Automobile CVT Shift and Park Mechanism and Powered Lift Gate Simulation Using ADAMS and CATIA

J. Shane Sui, John A Hirshey II
DaimlerChrysler Corporation

1. Introduction

Conventional mechanism design concept using only kinematics verification has many limitations such as no forced response simulation, no contact friction simulation and no control simulation. With the application of many complicated mechanisms and powered devices in automobile design, dynamic verification becomes necessary for safety as well as for reducing the time and cost of testing.

To build and debug a dynamic mechanism model is time consuming and sometimes frustrating. Geometry manipulation and design modification are much easier to be done in CAD tools such as CATIA compared with in ADAMS. ADAMS View as a preprocessor of ADAMS Solver makes ADAMS simulation easier but is not designed to replace CAD tools for most geometry manipulation. An update design in CAD software maybe quite different compared with before with the consideration of packaging and system requirements, so the ADAMS model need to be rebuilt quickly to perform the dynamic simulation.

CAT/ADAMS serves as a bridge between CATIA and ADAMS. CATIA geometry, hardpoints, mass and moment of inertia properties as well as CATIA/Kinematics model can be transferred to ADAMS easily through CAT/ADAMS. The initial design is done in CATIA and CATIA/Kinematics is used to check the basic kinematic requirement of the mechanism. ADAMS model building time will be greatly reduced by using CAT/ADAMS. After ADAMS simulation and optimization, the suggested hard points can be transferred back to CATIA. When the CATIA design update is done based on ADAMS result and system requirements, CAT/ADAMS is used again to build the update ADAMS model to confirm the dynamic simulation.

Two typical applications are presented in this paper. One is the simulation of the shift and park mechanism of Continuously Variable Transmission. The dynamic cable force was simulated with contact and friction consideration. Another example is the simulation on automobile powered lift gate. The dynamic performance of the mechanism is verified and the gas spring properties are tuned. The stopping displacement of the powered lift gate is also simulated when the sensor senses an obstacle in the closing path. The results are very helpful for setting up the anti-pinch sensor.

2. CVT Shift and Park Mechanism

Continuously Variable Transmission is not a new idea. The advantage is obvious like no abrupt shift and good fuel economy, but because of the manufacturing cost and durability concern, it isn't being taken seriously until recently. DaimlerChrysler Corporation is also preparing to put CVT in its future vehicle. One of the tasks is to design a shift and park mechanism for the proposed CVT (see Figure 1). The shift and park mechanism of CVT is quite similar to the one of automatic transmission. So based on experience the proposed shift and park mechanism is designed by the design engineers in CATIA as shown in Figure 2.

