MATSING®

LENS TECHNOLOGY ENABLED

Wind Load Calculations for MatSing Spherical Lens Antennas

MatSing has developed and patented new metamaterials to create the world's first lightweight multibeam lens antennas. This new approach for high-performance, high-capacity antenna design is more efficient and offers key advantages over traditional antennas, the ability to provide broadband coverage, emit and maintain multiple beams (up to several hundreds), and to do so cleanly with minimal RF interference.

MatSing has introduced the Lens antennas that differs from the generally accepted panel antennas that existed in the industry.

In addition to the main parameters characterizing the lens antenna, it is necessary to consider the safety of the tower and reliability of mounting hardware and supporting structures.

In this regard, it becomes important to assess the wind load acting on antennas at the development stage.

So far majority of guidance documents for estimation of wind force acting on antenna were devoted to standard panel antennas.

The shape of MatSing Lens Antenna is determined by the lens used in this antenna, that is, the predominant part of the antenna is a sphere.

The following parts of this document discuss the possibility of applying existing recommendations to MatSing Ball Lens antennas and notes on MatSing approach.

Methods for Wind Load Estimation

1. Wind Tunnel Testing

The standardization organization NGMN-P-BASTA has elaborated the document P-BASTA V12 standard as a guidance for estimation of wind force acting on base station antennas.

Wind loads and their desired reduction are discussed in this document in relation to panel antennas that are characterized by a constant radome cross-section along the entire length.

This document contains recommendations related to the preparation and processing the results of wind tunnel test.

Special attention is paid to testing various antenna positions (rotations of the antenna around its axis) and the resulting cross-wind force.

Considered panel antennas significantly differ from Matsing lens antennas in size and shape.

When planning a wind tunnel test of Lens Antennas, we need to take into account the following considerations:

1.1 Wind Tunnel Size

When air flows around an object it is free to expand in three dimensions.

On the other hand, a wind tunnel is limited in all dimensions by the walls, roof, and floor of the working section. If these are too close, the resulting contraction will force the flow to speed up around the model, leading to inaccurate results. This is called the blockage effect and it gets worse as the blockage factor (the ratio between the model cross section and the tunnel cross section) increases.

In general, it is recommended to keep this blockage factor below 5-10% to obtain

reliable results [6]:

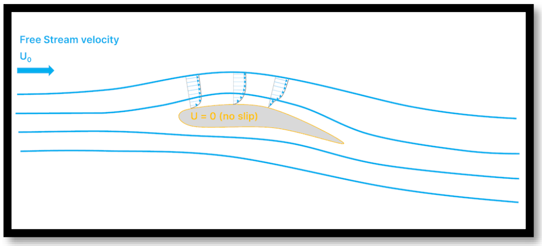
$$Blockage\ factor = \frac{Test\ item\ frontal\ area}{Test\ section\ cross\ sectional\ area}$$

Considering size of antenna (See Pic.1 with installation team) it may be difficult or extremely expensive to use large wind tunnel.

Pic. 1 Tower with antennas

1.2 Boundary Layers

Another problem with testing in wind tunnels is the effect of boundary layers. Air flowing over a solid surface will create a boundary layer which is the region where air speed drops from free stream to zero.



Pic. 2 Example - Boundary layers forming over an aerofoil.

In the real world, boundary layers are not an issue in many applications. However, in a wind tunnel, boundary layers are present on the walls, floor, and ceiling. Therefore, when conducting wind tunnel tests, it is important for the characteristics of the boundary layers to match with reality.

Furthermore, the walls of the wind tunnel can also interfere with the flow and pressure patterns surrounding an object if they are too close.

Overall, the blockage effect together with the interference and boundary layers of the wind tunnel walls limits the size of objects that can be placed within a working section. However, testing scale models comes with a whole new set of challenges and correlation issues which must be addressed to maintain accurate results.

