EXPERIMENTAL STUDIES OF ATMOSPHERIC FLOW PATTERNS AT LAUNCHING PAD AREA OF ALCÂNTARA SPACE LAUNCHING CENTER

F. Rufino[1*]; A.F. Faria[2]; A.C. Avelar[3], C.F. Prado[3] and V. Siqueira[1]

1 Faculdade de Tecnologia de São José dos Campos - Professor Jessen Vidal
Av. Cesare Mansueto Giulio Lattes, 1350 - Eugênio de Melo, São José dos Campos/SP,
CEP: 12247-014, Brazil.
Telefone: (12) 3905-2423
2 Instituto Tecnológico de Aeronáutica (ITA)
Praça Mal. Eduardo Gomes, 50 - Vila das Acácias, São José dos Campos, SP,
CEP: 12228-900, Brazil.
Telefone: (12) 3947-6496
3 Instituto de Aeronáutica e Espaço (IAE)
Praça Mal. Eduardo Gomes, 50 - Vila das Acácias, São José dos Campos, SP,
CEP: 12228-970, Brazil.
Telefone: (12) 3947-6493

*felipe.rufino@hotmail.com

ABSTRACT: The purpose of this paper is the investigation of the influence of the wind incidence angles and the coastal cliff inclination on the flow patterns at the Launching Pad Area (LPA) is located into the Alcântara Space Launching Center (ASLC), mainly close to Mobile Integration Tower (MIT). Here, a 1:120 scale model of the LPA was constructed and the experiments were conducted in the aerodynamic wind tunnel TA-2 situated at the *Instituto de Aeronáutica e Espaço* (IAE). During the experiments wind incidence angles of 0º, 35º, 45º, relative to the model front, face were used and to represent the irregular structure of the coastal cliff a step with inclinations of 90º, 45º, 70º were also employed. The Reynolds number considered was 1.7×10^5, 4.3×10^5 and 6.4×10^5. Velocity data for all experimental configurations was obtained using a Particle Velocimetry Image (PIV) system that enables the two-dimensional mapping of the velocity fields at different locations over the model.

KEYWORDS: wind tunnel; LPA; PIV; flow pattern and MIT.

1. INTRODUCTION

The Alcântara Space Launching Center (ASLC) is a very important site of rockets launching in Brazil. It is situated close to the Equator line (2º 19’ S; 44°22’ O) and located in Alcântara-MA. The ASLC is distant 150 m from the sea coast and is over an atypical topography called costal cliff, with approximately 40 m of height (FISCH, 1999 and AVELAR *et al.*, 2012).

The Launching Pad Area (LPA) is located into the ASLC, where the rockets are launched, Fig.1.1.

Figure 1.1. Launching Pad Area of Alcântara (LPA).

In the LPA, is sited the Mobile Integration Tower (MIT), the local where space vehicles are assembled and prepared for the launching. This construction is 33 m high and has a metallic structure with mobile system trails (AEB, 2016).

The MIT is characterized as a bluff body, because of its cylindrical shape, with square base, and does not have an aerodynamic profile.

For a better comprehension of the flow pattern in the LPA region, a 1:120 model scale of the LPA, has in Fig. 1.2, was constructed for being used in the wind tunnel experiments.

The model was painted in black in order to reduce the effects of laser reflections. It was fixed over a wooden platform for simulating the coastal cliff inclination, Fig. 1.3, and wind incidence angles were obtained through model rotation. For more details on the model installation procedures see Faria, 2016.

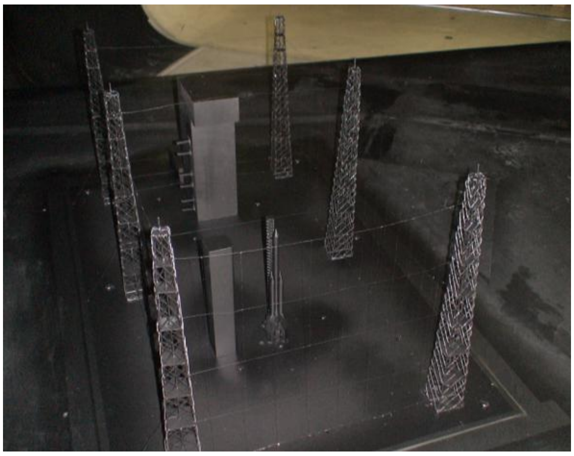


Figure 1.2. LPA Model.