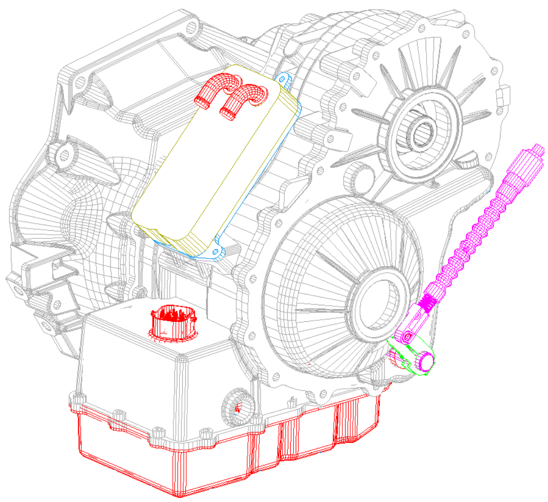

Figure 1 Continuously variable Transmission

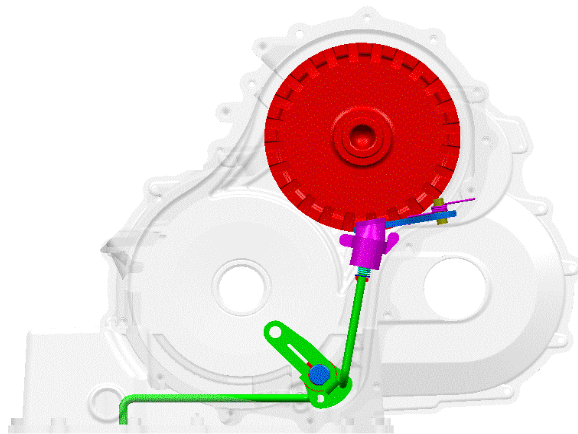

Figure 2 CVT Shift and Park Mechanism

2.1 Kinematic Analysis in CATIA

Once the initial design is done in CATIA, a series of checking need to be done in CATIA for kinematic requirements as well as packaging concerns. The difficult part for defining the CATIA kinematic model is the modeling of contact. There are several contacts in this mechanism. The first contact is between leaf spring roller and the rooster comb (see Figure 3). In CATIA this contact could be modeled by a roll curve joint. Since there is no such a joint in ADAMS, this joint is modeled by point curve joint so it could be transferred to ADAMS directly later. The contact between the bullet and the rider is a surface to surface contact. Using CATIA the bullet travel trace could be determined and a point curve contact is modeled in CATIA instead. The contact between the pawl and the bullet, and contact between the pawl and the sheave are modeled by combination of transnational joint and point curve joint.

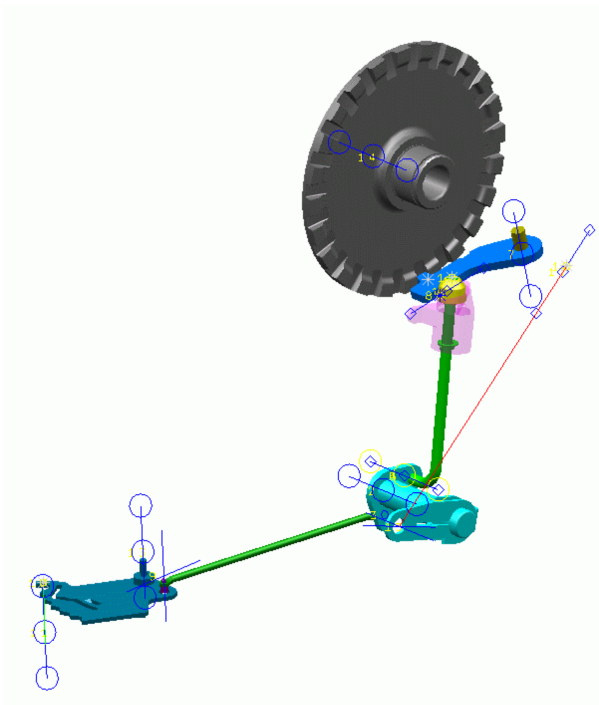

Figure 3 CATIA Kinematic Model of CVT

The big advantage to do kinematic analysis in CATIA is the ease to build a kinematic model and the ease to modify the design and refine the kinematic model. Based on kinematic and quasi-static requirement, several design changes are made in CATIA like cable and shift lever angle, rotating radius on rooster comb and bell crank and pawl and bullet rider position.

2.2 CATIA ADAMS Interface CAT/ADAMS

CAT/ADAMS is mainly an embedded CATIA function called ADAMS which can convert most CATIA/Kinematics definitions to ADAMS. It can also transfer CATIA design hardpoints as well as CATIA geometry to ADAMS. The elastic elements can also be defined in CAT/ADAMS and a limited dynamics analysis could be done inside CAT/ADAMS. CAT/ADAMS version 10 also has direct link to ADAMS/Post to do post-processing.

For our purpose, CAT/ADAMS is only used to transfer CATIA kinematic model and design hard points to ADAMS (see Figure 4). All the other ADAMS modeling is done in ADAMS/View.

