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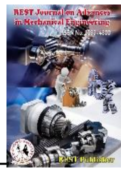

Theoretical Study on Burn Rate of Composite Propellant Strands Using Acoustic Emission Technique

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Abstract. Acoustic emission testing is one of the most common and effective non-perishable test methods that allow testers to collect data and provide accurate propellant results. Acoustic discharge occurs when an object is under pressure or due to holding a heavy load or from extreme temperature changes, heat stress, cold cracks, melting, bond failure, and fiber are sources of acoustic discharge. The sensors used to record acoustic emissions use piezoelectric material. The effects of various parameters on the combustion rate of solid propellants are discussed and reviewed. The preferred method of overheating heat reduction techniques is acoustic extraction as it is very simple, fast, expensive, and can be performed with 98% accuracy. However, with a more accurate burn rate using BEM. BEM, however, requires a large amount of propellant. So, in everyday practice, the acoustic extraction method is well used by geothermal scientists worldwide. The craw ford bomb is the oldest method of temperature measurement, the only one that is most suitable for double base propellants with an accuracy of 97 to 98%. Advanced technologies such as closed bombs, ultra-noise measurement, microwave, x-ray, and plasma power, etc. While the chimney-type laser method is very complex but naturally boring further with various diagnostic methods such as x-ray, method of -flash, and pressure. The capture method, the servo method measurement method, and the high-speed motion detection method to determine erosion are also important.

1. Introduction

Solid propellant composite temperature is a combined function of several physical, mechanical and chemical components such as temperature, pressure, temperature and flexibility, chemical reactions to the gas interface and abbreviated phases, etc. It is one of the most important quality measures. Features due to its ability. The combustion rate Solid propellant composite temperature is a combined function of several physical, mechanical and chemical components such as temperature, pressure, temperature and flexibility, chemical reactions to the gas interface and abbreviated phases, etc. It is one of the most important quality measures. Features due to its ability. The combustion rate determines, by the combustion point, the combustion processes, the flow rate of the mass and therefore directly controls the pressure and gravity of the vehicle. Strand burner methods are a common way of measuring the rate of constant burn. Advanced technologies such as ultrasonic waves, X-ray rays, microwaves, videography, plasma capacitance, fuse wire, acoustic emission, etc. Acoustic extraction is a higher and faster method compared to other hard-to-measure solid fiber burners. The ballistic behavior of a solid propellant composite is influenced by its combustion rate. The burning rate is defined as the line level of the propellant retreat with parallel layers in a straight surface on the surface itself. The parameters affecting the temperature pressure and the grain temperature of the propellant, the composition of the propellant, the size of the oxidizer particles, and the erosive combustion includes testing of small samples in the laboratory, shooting of small vehicles, and finally full shooting in designated testing areas. Acoustic emission testing is a method of testing that uses ultrasonic pressure waves to detect defects in objects. Temporary pressure waves are produced by the rapid release of energy from local sources, eg, fractures within an object. The AE then converts the waves into electrical signals for recording. AE sensors measure high-frequency energy signals produced during the removal of equipment and machinery involved in the process, so with the help of these sensors, the results can be achieved. found in software.

Various methods for determining the temperature levels of solid propellants can be explained. The parameters for improving the temperature of the heat can be explained with the help of graph pressure or thrust vs time. Test results and data acquisition results are good enough for a measure of burn rate. Measuring the combustion rate using an acoustical extraction method is one of the most reliable and robust methods for measuring propellants at a constant temperature. In this work, attempts were made to estimate the thermal conductivity of solid propellants in the form of acoustic emissions using mathematical tools. Determining acoustic heating rate as it is very simple, fast, expensive, and can be done with 98% accuracy. However, with the exact amount of BEM combustion used.

