Jacek GRAJNERT*
Zbigniew CHABRAŚ*
Piotr WOLKO*

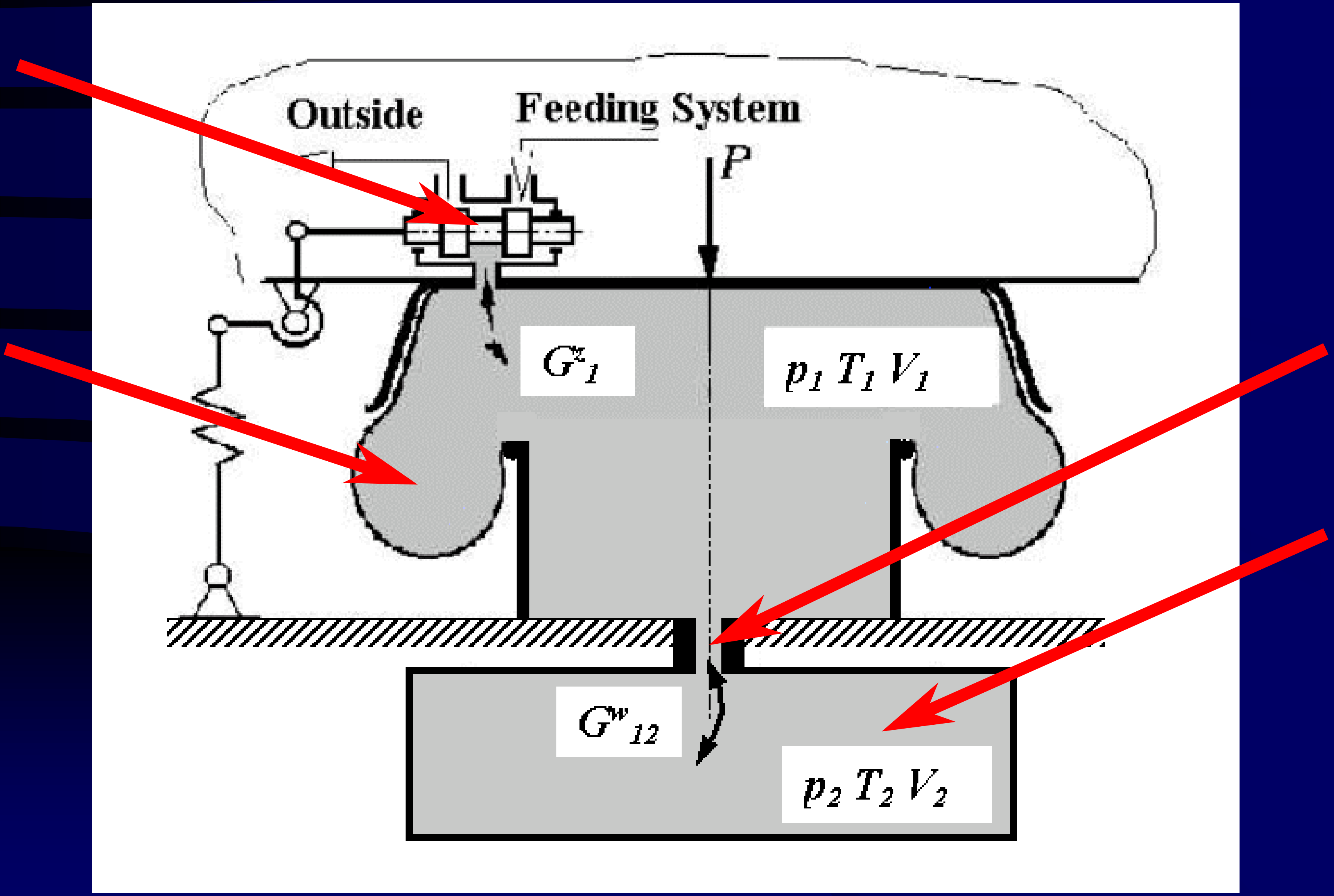
MDI
EUROPEAN
USER
CONFERENCE
2001

Airspring Modeled in MATLAB/Simulink as a Force Element in ADAMS

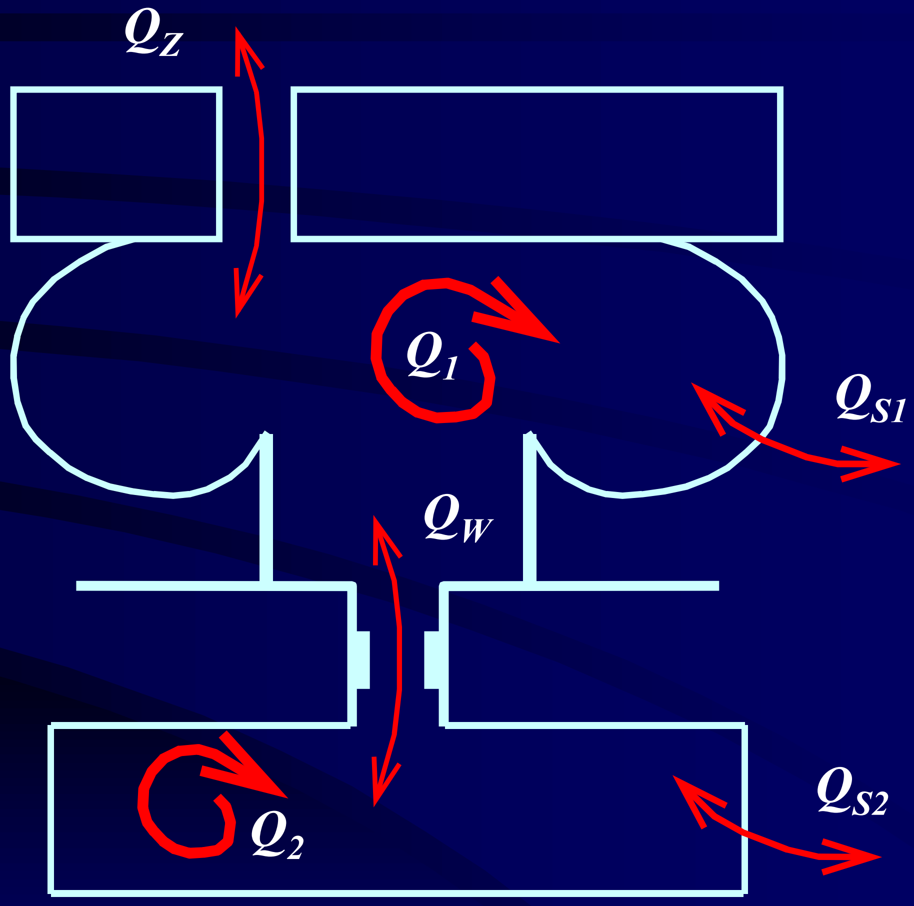
* Wrocław University of Technology

Examples of Pneumatic Suspended Vehicles

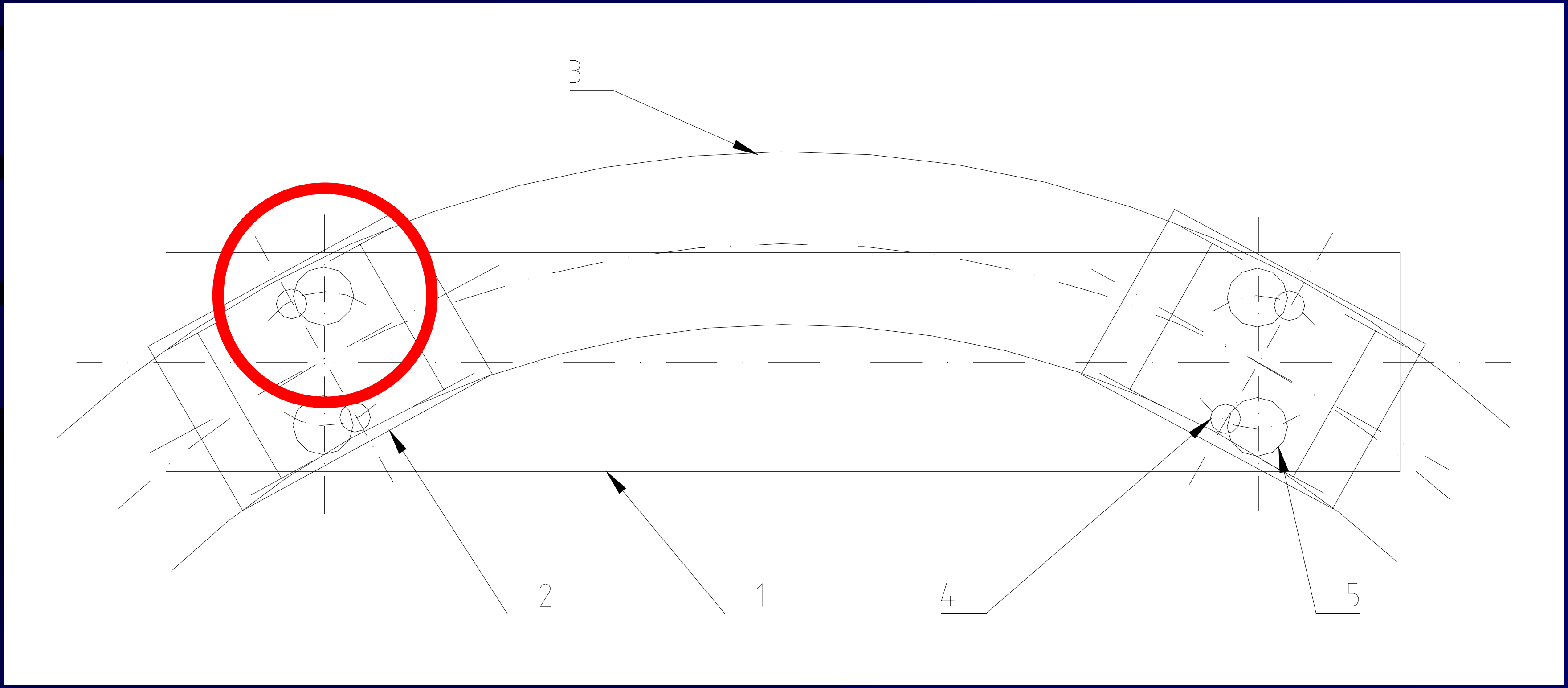
Elementary Pneumatic Suspension



Energy Flow in Elementary Airspring



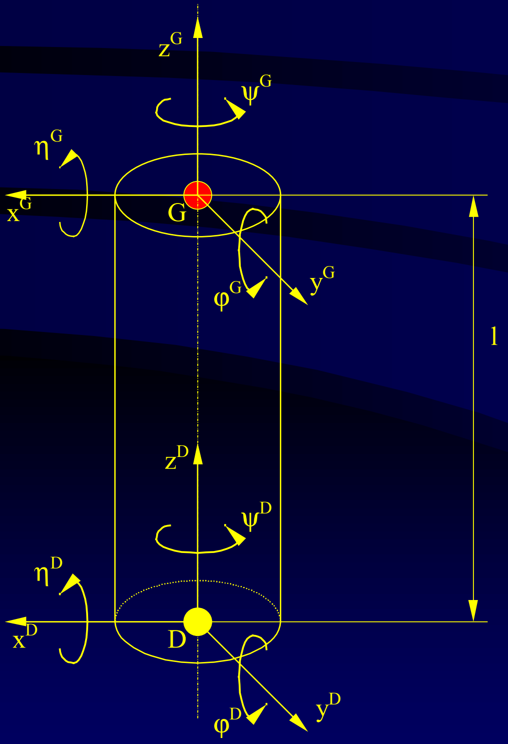
Railway Car on a Curve and Airsprings Deformations



