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Wind Tunnel Experimental Study of Coupled Rocking-Swivelling Model of Guyed Mast Shaft

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Abstract: Systematic monitoring of torsion (swivelling) of guyed mast shafts has been performed in ITAM since 2005. The occurrence of this phenomenon is conditioned by the fact that the guy ropes are attached to the surface of the shaft, i.e. out of its axis. The simple static calculation model serves for making the proof of the occurrence of the moment, affecting the shaft, which is guyed by three ropes. The exact theoretical solution of the real phenomenon assumes the introduction of dynamics of guy ropes, which vibrate in 3D shapes during the shaft's movement along the orbit and it´s torsion (swivelling).

Introduction

The theoretical analysis of the mast should always be corrected on the basis of monitoring of the real structure. From the measuring of the dynamic response of masts or of their models it was known that the resulting movement of the shaft in ground plan appears as an ellipse, whose major axis forms an angle smaller than 90° with the direction of the wind. Usually low intensity of turbulence and smooth surface of the shaft are conditions for the regularity and intensity of the vortex shedding. High intensity of turbulence disturbs the regularity of the shedding and thus also the cross-wind direction excitation and then the ellipse becomes more a circle.

Torsion or swivelling of the mast shaft

The shifting from zero position will result in changes of the forces in the ropes and moments in the points of connection to the shaft, which are out of the axis of the shaft. If the shaft is guyed by three ropes, there are 6 points on the elliptical track, in which the sum of the moments from the eccentric connection of the ropes is zero, and thus also the swivelling is zero (see Fig. 1). Theses points delimit the domains with positive or negative rotation of the shaft. The zero points may lie close to each other; in such a case the domains prevail with their size at the apexes of the ellipse. If the ellipse degenerates into a line, there are two domains of rotation which differ in the plus/minus sign.

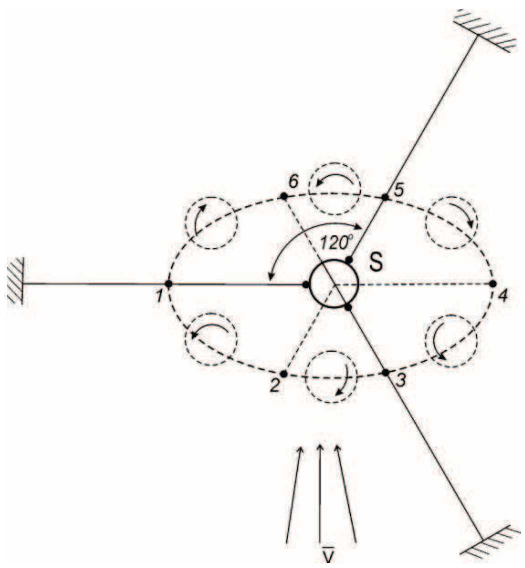

Fig. 1: Rotation of the shaft owing to the eccentricity of the ropes

The frequency of torsion or swivelling of the shaft depends on the position of the zero points on the ellipse (Fig. 1): if the zero points are far enough from each other, the torsion of the shaft is governed by the 6 domains of moments and the frequency of swivelling f_{tor} is

$$f_{tor} = 3\, f_b \tag{1}$$

If points (see Fig. 1) 2 and 3 merge into one, and so do points 5 and 6, then:

$$f_{tor} = f_b \tag{2}$$

Monitoring of swivelling on the model

In more detail and more stable aerodynamic conditions was the phenomenon of swivelling of the mast shaft examined on a simple model. The shaft was a tube of hardened PVC, of an outer diameter of 75 mm, supported by a point at the bottom and guyed by three wires in one level.

The flexural rigidity of the shaft is not modelled; the bending is substituted by the tilting. That is why there are no higher shapes of tilting and the orbit is always close to ellipse.

The torsion was verified in a wind tunnel and by deformations were determined. The experiments has been performed in the new aerodynamic tunnel (ITAM – Telč). Wind tunnel section size enabled experiment with model shaft up to 1500 mm high, anchored by three ropes at a height of 1000 mm. The top end of the shaft was equipped with a horizontal arm with two accelerometers attached on its ends; the distance between the accelerometers is 380 mm - see Figure 2. Accelerometers 1 and 2 sense the motion in the direction perpendicular to the horizontal arm. Besides the two accelerometers on the horizontal arm there is also the third accelerometer at the upper end of the shaft, which senses the motions perpendicular to the direction of the above pair of accelerometers.

The mast model was adjusted within the admissible limits by means of stressing of the wires and increasing of the mass concentrated on the top of the shaft. Fig. 3 shows the records of the orbit and swivelling of the shaft relative to it.

Fig. 2: The model of the guyed mast

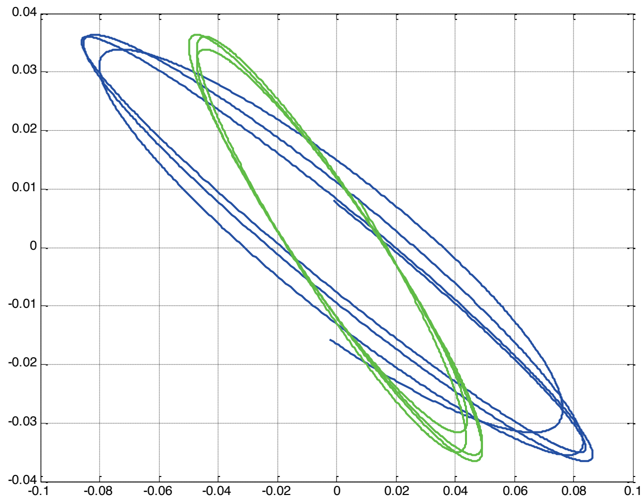

Fig. 3: Examples of the superposition of the shaft motions.
The green (less inclined) line is the orbit and the blue line is the swivel according to the parallel sensors.

The existence of torsion (swivelling) takes short time in which orbit of the shafts the shape is near the ellipse. The curve which intersects the ellipse in several points formulates shaft rotation of the positions place of the sensors.

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