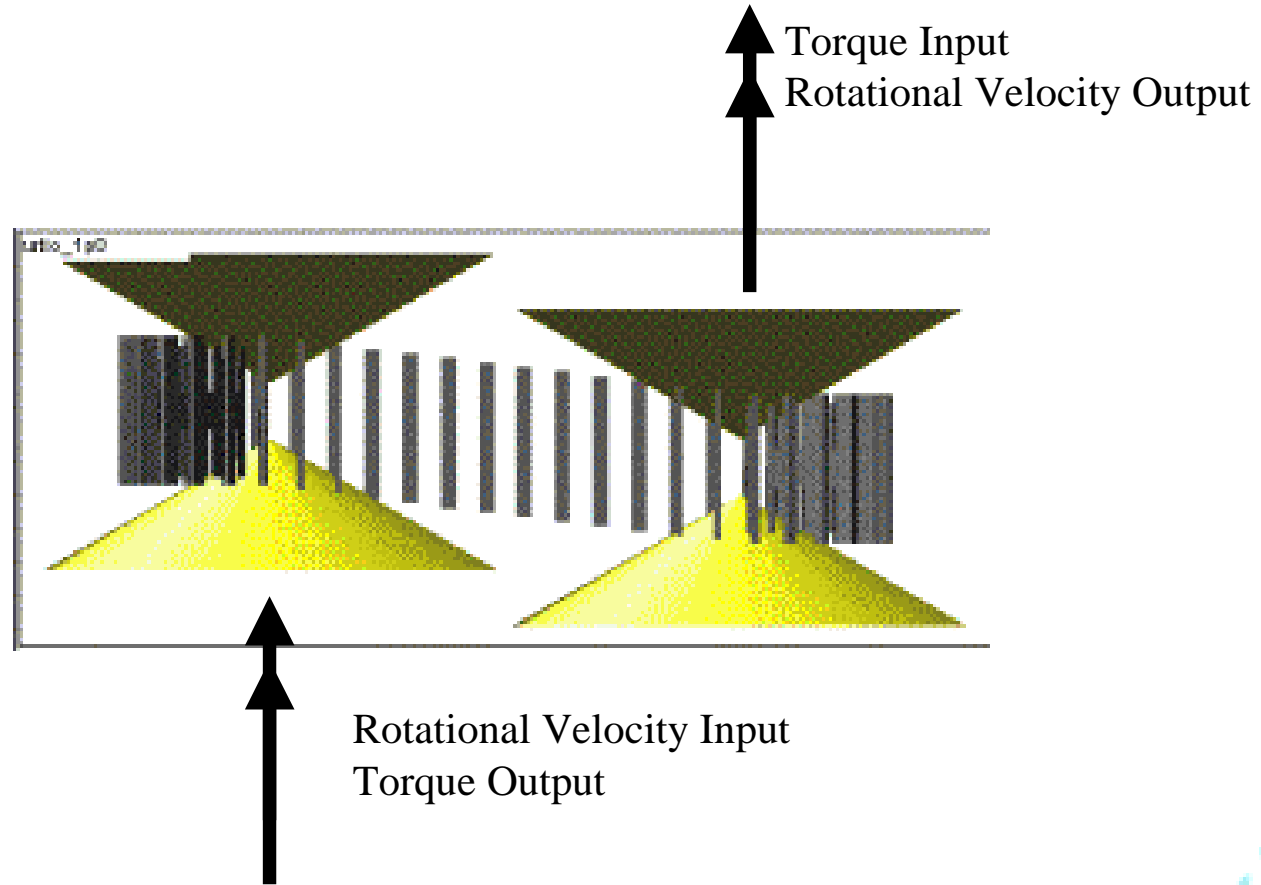
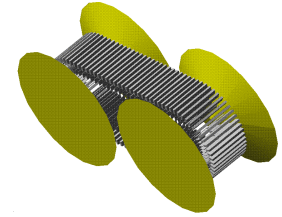
Translational Inputs





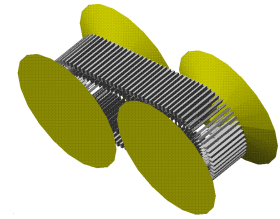
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Rotational Inputs





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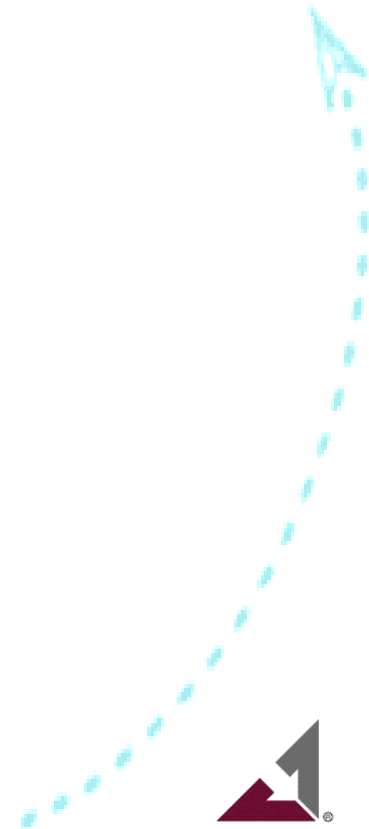
Description of ADAMS model

- **Physics-based model and simulation**
 - ◆ physical properties and boundary conditions in
 - ◆ displacement, velocity, acceleration, forces, loads out
 - ◆ Fully 3d

- **Parameterized model**
 - ◆ inputs from ASCII parameter files
 - ◆ preprocessor in ADAMS/View or batch mode

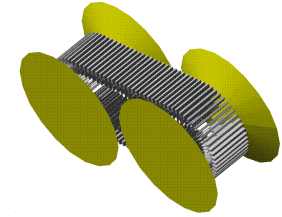
- **Simulation by ADAMS/Solver**
 - ◆ robust for all reasonable parameter range
 - ◆ more instrumentation than possible with physical test

- **Data processing**
 - ◆ data processing instructions from ASCII file
 - ◆ postprocessor in ADAMS/View or batch mode
 - ◆ ADAMS/View potting and graphical display