Matrix of Variation Coefficients of Effective Surfaces of 3-D Airspring

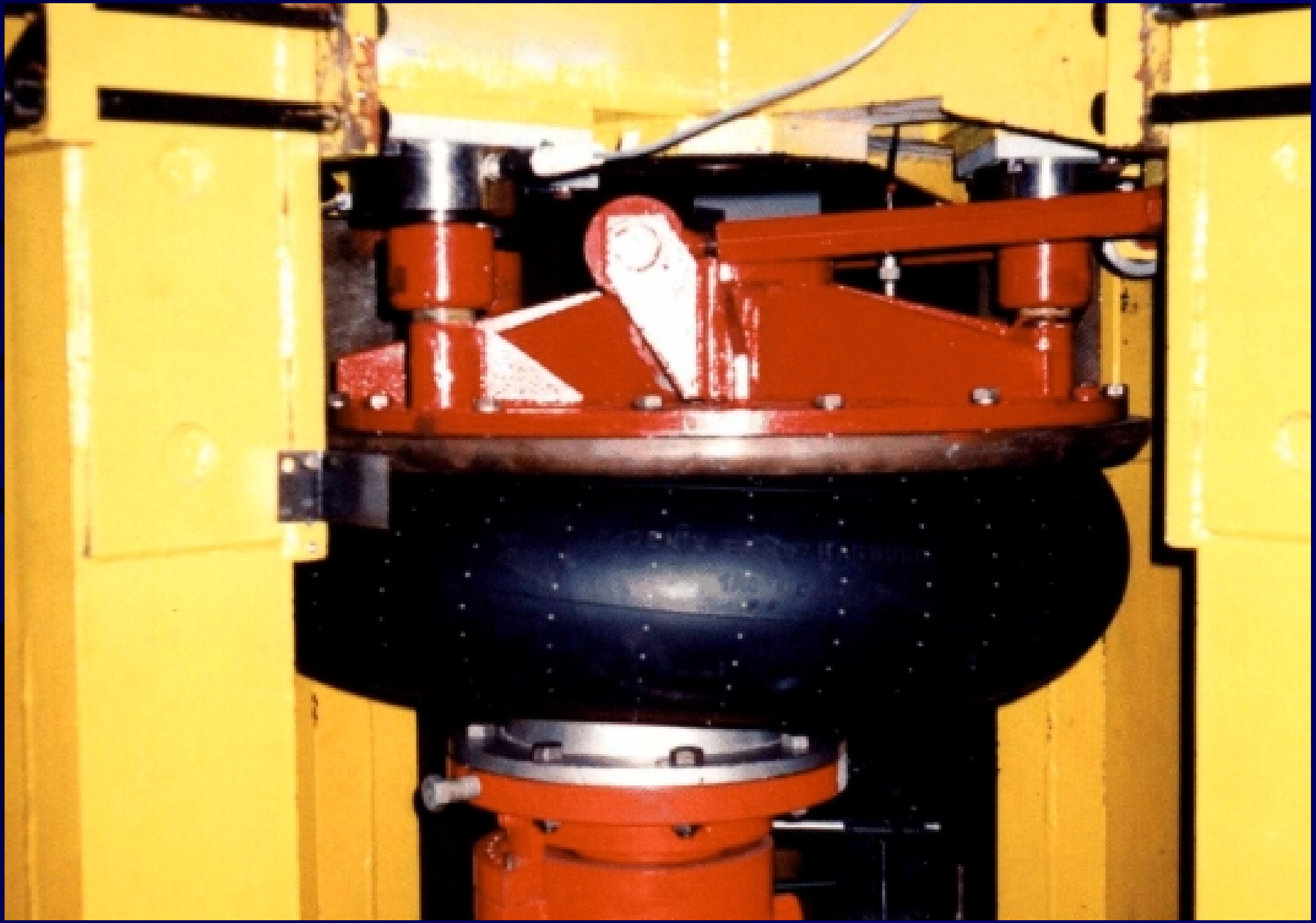
$$\overline{\mathbf{P}} = \overline{\mathbf{S}} \cdot \left(p - p_a\right)$$

$$\overline{\mathbf{S}} = \overline{\mathbf{S}}^{\mathbf{O}} + \mathbf{C} \cdot \overline{\mathbf{X}}$$

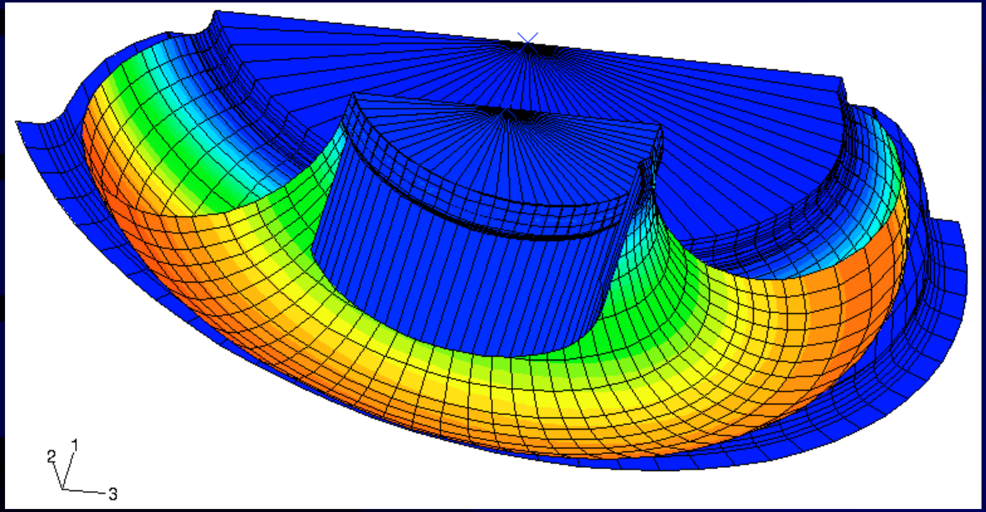


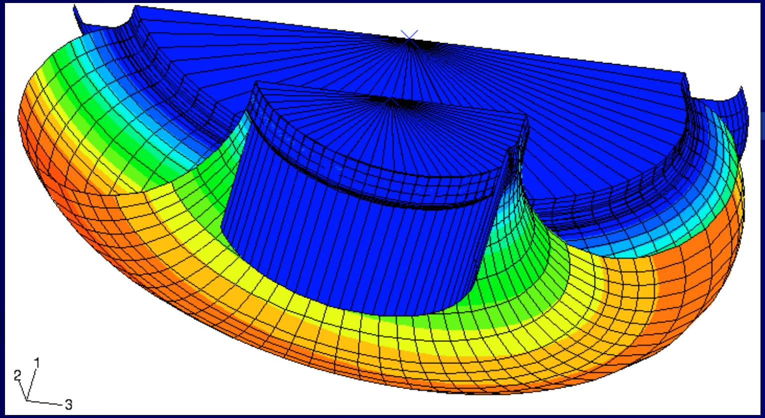
$$\mathbf{C} = \begin{array}{c|cccccccccccc}
 & x^D & y^D & z^D & \eta^D & \varphi^D & \psi^D & x^G & y^G & z^G & \eta^G & \varphi^G & \psi^G \\
\hline
F_x^D & c_x & & & & c_o & & -c_x & & & & -c_1 & \\
F_y^D & & c_x & & -c_0 & & & & -c_x & & c_1 & & \\
F_z^D & & & c_z & & & & & & -c_z & & & \\
M_\eta^D & & -c_0 & & c_\varphi & & & & c_1 & & -c_2 & & \\
M_\varphi^D & c_o & & & & c_\varphi & & -c_1 & & & & -c_2 & \\
M_\psi^D & & & & & & c_\psi & & & & & & -c_\psi \\
F_x^G & -c_x & & & & -c_1 & & c_x & & & & c_0 & \\
F_y^G & & -c_x & & c_1 & & & & c_x & & -c_0 & & \\
F_z^G & & & -c_z & & & & & & c_z & & & \\
M_\eta^G & & c_1 & & -c_2 & & & & -c_0 & & c_\varphi & & \\
M_\varphi^G & -c_1 & & & & -c_2 & & c_0 & & & & c_\varphi & \\
M_\psi^G & & & & & & -c_\psi & & & & & & c_\psi
\end{array}$$

