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A strength analysis of light signal pole using the finite elements method

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Zum Titelbild: Die Linienzugbeeinflussung LZB ist das Rückgrat für den Verkehr auf den deutschen Hochgeschwindigkeitsstrecken. Die bisher meist verwendete LZB 80 ist nun zur LZB 80E weiterentwickelt worden und integriert die Funktionen PZB 90, L 72 und LZB CE. Eine unbefristete Typzulassung durch das EBA steht bevor. (Foto: DB AG/Jazbec)

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FEM analysis of light signal pole

Jerzy Mikulski / Aleksander Sładkowski / Jakub Młyńczak

A strength analysis of a light signal pole using the Finite Elements Method demonstrated that the structure of the pole fulfils strength requirements as well as ensuring safety for persons performing servicing and installation activities.

1 Short description of the light signal pole with a rig

The light signal pole is designed for installation of typical signal lights on its jib, as commonly used on Polish Railways. The signal pole consists of a flange with milled holes enabling turning of the pole so that the jib's axis may be set perpendicular to the tracks. The pole tube is welded to the flange. Its length enables installation of the light on the required height. Connection of the flange with the tube is stiffened with four ribs. A hole of 50 mm is drilled through the pole tube at the height corresponding to the height of jib installation, thus enabling routing of a cable. The pole tube has a suitable busbar element to fulfil the regulations concerning protective busbar installation in the railway traffic management equipment. The pole is equipped with a jib enabling installation of a light and fulfilling the conditions of the railway clearance gauge. The jib is mounted to the pole with two brackets using M 16 screws.

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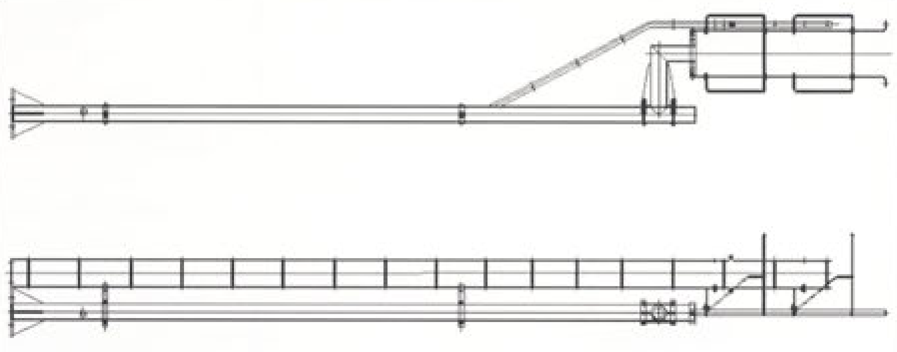

Figure 1: General view of pole under analysis

The pole is equipped additionally with a ladder and protective basket enabling lamp maintenance.
The signal pole differs from the semaphore poles used hitherto, as the jib and mounting flange are not made as casting but as a welded structure. The complete pole without installed signal lamp is shown in *Figure 1*.

2 Computer strength simulation of the pole using the Finite Elements Method (FEM)

The strength analysis was carried out using the software MSC NASTRAN 2003 and MSC MARC 2003.
In order to perform a strength analysis, a model of the pole in question was prepared, with all main parts of the pole separated. The tube was divided into three parts: the first working in team with the base, the second with the jib arm and the third connecting both former parts. Also models of all welds connecting the flange elements with ribs and tube were prepared. The welds on the jib arm were disregarded because of their low loading. Thus prepared, these models were subjected to division into finite elements.
The finite element grids were performed similarly for all remaining components of the pole. The size of the elements was selected such that the grids of cooperating parts are of the same size at the place of contact.

3 Load on the pole

The model of the pole takes into account the load on the structure with force exerted by the weight of the semaphore head and by air pressure during passage of the train or strong wind. The distribution of forces is shown in *Figure 2*.

F_{Ym} and F_{Yr} designate forces from wind pressure (direction Y) whereas F_Z is a force coming from the semaphore head (direction Z).
In accordance with [3] the maximum velocity of the air stream caused by a train passing with a speed of 160 km/h at a distance of 1 m from the train is 78 km/h, whereas for a speed of 240 km/h the air stream reaches a maximum of 116 km/h. The strength analysis was performed

