The VLT in the Wind Tunnel

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Introduction

Increasing evidence collected over recent years has shown that the best local seeing conditions are found when the telescope is exposed to an undisturbed moderate wind flow. This recognition has contributed decisively to direct the design of new telescope buildings towards more open and, incidentally, cheaper solutions than the conventional domes.

The unit telescopes of the VLT are being designed for operation in the open air with a fully openable inflatable dome at present considered for daytime protection. With this concept the wind becomes an important loading condition in the design of the telescope and its effects must be quantified accurately. In order to provide the required data, a series of wind tunnel tests has been performed with models of the VLT unit telescope and its enclosure.

Wind Tunnel Simulation

The basic problem of tests at a reduced scale is that it is seldom possible to scale down all intervening quantities. This is also true for wind tunnel tests where, for instance, it is obviously not possible to scale down the air molecules and gravity. One has to identify the main factors which determine the amplitude of the aerodynamic force for each particular case, then try to simulate those factors as accurately as possible and estimate the corrections due to other parameters which cannot be simulated rigorously.

The aerodynamic force applied on an object is conventionally defined as:

\[ F = \frac{1}{2} C_D S v^2 \]  

with \( v \) the flow velocity, \( p \) the air density, \( S \) a reference surface (generally the exposed cross-section) and \( C_D \) an adimensional coefficient mainly dependent on the object shape, but also on the relationship of some flow characteristics to the scale of the object.

In general, the largest part of the aerodynamic force applied on an object depends on the size, number and type of the vortices generated in the wake. For low velocity flows such as atmospheric wind, this wake turbulence, hence \( C_D \), is mainly affected by two parameters: the turbulence already present in the upstream flow and the Reynolds number, which expresses the product of geometry and velocity scales, relative to viscosity.

The first consequence is that, since the atmospheric boundary layer is turbulent, this turbulence must be reproduced in the wind tunnel upstream of the model. This requires special installations, properly called boundary layer wind tunnels, which have a rectangular cross-section and a length sufficient to build up a scaled down atmospheric turbulence upstream of the test model.

With \( C_p \) the pressure coefficient, the aerodynamic force is given by:

\[ F = \frac{1}{2} C_D S v^2 \]

Even in such wind tunnels, however, it is not possible to achieve a complete Reynolds number similarity; this would require that velocity be increased by the same factor as the geometry scale is reduced, which in many cases would make the flow supersonic. Nonetheless, the \( C_p \) of sharp-edged objects is not too dependent on the Reynolds number, so that the measurements are generally accurate enough for most purposes in building engineering, where the objective mostly concerns the determination of ultimate dimensioning loads, to which some safety margin is anyway added.

In the VLT case, the determination of wind loading is required to quantify the "normal" performance of the telescope, hence a greater accuracy is desired than the one achievable in standard tests. Furthermore, the telescope structure is made of round section members, which have a low drag but also a \( C_p \) which is quite dependent on the Reynolds number. Therefore, the wind tunnel test measurements on the VLT model had to be complemented and corrected by separate tests of telescope bared elements at both full and model scale. The measurements were then used to calibrate and validate a detailed numerical model of the telescope. In this way, not only the full scale loads on the telescope were evaluated with better accuracy than otherwise achievable, but also further possible design changes of the telescope structure will not need new tests, but just a new run of the numerical model with updated inputs.

Some Results

While it is not the purpose of this article to present all the results of the VLT wind tunnel tests, below are a few examples which illustrate some interesting aspects of this work.

The scale of the VLT model was 1 : 80. Two different enclosure configurations were tested in the wind tunnel, both of which assume an inflatable dome fully open during observations. The first enclosure surrounds the telescope imbedded in a recess platform. (a) Telescope imbedded in a recess platform. (b) Open platform with the telescope exposed.
scope approximately up to the level of
the altitude axis, with the lower part
imbedded in a recess. This is at present
the preferred solution as it allows con-
control of the wind loading on the primary
mirror. The second configuration leaves
the telescope fully exposed to the wind
and was previously envisaged in con-
junction with a linear wind screen, which
was also simulated in the wind tunnel.

Static Wind Loading

The most important result concerning
static wind loading is the torque about
the altitude axis (Fig. 2), which is a main
parameter for the design of the drives.
The torque about the azimuth axis is, in
the worst case, only about half the pre-
vious one.

Flow in the Platform Recess

Some tests have provided evidence for
a recirculation pattern inside the
platform recess (Figs. 3 and 4). This may
be very useful in order to ensure a mod-
erate ventilation around the primary
mirror. In any case, the final enclosure
design will include doors and semi-
permeable wind screens integrated in
the recess wall which will allow altera-
tion of the flow pattern in order to
achieve anything between a very still
environment and natural ventilation with
ambient air.

Wind Loading on the Primary
Mirror

The wind loading on the primary
mirror was measured by means of 32
tiny pressure tubes, which allowed
accurate mapping of the distribution of
pressure coefficients.

Dynamic Wind Loading

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Figure 2: Full scale altitude torque for the
telescope imbedded in the recess platform
as funtion of azimuth angle $\theta$ for elevation
angles $\alpha = 45^\circ, 60^\circ$ and $80^\circ$, with a mean
wind speed of 16 m/s.

Figure 3: Flow visualization with wool tufts
showing the recirculation pattern in the re-
cess.

Figure 4: Mean velocity profile measured just
in front of the telescope tube (set vertical).
Note that the height is given in the model
1:80 scale.

Figure 5: Contour map of pressure coeffi-
cients on the primary mirror for $0^\circ$ azimuth
and $60^\circ$ elevation. In this case the local
pressure coefficients vary between 0.05 and
0.27.

Figure 6: Wind velocity spectrum measured
just in front of the telescope tube B), com-
pared with the one measured at the same
location in the empty wind tunnel A). The
difference of the two spectra quantifies the
turbulence generated by the platform.