Simulation of an SM90 door system in ADAMS

Edward de Jong, Christiaan Wattèl *NedTrain Consulting BV*

Introduction

Nowadays the Dutch railways (NS) deals with a strong increase of the number of train passengers of approximately 6 percent per year. This means that the availability and reliability of the existing rolling stock is of major importance for the operator NS Passengers. Also the efficiency during train operation will have it's impact on the daily train services. The most important measure to indicate the efficiency of the train service is by means of the number of 'technical primary delays'. This means the number of delays caused by a (technical) failure which directly effect the train operation and results in a delay of more then 3 minutes.

When travelling by train, the travelling time is determined by aspects like travelled distance, braking/accelerating performance as well as the stopping time at the intermediate stations. This time is determined by the number of passengers leaving or entering the train, the door geometry, and the opening and closing movements of the doors. The stop length for stop trains varies from approximately 60 seconds to 180 seconds. The amount of time needed to open or close the doors is approximately 6 seconds. This means that the time needed to operate the door can be as high as 20% of the total stopping time. Any limitation of this value will lead a direct decrease of the stopping time and results in a better performance.

At the end of the closing and opening movement, the door is pushed in a overcentered position, resulting in a pretension of the system. The position and condition of the rubber stops define the amount of pre tension in the door system in the closed or opened position. In case these stops are degenerated by wear or settlement or when the position is modified during maintenance, this can result in operating failures. The door can not be closed and locked or does not stay in the open position. Both failures lead to delays in the train service and passenger discomfort while doors must be excluded from operation.

While closing the doors an obstacle inhibition device is active which detects possible objects between the door blades. A change of sign in the speed of the door movements indicates a possible object between the door blades, resulting in the doors automatically being opened. However the characteristics of the object defines the resulting response of the doors and will not automatically lead to a reverse speed of the door blades. In that case the closing movement will not be stopped resulting in possible passenger injury or hazardous situations. Reducing the closing time of the door will therefore require also a review of the proper operation of the obstacle inhibition system. This safety system is only operative for object larger then 65-70 mm. Smaller object will not be detected and the door will not be opened.

Purpose of this investigation

With NS Passenger being our most important client we are actively looking for any possibilities and improvements which are beneficial to our client. As NedTrain Consulting is specialized in the rolling stock we have a clear look at the possibilities ánd restrictions of the various train systems. With the ongoing technical possibilities and developments, the help of multi body software programs will give the opportunity to show the benefits by improving the functionality of the system. Because of the complex three dimensional mechanism of a door system and the interaction of various fields of engineering (mechanics, electrics and pneumatics) previous analysis methods proved to be limited to a certain complexity level. It is assumed that a multi body model will give insight in the various phenomena during door operation.

The following goals are defined:

- Improved insight in the door opening and closing action with varying geometric properties
- Safety failure analysis
- Improvement of the obstacle inhibition device controller
- Overhaul optimisation
- Investigate the feasibility and benefits of an improved controller.
- Door movements due to train passage and wind forces
- Door movements due to passenger induced forces

To determine the added value of simulation, an ADAMS model of a door system of an SM90 train has been developed. This presentation will focus on the first steps of development of the model and showing the feasibility to get to the above mentioned goals. The results will be used to convince NS Passenger of the potentials of these improvements in door system operation.

System description

The elementary working principle of a SM 90 swing-plug door system can be explained by figure 1.