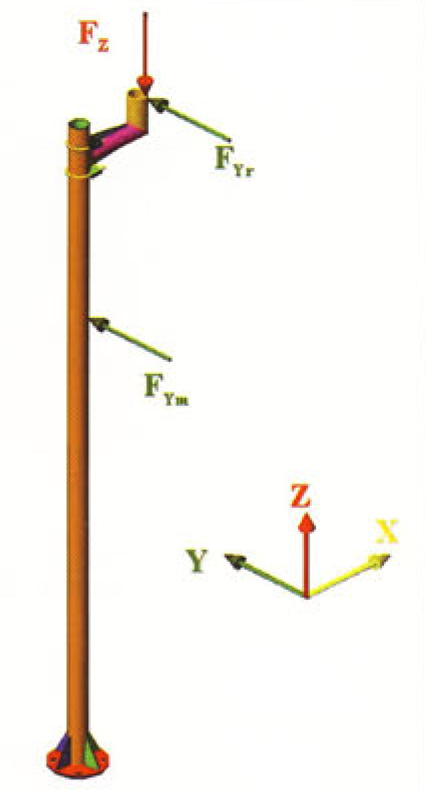

Figure 2: Distribution of forces in the pole mode

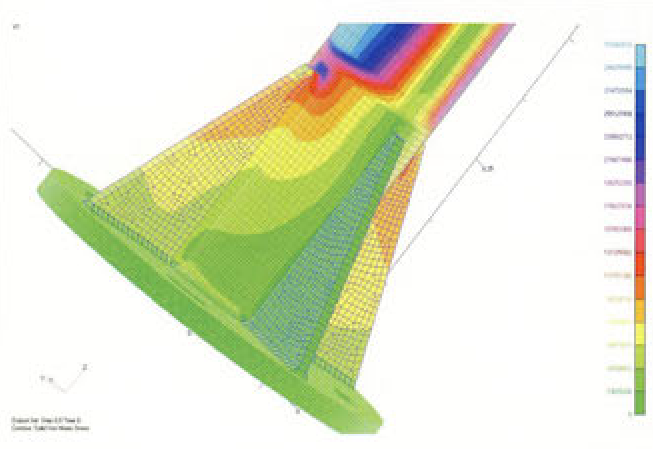

Figure 3: Reduced stresses in the bottom part of the pole (view of upper part of the ribs)

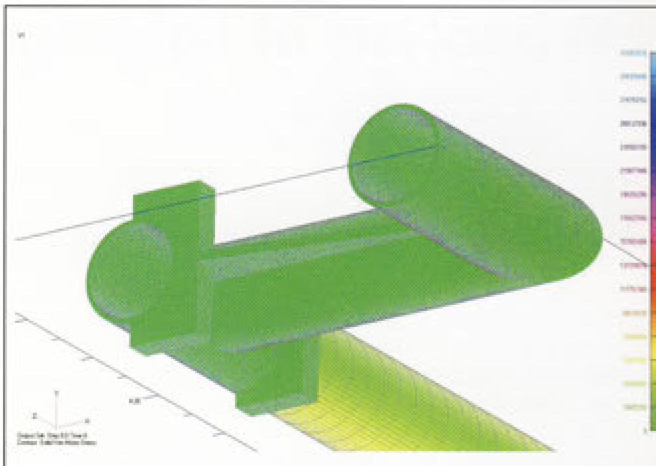

Figure 4: Reduced stresses in the jib arm (view from the top)

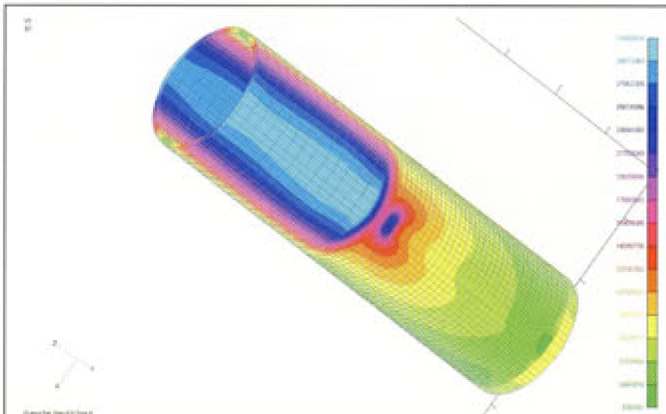

Figure 5: Reduced stresses in the lower part of the pole (view towards direction of force action)

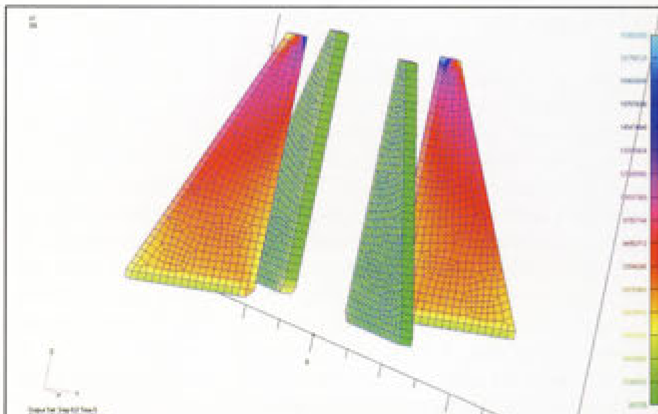

Figure 6: Reduced stresses in the ribs (view of side part of the ribs)

for two velocities of wind: 78 km/h and 160 km/h. Wind velocity at the level of 160 km/h was selected to ensure a 30 % safety margin.

