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ASIMETRIC PANTOGRAPH MECHANISM STATIC ANALYSIS BY FINITE ELEMENT METHOD

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Abstract: The paper deals with the static analysis of the asymmetric pantograph mechanism used in the railway electric traction. In order to model the asymmetric pantograph mechanism subject study through the finite element analysis, was used Autodesk Inventor Professional program, a software package that is part of the Computer Aided Design (CAD) family, enables 3D product modeling and assembly of parts, thus representing an integrated and intelligent solution for 2D/3D design dedicated to mechanical and electromechanical engineers. 3D modeling in Autodesk Inventor of the pantograph mechanism was accomplished using the principles of parameterized modeling and adaptability for Stable Part (Part) and 3D constraints: insertion, overlap, angular constraint, insertion (Insert, Mate, Angular, and Flush). After assembly of the component elements and after the introduction of 3D constraints, the pantograph mechanism kinematic verification was performed by simulating the movement. The conclusions and results obtained are useful in the design and operation of these types of mechanisms from the railway electric traction.
Keywords: railway electric traction, asymmetric pantograph, 3D modeling, static analysis, finite element method

INTRODUCTION

Rail transport is an important part of the general freight and passenger transport, which is steadily increasing, mainly due to the increase of the commercial speed by increasing the speed of the traffic and the automation of the related installations [1]. In electric traction, a modern and rational traction system that offers increased safety in trains circulation and technical-economic advantages in the railway transport, the vehicle movement on the rail road occurs as a result of the use of a propulsion system - made with rotary or linear electric motors - of the traction force that develops as a consequence of some pondero-motor actions in the electromagnetic field [2].

The electric locomotive, as an electric motor, captures energy from the contact line, and the mono, bi or trifilar contact captures can be made either from a classical line or from a rigid rail. With all the inconveniences generated by the amount of investment and construction required, in this moment, the power supply solution from an elastic contact line remains the most economical in the event of intense traffic and significant declines.

The electricity from the contact line is transferred to the locomotive via the pantograph mechanical arm supporting the current collector [3]. Since the supply of the locomotive must be continuous, the pantograph must exert a stable and constant force at the current collector shoe.

The contact force must be large enough to ensure continuity of current collection, but also small enough to prevent overturned vertical movements by forced lifting of the catenary, especially in the middle areas between the supporting posts, which would accentuate the dynamic character of phenomena in the behavior of the ensemble [4].

The problem of ensuring continuous current collection depends on kineto-static characteristics of pantograph and flexibility characteristics of the catenary: the pantograph geometry in motion should allow easy tracking of the catenary route to ensure continuous electric contact, but not to displace the catenary in an appreciable manner; the catenary suspension should be as rigid as possible, but with the most uniform stiffness of the assembly, to ensure minimum displacements in the wire [5].

Ideally, the pantograph must touch the wire fairly firmly to ensure a good electrical contact, but easy enough not to move the catenary significantly [6].

MODELING ASYMMETRIC PANTOGRAPH MECHANISM

Pantograph mechanism in Autodesk Inventor [7] 3D modeling was made using parametric modeling principles and adaptability for independent benchmarks (Part) and 3D constraints: insert, overlay, and angle constraint, restraint (Insert, Mate, Angular and Flush).

Thus modeled, the components of the asymmetrical pantograph mechanism studied are shown in Figures 1-5.