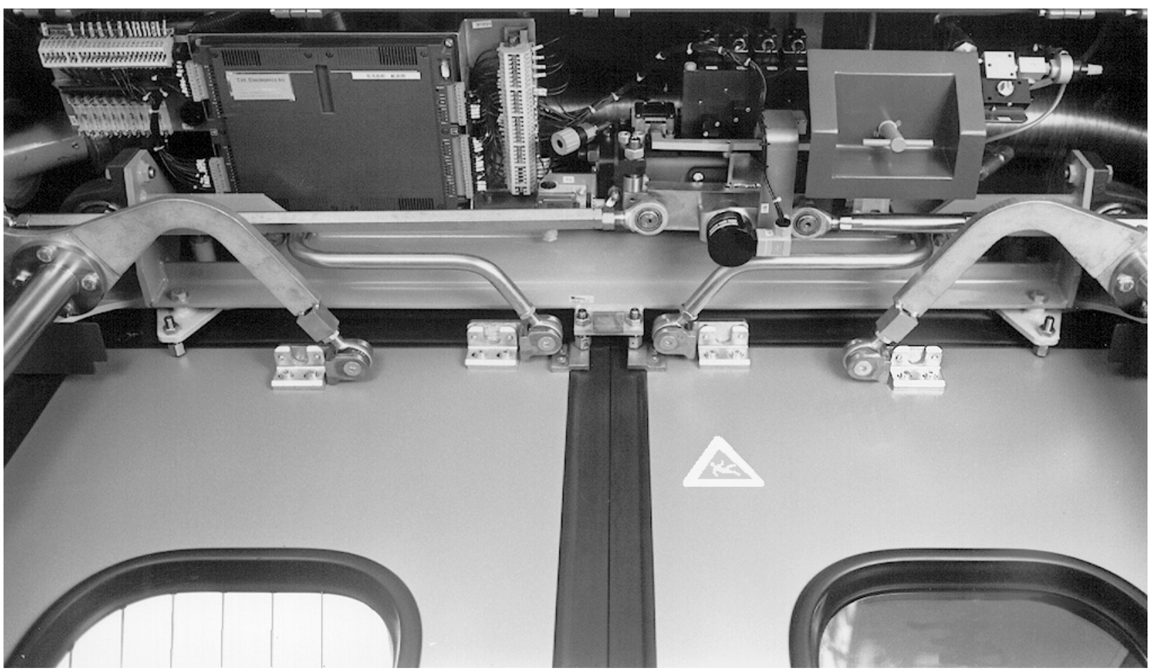

Figure 1 SM 90 door system

Pushing an open or close button activates a microprocessor and puts full pressure on the driving compartment of a torque cylinder. To increase the speed of the door, the exhausting compartment of this cylinder is connected with the atmosphere via a depressurisation valve which is pulse width modulated. The microprocessor controls the depressurisation by varying this outflow. The momentary outflow control is found on the basis of the angular velocity of the door and a non-linear controller. The microprocessor can reduce the speed of the door by raising the pressure in the exhausting department using inflow control of a pressurisation valve. This pressurisation valve is activated in case the angular velocity is far too high and thereby exceeds a certain threshold value. It is a general rule that by controlling the exhausting compartment, the stick-slip phenomena are minimized.

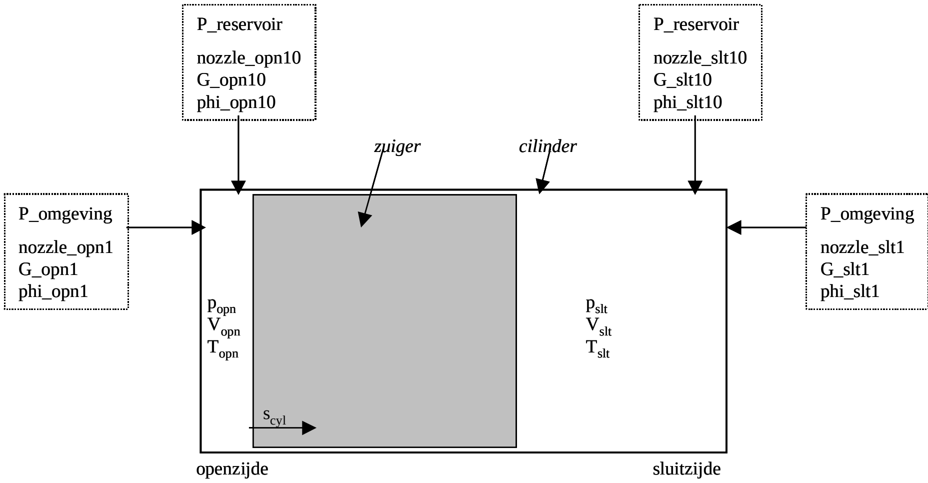

Figure 2 Torque cylinder

The pressure difference leads to a displacement of the piston in the torque cylinder.

