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Design and Development of a Lightweight Chassis Frame for a One Passenger Electric Vertical Takeoff and Landing (eVTOL) Vehicle Based on Jetson One

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***Abstract*—The advent of electric vertical takeoff and landing (eVTOL) aircraft presents a transformative opportunity in urban air mobility. With reference to Jetson One, this project aimed to design a multi-rotor lightweight chassis frame and body structure for one passenger eVTOL to enhance its energy efficiency and flight time. The design process incorporates finite element analysis (FEA) in SOLIDWORKS software to explore design alternatives and validate their feasibilities in the stages of development**

***Keywords*— Chassis Design, eVTOL, Finite Element Analysis (FEA)**

I. Introduction

Electric vertical takeoff and landing (eVTOL) aircraft and flying cars are promising future transportation systems. They can erase traffic congestion by providing on-demand, point-to-point transportation with reduced/zero-emission [1]. Driven by the recent advancements in batteries, motors, and power electronics, and flight control technologies, hundreds of new eVTOL projects are in the development stage by many companies. There are three major flight mechanisms: wingless with multiple rotors for lift, independent thrusters for lift and cruise, vector thrust with tiltrotor, tilt-wing, or ducted vectored thrust [2].

While no official regulations have been set for Urban Air Mobility (UAM) vehicle safety design, eVTOL vehicles development needs to provide adequate protection to the occupant in a crash event. Putnam and Littell [3] studied the crashworthiness design mechanisms of an eVTOL under multi-axis dynamic loading using FEA. Ding, et al. [4] conducted an optimization of energy absorption design to protect eVTOL occupants through a variety of designs for skid landing gear, energy absorber, structures in the cockpit, and the combination of them.

Jetson One [5] is the first affordable one passenger eVTOL without a pilot's license required to fly. It has a quadcopter configuration with eight electric motors and propellers for greater redundancy and stability compared to traditional quadcopters with only four rotors. It is constructed of a Formula One race car inspired lightweight aluminum space frame and carbon fiber composite body. The innovative design includes using the bottom frame as the landing gear and a race car inspired safety cell to protect the pilot [5].

Chassis is the central frame of a vehicle, carrying all the components and supporting all the loads. A well-designed chassis is important to ensure safety and performance during the normal operation of the vehicle and protect the driver in the event of crash [6]. Space frame chassis has been found to be an ideal chassis for one-driver vehicles, such as Formula One race cars [7-11], and 'Eco-Challenge' race cars [6]. Finite element analysis (FEA) has been used to design evaluation of chassis under various load conditions, such as static load, braking load, acceleration load, torsional load, and impact load [6-11]. Dynamic analysis, fatigue analysis, model analysis, and vibration analysis have also been carried out to evaluate the dynamic characteristics [11].

This project aims to design and develop a Jetson One style personal eVTOL aircraft. This paper focuses on the design of a lightweight frame that is strong and safe for flight. The creation of the 3D model and the finite element analysis (FEA) on the structure is conducted in SOLIDWORKS, a computer aided engineering package.

II. Jetson one

Jetson One was developed by Jetson Aero, a Swedish company founded in 2017 by Peter Ternström and his team [5]. The vision of Jetson One was to create an accessible personal flying vehicle that could democratizes air travel. The first prototype was unveiled in 2020, showcasing the potential of eVTOL technology for personal use [5]. The aircraft is powered by electric motors that drive multiple rotors, allowing for vertical takeoff and landing capabilities. It has a top speed of 102 km/h and a flight time of 20 minutes [5].

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Jetson One is equipped with a radar sensor driven auto landing system, and advanced safety systems that gives its ballistic parachute ability to deploy rapidly and fly safely with the loss of one motor. Fig. 1 shows Jetson One is in flight and Fig. 2 shows an empty model. The design of Jetson One has dimensions 2700 x 1600 x 1120 mm (8.86 x 5.25 x 3.67 ft), has a total weight of 55 kg without battery and can handle a maximum pilot weight of 95 kg [5].