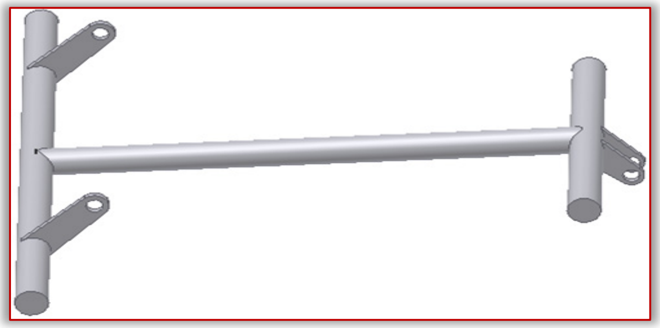

Figure 1. Support subassembly

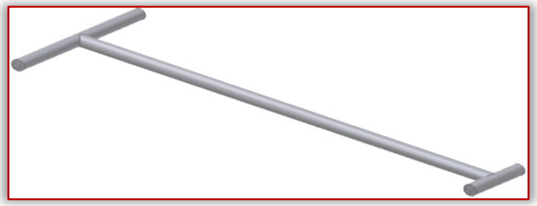

Figure 2. Pantograph mechanism connecting rod

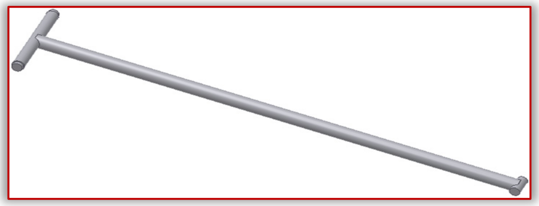

Figure 3. Pantograph mechanism rocker

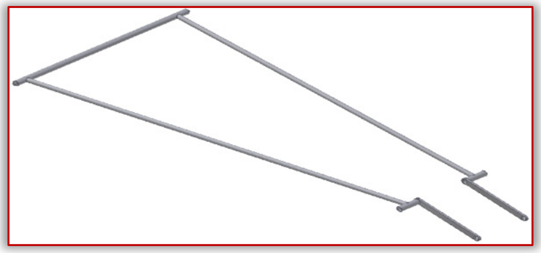

Figure 4. Upper arm subassembly

Figure 5. Pantograph sleigh

PANTOGRAPH MECHANISM FUNCTIONING SIMULATION

As a result of the assembly of the component elements presented in the previous figures and after the introduction of the 3D constraints (Angular, Mate), the pantograph mechanism kinematic verification was performed by simulating the movement. It was found that between its extreme positions (Figures 6 and 7) given by the angular constraint of the driving element (rod) - min.5^0 and max.54^0 - the maximum travel of the sleigh is related to a vertical direction displacement of approx. 2600mm, which demonstrates that the modeled mechanism works correctly.

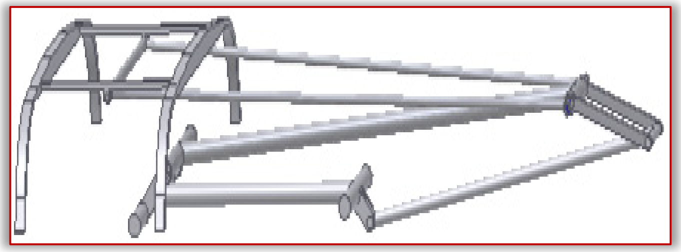

Figure 6. Minimum angular position for opening the pantograph mechanism (pantograph lowered position)