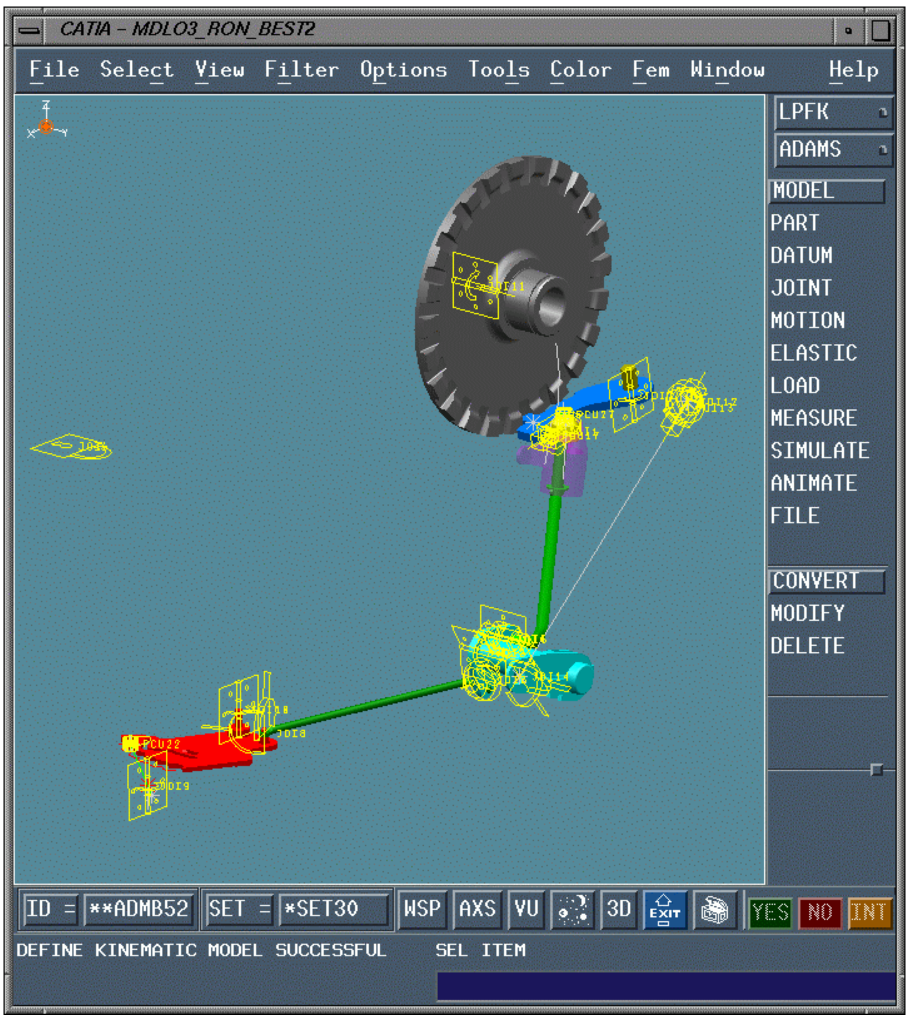

Figure 4 ADAMS Kinematic Model in CAT/ADAMS

2.3 Dynamic Analysis in ADAMS

Once design hard points and kinematic model are transferred to ADAMS/View, the elastic elements and frictions can be defined easily based on some testing results. Two scenarios need to be simulated in ADAMS for this mechanism.

2.3.1 Shift cable force when vehicle parked horizontally

In this scenario, there is no torque from the sheave. Cable is pulled very slowly and the pulling force is determined by the rotating spring on the pawl, the leaf spring, valve spring and the contact frictions. The shift cable force is calculated in the pulling range in ADAMS (as shown in Figure 5).

