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Analysis of the Transmissibility of Induced Vibration in Solid Propellant Rocket Motors during Transport

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Abstract

The choice of packaging for the transport of sensitive cargoes can influence the propagation of vibrations produced by the vehicles and the roads used during transport operations. This article presents a study of the transmissibility of vibrations in the phases of terrestrial and air transport of a rocket engine and its parts. During measurements, the parameters were monitored at intervals of five minutes between measurements, using sensors distributed along the body of the rocket motor, the engine supports and the starting device. The data measured on the pallet was used as excitation input vector and the measurement points distributed throughout of the engine body and its part as output response vector. The vibration and shock levels found in the measurements indicated that there was no increase in vibration levels above that established by the Transport Standard. A significant reduction of vibration levels along the transmission path was observed, greater than 50%, showing that the packaging used for this transport did not amplify the vibration levels.

Keywords: Transmissibility; Motor-Rocket; Transportation; Air; Ground

Introduction

Space vehicles, including their engine and all space systems are primarily designed for the flight environment; however, in the case of our vehicles that are produced and tested away from the launch site, there is a need to be transported by truck and airplane and the handling and transport operations need to be known and the parameters characterized. During these movements, the aerospace components and its segments are subject to loads that may act differently that it's subject in transport phase, most likely due to the conditions of the vehicle and the roads; therefore its components must be packed in containers that protect against environmental influences and loads induced by the transport and handling when the engine is moving from the place of manufacture to the launch site. In 2006, it started a project to survey dynamic and environmental loads on the vehicles used to transport aerospace components [1], based on the criteria adopted by NASA [2]. This work presents an experimental study performed during the transport of the rocket motor S43 [3], which the main objective was to know the transmissibility of the vibration level induced, on the packaging used for the transport of the rocket engine due to the vehicles used for this purpose [4] and [5]. This work was based on the first monitoring of the S43 engine rocket, the largest produced in Brazil.

Experimental Set-Up

The rocket engine and its part were transported in a metal container (Figure 1). The components were transported by open truck on the route between the manufacturing site and the airport and by plane between São José dos Campos and Alcântara, where the launch site is located.

For the measurements in the handling phase, the data acquisition system was connected before starting any operation with container involving operations with the forklift truck, overhead crane and truck loading; in this phase there is a higher incidence of mechanical shock in the monitored structure. In the transport phase, the system was activated every time the vehicles were started, and each measurement was carried out in cycles of 5 minutes until the vehicle stopped.

The measurements were performed with the 54-channel dynamic data acquisition system. Seven tri-axial sensors were distributed along the rocket motor body, four triaxial sensors in the container cradle, two tri-axial sensors in the igniter and four tri-axial sensors in the Pallet (red points), monitoring the vibration on the container, as can be seen in Figure 2.

For the calculation of the transmissibility (Equation 1), it was considered the global value of the

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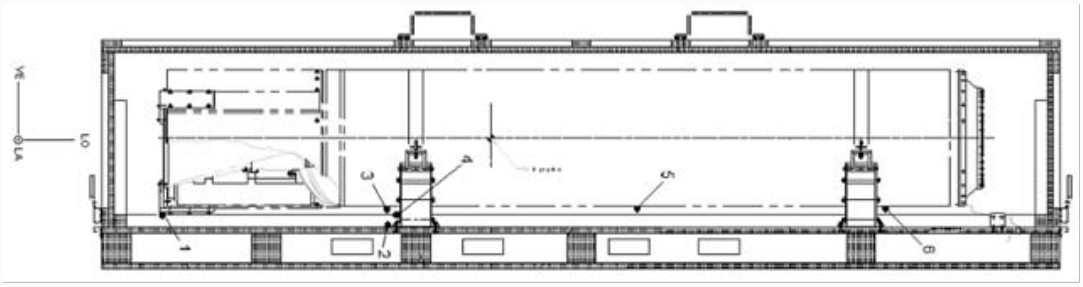

Figure 1: Packaging used for transport and the respective positions of the sensors on the body of the rocket engine.

Figure 2: Position of sensors along of the pallet.

vibration found for each measuring point of the motor.

$$TR = \left| \frac{\text{Re } sponse}{Excitation} \right| \qquad (1)$$

The measurements acquired on the pallet were used as parameters for the input excitation of the container and the measurements along the rocket components were used as response.

Results and Discussion

The vibration levels in the engine did not exceed the limits established by Standard [2], only a few isolated points in the pallet registered values above the limit. As can be seen in Figure 3, there was a significant reduction of the vibration levels along the transmission path, greater than 50%, for the terrestrial phase.

The charts above shows the transmissibility of vibration levels in the motor housing (a), the engine support (B), along the engine body (c) and the ignition component (d). As can be seen there is no increase in the levels of vibration measured in the container, the motor support and on your components, indicating that the used package absorbs vibration levels produced by the transport vehicles. During the flight a reduction of more than 80% in vibration levels could be observed as well.

Conclusions

This work presented the results of the analysis of transmissibility of the vibration and shock levels on the S43 rocket engine subjected during transportation between the Aeronautics and Space Institute in São José dos Campos and the Alcântara Launch Center in Maranhão. The 4-point vibration levels on the pallet were measured as the reference input excitation vector on the pallet and the values found as response, on the engine body, indicated that there was no increase in vibration levels above that established by the Transport Standard. The propagation of the vibration levels induced by the transport means as well as the handling operations for the used packaging showed that there was a significant reduction of the vibration levels when compared to the measurements made in the input vector, in this way it can be concluded that The container used to transport the engines

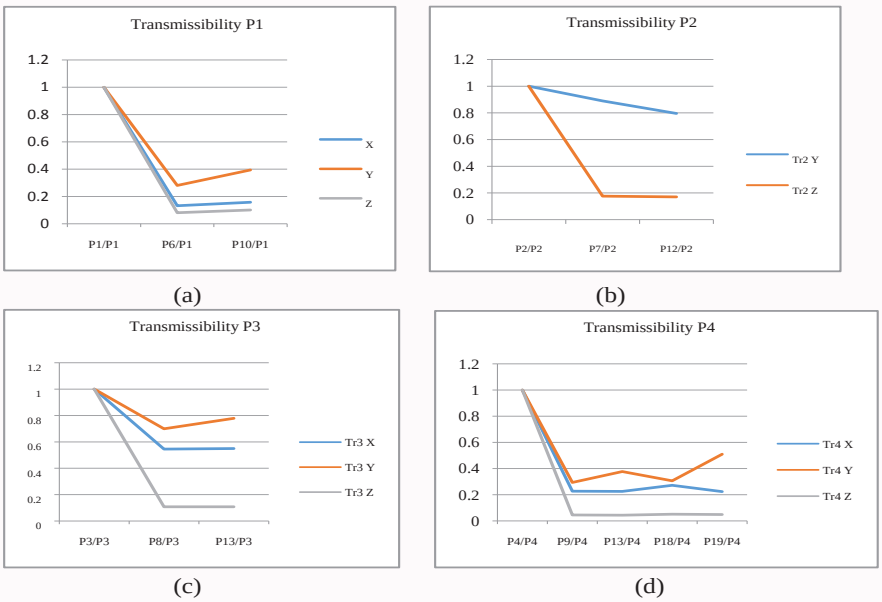

Figure 3: Transmissibility on the engine pack related to the (a) P1; (b) P2; (c) P3; (d) P4.

did not amplify the vibration levels in the engine and the igniter, guaranteeing their integrity in all transport phases.

Acknowledgment

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