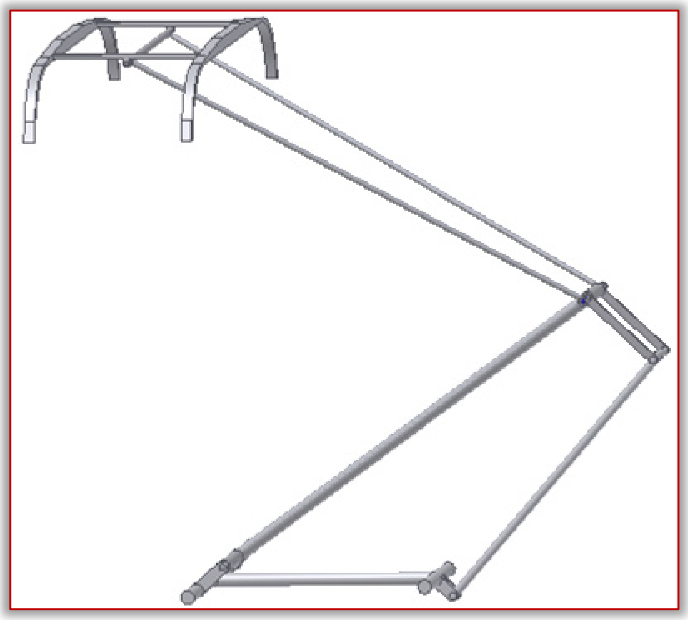

Figure 7. Maximum angular position for opening the pantograph mechanism (pantograph higher position)

PANTOGRAPH MECHANISM ELEMENTS STATIC ANALYSIS

Pantograph mechanism elements static analysis was done using the finite element method in Autodesk Inventor Professional [7]. Parametric 3D models, which have the property to change automatically with size changes, are obtained by geometric generation using the specific operations of: extrusion, rotation around an axis of the profiles, etc.

Therefore, in a first phase is being drawn contours open or closed mostly made up of a series of lines and arcs called sketch, which follows a series of geometric and dimensional constraints, and the sketch after applying constraints becomes profile. A sketch needs geometric and dimensional constraints to be defined as shape and size, and constraints reduce degrees of freedom between sketch elements and control how it behaves when a dimension is changed.

In order to realize a profile, do the following steps:

- Making the sketch;
- Validate and obtained the profile;
- Applying geometric constraints.

For the static analysis of the pantograph mechanism, it was considered that on the mechanism structure a contact force acts at the level of the skate F_c=90N, and the efforts are taken over by the upper frame elements and the support subassembly, assumed as a fixed element.

For the analysis by the finite element method, we have to make the following steps:

- Launching the FEA module;
- Defining the piece's material;
- Determining the static and loading scheme for each element-part by declaring the forces and the supporting mode (figures 8-10);

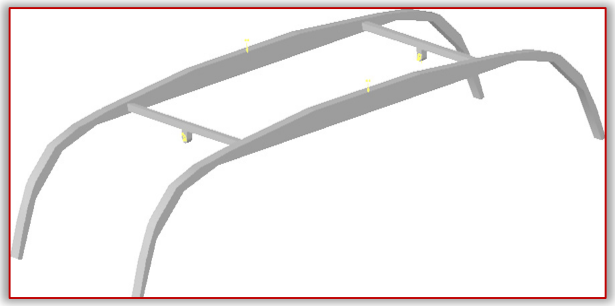

Figure 8. The static and loading scheme of the frame substructure of the pantograph sleigh

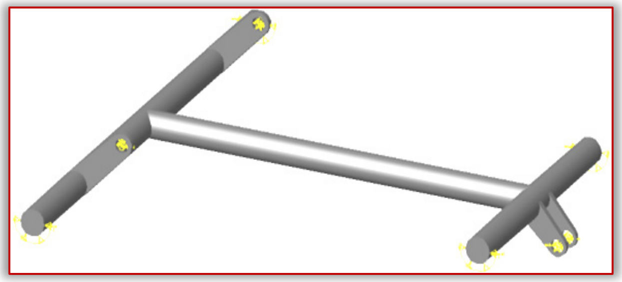

Figure 9. Static and load scheme of the support subassembly

Figure 10. Static and load scheme of the connecting rod element

- Component parts and pantograph subassemblies meshing (figures 11–13);