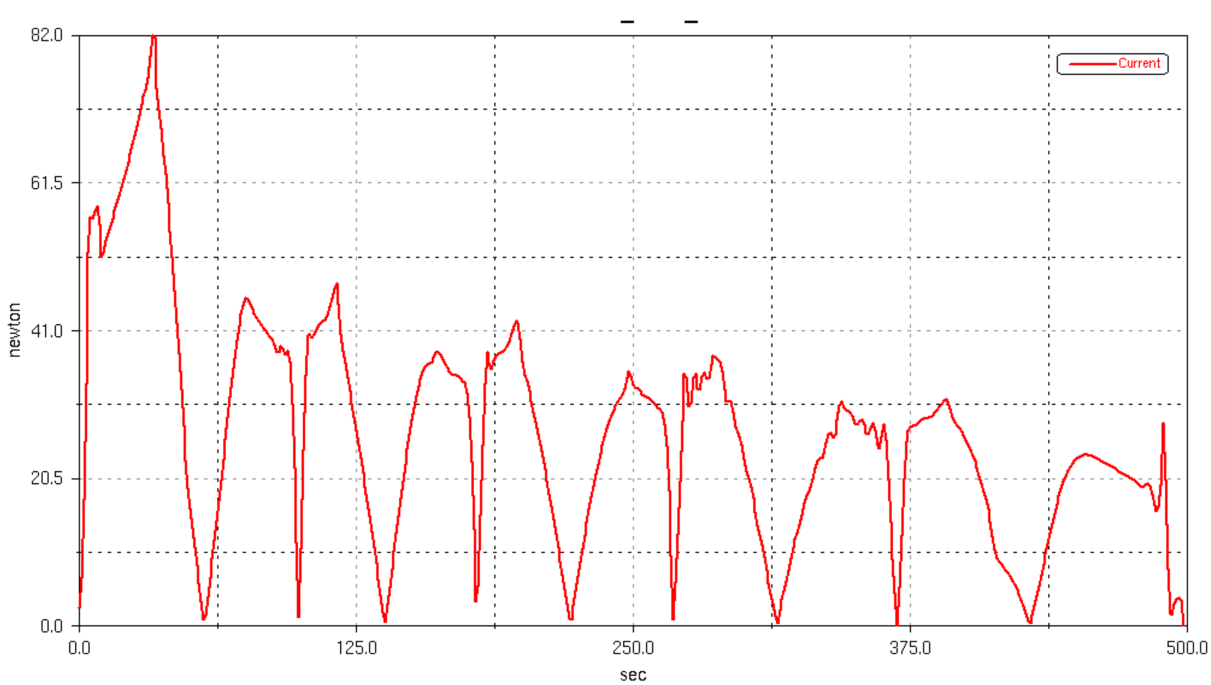

Figure 5 Shift cable force when vehicle parking horizontally

2.3.2 Max shift cable force when vehicle parked on a slope

When a vehicle is parked on a slope, there is a large torque acting on the sheave due to vehicle weight through transline. This torque could be determined by the vehicle weight, the slope angle, tire radius and gear ratio to the sheave. All other parts of the model are very similar to scenario one (2.3.1). The max shift cable force is predicted as shown in Figure 6.

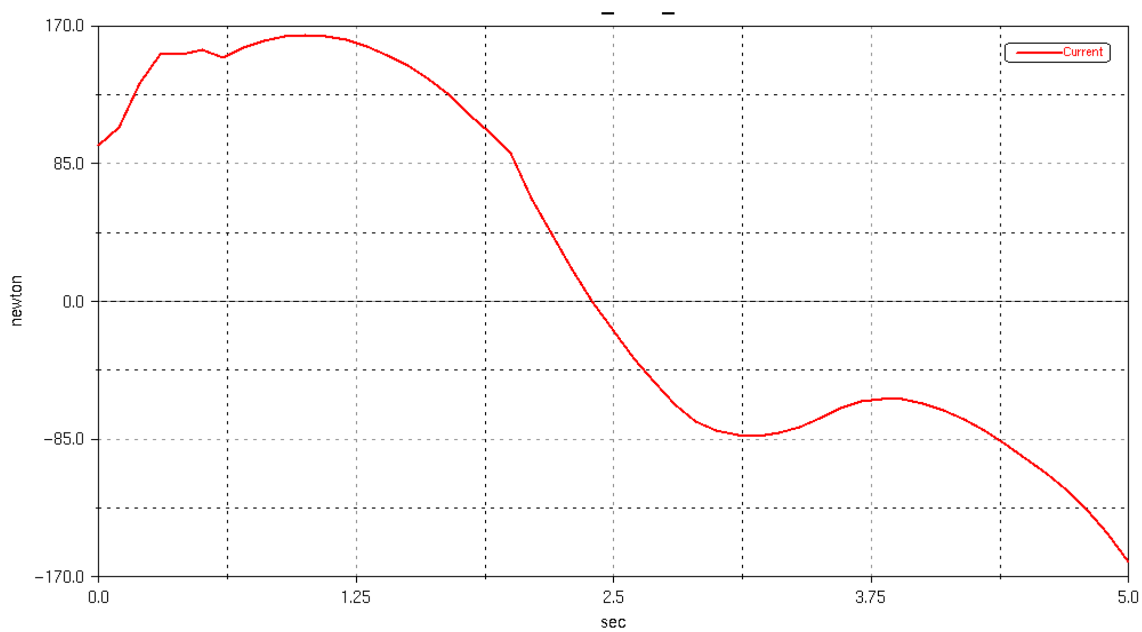

Figure 6 Maximum shift cable force when vehicle parking on a slope

3. Simulation of Response Distance of Powered Lift Gate

Lift gate is commonly used in minivan, SUV, hatch back and special small car like Chrysler PT Cruiser. Most of the lift gates are equipped with gas "springs" but few have a powered device to open and close the gate. To design a powered lift gate, one of the concerns is how to prevent pinch when the gate closes. An anti-pinch sensor is designed to detect if there is any obstacle in the gate closing path. Once the obstacle is sensed the motor will revert immediately to overcome the gate momentum to stop the gate and open the gate. The question is what is the response distance when the obstacle is sensed.

