Acoustic behavior of the VEGA launch pad environment

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Abstract

The acoustic pressure levels experienced by the spacecraft and launchers during the lift-off is due among other factor by the reflection of the sound waves on the launch pad. The acoustic load distribution in the area of the launcher depends on the geometric, mechanical and acoustic characteristics of the ground facilities. This work is intended to study the acoustic environment of the launch pad. A numerical and experimental investigation is developed in order to study in the linear regime the acoustic behaviour of a subscale model of the VEGA's launch pad. The acoustic measurements are performed in an anechoic chamber using an electroacoustic source that emits incoherent noise, mimicking the real acoustic source. The acoustic pressure field is measured at different positions in front of the launch pad mock-up, in the area where the acoustic waves are reflected. Among the future perspectives of this work is to study and develop new methods for the mitigation of the sound pressure levels.

Keywords: launch pad, acoustic load, scale model test, lift acoustic environments

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1 Introduction

The launching of space aircrafts is an extreme event, where the physical magnitudes involved (temperature, gas flow, pressure) exceed those in conventional situations by orders of magnitude [1]. The liftoff phase induces acoustic loading over a broad frequency range for a launch vehicle. Payloads support a maximum noise and vibration levels, and excess in these levels may cause damages with high economic impact. The liftoff acoustic environments determine the internal vibration responses of the vehicle and components. Therefore, noise reduction is becoming a relevant issue, since it would improve the reliability and operations of future launchers. However, the situation is changing since payloads are becoming more and more sensitive and may be affected by the strong acoustic loads during the lift-off, putting at risk the missions and having strong economic consequences. A particular payload is designed to support a maximum noise and vibration levels, and acoustic conditions may cause damages when these levels are exceeded. The topic of noise reduction is becoming more relevant, since it would improve the reliability and operations of future launchers.

Up to now, the design of launch pads, involving a given geometry and materials, is mostly motivated to act on exhaust gases. But the walls and concrete surfaces currently used in the launch pads are highly reflecting for sound waves, and therefore far to be optimal from the noise management point of view. Intense sound waves reflecting from the pad and adjacent structures reach the launch vehicle before the lift-off, and excite unwanted vibrations in the fairing structure, which at the end are the responsible for the damage of the satellite and other sensitive machinery inside the fairing. Some recent results related to acoustically induced vibrations during launch events are described in [2-3].

Several strategies have been used up to now to reduce the noise pressure levels. The most used strategy to reduce the noise pressure level is the injection of a hot supersonic pressurized water flow injected all around the pad [4]. Water has a double effect of cooling, and absorbing sound, to noise levels that are just below the design requirements. Typical level reduction of water deluge systems is 3-5 dB. This strategy has however an important drawback: water is often a degrading agent for materials and structures (creating corrosion or other damages). Other strategies have been proposed like optimizing the shape of the launchpad [5]. But optimization may not be possible for already built launch pads. [6, 7].

Less attention has been paid to the acoustic field performance of launch pads, since it is primarily designed for solving another two important problems: channeling of exhaust gases and withstanding extreme heat. However, some studies account for the influence of the flame deflector shape [8] or the use of covers in the Launchpad [6] on the acoustic level on the launch vehicle at lift-off.

Figure 1: Pictures of VEGA launch pad: (left) general view and (right) detail of one of the ducts.

In this work, we take as a reference VEGA, a small European launch vehicle. In Figure 1 two pictures of the VEGA launch pad are shown, where two big channels are present. The aim is to study the acoustic behavior of the launch pad and to evaluate the acoustic impact of its structural elements like covers and/or deflectors. For this purpose, we use a subscale model using a speaker as a noise source pretending the rocket. The overall acoustic power from the plume of the advanced solid rocket is estimated to be higher than 180dB. A source of such characteristics cannot be used in an acoustic laboratory environment. We use a speaker with the purpose of characterize the acoustic response of the launch pad in a controllable way.

2 Experimental setup

Experimental measurements were carried out in an anechoic chamber. A 1:25 (4%) subscale model of the VEGA launch pad was designed and built-up with Medium Density Fiberboard (MDF). The choice of the appropriate scale was a compromise between two criteria: 1) the size of the scaled launch pad to fit in the anechoic effective space of the room and 2) the working frequency band of the loudspeaker. The main acoustic elements of the launch pad are the carneaux, the gas deflectors and cover. The sound absorption and impedance of this material are practically null and infinite at the working frequencies, respectively. The woofer of a high quality studio monitor Genelec 8030A was used as a source. The diameter of the loudspeaker is 5'' and it is suitable to work in the working frequencies [500Hz-3kHz]. The tweeter of the monitor was off during the experiments. The speaker is oriented towards the gas deflectors as it corresponds to the rocket in the ignition phase.

