

CAE Design of Controlled Pantographs

For high speed trains currently under development, satisfactory power collection by conventional pantograph/catenary systems arrives at its limits. Therefore, in a research project of Deutsche Bahn AG and DLR, a concept for an environment had to be set up to develop new or enhanced pantograph systems by using all required computer aided design (CAE) facilities. Additionally, the potential to improve the present systems of the DSA 350 series used in the German ICE trains by replacing purely mechanical by mechatronic components was investigated.

Project Goals

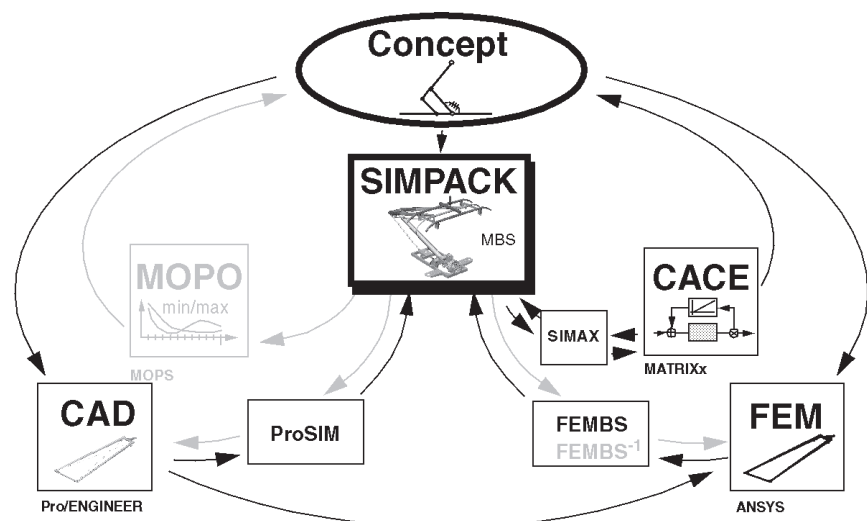
When running with several pantographs in a train set, when tilting trains are employed and when running on low quality catenary sections which have been designed for operation at low speed, the pantograph system becomes the speed limiting factor of a train rather than the running gears. The decisive criterion for assessing the contact quality and consequently the quality of the energy transmission is the time response of the contact force between pantograph slipper and contact wire. Low contact forces result in contact interruptions. If the contact forces are too high, unacceptable catenary lift can occur. Thus active pantographs must allow an adaptation of their vibration-dynamic behaviour to the operational conditions and must efficiently control the contact force variations.

Computer simulations within this project are used to understand the complex dynamic behaviour of the catenary together with the pantograph. It assists in the investigation towards the behaviour of present systems and to predict the characteristics of new or modified concepts. The main focus-point in this project was the implementation of a CAE environment

to accelerate the development of new pantograph systems, finding out how to improve the present ones and developing a concept for future controlled systems.

CAE Environment

For a fast and cost effective development of advanced pantographs a range of computer based engineering tools and their interaction is essential. The figure below shows the concept of the modelling, simulation and design environment with the used CAE packages. Since the 3D dynamic behaviour of the pantograph is the key problem of the development, SIMPACK with its extensive interfaces to other prod-



ucts and its suitability to unite different simulation approaches, was placed at the centre of this CAE environment. The generation of a multi-body simulation model is linked directly to the design of the pantograph using a CAD package, thus providing mass and inertia data in a very early design phase. The corresponding data is exchanged via the interface ProSIM. Since some parts of the pantograph exhibit structural elasticity in the frequency range of interest, FEA models have to be provided as well. The flexible data of these bodies are transformed to SIMPACK by the interface FEMBS. The design of control elements is enabled by the interface SIMAX, allowing the combination of 3D mechanical SIMPACK models with control loops modelled in the CACE tool MATRIXx.