Figure 1.3. LPA model in the test section.

The main objectives of these experiments are study the flow pattern characteristics in the LPA region, mainly near the MIT, and the analysis of the wind incidence angles influence and the coastal cliff inclination at the LPA during launching events.

2. EXPERIMENTAL SETUP

The experiments were conducted in the subsonic aerodynamic wind tunnel (TA-2), located at the *Instituto de Aeronáutica e Espaço* (IAE), inside the campus of the *Departamento de Ciência e Tecnologia Aeroespacial* (DCTA). The TA-2, Fig.2.1 and Fig.2.2, wind tunnel reaches maximum velocities around 120 m/s and its test section dimensions are 2.1 m high and 3.0 m wide.

Figure 2.1. Aerial view of TA-2 wind tunnel.

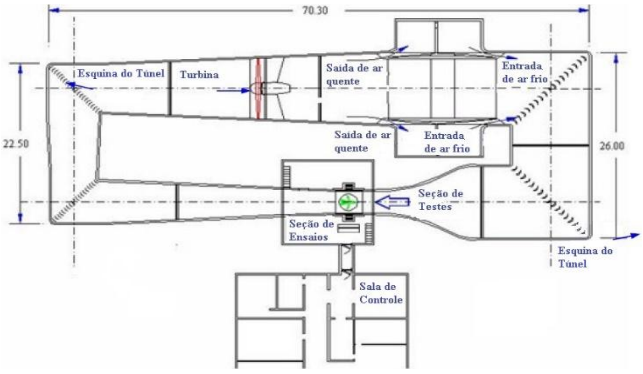


Figure 2.2. Representation of the TA-2 circuit.

2.1. Particle Image Velocimetry (PIV)

The Particle Image Velocimetry (PIV) is a flow visualization technique that uses a laser sheet that is synchronized with a high-resolution camera and illuminates particle tracers added to the flow, Fig.2.3, that can be mapped between pulses, enabling the attainment of the velocity field at the laser illuminated are. More details see Raffel *et al.* (1998) and Abrantes *et al*. (2012).

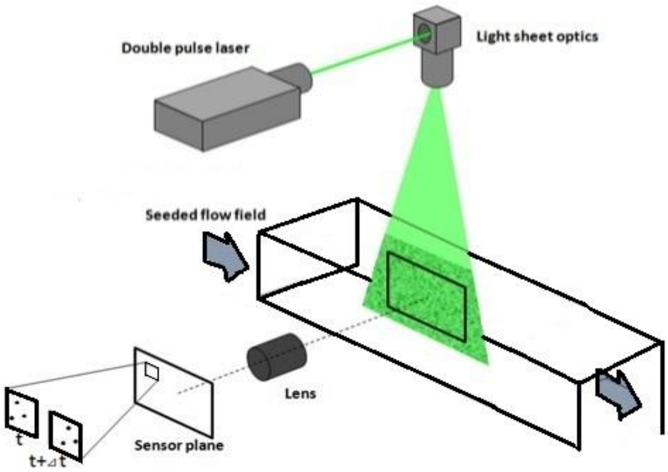


Figure 2.3. Experimental PIV (Adapted of RAFFEL *et al.*, 1998).

A Dantec Dynamics two-dimensional PIV system was used for obtaining velocity flow maps. This system utilized a two HiSense 4M CCD camera by Hamamatsu Photonics, Inc., that is synchronized with a double-cavity pulsed laser, Nd:Yag. The camera has a spatial resolution of 2048 × 2048 pixels, 7.4 µm pixel pitch, acquisition rate of 11 Hz and used a Nikon f# 2.8 lenses with 105 mm of focal length. The laser has a frequency of 15 Hz, with an output power of 200 mJ per pulse at the wave length of 532 nm (New Wave Research, Inc.). The flow was seeded with theatrical fog (polyethylene glycol water-solution) produced by a Rosco Fog Generator located in the wind tunnel diffuser section. The pictures were treated using the adaptive correlation tool of the commercial software Dynamic Studio, industrialized by Dantec Dynamics. The interrogation area was 32x32 pixels, with 50% overlap and moving average validation.

