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Material Selection for Space Launch Vehicles: Theoretical Perspective

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ABSTRACT: Around the aerospace domain the featuring of advanced missiles and rockets results in search of new and novel materials. We may employ newer and lighter materials in the production of missiles and rockets to reduce the dead weight of missiles and rockets. These materials are composite materials. When a high strength-to-weight ratio, low cost, and simplicity of manufacture are required, composite materials have a wide range of technical applications. This short review paper discusses the alloys, composites, 3D printing, polymer materials used while selection for missiles. Here implies that usage of light material increases the efficiency, life cycle and productivity of the missiles and other aerospace applications.

KEYWORDS: 3D printing, missiles, lighter materials, alloys

I. INTRODUCTION

From early ages defence is one of the prim requirement to sustain, this necessity evolved as need for security of nations leads to development of military weapons like missiles. Missile is a self-propelled unmanned guided airborne range weapon carries warhead to destroy aimed target with accuracy and high speed, they are lunched by rocket motor or jet engine using solid, liquid or hybrid as a propellants. Missiles are designed to achieve performance values beyond human tolerance. Missiles contains five major system components which are target system, guidance system, flight system, engine and warhead missiles are further classified into different types according to location and variance in type of target and they are surface to-surface, air-to-air, air-to-surface, surface to air missiles and anti-satellite weapons. Missiles are widely used in warfare to destroy enemies' armaments accurately and promptly.

II. LITERATURE REVIEW

Theoretical study has also been presented which highlights the propellants being used in the solid rocket motor. The performance parameters are also being described along with the material selection as described by Ankit et.al [8]. Ankit et.al presented a study on nozzle flow partition that is carried out by simulation of rocket nozzle designed Fusion 360 and ANSYS to inspect the laminar as well as turbulent regime for deviating section of nozzle [1]. Ankit et.al reviewed about pintle injector used in rocket nozzle along with motor combination for generating higher amount of thrust. It show the influence of spray angles and characteristics such as flow as well as combustion on spray images, droplet size, momentum ratio, opening distance and SMD distributions which affect the injector geometry [2]. Ankit et.al paper discussed a theoretical and conceptual design for compact size 2 stage sounding rocket by focusing on mechanical optimizations at various levels. The aim of the paper is to develop a two-stage sounding rocket with overall length constrained equal to 1m [3]. The aim of paper is to design a two stage sounding rocket and its nozzles using fusion 360 and analysis of different properties using simulation on ANSYS software. The rocket is designed to reach maximum peak to perform technical experiments and can be recuperated safely after use [4]. Ankit et.al presented a work caused by lack of data on aerodynamics for profile of elliptical nose cone and especially improved aerodynamic qualities that can be used in designing aircrafts. Flow phenomena observed in numerical simulations for different AOA for elliptical nosecone profile are highlighted, critical design aspects and performance characteristics of selected nose cone are presented [5]. Kabhilesh et.al reviewed about the materials like ceramics, hydrogels, smart metal alloys. This paper also incorporates the survey of smart materials and multi-materials along with its applications in field of space technology, biotechnology etc. depending upon the level of compatibility [10]. Ankit et.al described about different classification of propellants used for launch vehicles. The cryogenic propellants taken for comparison are liquid hydrogen, liquefied methane and for semi cryogenic fuels considered are RP-1 (kerosene) and UDMH with liquid oxygen as the oxidizer. The scope of this work addresses the comparison among the propellants, on their chemical properties, overall efficiency and fatigue life which is a major criterion for launch vehicles [6]. Ankit et.al reviewed on



magnetic pulse welding (MPW), hybrid laser arc welding (HLAW), ultrasonic resistance spot welding (URSW) of Al and its alloys with other metals. These processes are faster than other conservative processes, are useful in mass fabrication. Micro hardness, microstructure, absorbency, tensile and shear strength, rupture and let-down of the joints welded using these processes were studied and equated for major aerospace applications. The welded joints obtained showed more strength than base metal [12]. Aerodynamic thrust variation and performances play a key role in estimating forces along with the injected flow and their characteristics. This review paper deals with the aerodynamics representation, its properties at different conditions in addition with the performance investigation of the aerospike nozzle study carried by Ankit et.al [7]. Eldho Jose et.al reviewed about carbon-based nanomaterials such as nanodiamonds, metal-based nanoparticles such like gold, silver, and aluminium nanoparticles, and electro spun nanofibers. The characteristics and uses of these chosen materials were described along the review. In addition, some of the most notable characteristics or qualities of each material are addressed, as well as their purposes [11]. Ankit et.al discusses about composition of chemical substances that affects the launch vehicle in ground station as well as atmospheric conditions is been presented. During the rocket-launching the large amount of inhalation of an exhaust gas released and it majorly affects the surface of the launch pad as well as the atmosphere [9]. Ankit et.al describes about a sounding rocket which is developed to perform certain scientific experiments in low earth orbit. The propulsion characteristics and calculations related to nozzles for both the booster stage and the sustainer stage of two-stage sounding rocket have been discussed and calculated using isentropic relations [14]. This review paper sums up major properties for the selection of material includes its tensile properties and its effects, rupture mechanism, most importantly fatigue life cycle, grainsize, and its morphology, etc. The study over different grades of Al-Li alloy is précised along with its aerospace applications stated by Ankit et.al [13].