Pantograph Simulations

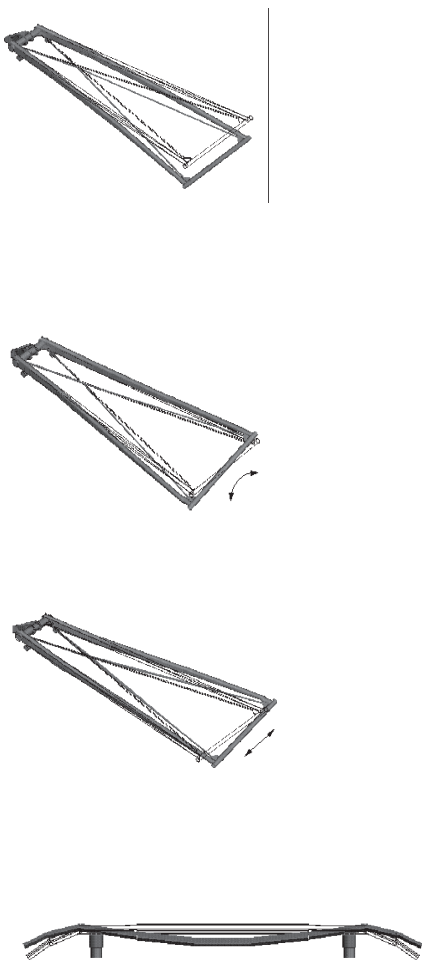
To verify the presented development concept, two passive high performance pantographs, the DSA 350 S and DSA 350 SEK, have been analysed, since numerous measurement data were available. The models, first created in Pro/ENGINEER and then exported to SIMPACK, contain full 3D kinematics. Three bodies, the two contact strips and the upper frame are modelled as elastic bodies. The above mentioned interface FEMBS uses a modal approach to describe elastic bodies in SIMPACK. For the contact strips only the first bending mode is used, the description of the elastic movement of the upper frame requires two bending modes and one torsional mode, as shown besides. The FEA model of the contact strip was set up by using the FEA pre-processor, whereas the mesh of the upper frame was created directly from the CAD data. Finally, the light grey arrows in

the figure are options available by the CAE products but not yet employed within that project: A multi-objective parameter optimisation tool allows the automatic optimisation of specific parameters according to chosen criteria functions, the interface LOADS can be used to consider loads obtained from the multi-body simulation in the FE tension analysis.

The behaviour of the whole system was compared to measurements of the so-called apparent mass to verify the complete multi-body model including elastic bodies, structural damping and joint friction. Due to the need of simulating non-linear effects, the result of the frequency response figure aside have been achieved by time integration of the systems response on a number of different excitation frequencies. The result shows the influence of the flexibility of the upper frame and contact strips. The deviations between both, the measured and the simulated frequency response histories are a result of not exactly reproducible excitation conditions of the pantograph on the test rig.

Coupled Pantograph/Catenary Simulation

The rating of new or enhanced pantograph concepts is based mainly on the time history of the contact force and the lift of the contact point while running along overhead lines. For that purpose it is not sufficient to approximate the catenary dynamics by deterministic or stochastic force excitations. These may be applied for basic investigations of the pantograph behaviour, but for simulations striving for verification of new concepts the full catenary dynamics must be taken into account. Therefore ProOSA, a specialised tool for the simulation of



FEA-Calculated Mode Shapes, representing elasticity in the multi-body simulation

catenaries, was coupled to SIMPACK. PrOSA allows to model and solve the partial differential equations needed to describe catenary equations. The original development of PrOSA was performed at the Heinz Nixdorf Institute in Paderborn and is now further developed and validated at the Deutsche Bahn AG. The interface between PrOSA and SIMPACK enables a co-simulation of controlled pantographs and overhead lines. The programs exchange data at discrete time steps using a certain sample rate, up to now realised in a two-process solution. The data exchange is achieved by the IPC-function (Inter Process Communication) elements of UNIX-sockets, while an interface control program ensures a correct synchronisation of the two programs to avoid misinterpretation of the data exchanged. The advantages of this interface concept are that the corresponding system equations can be solved with their own specialised solver and that both tools can be developed independently and even modified fundamentally without compatibility problems, unless the standard of the data exchange format is changed.

New Control Concept

The first control concept, which was developed by using the CAE environment presented including PrOSA, showed its efficiency. It is based on a dynamic isolation of the catenary and the pantograph main frame. In the present realisation of this principle, a passive element is suggested to isolate the contact strips from the pan head by a constant force between both components independent of the relative dynamic motion. In consequence of the relatively small working range, it is necessary to add a control system in

order to guarantee the service of the passive element. Therefore an active position control element is planned to influence the lift drive of the pantograph. The applied drive units contain a pneumatic bellow, which introduces a torque in the lower frame by a lever. The first simulations with approximated force excitations or simplified catenary designs showed good improvements achieved with this concept, however, the co-simulation with the catenary program PrOSA showed, that the improvement is less than predicted using the simplified catenary models. This demonstrated clearly that the influence of the catenary dynamics cannot be neglected. Only the calculation of the full dynamic interaction between both systems can verify new mechatronic approaches.

