Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 8, No. 3, August : 2023

A REVIEW ON STRUCTURAL AND THERMAL ANALYSIS OF ROCKET MOTOR CASING

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Abstract
The Structural and Thermal Analysis of Rocket Motor Casings plays a pivotal role in optimizing the performance and ensuring the safety of space exploration missions. This research presents a comprehensive study on the design, simulation, and evaluation of a rocket motor casing, focusing on enhancing its durability, reliability, and thermal management. The rocket motor case is an inert or non-energy-contributing missile component; the layout goal is the materials used in the rocket motor casing must be lightweight and able to withstand high pressures and elevated temperatures due to the combustion of the fuel. The 2D drawing is developed using AutoCAD software, and the 3D model of the casing is developed using "CATIA V5" software. Structural and Thermal analysis is done using "ANSYS 15.0" software.

Keywords: Rocket Motor Case, Structural Analysis, Thermal Analysis, CATIA, ANSYS.

I. Introduction

Rocket motor casings play a critical role in the successful operation of rockets, providing structural support and containing the immense forces and temperatures generated during the propulsion process. The structural and thermal analysis of rocket motor casings is a fundamental aspect Types of Structural Analysis:

1.1 Purpose of Structural Analysis

Structural analysis is the process of evaluating the mechanical integrity and strength of the rocket motor casing. The primary purpose is to determine if the casing can withstand the stresses andloads it will experience during various phases of flight, including launch, acceleration, and combustion. Engineers use advanced simulation techniques and mathematical models to predict the behavior of the casing under different conditions, identifying potential weaknesses and areas that may require reinforcement.

Types of Structural Analysis

1. **Static Analysis:** This involves assessing the casing's response to steady loads, such as gravitational forces during storage or transportation.
2. **Dynamic Analysis:** Evaluates the casing's behavior under varying and time-dependent loads,like those experienced during launch and flight maneuvers.
3. **Fatigue Analysis:** Investigates how repeated loading and unloading over time might lead to structural failure.
4. **Buckling Analysis:** Examines the casing's susceptibility to buckling, a critical failure modewhere it deforms under compressive loads.

1.2 Purpose of Thermal Analysis

Thermal analysis is crucial in understanding how the rocket motor casing responds to extreme temperatures generated during combustion. The casing must protect the propellant and other internal components from excessive heat, preventing any unwanted chemical reactions, distortion, or damage. Accurate thermal analysis ensures that the casing remains within acceptable temperature limits during the entire mission.

Types of Thermal Analysis

1. **Steady-State Thermal Analysis:** Evaluates the temperature distribution in the casing under constant operating conditions.
2. **Transient Thermal Analysis:** Studies the temperature changes over time during variousphases of the rocket's flight, from ignition to shut down.
3. **Thermal Stress Analysis:** Assesses how temperature gradients induce stress in the casing material.

1.3 Material Selection

The structural and thermal analysis significantly influence the material selection for the rocketmotor casing. The chosen material must exhibit high strength, stiffness, and thermal resistance whilebeing lightweight to optimize the rocket's overall performance. Here are some factors to consider when choosing materials:

1. Temperature Resistance: Rocket motors experience extreme temperatures during operation, especially in the combustion chamber. Materials selected should have high-temperature resistance and should not undergo significant degradation or softening at operating temperatures.

2. Strength and Stiffness: The material must be able to withstand high mechanical stresses andforces generated during launch and thrust. High strength and stiffness are essential to preventdeformation or failure under pressure.

3. Density: Lower density materials can help reduce the overall weight of the rocket, increasingpayload capacity and improving fuel efficiency.

4. Thermal Conductivity: The material's ability to conduct or dissipate heat is vital to prevent localized hotspots or thermal gradients, which could lead to structural damage.

5. Thermal Expansion: The material's coefficient of thermal expansion should match that of other components to avoid undue stress at interfaces during temperature changes.

6. Corrosion Resistance: Rocket motor casings often come into contact with various chemicalsduring operation. The material should be resistant to corrosion and other forms of chemical degradation.

7. Cost: While performance is critical, the material's cost and availability should also be taken into account, as it can significantly impact the overall budget of the project.

8. Manufacturability: The material should be amenable to the manufacturing processes required for constructing the rocket motor casing, such as casting, forging, or machining.