For this design, a similar process is taken like the previous one. The CATIA kinematic model is built to check the basic motion and position of the gas spring with quasi-static analysis. An ADAMS model is built through CAT/ADAMS for dynamic analysis. The mass and moment of inertia of the lift gate are calculated in Nastran and hand input into ADAMS/View Mass and moment of inertia properties of all other parts are transferred from CATIA through CAT/ADAMS.

3.1 Modeling of gas spring

The gas "spring" has many advantages over the mechanical spring. No damping on compression makes it easy to close. The damping could be added to the extend direction to prevent the device open too fast. The "spring" could be set to high preload and lower stiffness without using additional hardware to achieve. The high damping could be achieved at the extension end to slow the motion gradually. With these nice features, the gas spring is extensively used in automobile lift gate, hood and trunk. To build a complete gas spring model takes a lot of effort. In many cases it can be simplified for special simulation. In our simulation we only care about the compression process so the damping could be ignored. Without damping the force displacement diagram can be simplified as shown in Figure 7. The difference between the compression and extension is the friction which increases the force for compression and decreases the output force when the spring extends. The forces increase with an increase in ambient temperature.

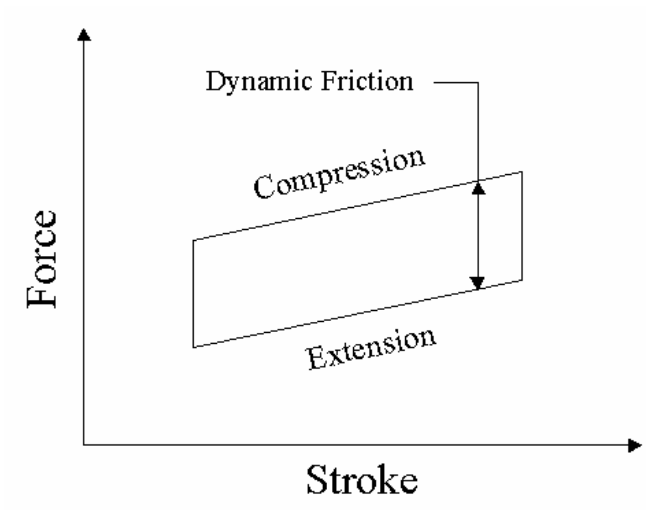

Figure 7 Gas spring force vs. stroke without damping

3.2 Modeling of the motor

The motor has a certain output power and a maximum output torque for lower speed. As the motor rotating speed increases the output torque will be limited by the output power as shown in Figure 8. When the anti-pinch sensor receives the signal, the motor starts to reverse after a very short time lag. The gaps between the different gears and the frictions through all the joints are assumed to be zero.

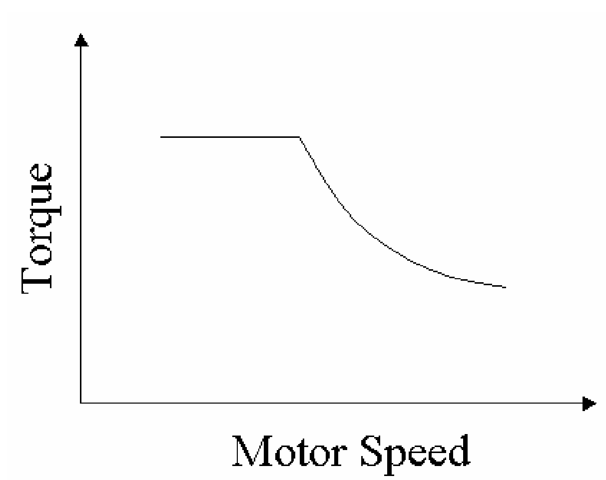

Figure 8 Motor torque output vs. motor speed

3.3 Simulation Results

Pinch could happen in any position along the door seal. Generally speaking the closer to the gate hinge the more dangerous it will be. Several points are selected along the door seal to run the analysis. There are two measures shown in the ADAMS/View window (Figure 9). The left measure shows the angular velocity of the crank arm and the right one shows the gate rotation angle. When the sensor senses the pinch, after a very short delay the torque on the crank arm will change direction and decelerate the rotation speed to zero, then lift gate starts to open. The geometry and location of the anti-pinch sensor as well as the entire system parameters will be modified according to the simulation results.

