ANNALS OF THE FACULTY OF ENGINEERING HUNEDOARA
2004, Tome II, Fascicole 3

THEORETICAL ASPECTS ABOUT THE ACTUAL RESEARCH CONCERNING THE PHYSICAL AND MATHEMATICAL MODELING CATENARY SUSPENSION AND PANTOGRAPH IN ELECTRIC RAILWAY TRACTION

MIKLOS Cristina Carmen, MIKLOS Imre Zsolt

UNIVERSITY POLITEHNICA TIMISOARA
FACULTY OF ENGINEERING HUNEDOARA

ABSTRACT:

This paper presents actual directions and possibilities about the modeling and simulation behavior catenaries - pantograph suspension. The actual direction about the elaboration instruments and useful techniques in catenaries - pantograph suspension mathematical modeling is done with the special automatic software specific this modeling, on the assumption at scenario elaborate for different level of utilization.

KEYWORDS:
electric railway traction, catenaries suspension

1. INSTALLATION PROBLEMS IN ELECTRIC RAILWAY TRACTION EXPLOITATION

The contact line on electric railway traction is made by longitudinal suspension or catenary suspension composed of contact wire sustained by a massager cable through dropper; the assembly formed of contact wire and supports necessary for sustained this at a constant height over the track represent the contact suspension. Catenary suspensions can be either simple - for a use at 100km/h speed, or compose - used at 200-300km/h speed. Contact wire, has a nominal section aria of 50-600mm^2 composed of copper, steel-copper, or steel-aluminum. In general, the main demand required for a current collector system is that at any requested power, rate of travel and working depth, a continue collection is assured. In this content, the collecting devise must satisfy some static and dynamic criteria. The special interest for current collector system performance problems increases in context of railway systems functioning with high speed trains, used all over the world, but especially in Europe and Japan (TGV in France - 300km/h and Shinkansen in Japan - 250km/h). High speeds create dynamic behavior problems which solutions impose to find technical and economical efficient facts determined in the last few years with theoretical studies and experimentation investigations intensification by researchers from powerful countries, like Sweden, Italy, France, Japan, Germany and England.

2. QUALITATIVE PRESENTATION OF DYNAMIC BEHAVIOR OF CATENARY PANTOGRAPH SUSPENSION ASSEMBLY

The problems of continue collecting assurance of current depend both of kinetic-static's pantograph performances, and flexibility catenary performances. Pantograph displacement must allow the catenary to follow the move to assure continues electric contact, but it must not induce a catenary significant displacement. Catenary suspension must be as stiff as possible, but with a stiffness of assembly as uniform as possible, to ensure minimum displacements at the wires level. Ideal, the pantograph must touch the wire enough to ensure a good electrical contact, but light enough for not a significant catenary displacement. Accordingly, the main factor that induces reliability and performance of catenary pantograph system is the dynamic interaction between catenary suspension and pantograph. However, to accomplish this duty the pantographs which are used have different configurations, (symmetric and asymmetric - fig.1) all work to the same principle - the articulated movement of arms which are in relation - and accomplish the same function, to maintain continue electrical contact.

DSA150 (max.160km/h)

- lower arm with tubular structure steely;
- upper frame with aluminum arms;
- total weight aprox. 125kg

DSA200 (max.200km/h)

DSA250 (max.230km/h, weight 115kg)

DSA350SEK (max.280km/h, weight 105kg)

DSA350G (max.220km/h, weight 125kg)

