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# A Review on the Influence of Test Bed Dynamic Characteristics on Thrust measured during Static Fire Testing of Solid Rocket Motor case

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***Abstract: Solid propelled rocket motors (SRMs) static firing tests are crucial tests in the aerospace industry while developing new motors as well as to ensure the quality of a motor batch. The operator can use this sort of test to determine whether the motor performance meets the project criteria by obtaining the measured "thrust versus time of burning" graphic the motor produces while burning. In this paper over all thrust measurement uncertaintyof a solid propellant rocket motor test bed is studied. During static test of solid motors requires the dynamic characteristics of the Static test configuration. To find out the magnitude of thrust oscillation, characterization of test setup and force transfer characteristics from motor case to load cell are required.***
***Keywords: Static fire tests, solid propellant rocket motor case, static test configuration.***

## I. INTRODUCTION

A rocket is a missile, spacecraft, aircraft or other vehicle which obtains thrust from a rocket engine. In all rockets, the exhaust is formed entirely from propellants carried within the rocket before use. Rocket engines work by action and reaction. Rocket engines push rockets forwards simply by throwing their exhaust backwards extremely fast. Chemical rockets are the most common type of rocket and they typically create their exhaust by the combustion of rocket propellant. Chemical rockets store a large amount of energy in an easily released form, and can be very dangerous. However, careful design, testing, construction and use minimize risks. Here we are concerned with the dynamic analysis of solid rockets motor case. In solid propellant rocket motors the propellant to be burned is contained within the combustion chamber or case. The solid propellant charge is called the grain and it contains all the chemical elements for complete burning. Once ignited, it usually burns smoothly at a predetermined rate on all the exposed internal surfaces of the grain. Initial burning takes place at the internal surfaces of the cylinder perforation and the four slots. The internal cavity grows as propellant is burned and consumed. The resulting hot gas flows through the supersonic nozzle to impart thrust. Once ignited, the motor combustion proceeds in an orderly manner until essentially all the propellant has been consumed. There are no feed systems or valves.

## II. SOLID PROPRELLANT ROCKET MOTORCASE

The Solid Rocket Motor, that stores the fuel required to propel the rocket, is an important part of the rocket. An insulator, combustion chamber, nozzle, tube, grain, and solid rocket motor are typically included. The rocket motor runs by ejecting out high-temperature flue gases via the nozzle to produce enough thrust for the rocket to drive; because they store the propellant, it functions like a pressure vessel. A simple solid rocket motor consists of a casing, nozzle, grain and igniter. The grain behaves like a solid mass, burning in a predictable fashion and producing exhaust gases. The nozzle dimensions are calculated to maintain a design chamber pressure, while producing thrust from the exhaust gases. Once ignited, a simple solid rocket motor cannot be shut off, because it contains all the ingredients necessary for combustion within the chamber in which they are burned. More advanced solid rocket motors can not only be throttled but also be extinguished and then re-ignited by controlling the nozzle geometry or through the use of vent ports. Also, pulsed rocket motors that burn in segments and that can be ignited upon command are available. The combustion takes place in the motor case; therefore, sometimes it is referred to as combustion chamber. The case must be capable of withstanding the internal pressure resulting from the motor operation with a sufficient safety factor. Therefore motor case is usually made either from metal (high-resistance steels or high strength aluminum alloys) or from composite materials (Glass, Kevlar and Carbon). Motor case design is governed by the motor and vehicle requirements, such as performance characteristics (including motor propellant grain design), envelope constraints, mission profile, and other components within the individual stage and the vehicle. These factors are interdependent in their influence on the case design.

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In some programs, the basic case design parameters, including length-to-diameter ratio, external constraints, internal pressure, motor case flight loads, and propellant mass fraction, are specified. In other programs, these design requirements must be determined in studies to define the optimum trade off relationship between the case design parameters and the motor and vehicle design parameters.

## III. PRESSURE OSCILLATONS IN SOLID ROCKET MOTORS

Large solid rocket motors' (SRMs') well-known issue is pressure oscillations. Pressure oscillations in this type of engine result in thrust oscillations and large dynamic loads which often demand dampers on the payload, lowering the payload mass capacity and launcher use. Although pressure oscillations cannot yet be totally regulated, the physics of the process that creates them in SRMs has caught the interest of several researchers over the past few decades. After the majority of the fuel has been burned and vortices have formed in the flow of the gaseous combustion products, pressure oscillations start to occur in the combustion chamber of an SRM.