2. Literature Review

Garima Gupta et.al studied the combustion rate of solid propellants, whether stable or solid, under a variety of conditions operating conditions are very important for the use and application of important reasons. The average burnout rate is web crowding to burn time. The effects of the real world as a unique and unique web - rapid fatigue makes accurate temperature measurements difficult. The size/time method and large balance method are two measurement methods for determining the temperature range [1]. Ehtasimul Hoque et.al explained the pressure exponent is lower in the middle than the average pressure range. Parameters such as bore offset, feature-length, neutral track design, measurement number, etc., influence heat. Neutral error, incorrect - Quick error, error saving a lot of three errors that occur during retrieval of simulation results. The pressure duration is greater than the average pressure. The propellant neutrality error will increase with low pressure due to the fatigue process that extends to a large part of the tail process. Measurement engine on a full scale in a strand gauge is a standard measurement feature [2]. R. S. Fry et.al observed the temperature sensitivity structure is easily measured in the strand burner and can therefore be compared between propellants without the influence of motor geometry. Cost - The efficiency of a ballistic test engine as a generator cannot be added without increasing the sensitivity of the pressure gauges. The acoustic extraction method is approved as a standard ballistic manifestation of propellant strand [3]. The burning rate of solid propellant is important for its validity, and is determined by performing small sample experiments, and if successful small sample experiments will then proceed with larger scale scaling.

S. Krishnan et.al presents an experimental study of un metalized AP/HTPB composite propellants utilizing various burning rate modifiers. The burning rate of a propellant with a depressant can, even more, be depressed by the reduction in the AP size particle. The burning rate enhances and decreases LPDL whereas the depressants augment it. For a propellant composition, when the reduction in AP particle size increases the burning rate of LPDL is decreased [4]. The effect of correlation is a redaction of the standard error of the burning rate formula [5]. The solid propellant's steady burning rate which varies according to formulation, pressure, crossflow velocity, radiation, and initial temperature plays one of the most important roles in controlling solid propellant rocket motor operation. The burning rate is a complex physical property due to associated high-temperature heat transfer, mass transfer as well as a chemical reaction occurring in the gas phase, interface, and condensed phase of the burning solid propellent [6]. The microwave system can be used for precise determination of the base burning rate of solid rocket propellants under different pressures during only one test at a defined initial temperature in laboratory conditions similar to those in a real rocket motor. The burning rate of solid propellants depends on pressure and initial propellant temperature, cross-flow velocity, propellant type, fuel-to-oxidizer ratio, and oxidizer particle size in the case of composite propellants [7]. The burning rate is defined as the distance traveled by the flame front per unit of time perpendicular to the free surface of the propellant grain at a known pressure and temperature. Paper presents the inclusion of metal filaments or wires in propellant in enhances the burning rates without modification of chemical composition [8].

3. Methodology

Burning Rate measurement using acoustic Technique: A strong propellant cord should be 6 * 6 * 131 size that falls below the limited parameter. We then connect the nichrome igniter cable to one part of the propellant series, allowing about 3 mm of propellant over the lamp cord, thus setting the panel. The prepared sample is then blown inside a closed bomb while immersed in water. A heartbeat is given when the bomb is pressed with nitrogen gas to meet the desired combustion. Although the water level in the vessel should be 1100ml at a temperature of 24 degrees. Therefore, Water acts as a natural sideburn inhibitor and a device for delivering sensory signals produced by propellant combustion. An external sensor attached to a burning bomb captures these sensations. Then this data acquisition program captures and displays the output signal from the voltage vs. time domain. Finally, the rate of propellant combustion is calculated by measuring the time it takes for the flame to consume a certain propellant length by a certain pressure.

Experimental methods employed for the determination of burning rates:

Crawford Bomb Technique: The Crawford Bomb was designed to measure the temperature of solid propellants in an inactive area where fuse wires are inserted into the propellant strand, as well as the distance between the fuse wires and the heating time between the fuse wires are monitored.

Closed Vessel Technique: In the closed vessel case, the pressure is recorded as a time function and the temperature is calculated.

Line ln (DP/dt) v / s ln P provides a straight line and fixed a1 can be calculated from ln crossing (qa1/LCpTo)

Ultrasonic Measurement Technique: By showing the machine wave with an explosive sample in a closed bomb, the ultrasonic method tests the burn rate as a pressure function in a single test. Keiichi et al. modified the ultrasonic method for measuring the combustion rate of propellants using the Doppler effect and Wavelet analysis on an electronic device that uses the sonic speed of the propellant.

Microwave Techniques: Microwave techniques are used to measure the temperature of the propellant strand. The negative effect of additional time-varying displays has been imitated and the improved data reduction method for predicting the temperature range has been used.