Fig. 1. Jetson One in flight [5]

Fig. 2. Empty model of Jetson One [5]

III. METHODOLOGY

A Jetson One style space frame chassis is designed and evaluated using SOLIDWORKS.

A. Chassis Design

As shown in Fig. 3, an aluminum alloy space frame chassis is designed using the Weldments feature in SOLIDWORKS [] with reference to Jetson One. While Jetson One chassis uses circular tubes, this chassis design uses square tubes. Compared to a circular tube, a square tube gives a better strength to weight ratio against bending. The square tube can achieve a lightweight design by increasing structural rigidity without adding additional weight. It is also easy to fabricate and assemble and improves ground clearance for stable landing.

The square tube design used for our model is an Aluminum chassis pipe with a yield strength of 1.100e+04 pound square inch (psi) was model in Solidworks Computer Aided Design software package (Fig 3).

The dimensions of the chassis are 2540 mm x 1700 mm x 1554mm (8.33 ft x 5.58 ft x 5.10 ft). The square tubes have a width of 40 mm and thickness of 2 mm (40 mm x 40 mm x 2 mm).

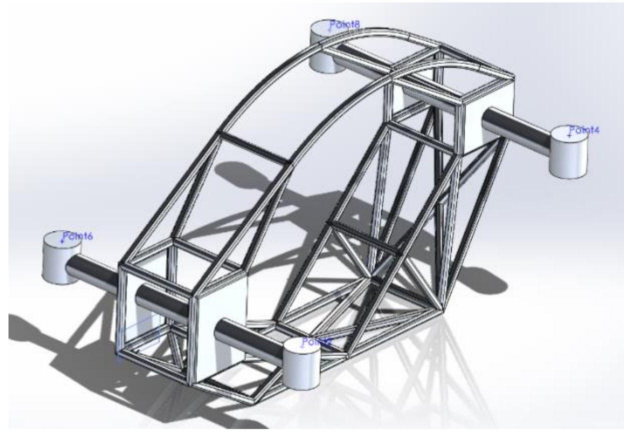

Fig. 3. 3D model of the designed chassis frame.

B. Thrust Force Calculations

The design of an eVTOL starts with estimating the vehicle's total mass, which is used for selecting the propulsion system, which includes the battery, power distribution, motor controllers (inverters), motors, and propellers [1, 11, 12]. The vehicle's total weight is categorized into three types: payload (passengers and pilot), battery, and the rest [1, 12].

The total mass for this study is calculated with the following components based on Jetson One [3]:

- Empty mass = 55 kg
- Maximum battery weight = 60 kg
- Maximum pilot weight = 95 kg

The total mass is 210 (= 55 + 60 + 95) kg, thus the required lift force during cruise is 210 kgf (2060 N). As there are 4 sets of propulsion systems, the thrust force from each set is found as 515 (= 2060/4) N.

C. Static Finite Element Analysis

Static finite element analyses (FEA) were performed to evaluate the performance of the designed chassis and the arms. The chassis and arms are modeled separately for computational efficiency.

Fig. 4 shows an FEA model with thrust applied as a remote force at each motor mount location. An upward 515 N thrust is applied as a remote force at the locations shown in Fig. 5. The base of the frame is fixed. Pilot's weight is also added at the elements where the seat is located.

Default standard mesh with mesh controls at the critical joints was applied to increase the results accuracy of the FEA analysis. The meshed model is shown in Fig. 6. The chassis are modeled as beam elements while the arms are modeled as solid elements.