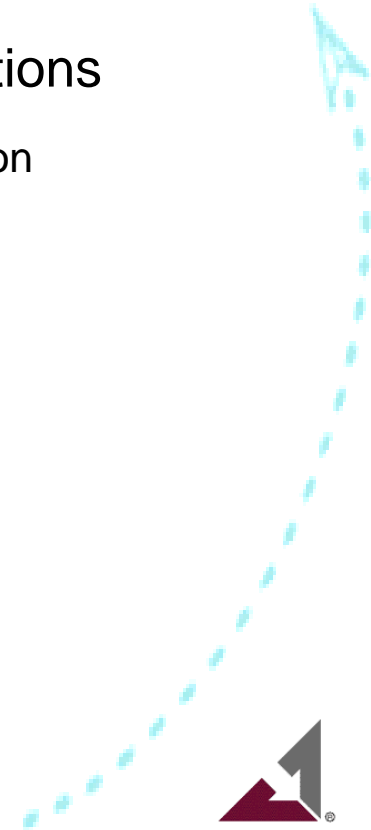


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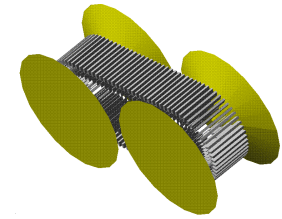
Types Of Input (Partial)

- Belt
 - ◆ Block Shape
 - ◆ Belt Length
- Pulley
 - ◆ Location
 - ◆ Angle
- Properties
 - ◆ Mass
 - ◆ Friction
 - ◆ Stiffness and Damping
- Boundary Conditions
 - ◆ Thrust Forces
 - ◆ Pulley Separation
 - ◆ Driving Speed
 - ◆ Output Torque
 - ◆ Drive Ratio





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Types Of Output (Partial)

■ Time Based Outputs

- ◆ belt acceleration
- ◆ belt elastic force
- ◆ pulley clamping forces and displacement
- ◆ pulley rotational speed and speed ratio
- ◆ pulley torque and torque ratio

■ Snapshot Outputs

- ◆ belt block force
- ◆ belt pulley force
- ◆ belt-pulley relative slip velocity
- ◆ belt shape

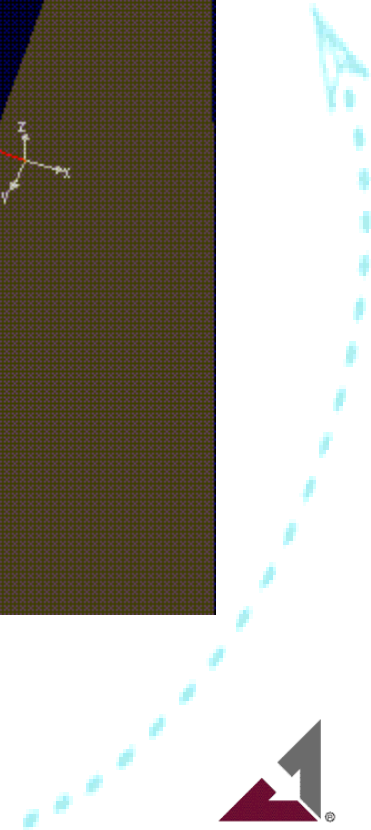
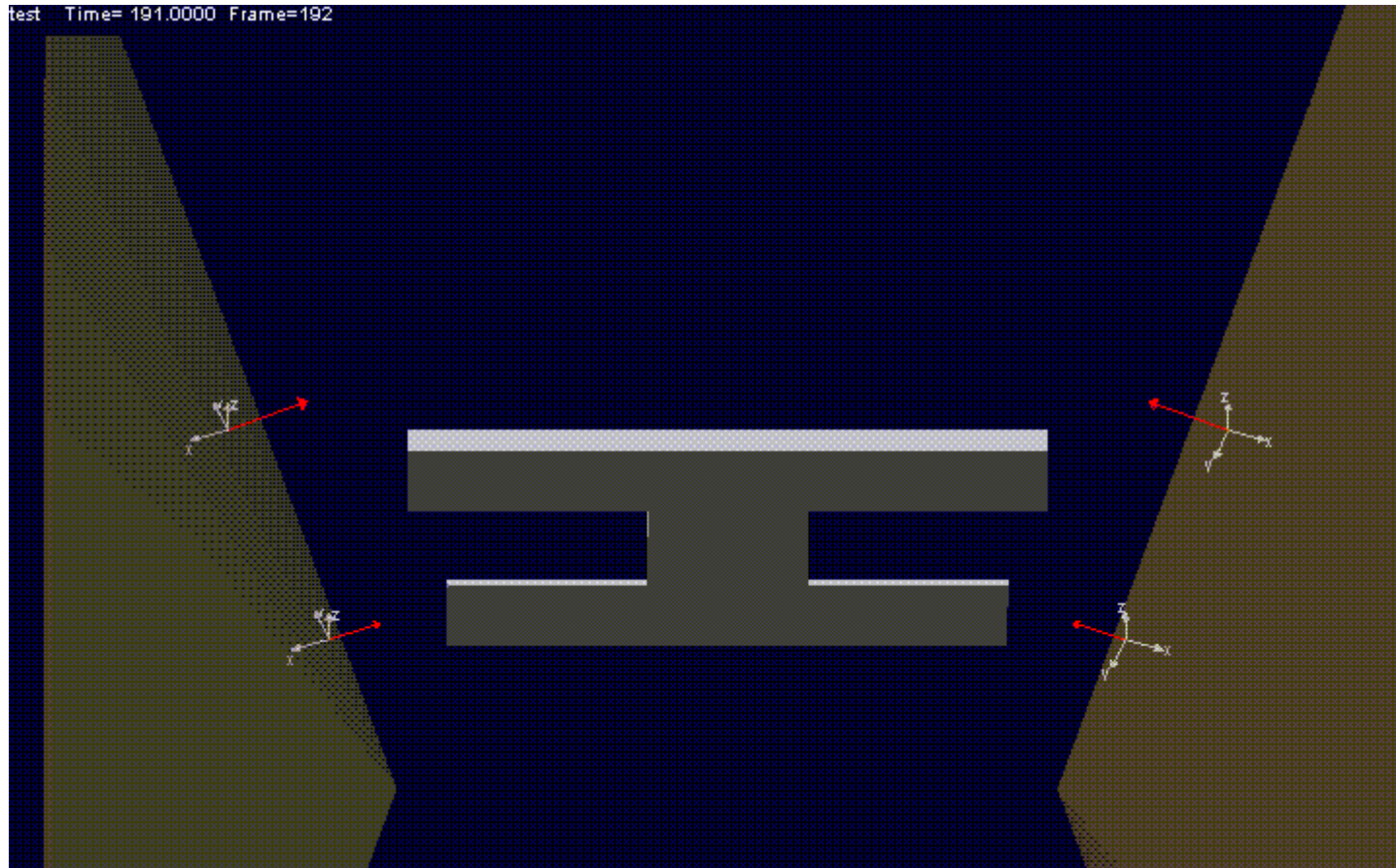
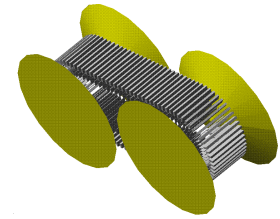
■ Snapshot Profiles

