LBT PROJECT

EFFECTS of WIND on LBT672 SHELL and COUNTERMEASURES

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Prepared by : MICROGATE
R.Biasi ....
....
....

Checked by : ....

Approved by : ....

Released by : ....

Microgate Srl – Via Stradivari, 4 – 39100 Bolzano – ITALY
ADS International Srl –via Roma, 87- 23868 Valmadrera (Lc) – ITALY

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1 INTRODUCTION

This document contains a report of the CFD simulation performed to estimate the pressure distribution on the LBT672 adaptive secondary mirror shell. We address also the implications on the system safety and propose a possible strategies to reduce the risk of damage to the thin shell.

2 CFD SIMULATION

2.1 Model description and simulation parameters

The pressure distribution on the LBT672 shell has been analyzed by the aerodynamic research group of the Aerospace Department of Politecnico di Milano. The CFD simulation code used for this scope is Fluent 3D version 6.1. The 3D structure of the hub+adaptive mirror has been simulated as a cylinder of same height of the whole hub with one flat end and a spherical concave surface on the other end, simulating the thin shell optical surface. The connection to the swing arm and other details, like the hub ribs, have not been modeled.

We assumed the following conditions:

- Wind speed: 22ms^{-1}
- Air density: 0.88 kgm^{-3} (corresponding to standard air at site altitude)
- Elevation angle: 90 deg (zenith pointing)
- Wind parallel to the earth surface, i.e. perpendicular to the optical axis

The most relevant simulation parameters are resumed hereafter:

- test volume: 15x15x15m^3
- boundary conditions: velocity inlet, outflow, symmetry on outer walls
- turbulence model: realizable k-ε

2.2 Simulation results

The simulation results put to evidence the presence of a static vortex on the shell leading edge. The pressure distribution shows a quite large area with negative pressure, in corresponding to the vortex (in our convention, negative forces tend to separate the shell from the reference body). The total force obtained by integrating the pressure over the whole mirror surface is also negative. The total force applied to the thin shell is not particularly intense, it is quite comparable with the force exerted by the bias magnets.

In order to give a more direct perception of the forces acting on the shell, we have integrated the pressure distribution over the average shell area controlled by one actuator. This corresponds to the load that would be seen by each actuator assuming a zero-stiffness shell. The simulation results are reported hereafter:

The simulation results are summarized hereafter:

- Total pulling force on the shell: 75N
- Mean pulling force acting on each actuator: 0.112N (as reference, the typical force exerted by the bias magnet amounts to 0.1N and the gravity force at Zenith to 0.065N)
- Maximum pulling force on mostly loaded actuator (see Figure 1): 0.22N