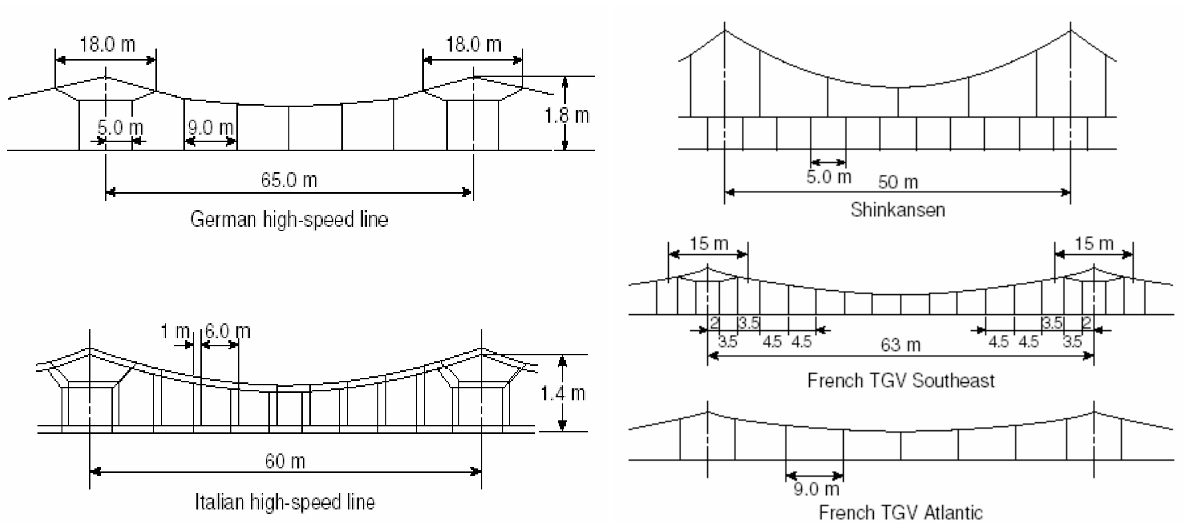
DSA380D (max.330km/h, weight 109kg)

- aluminum lower arm structure and upper arm

DSA380F (max.330km/h, weight 109kg)

Figure 1. Pantographs - producer STEMMANN -TECHNIK GmbH

For higher speed train, dynamic interaction problems increase; this means that for high-speed railway traffic, trains utilized special catenary geometrical configuration characteristics (representatives types are in fig.2a and 2b).



a) b)

Figure 2. Japan Railway&Transport Review 16, June 1998-Railway Electric Power Feeding Systems/

3. CONSTRUCTION EVOLUTION IN MATHEMATICAL AND PHYSICAL MODELING PROBLEMS IN CATENARY-PANTOGRAPH SUSPENSION ASSEMBLY

The actual tendency on structure modeling research for example catenary-pantograph assembly is to analyze dynamic behavior with simulation software and to make a new research departure to obtain new results in plant practice. Using the hard/soft performance components allows to accomplishing this. In complex structure modeling, the methods that are currently used for dynamic response evaluation, [1], [2], are in matrix form formulation and are solved with the automatic software, most of the results being like FEA method. In conclusion from the mathematical modeling approach on assembly catenary-pantograph suspension described in recent publications and presentations in November 2001 "World Congress on Railway Research" Köln-Germany – result conceptual evolution on mathematics and physics catenary pantograph suspension models.

3.1. Equivalent mechanical model for the pantograph and catenary

The choice of a simple catenary for simulation is made because this system has the same behavior under dynamic action effect like compound catenary. Catenary equivalent mechanical model is presented in fig.4.

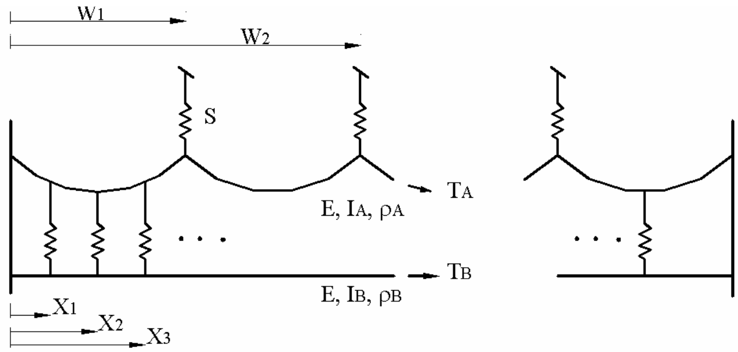
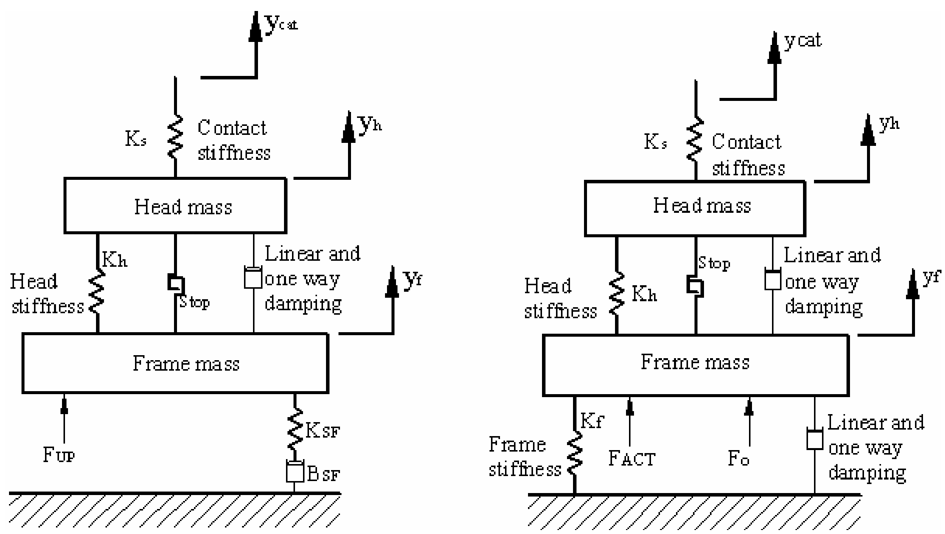