- ◆ belt block force
- ◆ belt pulley force
- ◆ belt tension force



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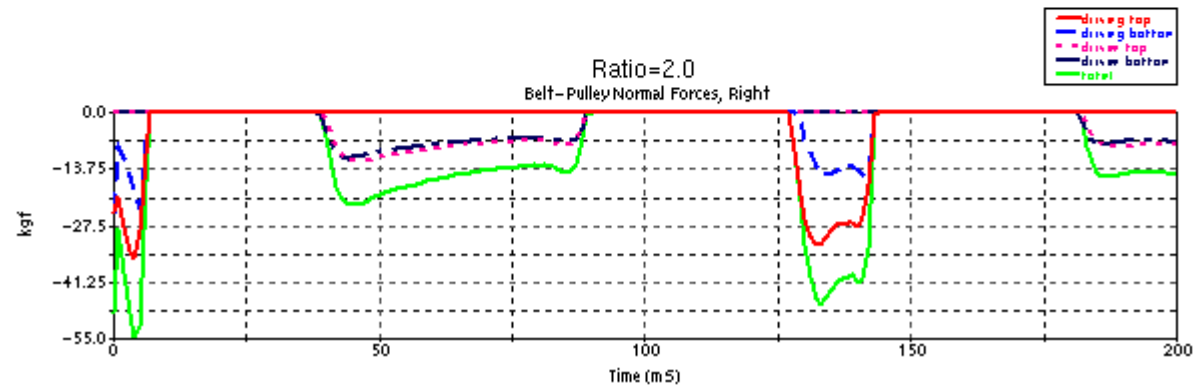
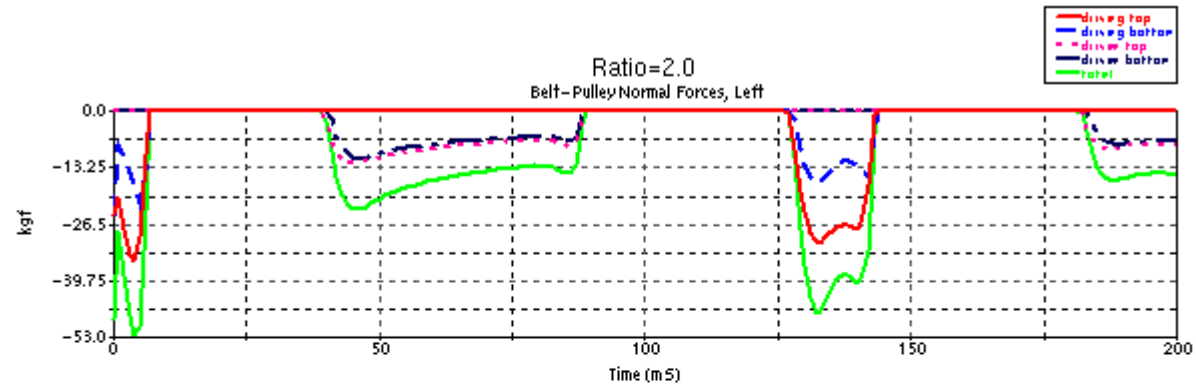
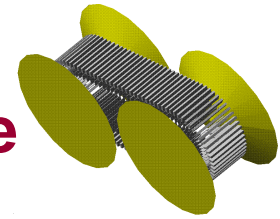
Belt-Pulley Forces





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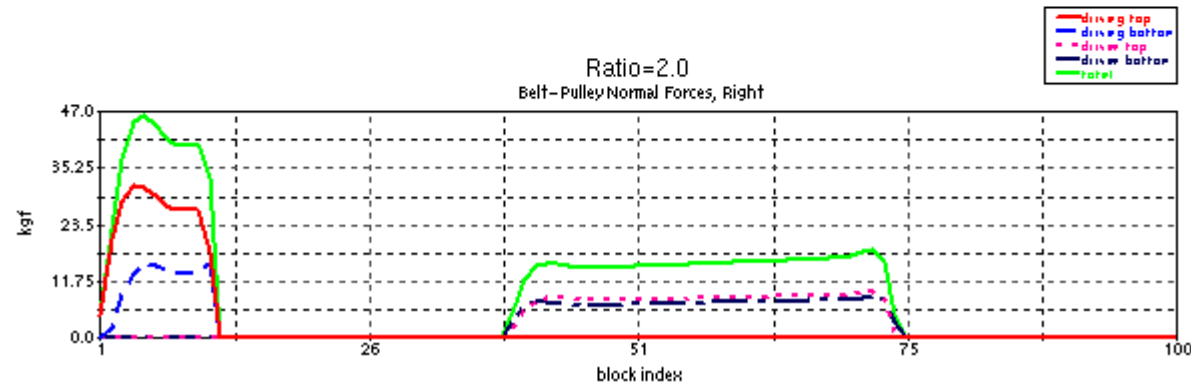
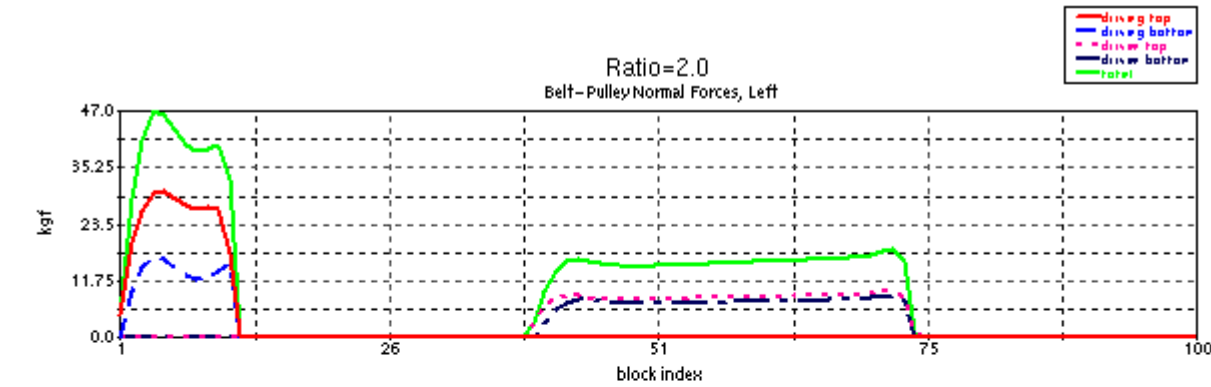
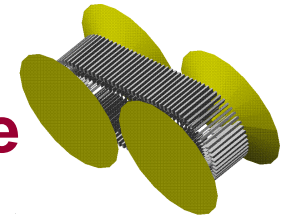
Example Time History Belt-Pulley Normal Force