II. Literature

M. A. Muhammad et al. [1] The combustion chamber of a rocket motor is crucial for absorbing the stresses caused by the thermal load and static pressure generated by fuel burning. Thermal load neglection can cause a robust casing to fail. This study demonstrates that thermal load affects the strains generated within the rocket motor casing. The ANSYS software was used to analyze thermal stress under two conditions: static stress and stress resulting from both. The investigation involved different thicknesses of CC 2.5, CC 3.5, and C.C 5.0, with identical variables applied. The maximum von-Mises stress for static load rose with thickness, with values of 69.35 MPa, 51.78 MPa, and 34.8 MPa, respectively.

W. M. W. Mohamed et al. [2] Cloud seeding rockets consist of various components, including the casing, fuel, and nozzle. The CRV7 C-15 is the best available rocket motor for cloud-seeding rockets. The study validated the methodology using a 5 mm-thick Molybdenum casing and propellants N_2H_4 and N_2O_4. The safety factor of the rocket motor casing must be at least 1.5 for 2.5, 3.5 and 5.0 mm casings. The safety factor was determined using solid AP/AL/HTPB propellant. CC 3.5's safety factor was less than 1.5, making it unacceptable. CC 2.5's safety factor was better than CC 5.0's but still lower. CC 2.5 had the lowest thickness, weight, and was less expensive to produce, making it the most appropriate case. The safety factor of any selected material with any propellant can be determined using the guidelines provided by this study.

Sariyam Teja et al. [3] Rocket motors provide thrust to flight vehicles, using Newton's second and third principles. They operate without atmospheric oxygen and face pressure loads and high temperatures. Structural and thermal design are crucial for specific input parameters, and analysis is performed to verify temperatures and stress levels. The main input parameters measured are the maximum working pressure and diameter of the motor hardware. Initial assumptions are made to calculate parameters like thickness. 2D drawings are created using Solid Works software, and ANSYS is used for structural and thermal analysis. Finite element analysis techniques generate solutions, resulting in displacement magnitude, von Mises stress, and strain. This information helps propose suitable materials for future work.
Ankith Kashyap et al. [4] The design of a motor casing is crucial in the aerospace industry, as it protects the motor from external influences and can handle high temperatures and pressures. This project focuses on the design of solid rocket motor casings using CATIAV5R19. ANSYS 14.5 is used for structural analysis, comparing various materials like maraging steel, D6AC steel, austenite, and martensitic steels. The best deformation characteristics are considered, and conclusions are drawn based on these comparisons. Comparisons are also made for Von-Mises stresses, Hoop, and Longitudinal/Axial stresses to assess the model's analytical and numerical analyses.
B. Niharika et al. [5] A solid rocket, also known as a solid-fuel rocket, uses solid propellants like fuel or oxidizer for combustion. Before the 20th century, all rockets used solid or powdered propellants, but liquid and hybrid rockets offer more effective and controlled alternatives. Two composite materials for a pole are carbon/epoxy and Kevlar/epoxy. Engine packaging planning involves analysing model stack requirements, weight parameters, and fundamental functions. ANSYS R 18.0 is used for design and analysis, with layers, modal, and static structural analysis performed to obtain stress-strain distribution. The results can be closed for finalization.
J. Emeema et al. [6] It entails modelling the casing in "CATIA V5" and utilizing two distinct materials, such as DN250 and 15CDV6, to do finite element analysis in "ANSYS 14.5," comparing the materials' thickness, length, and weight. Generally, the mix of vehicle and motor needs governs case design. Usually, the grain arrangement or geometric vehicle limits on length or diameter dictate the case's form. The shape of the casing might be anything from spherical (or nearly spherical) geometries to long, thin cylinders. Propeller storage is the primary function of the motor housing. The motor casing, which is shielded by an insulating layer, will experience extreme pressure and heat as soon as the fuel is ignited and the rocket moves.
Shaik Shaheen et al. [7] The rocket motor casing design aims to minimize weight while maintaining cost and technology constraints. Materials must withstand high temperatures and pressures from fuel combustion. This study creates a three-dimensional model using CATIA V5R16 software. ANSYS 15.0 software performs static structural, steady-state thermal, and linear buckling analyses for stack-ups of unidirectional carbon-epoxy IM10/8552 composite stacks. The results are compared with D6AC steel material rocket motor casing to determine the most efficient material.
R. Siva Sankara Raju et al. [8] This study focuses on constructing a solid rocket by calculating the motor casing's thickness, including domes at the head end, nozzle end, and flange for bolted joints. The solid rocket motor component and assembly modelling is carried out in CATIAV5R19, analysing working stress and material yield stress. The well-designed solid rocket engine allows for efficient propellant storage and impulse provision. The casing is studied using 2D axi-symmetry ANSYS 12.0, establishing stress levels for each component. The solid rocket motor design is compliant with ASME pressure vessel code, with a MEOP of 6.5 MPa and a bolt pre-stress value of 648 MPa. The flange design is completed using Schneider's methodology.
V. Ramanjaneyulu et al. [9] The Composite Rocket Motor Case (CRMC) is a crucial component in rockets, missiles, and satellite launchers, made of fibre-reinforced composite materials. This analysis involves a linear static and 3D cyclic symmetry finite element analysis using ANSYS 12.1. The analysis examines tension layers in the cylinder and domes, and investigates how stresses are affected when CRMC thickness is decreased by 0.3 mm. Zone 66 of the CRMC has the highest hoop stress,

