Influence of wind on aerodynamic drag for the second case of the arrangement of the equipment on the LE 060EA locomotive bodywork

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Section 2 – Flight dynamics simulation

Abstract: *The electric power supply equipment of electric railways vehicles of surface is placed on the their body. The arrangement of the equipment on the vehicle body determines the variation of the aerodynamic drag. The gusts of wind occurring during the vehicle movement result in additional requests. The case of the locomotive of type LE 060 EA 5100kW moving with the second driving position is analyzed in this paper. For this particular case the components ensemble of the power supply system was geometric modelled in 3D format at 1:1 scale. The resulted model was placed in air flow simulation software to determine the aerodynamic resistance. The wind influence is analyzed for five point values of its speed. The wind direction is simulated by eight point values of the angle that it makes to the longitudinal axis of the vehicle.*

Key Words: *aerodynamic drag, wind influence, air flow simulation, electric power supply equipment.*

1. INTRODUCTION

The railway electric vehicles are powered with electricity needed to their movement from the contact line by means of the active pantograph. The pantographs, the connection bars, the automatic circuit breaker and the voltage insulators form the electrical supply system which is placed on the bodywork of the electric vehicles. The equipment arrangement on the bodywork, leads to the increase of the aerodynamic resistance of the vehicle by extending the cross-sectional area. [1-4]. Whereas, for the locomotive LE 060 EA of 5100 kW the motion of the railway vehicles can be done in both directions (both forward- using the P1 driving position, as well as backward – using the P2 driving position),this will determine two distinct situations related to the disposition of the equipment on the bodywork, see Fig. 1.

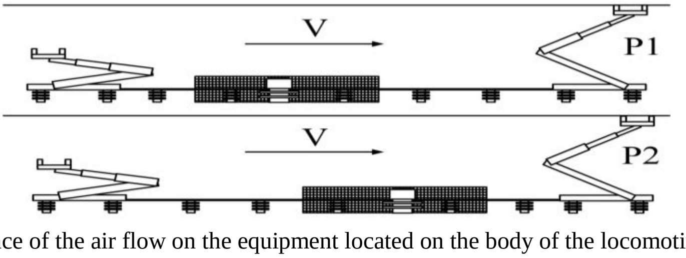

Fig. 1 – The influence of the air flow on the equipment located on the body of the locomotive according to its mode of movement. P1 - moving with the driving position 1; P2 - moving with the driving position 2

In normal conditions of travel, the railways vehicles have to overcome both their own aerodynamic resistance and that caused by the wind gusts [5-9].

The air resistance of the power supply device can be determined by the relationship 1, according to [10]

$$F_{x.saj} = \frac{\rho \cdot (C_x \cdot S_{sa})_j \cdot v_{rel.p}^2}{2} \tag{1}$$

where: j-indicates the components of the power system, $F_{x.saj}$ - the aerodynamic resistances on each component of the power system [N], $v_{rel.p}$ - the incident relative speed of the air flow [m/s]; S_{sa} - the frontal surface-of the supplying system in cross-sectional area [m^2], ρ - the air density in which the vehicle travels [kg/m^3]; $(C_x)_j$ – the aerodynamic coefficient for the resistant force, resulting for each element j of the supplying system.

The determination of the relative velocity of the air (Eq. 2) depends on the direction and angle in which the wind is blowing in relation to the longitudinal axis of the vehicle in accordance with Fig. 2.

$$v_{rel} = v + v_v \cdot \cos(\alpha) \tag{2}$$

where: v-velocity of movement of the vehicle; v_v -wind speed; a -the angle between the direction of movement of the vehicle and the wind speed.

