Handling of Complex Kinematics of a Crash Model in ANSA

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Summary:

The increased sophistication of impact models and the existence of many kinematic mechanisms in them, along with the need to study many load cases, has forced the analysts to use multi-body solvers to reposition their models. This has been a complex task, so the need for the development of such tools within the preprocessors is necessary. BETA CAE Systems, a leader in the development of sophisticated tools in the area of preprocessing, developed such advanced tools integrated in the ANSA pre-processor. This integration is taking advantage of all the existing functionality for crash preprocessing and process automation.

Keywords:

Kinematics, multi-body, crash, occupant safety, task management.

1 The Kinematic Problem

Kinematic mechanisms have long been used in crash models. Their most popular application is in dummies. The dummy being an open tree kinematic structure has an easy analytical solution. ANSA has, for many years, provided a tool to reposition and articulate dummies taking care not only the correct transformation of node coordinates, but also transforming any other space dependent variables in the model, like inertias etc.
This functionality has also been extended to four bar mechanisms, which also has analytical solutions. This way seats could be decomposed in four bar mechanisms representing the various adjustments and get repositioned.
Nevertheless this was an intermediate solution. Not all mechanisms are four bars, and even four bars mechanisms have extra members like the dumpers, motors, levers etc. These extra members become very important when the structure needs to be modeled in great detail. The current practice followed by the analysts, is to solve the kinematic problem in a multi-body solver, and then try to map the results back into the crash model. This procedure may be cumbersome, error prone and ineffective.

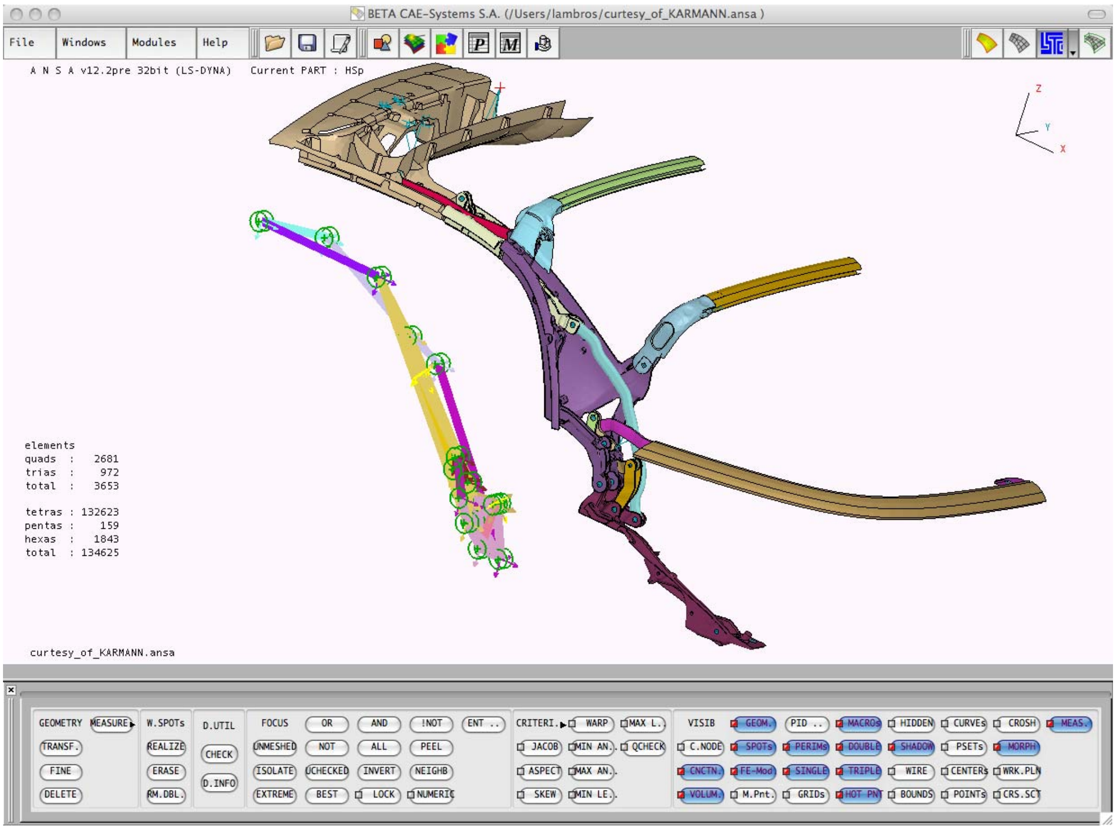

Fig .1: Complex kinematics in a model (model courtesy of KARMANN)

2 The ANSA approach

To fully address the problem, a multi-body solver had to be implemented within the preprocessor. After evaluating the various possible solutions a modern and robust implementation was selected. The time response of the equations of motion of the multi body system, subjected to the kinematic constraints, is evaluated with the use of the HHT-I3 implicit method. The resulting system of non-linear equations is solved by a Newton like algorithm. The estimation of the integration error is calculated in order to evaluate the accuracy of the solution. Based on this, the correct time step size is selected to accelerate the convergence of the solution. The end result is that a robust, fast and accurate algorithm has been programmed that can solve any kinematic problem.