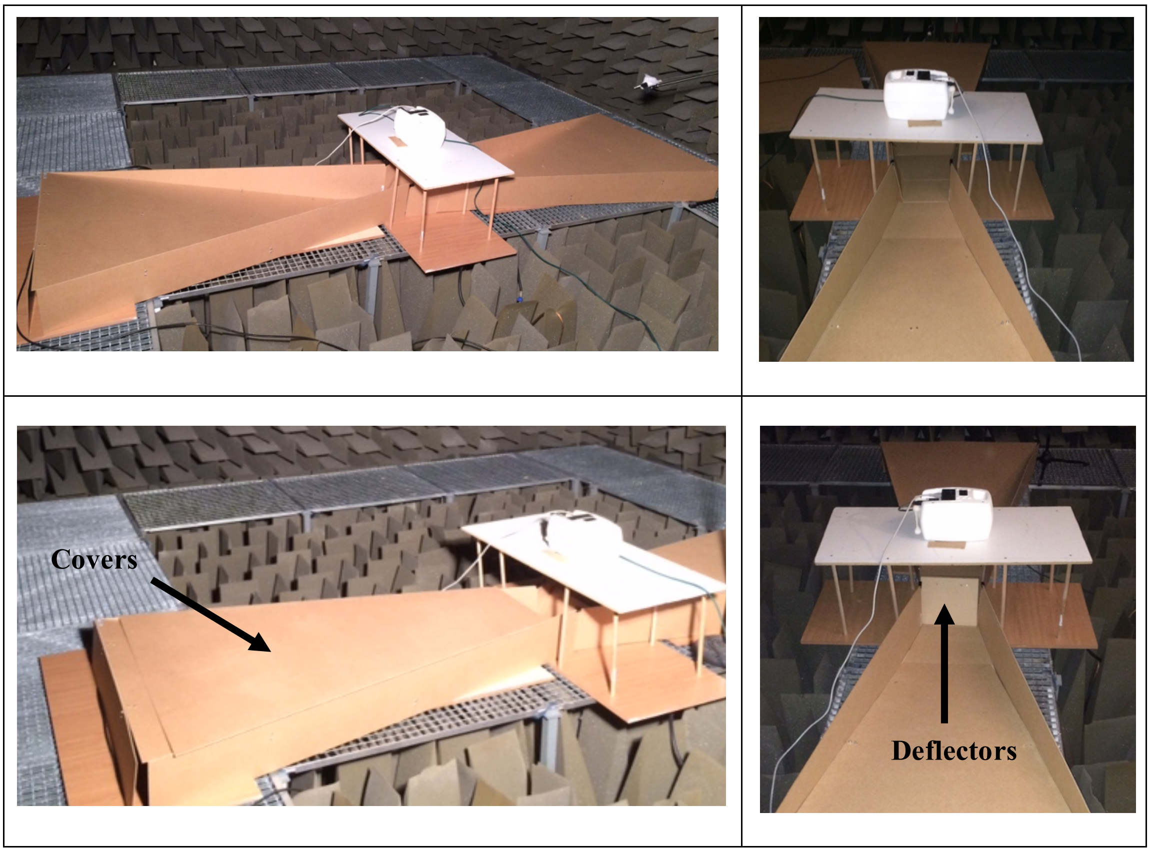

Figure 2: Pictures of the experimental setup with and without covers and deflectors.

Several pictures of the experimental setup are depicted in Fig. 2 in different configurations (with and without cover and deflectors). The receiver is a free-field microphone of 0.5'' with flat response and an omnidirectional directivity in the working frequency range. The acoustic measurements were made in a quarter circumference of radius 1.8m centered in the source with a free-field microphone, spaced every 30° in azimuth. The location of the microphone in 90º corresponds to the fairing level of the launch vehicle at the end of a carneaux and 0º is the vertical position above the source as shown in Fig. 3.

The purpose of this study is to study the acoustic behavior of the launch pad. For this purpose, white noise is emitted by the speaker to reproduce the incoherence of the original source (the nature of the real signal is a combination of the blast wave and a continuous regime of random, ergodic and quasi-stationary noise.). Acoustic measurements were time-averaged to reach stable values. The experimental setup is designed to analyze the effect of two parameters on the acoustic behavior of the launch pad: the presence/lack of cover and deflectors.

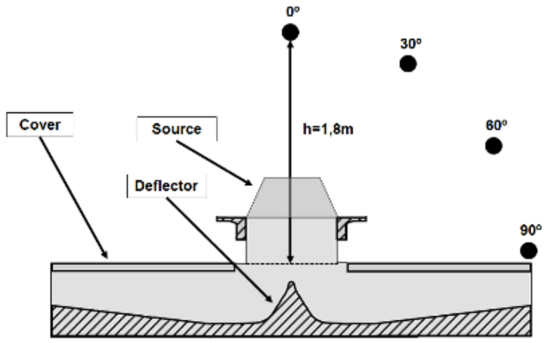

Figure 3: Schematic frontal view of the ducts at the carneaux with deflector and cover. Dots represent the microphone positions.

