The research of the maximum wind speed in Tomsk and calculations of dynamic load on antenna systems

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Abstract. The work is concerned with calculations and analysis of the maximum wind speed in Tomsk city. The data for analysis were taken from the TOR-station located in the north-eastern part of the city. The TOR-station sensors to measure a speed and a direction of wind are installed on the 10-meter meteorological mast. Wind is measured by M-63, which uses the standard approach and the program with one-minute averaging for wind gusts recording as well. According to the measured results in the research performed, the estimation of the dynamic and wind load on different types of antenna systems was performed. The work shows the calculations of wind load on ten types of antenna systems, distinguished by their different constructions and antenna areas. For implementation of calculations, we used methods developed in the Central Research and Development Institute of Building Constructions named after V.A. Kucherenko. The research results could be used for design engineering of the static antenna systems and mobile tracking systems for the distant objects.

1. Introduction

All constructions, rising above the earth's surface, are exposed to wind actions to varying degrees [1]. For hardwall buildings, it mainly results in the increase of their heat. When designing television masts, radar antennas, electric pylons, and chimneys, a wind (dynamic) load is considered as the main characteristic. Also, it is taken into account when defining construction cross-sections, the amount of building material to be used, which all together affects the cost of a construction, its reliability and the life period.

The wind regime in Tomsk region has been already discussed in many research papers [2-5]. However, the focus was primarily done on the average characteristics, which, by the way, are not the key ones for reliability and durability of buildings. To this end, it is reasonable to analyze the maximum characteristics of wind in the region, which are necessary when designing antenna systems developed by one of the institutions and the authors of this paper.

## 2. Analysis of meteorological data

The data for analysis were taken from the TOR-station, the full description of which is referred in [6, 7]. The TOR-station is located in the north-eastern part of the city, in one of the city districts, called Academgorodok. The measurements of the wind parameters and other atmosphere characteristics have

been executed since 1992. The TOR-station is equipped with the sensors to measure the speed and the direction of wind, which are installed on the 10-meter meteorological mast, which, in its turn, is located on the roof of the building. The height of the building is 15 meters. It means that the sensors are located at the height of 25 meters that is approximately 10 meters higher than tree limbs. Wind is measured by M-63, which uses the standard approach and the program with one minute averaging for wind gusts recording as well. Regarding the landscape around the station, it is hilly terrain with a mixed forest.

In [4], the comparative analysis of the TOP-station data and the data taken from Tomsk hydro-meteorologist station (Roshydromed) was conducted, where the latter one used the standard measurement approach. The distance between these two stations is 6 km. The difference between the average speed is equal to 0.3 m/sec, thereby the average difference between a single speed value of wind at two stations did not exceed 1 m/sec. In order to approach a measurement error of a wind speed, we measure it using this type of device [8]. In Figure 1, we have described the repeatability of different values of wind speed in Tomsk for the period of 1993-2016. The graph was built on 195870 measurements performed hourly.