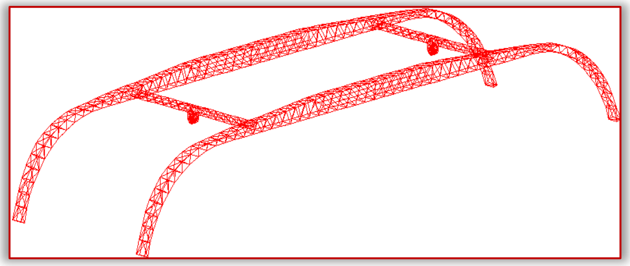

Figure 11. Frame substructure of the pantograph sleigh meshing

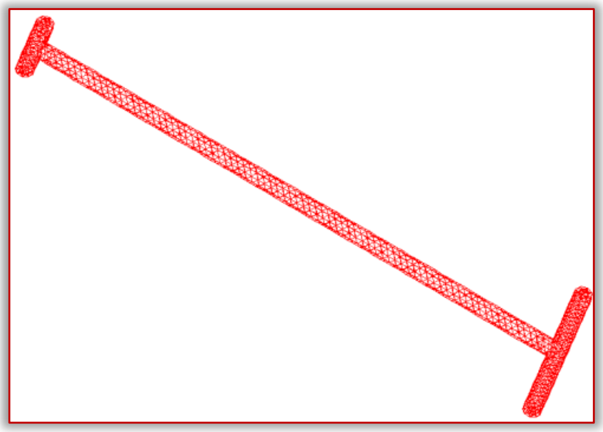

Figure 12. Structure rod element meshing

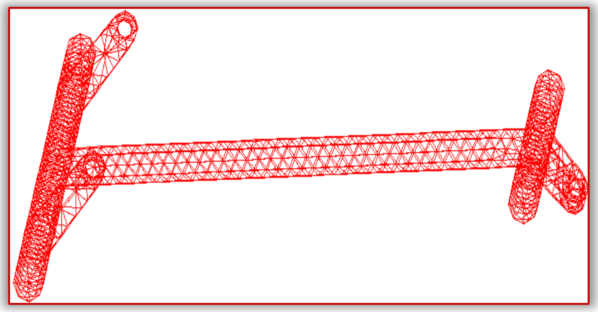

Figure 13. Support part structure meshing

- Running the program for finite element analysis and displaying the results of the unit efforts and deformations distribution (example in figures 14–16) determined for each assembly components based on VonMises theory.

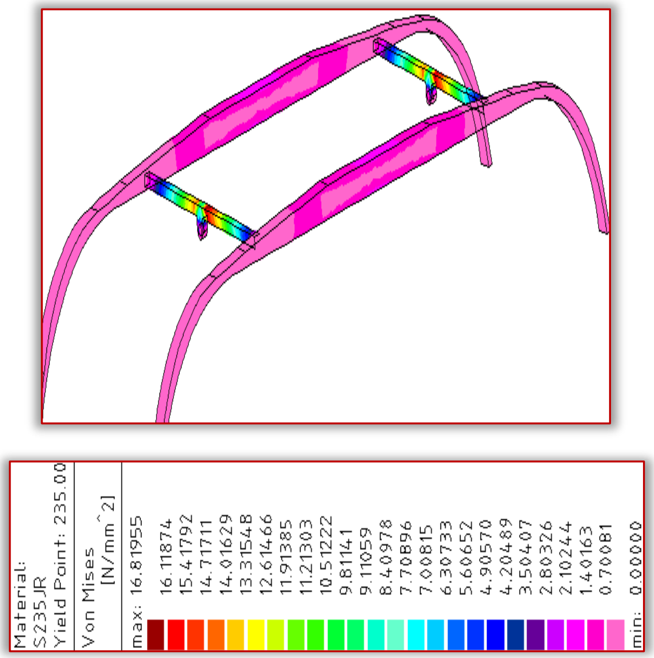

Figure 14. Stress distribution in the frame type substructure of the pantograph sleigh