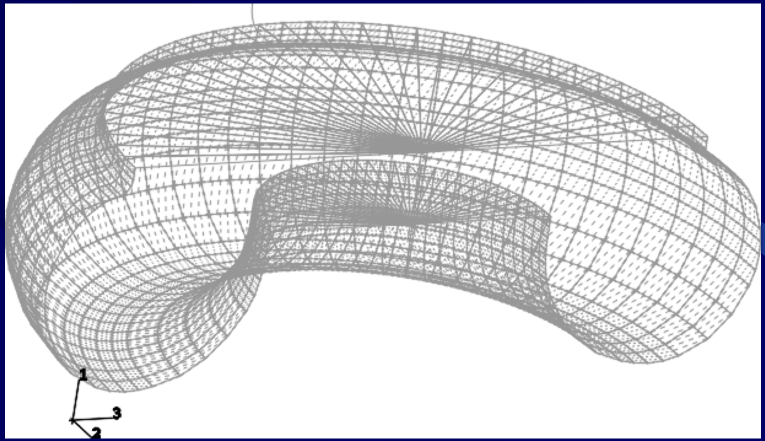
Laboratory Tests



Airspring FEM Model in ABAQUS*

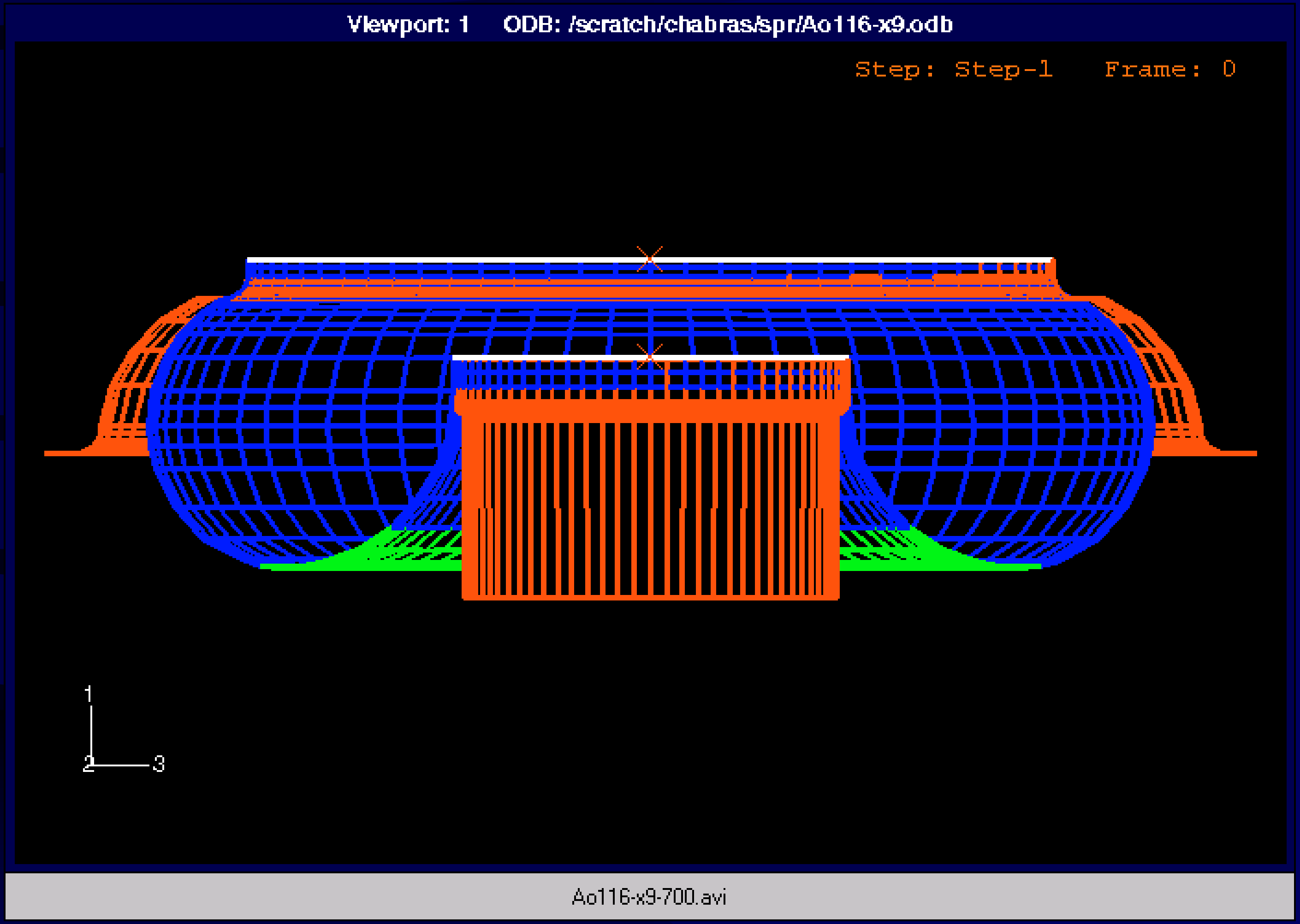






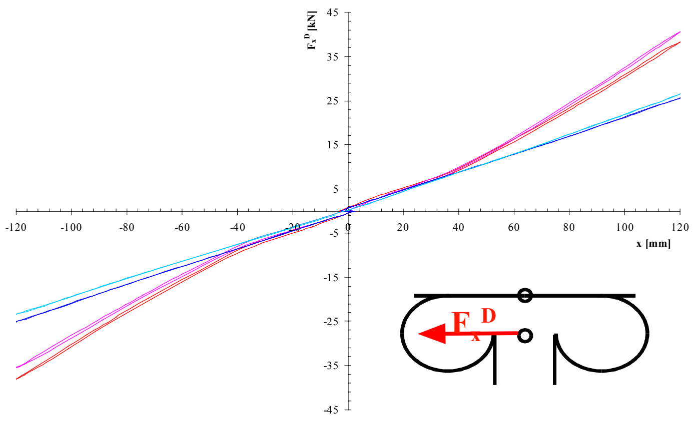
* calculated by Wroclaw Centre of Networking and Supercomputing

Example of Load Cases

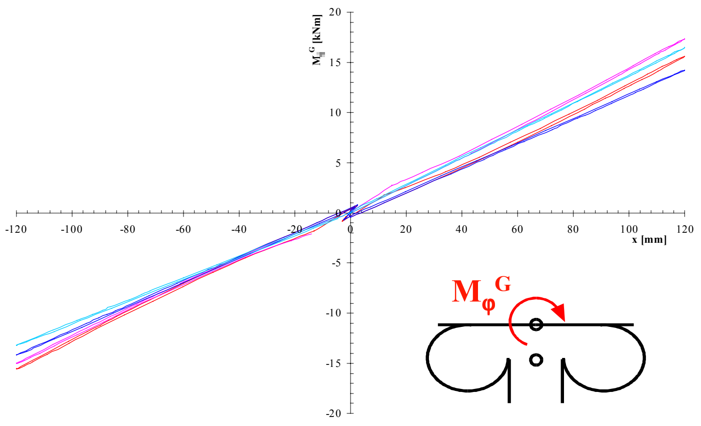


- inflation (0.0÷0.5 MPa),
- axial deflection (35÷105mm),
- rotational deflection (-5°÷5°)
- lateral deflection (-120÷120mm)

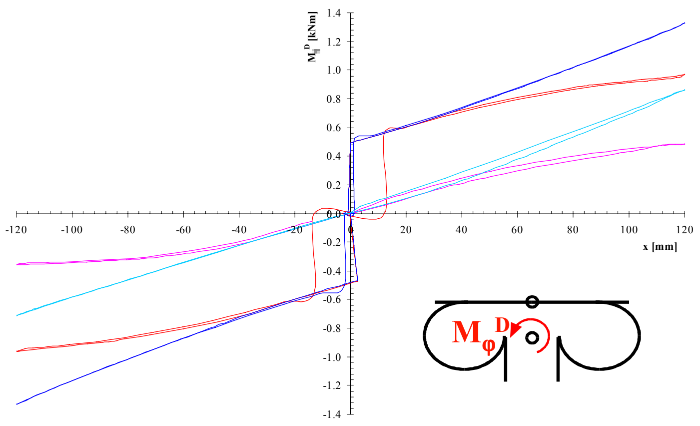
Airspring Characteristics Calculated by FEM