Figure 1a. Repeatability (%) of the low and mild wind speed in Tomsk.
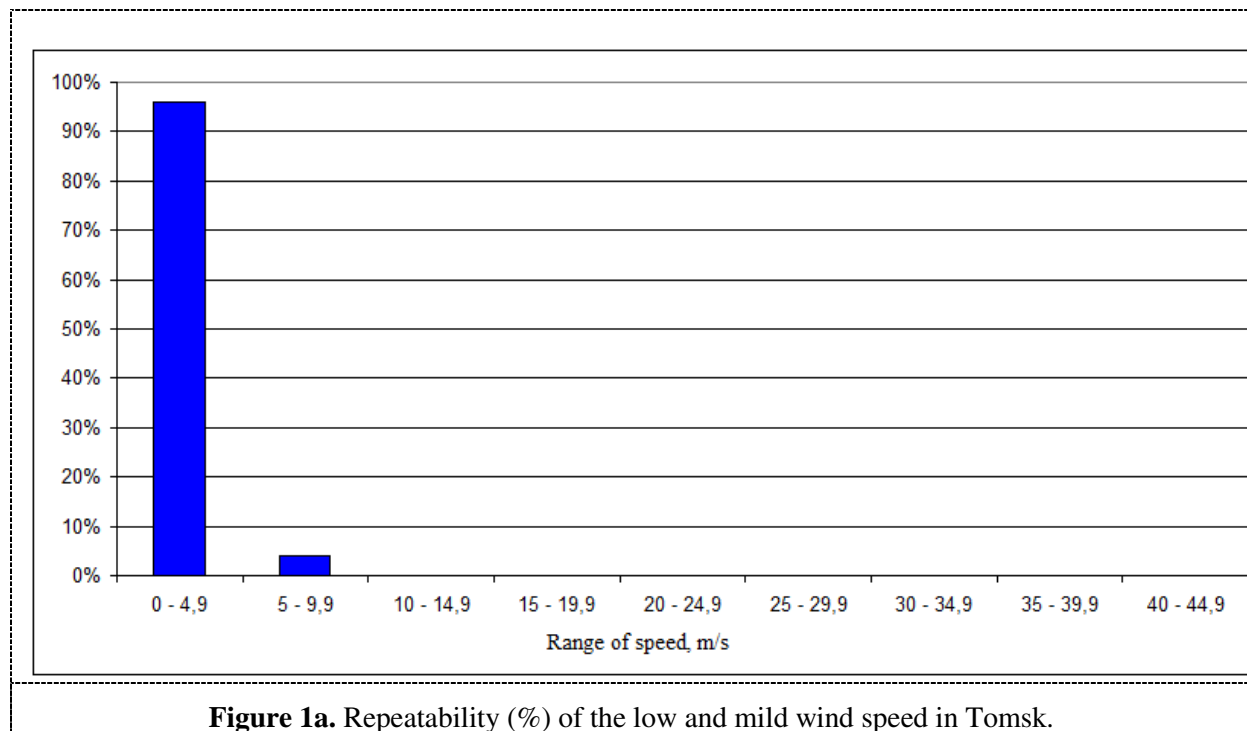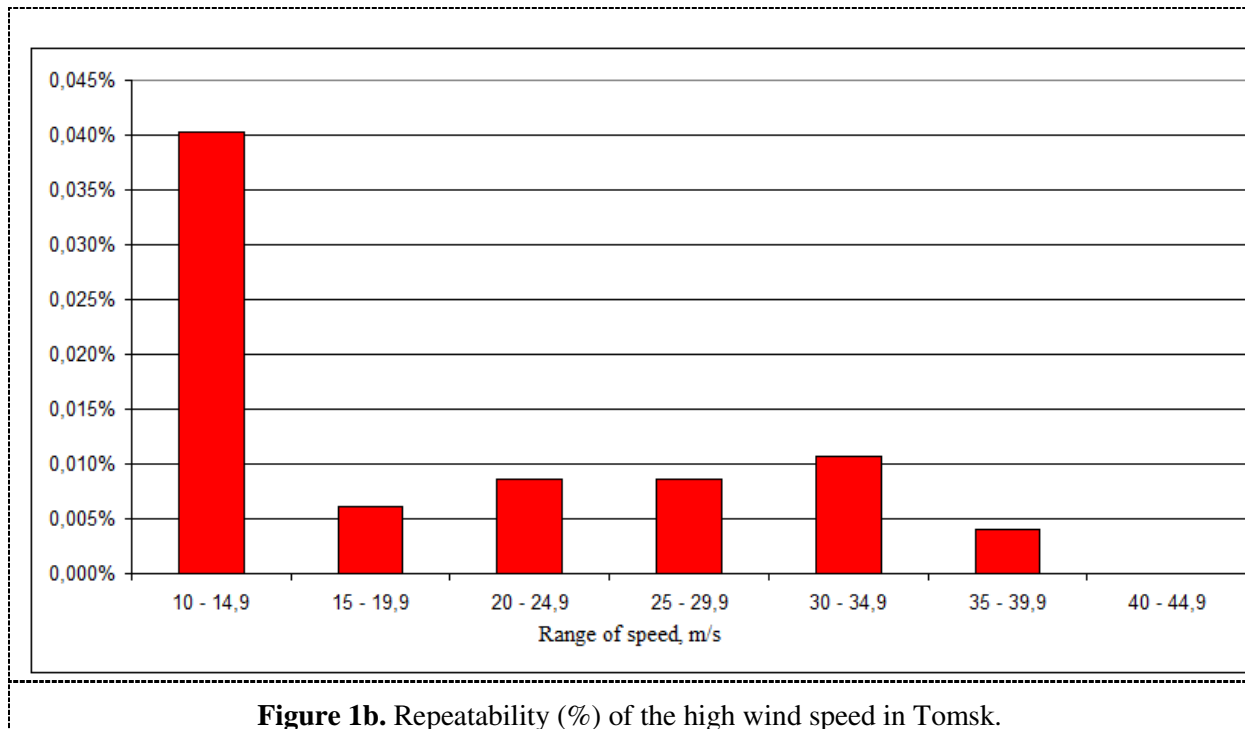
Figure 1b. Repeatability (%) of the high wind speed in Tomsk.

As seen in Figure 1a, Tomsk region is inclined to low and mild wind speeds. Their repeatability, including the whole scale of measurements, amounts to not more than 99%. However, Figure 1b shows that in a dozen of cases, high and very high wind speeds can be observed in the region with the value of 40 m/sec. In this way, the maximum value of the wind speed, recorded within the period under review, amounts to 38.4 m/sec. This is higher than that presented in the Sourcebook about Tomsk for the period of 1972-1985 [9].