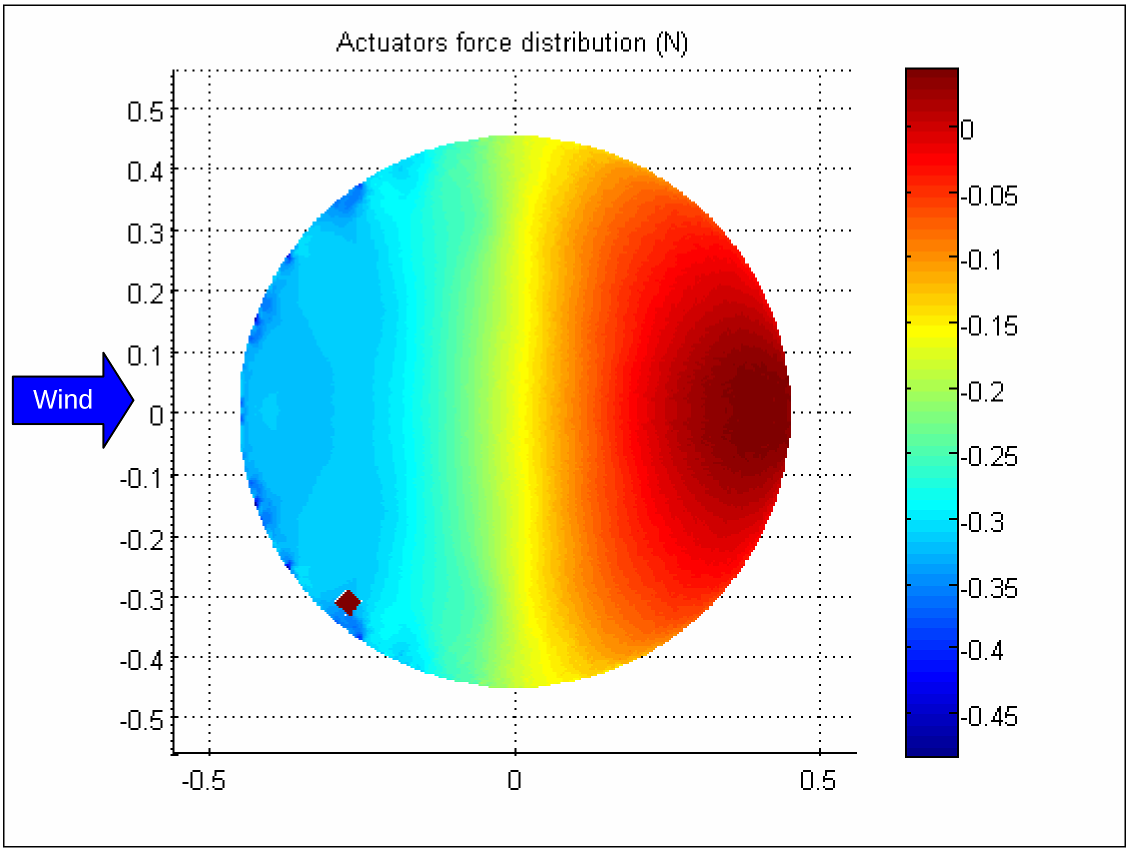

Figure 1 – Force distribution on the actuators, assuming a zero-stiffness shell (represented values correspond to the pressure distribution integrated over the average area controlled by one actuator). The purple square indicates the mostly loaded actuator.

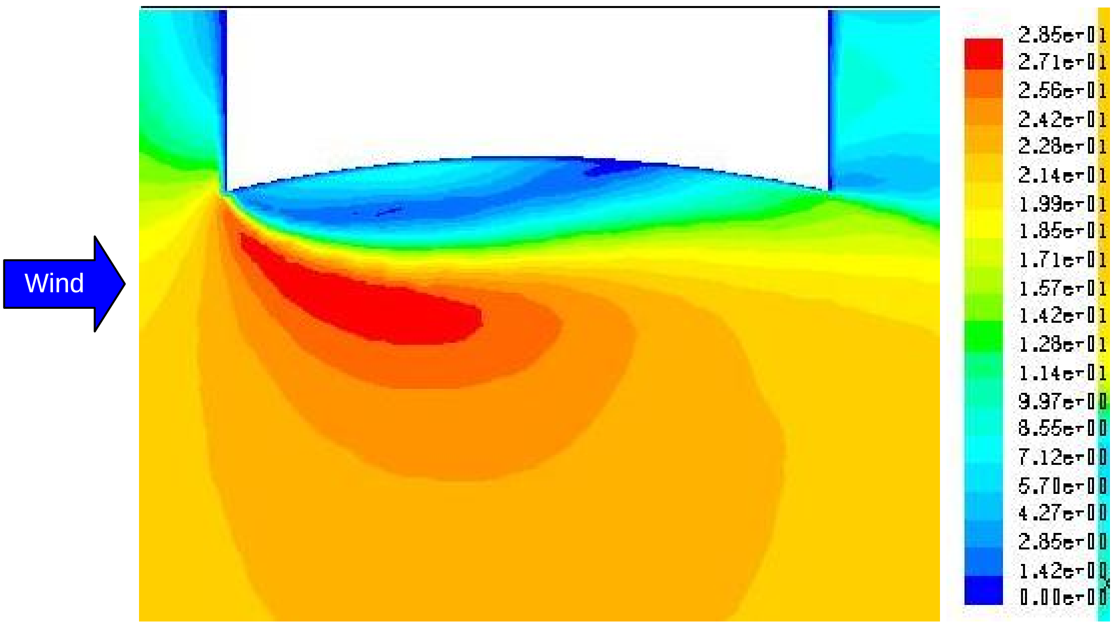

Figure 2 – Velocity distribution over the mean section of the mirror, along wind direction. Given values are in ms^{-1}. 22 ms^{-1} asymptotic wind speed.

2.3 Comments to the simulation results

The presented results cover just one elevation angle, therefore they can not be considered as fully exhaustive. However, the experience gained on a different deformable secondary (VLT DSM) let us assume with some confidence that the zenith condition should be the most severe one.

