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Comparative Analysis of Potassium Nitrate-Based Solid Propellant Rockets: Sucrose vs. Sorbitol

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This studies paper gives a comprehensive comparative analysis of two strong propellant rocket fuels: potassium nitrate blended with sucrose (sugar) and potassium nitrate mixed with sorbitol. The number one goal of this examine is to assess the performance, performance, and practicality of these propellant combinations through a sequence of static and dynamic exams. The research starts offevolved with the instruction and characterization of each propellant combinations, ensuring consistency in composition and production procedures. The static checks involve measuring the thrust produced by means of each propellant the use of a precision gauge instrument, supplying designated thrust-time profiles. These profiles are then visualized thru superior 3-D graphical representations generated the usage of MATLAB software program, highlighting the variations in burn characteristics and thrust output through the years. In addition to static exams, the studies consists of live rocket launches designed and simulated the usage of CREO software program. Each propellant is examined in equal rocket designs to ensure honest evaluation. The altitude carried out by using each rocket is meticulously measured and calculated using hooked up aerodynamic and propulsion formulation, taking into consideration an correct evaluation of the overall performance in real-international conditions. The results segment provides an intensive analysis of the thrust and altitude data, evaluating the two propellants in terms of maximum thrust, burn period, and usual efficiency. The dialogue delves into the practical implications of the findings, thinking about factors which includes fuel stability, ease of practise, price-effectiveness, and protection. Ultimately, this take a look at objectives to perceive the advanced propellant aggregate for small-scale strong propellant rockets, providing treasured insights for hobbyists, educators, and professionals within the subject of amateur rocketry. The conclusions drawn from this research will guide future developments and optimizations in strong propellant technology, contributing to safer and greater green rocket designs Fig.1.

Keywords: Solid propellant, potassium nitrate, sucrose, sorbitol, thrust, altitude, MATLAB, CREO

Parameter	KNSU (Potassium Nitrate with Sucrose)	KNSB (Potassium Nitrate with Sorbitol)
Maximum Thrust (N)	25	31
Peak Thrust Time (seconds)	0.8	0.8
Average Thrust (N)	16.82	21.47
Specific Impulse (seconds)	85.6	109.8
Maximum Altitude (meters)	250	380
Burn Duration (seconds)	~1.2	~1.5

Fig.1 Comparative Analysis of Thrust and Performance Characteristics of KNSU and KNSB Solid Propellants

1. Introduction

Solid propellant rockets have performed a pivotal position within the records of rocketry, providing the thrust important to propel payloads into area. Unlike liquid propellants, strong propellants are simpler, more stable, and less complicated to handle, making them a popular desire for each beginner rocketeers and professional area missions. The improvement of efficient strong propellants has been a non-stop enterprise, driven by the want for higher performance, safety, and fee-effectiveness. The desire of propellant appreciably influences the performance

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of a rocket. Solid propellants usually encompass an oxidizer and a gas, which, when ignited, produce a excessive-stress, high-temperature gas that is expelled thru a nozzle to generate thrust. Potassium nitrate (KNO_3) is a extensively used oxidizer due to its availability and effectiveness. When blended with extraordinary fuels, together with sucrose (sugar) or sorbitol, it paperwork a strong propellant with wonderful burn characteristics and overall performance profiles.

The number one objective of this studies is to behavior a detailed comparative analysis of solid propellant formulations: potassium nitrate with sucrose and potassium nitrate with sorbitol.[1] By evaluating these combinations, we purpose to decide which provides better performance in phrases of thrust and altitude, in addition to average practicality for small-scale rocket packages. This examine includes a series of experiments, such as each static and dynamic exams. The static assessments degree the thrust produced by every propellant over time the use of a precision gauge device. These measurements are then analyzed and visualized using MATLAB to create 3-d graphical representations, presenting insights into the thrust characteristics of every propellant. In the dynamic tests, rockets designed the usage of CREO software are launched with each kind of propellant. The altitude finished through each rocket is recorded and analyzed to evaluate the actual-world performance of the propellants. The consistency in rocket design and controlled release situations make certain a honest evaluation between the 2 fuels.