Acoustic Emission System: The combustion rate of solid propellants is measured by acoustic emission testing as a pressure function. This technology is used in large-scale production based on composite propellants for rapid testing or quality control. The acoustic emission system includes a bomb, a transducer, a preamplifier, a panel made of protective material, and a transducer mounted on one side of the bomb. Using acoustic emission, the propellant strand is plugged into the board, ground with nitrogen gas at the required pressure, the shield is ignited electrically and the acoustic output signal is used to calculate the propellant combustion rate.

Burn Rate Physics: The main objective of small-scale motors is to measure the burning rate in a motor environment by saving time and money during the actual motor development.

4. Burning Rate Measurement Analysis Methods

Our understanding of thermal analysis methods can be improved by examining the processes used by the various institutions and countries involved in measuring and analysing the thermal conductivity of solid power systems. Developed methods in different institutions often present different estimates of the value of combustion. Another way to differentiate data analytics methods for propellant, motor, and metal variants is to generate and analyse time-compressed vehicle compression data to find the right “safe” engine with “perfect” components. The real one may be unseen by adding a known propellant, engine, or instrumentation to the car's imitated data. Alternatively, the "real" vehicle data may be analysed to disclose any improperly created results using simulated data.

Description of Methods of Burning Rate Analysis: Two families of fundamentally different burning rate determination methods exist. One is based on propellant thickness and the burning time and is referred to as the thickness/time method, and the second is based on the conservation of mass in the ballistic test motor and is accordingly termed mass conservation or mass balance method. These two families may be further divided into the following categories, which are more descriptive of their specific application:

1) **Thickness/Time Methods**
   A. Thickness/time Rate (rTOT or RTOT)
   B. Iterated Thickness/Time Rate (rTOTn or RTOTf)
   C. Iterated Two-Point Thickness/Time Rate (rHG or RHG)
2) **Mass Conservation Methods**
   A. Mass Balance Rate (rMB or RMB)
   B. Iterated Mass Balance Rate (rMBf or RMB)

Mass Balance (MB) Rate: Another method based on other estimates of cost savings was developed around 1960-64 to address factors that affect density/duration. Generally, a large balance ratio shows less data scattering than density/time, because it corrects instantaneous fatigue.Bulk balance methods check the constant rM temperature, indirectly, from the balance between the input flow from the blazing bullet out and the large flow through the vent throat. The latter includes the quantities collected at room temperature due to the increase in pressure and the volume increase (due to the propellant used). The burn is thought to have occurred during the operation of the vehicle, which consistently proves the instantaneous fatigue.Representative mass balance methods currently in use by facilities surveyed by WG01 6 include:Common Mass Balance Method, Vellacott's Method, Brooks' Improved Method, and Jordan’s Combined Mass Balance with Thickness/Time Method.

Another unexpected increase in pressure may be due to a non-uniform regression of the grain surface, resulting in a burning rate enhancement along the inhibitor called "coning".

1. Strain on the propellant;
2. Migration of curing agent or other propellant ingredients (from within the propellant and/or from the inhibitor into the propellant) that may increase the burning rate,
3. A different propellant composition near the inhibitor (e.g. a local concentration of fine particles),
4. Deviation from the 1 D heat transfer situation due to better heat conduction along the inhibitor.

For all grain shapes the propellant burning "situation is considered one-dimensional (burning velocity vector pointing perpendicular inwards). This assumption is most realistic for the end-burning grains, it is less realistic for the centrally perforated (CP) grains, while it is even less realistic for the star-shaped propellant grains.

5. Burning Time Definitions

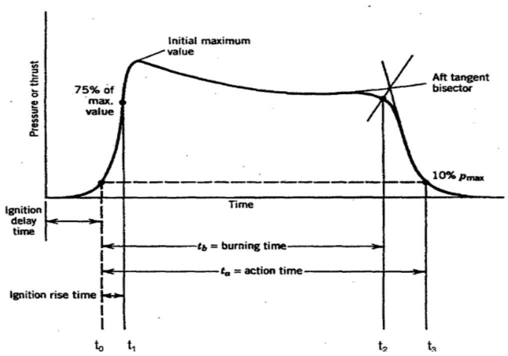

FIGURE1. Definitions of the Burning Times

Motors can experience an effect, called "hump" or BARF (Bum Anomaly Rate Factor) effect in motor pressure-time behavior. This effect can create varying challenges for the burning rate analysis methods. This effect is the result of radial variations in the burning rate caused by the rheology of the grain manufacturing process, e.g., casting the grain and subsequently plunging the mandrel.

