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# FLOW ANALYSIS OF THE OPTIMAL PANTOGRAPH POSITION AND DESIGN

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**Abstract:** *This article deals with possibilities of using modern and advanced computational methods to determine how mechanical system is influenced in air flow.*

*Simulations of different orientations and positions of mechanical system in air flow are performed. The main aim is to identify the most suitable design in terms of total energy of whole system.*

*This article also examines the effect of flow redirecting and effect of this phenomenon on drag forces and energy consumption. Analyses are performed on example of a pantograph mounted on roof of railway vehicle.*

*Key words: Pantograph, Finite Element Method, Computational Fluid Dynamics, train, flow*

## 1. INTRODUCTION

Nowadays is necessary to decrease energy consumption of all devices. Also energy consumption of trains should be decreased. One of possible ways is decreasing of resistance against air flow and improving of aerodynamical properties.

One of most important parts is pantograph. Drag forces during train movement can influence a lot dynamics of pantograph. Pantograph, as a device, is located on the top of the train and is directly exposed to the air flow. It affects also energy consumption of the train, and captures electrical energy from catenary. This article has the main aim to analyse, using advanced CFD simulation, how the drag acts in the pantograph, how can be significant to the train's dynamics, and propose solutions to minimize that.

## 2. PANTOGRAPH DESIGNS AND POSITIONS USED AMONG PRODUCERS

Among producers of electrical trains is no rule for choosing position of pantograph. Generally nowadays have trains two pantographs. One in front and one in rear are of train. As is visible on following pictures, some trains uses forward and some backward orientation.

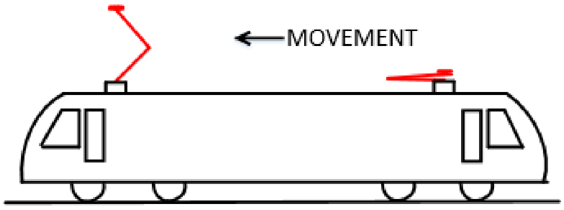

Fig. 1. Train with backward position of pantograph – Position P1

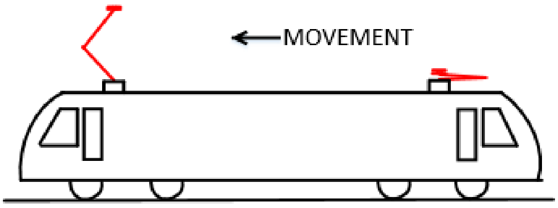

Fig. 2. Train with forward position of pantograph – Position P2

According research among producers, the main configuration is when the pantograph is mounted forward (i.e. the middle join is located in front of the pantograph, see figure 2), despite the Bombardier producer is making some of their trains with pantograph in the backward position (see figure 1) [1].

## 3. DETERMINATION OF OPTIMAL POSITION

The software which was used to do all the models and simulations is Siemens NX 10 with advanced flow solver NX Nastran.
The simulations were done with the input velocity of train 100 km/h, atmospherical pressure of 0.101325 MPa and gravity of 9.81 $m/s^2$. Any change in these conditions is described and noted in following text.
For flow analysis is very important to choose most suitable model of flow.
The most commonly used are:

- K-epsilon
- K-omega
- SST (Shear Stress Transport, mixture of previous)

After an evaluation, the best model for the simulations is the SST — Shear Stress Transport model. Because at the same time that we are interested in the behaviour of the flow near to the walls, we also would like to know how it behaves through into the flow domains. This model is complex and suitable for our this kind of simulations [2,3,4].

### 3.1 Orientation of pantograph geometry with respect to air flow

As it has already shown before, there are two possibilities to mount the pantograph on the train, P1 (backward) or P2 (forward) position. In order to decide which position is the more suitable one (in terms of flow attributes), simulations were done to analyse the lift and drag forces, which are generated by each position. Also evaluation of velocity gradients and profiles is very important.