Reaction Force F_x^D at lower mounting point

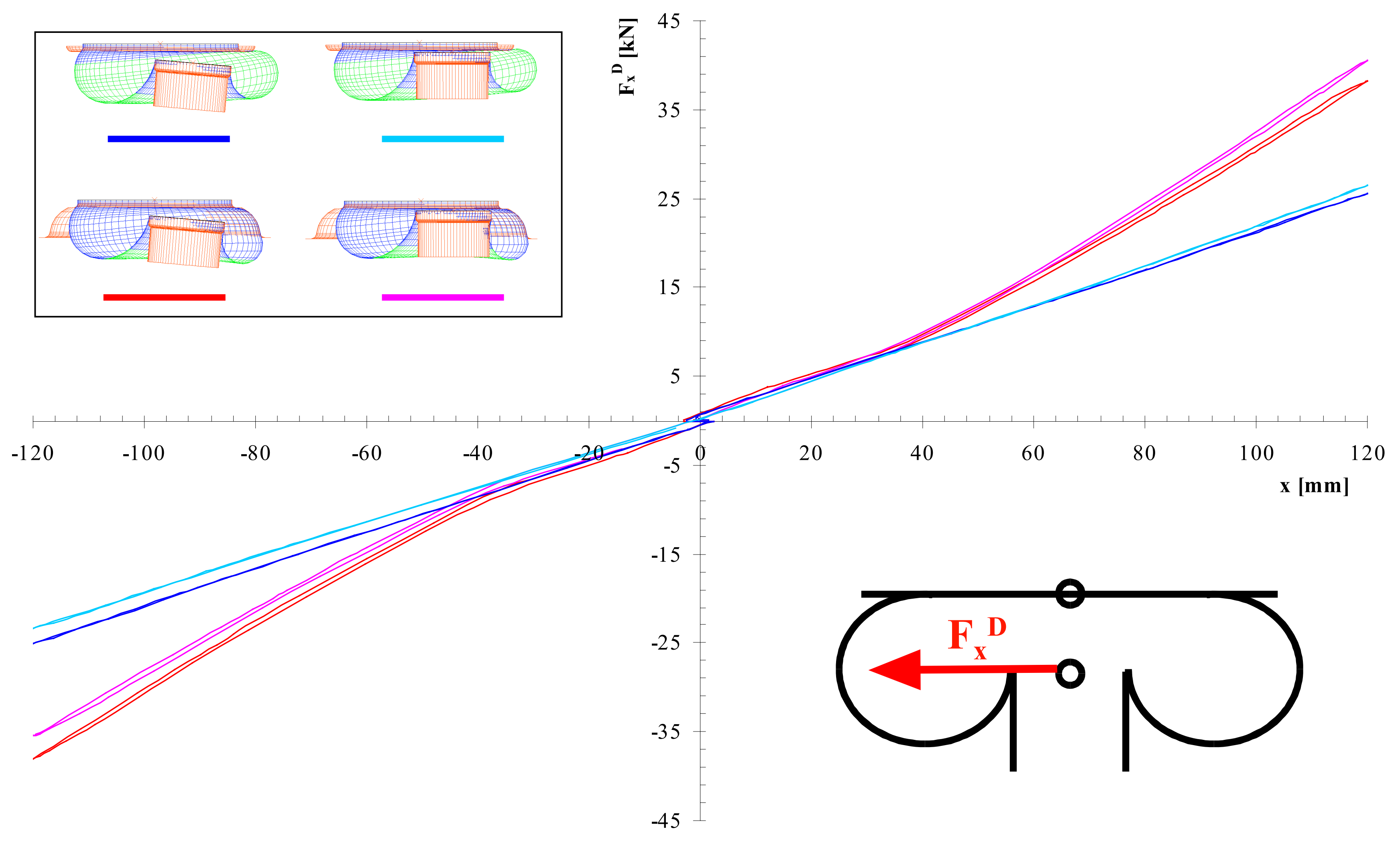


Reaction Moment M_φ^G at upper mounting point

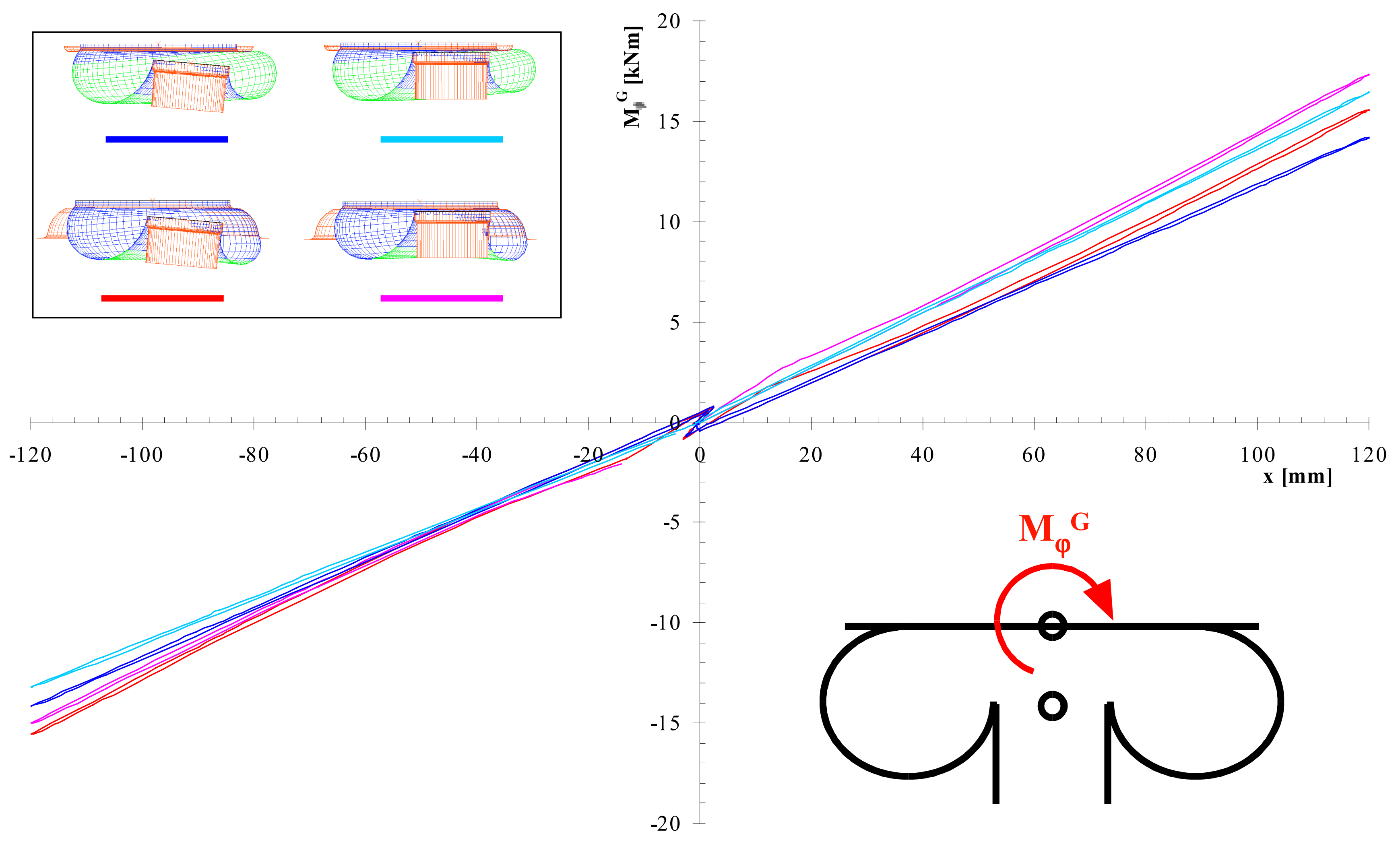


Reaction Moment M_φ^D at lower mounting point

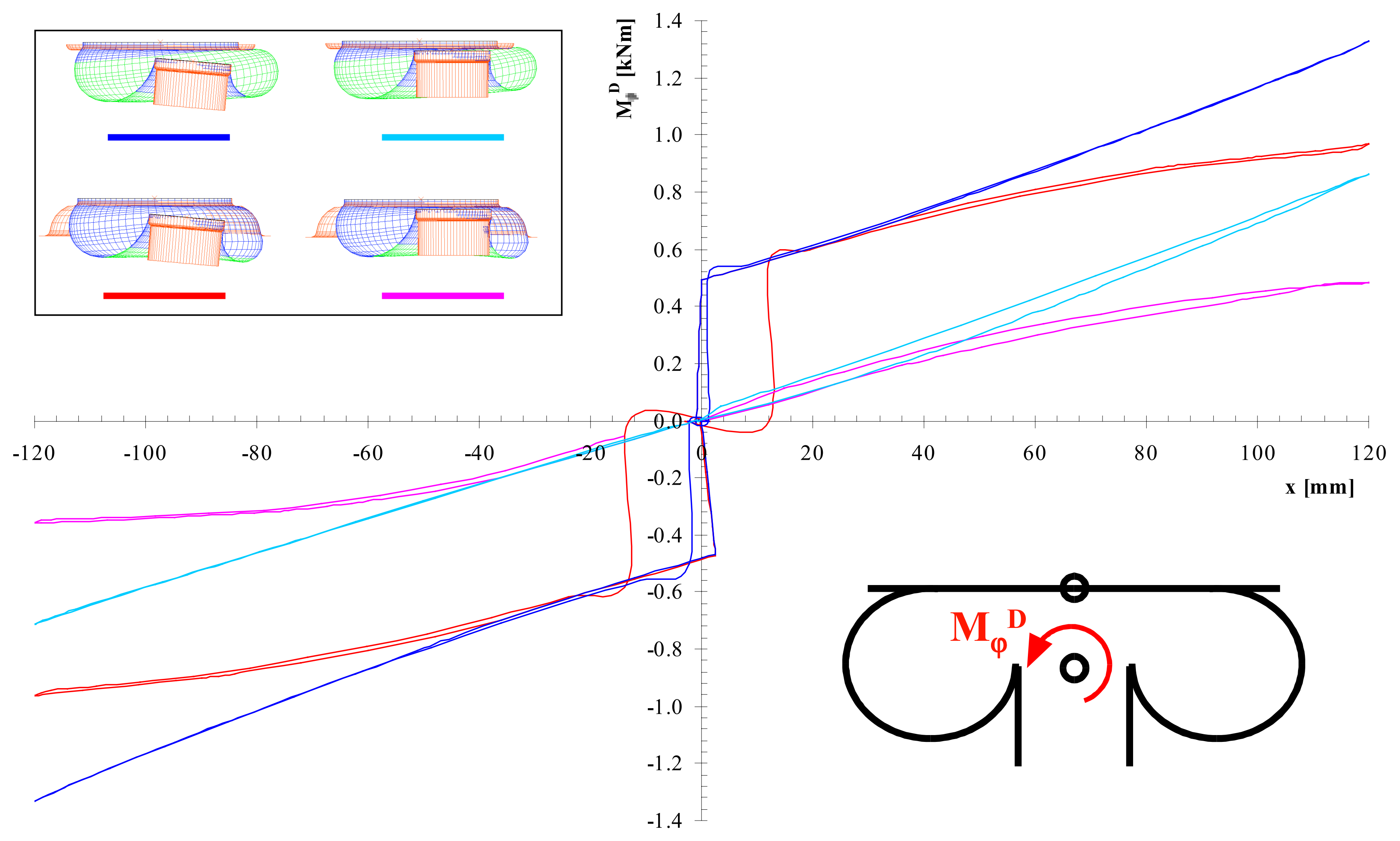
Reaction Force F_x^D at Lower Mounting Point