1.3 Reynolds number for scale model

Reynolds number Re is used to compare different flow regimes, in particular characterizing whether the flow is laminar or turbulent. For any test set-up, Reynold's number is given by using fluid density (r), velocity (v), viscosity (µ) and a reference dimension of the object under test (L).

$$Re = \frac{v * L * \rho}{\mu}$$

One of the most important factors to consider when using scale models is the Reynolds number. To achieve the same flow patterns when testing a scale model, the Reynolds number needs to match the Reynolds number used in full scale testing. Essentially, to keep the Reynolds number the same when scaling down an object size by a factor X, you need to scale up the wind speed by a factor X.

For example, if L is 50% of full scale, then to match the full-size Reynolds number something must be done with r, u or µ. Doubling the speed or density or halving the viscosity would work. This is not so simple, however.

And in addition, scale models are not recommended according to P-BASTA V12 ("*Antennas must be tested in real dimension. Length scaling for same cross section is allowed as described below. Scaled models are not allowed*")

1.4 Mounting Pole

Mounting pole in wind tunnel is used to keep tested antenna in vertical position. Depending on size(diameter), distance between antenna and pole and air flow parameters flow field around antenna can be significantly affected. Even small change in velocity may lead to noticeable change in pressure and therefore on wind force acting on antenna.

Summary:

Wind tunnel testing if correctly performed gives reliable and important results but in case of simple standard shapes numerous verified existing data can be used.

2. CFD Simulation

Computational Fluid Dynamics (CFD) simulations can provide a deeper understanding of the flow behavior and physical phenomena within a system and provide a visual representation of flow patterns to make informed design decisions.

Full system of Navier-Stokes equations is usually used as mathematical model of subsonic flow field around object.

CFD approach also has some disadvantages:

- CFD simulations can be complex to set up and run, requiring specialized expertise in fluid dynamics and numerical methods.

- CFD simulations are based on mathematical models that are approximations of real-world systems, and these models may not accurately represent all the physical phenomena present in a system.

- CFD simulations are subject to uncertainty and error, which can arise from factors such as mesh size and shape (especially in cases of not streamline objects), boundary conditions, and turbulence modeling.

- CFD simulations must be validated against experimental or physical data to ensure accuracy, and this can be a time-consuming and expensive process.

But the biggest assumption that air flow has a constant speed and direction is more reasonable

in case of objects flying with constant speed, than in case of antennas affected by large-scale turbulent air stream, terrain, surrounding buildings, trees etc.

Summary:

CFD simulations can help in some cases (streamline objects) to optimize radome shape using so called "numerical experiment" but in case of MatSing antennas shape of lens can't be changed and numerical calculation may not provide realistic results.

3. Using Existing Standards

Standards [2,3] are important documents which provide guidance and determination of natural wind actions for the structural design and civil engineering works for loaded areas.

It is mandatory to comply with these documents and provide data in the prescribed form for subsequent structural design.

The following is a well-known formula for calculating wind load:

$Fw = Cd * P * A$

Where:

Fw - wind load (N)

Cd - drag coefficient. Found in accordance with the Standard.

P - wind pressure (Pa)

A - area of antenna surface perpendicular to wind direction (projection area) (m^2)

The wind pressure depends on air density and square of wind velocity. Its calculation formula is shown below:

$$P = 1/2 * \rho * v^2$$

Where, ρ - Air density (kg/m3)

v - Wind speed (m/s)

The drag coefficient Cd is calculated according to different Standards locally accepted.

North American standard TIA-222-G suggests only two options: flat panel and circular cylinder.

European standard EN1991-1-4 describes more accurate method for wind load calculation based on correction coefficients for antennas with rectangular or semi-rectangular cross-sections, cylindrical objects, spheres etc.

All details can be found in publications [2], [3].