6. Small Motor Data Quality

Measurement of a mean burning rate, in any device, depends upon several general, typically implicit, assumptions, including at least the following;

The propellant is homogeneous, with isotropic properties, Specimen has uniform bulk formulation and properties, specimen has known dimensions, the specimen is at a constant temperature, Equilibrium 1ID burning prevails throughout, the Test environment remains constant during the entire test, and Instrumentation is accurate and noiseless.

Propellant Effects: Burning rate is considered a bulk propellant property, dependent upon chemical composition (e.g. oxidizers type(s) and size distributions, binder type and content, binder curing, binder additives, catalysts, burning rate modifiers, and their particular fractions). In manufacturing a batch of propellant, considerable care is normally taken to assure the proper weight fractions of the several ingredients and the even distribution over the propellant mixture, however, due to various reasons some small variations always persist.

Variations in Propellant Formulation**,** Formulation Gradients**,** Cure Shrinkage Variations**,** Non-Steady Combustion**,** Surface Texture Evolution**,** Ignition Pressure**,** Burnout Point**,** Size Effect**,** Hump effect.

On a macroscopic scale, solid propellants are seen burning in a normal hot spot, such as the planar areas remaining stable and receding with a continuous degree of given pressure and initial temperature. On a macroscopic scale, solid propellants burn as an equal material. Such recognition has led to the basic definition of the degree of heat as the heat dissipation per unit of time.

On a microscopic scale, however, composite propellants are not homogeneous but contain particles in the binder matrix. Composite propellant combustion rates are considered sensitive to the distribution of particle sizes, and burn models show that individual heat levels vary in size. This significant difference in ambient temperature is associated with improved microscopic surface texture. It is thought that the flat surface of the macro-surface shrinks as a stochastic combination of cells of the outer texture, in such a way that the maximum flexibility and degree of burn varies both locally and temporarily.

Testing Effects: Testing of propellants has the objective of obtaining the propellant (ballistic) properties at certain well-defined test conditions (e.g., temperature, accuracy of the data acquisition, and data reduction equipment). In real experiments, however, this ideal situation can only be approximated:

Temperature Gradients**,** Temperature Variations**,** Transducer Frequency Response**,** Characteristic Motor Noise**,** Estimated Combustion Noise**,** Small Natural Pulses in the Motor**,** Acquisition Card Error**,** Instrumentation Noise Considerations

Ultrasonic Instrumentation is recommended for the use of standard ballistic tests of propellants in research and industrial settings. The Plasma Capacitance Gage (PCG) is recommended for improvement. The acoustic extraction method has been approved as a standard ballistic representation of moving strings, as well as further improvements in the use of full-scale motors to monitor the emergence of grains. X-ray diagnoses and microwave methods are not recommended as standard ballistics tools. Recommendations have been made to develop existing strategies, which may provide further improvements in measuring the temperature.

Acoustic Technique: It is well known that the Crawford bomb is an acoustic extraction machine that provides solid propellant combustion concentrations with high pressure to obtain thermal propellant properties. This section describes the complete structure of the Crawford bomb system. The explosive device is connected to a control PC to monitor all remote sensing. The software includes all security keys and checklists. Also, it provides user usage to display both Acoustic sensor responses and Pressure transducer. The total sub-systems used in the Crawford apparatus are described as follows:

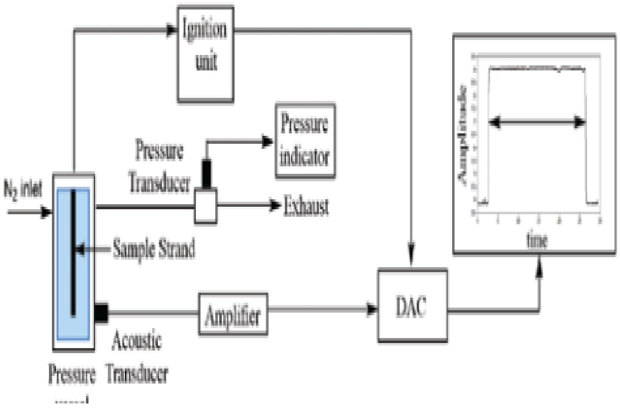

FIGURE 2. Burning rate measurement using acoustical emission technique.