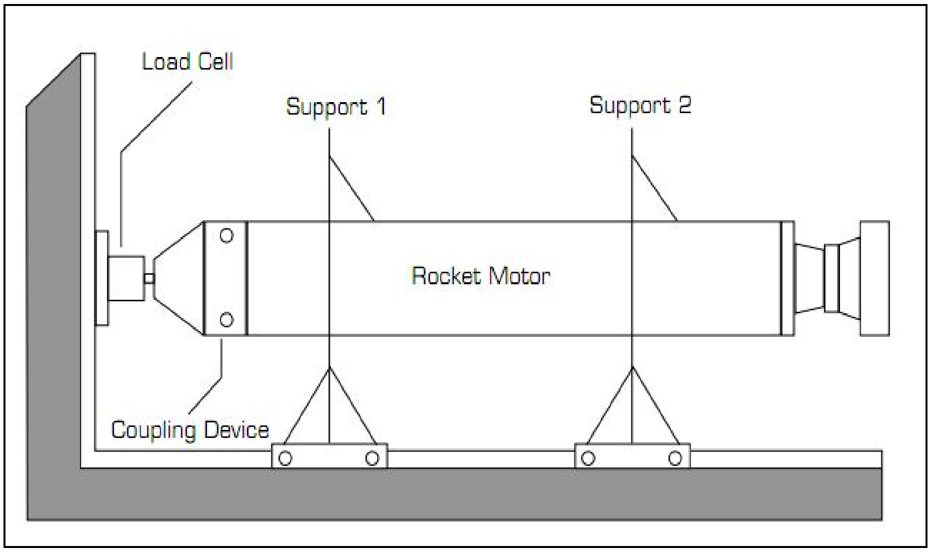


Fig.1. Typical set up of a SRM firing test.

The rocket engines are tested statically to evaluate the performance of engine based on thrust produced. One of the most important parameters of the rocket engine static testing evaluation is to measure the thrust produced by the engine. The thrust produced is measured using a Thrust Measurement System (TMS)which is a structural element equipped with load cells. The upward movement due to the thrust developed bythe rocket engine is felt through the load cells and its linkages.TMS consists of structural elements and load cell link assembly so as to measure and transfer the thrust to the test stand structure. Every thrust stand usually has three characteristics in common. The first thing to note is that every thrust stand makes use of a fixed support structure to which all thrust loads are finally applied and reacted. Second, each thrust stand contains a floating component that affects how the thrust forces are transmitted to the response structure. Last but not least, all thrust stands introduce some tare into the raw data that is being captured due to the principles of physics, therefore the raw data must be further reduced to the actual, delivered thrust. The engine or motor type being examined determines all of these characteristics. However, the third is sometimes forgotten while being as important for correct thrust measurement.

## IV. THRUST MEASUREMENT UNCERTAINITY

Thrust is defined as the force created as a result of the working fluid's acceleration reacting. It can also be described as the force created when the propellant's momentum changes. Based on Newton's third law, which states that there is an equal and opposite response to every action, thrust is created. The force is what propels the rocket through the atmosphere and into outer space. It is created by the rocket motor, which is part of the rocket propulsion system. When the propellant leaves the nozzle at a high rate of speed and travels in one direction, the thrust force develops in the opposing direction. Determining the accuracy and precision of a measurement is an important distinction in thrust measurements. It is widely known that it is very possible to measure accurately but not precisely. Conversely, it also possible to very precisely measure an inaccurate value.

The relative certainness of a measurement is rather peculiarly referred to as measurement 'uncertainty'. Uncertainty is, by its very definition, being in a state of doubtfulness or unknowingness. Analogous to the critical nature of thrust data acquisition integrity, the uncertainty estimates of this acquired data is of equal importance. It seems reasonable, considering the amount of effort and attention to detail required to accurately and precisely measure thrust, that the same rigor be applied to determining the goodness of the acquired data.

There has been many papers and books written concerning uncertainty and its calculation. This specific work discusses how uncertainty should be generally applied to both theoretical endeavors and empirical studies where data is directly acquired; but it does not specifically address the unique case of thrust data acquisition from a static test stand. Detailed uncertainty analyses of thrust measurements on a large-scale liquid rocket motor static test stand was studied in recent research paper. This analysis revealed that alignment and load cell uncertainties were the major contributors to thrust measurement uncertainty. Finally, Sims and Coleman share an enormous amount insight into large rocket motor alignment for a permanently mounted static test stand. This worked proved path hysteresis is an excellent indicator of rocket motor misalignments and can be used as a tool to ensure the trueness of coaxial centerlines between a rocket motor and a static test stand. Although similar in some aspects, none of the aforementioned research specifically chronicles the physical setup of a mobile static test stand in regards to alignment and dynamic response of a load cell employed to measure thrust at this test area.

It will build on the current knowledge base, identify the major contributors to alignment and dynamic issues in regards to mobile static test stands, and attempt to present a methodology to optimize the acquisition of consistent, accurate, and reliable thrust data from mobile static test stands. The data acquired from rocket motor static firing tests was analyzed solely in the time domain with little or no emphasis placed on frequency-based analysis[6].

The frequency response of the fixtures and the resulting mechanical pathways encountered during these tests were of little, if any concern. Fixtures were generally regarded as no more than a captive component of the test and not as an integral part of the data collection process. As a result, and to varying degrees, many thrust curves generated contain a "ringing" component. Depending on the frequency of this ringing, it could be attributed to electrical noise. However, at other frequencies where the values did not fit nicely into a harmonic of electrical noise, mechanical resonances were identified as the possible source. Without benefit of the high-end modeling and analysis tools that are now readily available; the simple principle of compression, through the use of in house fabricated preload-rigs, was employed in an attempt to 'tighten' and tune-out unwanted mechanical resonances. Currently, preload-rigs are still in use at this test area.