Figure 4. Catenary equivalent mechanical model

Where: Tower stiffness: S; Dropper stiffness: K; Distance to the j-th tower: W_j; Distance to the i-th dropper: X_i; Stiffness of the two wires: EI_A, EI_B; Density of the two wires: ρ_A, ρ_B; Tension in the two wires: T_A, T_B

Pantograph equivalent mechanical model is presented in fig.5.



a) b)

Figure 5. Pantograph equivalent mechanical model

The two models are coupled through the spring that represents the stiffness of the carbons on flexure of the head, K_s (fig. 6).

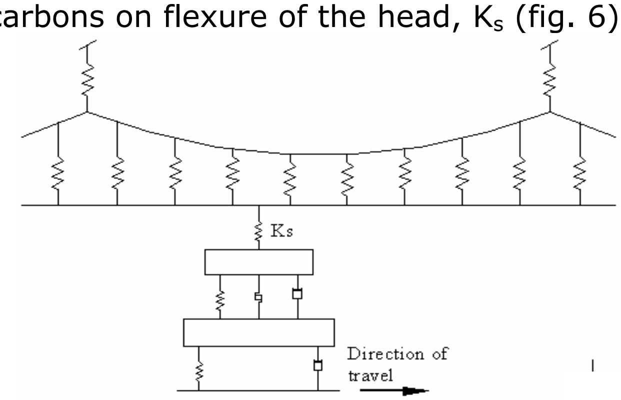
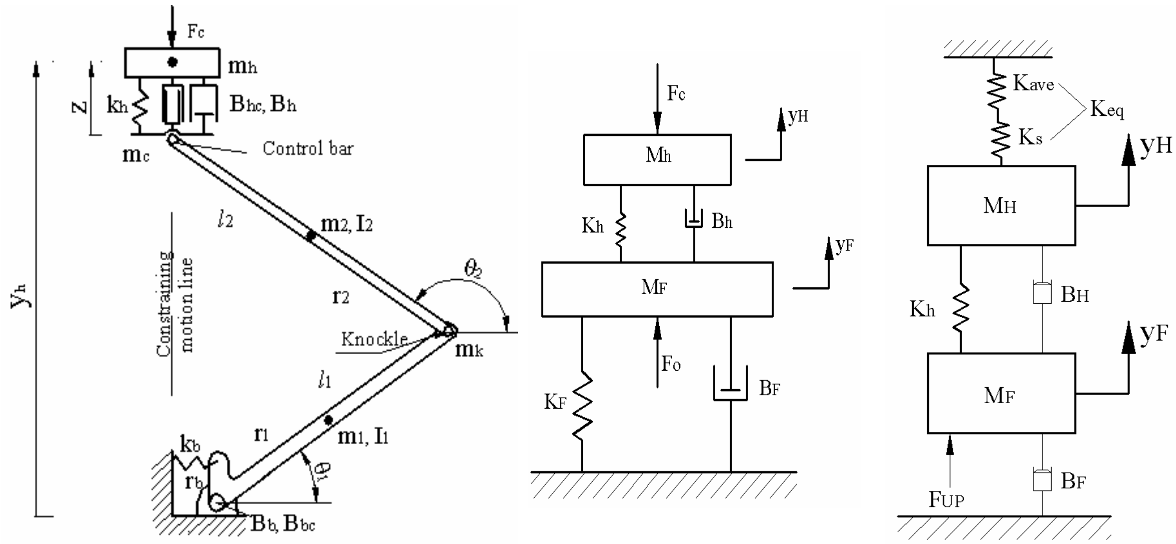


Figure 6. Coupling of the pantograph and cat y models

3.2. Nonlinear pantograph model

Physical description of a nonlinear analytical model is presented for the following mode (fig. 7a and 7b):

1. Nonlinear pantograph model;
2. Static model;
3. Linear model.



a) b) c)

Figure 7. Pantograph models

The pantograph model used to control the design is the same for two-mass model [3]; but, the wire height, y_{cat}, cannot be realistically measured; catenary is modeled as a constant spring which value is the average catenary stiffness, k_{ave}. Fig. 7c shows this scheme.