2.2. Configurations

The scaled model of Launch Pad Area (LPA) was placed over a wooden platform for simulating the coastal cliff inclination angles (β) and the wind incidence angles (α). For each arrangement, wooden blocks were used in front of the wooden platform, for simulating the coastal cliff inclination. For simulating the wind incidence angles, the LPA model was rotated over this wooden platform, Fig. 2.4. The velocity values (U_∞) considered were 8 m/s, 20 m/s and 30 m/s, corresponding to Reynolds number (Re) of 1.7×10^5, 4.3×10^5 and 6.4×10^5.

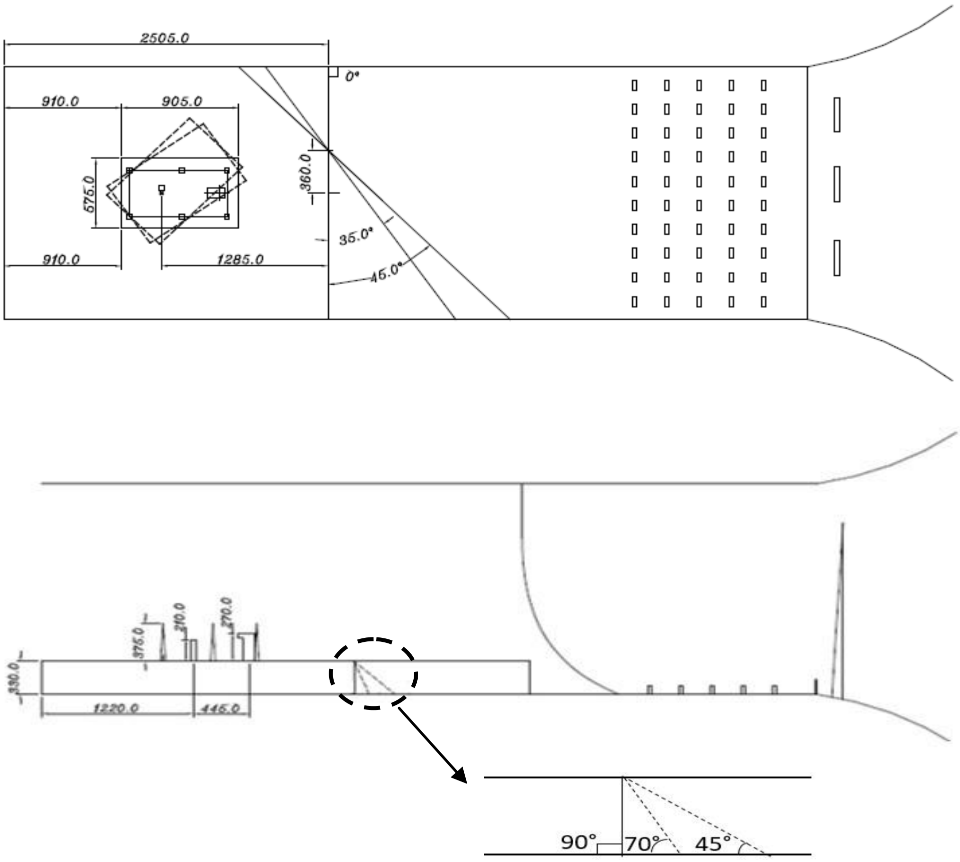


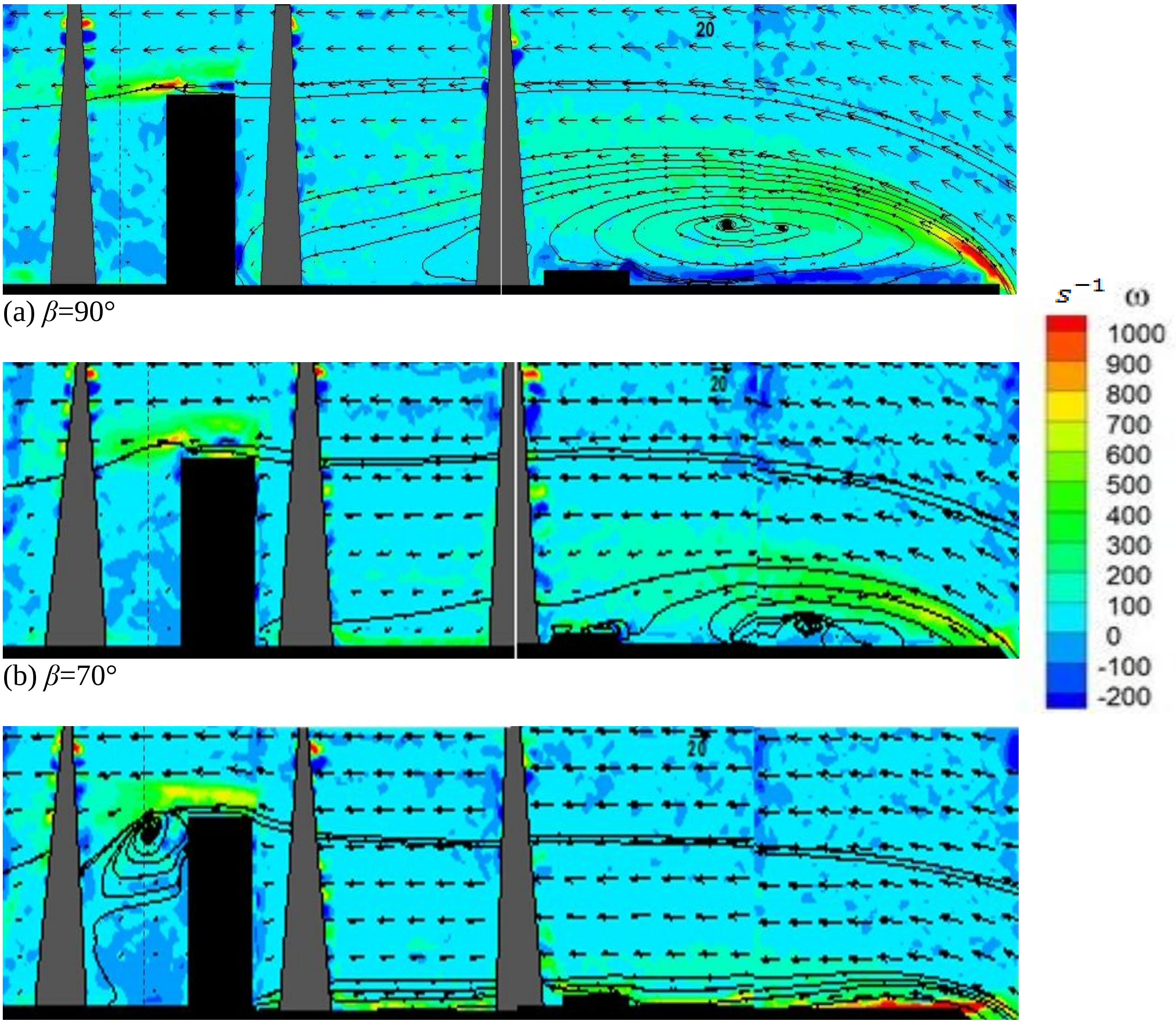
Figure 2.4. (a) Top view the α positioning, (b) Frontal view the different β inclinations (Adapted of Faria, 2016).

3. RESULTS

Here, some results of vorticity contours and velocity vectors for the region near the Mobile Integration Tower (MIT) are presented.

Figure 3.1 shows the flow pattern behind the MIT, for velocity of 20 m/s, α=0° and varying the β=90°, 70° and 45°.