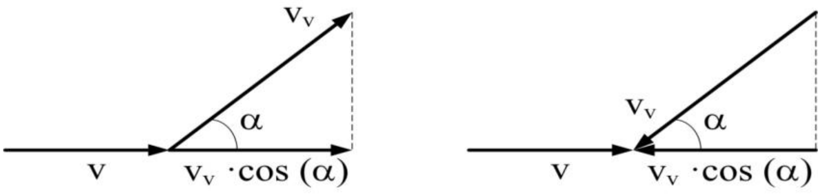

Fig. 2 – The influence of the wind on the angle and direction its

In this/ The aerodynamic coefficients can be written in these conditions as follows:

$$C_{xj} = \frac{2 \cdot F_{x.saj}}{S_{saj} \cdot \rho \cdot v_{rel}^{\;2}} = \frac{2 \cdot F_{x.saj}}{S_{saj} \cdot \rho \cdot (v + v_v \cdot cos(\alpha))^2} \tag{3}$$

2. SIMULATION OF THE AIR FLOW

We have performed the analysis of air flow starting from the design of the EP3 pantograph, of the automatically switch type IAC and of the high voltage insulators, which have been redesigned to a scale of 1:1.

The assembly of the elements resulted from the 3D graphics is realised so as to correspond to the situation when the locomotive is moving forwards with the second driving post (P2) and the active pantograph is raised at the capture maximum height (2.5m)

A constant value of 144 km/h = 40 m/s. was considered as speed of the vehicle. The following point values were considered as wind speed values: 0 m/s, 5 m/s, 10 m/s, 15 m/s, 20 m/s and 25 m/s.

With regard to the angle between the longitudinal axis and the wind direction eight values are analysed, namely :0 deg.; 30 deg.; 45 deg.; 60 deg.; 90 deg.; 120 deg.; 150 deg. and 180 deg., ranging between 0 deg. and 180 deg.

Taking into account the specified conditions 41 distinct situations to be analysed have resulted. For simulating the air flow we considered a volume delimited as follows:

- in vertical plane: the plan corresponding to the roof of vehicle body and another plan found at 5m of it were considered;

- for the cross section: two planes symmetrically located at 5 m from the longitudinal plane of the vehicle were considered;

- for the longitudinal section, we considered two planes located at 10 m and 20 m from the transverse plane of the vehicle.

As input parameters regarding the atmospheric conditions we considered a pressure of 101325 Pa and a temperature of 293.2 K.

If the locomotive moves under atmospheric conditions without wind gusts, through simulation. a pressure distributed according to Fig. 3 will operate on the power system. The distribution of the pressure contour lines in the median longitudinal plane of the vehicle is shown in Fig. 4.

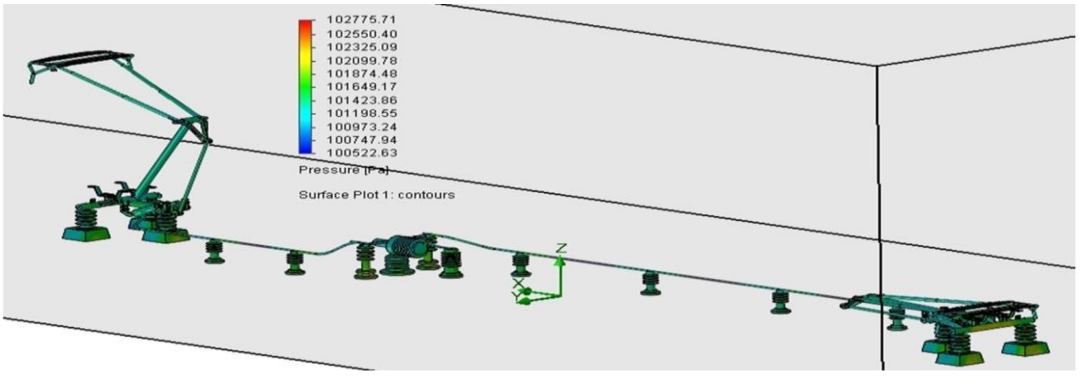

Fig. 3 – Air pressure exerted on energy supply equipment when the vehicle moves in an atmosphere without the influence of the wind