3 Integration into the preprocessor

As stated earlier the primary problem of the engineer, in our case, is not the solution of the kinematic problem, but the reposition and articulation of a crash model. For this to become easy, ANSA provides a user friendly interface that allows the user to seamlessly set up the kinematic problem and do the necessary repositionings.

3.1 Kinematic model definition

For the easy definition of the kinematic model an advanced functionality has been developed, that based on the existing information of the model and on its connectivity, can detect and split the model in the various kinematic parts (rigid bodies and kinematic joints). This functionality can be fully automatic or semi automatic in the worst case. Useful information from the crash model such as the type of joints, orientation and stop angles (taken from *CONSTRAINED_JOINT, *ELEMENT_DISCRETE, *CONSTRAINED_GENERALIZED_STIFFNESS etc) are transferred to the kinematic model and used by the kinematics tool during repositioning. In addition manual and script driven procedures can be used to accomplish the same task.

Dummies and models that contain kinematic information in the input deck files are automatically treated and the corresponding kinematic definitions created.

The kinematic definition has been extended to also include the various combinations of locked and unlocked joints that constitute the different discrete movements that a complex mechanism can perform. In the case of a seat model, the tilt adjustment, height adjustment back rotation adjustment etc can be predefined together with the actuator joints that control them. This is called a Kinematic Configuration. In this way the engineer can get a model with all the kinematic information predefined and work in a natural way of selecting the movement he wants to perform (tilt, height etc). This approach is a lot more powerful than releasing and fixing degrees of freedom of kinematic entities.

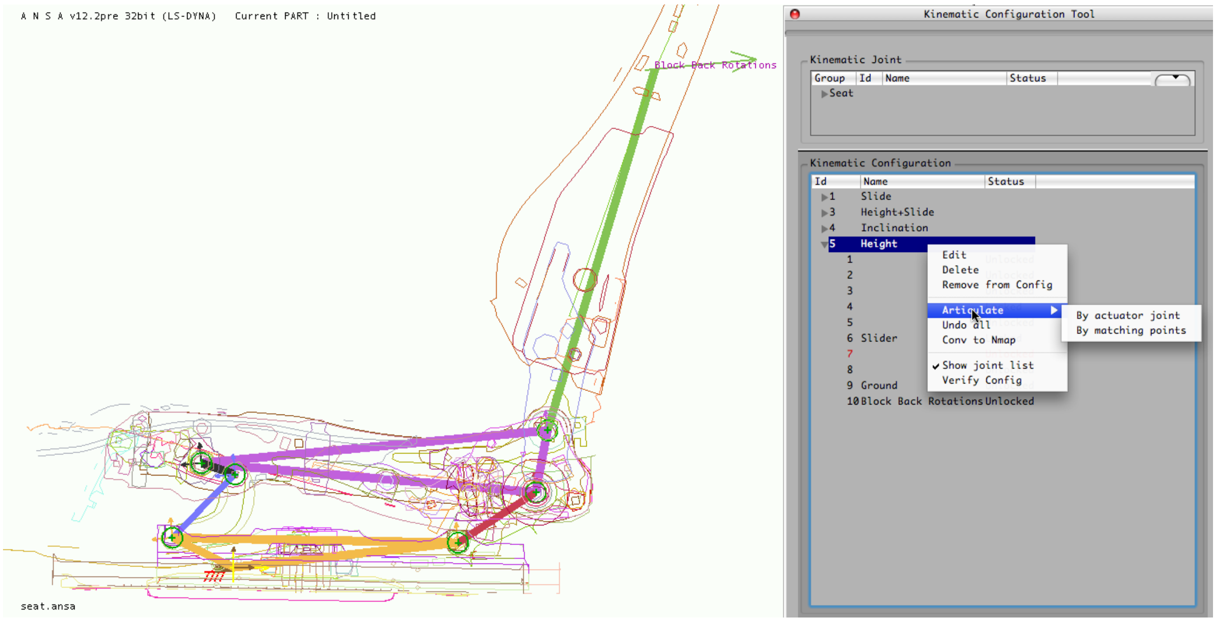

Fig. 2: A complete seat model with it's various discrete movements predefined. (model courtesy of BMW)

3.2 Model articulation

Since the reposition of the model is based on spatial data two methods can be used. The first is specifying the desired value (translation or rotation) of the actuator joint. The second is by giving target locations for any number of points in the mechanism. Any intermediate positions of the mechanism can be saved for later use.