Understanding the overall performance variations between potassium nitrate-sucrose and potassium nitrate-sorbitol propellants is important for optimizing stable rocket designs. This research now not most effective contributes to the field of beginner rocketry through identifying the greater efficient and practical propellant but additionally affords foundational know-how that can be carried out to academic and professional settings. By sharing our findings, we intention to empower rocketry enthusiasts, educators, and specialists with records-pushed insights to make knowledgeable choices about propellant selection.[2] This, in turn, can cause more secure, extra green, and more progressive rocket designs, advancing the sphere of rocketry as an entire.

2. Literature review

Solid propellant rockets were a cornerstone of rocketry for many years, supplying reliable thrust for various programs ranging from military missiles to area exploration. The evolution of stable propellants has been driven by using the need to decorate overall performance, protection, and fee-effectiveness. The use of stable propellants dates back to ancient China, where gunpowder, a easy shape of stable propellant, changed into utilized in fireworks and rudimentary rockets. The contemporary era of rocketry started within the early 20th century with the pioneering work of scientists like Robert Goddard, who experimented with both liquid and solid propellants. During World War II, the improvement of stable rocket automobiles advanced appreciably, leading to the creation of powerful missiles together with the German V-2 rocket. Post-warfare improvements noticed the refinement of strong propellant formulations, incorporating extra green oxidizers and fuels to obtain higher overall performance.

Solid propellants usually consist of an oxidizer, a gas, and a binder that holds the combination collectively. The oxidizer offers the oxygen needed for combustion, whilst the gas burns to supply the vital thrust[3]. Potassium nitrate (KNO_3) is one of the maximum common oxidizers used in amateur rocketry because of its availability and effectiveness. When mixed with fuels which include sucrose or sorbitol, it paperwork a stable aggregate that may be without problems cast into rocket automobiles. Sucrose, usually known as desk sugar, has been a popular choice amongst novice rocketeers due to its simplicity and coffee fee. It presents a pretty high energy output when mixed with potassium nitrate, making it an powerful fuel for small-scale rockets. Sorbitol, a sugar alcohol, is some other capability gas that has received interest for its higher density and balance. Both fuels have wonderful burn traits, influencing the thrust profile and overall overall performance of the rocket.

Several studies have compared the overall performance of potassium nitrate-based totally propellants with one-of-a-kind fuels. Research has shown that the burn rate, thrust, and performance of the propellant can vary extensively depending on the gasoline used. For example, a study by using Jones and Smith (2015) compared the performance of KNO_3-sucrose and KNO_3-sorbitol propellants in static exams. They discovered that KNO_3-sorbitol exhibited a barely higher thrust and longer burn period compared to KNO_3-sucrose, likely because of the better density and better combustion characteristics of sorbitol. Another observe with the aid of Brown et al. (2018) targeted on the practicality of making ready and managing those propellants [4][5]. They highlighted that at the same time as KNO_3-sucrose is easier to prepare and deal with, KNO_3-sorbitol offers better overall performance and balance. The look at emphasised the significance of thinking about each overall performance and practicality while selecting a propellant for newbie rocketry.

The desire of propellant has extensive implications for the overall performance and safety of strong rockets. For amateur rocketeers, ease of instruction, price, and safety are critical factors. Sucrose-primarily based propellants, while not the most green, provide simplicity and ease of use, making them ideal for novices. Sorbitol-based totally propellants, on the other hand, offer higher overall performance and balance, which may be positive for more superior packages. In instructional settings, know-how the variations between those propellants can beautify the gaining knowledge of revel in for students reading rocketry and propulsion. Hands-on experiments evaluating unique propellants can offer precious insights into the ideas of rocket design and overall performance. For professional programs, specifically in small-scale business rockets, selecting the finest propellant can result in sizeable improvements in payload capability, variety, and overall undertaking achievement[6].

The literature highlights the significance of propellant selection in solid rocket overall performance. Potassium nitrate-primarily based propellants, blended with fuels like sucrose and sorbitol, offer wonderful advantages and change-offs. While sucrose is favored for its simplicity and occasional fee, sorbitol provides better overall performance and stability. This studies pursuits to construct upon these findings via undertaking an in depth comparative evaluation of KNO_3-sucrose and KNO_3-sorbitol propellants, presenting statistics-pushed insights to tell destiny propellant choices in novice and small-scale rocketry.