Summary:

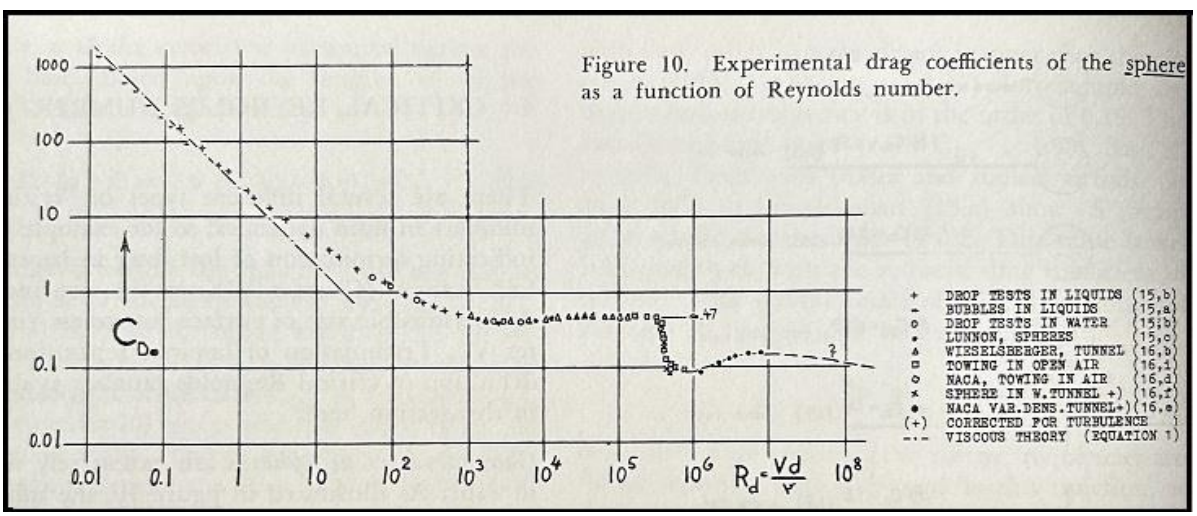
The standards have been used successfully for some period. In some publications comparison of wind load values obtained by different methods indicate that calculations performed in accordance with the Standards give increased values of wind forces acting on the antennas.

This fact may make the antenna less marketable, but overall, it contributes to installation safety.

4. Experimental Data used by MatSing

In case of MatSing Spherical Lens Antennas, we have huge amount of **reliable** experimental data for spheres (Pic.3).

Engineers and scientists intensively tested spherical objects during last hundred years, and all results can be easily found in numerous textbooks on fluid dynamics [4, 5]. So, drag coefficient of sphere is well known.



Pic. 3 Numerous verified experimental Cd values for spheres.

Wind forces on open structures can usually be estimated by adding together calculated forces on individual members [4].

In cases when back part of antenna is exposed to the air flow wind force acting on this part is calculated using its area and its own Cd (also well-known Cd of short cylinder or flat surface at yaw angle [4]).

In MatSing datasheets combined wind load is provided.

5. Conclusion

- ***MatSing antennas have shape close to optimal possible shape in terms of minimization of expected wind force acting on lens antennas.***
- ***MatSing wind loading calculations are based on solid theoretical and experimental foundation. This is evidenced by the successful use of MatSing antennas in numerous stadiums and arenas.***
- ***As it was mentioned earlier, site engineers may encounter different situations and different environments, so data from datasheet should be considered as a guidance.***

6. References

1. NGMN-P-BASTA Recommendation on Base Station Antenna Standards V12,March-2022.

2. Eurocode 1: Actions on structures- Part 1-4 General actions- Wind actions, EN 1991-1-4:2010:E.

3. TIA-222-G Structural Standard for Antenna Supporting Structures and Antennas, August 2005.

4. S.F.Hoerner, Fluid-Dynamic Drag, 1965. Library on Congress Catalog Card # 64-19666.

5. Peter Sachs, Wind Forces in Engineering, Pergamon Press, 2011.

6. NASA Ames Unitary Plan Wind Tunnel Blockage Recommendations.
NASA Ames Research Center.