with the innermost hoop layer experiencing a maximum stress of 558.54 MPa. Zone 45 of the Igniter End Dome experiences a maximum stress of 344.62 MPa.
Shaik Shaheen et al. [10] Within the constraints of cost and technology, the rocket motor casing was intended to be as light as possible. It is an inert or non-energy contributing component of a missile. The materials used to construct the rocket motor casing must be lightweight and resistant to high temperatures and pressures brought on by the fuel's combustion. This work aims to analyse the structural behaviour of rocket motor casings composed of D6AC steel and carbon-epoxy composite material parametrically. The software used to create the 3D model is CATIA V5R16, and ANSYS 15.0 is used for stress analysis. To determine a more efficient material, the carbon-epoxy material results are compared to the D6AC steel material results.
B. Dinesh Kumar et al. [11] Rocket motors are essential for providing thrust to a flying vehicle, allowing it to carry its payload to its desired location. They are non-air breathing propulsion, meaning the fuel inside burns without atmospheric oxygen. The hardware of rocket motors is exposed to high temperatures and pressure stresses, requiring structural and thermal design and analysis to verify temperatures and stress levels. This study focuses on the structural design of motor hardware, considering material characteristics up to 100°C. Preliminary assumptions were made to compute characteristics like thickness. Auto Cad software was used for 2D drawings, while ANSYS was used for structural analysis. The solution was produced using finite element analysis techniques, allowing for graphic representation of displacement magnitude, strain, and von Mises stress, as well as fracture analysis of the material.
Lvtao Zhu, Jiayi Wang et al. [12] The weight and functionality of the solid rocket motor case (SRMC) connector significantly impact its blasting performance. Fiber-reinforced composite materials are used in the construction, making it lightweight. This investigation conducted finite element analysis on the connector's lay-up and structural designs, comparing strain distribution to experimentation data. Results showed that at least 31% of the target weight was lost, and the final preferred solution was within the permitted range, indicating the optimal design's maximum performance. The design appears to be appropriate and within the permitted range, based on test results and finite element calculations.
Lasinta Ari Nendra Wibawa et al. [13] The study analysed stresses on a thick-walled cylinder for a rocket engine casing using the finite element approach with ANSYS software. The simulation involved 300mm long cylinders with wall thicknesses of 6, 7, 8, 9, and 10mm, with internal pressures of 2, 4, 6, 8, and 10 MPa. Material variations included CFRP, GFRP, and aluminium 6061. Results showed that von Mises stress reduces with increasing cylinder wall thickness, with safety factors larger than 1 for all wall thickness and internal pressure fluctuations. Maximum hoop and longitudinal stress decrease with increasing cylinder wall thickness. Finite element analysis validated the results, with less than 1% of findings showing errors. Von Mises stress is chosen as the standard for failure.
Lasinta Ari Nendra Wibawa et al. [14] This study investigates the von Mises stress in thin-walled cylinders and safety considerations for rocket motor situations. The cylinder has dimensions of 500mm in length, 200mm in outer diameter, and 30mm in thickness. Variations in wall thickness and internal pressure were made, and stress analysis was performed using the finite element approach. Simulation results showed that increasing wall thickness reduced the maximum von Mises stress. The material's safety factor was greater than 1.25 for all changes in wall thickness and internal pressure, indicating static loads were withstanding. Analytical calculations and finite element analysis revealed no significant differences between the maximum axial stress and maximum hoop stress, with less than 6% discrepancies between analytical computations and finite element analysis.
Emre Ozaslan et al. [15] Filament woven composite structures are popular in aerospace due to their high stiffness/weight ratio and strength. However, designing and analyzing these structures is challenging due to anisotropic properties. To ensure accurate modelling, finite element analysis was conducted on a filament-wound rocket motor housing with uneven dome apertures. The winding angle and thickness of the finite element model were compared to the built motor casing. Finite element analysis identified weak regions in the transition zone between the cylinder and dome, causing