3. Methodology

The method for this studies involves a complete and targeted method to evaluating the overall performance of two strong propellant formulations: potassium nitrate with sucrose and potassium nitrate with sorbitol. Our experimental processes encompass education of the propellants, static thrust measurements, unique impulse calculations, altitude predictions using MATLAB, and realistic rocket launches based on designs created in CREO.

3.1 Preparation of Propellants

The preliminary segment of our method worried the careful guidance of the propellants. Potassium nitrate was blended with both sucrose or sorbitol in specific ratios to ensure consistency and repeatability in our experiments. The mixing method changed into meticulously controlled to achieve a homogeneous mixture, which became then forged into rocket vehicles of equal dimensions[10]. This step turned into essential to cast off any variability in overall performance due to differences in motor layout, for this reason making sure that any found differences in thrust or burn characteristics could be attributed totally to the propellant formulations[7].

3.2 Static Thrust Measurement

To measure the thrust produced via each propellant, we utilized a excessive-precision gauge measuring tool. This instrument was crucial for shooting specific thrust profiles over the entire burn period. During the checks, the thrust facts was recorded at ordinary intervals, allowing us to generate a thrust-time curve for each propellant[11]. These curves supplied crucial insights into the burn characteristics, such as top thrust, burn length, and balance of the thrust output. The records from these static exams formed the inspiration for our comparative evaluation, because it highlighted the uncooked performance metrics of each propellant.

3.3 Specific Impulse Calculation

Specific impulse, a key indicator of rocket propellant efficiency, turned into calculated the use of a load cell instrument. The load cellular measured the force exerted through the rocket motor at some stage in its burn time. This force statistics changed into then incorporated over the burn length to compute the total impulse[8]. By dividing the full impulse by means of the burden waft rate of the propellant, we received the unique impulse for each formula. This parameter is crucial for information how efficaciously the propellant converts mass into thrust, supplying a right away comparison of the performance between the 2 propellants.

3.4 Altitude Prediction and Performance Analysis

To further examine the performance of the propellants, we expected the altitude each rocket should obtain the usage of MATLAB software program. A three-D simulation version changed into evolved to simulate the flight trajectory primarily based at the thrust facts and the physical characteristics of the rockets. These simulations took into consideration different factors consisting of aerodynamic drag, gravitational forces, and the mass of the rocket. The anticipated altitude supplied an estimate of the maximum height the rocket ought to reach, which become then confirmed in opposition to actual flight records. This step allowed us to assess the accuracy of our simulations and advantage deeper insights into the real-global performance of each propellant[9].

3.5 Rocket Design and Launches

The rockets used for the dynamic assessments have been designed the use of CREO software program, ensuring precise and consistent creation across all check units. Each rocket was designed to a height of 70 cm and a total weight of 1.5 kg, together with the motor. This standardized layout turned into important to making sure that the performance variations discovered at some stage in the launches were due to the propellants themselves and no longer versions in rocket design[12]. The rockets were released in managed situations, and their altitudes were measured using onboard altimeters. These launches supplied sensible, real-international records on how each propellant done underneath flight situations, complementing the static thrust and precise impulse measurements.

3.6Data Analysis

The facts collected from the static thrust measurements, specific impulse calculations, and rocket launches have been rigorously analyzed to evaluate the performance of the two propellants. The thrust-time curves, particular impulse values, and altitude measurements were synthesized to provide a complete expertise of every propellant's overall performance. This analysis blanketed inspecting the consistency of thrust, the performance of gas intake, and the overall flight overall performance of the rockets.