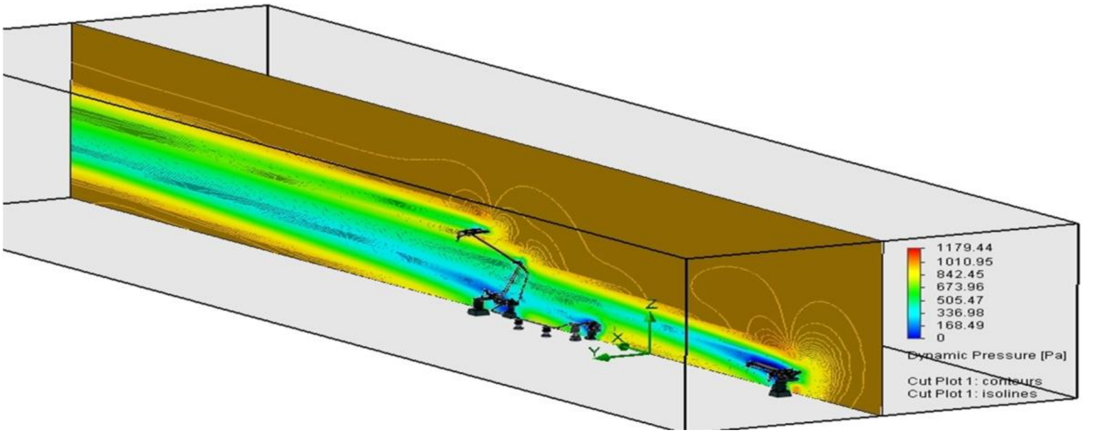

Fig. 4 – Contour lines of the dynamic pressure of air in the median longitudinal plane of the vehicle

Fig. 5 shows the variation of the aerodynamic resistance of the power supply equipment located the body of the LE 060 EA of 5100kW locomotive.