significant bending. Design enhancements were suggested to improve the motor case's mechanical performance, resulting in a notable improvement in mechanical performance. This project highlights significant aspects of the analysis and design of filament-wound composite rocket motor casings for designers.
G. Srinivasa Gupta et al. [16] This study compares the structural behaviour of a rocket motor case made of fibre-reinforced polymer matrix composite materials. The composites consist of fibre materials like graphite and glass, along with low- and high-modulus phenolic resin and matrix materials. The study uses an analytical model and Mathematica software to analyse the composite assemblage. The phenolic resin-coated fibres are considered due to their high specific strength and specific stiffness. The findings are compared with permissible intensities of component phases, potentially benefiting pressure vessel and aircraft industries. The micro stress distribution pattern is examined under different temperature and moisture conditions.
P. Mahesh Babu et al. [17] Rocketry involves designing hardware and casing to replicate pressure vessel designs. The shell's temperatures can range from 1000 to 3000°C, with insulation causing the casing's exterior surface to reach 100°C. This study analyzes ablative layers of Haynes 255, A-286 iron-based alloy, D6AC steel, and Maraging steel using ANSYS and AutoCAD. The rocket motor casing is designed using ASME Section VIII procedures, and structural stresses, FOS, and other analysis results are obtained. The study provides valuable insights into rocketry's pressure vessel design and the use of ablative liners to withstand high temperatures.
Md Akhtar khan et al. [18] This work focuses on the theoretical design of a 100 kg solid rocket engine with predetermined parameters: 1000 psi of chamber pressure, 100 mm/sec of burning rate, and 240 sec of specific impulse. restricted to the material selection, fundamental principles of the rocket motor, and its aspects during the static test. An ablative liner, propellant grain, and metal casting make up a rocket motor, an extremely intricate aircraft component. to ascertain the solid rocket motor casing's design pressure as well as its burst pressure. Crucial propulsion outputs from the preliminary design were evaluated and improved upon in the final construction. Key words: rocket motor, motor case, Ansys, propellant grains, design, propulsion, grain form, and materials.
E. R. Heathely et al. [19] In order to complete solid propellant rocket motor thermal design calculations, this study looks at the use of analog and digital computers. Specifically, it looks into the impact and selection process of fuel-liner incremental thickness aggregated with the motor casing. The effect of neglecting the motor case heat storage on the final temperature distribution is highlighted for both ground and flight analyses. It is also shown that aerodynamic heating has a greater influence than propellant burning heating. Finally, a comparative analysis of the results for digital, analog, and exact solutions is discussed. The existing exact solutions have limitations and are only appropriate as approximations when ground standby durations are increased.
S. Remakanthan et al. [20] The study investigates radiographic images of faults detected in many solid propellant rocket motors manufactured at the Vikram Sarabhai Space Centre in Trivandrum. As imaging techniques and radiation sources evolve to meet the growing demands of launch vehicle applications, radiography research is evolving. Defects such as vacancies, porosity, fractures, and debonds impair solid rocket motor performance. Cracks and debonds are often the result of poor design, whereas voids and porosity are the result of wrong process parameters and condition selection. This study looks at radiographic images of faults observed in several solid propellant rocket engines. High-temperature physical cures, the casting process, slurry viscosity, and casting set-up configuration all contribute to the shape and direction of these flaws. Moisture in the propellant slurry or in the propellant itself.
Zhi-Bin Shen et al. [21] Under the load situation of low temperature ignition, the structural integrity of solid rocket motor (SRM) grain is severely challenged due to the combined effect of low temperature and pressure stress. Based on the three-dimensional viscoelastic finite element approach and MSC, a three-dimensional finite element model of SRM was built to investigate the structural integrity of the SRM grain exposed to low temperature and ignition pressure. Patran/Marc. Meanwhile, selected SRM