This displacement results (via a gear-rack transmission) in a rotation of the cylinder. A rod-linkage translates this rotation into a transportation of the two door leaf mechanisms. In this way the position is linked (by means of a non-linear mechanical transmission) to a uniquely defined position of the door. The angular displacement of the torque cylinder is measured by means of a displacement sensor. on the basis of this angular information the microprocessor control the time-dependent position of the torque cylinder and thereby the position of the door system. Figure 3 shows a graphical representation of the model.

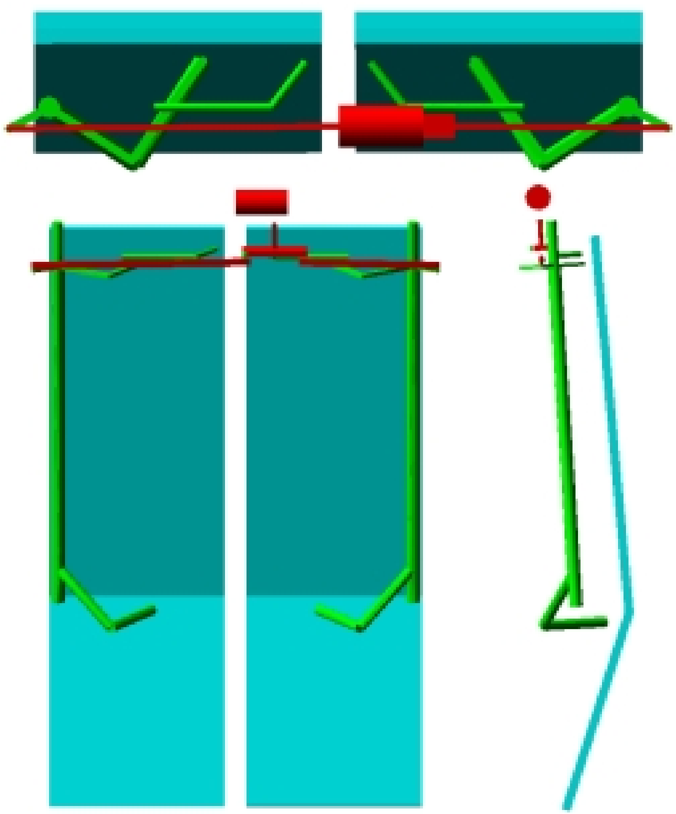

Figure 3 ADAMS door model

The simulation model is able to reproduce the opening and closing action of the door. It consists of the mechanical door system (door blades, levers, seals, stops) pneumatic units (piston and high pressure chambers, pneumatic valves) and electronic units (measuring and control part). All systems have been modelled within the ADAMS/View environment. For the pneumatic system the Saint Vennant equations have been used for the state description of the gas medium in the chambers.

The model has been verified with measurement results. Figure 4 shows the response of the system during a closing operation.