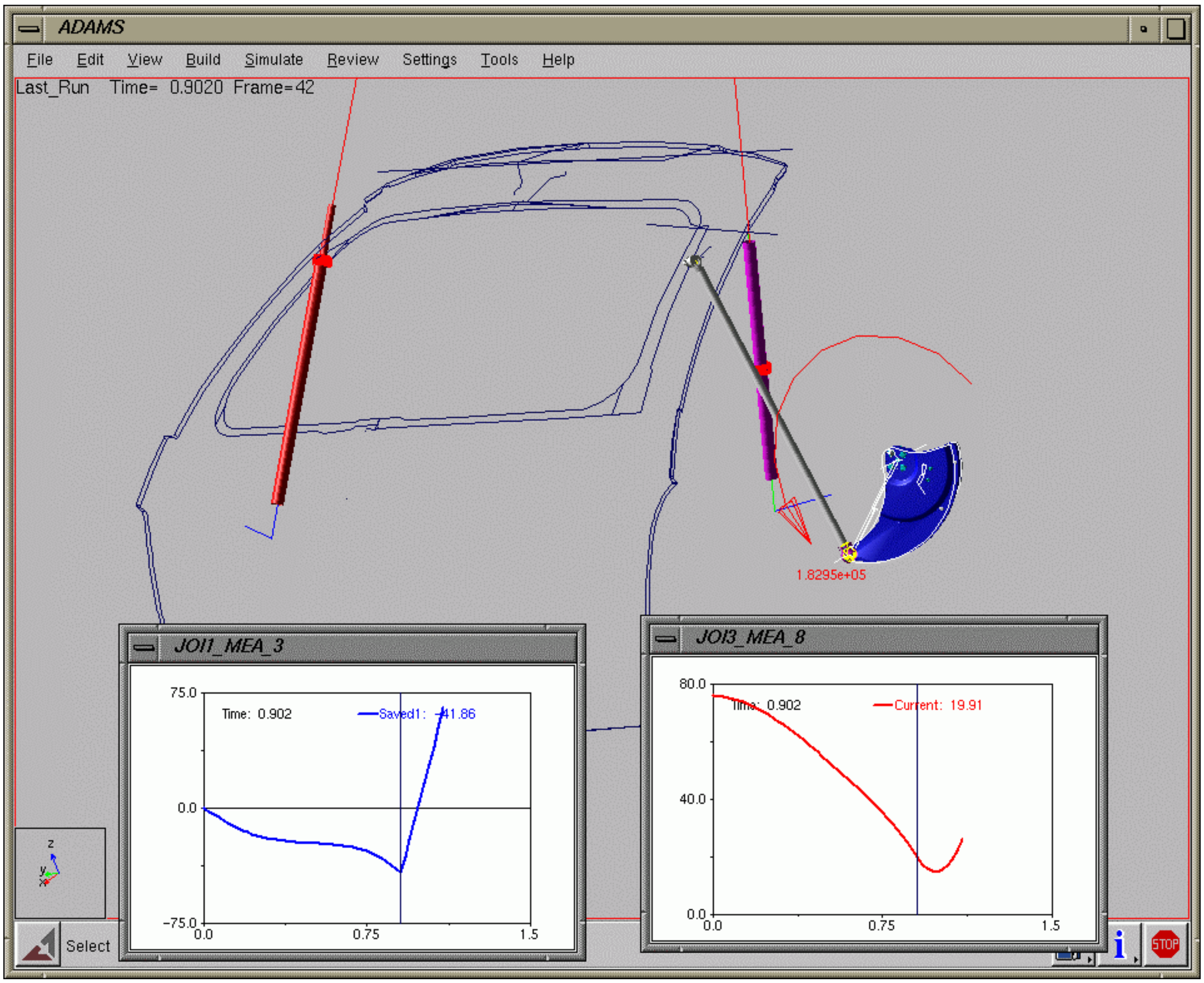

Figure 9 Stopping distance when sensor sense the pinch signal

4. Conclusions

The intention of this paper is to show the methodology instead of detailed design changes and specific simulation results. The data shown in this paper is for general reference only.

Using this methodology, simulation can be quickly run many times before the first prototype is even built. Product development cost and the development time are greatly reduced.

Acknowledgements

The authors would like to acknowledge the Ronald Kruger and Chris Domaradzki for their contributions on design modification and data supply.

References

1. Tech Manual of Gas Spring from AVM, Inc.
2. CATIA/Kinematics in CATIA User's Reference Manual.
3. Using ADAMS/View Manual.
4. Using CAT/ADAMS Manual.