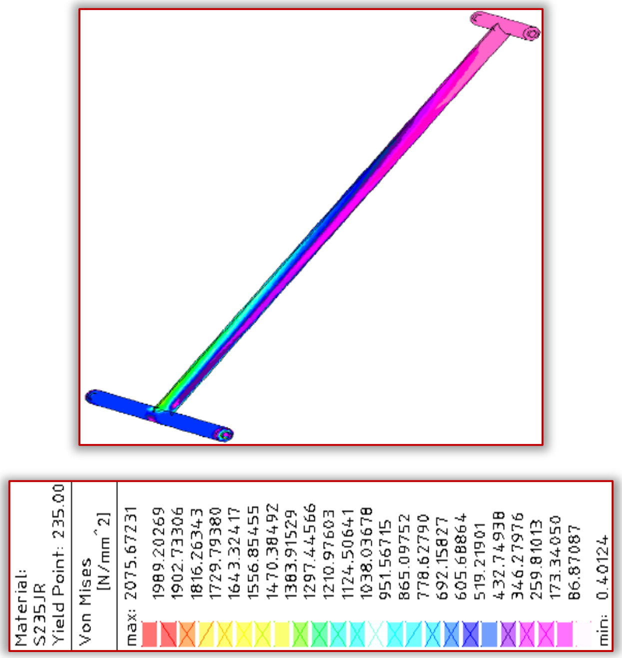

Figure 15. Stress distribution in rod element

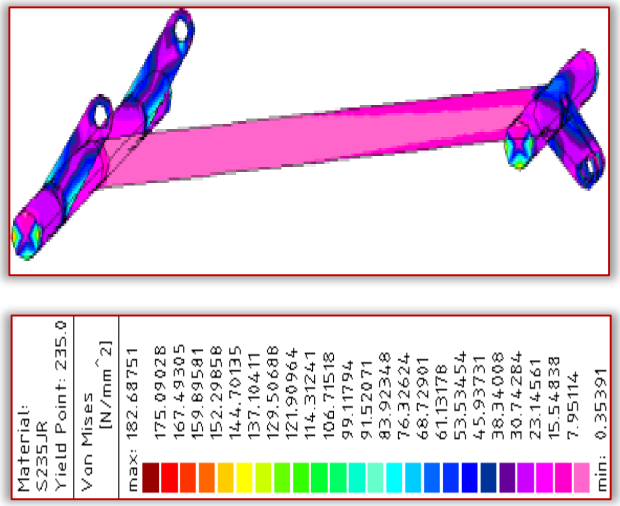

Figure 16. Unitary efforts distribution in the support subassembly

CONCLUSIONS

The results obtained from the calculation show that both the values of the unitary stresses and the deformations produced in the structural elements of the pantograph mechanism, fit within the limits imposed by the available norms. It was found that between its extreme positions (Figures 6 and 7) given by the angular constraint of the driving element (rod) - min.5^0 and max.54^0 - the maximum travel of the sleigh is related to a vertical direction displacement of approx. 2600mm, which demonstrates that the modeled mechanism works correctly.

Bibliography

[1] Alic (Miklos) Cristina, Studiul ansamblului suspensie catenară-pantograf în tracțiunea electrică feroviară, în vederea îmbunătățirii transferului de energie, teză de doctorat, 2011
[2] Bandi Punit, High Speed Rail Pantograph Control System design, University of Notre Dame, USA, May 1, 2009
[3] Belongie, S., Malik, J., et Puzicha, J., Shape matching and object recognition using shape contexts. IEEE Transactions on pattern analyses and machine intelligence, 24: 509-522, 2002
[4] Benet J., Cuartero F., Rojo T., A tool to calculate mechanical forces on railway catenary, Escuela Politecnica Superior, Univ. de Castilla-La Mancha, Campus, 02071 Albacete, Spain
[5] Bocciolone, M., Resta, F., Rocchi, D., Tosi, A., et Collina, A., Pantograph aerodynamic effects on the pantograph-catenary interaction. Vehicle System Dynamics, 44 Supplement: 560-570, 2006
[6] Nordborg, A., Vertical rail vibrations: noise and structure-borne sound generation. Thèse de doctorat, Kungl Tekniska Hogskolan, 1995
[7] ***, Autodesk Inventor Professional 2011 – User guide, 2011

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