4. CONCLUSION

Assessment method using the dynamic system concept is presented in the first three horizontal blocks from fig.8, and is particularized in the following blocks with specific details on modeling catenary-pantograph suspension.

In the last decade, thanks to collaboration between engineers and computer science specialists in simulation, some of models with high practical applicability were elaborated, especially developed with technical-engineers implements aim. Some of these models are based on the fact that catenary-pantograph suspension is a critical component of the system, [4], especially when the train speed increase.

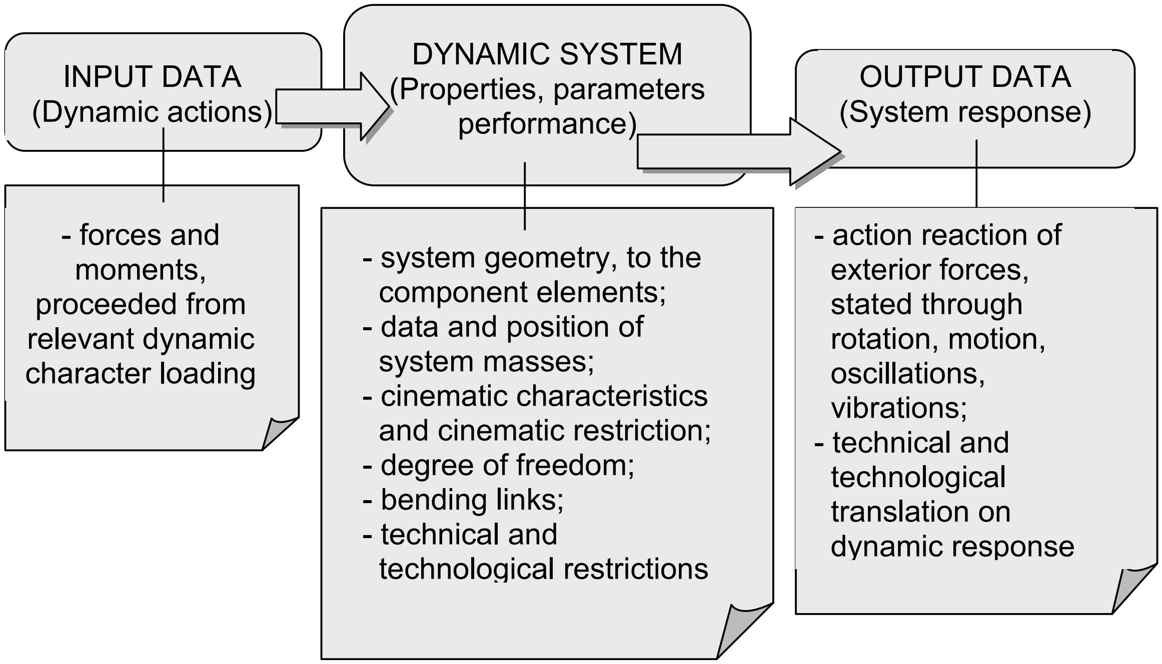


Figure 7. Dynamic system concept used in modeling catenary-pantograph suspension

5. BIBLIOGRAPHY

1. BELYAEV, I. A., VOLOGINE, A. A., FREIFELD, A. V. "Improvement of pantograph and catenaries and method of calculating their mutual interactions at high speeds", Rail International, June, 1977, pp.309-328
2. BOISSONADE, P. "Catenary design for high speeds", Rail International, March, 1975, pp.205-217
3. O'CONNOR, D "Modeling and simulation of pantograph-catenary systems", Submitted to the Department of Mechanical Engineering in partial fulfillment of the requirements for the degree of Master of science in mechanical engineering at the Massachusetts Institute of Technology, February, 1984
4. *** www.agir.ro