Reaction Moment M_{φ}^{G} at Upper Mounting Point

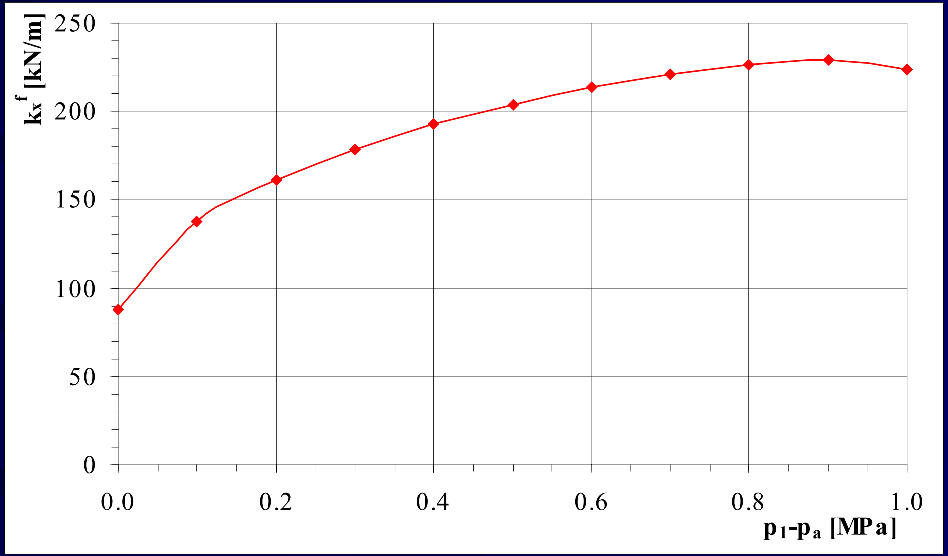


Reaction Moment $M_\varphi{}^D$ at Lower Mounting Point

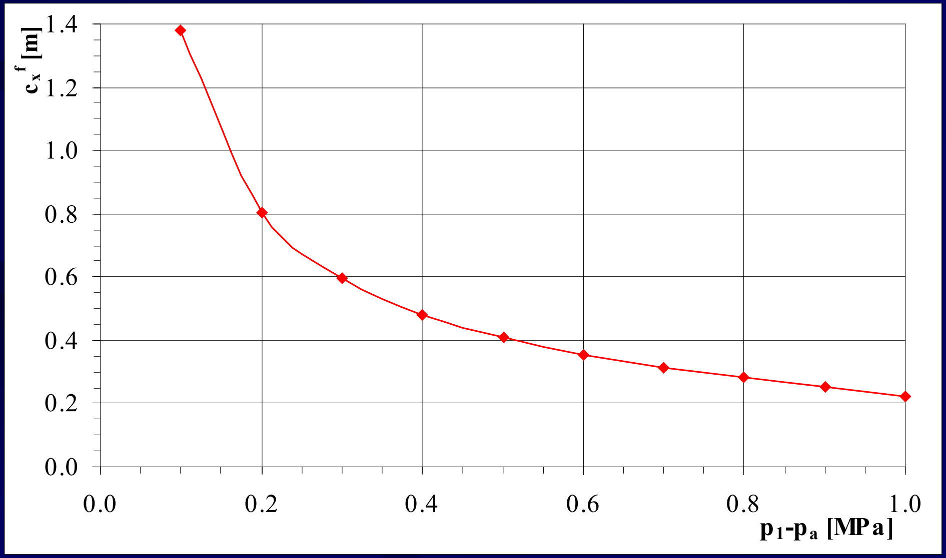


x-Coefficients

$$k_x^f = \frac{F_x^D}{x}$$

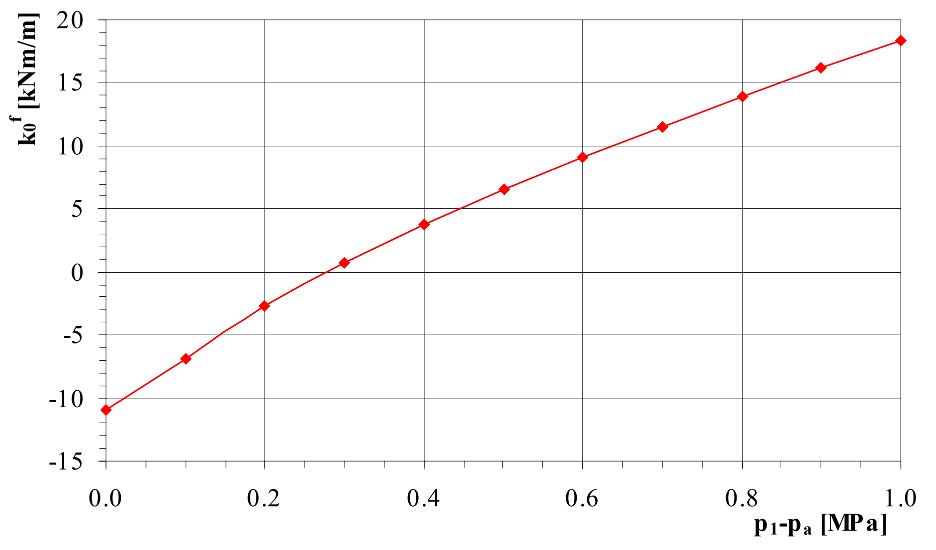


$$c_x^f = \frac{k_x^f}{p_1 - p_a}$$

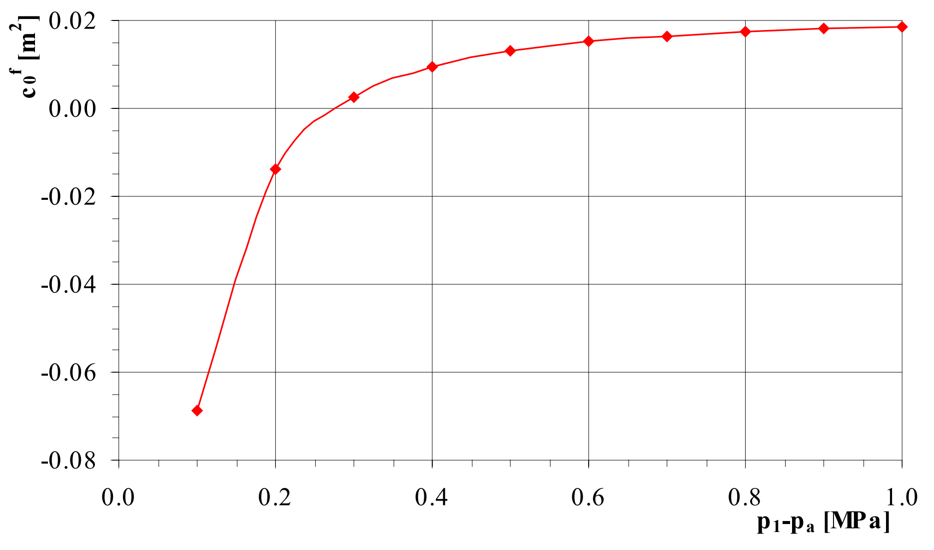


ϕ-Coefficients

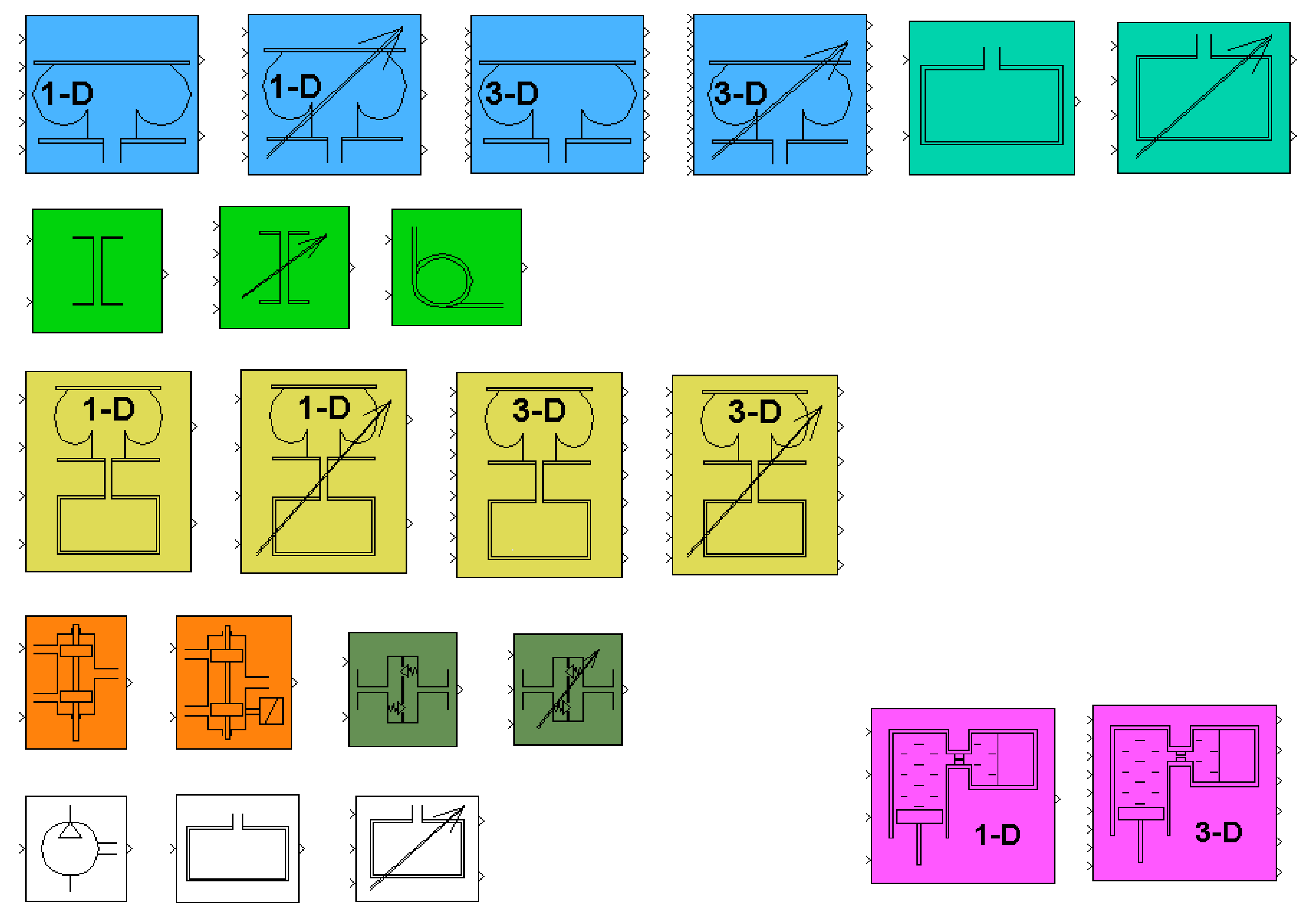
$$k_0^f = \frac{M_\varphi^D}{x}$$



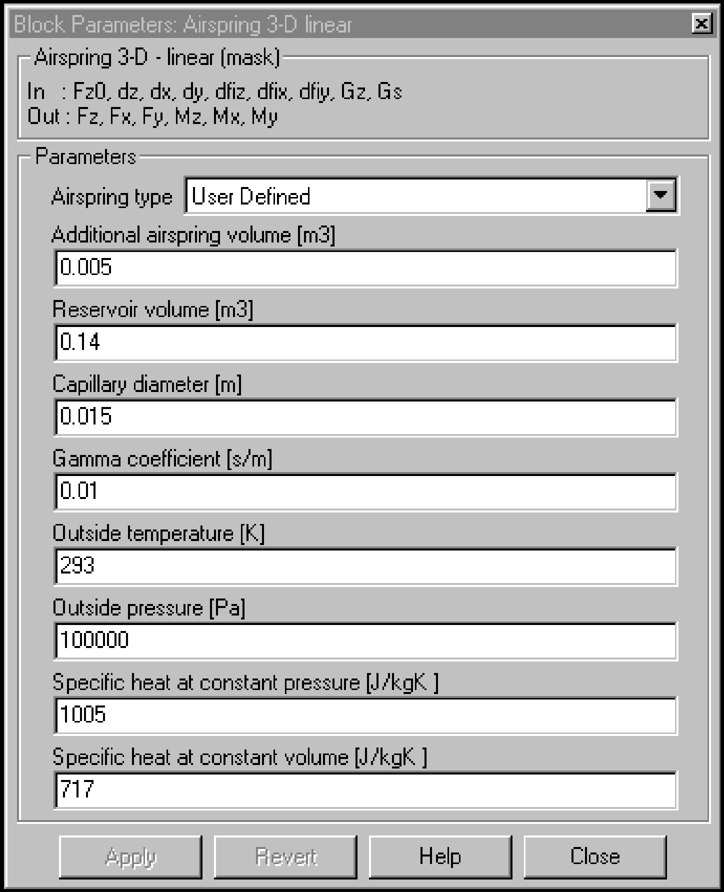
$$c_0^f = \frac{k_0^f}{p_1 - p_a}$$



Library of Components of Pneumatic Suspension System



Airsprings - Linear and Nonlinear



Block Parameters: Airspring 3-D linear

Airspring 3-D - linear (mask)

In : Fz0, dz, dx, dy, dfiz, dfix, dfiy, Gz, Gs
Out : Fz, Fx, Fy, Mz, Mx, My

Parameters

Airspring type: User Defined

Additional airspring volume [m3]: 0.005

Reservoir volume [m3]: 0.14

Capillary diameter [m]: 0.015

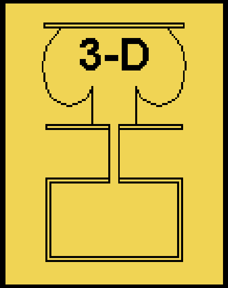
Gamma coefficient [s/m]: 0.01

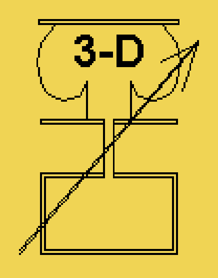
Outside temperature [K]: 293

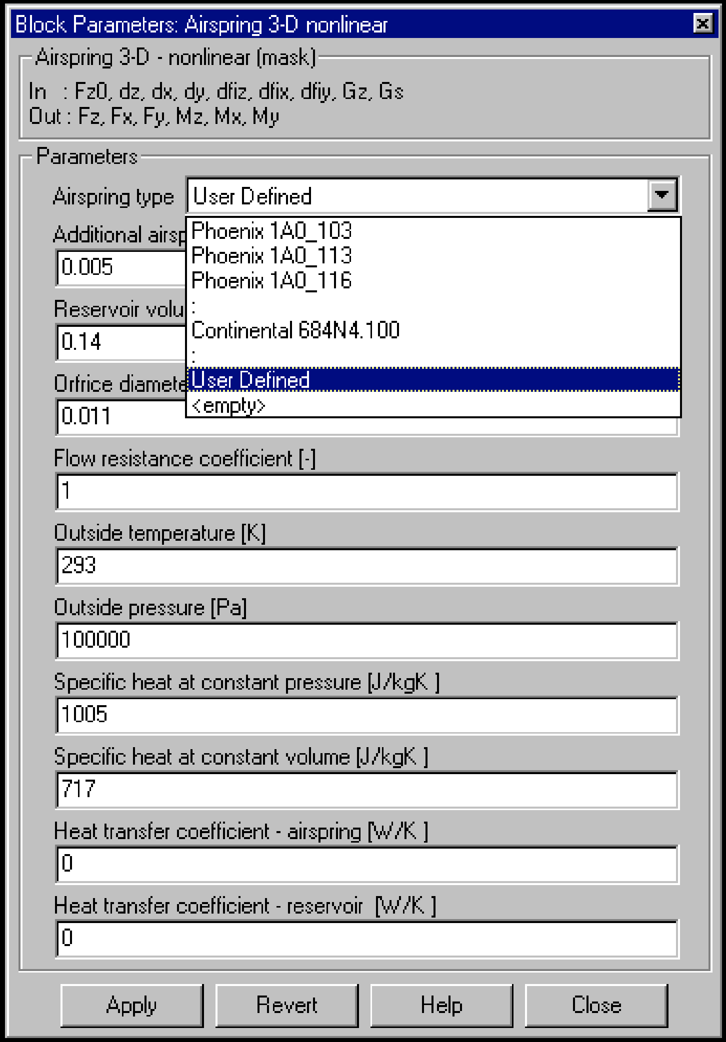
Outside pressure [Pa]: 100000

Specific heat at constant pressure [J/kgK]: 1005

Specific heat at constant volume [J/kgK]: 717







Block Parameters: Airspring 3-D nonlinear

Airspring 3-D - nonlinear (mask)

