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Design of an Accumulator Hand Cart for FSAE Electrical Vehicle

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ABSTRACT – *The Formula SAE Electric (FSAE) competition encourages engineering students to design and manufacture advanced electric race cars with a strong emphasis on safety, performance, and innovation. One aspect of the electric vehicle (EV) system that is often overlooked is the handling and transportation of the high-voltage accumulator. This paper presents the design of an accumulator hand cart specifically tailored for FSAE electric vehicle regulations. The hand cart is intended for safe and efficient transportation of the accumulator during vehicle assembly and maintenance activities, especially at competition venues. Key design considerations include mechanical stability, maneuverability, the required range of motion for operation, the safe lifting and removal of the accumulator from the chassis, and compliance with FSAE safety standards. The integration of a jack-lift mechanism enables controlled and secure lifting of the accumulator into the chassis, while a dead-man braking system is incorporated to prevent unintended movement and potential damage to the accumulator enclosure. Overall, the design of the hand cart is intended to improve safety during maintenance and competition operations, minimize setup time, and offer a practical solution for handling high-voltage components in FSAE electric vehicles*

KEYWORDS: EV accumulator, hand cart, FSAE EV

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1. INTRODUCTION

The rapid growth of the electric vehicle (EV) industry has driven increased demand for advanced, efficient, and safe maintenance equipment to support modern EV servicing needs. The growing adoption of electric vehicles globally reflects a shift towards more sustainable transportation solutions, but it also brings new challenges for maintenance practices, particularly when it comes to handling EV battery systems. One of the most critical aspects of EV servicing involves the safe and efficient management of large, heavy, and complex battery packs that are integral to the vehicle's performance and safety (See et al., 2022).

In Formula SAE Electric (FSAE EV), the accumulator or known as battery pack, is one of the most critical and heaviest components of the vehicle (Meah et al., 2020). The accumulator's significant weight, high-voltage characteristics, and limited accessibility within the chassis make safe handling during charging, maintenance, and installation critically important. Thus, these accumulator systems require special consideration when being lifted, transported, or replaced during maintenance procedures. Improper handling of the accumulator can result in significant safety risks, including damage to the accumulator, the vehicle, or even to personnel. Other than that, FSAE Electric competitions require teams to meet strict safety standards set by the rules, especially in handling and transporting high-voltage components like the accumulator (Bisschop et al., 2020). An accumulator cart not only ensures compliance with FSAE EV safety rules but also significantly aids in ergonomics and workflow in the garage and during events.

The sheer weight and sensitivity of accumulators present serious risks to both the personnel involved and the equipment being serviced. Improper lifting and movement of these heavy components can result in severe injuries and damage to the battery modules themselves, or even accidents that could potentially disrupt the competition team and affect the safety of the entire working environment. As such, the introduction of specialized equipment, such as accumulator handling carts, is essential in mitigating these risks and ensuring that battery replacement, installation, and maintenance processes are conducted in a safe, efficient, and organized manner (Timbadia et al., 2017). By providing a stable, secure platform that can safely support the weight of an EV battery, a handling cart serves to alleviate the dangers of manual lifting, thus reducing the risk of workplace accidents and improving operational workflow within automotive service environments.

An accumulator hand cart is not just a simple support platform; it is a critical piece of equipment designed to enhance safety and productivity. Thus, the cart must be equipped with features that enable stable lifting and lowering capabilities to transport the battery pack without causing undue stress on both the personnel and the battery. Additionally, the integration of advanced safety mechanisms, such as a dead man brake, a mechanism that automatically halts any movement of the cart if the user releases control. It plays a pivotal role in preventing unexpected accidents or unintended movements during operation. Although similar safety systems are widely adopted in other heavy-duty equipment, such as industrial lifts, medical trolleys, and warehouse machinery, their application in the EV maintenance sector is still in its early stages, leaving room for significant innovation and improvements. (Čuchor et al., 2021). Incorporating these safety systems into a battery handling cart represents an opportunity to elevate industry standards and enhance safety measures specific to the needs of EV servicing.

In addition to safety, ergonomic considerations are the most important in the design of an accumulator hand cart. The physical demands of lifting and moving heavy EV accumulator packs can lead to operator fatigue, which not only reduces efficiency but also increases the likelihood of accidents caused by human error. Therefore, the design of the cart must incorporate ergonomic principles that reduce the strain on the operator's body while performing tasks over extended periods. These considerations include optimizing handle positions, adjusting lifting heights to suit different tasks, and minimizing the force required to move the cart effectively. The combination of safety, usability, and ergonomics will ensure that the handling cart enhances overall operational efficiency in the workshop while minimizing the physical demands on operators

In addition to safety concerns, another major issue is the inefficiency in workshop operations caused by the lack of appropriate equipment for handling EV batteries. The process of lifting, moving, and replacing these heavy battery packs can be time-consuming and labor-intensive. Without the right tools, technicians may spend excessive amounts of time and effort performing routine maintenance tasks, reducing overall productivity and increasing operational costs. Delays in battery handling may also affect the service timeline, potentially frustrate the working team, and disrupt the working schedule. Therefore, improving the efficiency of EV accumulator handling is crucial to optimizing workshop productivity and maintaining a smooth workflow.