3 Results

3.1 Frequency response

The aim is to evaluate the acoustic effect of inserting or removing elements in the launch pad like the cover or the deflectors. In Fig. 4 is presented the Sound Pressure Level (SPL) in dB ~~is presented~~ at 0º with and without cover. Remark that the frequencies represented have been transformed to the real scale 1:1, and correspond to the range [12.5Hz-125Hz]. It can be seen that the effect of covers depends on frequency. In general terms, the inclusion of covers reduces the acoustic pressure above 80Hz. For lower frequencies a significant increase of the SPL is observed. A plausible explanation of these peaks is that the resonant behavior of the channels in the launch pad is enhanced as a consequence of closing them with covers. Variations up to 5dB are observed due to the acoustic effect of covers.

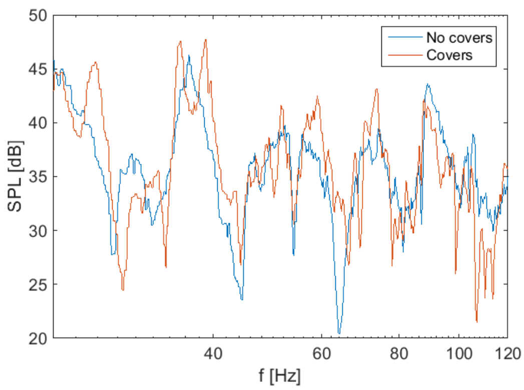

Figure 4: Sound Pressure Levels (dB) with and without cover at the 0º.

In Fig. 5 the results are presented for different microphone positions in 1/3 octave bands. In this figure, the above mentioned effect of resonances on the acoustic response of covered channels at 0º is reduced because of the integration in frequency bands. For other microphone positions, important variations are also observed, but there is not a general rule.

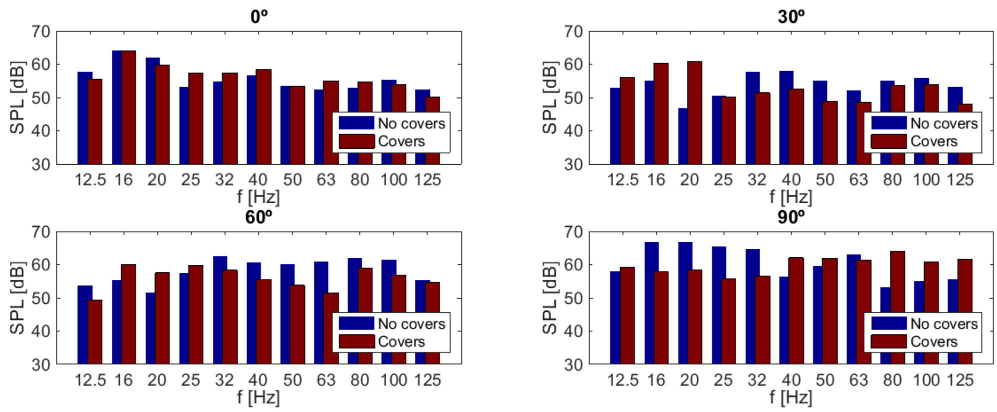

Figure 5: SPL (dB) in 1/3-octave bands with (red) and without (blue) covers at different microphone positions.

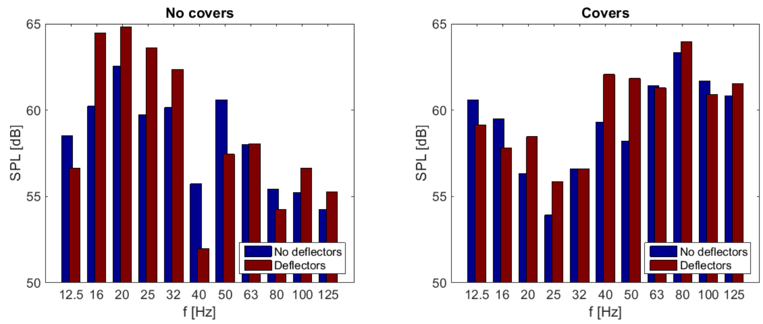

Figure 6: SPL (dB) in 1/3-octave bands with (red) and without (blue) deflectors in both configurations without (left) and with (right) covers. Measurements correspond to the 90º microphone position.

The effect of removing deflectors in the acoustic behavior of the launchpad is observed in Fig. 6, with and without covers. Although, the flame deflector is not designed for acoustic purposes, it can be seen that differences up to 5dB are measured when the deflector is removed. It can then be concluded that they have an important acoustic effect.

4 Conclusions

A 1/25 scaled model of the VEGA launcher has been designed, built and tested in an anechoic environment. The acoustic behavior of the launch pad has been tested. The effect of covering the channels is sensitive for different angular positions. The sound pressure level reduction is important for frequencies above 80Hz. Helmholtz resonances of the covered pad enhance the acoustic modal response for very low frequencies. Flame deflectors also show an important influence in the pad response. A good comprehension and a precise evaluation of different parameters is necessary in order to determine its influence in terms of SPL in the launch pad area.

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