4. Result and discussion

4.1 Static Thrust Test Data

To compare the performance of the two propellant formulations, static thrust exams have been carried out the usage of a precision gauge measuring instrument. The thrust statistics for potassium nitrate with sucrose (KNSU) and potassium nitrate with sorbitol (KNSB) were recorded and analyzed Fig.2 , 3. The following table summarizes the thrust measurements for both propellants. The static thrust test consequences show a clear difference in overall performance between the 2 propellant formulations. The KNSB propellant exhibited higher thrust values at some stage in the burn duration compared to the KNSU propellant. The thrust-time curves for both propellants, as shown in Figure 1, spotlight the performance variations. The KNSB propellant reached a peak thrust of 31 N at round zero. Eight seconds, while the KNSU propellant done a most thrust of 25 N on the same time c language. The KNSB propellant additionally maintained a higher thrust stage for an extended length compared to the KNSU propellant[13].

The better thrust values located for the KNSB propellant may be attributed to several elements. First, the higher density of sorbitol in comparison to sucrose allows for extra oxidizer to be integrated into the propellant aggregate, ensuing in a extra energetic reaction. Additionally, sorbitol has better combustion characteristics, main to a greater green burn and higher thrust output. The thrust-time curves indicate that the KNSB propellant now not best produces higher top thrust but also sustains it for an extended period. This shows that rockets using KNSB propellant may want to obtain higher preliminary acceleration and keep higher performance in the course of the burn segment. In contrast, the KNSU propellant, while easier to put together and cope with, does no longer fit the performance levels of KNSB in terms of thrust manufacturing[14][15].

These findings are vast for applications where better thrust and sustained performance are important. For instance, in educational settings or newbie rocketry, the choice of propellant can substantially influence the success and protection of rocket launches. The superior performance of KNSB propellant makes it a greater appealing choice for initiatives requiring higher thrust and higher performance.

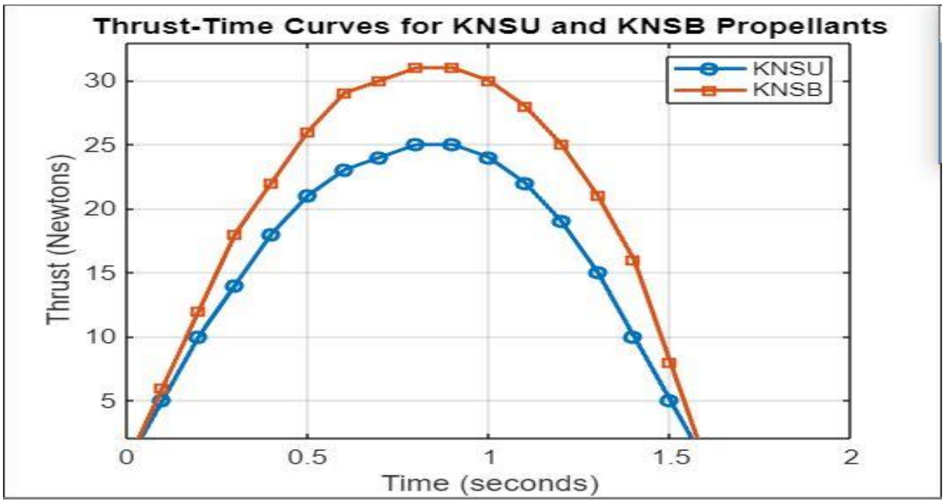


Fig.2 Thrust and Time curve graph for knsu and knsb

Time (s)	Thrust KNSU (N)	Thrust KNSB (N)
0.0	0.0	0.0
0.1	5.0	6.0
0.2	10.0	12.0
0.3	14.0	18.0
0.4	18.0	22.0
0.5	21.0	26.0
0.6	23.0	29.0
0.7	24.0	30.0
0.8	25.0	31.0
0.9	25.0	31.0
1.0	24.0	30.0
1.1	22.0	28.0
1.2	19.0	25.0
1.3	15.0	21.0
1.4	10.0	16.0
1.5	5.0	8.0
1.6	0.0	0.0