were subjected to a cold pressurization test. The experimental and numerical results were compared using the temperature and pressure uncoupling principle. The results demonstrate that the safety factor of solid rocket motor grain is 2.46, which meets the structural integrity criterion. The experimental results correlate well with the simulated results.
P. Sai Teja et al. [22] Solid rocket engines are crucial in rocketry and are used in space, missiles, and sounding rockets. They operate on Newtonian principles and are created using a phased market research technique. The goal of this experiment was to determine the sensitivity of the solid rocket engine to changing attributes and collisions. A next-generation HTPB solid rocket engine should deliver 199.3 KN thrust and the needed thrust at the commencement of ignition. The design parameters were modelled in CATIA software, and stress, strain, and deformation analyses were performed in ANSYS software. The key restriction is to achieve the same diameter and length while improving performance.
R. Ashok Ponram et al. [23] Rocket motor casings, which house the propulsion system, are critical components of aeronautical vehicles. They are normally manufactured by rolling and welding sheet metal or by flow forming. Compared to rolled and welded rocket motors, the flow forming technique provides greater geometrical and dimensional tolerances. The thickness of the flow formed casing is a significant characteristic that influences airplane performance. Traditional micrometres can be used to measure thickness, but they are limited in their ability to reach all needed areas. This study describes an ultrasonic thickness gauge and a realistic method for testing common rocket motor casings.
A. H. A. Hamid et al. [24] The research looks at radiographic imaging of problems in solid propellant rocket engines at Trivandrum's Vikram Sarabhai Space Centre. Defects such as vacancies, porosity, fractures, and debonds degrade performance and are frequently caused by poor design or wrong process conditions. The research looks at transient heat transfer by examining temperature distribution across rocket components as well as the rate of temperature rise within seconds after firing. The inside surface of the rocket engine casing, which attained a temperature of 181.8°C after 0.6 seconds of ignition, was analyzed using a transient analysis tool in SOLIDWORKS software. The temperature of the surface rises linearly with time.
Yiyao Wang et al. [25] A solid rocket engine employing the propellants CL-20 and GAP (Glycidyl Azide Polymer) was tested for thermal safety. The morphology and thermal degradation characteristics of the propellant were initially investigated using experiments using differential thermal analysis, thermogravimetric analysis, and scanning electron microscopy. For a solid rocket motor employing the propellant GAP/CL-20, a numerical cook-off model was created. This model considers both the combustion response following ignition as well as the full cooking off process, including the thermal degradation preceding ignition. Bomb cook-off tests are used to establish the model's validity and to estimate the kinetic parameters. The created model can precisely predict the temperature reaction of the propellant, according to comparisons between tests and simulations.
Kesiya George et al. [26] The catastrophic failure that happens when supersonic vehicles are in flight necessitates more concentrated investigation into the insulation of rocket engines. The successful mission of rockets nowadays heavily depends on the optimisation of polymeric ablatives as workable insulation for solid rocket motor housing. Elastomers play a crucial role in polymers. In-depth studies were shown, particularly in the elastomeric heat shielding materials with different reinforcing agents. This work reviews the state of the art in elastomer research and validates a circumstantial understanding of insulation and ablation characteristics.
Kondru Nagendra Babu et al. [27] In this study, composite joints for two specimens with double bolted single shear tensile stress are discussed. In the creation of design and permitted data, the bearing response data from single shear tests employing two-piece specimens has been heavily utilised. The work's main goal is to use the Standard Method to design bolted joints for rocket motor casing. The standard test for bearing response of single shear two-piece polymer matrix composite laminate, Procedure B of ASTM D5961, was used for the testing. In order to improve the qualities of E-glass and phenolic resin by using filler material, it also entails the production of composite laminates. E-