III. METHODOLOGY

Alloy Materials

There are certain qualities a missile must possess to have the operation held with no mistake and fault. As, most commonly mentioned, the strength of the material is of high importance and the weight and body to weight ratio is also to be considered as light-weight materials can easily make the missile fly with minimal propulsion [19]. The material should also be easily manufacturable, so that production in mass can be possible and the storage will also be in condition with corrosion resistance properties. The alloys, which are a combination of many other elements in proportionate quantities can provide the desired qualities and make the missile much more efficient in operation. For the external surface and the wings, magnesium alloys can be used as it is a lighter material with less density and can provide required lift to drag ratio on operation. Aluminum alloyed with manganese, silicon, and magnesium can provide the required strength for the frame work of the missile and can be drawn and extruded as sheets. This alloy can be the optimum material that can be used at the propulsion system and structure because of its high corrosion withstanding property, the ease in manufacturing and availability. The titanium alloys are the best for the consideration for the whole missile manufacturing as it meets most of the requirements of the missile qualities. Titanium when alloyed with aluminum and vanadium in certain quantities can be used for the high pressure point in the missiles. The high strength steels like the maraging steel can be used for the manufacturing of the combustion chambers and rocket motor casing because of their high fracture withstand ability[15]. Numerous alloys with possible quantity matching are available for the manufacturing of missiles.

3D printing materials

The traditional method for making the missile parts take long time and may cost more as the wastage of the materials would be high. The additive manufacturing or 3D printing lessens the time taken for manufacturing a component of the missile and provide higher structural strength and finishing which the traditional manufacturing methods like welding, forming, casting and machining cannot provide [16]. The mass of the components is controlled and the accuracy is high as 3D printing has internal structures or layers which it lay down to manufacture the component. When a component has to be traditional manufactured, the complex design of the component with asymmetrical curves may make the machining process arduous and may lead to high accumulation of waste materials, whereas when done with 3D printing materials can be saved and the designer can become innovative and design much efficient designs for the component. The missile component can be 3D printed with the metallic alloys that are of light weight, high corrosion and of high strength[15] and can also be 3D printed with polymers that are thermally stable and of high toughness. These polymers find numerous applicative areas in the manufacturing of aerospace applications [15].



Composite materials

The objective of minimising construction weight while keeping high strength qualities. Composites are being used to make load-bearing constructions for gliders, motor gliders, ultralight category aircraft, and Unmanned Aircraft Vehicles (UAVs) [18].

TABLE 1- MATERIALS AND ITS APPLICATIONS [17]

S.No	Materials	Application
1.	Low case Carbon Steel (15 CDV6) [17]	Used in solid rocket motor case [17]
2.	Maraging Steel (M250) with high strength and high toughness [17]	Used in booster solid rocket motor case [17]
3.	Titanium Alloy (Ti-6Al-4V) [17]	Used in high pressure gas bottles [17]
4.	Aluminium Alloys (AA 2219, AA2014, AA6061) [17]	Used in liquid propellant tanks, engine Components, airframe in reusable Launch vehicles. [17]
5.	Magnesium/ Mg-Lithium alloys [17]	Used in upper stage structure like payload adopter, avionics decks, equipment bay structure. [17]
6.	Carbon F/Kevlar F- Epoxy resin [17]	Used in solid motor case, pressure vessel, inter stages, payload adopter. [17]
7.	Carbon Fibre / Silicon Carbide Ceramic Matrix [17]	Used in nose-cap of heat-shield, leading edge and control surface of Rocket Launching Vehicle (RLV) [17]
8.	SiC F/SiC Ceramic Matrix Composite [17]	Used in high temperatures / hot Structures [17]
9.	Silica tiles: (Silica Fibre in Si gel) [17]	used in space shuttle and SRE (capsule) mission [17]
10.	Different coating materials [17]	Used for protection and imparting certain characteristics to surfaces, potting of connectors [17]

According to the study, many metals casings have a stress corrosion cracking issue, which might result in sudden collapse with no outward signs of imminent disaster. The importance placed on lightweight thin metal casings aggravates stress corrosion and fracture propagation, which frequently begins with a fault in the metal, with failure happening at a stress level below the metal's yield strength. The casings are made of composites, which have the benefit of being lighter [17].



IV. CONCLUSION

Recent research over the material selection for missiles or any other aerospace applications reveals lot of new composites, alloys to be utilized. Solid propellants will continue to be widely used in military and commercial applications due to their low cost, extended shelf life, and quick readiness. There are several modelling attempts addressing composite binder failure; however, these efforts are limited by the typical constraints of rubber modelling, which are especially apparent when composites are subjected to reversal strain. Exploring additive manufacturing, which allows for better control over grain geometries, is over recent study. Here it includes short review over the material selection and its advantages.

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