In : Fz0, dz, dx, dy, dfiz, dfix, dfiy, Gz, Gs
Out : Fz, Fx, Fy, Mz, Mx, My

Parameters

Airspring type: User Defined

Additional airsp: 0.005

Reservoir volu: 0.14

Orifice diamete: 0.011

Flow resistance coefficient [-]: 1

Outside temperature [K]: 293

Outside pressure [Pa]: 100000

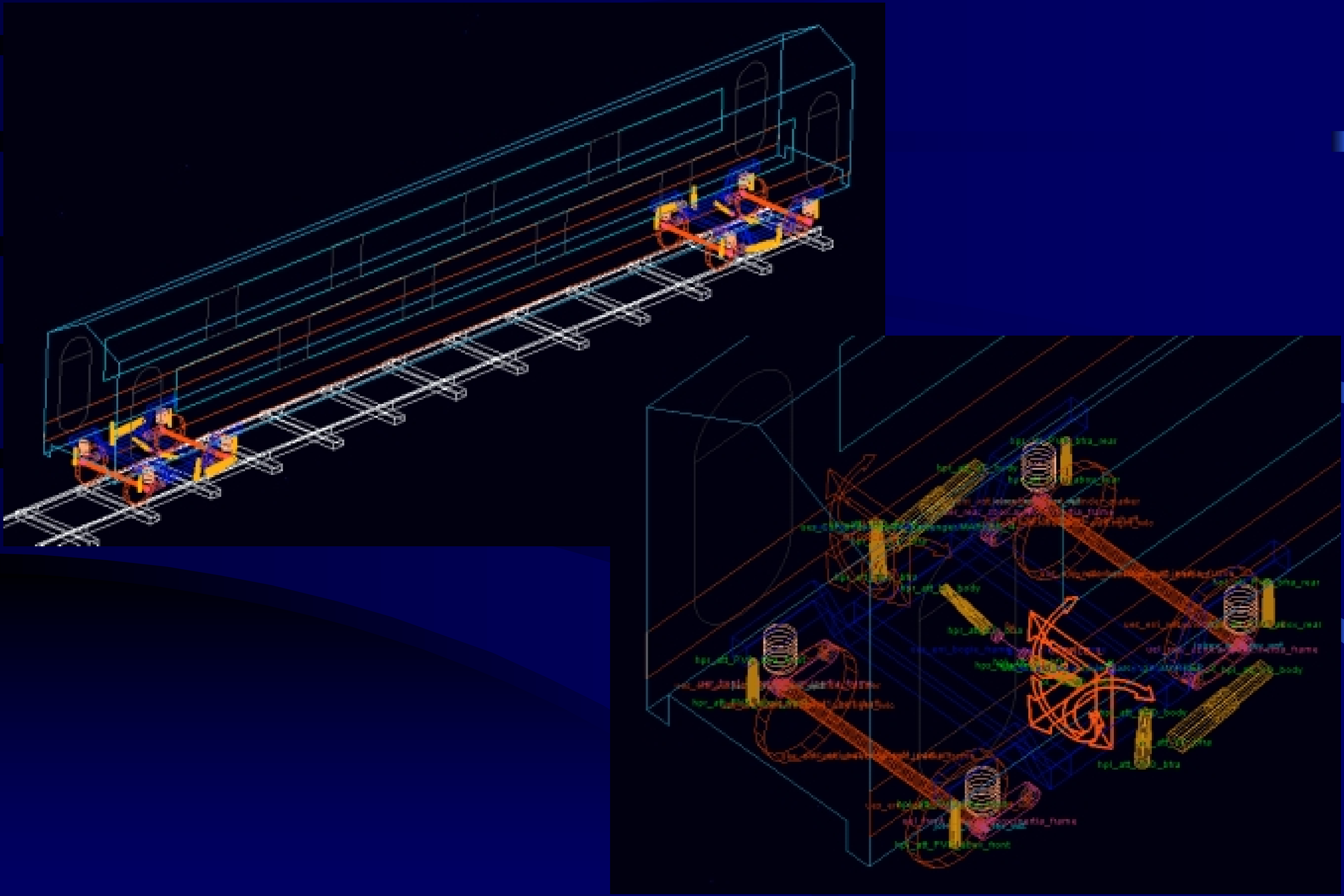
Specific heat at constant pressure [J/kgK]: 1005

Specific heat at constant volume [J/kgK]: 717

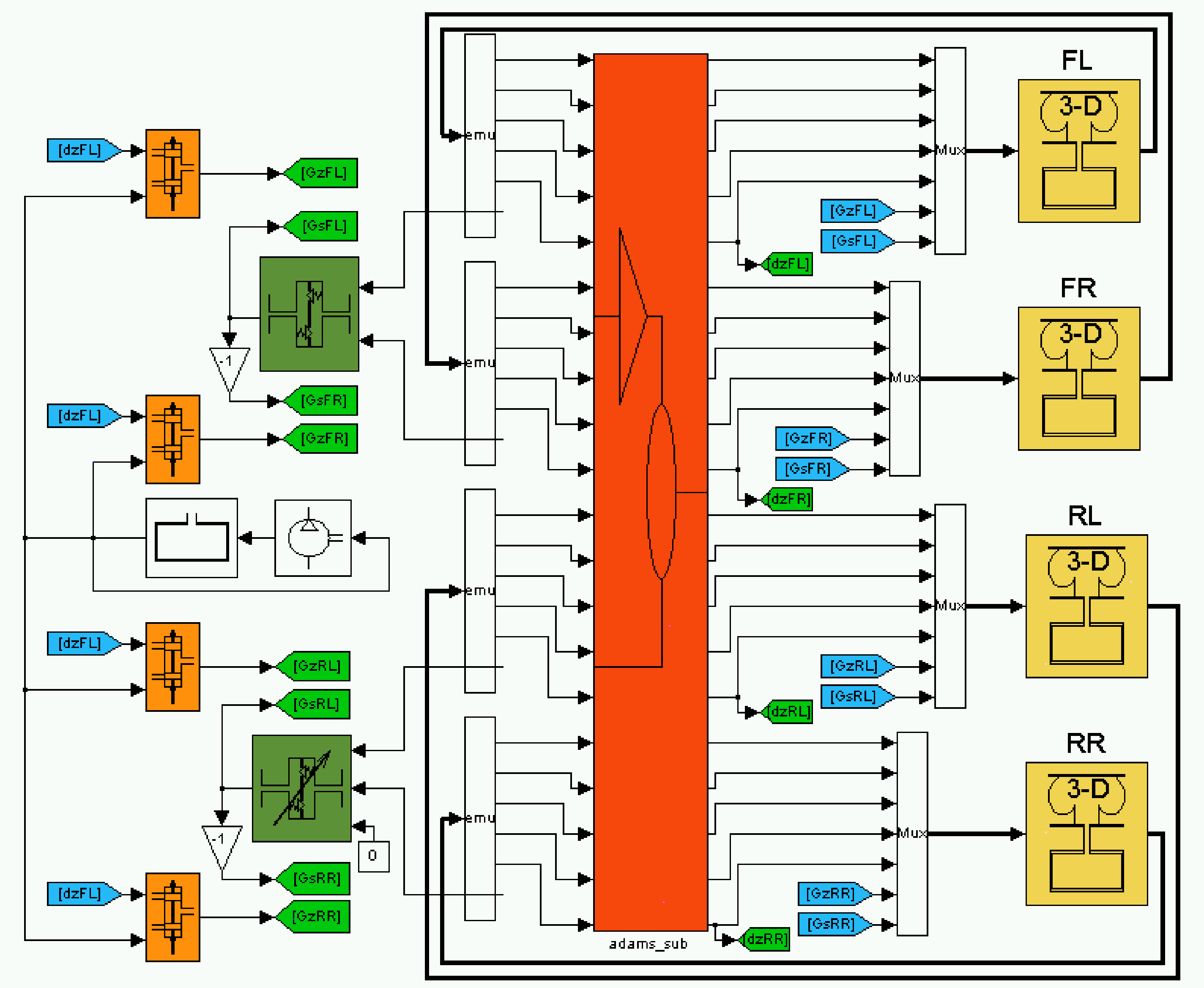
Heat transfer coefficient - airspring [W/K]: 0