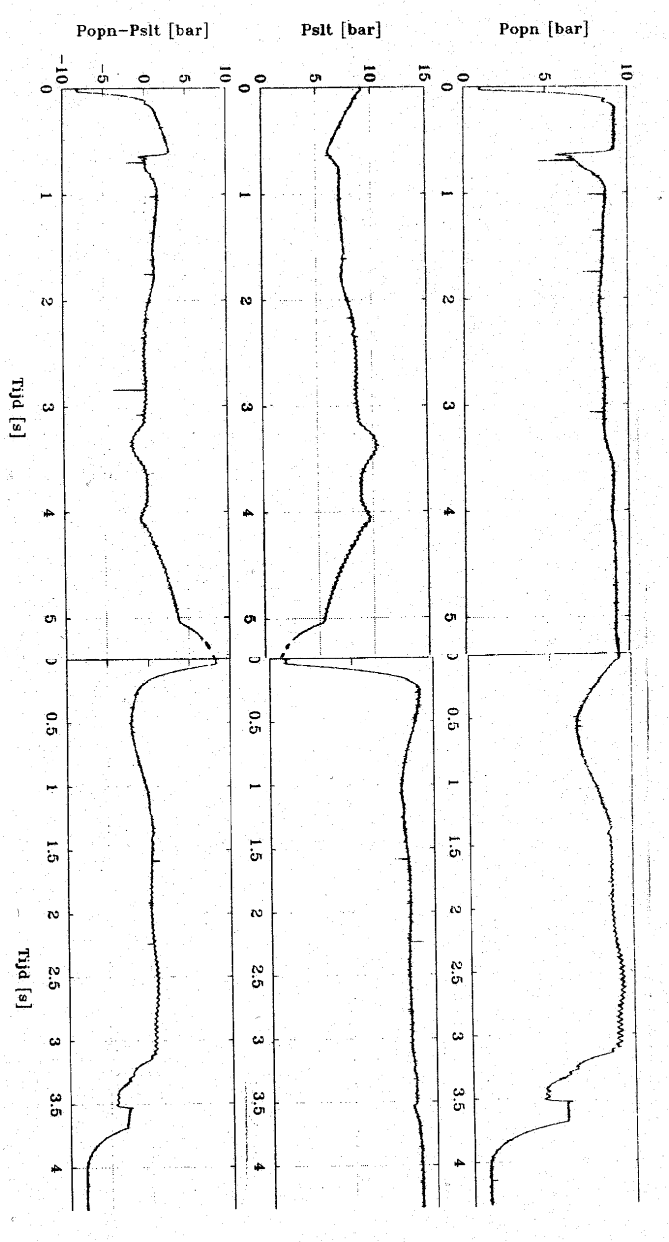

Figure 4 Measured response during closing operation

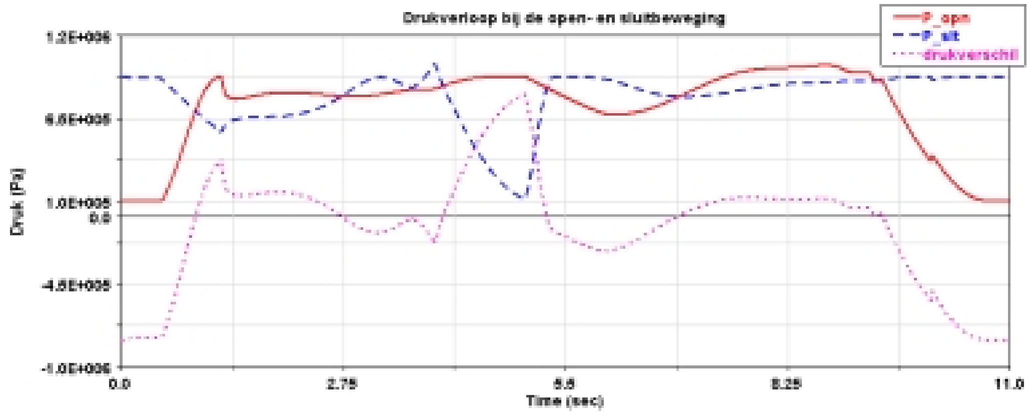

Figure 5 Calculated response during closing operation

During opening the pressure in the opening chamber increases quickly from 1 bar to 10 bar, while the pressure in the closing chamber decreases and is controlled by the controller to maintain the desired door movement. The pressure at the opening side changes a little due to the movement of the piston resulting in a volume increase. This phenomena is clearly visible during start of the opening movement as the mechanism moves through the overcentering position resulting in a high opening speed at a relieve small chamber volume. At t=5 s the door is closed and the opening movement starts. The measured and computed response show good correspondence. When in overcentering position the pressure temporarily increases which is in the measured response more visible then for the calculated response. This is due to the existing of a bypass valve which limits the fast decreasing pressure by connecting the closing chamber temporarily with the high pressure (10 bar) reservoir. This valve has not yet been modelled in the calculation program.