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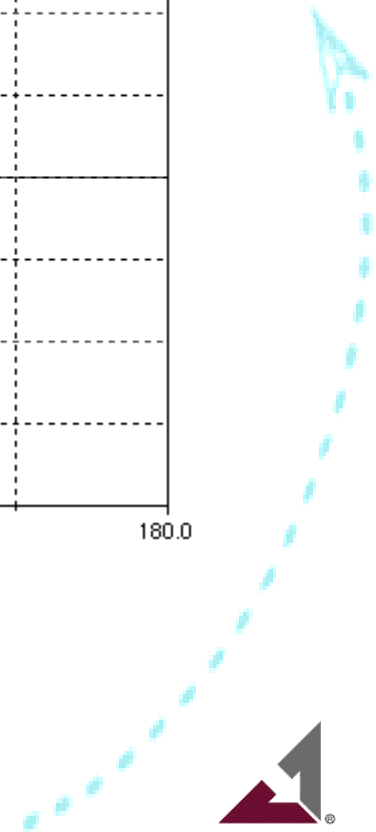
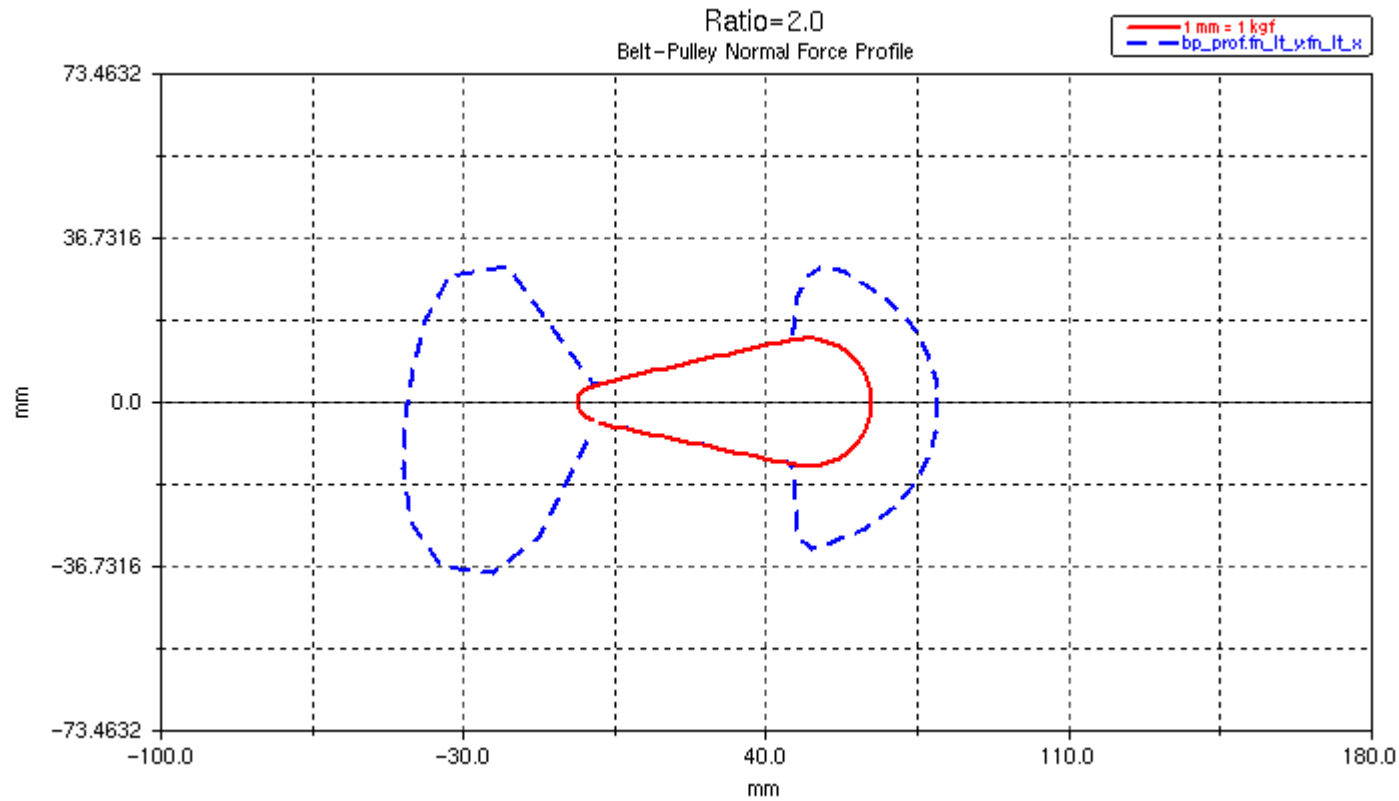
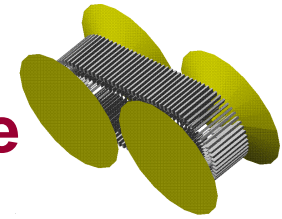
Example Snapshot Belt-Pulley Normal Force