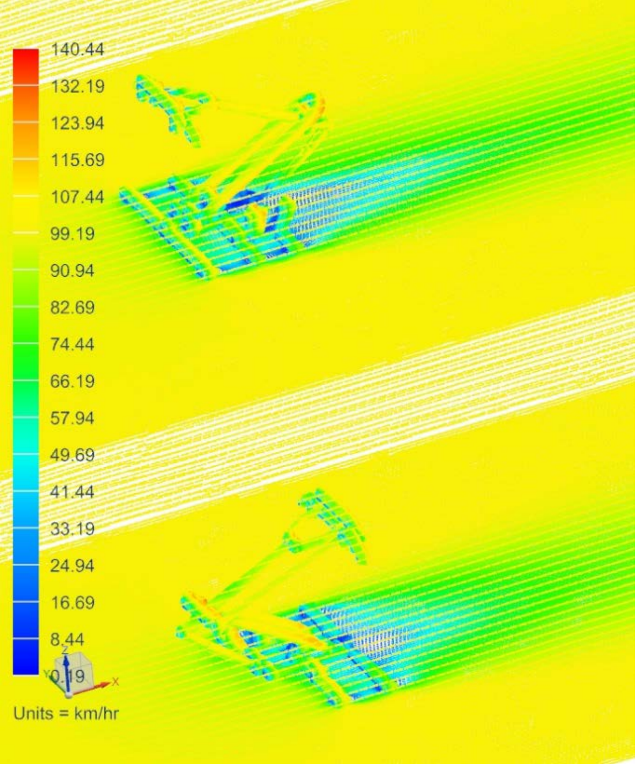

Fig. 3. Velocity profile [km/h] for position P1 (upper) and P2 (lower), show as streamlines

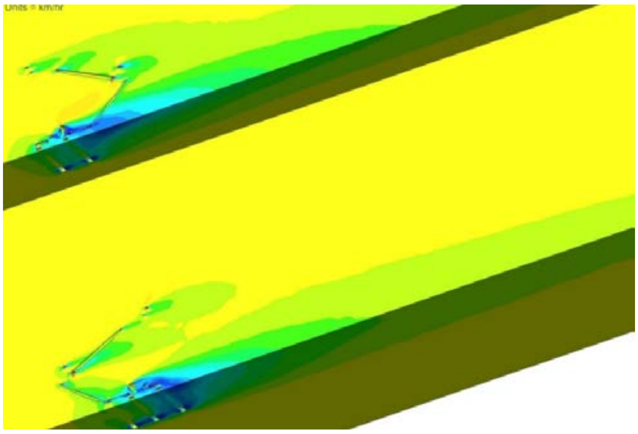

Fig. 4. Velocity profile [km/h] for position P1 (upper) and P2 (lower), section cut through geometry of air; legend same as Fig. 3

On previous pictures (Fig. 3 and Fig.4) is visible air flow around geometry of pantograph. It is obvious, that backward position indicates bigger area of flow with higher speed (see Fig. 3, blue colour borders, Fig. 4, green colour borders).

| **Pantograph position** | **Lift force (N)** | **Drag force (N)** |
|---|---|---|
| P1 | 92,04 | 397,24 |
| P2 | 177,64 | 389,12 |

Table 1. Lift and drag forces generated by each position

From CFD simulation is possible to get results of lift and drag forces. This result tells force in Newtons, in direction of movement (drag) and in vertical direction (lift) [5]. As is visible in Table 1, drag force, which is force against air flow in its direction, is lower on forward position P2. Lift force is higher on this position, but this force helps us to stay connected to catenary. According these results is position P2 chosen as one to continue in simulations.

### 3.2 Position on train roof

For choosing best position on train roof are used two types of simulations. The easiest one is simulation only of a train and finding of a place with lowest velocity gradient caused by geometry of train.
More complex is simulation of train with pantograph and finding optimal position.