Door settlement

During the life of the train the position of the stops on the door and coach structure can change due to wear, plastic deformation of rubber or steel components or maintenance operations. It is known from practice that a false position of these stops can lead to doors not being closed or an insufficient pretension of the door in the closed position. Also the guidance mechanism of the door blades has shown strength failures due to this phenomena.

To study this behaviour the position of the stops have been varied by 1 mm. Figure 6 and figure 7 below show the resulting pressures in the opening and closing chambers as well as the forces exerted on the bump stops (displayed for opening action only).

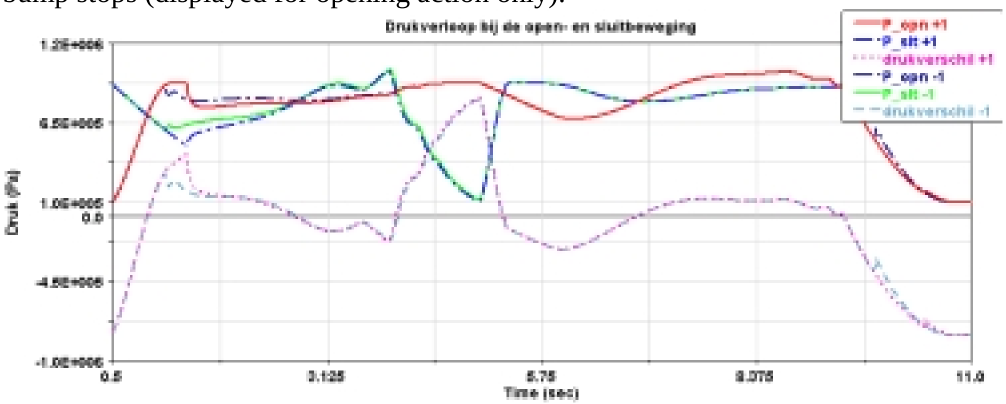

Figure 6 Calculated response with varying bump stop position: pressures

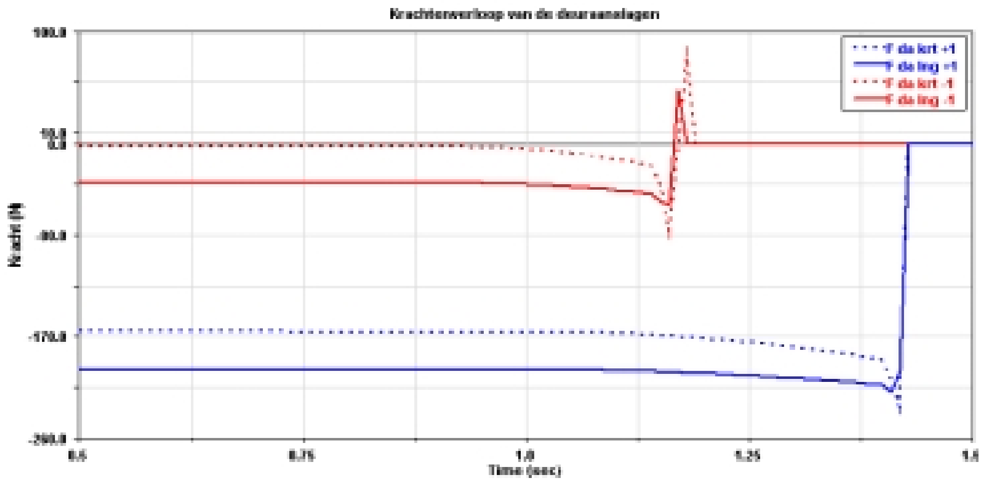

Figure 7 Calculated response with varying bump stop position: forces

It is clear that the pressure show only deviations form the standard situation at the end of the opening or closing movement. The forces on the bump stops and as a result also on the guidance mechanism of the door blades show an increase of approximately 190%. This indicates the serious implications of small disturbance of the bump stop position.