Thus, the dynamic pressure of wind and load on constructions in Tomsk region should be assessed when the wind speed is not less than 40 m/sec.

3. Calculation of dynamic load

The problem of calculation of wind load on any type of constructions was addressed in [10-13]. The results, obtained in the papers referred, have been analyzed and presented in the code of practice "Loads and Impacts" (CP 20.13330.2011) published by Kucharenko Central Research Institute of Architectural Constructions – a research center "Building", with the participation of the Russian Academy of Architecture and Building Sciences and Voeikov Main Geographical Observation (MGO). Based on the technical regulatory documents, we carried out the calculations of wind load and pressure on different constructions. According to them, wind load is defined by the following formula:

$$F = P \cdot S , \qquad (1)$$

where P – wind pressure; S – calculated element area.

The wind pressure is defined by formula

$$P = q \cdot n \cdot k \cdot c_x , \qquad (2)$$

$$q = p \cdot \frac{v^2}{2} , \qquad (3)$$

where q – dynamic pressure of wind; n – an overload coefficient; k – a coefficient which takes into account all changes in dynamic pressure on the height; c_x – a coefficient of aerodynamic force; v – wind speed; ρ – air density ($\rho = 1.225$ kg/m^3).

According to Public standard 1451-77, in general case, n = 1.1 that agrees with the method of limit states; k = 1 because the height of an antenna system is not less than 10 meters; c_x = 1.15 according to Public standard 92-9249-80, table 3, p.28.

The wind speed is statistical and equal to v = 40 m/sec.

Based on 2.2, table 2, Public standard 1451-77 and the RF territory district map depicting wind pressure, we calculate q_2 for the wind speed of 40 m/sec:

$$q_2 = p \cdot \frac{v_2^{\,2}}{2} = \frac{1.225 \cdot 40^2}{2} = 980 \mathrm{H} , \tag{4}$$

where $\rho = 1{,}225\,\frac{kg}{m^3}$ - air density.

The calculation of wind pressure in case when the wind speed is 40 m/sec is the following:

$$P_2 = q_2 \cdot n \cdot k \cdot c_x = 980 \cdot 1.1 \cdot 1 \cdot 1.15 = 1240 \mathrm{Pa} , \tag{5}$$

The area of the solar energy module surface is 20 m^2. Wind load at the wind speed of 40 m/sec respectively equals

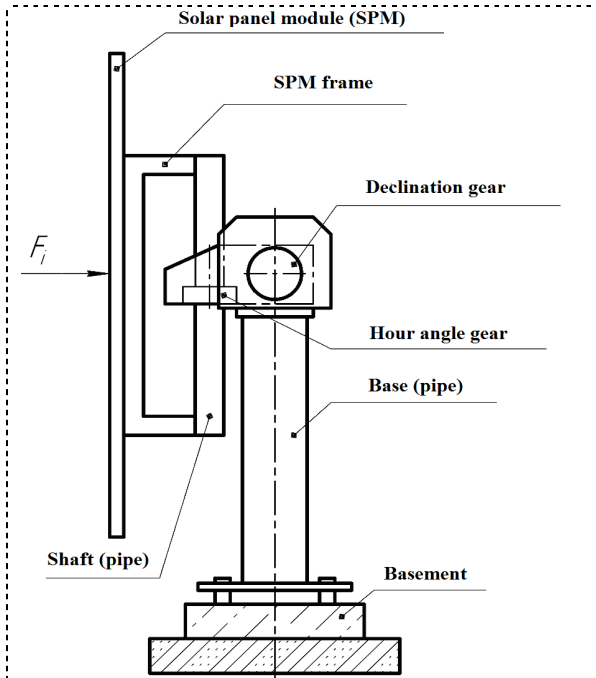$$F_2 = P_2 \cdot S = 1240 \cdot 20 = 24800 \ \mathrm{Pa} . \tag{6}$$

Other parameters for the rest of the constructions were calculated similarly within the same procedure. The examples of constructions are shown in figure 2. The results of the calculations are presented in the table 1.

