EQUATIONS OF MOTION AND VIBRATION A SWITCH POINT - A CURVED BEAM WITH A VARIABLE CROSS-SECTION

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1. Abstract

The article presents mathematical considerations describing the dynamics of the springing switch point, which is an element of the railway turnout. Stages of mathematical analysis due to the structure of the switch point were divided into two stages. The first phase refers to the analysis of the dynamics of the switch point as a beam with variable rectilinear stiffness to which three forces are applied (coming from three closures of switch drives) placed in the initial section of the switch point. The next stage of the analysis concerns the same beam, but curved with a variable cross-section. In both cases, the normal force reflecting forces from the rail vehicle will act on the beam. The calculations will refer to a switch point with a length of 230 [m] and a radius of curvature R = 1200 [m]. The analysis of the switch point in the first stage will refer to the case of movement of the rail vehicle on the straight rail, and in the second stage it will concern the movement of the rail vehicle on the closure rail.

2. Mathematical model of a curved switch point

Considering the switch point as a trapezoidal curved beam described by the width b (Fig. 1), lying on a continuous elastic substrate and subjected to vertical load, which passes through its neutral axis, let F be the shear force in the cross-section of the beam, located at a distance x from the beginning of the coordinates, and by M the moment of external forces relative to this cross-section. If by F we will understand the sum of all vertical forces acting on the beam from the side of the cross-section on which the origin of the coordinates is located. In the literature [1], [2] and [3], one can find mathematical models describing the dynamics of a beam with a variable cross-section except that they lack the impulse of forces acting on the surface in the vertical direction (wheel pressure on the switch point) and horizontal (force holding a railway turnout drive).

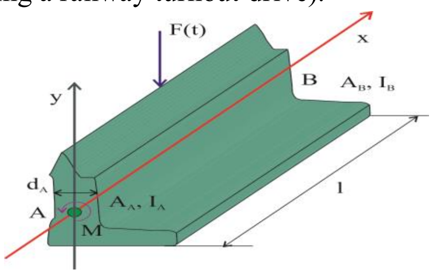

Fig. 1 Parameters characterizing the switch point

At the beginning, assumptions were made, which simplify the process of describing by differential equations the movement of a curved beam with a variable cross-section, which is an element of a beam associated with two degrees of freedom. Thus, one rotary movement and one progressive movement takes place at both ends of the beam. The action of force F causes deformations (displacements) in the direction x of the narrower part of the switch point. In the drawing by A, the beginning of the switch point was marked, the end by B. In turn, the cross section of the beam with a variable cross-section was determined by d_a and d_b. The length of the beam was determined by the quantity of l.

For the switch point - trapezoidal beam, the cross-section area can be written by the relationship:

$$A_x = A_A \cdot \left[1 + \left(\frac{d_B}{d_A} - 1 \right) \cdot \frac{x}{l} \right]^m . \tag{1}$$

The change of the moment of inertia for the analyzed section of the beam cross-section around the deflection axis was defined as:

$$I_x = I_A \cdot \left[1 + \left(\frac{d_B}{d_A} - 1 \right) \cdot \frac{x}{l} \right]^n . \tag{2}$$

by A_A and I_A the cross-sectional area and the moment of inertia at the beginning of the switch point were denoted respectively, with the subscript *B* defined the above-mentioned values at the end of the beam. Parameters *m* and *n* refer to the shape factor, which depends on the section and dimension of the beam with a variable cross-section.

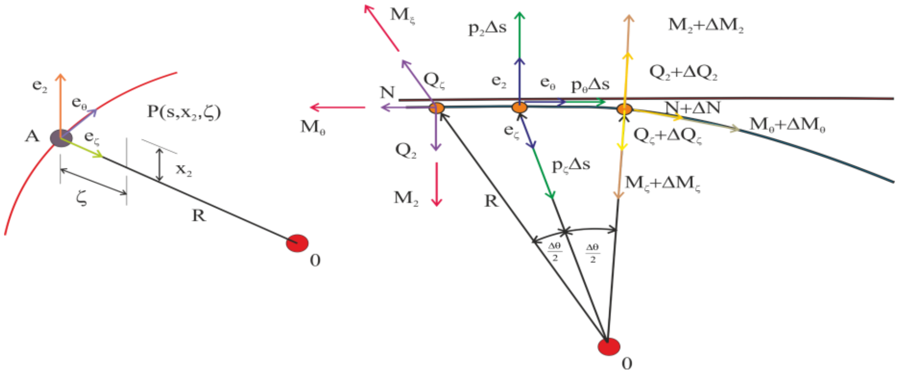

Fig. 2 Nominal model of the switch point - determination of forces

Based on the presented nominal models, mathematical models were determined and calculations were made for the beam, which is in fact a turnout switch point with a radius of 1200 [m], and the forces that arise when the rail vehicle travels through the turnout on straight and closure rail were taken into account. The results of simulation tests performed in the software.

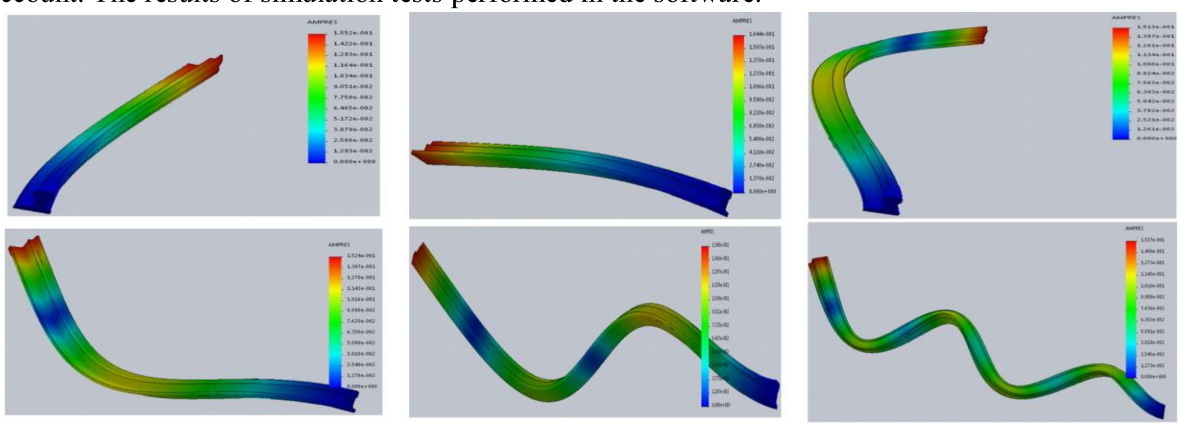

Fig. 3 The own vibrations of the beam with a variable cross-section (from the first harmonic to the sixth - from the left)

References

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