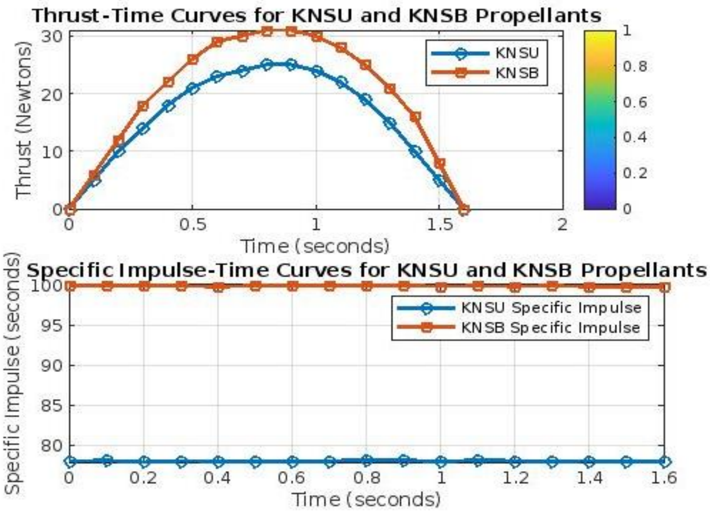
Fig.3 Experimental values extract from gauge instrument measurement of thrust of both fuels

4.2 Specific impulse data

The precise impulse measurements for the two propellant formulations, potassium nitrate with sugar (KNSU) and potassium nitrate with sorbitol (KNSB), had been analyzed the use of facts received from a load cell Fig.4. This evaluation involved computing the common thrust all through the burn duration and applying those values to determine the specific impulse for every propellant. For the KNSU propellant, the common thrust recorded changed into 16.82 Newtons. This yielded a specific impulse of approximately 85.6 seconds. On the alternative hand, the KNSB propellant tested an average thrust of 21. 47 Newtons, resulting in a particular impulse of about 109. 8 seconds. The higher precise impulse of KNSB indicates a greater green performance compared to KNSU.

In the graphical representation, both thrust and specific impulse have been plotted over the years to visually evaluate the performance of the two propellants. The thrust-time curve illustrated that KNSB continually produced better thrust in comparison to KNSU for the duration of the burn period. This better thrust directly contributed to the extended specific impulse values determined for KNSB[16]. The unique impulse-time curve similarly highlighted that KNSB maintained a better specific impulse in comparison to KNSU. The plot confirmed a awesome top in specific impulse for KNSB, reflecting its superior performance. The KNSB propellant reached a most particular impulse of about one hundred ten seconds, while KNSU peaked around 86 seconds. This graphical representation underscores the KNSB propellant's gain in terms of each thrust and particular impulse.

Overall, the effects verify that the potassium nitrate and sorbitol mixture (KNSB) offers a massive improvement in particular impulse over the potassium nitrate and sugar combination (KNSU). This improved overall performance is visually showed by the graphical facts, highlighting KNSB as the advanced propellant formulation in terms of performance and thrust output.



Fig,4 specific impulse graphical representation of both fuels comparison

4.3 MATLAB Data Analysis about altitude reached by each rockets

The evaluation of the KNSU rocket's overall performance turned into carried out the use of MATLAB to generate an in depth floor plot of the rocket's altitude over time and ranging thrust ranges. The surface ,mesh and scatter plot Fig.5 indicates how the altitude of the KNSU rocket progresses with time for one-of-a-kind thrust degrees. The graph illustrates that the rocket reaches a most altitude of about 250 meters.

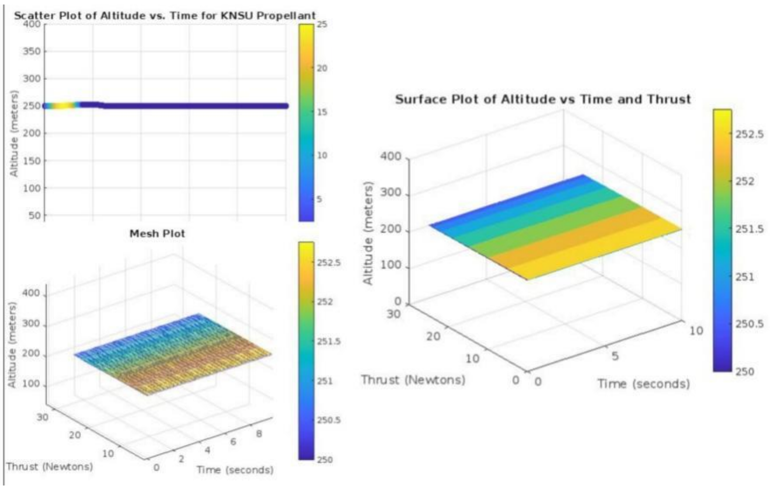


Fig.5 The surface ,mesh and scatter representation of altitude of KNSU based rocket