The absence of more details, in particular the swing arms, are not expected to influence significantly the given results.

On the contrary, the presence of the telescope enclosure could modify quite significantly the wind direction and/or induce large scale turbulence. All this could impact quite significantly the results, but taking into account such effects would imply a much more complex model and simulation grid, that was not affordable within the given time.

3 SHELL RETENTION

In this paragraph we analyze the current status of the electronics and propose some modifications and operational strategies to counteract the wind-generated pressure distribution on the shell.

3.1 Actuator safety forces dimensioning

Two different operating conditions shall be considered:

The adaptive secondary mirror is in **closed loop**. In this case, we can clearly state that the forces can be easily handled by the actuators. In fact the maximum forces to be generated are 7 times lower than the force range of the actuators. Moreover, the wind power spectral density is already negligible at the closed loop control bandwidth of the mirror.

The adaptive secondary mirror is in **open loop** and the shell is kept passively in contact with the reference body by means of the bias magnets. This situation is more critical because the bias magnets retention force (0.1N per actuator, of which 0.071N are used to counteract the gravity force) is by far not sufficient to handle the wind forces. To counteract the wind pressure distribution when the mirror is in open loop, one can think of applying on all actuators the *maximum* force seen by one actuator, as computed in §2.2. This is quite conservative assumption, in fact:

- the force does not consider any shell stiffness. In real terms, the shell will spread the load reducing the differences over the shell surface
- the resulting total pulling force is 2.00 times higher than the actual total force exerted on the shell

The force can be computed as follows:

$$F_{act\_safety} = F_{act\_wind\_max} + F_{weigth} - F_{bias\_magnet} = 0.22N + 0.065N - 0.1N = 0.185N$$

The total dissipation at the level of the actuators amounts to:

Total coils dissipation = 109W (assuming 0.46 N√W efficiency)

Such dissipation can be continuously handled by the adaptive secondary unit, even in case of complete failure of the cooling system.

3.2 Proposed safety policy to handle the mirror open loop condition

The most straightforward solution to handle the wind loads with the mirror in open loop is simply to keep the control electronics on when and to apply the retention force computed in §3.3. This should be always done when the telescope enclosure is open.

However, this solution is not fully satisfactory in fault condition, i.e. when the control system can not apply the desired current due to a malfunctioning or a general power failure. The risk is quite limited, in fact it is relevant only when the enclosure is open, the system fails and the enclosure can not be rapidly closed.

If the risk can not be accepted, then one has to conceive an independent mean of injecting current into the coils.

3.3 Current status of the electronics

The current status of the electronic components, that are completely assembled and tested for LBT672a and in the final assembly phase for LBT672b, does not foresee an independent electromagnetic retention system. Such system was planned and actually tested in the first version of the electronics (in particular, the Power Backplanes included the dedicated circuitry), but then, when it was decided to introduce the *bias magnets*, it was jointly agreed to simplify the power backplanes and to remove the shell retention system (TSS) dedicated circuitry. Nevertheless, we left on the Power Backplane the connections suitable to bring an independent current source to the coils and, on the DSP boards, the diodes that disconnect the coils from each other during normal operation. Unfortunately, this circuitry (and in particular the polarization of the diodes) was implemented to be used as an independent mean to *separate* the shell from the backplane (without active control system) for maintenance purposes.

As a consequence, at the present status there is no way of injecting a current (independent from the control one) generating *pulling* forces to the shell.

3.4 Required modifications on existing electronics

In order to re-enable the possibility of generating independent pulling force to the shell, the following modifications are necessary:

- on the DSP boards, the diodes injecting the additional current shall be inverted (actually, they are double diodes configured as common anode that shall be replaced with the common cathode version)
- on the power backplane boards, the reverse polarization of the above mentioned diodes that disconnect them during normal operation shall be connected to the opposite supply rail (positive vs. negative)

Both modifications are relatively simple and can be quite easily done on the already assembled boards without dismounting the cooling plates.

As far as the LBT672b electronics is concerned, we were able to introduce the modifications before the boards were assembled, thus avoiding any reworking.

The modifications on the LBT672a electronics is currently in progress. The risk connected with such reworking is very moderate and does not influence at all the board calibration, so we are testing just this feature and will <u>not</u> re-test thoroughly the boards (this is a very long activity!).