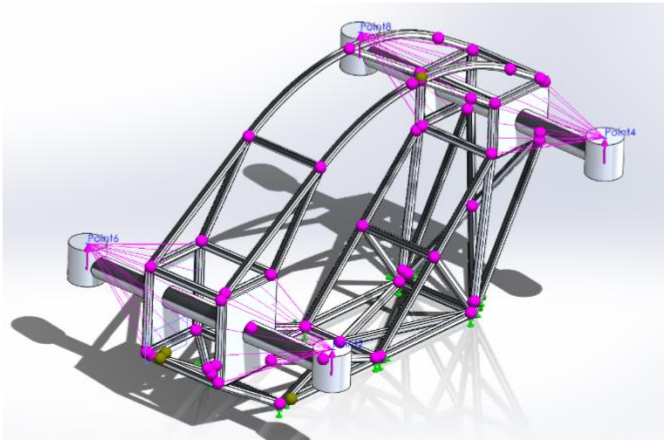

Fig. 4. Remote/force applied at points and fixtures

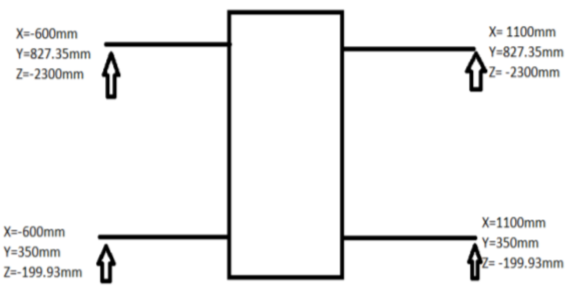

Fig. 5. Coordinates representing the positions of applied thrust

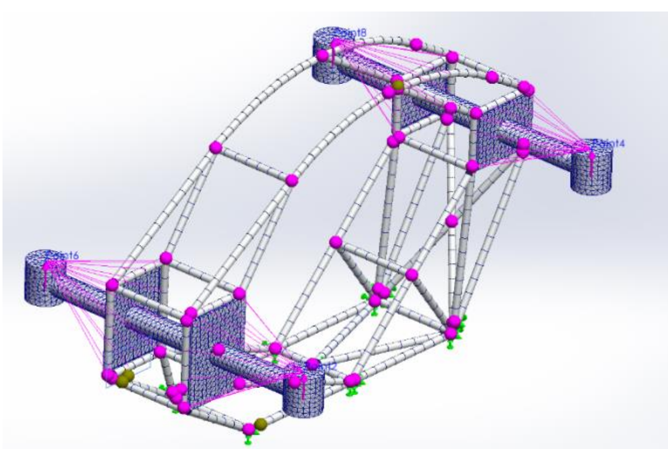

Fig. 6. Mesh model

IV. FEA RESULTS

Two separate static structural finite element analysis (FEA) were conducted to evaluate the performance of the square chassis frame and arm under the applied thrust and pilot's weight.

Figs. 7 and 8 show the stress distribution and factor of safety (FOS) distribution respectively for the chassis under the applied remote force and pilot's weight at the location of the seat. The maximum is 6.976 ksi, below the yield strength of aluminum alloy, 11 ksi. The aluminum alloy chassis has a factor of safety (FOS) of 1.6.