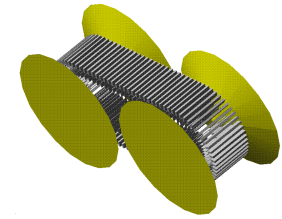
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Example Profile Belt-Pulley Normal Force

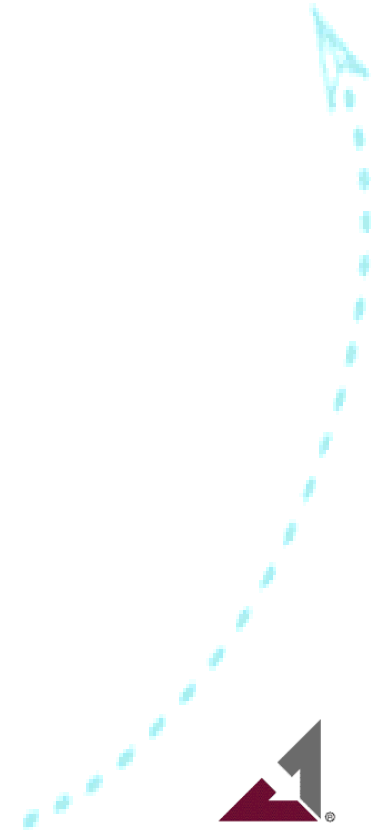
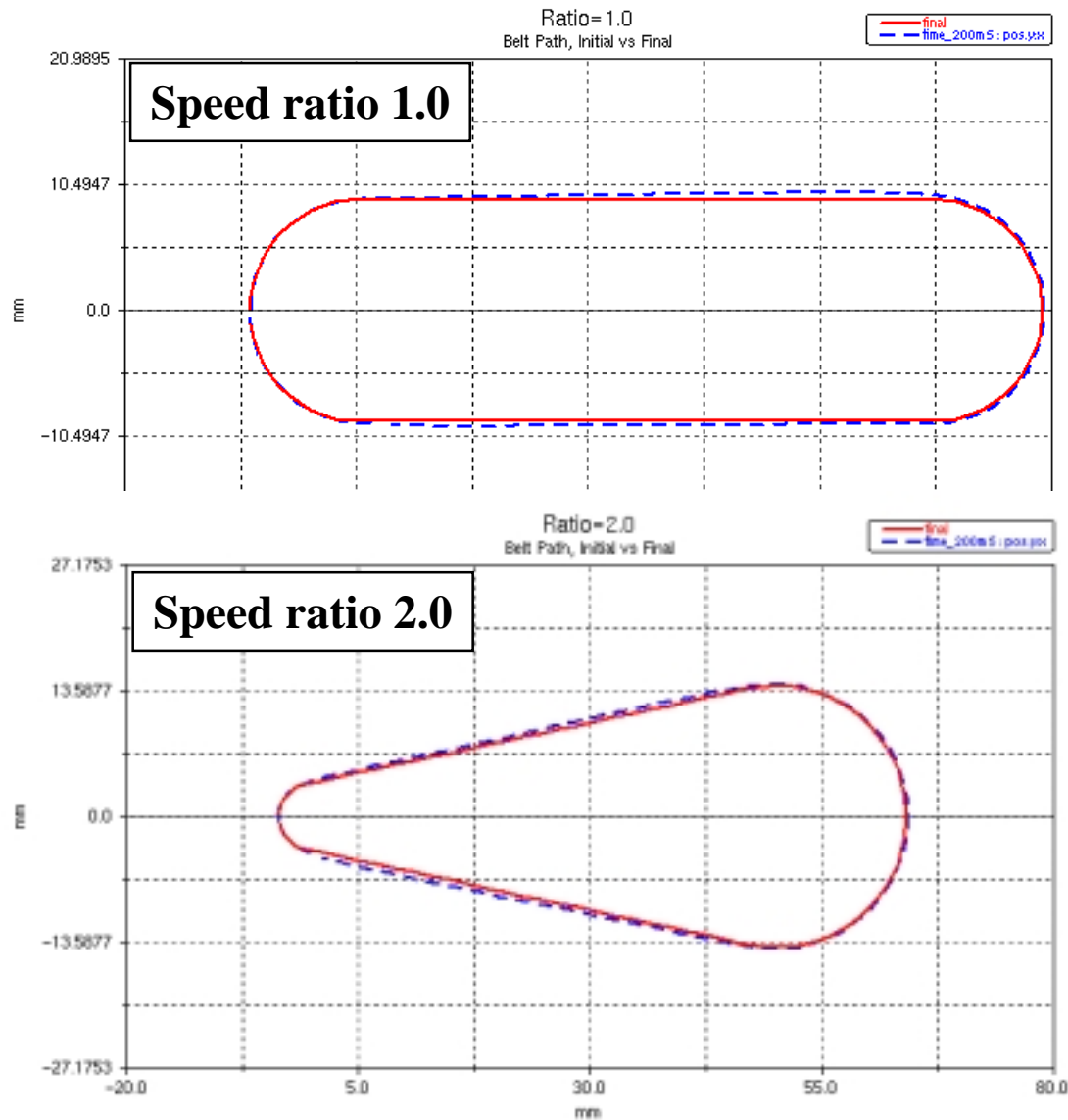




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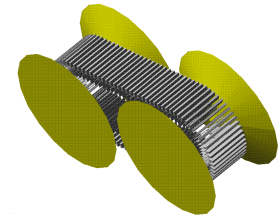
Belt shape at constant speed