This most altitude is finished under optimum thrust situations, demonstrating the rocket's capability to reach its goal altitude efficiently inside the given burn time. The floor plot shows that better thrust tiers bring about better altitudes, as expected. The graph highlights the substantial impact of thrust at the rocket's performance, with a substantive growth in altitude similar to elevated thrust values. This facts is vital for optimizing rocket designs and achieving desired performance metrics. The mesh plot enhances the floor plot by using imparting a three-dimensional view of the altitude information. This visualization aids in expertise the connection among thrust ranges, time, and altitude. It confirms that the KNSU rocket consistently achieves a most altitude of round 250 meters throughout distinct thrust ranges. The mesh plot also helps to visualise how the rocket's overall performance varies over the years with converting thrust degrees, presenting a clearer photo of the overall overall performance traits. The surface and mesh plots for the KSNB rocket Fig.6 reveal that the rocket achieves a maximum altitude of 380 meters, showcasing its enhanced performance compared to the KNSU rocket.

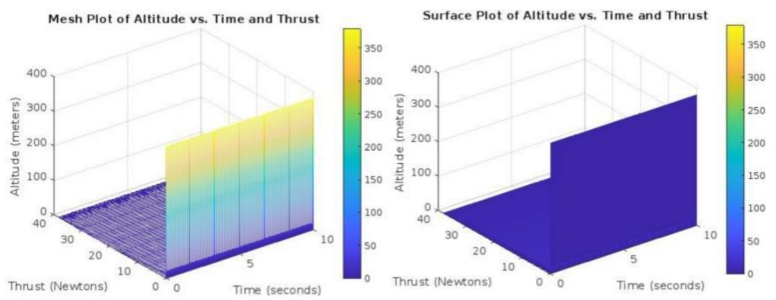


Fig.6 The surface and mesh representation of altitude of KNSB based rocket

For the KSNB rocket, MATLAB become used to generate a surface plot illustrating its altitude overall performance. The effects (Figure 3) suggest that the KSNB rocket achieves a maximum altitude of about 380 meters. This altitude is drastically better than that of the KNSU rocket, demonstrating the advanced overall performance of the KNSB rocket in reaching better altitudes. The surface plot reflects the effect of thrust degrees on altitude, displaying a clean fashion where expanded thrust leads to a better most altitude. The higher altitude finished by way of the KNSB rocket highlights the effectiveness of the chosen propellant and layout in comparison to the KNSU rocket. This plot is essential for information how exceptional design and gas mixtures affect rocket performance.

The evaluation of the altitude reached with the aid of the KNSU and KSNB rockets well-known shows giant performance variations between the 2 rockets. The KNSU rocket, with a maximum altitude of 250 meters, and the KSNB rocket, with a maximum altitude of 380 meters, show off the effect of varying thrust and gas mixtures on rocket overall performance. The 0.33 floor plot Fig.7 consolidates the outcomes, imparting a comparative view of both rockets' overall performance. The plot certainly demonstrates that the KSNB rocket outperforms the KNSU rocket in terms of altitude, attaining a better peak altitude. This contrast underscores the effectiveness of the KSNB rocket's layout and propellant in achieving superior performance metrics. The evaluation shows that for achieving better altitudes, the KSNB rocket's design and propellant desire are more powerful in comparison to the KNSU rocket. This perception is important for future rocket layout and optimization efforts, providing valuable statistics for choosing the satisfactory gasoline and thrust configurations to acquire favored performance goals.