Heat transfer coefficient - reservoir [W/K]: 0

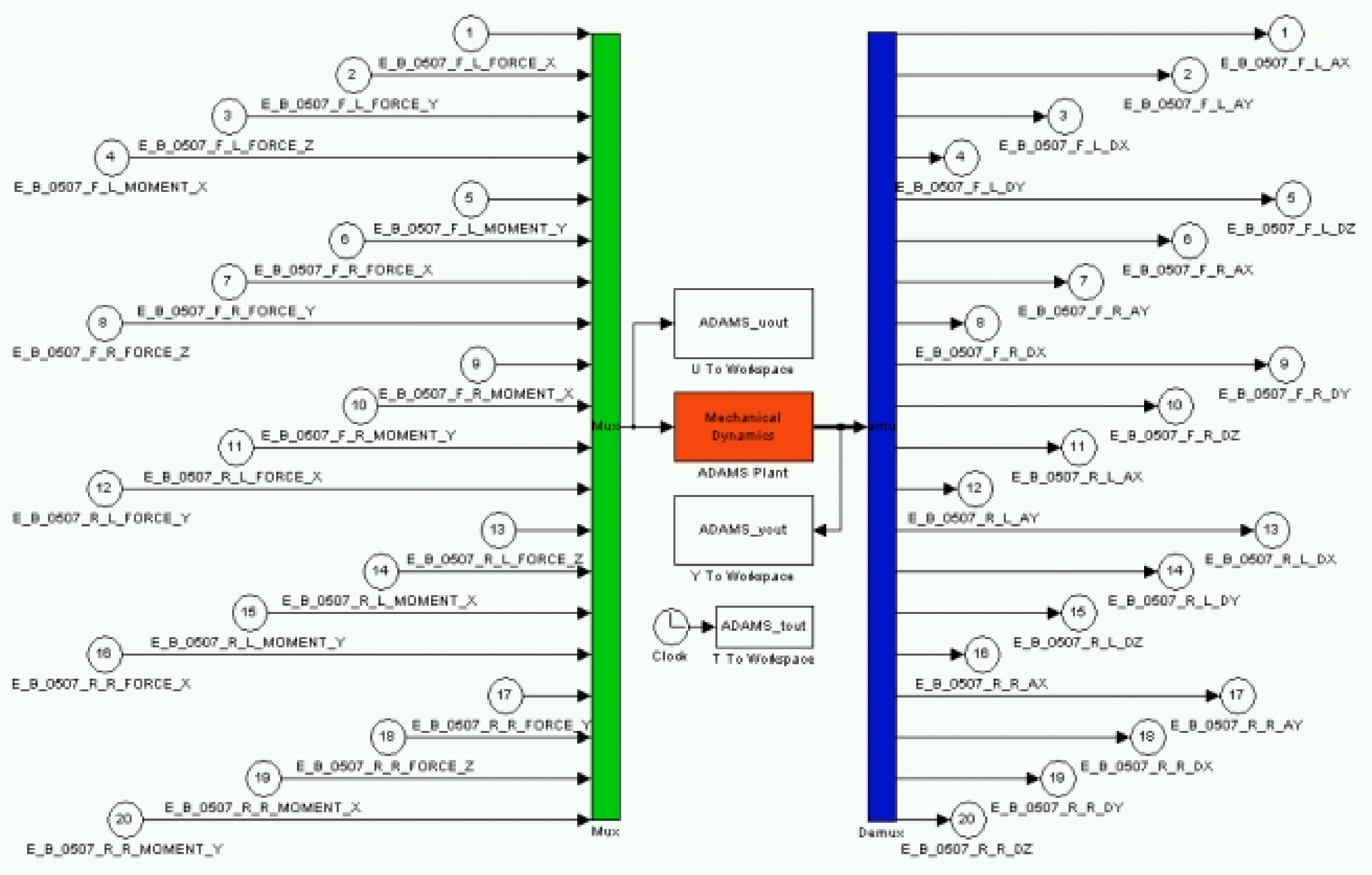
Example - Model of the Railway Car



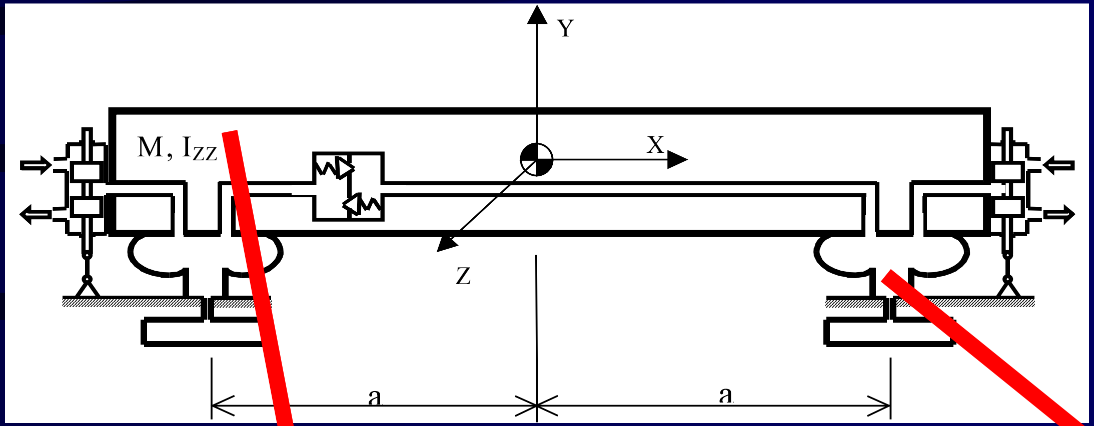
MATLAB/Simulink Part of the Railway Car Model