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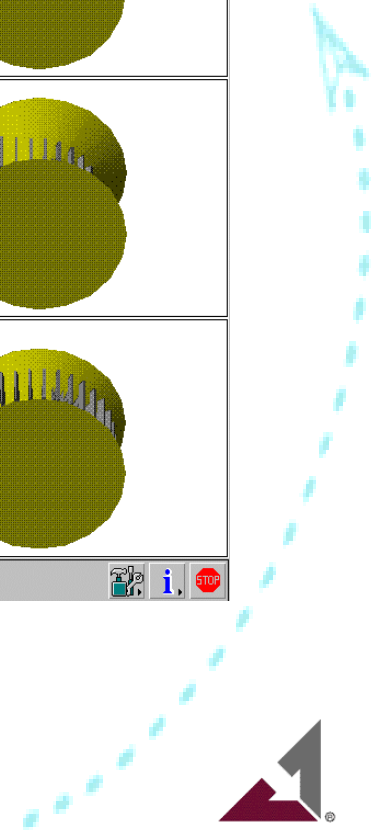
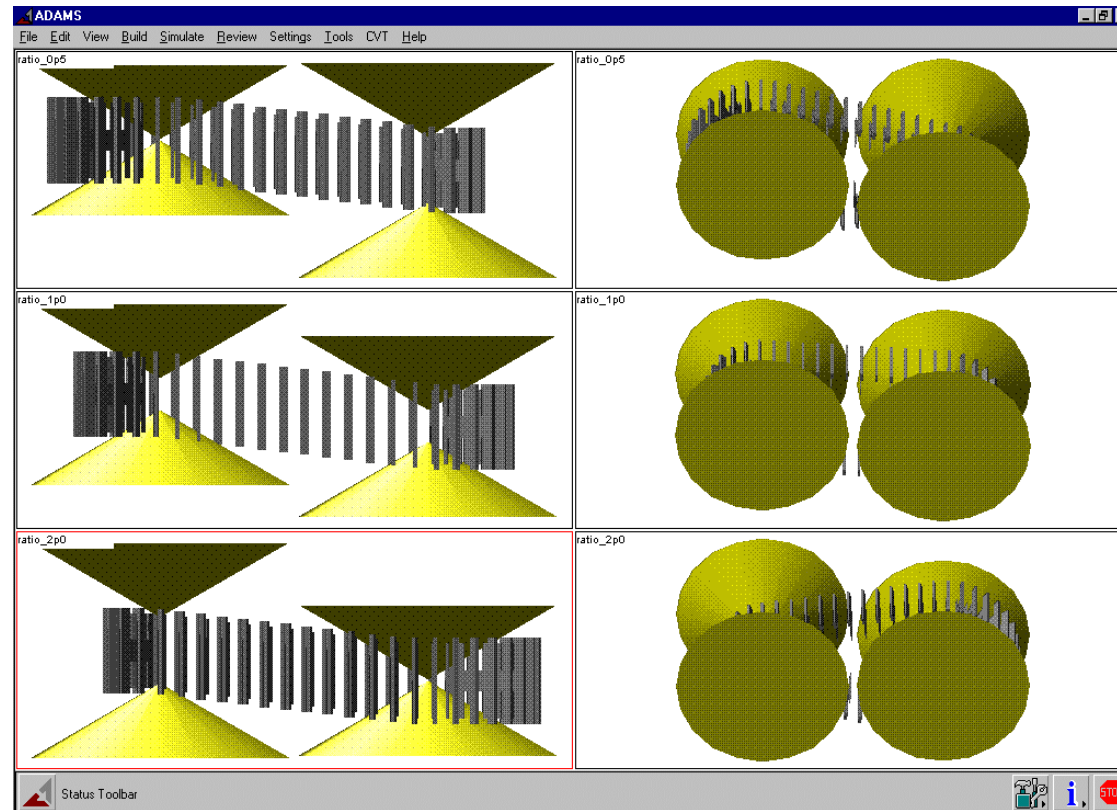
Model Topology



Ratio = 2

Ratio = 1

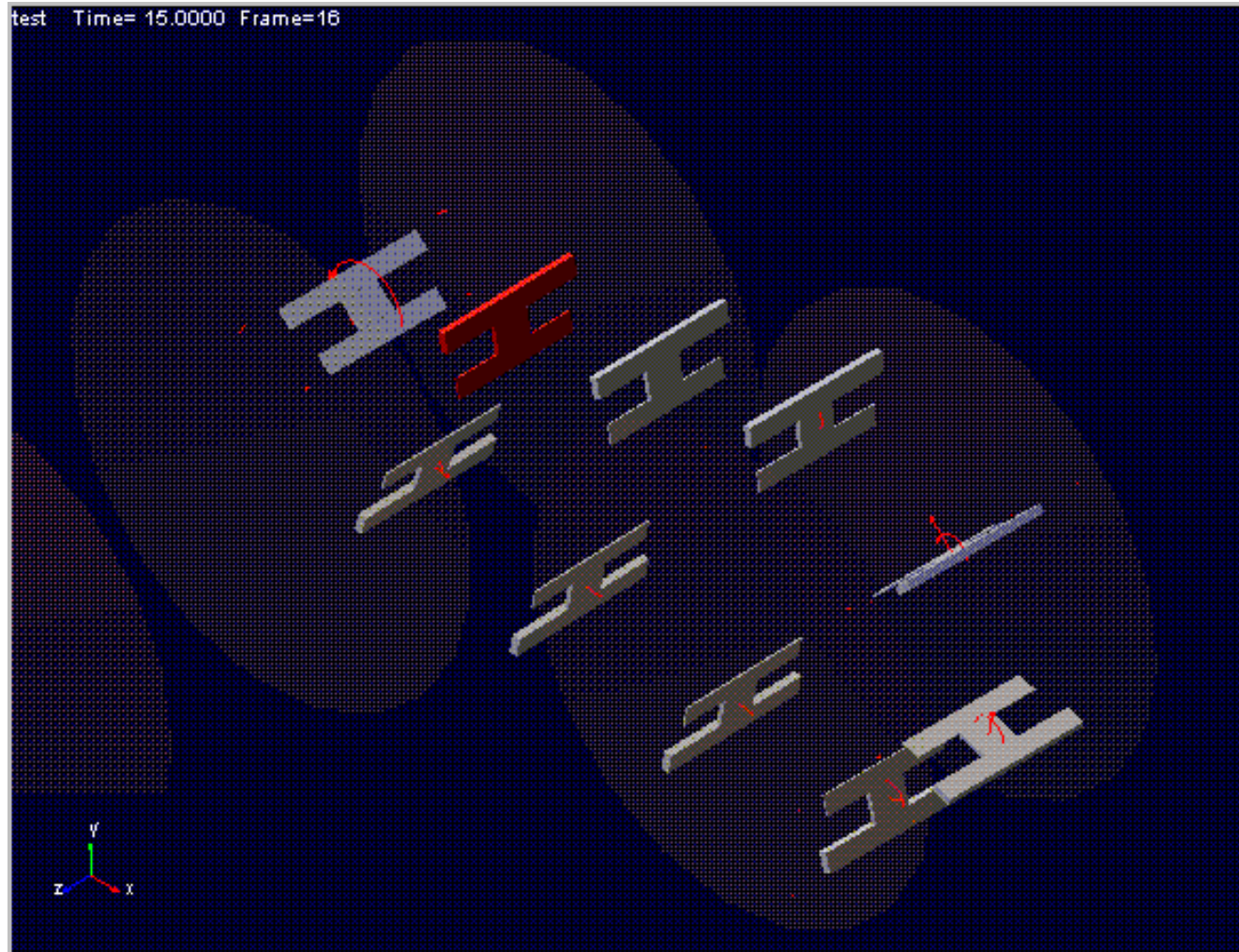
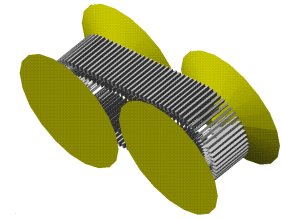
Ratio = 0.5