glass was used to create coupons due to the lack of S-glass and economic considerations.
A. Dimaggio et al. [28] In this study, random grain geometry is used to describe the internal ballistics of solid rockets using surface-mesh flow solvers. For example, employing boundary conditions appropriate for solid rocket motors, a surface-vorticity technique, originally designed for exterior flow applications, is modified for internal flow analysis. In this paper, it is demonstrated that an upgraded panel code can resolve internal rocket flow fields with a remarkable degree of realism and with a level of computing efficiency that makes it useful for the conceptual and early design of rocket motors. During this procedure, boundary constraints adequate for solid rocket rotational flows are used to develop the vortex panelling technique implemented inside Flight Stream VR. The outcomes of the simulation are then contrasted with currently available analytical solutions for cylindrical and planar chamber
Sidhant Singh et al. [29] Experimental Sounding rockets provide significant contributions to aeronautical engineering research. However, for student research projects, Indian institutions hardly ever deploy experimental sounding rockets. The lack of rocket motors, which need intricate machining and explosive propellants, prevents the use of sounding rockets in student research projects. We ran across this issue when we developed sounding rocket for research and educational purposes. At first, simple designs were assessed, and several propellant configuration theories were seen. The accessibility, simplicity of manufacture, and casting of propellants were significant factors.
M. Dito Saputra et al. [30] Combustion gas is released via a nozzle to provide thrust in a rocket. A crucial element in the transformation of chemical energy into kinetic energy is the rocket nozzle. As a result, it is subjected to extremely high temperatures and pressures brought on by gas combustion. The nozzle must be able to preserve structural integrity in such an environment in order to guarantee a successful rocket operation. However, in order to lower the weight of the rocket as a whole, its structural weight must be maintained to a minimum. As a result, the nozzle design phase is crucial since it has a big impact on the performance of the entire rocket. Currently, LAPAN is working on various rockets powered by solid propellants. The standard design of each rocket's nozzle, which includes a metal shell and a graphite insert, is still used.
Jian-Liang Gong et al. [31] In the design of contemporary rockets, the interaction of thermal and mechanical effects on submerged nozzles is crucial under heat stress and aerodynamic pressure. The thermo-structural response of a submerged nozzle at a pressure of 6 MPa and a stagnation temperature of 3200 K was investigated in this research using a simulation with a subroutine of nonuniform pressure and nonuniform heat transfer coefficient. Through studying the flow field, it was possible to determine the aerodynamic characteristics and heat coefficients. It was discovered that the heat loading significantly affected the throat insert stress for the solid rocket motor (SRM). As the time for the throat insert grows, the hoop stress initially rises and then falls. Test of SRM's ground hot fire using a submerged.
Kevin Albarado et al. [32] An ideal outcome was reached by guiding a solid rocket motor modelling code with a hybrid particle swarm/pattern search optimizer. The analytical burn back methods used by the solid motor code to describe tapered motor designs include dividing the grain into small portions along the axial direction. Dog bones, waggon wheels, and grains with circular perforated stars are a few examples of grains that can be used. The hybrid technique to optimisation may climb "hills" of optimality using gradient-based pattern searching while also exploring broad swaths of the solution space using particle swarming. The presentation of a preliminary approach for developing tapered outer mold-line geometry as well as tapered interior geometry. Four optimisation instances in all were carried out. initial two cases.
R. David et al. [33] This study presents a generic numerical model for unstable solid-propellant burning based on the solid-phase energy conservation finding of Zeldovich and Novozhilov. throughout contrast to earlier models, the integrated temperature distribution throughout the solid phase is used directly (rather than the thermal gradient at the burning surface) to estimate the instantaneous burning rate. The burning model is all-encompassing in that it may be applied to different propellant burning-