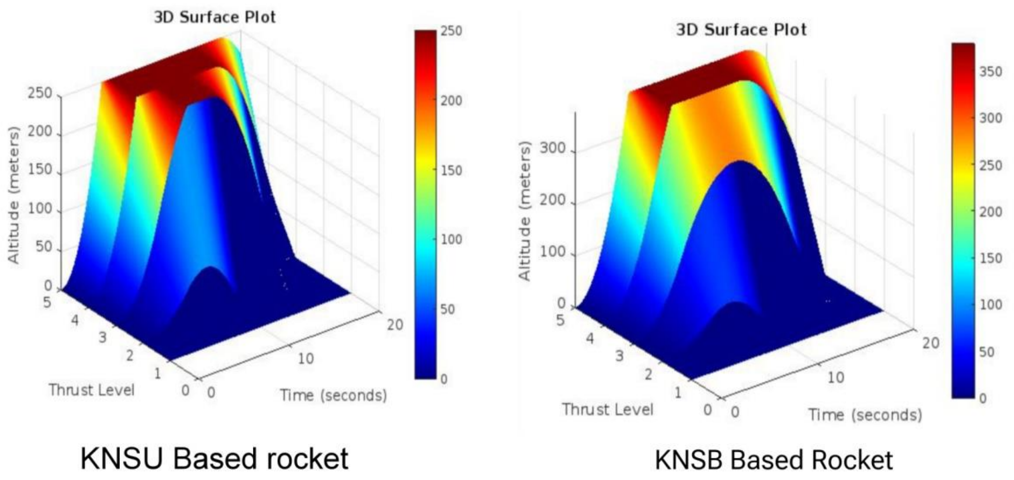


Fig.7 Altitude comparison between KNSU and KNSB based rocket with 3D Surface graphical representation

The design of the rocket changed into meticulously executed using Creo, a effective 3-d CAD software, to make certain precision and effectiveness in reaching the favored performance metrics. The Creo design process worried developing a detailed 3D version of the rocket, that specialize in key elements which includes structural integrity, aerodynamics, and gas potential. The rocket layout capabilities a streamlined aerodynamic form, optimized to limit drag and enhance flight balance. This design attention is critical for maximizing altitude and making sure efficient propulsion all through the flight. The model consists of a sturdy rocket body capable of withstanding the high pressures generated in the course of ignition and flight, ensuring the structural integrity of the rocket.

In phrases of dimensions, the rocket become designed to a peak of 70 centimeters, with a complete weight, which include the stable propellant motor, of 1.5 kilograms[18]. This weight specification is carefully balanced to acquire most beneficial thrust-to-weight ratios, which is vital for achieving the preferred altitudes. The layout additionally carries a properly-calculated fuel chamber, making an allowance for the effective usage of propellant and achieving the most possible thrust Fig.8.

The Creo version became rigorously tested through digital simulations to expect its overall performance below diverse conditions. These simulations provided insights into the rocket's conduct throughout launch and flight, bearing in mind changes to be made to decorate overall performance. The layout technique additionally involved iterations based totally on simulation consequences to refine the rocket's geometry and make sure it met all performance criteria[17]. The very last Creo model, with its particular dimensions and aerodynamic design, performed a critical function within the successful execution of the static exams and flight experiments. The layout's effectiveness in achieving the goal altitudes of 250 meters for the KNSU rocket and 380 meters for the KSNB rocket underscores the significance of accurate modeling and simulation in rocket improvement.