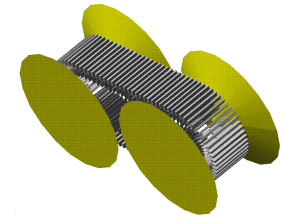
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Animation of variable speed

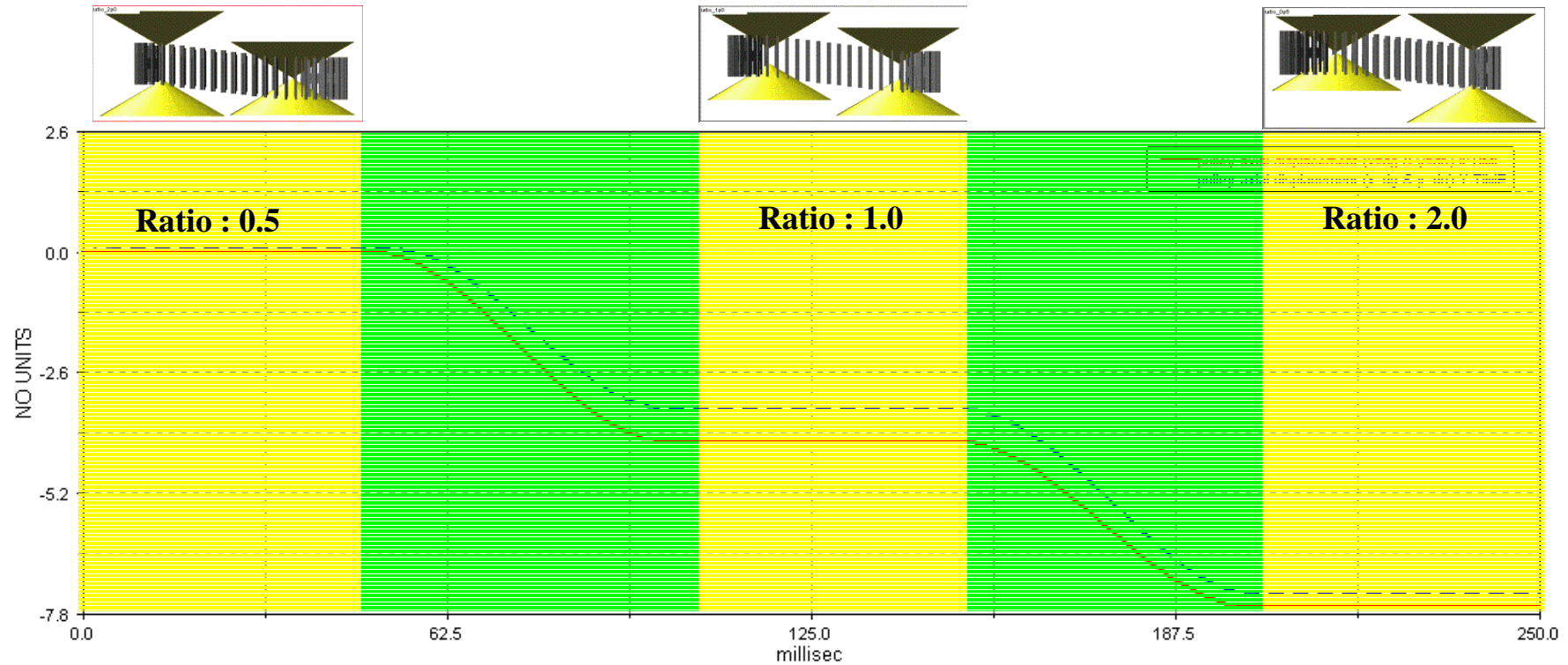




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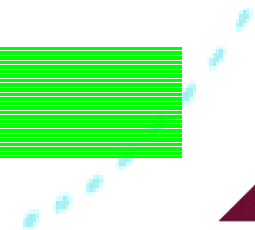


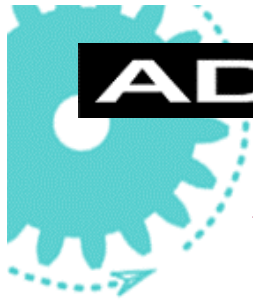
Analysis results of variable speed (Pulley axial displacement)