3.5 Required new equipment

The following elements need to be newly installed on the system:

- current generator for the coil bias current and related logic
- battery backup system

3.5.1 Current generators

As current generators, we plan to use isolated DC-DC converters (power bricks) with 48V input and adjustable output, similar to those already employed in the Power Backplane. The DC-DC converter output would be regulated to generate a constant current rather than a constant voltage. In this way, the voltage drops along cables and connectors can be compensated and the actual force exerted by the coils would be directly controlled.

For the sake of redundancy, we plan to use six independent units, one per backplane.

The current generators, which size is expected to be approx 50x70x25mm (six unit needed), could be positioned in different places:

- On the back wall of the Power Backplanes, placed into a custom made aluminum case
- On the interface flange between hexapod and adaptive secondary unit
- In the swing arm rack

The first two solutions are definitely advantageous in terms of cabling. In fact the third one would require six additional pairs of cables with at least $6mm^2$ copper section to avoid excessive voltage drop.

As drawback, the first two solutions would slightly increase the dissipation at the level of the adaptive secondary. Assuming 75% efficiency for the current generators, the additional dissipated power would be

8.4Wx6 (current generators) + 41.8W (diodes on DSP board) = 92.3W

(this is the power dissipated by the current generator and DSP boards and does not include the power dissipated by the coils, which is reported in §3.1).

3.5.2 Shell retention logic

We intend to keep the shell retention logic as simple and safe as possible. Considering that the level of dissipation can be continuously handled by the system, the simples way is to have the shell retention system on when the coil drives are not enabled and/or when the system is in fault condition. A 'fault/drives disabled' signal is already available and reported to the adaptive optics supervisor. We plan to use the same signal to enable the shell retention circuitry.

We consider important the possibility of switching off the shell retention circuit when the enclosure is closed, in order to reduce the heating of the unit. This can be achieved by adding an additional output to the digital I/O interface controlled by the adaptive optics supervisor. Clearly a fail-safe design shall be adopted, so the 'retention disable' signal shall be automatically de-asserted in case of power failure or communication fault.

One more diagnostic flag signaling the activity of the shell retention system should be added to the output diagnostic and connected to the same digital I/O interface.

3.5.3 Battery backup

The battery backup will be placed in the swing arm rack and consist of a 48V battery in parallel (through diodes) with the 48Vdc main output from the AC-DC power supply unit. An independent battery charger guarantees that the battery is kept continuously in a fully charged state.

The battery capacity can be dimensioned considering 1 hr of backup capacity (TBC).

If the current generators will be installed into the adaptive secondary unit, then the capacity shall be:

201W * 1hr /48V = 4.2 Ah

If the current generators will be installed into the swing arm cabinet, then the capacity becomes significantly higher due to the power dissipation along the cables ($6mm^2$ section assumed):

431W * 1hr /48V = 9 Ah

4 FINAL REMARKS

We can conclude that it is still possible to handle the wind problem on the current architecture. The required modifications are not negligible, but still doable without large impact on system layout.

This document presents a possible implementation, but some aspects need to be evaluated jointly with the design group in order to take quickly the relevant decisions, in particular:

- General agreement on the proposed solution
- Dimensioning of retention forces. Shall we consider a safety factor?
- Decision on final implementation details, in particular current drives positioning, detailed activation logic and battery backup

As far as the schedule is concerned, we are already implementing the necessary modifications on the DSP boards Power Backplanes (see §3.4). If a final agreement on the solution will be found within short (< end of January), it shall be still possible to refurbish the LBT672a unit currently being integrated at Microgate before it will be transported to Arcetri. This would be in our opinion by far the wisest option. In fact a later refurbishment would have a much heavier impact on schedule and expose the thin shell to more risks.

Based on this assumption, we would propose the following schedule:

- Complete the modification on the existing electronics, to be completed before **Jan 31st**
- Agree on the solution before **Jan 31st**
- Proceed immediately with final design, procurement and realization of the required electronics. Complete by **March 31st**
- Proceed with the original integration and test planning without any modification, until the modularly tested shell retention electronics will be available
- Stop temporarily the test and optimization activities to allow installation and test of the shell retention circuitry. This activity can be estimated in 1 working week and can be tentatively planned for the **first week of April**

This way of proceeding would allow to limit to one week (+ one for contingency) the impact on the current schedule.