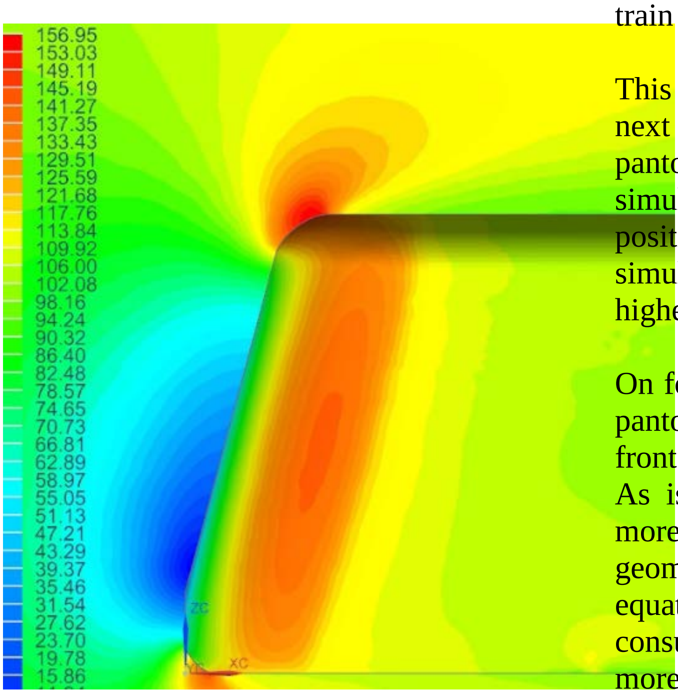

Fig. 5. Velocity profile [km/h] around train

As we can see in the figure 5, there is a region right above the train (starting with green) that has the lowest speed in the flow around the train's upper body, meaning that is the region which could be the best place to allocate the pantograph, because will generate less drag. We have to avoid to place the pantograph in the zone with high speed (i.e. yellow to red).

In regions where the velocity is higher is also drag force higher, according equation for aerodynamic force (1).

$$F = \frac{1}{2}.\rho.\, V^2.C.A \qquad (1)$$

F: Aerodynamic force
ρ: Fluid viscosity
V: Velocity of the body
C: Aerodynamic coefficient
A: Transversal area of the body

Importance of decreasing resistance against air flow is higher when higher speed is used (speed effect on aerodynamic force is by square) as is visible in equation (1).

Suitable distance to allocate the pantograph is around 4840mm from the front of the train (in our case).

This position and design is simulated in next step in complex model with train and pantograph. Using this complex simulation we can get confirmation of position from previous simulation. But simulation time of this task is at least 5x higher comparing previous one.

On following picture is velocity profile for pantograph position 4840 mm from train front area.
As is visible, areas with higher velocity, more than 120km/h, are not attaching geometry of pantograph. According equation (1) is at this position lower energy consumption, comparing pantograph in more frontal positions. Of course is much more suitable put pantograph just in the

middle, but it is not suitable in terms of design of train and electrical equipment attached on roof.

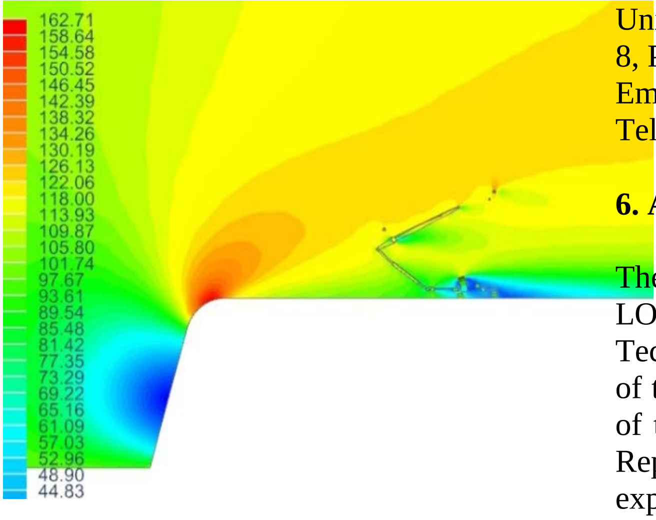

Fig. 6. Velocity profile [km/h] around train and pantograph- position 4840 mm

## 4. CONCLUSION

This article shows advantage of using advanced CFD simulations methods, which can lead to minimizing energy consumption caused by resistance against air flow.
As is visible among producers of electrical high speed trains is not unified design of pantographs. Our research shows, that forward position is better, because drag force is smaller, and also lift force is higher. Higher lift force caused not so big needs on springs generating contact force between catenary and pantograph.

For our simulation was considered universal and general design of pantograph with basic attributes of all commonly used pantographs. Special designs of pantographs were not considered. Research will continue with placing of sheet for directing the flow outside geometry of pantograph and verification using real experiments.

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