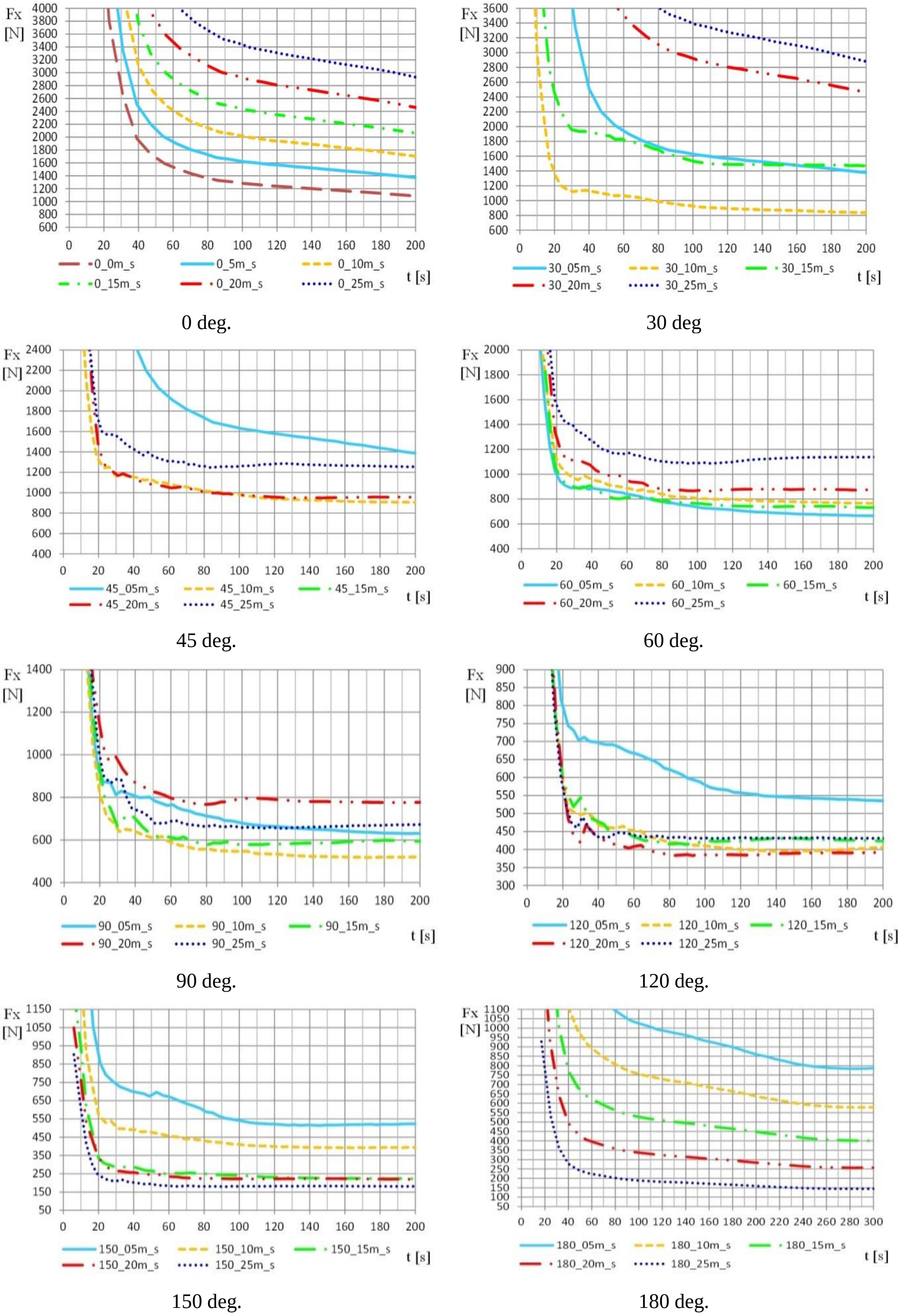

Fig. 5 – The variation of the aerodynamic drag during simulation

Some stabilized values of the aerodynamic drag generated by the power supply system of the locomotive (and resulted from simulations) are presented in Table 1.

Table 1 – Stabilized values of aerodynamic resistance

α [deg.]	v_v [m/s] / Parameter – system of units	0	5	10	15	20	25
0	F_x – [N]	1025.15	1296.07	1598.84	1940.80	2290.13	2698.92
30	F_x – [N]		1295.79	832.14	1462.75	2292.27	2691.95
45	F_x – [N]		1306.68	902.45	1554.47	1004.48	1259.39
60	F_x – [N]		649.28	777.77	773.59	909.66	1127.64
90	F_x – [N]		638.47	541.98	602.55	778.92	691.34
120	F_x – [N]		545.92	416.52	429.70	393.78	441.13
150	F_x – [N]		521.22	389.06	244.97	225.11	182.50
180	F_x – [N]		808.26	593.06	412.075	264.33	147.89

To observe the influence caused by the wind gusts on the aerodynamic resistance, generated by the power supply system we performed an percentage analysis of the values obtained from simulations. As landmarks, we successively considered two types of values: first, for the case of the vehicle moving under atmospheric conditions without wind gusts (Fig. 6), and then for the case of the vehicle moving in an atmosphere with frontal wind (Fig. 7).

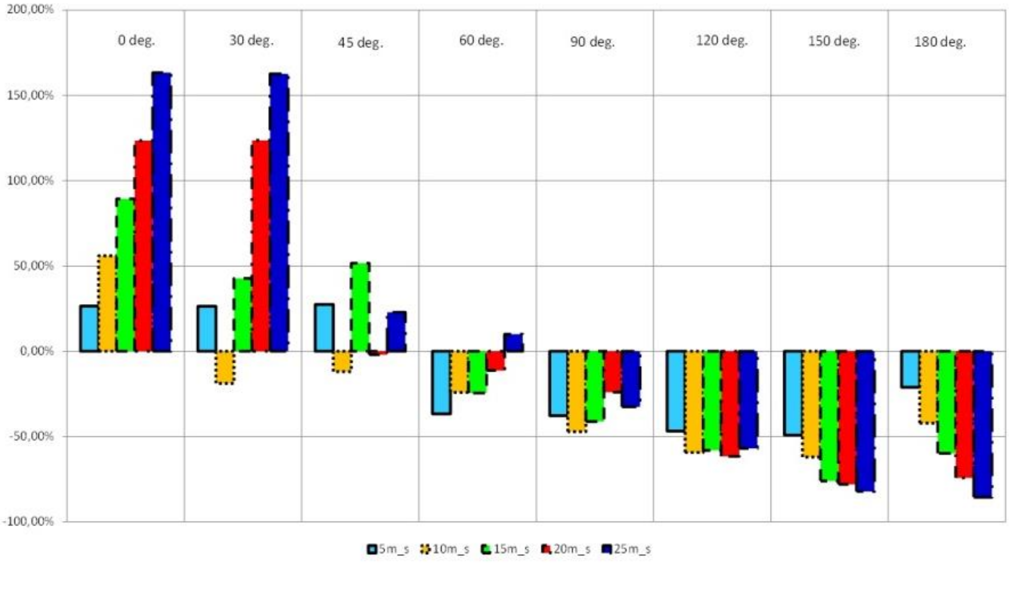

Fig. 6 – Percentage analysis of the aerodynamic resistance generated by the equipment mounted on the bodywork in an atmosphere without gusts of wind