Door movements due to train passage

For safety reasons it is obvious that the door should be closed at all times when the train is moving. No significant displacement should occur as a results of external forces on the door blades, e.g. when passing train, tunnel passage or passenger leaning on the door. When these situations occur the system should be pushed further into the locking position. As an example the following requirements are used:

- At vehicle speed 160 km/h: passing train with 200 km/h at 1 m distance
- Leaning passengers: 800 N, 400 N per door blade

The resulting forces where added to the model with a short delay between the two door blades as a result of the vehicle speed. The resulting forces are show in the figure below:

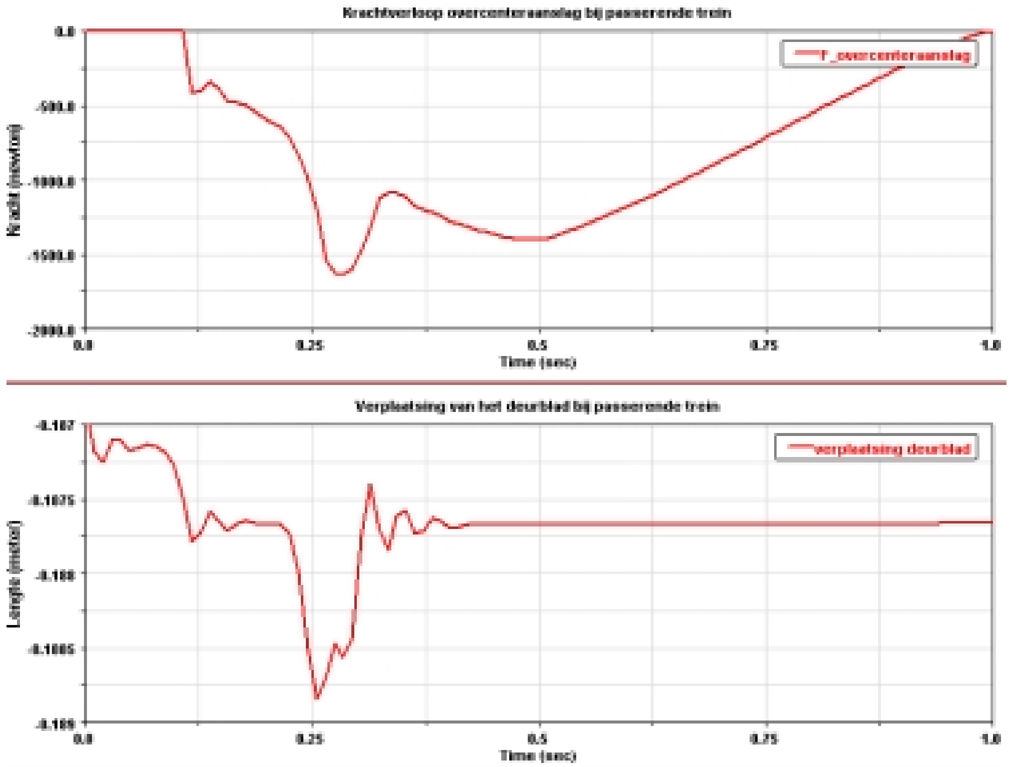

Figure 8 Door movements with external forces on door blades

The maximum lateral displacement is approximately 1 mm. The maximum moment in the guidance mechanism of the door is approximately 1000 Nm. The results show that the doors are pushed further into the locking mechanism.

Conclusion

A multi body model of a SM90 door system is developed where the mechanical, pneumatic and electric systems are integrated in one model. Although the model needs improvements to fully represent the real life situation, the simulation results up till now are promising. Further model improvement have to be integrated including friction of the rubber seals in the pneumatic chambers and the implementation of the speed reducing valve.

It has been shown that the current model is capable to deal with the various real life problems with the existing door system currently in operation by Dutch Railways. The preliminary results of the model will be used to show the benefits of multi body simulation for future improvement of the SM90 train door system.