It can be seen that flow detachment occurs at the entrance of coastal cliff, for β=90° and α=0° creating a recirculation bubble. This happens because the coastal cliff simulates a step. For β=70° and α=0° the detachment also occurs in the border of the coastal cliff and creates a recirculation bubble in this region. The detachment in this region is less strong than β=90°, because the coastal cliff is less steep than β=90°. For β=45° and α=0° the coastal cliff slope is mellow in comparison to the other two configurations. The recirculation bubble occurs behind the MIT and does not on the entrance of coastal cliff.



(a) β=90°

(b) β=70°

(c) β=45°

Figure 3.1. Vorticity contours and velocity vectors – α=0°, 20 m/s.

The Fig. 3.1 shows that the average vorticity values are in the range of -100 s^{-1} until 300 s^{-1}, the maximum vorticity value is 1000 $s^{-1}$and the minimum is -200 s^{-1}. It can be observed an intense vorticity near the border of MIT and on the entrance of the coastal cliff, because of the deceleration of flow near these regions.

4. CONCLUSIONS

Based on the experiments presented can be concluded that:

- When β=45° the recirculation bubble occurs behind the MIT, because of the coastal cliff boarder is more slope;
- The vorticity is more intense near the entrance of the coastal cliff and on the boarder of the MIT, due to the flow separation in these regions.

In general, changes in the coastal cliff inclination slopes modify the flow patterns near de Launching Pad Area (LPA) and this can cause vibrations or load excess on the MIT structure if stay there a long time and can damage the rockets launching.

This study is an important scientific contribution for the Brazilian Space Program.

5. REFERÊNCIAS

[1] AEB. Agência Espacial Brasileira. Ministério da Ciência, Tecnologia e Educação. Disponível em: <http://www.aeb.gov.br/equipes-do-iae-e-do-cla-trabalham-no-sistema-plataforma-de-lancamento-do-vls-1/>. Acesso em: 2 abr. 2016.

[2] AVELAR, A. C. et al. Wind tunnel simulation of the atmospheric boundary layer for studying the Wind pattern at Centro de Lançamento de Alcântara. **Journal of Aerospace Technology and Management**, v. 4, n. 4, p. 463-473, 2012.

[3] FISCH, G.Características do perfil vertical do vento no Centro de Lançamento de Foguetes de Alcântara (CLA). **Revista Brasileira de Meteorologia**, v. 14, n.1, p. 11-21, 1999. Disponível em:<http://www.rbmet.org.br/port/revista/revista_busca_resultado.php>. Acesso em: 15 jun. 2015.

[4] ULRICHS, E.; HERWIG, H. Between two limits: flow separation behind a bluff body close to a wall. **Forschung im Ingenieurwesen**; v. 68, n. 1, p. 36-38. 2003.

[5] FOX, R. W.; MCDONALD, A. T.; PRITCHARD, J. P. **Introdução à mecânica dos fluidos**.8. ed. Rio de Janeiro: LTC, 2014. 871 p.

[6] Faria, Amanda. F. "Análise Experimental do Escoamento Atmosférico no Centro de Lançamentos de Alcântara utilizando Túnel de Vento". 2016. 130f. Dissertação de mestrado em Ciências e Tecnologias Espaciais – Instituto Tecnológico de Aeronáutica, São José dos Campos, SP.

[7] PALACIOS, S. F. M. "Estudo experimental do escoamento de fluido newtoniano em contração abrupta assimétrica com a técnica de velocimetria por imagem de partículas". 2011. 174f. Dissertação (Mestrado em Engenharia Mecânica e Materiais) – Universidade Tecnológica Federal do Paraná, Curitiba, PR.

[8] RAFFEL, M.; WILLERT, C. E.; KOMPENHANS, J. **Particle Image Velocimetry:** A Practical Guide. 1 ed.Germany: Springer, 1998. 253p.

[9] ABRANTES, J.K.; PAULA, I.B.; AZEVEDO, L.F.A. Medição de escoamentos turbulentos utilizando velocimetria por imagem de partículas. In: ESCOLA DE PRIMAVERA DE TRANSIÇÃO E TURBULÊNCIA, 8., 2012, São Paulo, SP. **Anais...**Rio de Janeiro: ABCM, 2012. v.8, cap. 5, p.133-209.