Based on the percentage analysis from fig. 6 it can be seen that the influence of the wind on the aerodynamic resistance of the power supply equipment differs depending on the wind speed and direction. In the case of the front or side wind when the angle with the longitudinal axis of the vehicle it is small (up to or equal to 30 degrees) resulted higher values of aerodynamic resistance.

For the interval 45 deg. - 60 deg. the aerodynamic resistance ranges from more than reference considered (the value of aerodynamic resistance when are not gusts of wind) at values lower than this.

In the remaining part remaining up to 180 deg. the aerodynamic resistance decreases.

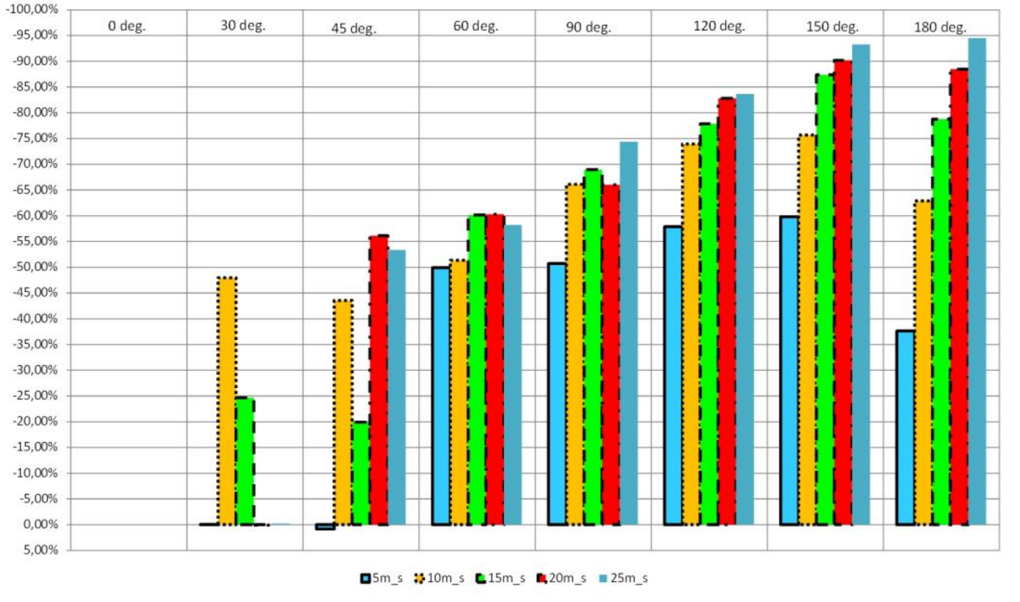

Fig. 7 – Percentage analysis of the aerodynamic resistance generated by the equipment mounted on the bodywork in an atmosphere without gusts of wind.

4. CONCLUSIONS

The wind speed influences the pressure exerted on the equipment installed on the vehicle body and its aerodynamic resistance, implicitly.

According to the simulations, the aerodynamic resistance values are positive (Table 1 and Fig. 6) which results in an increase of the total resistance to motion of the locomotive.

In the considered case of the locomotive using the P2 driving position, the maximum value of the aerodynamic drag resulting from the simulation is approximately 2699N with a front wind of 25m/s.

The minimum value of about 148N is obtained for the same amount of speed but with a wind blowing from the back.

From the comparative percentage analysis on the change in aerodynamic drag generated by the equipment placed on the body of the locomotive (Fig. 6 and Fig. 7), we find that: in the range between 0deg. and 30deg. the greatest variations of this force are obtained for the α angle.

In the case of the first chosen comparative landmark, chosen a maximum increase of the aerodynamic resistance value of about 163%, with a front wind of 25m/s can be noticed.

The energy consumption is influenced by the resistance to movement of the vehicle, which includes the component due to the air resistance.

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