Fluid Power Vehicle Challenge - Frame Design

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***Abstract*—Fluid power is an integral subject of society, seen in numerous facets all around the world. Fluid power systems are used in everything from energy production to manufacturing, and can be seen embedded into many systems in various forms. Fluids provide an excellent method of generation, storage, and use of energy that have revolutionized the way the human race operates. The goal of this competition is to get more young people involved in the fluid power industry and provide a better understanding of where it has been, where it is, and where it is going. The project involves designing and building a frame for a vehicle that incorporates both human power and fluid power. Teams from many universities come together for a competition to evaluate which has developed an all-around dominant design.**

Keywords-Unidirectional; Omnidirectional; 3k 2x2 Twill Weave

I. Introduction

The Fluid Power Vehicle Challenge (FPVC) is arranged by the National Fluid Power Association (NFPA). The NFPA appoints judges for the annual competition. Each team is judged based on several criteria including sprint race performance, efficiency, endurance, best use of pneumatics, innovative use of electronics, design, reliability & safety, workmanship, teamwork and presentation. The vehicle must be produced to meet each of these measures adequately for a successful entry into the competition. A main objective in the competition is to achieve power transmission without the use of direct electrical or mechanical power conversion through the use of chains, linkages, or electric motors. The system involves a fluid link between a hydraulic pump and hydraulic motor that must serve to create motion. The use of pneumatics in any form other than power generation is required, but not specified as to how this must be achieved. It is recommended that each team integrates an electronic control system to regulate the components and assist in the monitoring of the system. Similar to pneumatics, electronics cannot contribute to the power generation of the vehicle. Another requirement involves the implementation of regenerative braking within the hydraulic circuit. With all of these considerations, it is imperative that the frame design allows for a strong, lightweight, ergonomic, and modular design capable of integrating the various systems effectively.

II. Methods and Materials

In order for entry into the competition, the overall weight of the vehicle produced must be less than 210 lbs. Due to the number of components required, and the size of these components, a lightweight material must be considered for the framework of the vehicle. Comparing material properties for various metals and composites shown in Figure 1, it can be determined that reinforced Carbon fiber provides a higher stress resistance at a fraction of the weight as opposed to some commonly used metals.

Table 20.1 Density (ρ), Strength (τ_f), the Performance Index (P) for Five Engineering Materials

Material	ρ (Mg/m^3)	τ_f (MPa)	$\tau_f^{2/3}/\rho = P$ [$(MPa)^{2/3}m^3/Mg$]
Carbon fiber-reinforced composite (0.65 fiber fraction)[a]	1.5	1140	72.8
Glass fiber-reinforced composite (0.65 fiber fraction)[a]	2.0	1060	52.0
Aluminum alloy (2024-T6)	2.8	300	16.0
Titanium alloy (Ti-6Al-4V)	4.4	525	14.8
4340 Steel (oil-quenched and tempered)	7.8	780	10.9

[a] The fibers in these composites are continuous, aligned, and wound in a helical fashion at a 45° angle relative to the shaft axis.

Figure 1: Comparison of common engineering materials [1]

With a performance index of 72.8, Carbon fiber provides a more-than-adequate strength to density ratio, allowing for sufficient reliability and safety, while maintaining a vehicle under the required weight restriction.

Since Carbon fiber is composed of woven composite strands, this makes fabrication and fastening a challenge as the fibers have a tendency to break apart and tear when they are disrupted e.g. drilling, cutting, bending. Because of this, it was crucial to find a solution that was less intensive on the material in order to maintain the integrity of the composite. The solution came from Rockwest Composites, which offers numerous types of carbon fiber tubing in different shapes and weaving to accommodate nearly any project. Along with unidirectional and omnidirectional patterns, a non-intrusive method of connecting the tubing was available with the CARBONNect ® connectors. The connectors are composed of 6061-T6 aluminum, and serve as the joints for the frame. The adapters are lightweight, and boast tremendous capabilities. CARBONNect ® connectors offer modular configurability and a mounting solution for metal plates to attach necessary components. These connectors were selected, as well as the INFINITubeV Standard Modulus round Carbon fiber tubing. The Carbon fiber tubing has a diameter of 1.5 inches, and consists of a 3k 2x2 Twill Weave for a balance of strength and formability.

III. FEA Analysis

With the fluid powered vehicle frame being a custom design, the frame design needed to be subject to analysis that would determine unknown characteristics. The CAD model of half the frame was imported from Solidworks into Ansys in order to perform a deformation and maximum stresses analysis. It was determined that half the frame provided accurate results due to the frame design being symmetrical, as well as simplifying the time of solving for the solutions. Once the loading conditions were determined and the boundary conditions, the total deformation of the frame was solved for. With a loading force of about 275 lbs on half of the frame, the total deformation was 0.053439in.

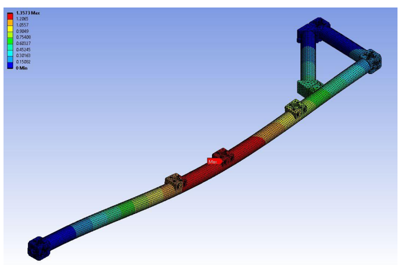

Figure 2. Ansys total deformation contour plot

Then the maximum stresses were found. Using the same loading conditions, the maximum stress was 21,450 psi.

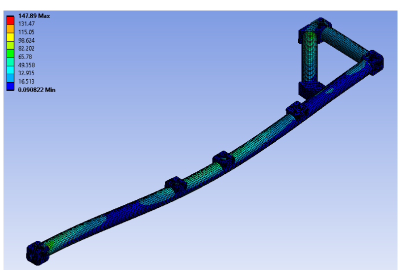

Figure 3. Ansys total deformation contour plot

To verify whether the solutions of the analysis were producing accurate results, a convergence study of both the deformation and maximum stresses was performed, and concluded that the solutions were accurate. As a result, this is a viable frame design to use for the vehicle due to little deformation, and its strength

IV. Results and Discussions

The frame prototype of the fluid-powered recumbent tricycle is designed to be lightweight and structurally sound holding the rider and all the hydraulic, pneumatic, and electrical components. The research into carbon fiber tubing is a beneficial part to the design of the frame to keep the frame lightweight. The main frame was made with carbon fiber tubing and CARBONNect ® connectors and the main mounting pieces were made with aluminum. Thick ¼” 6061 Aluminum plating is the plating used in the mountings for all the components. A majority of the mounting pieces were manufactured using DXF files and the OMAX ® waterjet in the NIU machine shop. This is another approach to reduce the overall weight of the vehicle. The frame is rigid and is capable of holding up a significant load. Although, due to an unforeseen reduction in the production timeline, the prototype was not able to be tested thoroughly. However, due to drawings in CAD, an FEA Analysis, and a circuit simulation using Simulink® it is shown that the frame prototype of the fluid-powered recumbent tricycle will be a success in the FPVC.

V. Conclusions

The frame prototype for the fluid-powered recumbent tricycle is an original design. The originality of the frame and the mounting components gives this tricycle an edge in the FPVC competition where a majority of the FPVC teams use pre-manufactured frames and parts. Although the manufacturing process of all these frame parts is time consuming, the end goal is reached. The end goal is to produce a strong lightweight frame capable of carrying a great deal of weight.

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VII. References

[1] Callister Jr. William D. (2001) Fundamentals of Materials Engineering (5th ed.)