

## Introduction

One of the greatest burdens of crash/safety simulation pre-processing is the fast and accurate positioning and articulation of kinematic mechanisms. Such mechanisms can be the occupant seat, the crash-test dummy, the seat with the dummy positioned on it, suspensions, rooftops, hoods etc.

Most of the software available in the market today, used for the above operations, requires advanced knowledge of dynamics in order to model and simulate these types of mechanisms. In addition, a detailed knowledge of the mechanism's structure is required for the set-up and use of such software.

On the other hand, ANSA's Kinematics Tool was developed to provide the CAE engineer with the ability to easily set-up and simulate the movement of mechanisms models without requiring a deep knowledge of the mechanisms' kinematics from the engineer.

An Implicit Multibody Dynamics solver (HHT-I3), wrapped around by a user-friendly interface, has been integrated within ANSA, in order to allow the users to efficiently and easily position such complex kinematics mechanisms.

## Basic Concepts of the Kinematics Tool

### Kinematic Rigid Bodies and Joints

The Kinematics Tool automatically extracts kinematic rigid bodies and kinematic joints from the FE model. The two main ways for the automatic identification of the definition of a kinematic mechanism is by:

- *Model Connectivity*: The tool automatically detects the connectivity of the model and separates the model into the appropriate kinematic rigid bodies and joints.
- *Sets*: This technique is more common in defining seat mechanism. The seat manufacturers usually provide the kinematic rigid bodies as nodal sets. Providing this set to the tool, the appropriate kinematic rigid bodies and joints are created.

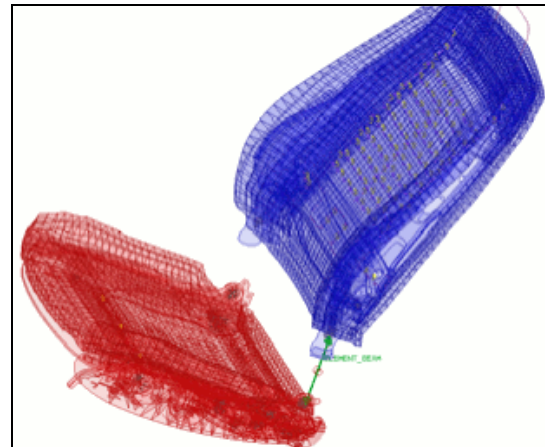


Figure 1: Automatic detection of Rigid Bodies and joints

### Kinematic Rigid Bodies

The Kinematic Rigid Bodies are groups of parts that move jointly during mechanisms motion.

### Kinematic Joints

ANSA offers the user access to a rich library of joint types that can be directly selected for mechanisms modeling. Many advanced joints types are supported by ANSA, such as: revolute, spherical, cylindrical, slider, screw, rack and pinion, universal and many more. This allows for the efficient set up of the kinematic configuration, without requiring from the user to turn on and off D.O.Fs for each joint definition, as in other software.

### Mechanical & electro-mechanical mechanisms

The above listed joints types fully serve the modeling of the mechanical kind of mechanisms. But how to address the modeling of modern electro-mechanical mechanisms that perform complex and coupled motions?

To model complex electro-mechanical mechanisms, the Coupler Joint is used in ANSA, which relates the translational and/or rotational relative motion of two or three joints.

## Creating Kinematic Configurations

The Kinematics Tool's intuitive interface allows the organization of the kinematic components so that different movement configurations can be **predefined** by the mechanism expert and made available to more engineers for modeling tasks. This is important because not all users need to know all the details of the kinematic configuration, so they can focus only on the positioning task.

Characteristic application examples may be the tilt and height adjustments of a seat model.