Table 1. The summary table of initial parameters

| Device	Solar energy module, the base form	Antenna system, base-01, without radome	Antenna system, base-02, without radome	Antenna system, base-03, without radome	Antenna system, base-01, without radome
Antenna area, m^2	20.0	5.0	2.5	1.2	5.0
Wind pressure, Pa	1240	1240	1563	377	1240
Wind load, H	24800	6200	7815	1885	3100

| Device	Antenna system, base-02, without radome	Antenna system, base-03, without radome	Antenna system, base-01, spherical radome	Antenna system, base-02, spherical radome	Antenna system, base-03, spherical radome
Antenna area, m^2	2.5	1.2	5.0	2.5	1.2
Wind pressure, Pa	1563	377	1240	1563	377
Wind load, H	3908	943	1488	1876	452

Figure 2a. The structure of the solar energy module.
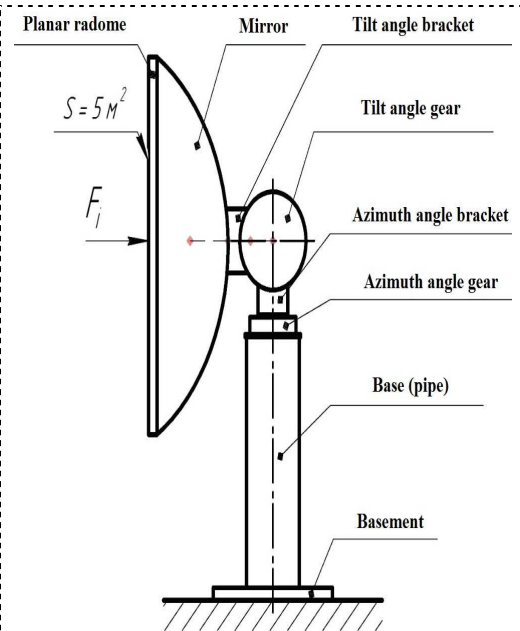
Figure 2b. The structure of the antenna (version-01) with a planar radome.
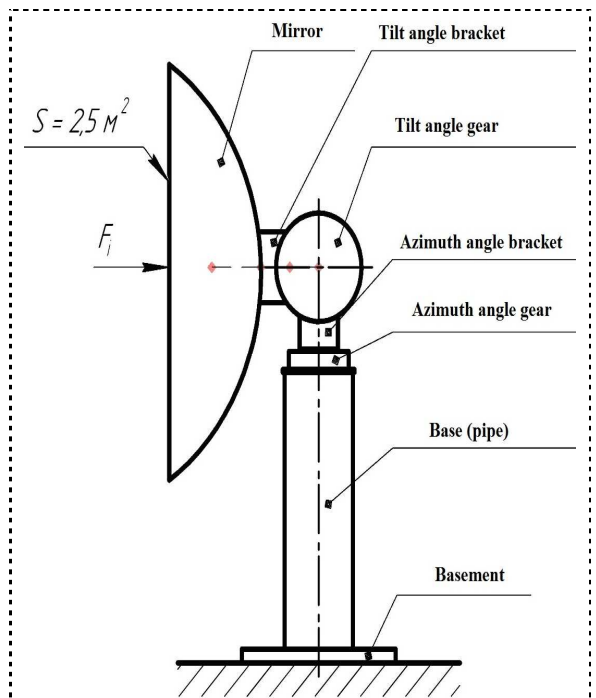
Figure 2c. The structure of the antenna (version-02) without a radome.
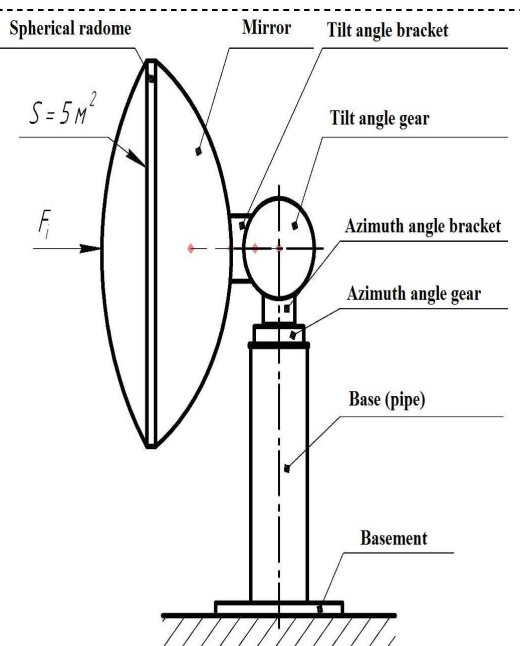
Figure 2d. The structure of the antenna (version-01) with a spherical radome.

4. Conclusion

The table shows that the antenna construction and its area affect the pressure which can change from 377 to 1563 Pa, that is approximately more than 5 times. In so doing, wind load varies greatly, from 943 to 24800 H, more than 26 times. Apparently, this scattering in values should be counted in

constructing antenna systems. A special focus should be on the fastener system and a pivot mechatronic mechanism when developing the static antenna systems and tracking antenna systems for the distant objects. The main ring construction should guarantee the dependable clamping of the antenna system. The pivot mechatronic mechanism should not load itself with construction weight; the main ring has to take the static and dynamic load.

5. Acknowledgements

6. References

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