In accordance with [4] the wind pressure on the pole and semaphore head was calculated. The calculations assumed the area of a three-chamber semaphore head (the dimensions were rounded to a rectangular shape). In order to calculate the forces, it was assumed that the wind acts perpendicularly to the pole head. The following values of wind force were obtained:

- For velocity 78 km/h, the force acting on the pole is F_{Ym} = 292 N, and on the head F_{Yr} = 522 N;
- For velocity 160 km/h, the force acting on the pole is F_{Ym} = 1227 N, and on the head F_{Yr} = 2194 N;
- The force exerted by the weight of the semaphore head was assumed to be F_Z = 500 N.

Besides the above calculations, an analysis was also made of the pole structure strength under the force F_z = 4 kN. This load was aimed at simulation of a larger light head (five chambers) and the weight of a man working on the pole.

4 Strength analysis

The analysis assumed interaction for velocity 78 km/h and 160 km/h respectively.

The scale on the right side of each drawing

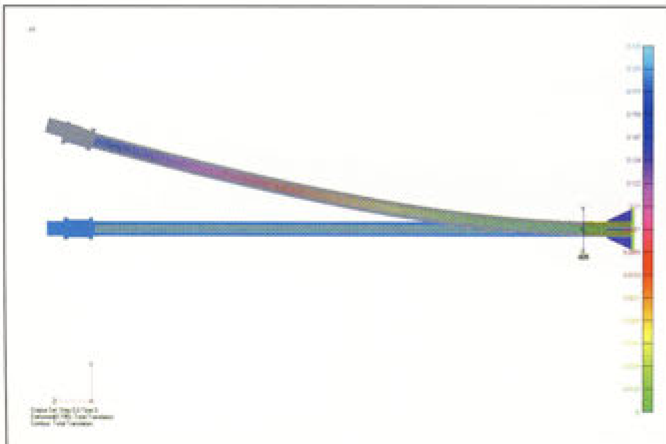

Figure 7: Maximum deformation of signal pole in the direction of acting force (side view scale 10:1)

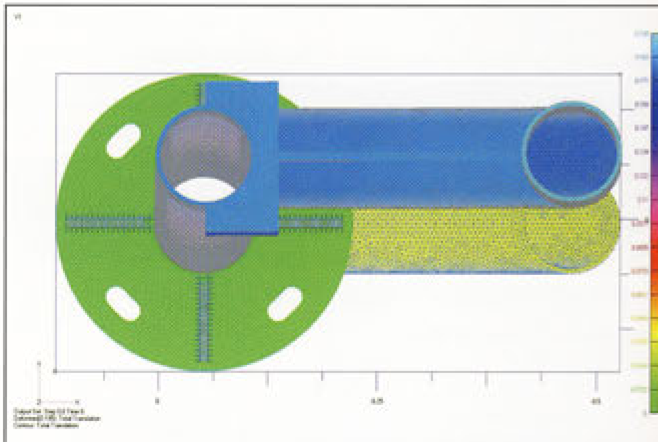

Figure 8: Maximum deformation of signal pole in the direction of acting force (view from the top 1:1)

tells us about the stress in Pa, whereas the coordinate system is drawn in the bottom left-hand corner.

5 Pole deformation

A deformation analysis was also performed for each particular element of the pole, depending on the wind force. The drawings show the results for wind velocity 160 km/h. For wind velocity 78 km/h the deformation direction will be the same whereas the value of deformation will be "proportionally" less. The displacement of the pole elements is shown in *Figures 7, 8 and 9*.

6 Analysis of the results

The model of the pole was fastened on the entire lower surface of the flange and for such mounting it was loaded with forces exerted by the mass of the signal head and by wind pressure acting on the head and pole.
For steel St3, from which the pole is made, the tensile strength value assumed is $R_m = 510$ MPa. The analysis takes into account only reduced stresses. As shown in *Figures 3 to 7*, no element of the pole structure is subject to stress higher than 380 MPa, thus the pole structure fulfils the strength requirements for such types of structures.
The analysis performed shows that the most heavily loaded parts of the pole are the ribs located perpendicular to the jib arm (*Figure 6*) and the pole tube where it cooperates with the above-mentioned ribs (*Figure 5*). However, even for the wind force at a velocity of 160 km/h the boundary stress value is not exceeded.