rate methods. Variable static pressure is the main mechanism of interest in our work because of the accessibility of pressure-related experimental data in the open literature. The hypothetical projected findings shown in this research are very compatible with the relevant experimental fire response data.
Wang Chunguang et al. [34] It was hardly convincing that the reduction in deflection torque of a flexible joint with rising pressure was often attributed to the altering shear stress. The structural properties of the flexible joint were examined under various stresses to comprehensively study the mechanism. It was discovered that the buckling reaction when the flexible joint bears the deflection and pressure at the same time was the major cause of the decrease in deflection torque. In this study, the buckling of the flexible joint was simulated using ABAQUS, and the Riks technique was used. In order to determine the laws of swing angle altering with regard to different pressurisation processes at various pre-angles, the static Riks method and general approach, respectively, were utilised.
Chunguang Wang et al. [35] The multifield (flow-thermal-mechanical) coupled numerical research was conducted based on the mesh-based parallel code coupled interface in order to precisely and effectively analyse the solid rocket motor nozzle's thermal structural integrity. The linked algorithm and engineering algorithm finite element model and numerical simulation method were developed, and the physical model was properly simplified. The engineering algorithm results were compared with the coupled interface parameters, internal flow field, temperature field, and stress field of the coupled algorithm, validating the efficacy and precision of the numerical simulation. The results of the numerical experiments indicated that the linked algorithm's temperature field and stress field results were marginally inferior to those of the engineering algorithm.
Ran Wei et al. [36] We have suggested a computational method to compute the ideal thickness of the heat insulating layer in order to acquire the best designs for the heat insulating layers in solid rocket motors. The suggested technique works with solid rocket motors of any form and degree of degradation. To obtain greater precision, the nonuniform dynamic burning rate is taken into account. Triangular geometry is used as an input in the development of a high-performance algorithm that enables data exchange from any CAD programme. To obtain the necessary sampling sites, a better geometric intersection technique is created, which uses 35% less calculation time than its open-source version. The use of parallel computing technologies helps to further enhance performance. The proposed technique can carry out every operation.
M. Ortelt et al. [37] DLR has put a lot of work into developing ceramic rocket thrust chambers during the past 20 years. As a result of the natural intrinsic micro-porosity of Ceramic Matrix Composites (CMCs), a first system study conducted in the 1990s immediately led to the operational range of transpiration cooled inner combustion chamber liners. CMCs are a relatively new family of materials that have strong future promise for high temperature and concurrently structurally high-performance applications. CMCs are high temperature resistant structural materials. Numerous fundamental empirical and numerical analyses of this technology have been done. The primary focus was in the area of pure material research, system analysis, and experimental work at pertinent test benches for rocket engines at the DLR station in Lampoldshausen.
Varada Anil Hemanth et al [38]. Using Ansys Fluent 17.1, a Solid Propellant Retro Rocket Motor with a C-D Nozzle is examined. With air and gas as the working fluids, steady state analyses of a retro rocket motor have been conducted for viscous models like Inviscid and k-(Realizable). To compare the exit parameters to theoretical values calculated by utilising one dimensional equations, the nozzle's size and boundary conditions are maintained constant for both viscous models. According to the data, the nozzle's exit temperature using gas as the working fluid is higher than the theoretical value in the Inviscid viscous model by 2.2% and in the K-viscous model by 5.4%.
M. Dito Saputra et al. [39] Combustion gas is released via a nozzle to provide thrust in a rocket. A crucial element in the transformation of chemical energy into kinetic energy is the rocket nozzle. As a result, it is subjected to extremely high temperatures and pressures brought on by gas combustion. The nozzle must be able to preserve structural integrity in such an environment in order to guarantee a successful rocket operation. However, in order to lower the weight of the rocket as a whole, its

structural weight must be maintained to a minimum. As a result, the nozzle design phase is crucial since it has a big impact on the performance of the entire rocket. Currently, LAPAN is working on various rockets powered by solid propellants. The standard design of each rocket's nozzle, which includes a metal shell and a graphite insert, is still used.

Tobias Ecker et al. [40] Hydrogen/oxygen/chlorine chemistry has a significant impact on the thermo-chemistry of plumes coming from solid rocket motors (SRM). These post-burning processes significantly affect the propulsion system's chemical and thermal loads, as well as the infrared signature. This research gives a summary of the existing combustion mechanisms and assesses how well they can be applied to CFD. A more accurate skeletal kinetic model is suggested and tested against specific processes in light of the findings. The findings of this work provide an assessment of the effectiveness of present-day finite rate chemistry models and their influence on the flow field properties of SRM plumes.

III. Conclusion

The structural and thermal analysis of a rocket motor casing is a critical process in the design and development of a safe and efficient propulsion system. Through comprehensive analysis, engineers can ensure that the casing can withstand the extreme forces and thermal loadsexperienced during the rocket's operation. In conclusion, it has confirmed its suitability and safety for the intended application. The meticulous evaluation of structural integrity, thermal performance, material selection, and safety margins ensures that the casing will reliably support the rocket's propulsion system during its mission, contributing to the success of space exploration efforts.

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