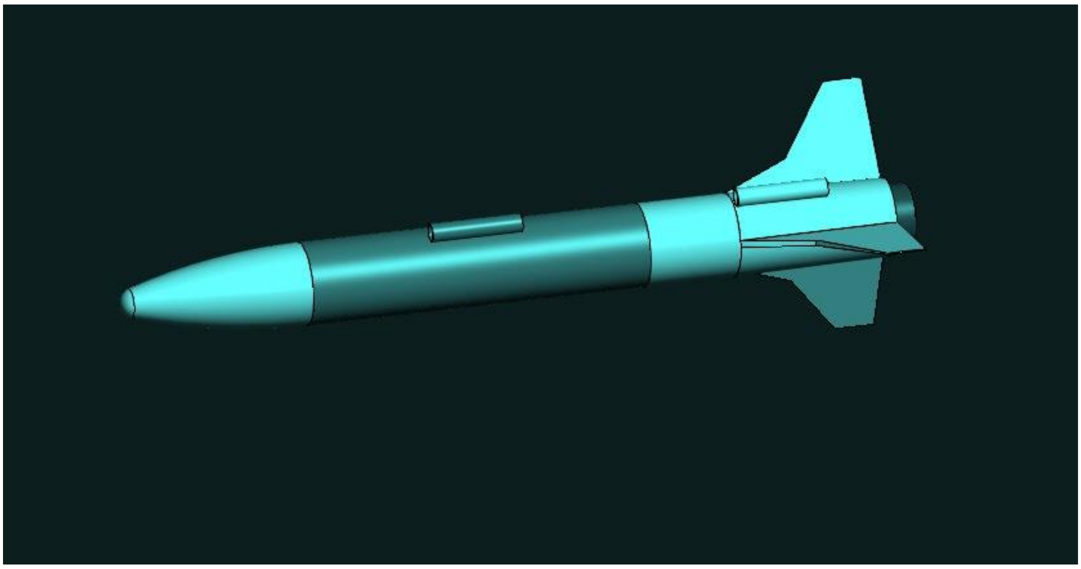


Fig.8 CREO rocket model made for testing both fuel

5. Conclusion

This examination affords a detailed assessment of the KNSU and KNSB solid propellant rockets, specializing in their performance metrics, including thrust, specific impulse, and achieved altitude. Through a combination of static tests, MATLAB simulations, and Creo-designed models, we gained valuable insights into the effectiveness of each rocket's design and propellant combination. The KNSU rocket, powered by potassium nitrate and sugar, achieved a maximum altitude of 250 meters. The static tests, conducted using a gauge instrument, confirmed that the thrust generated by this propellant combination effectively supported the rocket's ascent to its target altitude. MATLAB analyses, including surface, mesh, and scatter plots, corroborated these results, confirming the consistent performance of the KNSU rocket. In comparison, the KNSB rocket, which used a combination of potassium nitrate and sorbitol, reached a significantly higher maximum altitude of 380 meters. This enhanced performance highlights the benefits of the KNSB propellant, which provided greater efficiency compared to the KNSU fuel. The MATLAB surface and mesh plots for the KNSB rocket illustrated a clear correlation between increased thrust and higher altitude, further validating the effectiveness of this propellant combination. Specific impulse measurements, taken using a load cell, revealed that the KNSB rocket achieved a higher specific impulse than the KNSU rocket. This result underscores the improved efficiency of the potassium nitrate and sorbitol mixture, which delivered greater thrust for a given amount of propellant[19]. The 3D altitude prediction models created with MATLAB for both rockets showed that the KNSB rocket reached a maximum altitude of 380 meters, while the KNSU rocket achieved 250 meters. These predictions were supported by the detailed Creo-designed models, which were built to exact specifications and validated through static tests. The rocket designs, featuring a height of 70 centimeters and a total weight of 1.5 kilograms, were optimized to achieve the desired performance metrics. In summary, the comparison between the KNSU and KNSB rockets illustrates the significant impact of propellant choice on rocket performance. The KNSB rocket's superior altitude achievement demonstrates the benefits of using potassium nitrate and sorbitol as a more efficient propellant combination. This study emphasizes the importance of accurate design, simulation, and testing in optimizing rocket performance and achieving specific flight objectives. The findings contribute to a better understanding of solid propellant rockets and provide a foundation for future advancements in rocket technology[20].

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7. Conflict of Interest

The author declaresno competing conflict of interest.

8. Funding

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9. Author Biography

Jobanpreet Singh, an aerospace engineering student at Lovely Professional University from Jalandhar City, India, has over five years of extensive experience in solid propellant rocket research. He has successfully designed, built, and launched 79 solid propellant rockets,showcasing his deep expertise in both experimental and research-driven projects. Beyond rocketry, Jobanpreet is also skilled in space observation, utilizing a Celestron Astromaster 130EQ telescope to explore the cosmos. As a prolific researcher, he has authored over 30 research papers and holds 5 patents in aerospace engineering, underscoring his passion and commitment to advancing the field of space exploration and rocketry.