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Introduction to NedTrain Consulting

- Formerly NS Materieel Engineering
- Subsidiary of Netherlands Railways (NS)
- Rolling stock engineering and consultancy
- 200 qualified employees
- 50% owner of ADAMS/Rail

NedTrain Consulting

Operational issues:

•Door controller: up to 20% needed for opening/closing movement

Technical Primary Delays (TPD):

- Decreased reliability through varying door settlement
- Liability: increases risk of passenger injury through obstacle inhibition system
- Geometric properties
- Door movements due to external forces

Feasibility is investigated by using simulation

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ADAMS simulations

SM90 door system: first controlled door system

Goals:

- Define maintenance requirements
- Reduce opening/closing time
- Minimize forces generated by obstacle inhibition system
- Investigate the influence of wind forces and passenger induced forces

Total Service: Results will be used to show benefits to customer

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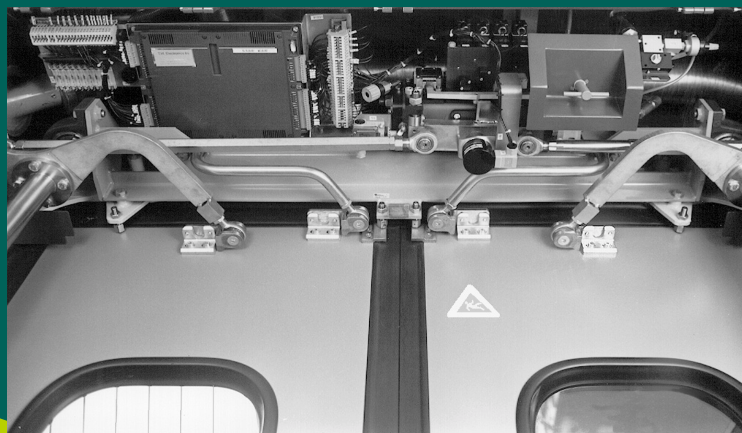
Door system SM90



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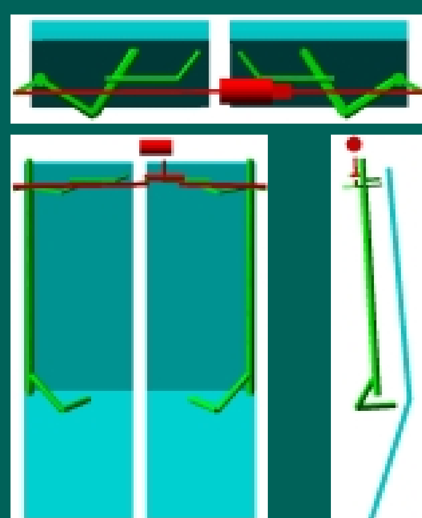
ADAMS door model

- Mechanical
- Pneumatic
- Electrical



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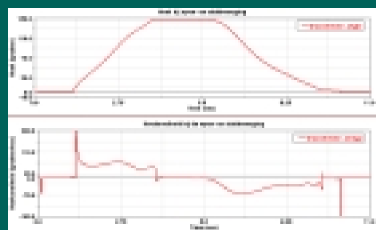
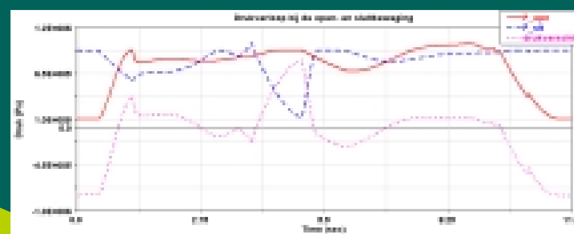
Validation results

- *Opening and closing movement*



Door angle and door velocity

Pressures



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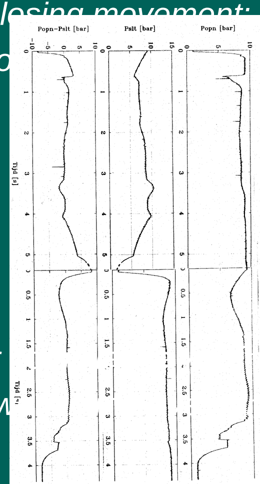
Validation results