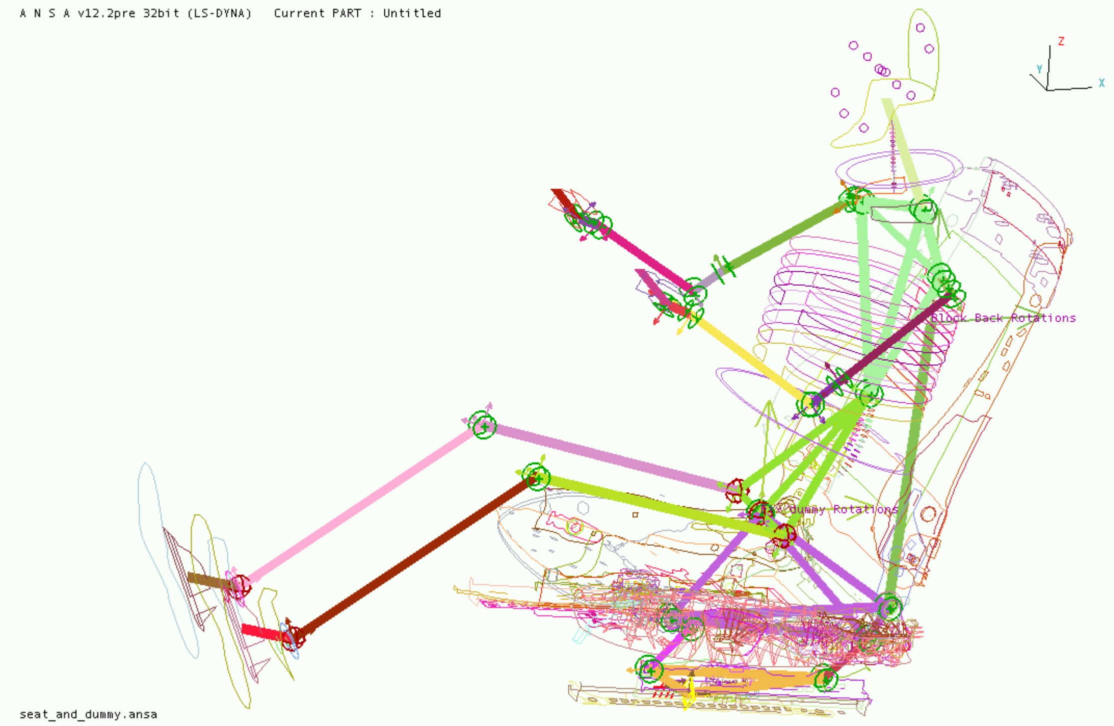

Fig. 3: A complete seat and dummy kinematic model

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3.3 Other features

Since the tool is integrated within the preprocessor advanced features can be used such as:

3.3.1 Morphing

FE entities that join different kinematic parts and have to be deformed can be assigned to the morph boxes and so that can be morphed during the movement.

3.3.2 Contact detection

Using ANSA contact detection algorithms, contact detection can be used in the solution. Whenever a contact is taking place a special contact-joint is created by the solver to prohibit any movement in the penetrating direction.

3.3.3 Output

Since seats and dummies are often models validated by the supplier it would be very useful for the user to output the model with as little changes as possible. For this, a special function has been implemented that can extract all the transformation information after the positioning, and create *NODE_TRANSFORM keywords together with the corresponding sets. Thus the original models need not to be touched at all, and only the transformation matrices outputted in the master include file.

3.3.4 Multi Solver compatibility

All the described functionalities can be applied not only to LS_DYNA models but to any other solver ANSA supports.

4 Integration of the tool in the process automation

The kinematics tool not only uses the the advanced functionality of ANSA but it is also integrated into the “Task manager”, the process automation tool that exists within ANSA. So any procedure that includes repositioning of a kinematic model for the creation of the analysis model can be predescribed and saved as a template (ANSA Task). This template can be re-runned to create new models upon model change or new loadcases.

In the case of an occupant safety simulation that includes both dummy and seat positioning all the appropriate steps can be predefined.
First the dummy and the seat have to be inputed in the model. Then the dummy has to be moved in position as a separate mechanism and attached to the seat. Seat back and dummy are rotated to get their final vertical orientation. Then the seat and the dummy together as one mechanism are positioned performing the predescribed seat movements (height etc). The limbs of the dummy are then moved in position on the pedals and the steering wheel. In the final stage the dummy and seat cushion get depenatrated and the seatbelt system is created and applied. The seat and dummy system can also be moved with the dummy limbs anchored on the pedals and steering wheel.
This procedure can be replayed with a minimum user intervention.

5 Summary

A multi-body solver has been integrated into the preprocessor in order to position complex crash models.
The kinematic details have been hidden by a user interface that is focused on the needs of the crash engineer.
The tool integrated with the rest of ANSA functionality under the umbrella of Task Manager can automate complex procedures and help the engineer stay focused on his analysis.