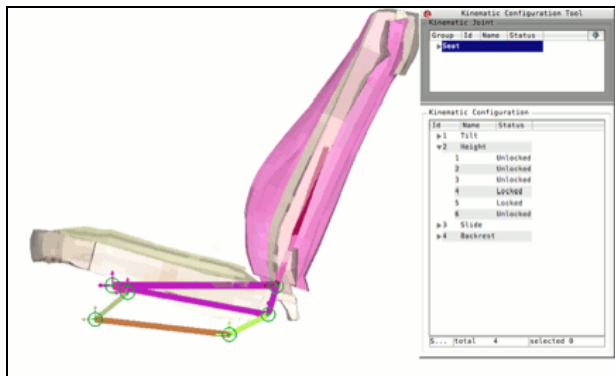


Figure 2: Complete seat configuration set-up.

With the definition of the Mechanism, kinematic configurations can be created to perform a specific type of movements.

Kinematic configurations are easily created by:

- locking or unlocking joints
- grouping the necessary joints
- selecting a joint to be the actuator joint.

## Kinematics Tool and Morphing

A tight integration with many software tools is already present in ANSA. This way, the Kinematics Tool works also in conjunction with the ANSA Morphing Tool.

Deformable components connecting different parts of the kinematic model can be controlled and reshaped automatically by the Morphing Tool, during mechanism's motion. Examples of such components are: stabilizing bars, springs, deformable ducts, stretchable fabric covers etc.

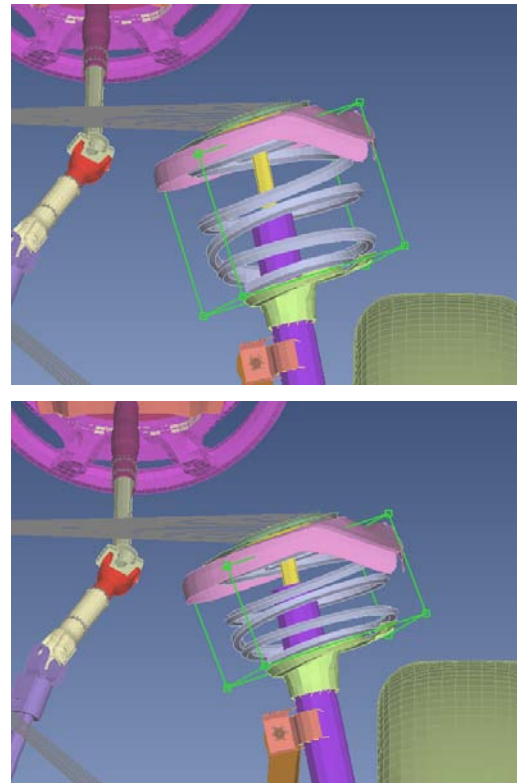


Figure 3: Suspension spring getting linearly compressed during the kinematic motion

## Motion

During the movement of the mechanism, relevant information from the LS-DYNA<sup>®</sup> model is taken into account.

For example, information of the `*CONSTRAINED_JOINT_` and `CONSTRAINED_JOINT_STIFFNESS_` keywords, such as the high & low stop angles values, are respected as constraints to the mechanism model kinematics.

At the same time, during mechanism model motion, values update is performed automatically on the LS-DYNA<sup>®</sup> model cards, taking into account the spatial information that is needed to be transformed (e.g. `PART_INERTIA` cards, `ELEMENT_DISCRETE` offsets etc).

## Output

In order to guaranty the robustness of a CAE process, validated models are used during model built up. A characteristic case is that of crash test dummy models. Reading and writing a dummy model to/from the pre-processor is something that is usually avoided.

In order to serve this practice, ANSA Kinematics Tool offers the option to treat imported validated sub-models as read-only, by outputting only their transformation information in the form of \*NODE\_TRANSFORM.

## Applications

The Kinematics Tool has a wide range of applications. Some of the most common applications are presented below.

### Seat and Dummy Positioning

A characteristic case of mechanisms motion in crash and safety is the positioning of the crash test dummy model, and its coupled motion with the seat, in a position dictated by the test protocol to be simulated.



Figure 4: A dummy seat coupling moving together

## Suspensions

The adjustment of the suspension height, without having to quit the pre-processor and use a third party solver, is an offered capability that saves a lot of time. With ANSA, the user can set-up the suspension mechanism and configure the suspension to the desired riding height and wheel angle.