Pressure vessel:The pressure vessel, also known as bomb housing, is made of SS 316 material. This tool is suitable for testing sample lengths up to 250 mm. Operating pressure ranges from 0-350 kg / cm2. The compression bag consists of a panel for mounting a rope. It should be made of protective materials such as Asbestoses.

Acoustic Transducer:Acoustic device for detecting and converting audio signals for purposes of measuring, transmitting, playing, recording, or analyzing. Transducers that convert acoustic signals into electric signals (electroacoustic transducers) are the most common. The most important characteristics of such transducers are sensitivity, which is the ratio between an electrical signal (voltage, current) and an acoustic signal (for example, sound pressure); frequency response; electrical self-control; and the directional pattern. Nowadays, acoustic wave devices are widely used to determine size, viscosity, conductivity, and density. They have the advantages of high accuracy, high sensitivity, easy integration, good reliability, small size, lightweight, and low power consumption.

In addition to transducers that produce an electrical signal that reproduces the time variations of the corresponding acousti c signal (pressure, fluctuating particle velocity), transducers also exist that measure the averaged characteristics of a sound wa ve. They include, for example, the Rayleigh disk and radiometers. Thermocouples encapsulated in the sound absorptive envelope are used in the ultrasonic range; their electromotive force is proportional to the ultrasound intensity.

TABLE1

Operating temperature (^{0}C)	0 to +100
Shock limit (G)	10,000
Case material	SS 304
Face material	Ceramics
Resonant frequency (kHz)	200 [800]
Directionality (dB)	± 1.5

Firing ignition system:The telephone process of the ignition system is used to measure the temperature. Three small holes were drilled precisely near the length of the cord using a needle. The igniter and two fuse cables are connected to these holes and are connected to electricity and a timer by electrically. An 18V DC supply is provided for wiring. 5 Amp batteries used to pass Nichrome cable.

Pressure Transducer:A pressure transducer commonly referred to as a pressure transmitter is a transducer that converts pressure into an analog electric signal. While there are different types of pressure transducers, one of the most common is the strain gauge-based transducer.

The conversion of pressure into an electrical signal is achieved by the physical modification of heavy gauges connected to the diaphragm of the pressure transmission and connected by cable to the configuration of the Wheatstone bridge. The pressure applied to the compression transducer produces a diaphragm distortion that introduces weight to the gauges. The difficulty will signal a change in electrical resistance in terms of pressure.

TABLE2

Measuring pressure range (bar)	0-200 bar
Normal bridge excitation	15 V DC ± 5mV
Temperature range	20^{0}C – 110^0 C
Sensitivity	2 to 2.5 mV/V
Insulation resistance	350 ± 5 **Ω**
Diaphragm material	Stainless steel

Signal Conditioner:Signal suspension is a data acquisition process, and a tool called signal conditioner is used to perform this process. This tool converts one type of electrical or mechanical signal (input signal) to another (output signal). The goal is to amplify and transform this signal into an easy-to-read and consistent way for data acquisition or machine control. The main function of the signal conditioner is to take the signal and convert it into a high-quality electrical signal. The signal conditioner helps to provide accurate measurements, which are important for accurate data acquisition and machine control. These instruments can perform an additional number of different functions.

TABLE 3

Sampling rate	200 kg/s
Input range	± 10V
Input gain	0.5 V to 100 V

Amplifier:An amplifier, amplifier, or (random) amp is an electrical device that can increase signal strength (voltage that changes time or current). It is a two-hole electronic circuit that uses electrical power from the power server to increase the amplitude of the signal used in its input terminals, producing an equally large amplitude signal at its output. The amplifier value provided by an amplifier is measured by its value: output voltage, current, or input power. An amplifier is a circuit that has the advantage of more than one power.

TABLE 4

	Pre-Amplifier	Post Amplifier
Power required	28 V	240 V AC ± 10 %
Operating current	25 mA	100mA current limit

Output voltage	20 Vpp into 50 Ω	-
Bandwidth	10-1200 kHz	-
Gain	40/60 dB	0-61dB
Noise (RMS rti)	<2 μV	25 V

7. Conclusion

The acoustic emission solid emission data were evaluated and rated accordingly to quantify the burn rate. Statistically, sensible sample members were obtained by measuring the solid-state temperature of solid propellants with different types of temperature levels. A concerted effort has been made to review the various methods of determining the temperature levels of solid Rocket propellants by highlighting their ease of use and the suitability and disadvantages of each strategy.

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