- *Opening and closing movement: measured respo*



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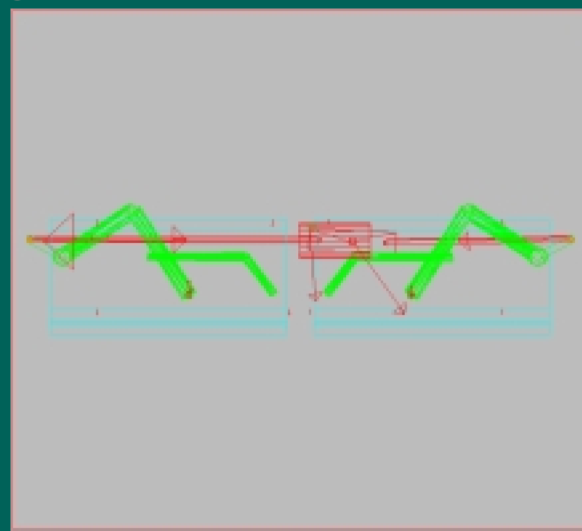
Animation

Normal closing and opening movement



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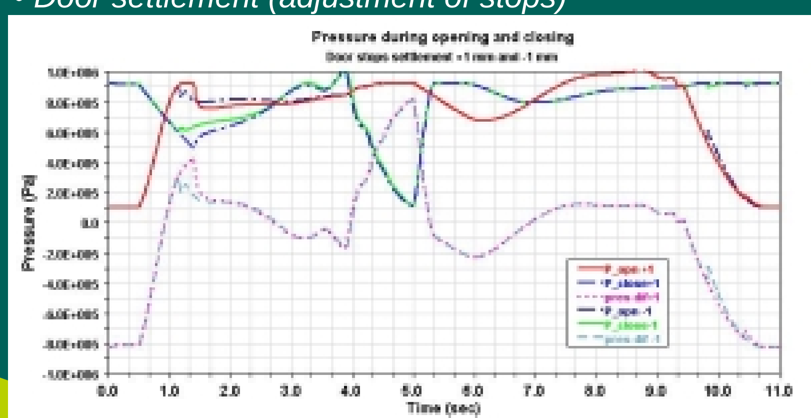
Simulation results (2)

- *Door settlement (adjustment of stops)*



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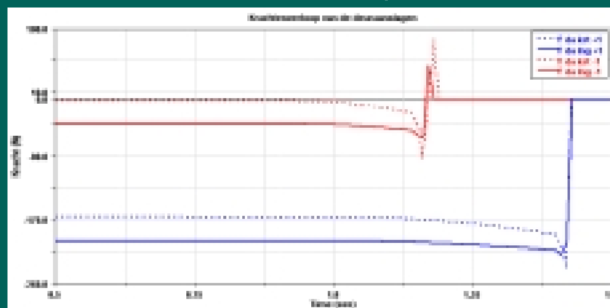
Door settlement

Forces exerted on door stops



Force increase of >190% within range +1 to –1 mm !

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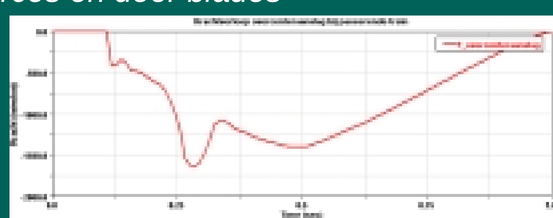
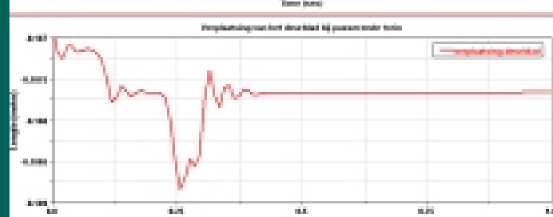
Simulation results (3)

- *External forces on door blades*





- Relative speed 360 km/h at 1 m
- Passenger exerted force 800 N

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Conclusions

- Model is capable of showing fair correspondence with measurements
- Can be used for various simulations
- Results will be used to initiate future improvements and optimization of door systems

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