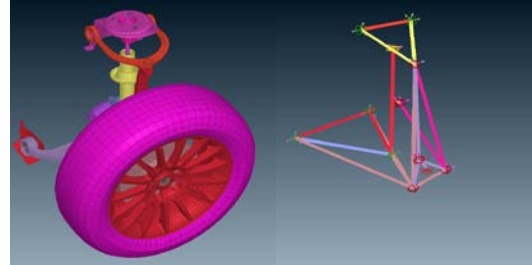


Figure 5: The FE model of the suspension and the extracted kinematic model

In the example depicted below, after the mechanism model has been extracted and the configurations are defined, the execution of a turn wheel kinematic configuration is a simple procedure.

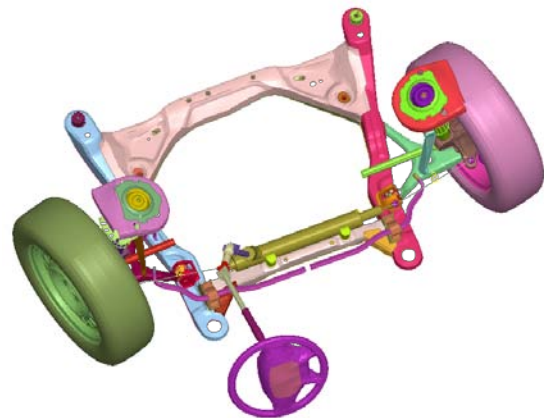


Figure 6. Wheel turn, kinematic configuration

## Roof Tops

For rooftop analysis, the Kinematics Tool allows the deployment of the roof model to various positions, from full folding to full extension. In this specific example the time that it takes to extract the kinematic model and perform the articulation is less than a couple of minutes.

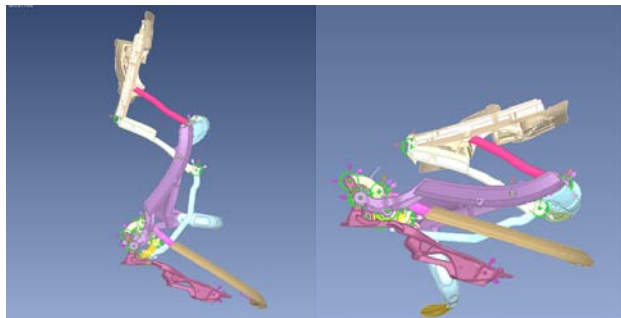
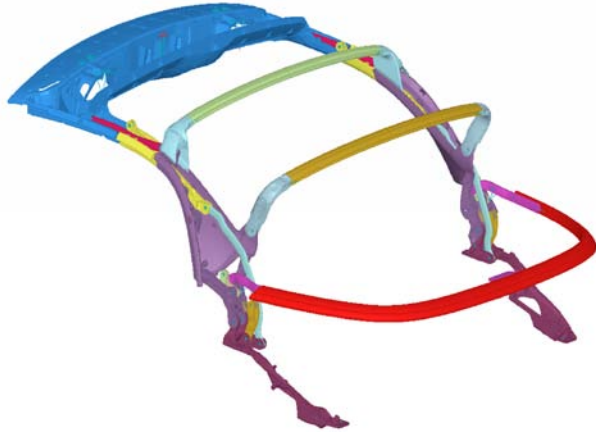


Figure 7: Folded rooftop

## Conclusions

The Multi Body Dynamics solver capability, embedded within ANSA, provides the user with impressive capabilities in positioning and articulating a FE model.

Any type of electromechanical mechanism can be positioned and articulated according to the load case requirements. All the set-up can be done, in advance, by the mechanism expert and shared with the rest of team for later implementation. Using the kinematic configurations, the non-experts can move the mechanism without needing to have a deep knowledge of the mechanism's kinematics.

## References

- ANSA v13.1.1 User's Guide, BETA CAE Systems S.A., October 2010

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