Higher capacity load cells require larger and bulkier mounting equipment and are more difficult to handle. Although this becomes more of an issue during large rocket motor testing, it can still cause setup issues and delays during small rocket motor testing. As a consequence, a general analysis of overall system dynamics was initiated to determine any measurable effects on the data collected and to devise a more practical and scientific way to resolve the aforementioned dynamic response concerns. The data acquired on the fwd end of the motor, at the thrust adapter / motor interface, indicates the motor itself is slightly influenced by the resonate response of the load cell / thrust adapter arrangement. For the datasets that captured this resonance, their values are at least an order of magnitude below what is seen at the thrust adapter. This too is most likely attributed to decoupling effects at the thrust adapter / motor interface.

## V. CONCLUSIONS

In a static test stand, there are few number of sources of uncertainty for thrust measurements. The sources that were examined include motor alignment, calibration processes, structural resonances, and data gathering. It was seen that increasing the spring constant, or the stiffness, of the load cell results the shifting of resonance frequency. This reduced the structural oscillations in the thrust measurement during motor firings, resulting from load cell resonance, to acceptable levels.

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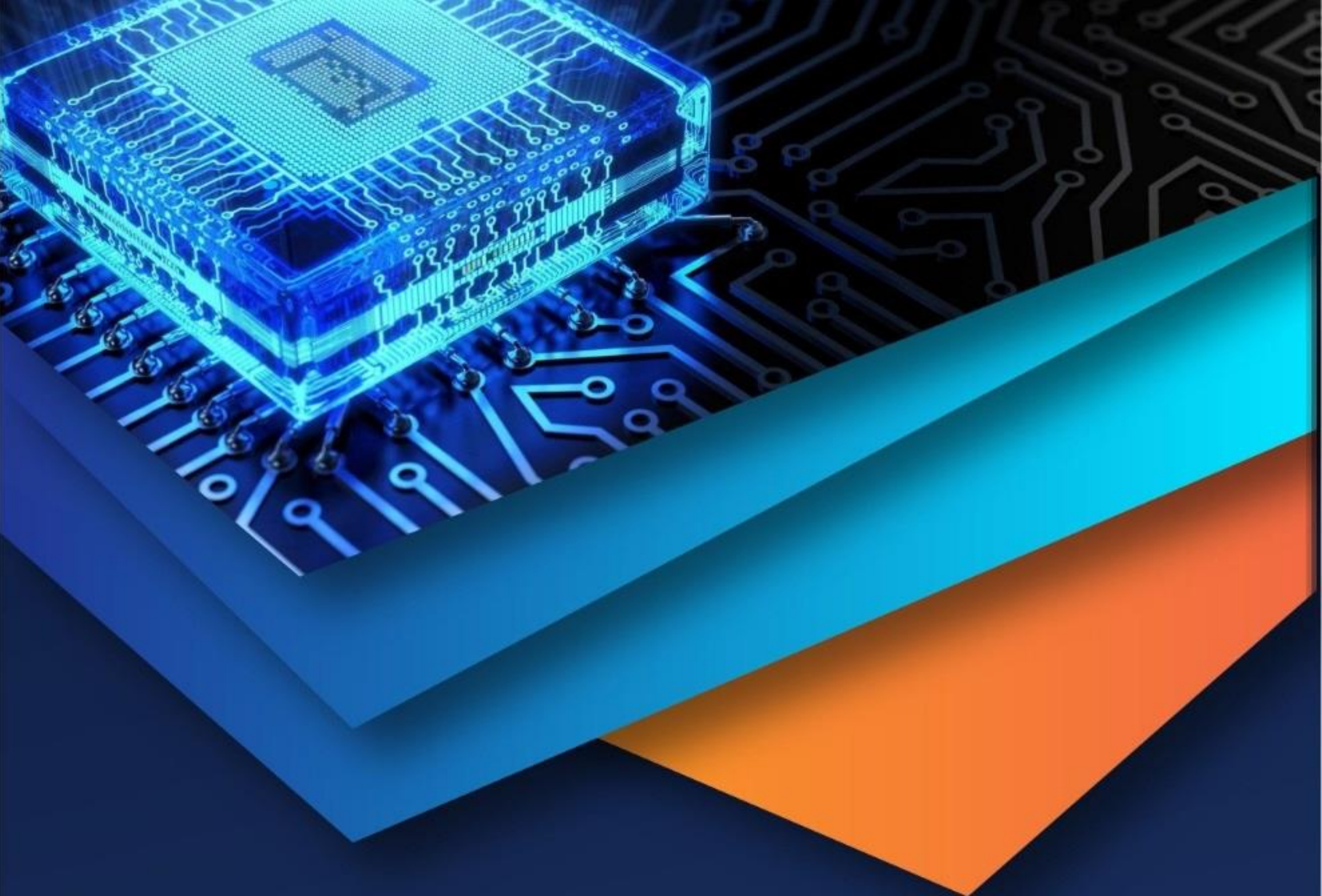


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