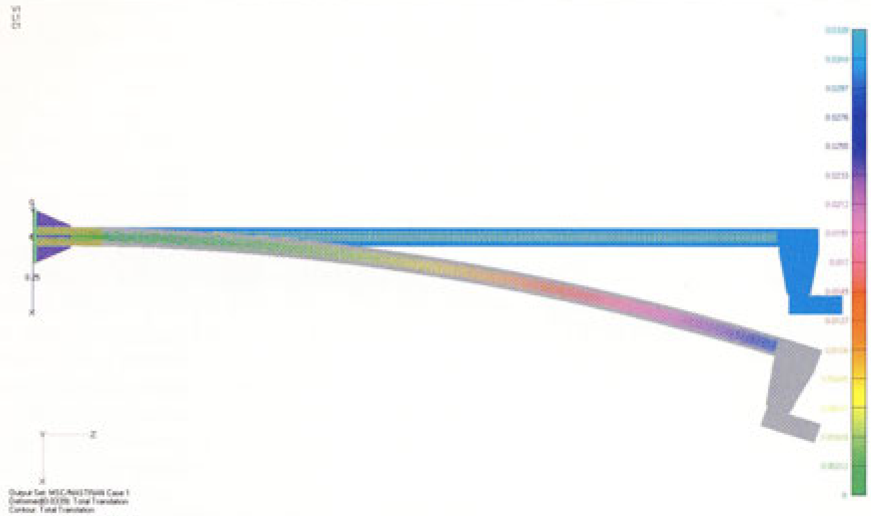

Figure 9: Maximum deformation of signal pole in the direction of acting force (side view scale 10:1)

The base flange and jib arm are the least loaded parts of the pole (*Figures 3 and 4*). It can be assumed that these parts may be also used even for larger signal heads.
The welds connecting the pole tube to the ribs are most heavily loaded in the case of the ribs perpendicular to the jib arm. The highest load is on their upper part. In the extreme case these stresses may reach 315 MPa.
In the case of welds connecting the ribs with the flange, the most heavily loaded are also those of the ribs perpendicular to the jib arm. However, in this case too, the stresses are below the boundary value, in the extreme case reaching a value of 58 MPa.
In the case of welds connecting the pole tube with the upper part of the base flange, the most heavily loaded are the parts of the welds located on the side opposite to the jib arm. The maximum stress value is 75 MPa.
In the case of welds connecting the lower part of the tube with the flange, the highest stresses occur in the part located along the direction of the acting force and that located against this direction (derivative of tube torsion); the stress value is about 67 MPa.
Figures 7 and 8 show the direction of signal pole deformation under the influence of the applied force. The direction of deformation, as well as the elements subject to the highest displacement, are in accordance with expectations. These drawings show the primary shape of the pole with lighter colour. It may be noted that the maximum deformation of the pole is about 195 mm from the primary position without load.
When the pole is loaded with force $F_z = 4$ kN the highest value of stress is 42 MPa occurring directly under the jib arm, in the upper part of the pole tube.
As can be seen from the analysis performed, the loads exerted by the semaphore head (in the simulation the value of 200 kg was assumed) and the weight of a man (in the simulation also 200 kg was assumed) have a relatively small impact on the load of the light semaphore pole. *Figure 2* presents the deformation of the signal pole caused by the above loads.

7 Conclusion

In light of the above considerations, the structure of the pole fulfils the strength requirements for two-, three-, four- and five-chamber semaphores, straight and with a jib, as well as ensuring safety for persons performing servicing and installation activities.

Literature

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[2] PN-EN 14067-2 Railway applications – Aerodynamics Part 2 – Aerodynamics on the line
[3] Assessment of potential aerodynamic effects on personnel and equipment in proximity to High-Speed train operations – Safety of High-Speed ground transportation systems – U.S. Department of Transportation – Federal Railroad Administration, Final Report, December 1999
[4] Basis of design and actions on structures ENV 1991-2-4:1995. Part 2-4:Wind actions.

ZUSAMMENFASSUNG

FEM-Analyse von Lichtsignalmasten

In einer Spannungsanalyse nach der Finite-Elemente-Methode wurde nachgewiesen, dass die üblicherweise bei der polnischen Eisenbahn verwendeten Lichtsignalmasten den Anforderungen an die Standsicherheit genügen.