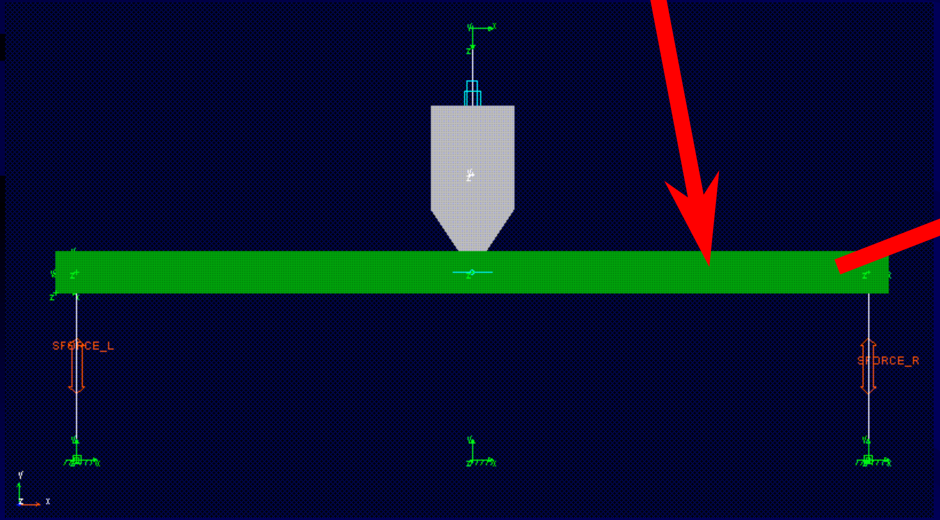


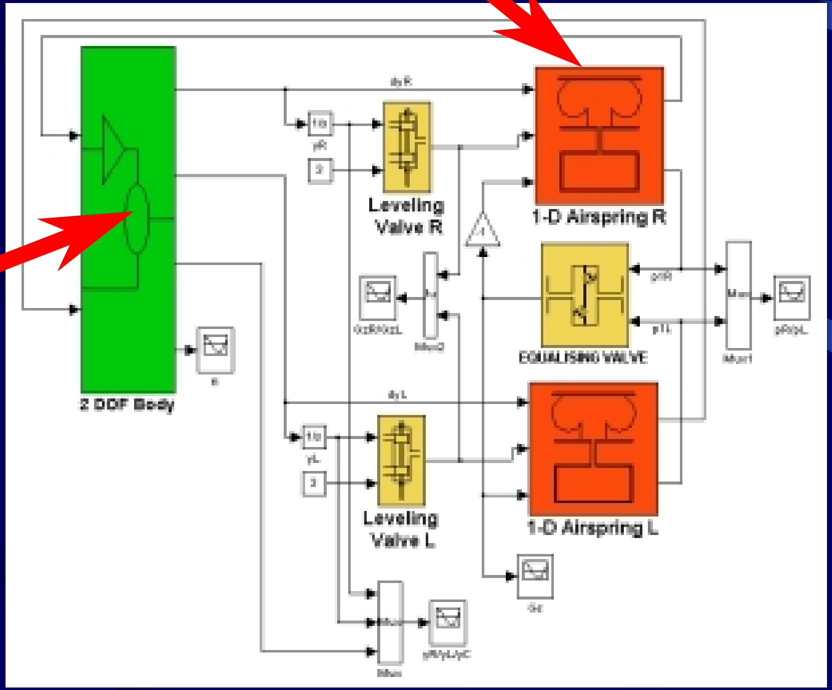
Structure of the „adams_sub” Block



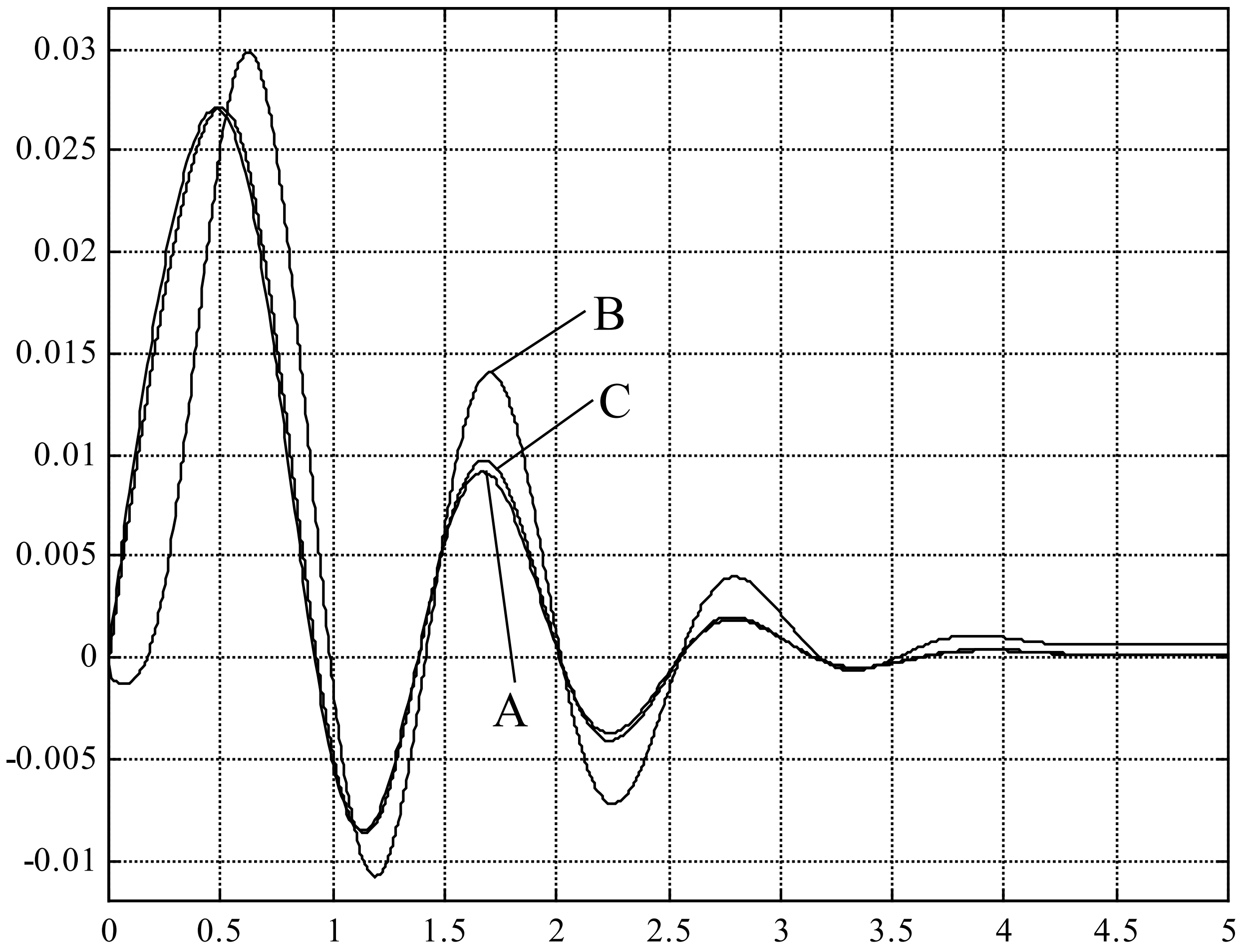
Simplified Railway Car Model



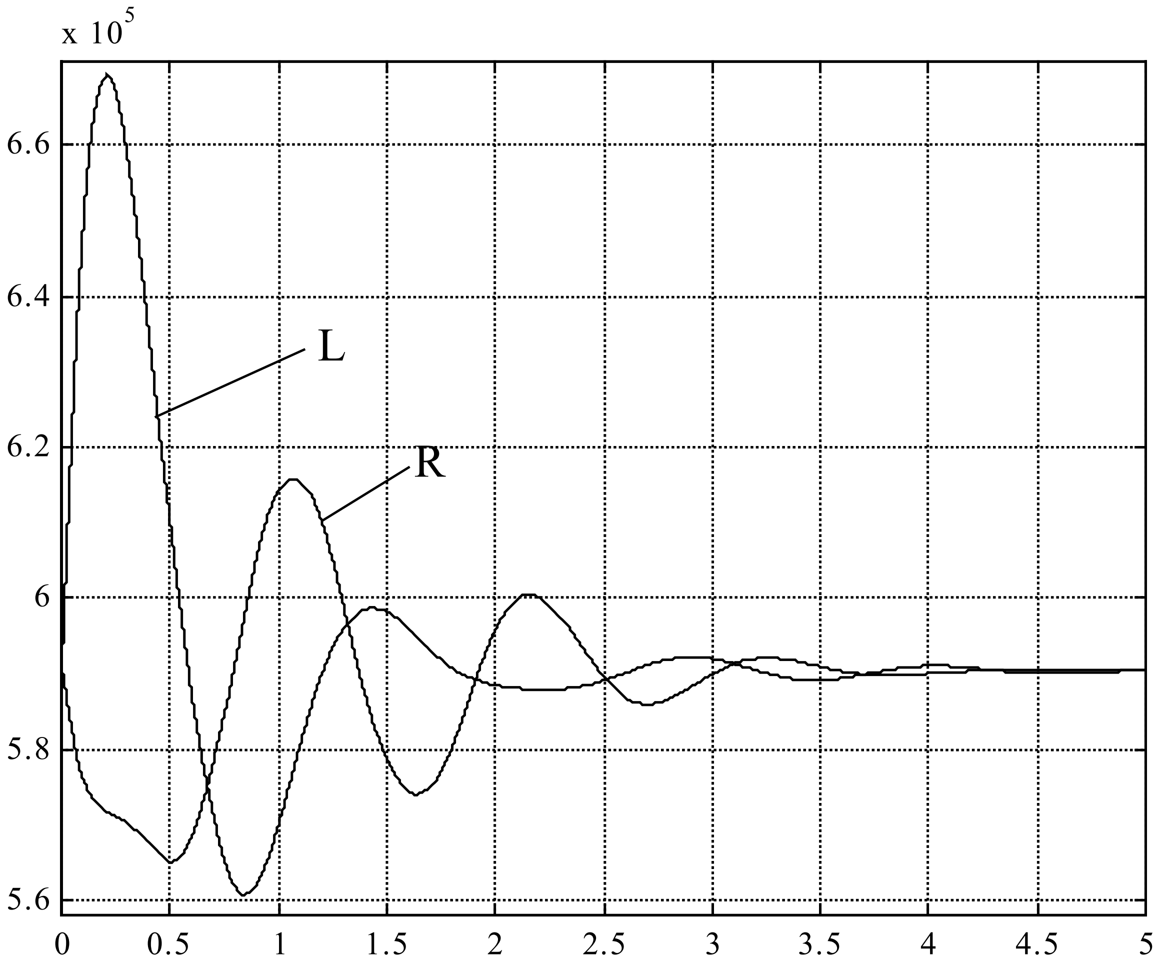




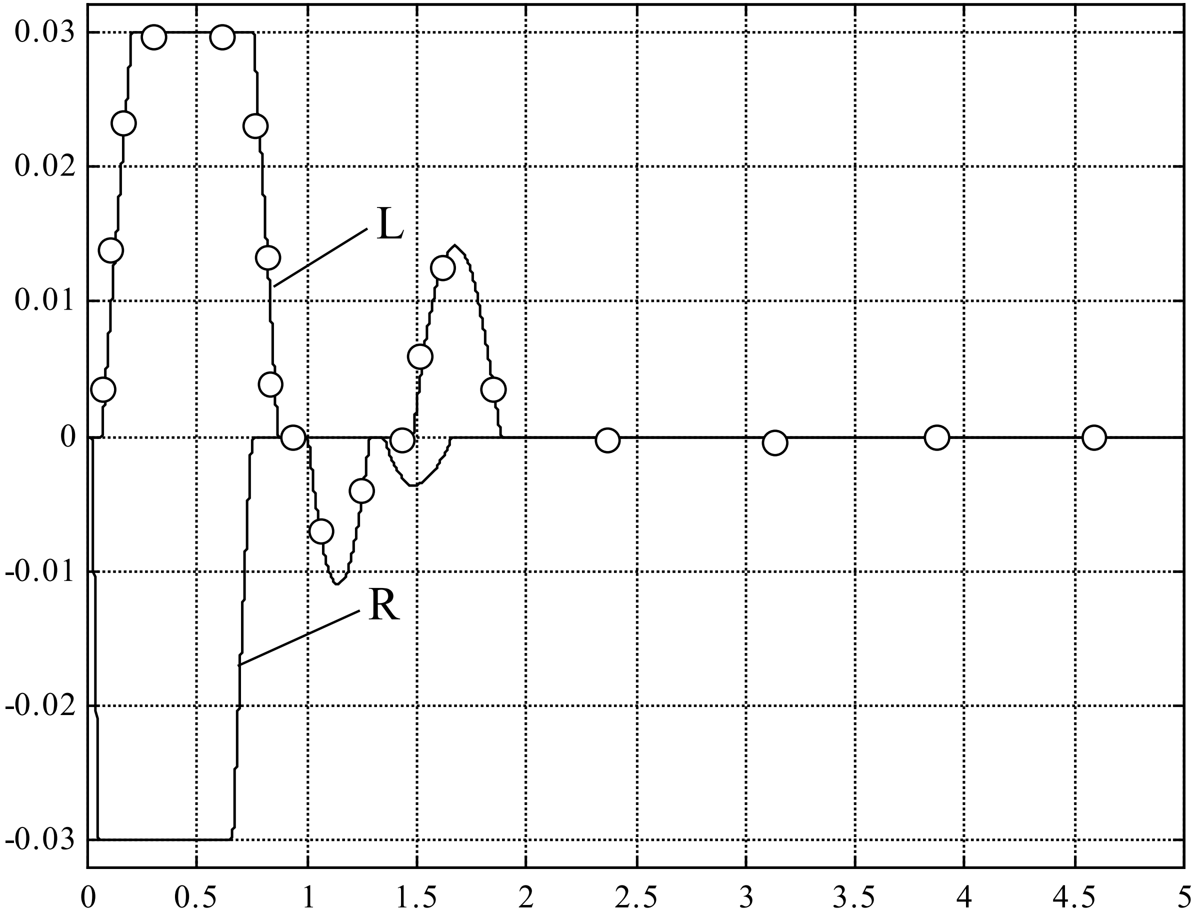
Vertical displacement „yR” for M_0.01 s (A), A-M_0.01 s (B) and A-M_ 0.001 s (C)



Pressure in Elastic Chambers



Air Mass Flow from Feeding System

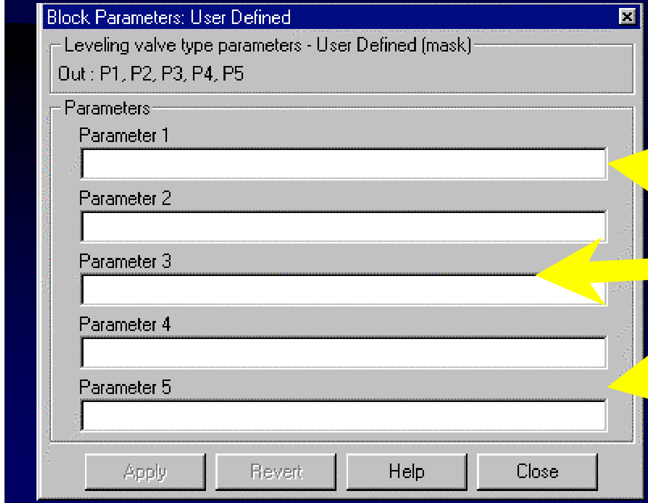


Conclusions

- Simpler building of vehicle models with advanced pneumatic suspension system
- Easy choice of the suspension system parameters
- Usability of linearized models
- Evaluation possibility of pressures, air mass flow and temperatures in each point of the suspension system
- Opennes for new models

Future Plans

- More detailed tests on airsprings to obtain full 3-D characteristics
- Collecting and eventual completion of the equalising and leveling valves charcteristics
- Broadening the pneumatics library with other components e.g. position sensors


Block Parameters: User Defined

Leveling valve type parameters - User Defined (mask)

Out : P1, P2, P3, P4, P5

Parameters

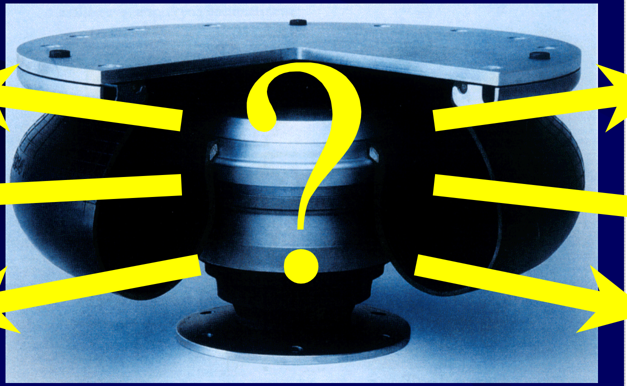
Parameter 1

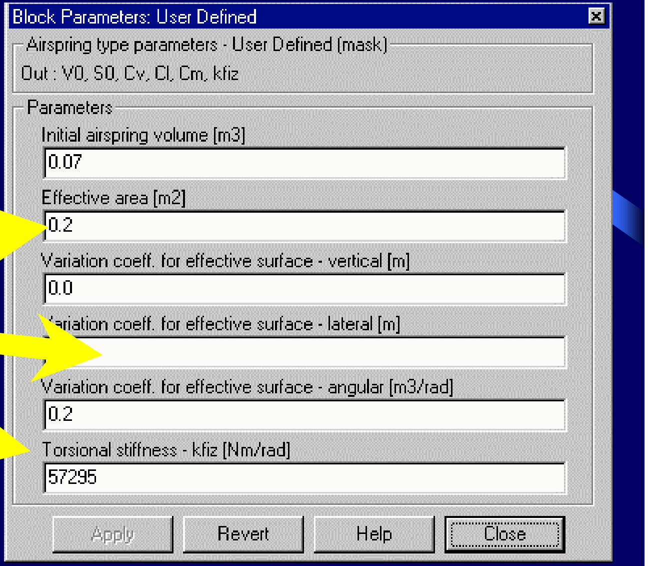
Parameter 2

Parameter 3

Parameter 4

Parameter 5




Block Parameters: User Defined

Airspring type parameters - User Defined (mask)

Out : V0, S0, Cv, Cl, Cm, kfiz

Parameters

Initial airspring volume [m3]: 0.07

Effective area [m2]: 0.2

Variation coeff. for effective surface - vertical [m]: 0.0

Variation coeff. for effective surface - lateral [m]

Variation coeff. for effective surface - angular [m3/rad]: 0.2

Torsional stiffness - kfiz [Nm/rad]: 57295

Bibliography

[1] Grajnert J. : Podstawy teoretyczno-doświadczalne projektowania zawieszeń pneumatycznych. Oficyna Wydawnicza PWr, Wrocław 1996.

[2] Grajnert J. : Improvement in Airspring Modelling. 4th ADAMS/Rail Users' Conference. Utrecht 1999.

[3] Grajnert J., Krettek O.: Zur Phänomenologie und Ersatzmodellbildung von Luftfedern. ZEV+DET Glas. Ann. 115 (1991), Nr. 7/8.

[4] Grajnert J., Wolko P.: Library of Components of Pneumatic Suspension System modeled in MATLAB/SIMULINK and Possibilities of its Application in ADAMS/Rail. 5th ADAMS/Rail Users' Conference. Haarlem 2000.

[5] Marcinkowski J.: Podstawy określania charakterystyk sprężyn powietrznych. Prace Naukowe IKEM PWr, Nr 68, Seria: Monografie Nr 19, Wrocław 1992

[6] Oda N., Nishioka K., Nishimura S.: Theoretical analysis of the diaphragm air springs for railroad vehicles. 40th General Meeting of Japan Soc. Mech. Eng., 1963

Summary

This paper is a continuation of a previous one "Library of Components of Pneumatic Suspension System Modelled in MATLAB/SIMULINK and Possibilities of its Application in ADAMS/Rail". It shows how to build a model of pneumatic suspension system using specialised library in MATLAB/Simulink and include such a model into structure of a vehicle model using Plant Export function in ADAMS/Controls. ADAMS and MATLAB work in a loop and exchange such parameters as velocities, displacements, forces and moments in each airspring. Such approach allows building complex models of pneumatic suspension sytem where connections between airsprings, feeding system and control system are taken into account. It is especially useful by studying untypical cases of suspension system and when you need to follow specified parameters not available in present version of airspring model.