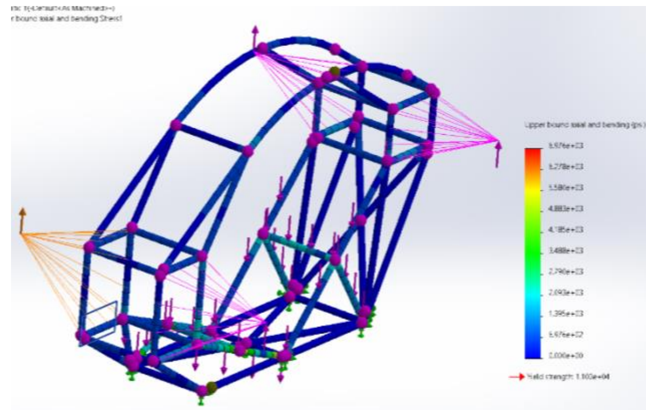

Fig. 7. Von mises stress distribution in the chassis

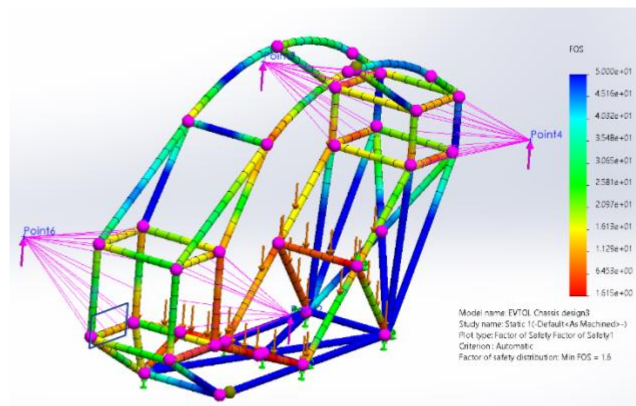

Fig. 8. Factor of Safety of the chassis

Figs. 9 and 10 show the simulation results and boundary conditions for the arm simulation. The arm is fixed at the surface connected to the chassis and has a thrust at the motor surface. The maximum von Mises stress is 8.385 ksi and the respective FOS is 1.1.

The results of the two simulations are summarized in Table 1.

TABLE I. FEA RESULTS

STRUCTURE	ELEMENT TYPE	MAXIMUM STRESS	FACTOR OF SAFETY (FOS)
CHASIS FRAME	BEAM	6.976 KSI	1.6
ARM	SOLID	8.385 KSI	1.1

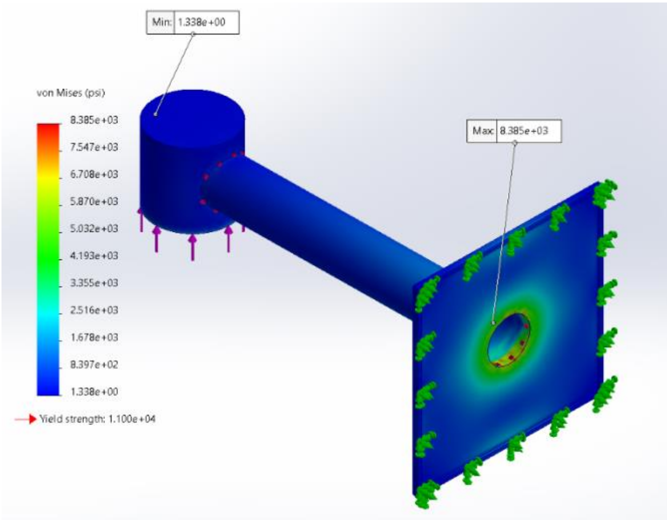

Fig. 9. Stress distribution on the arms at contact to the frame

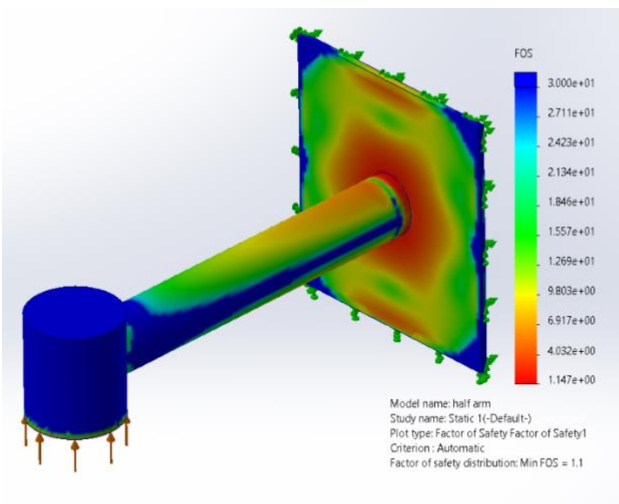

Fig. 10. Factor of safety (FOS) of the arm

V. .CONCLUSION AND FUTURE WORK

This project has designed a Jetson One inspired lightweight aluminum space frame for a One-passenger eVTOL. From the FEA analysis, it was found that the aluminum square chassis frame design is safe for cruise condition with a total weight of 210 kg.

Additional analysis will be conducted to evaluate the performance of the chassis under other conditions, such as roll over event, fatigue, model and vibration, and crashworthiness study.

Further design developments will be conducted for a complete eVTOL design model, including nose shape design to improve aerodynamics with computational fluid dynamics.

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