Constant

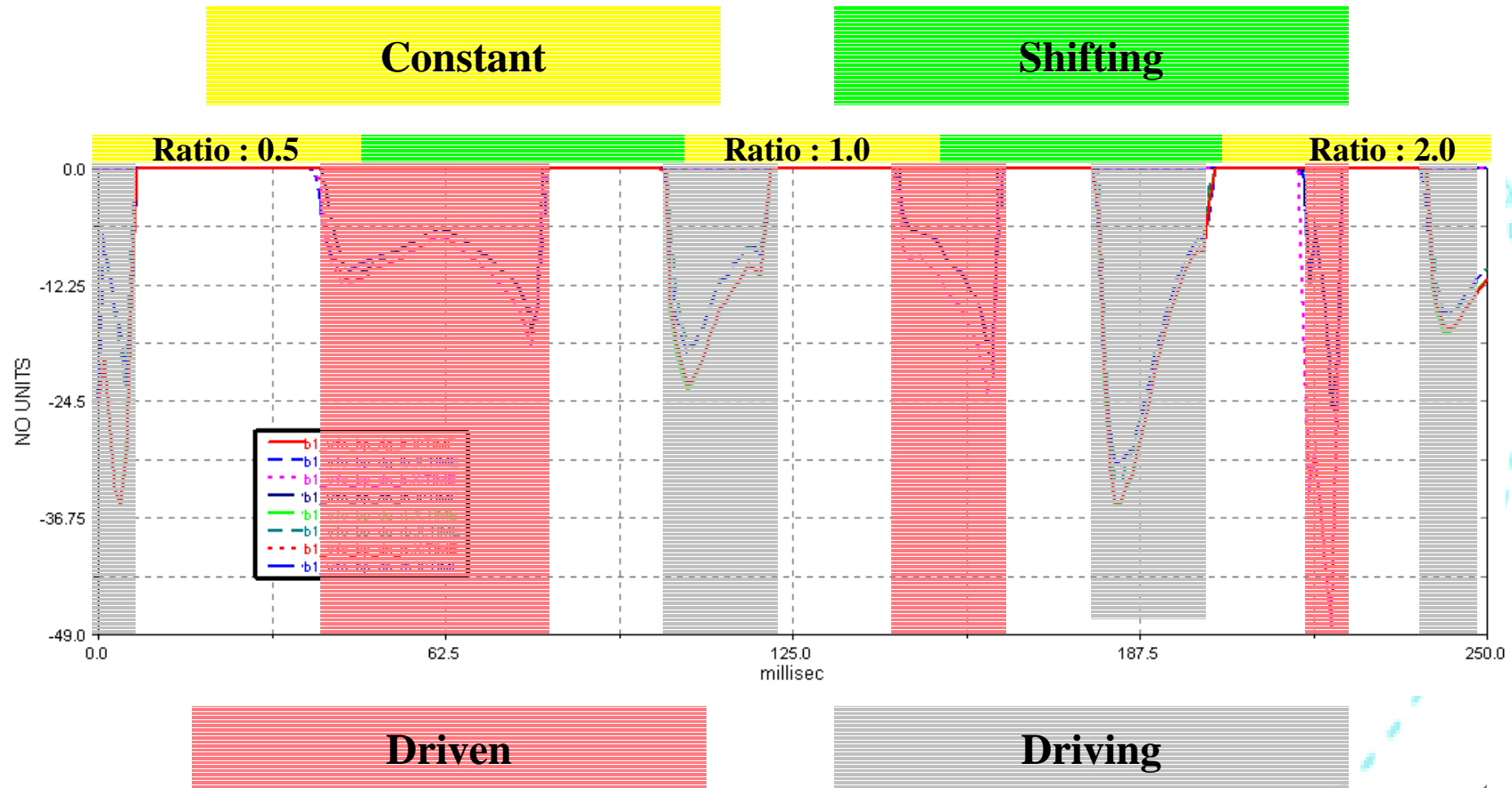
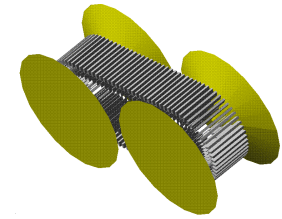
Shifting





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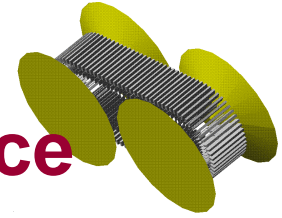
Analysis results of variable speed (Belt-pulley normal force)





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Future simulations for CVT performance and developing techniques



■ Items of future simulation

- ◆ Simulation in high speed
- ◆ Deformation effect of parts
- ◆ Durability of parts
- ◆ Effect of lubrication oil
- ◆ Design optimization

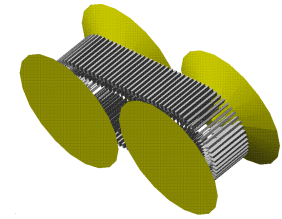
■ Developing technique

- ◆ Improvement of calculation speed
- ◆ Combine the flexible model of parts in the mechanism simulation model
- ◆ More accurate model to represent contact and friction
- ◆ Simplify the pre and post processor



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References



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- (2) Shinya Kuwabara et al., Study on metal pushing V-belt CVT, 1996 JSAE Autumn Convention Proceeding 964, (1996-10)
- (3) Tohru Ide et al., Experimental Investigation on Shift Speed Characteristics of a Metal V-Belt CVT, International Conference on CVT 96, (1996)
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- (5) Osamu Fujimura et al., Study on Shifting Mechanism of Metal Pushing V-Belt Type CVT, 1998 JSAE Autumn Convention Proceeding No.74-98 (1998-10)
- (6) Tukasa Yuuki, Application of CVT Using Dry Hybrid Belt, Nikkei Mechanical 1999.2 No.533
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- (8) Takeshi Miyasawa et al., Power Transmission Mechanism of a Dry Hybrid V-Belt for a CVT, SAE 1999-01-0751 (1999-3)
- (9) Makoto Imaida et al., Development of a Pulley System for a Belt-Drive CVT Application 2.0-Liter Engine Class Vehicles, 1999 JSAE Spring Convention Proceeding No.8-99 (1999-5)
- (10) Takeshi Miyazawa et al., Study on a CVT Using a Dry Hybrid V-Belt, 1999 JSAE Spring Convention Proceeding No.8-99 (1999-5)
- (11) Hirokazu Uchiyama et al., On the Shifting Mechanism of a metal V-belt CVT, 1999 JSAE Spring Convention Proceeding No.8-99 (1999-5)