Another significant problem is the potential damage to the battery packs during handling. EV accumulators are highly sensitive components that contain numerous cells and complex electrical systems. Any improper movement or pressure applied to the accumulator pack during lifting or transportation can cause internal damage, such as broken connections, misalignments, or even permanent failures of the battery module. Such damage not only compromises the performance and lifespan of the battery but also presents safety risks, as damaged batteries can become fire hazards or cause other operational failures. Thus, it is critical to ensure that the handling equipment does not put unnecessary strain or pressure on the battery during the transportation or replacement process.

2. METHODOLOGY

The design of the accumulator hand cart is intended to ensure a systematic, structured, and efficient approach throughout the project life cycle. Started from the initial design phase to the validation stages. A clearly defined methodology is essential to delivering a product that is functional, reliable, and fully compliant with applicable safety standards and ergonomic requirements for electric vehicle accumulator handling.

2.1 Design Consideration

The design of the EV accumulator hand cart project integrates a variety of essential engineering concepts aimed at ensuring the cart is not only functional but also safe, efficient, and user-friendly for competition environments. Several critical areas of engineering are taken into consideration during the design phase, including ergonomics, load distribution, mechanical stability, and modularity. Each of these elements plays a crucial role in enhancing the overall performance and usability of the accumulator cart, ensuring that it meets both operational demands and safety standards required set by the FSAE rules.

2.1.1 Design requirement in FSAE Rules

The design of the accumulator hand cart must adhere to the specified FSAE rule outlined below (Table 1):

TABLE 1: Hand cart requirements

Rule No.	Requirement
EV 4.10	Accumulator Hand Cart
EV 4.10.3	The hand cart must: a) Be able to carry the load of the accumulator container without tipping over b) Contain a minimum of two wheels c) Have a brake that must be: • Released only using a dead man type switch (where the brake is always on until released by pushing and holding a handle) or by manually lifting part of the cart off the ground • Able to stop the hand cart with a fully loaded accumulator container
EV 4.10.4	The accumulator container must be securely attached to the hand cart

While addressing load distribution, the cart is designed to evenly distribute the heavy weight of the EV battery pack to avoid undue stress on any single component and to maintain structural integrity during operation. Proper load distribution not only prolongs the lifespan of the cart but also improves safety by preventing tipping or structural failure under load. To further reduce the manual effort required during accumulator handling, the lifting mechanism incorporated into the cart design utilizes the principle of levers. The jack lift is capable of lifting the accumulator container into the chassis of the car. By applying this basic mechanical advantage, the system reduces the amount of force needed to lift and lowers heavy battery packs, thereby minimizing physical strain on the operator and enhancing the efficiency of the battery installation and removal process.

Mechanical stability is another vital consideration. Maintaining a low and controlled center of gravity is essential to ensuring that the cart remains stable when loaded or during movement. To support this, the selection of suitable caster wheels, both in terms of material strength and wheel size, is undertaken carefully to provide excellent load-bearing capacity, shock absorption, and directional control. The combination of a well-managed center of gravity and robust wheel systems reduces the risk of accidents such as tipping or loss of control, particularly when navigating uneven workshop floors or ramps.

As part of the overall safety strategy for FSAE compliance, a dead man brake system is integrated into the cart's design. This system is engineered to automatically engage the brakes and halt cart movement whenever the operator releases control, preventing unintended motion that could lead to accidents. Such a feature is crucial in environments where heavy batteries are being moved, as it provides an added layer of security and enhances operational safety standards.

2.2 Design Selection

Based on the requirement analysis, the conceptual design phase is initiated. In this phase, various design alternatives are brainstormed and evaluated based on criteria such as functionality, manufacturability, cost-effectiveness, and ease of maintenance. Sketches and preliminary CAD models are developed to visualize the basic structure of the cart, including the main frame, lifting mechanism, mobility system, and safety features. Concept sketches and rough CAD models are also created to visualize potential solutions, allowing for early detection of design issues and encouraging creative solutions for mechanical challenges. Comparative studies are conducted to determine the most suitable lifting system, whether mechanical, hydraulic, or electric, with careful consideration of load capacity, ease of operation, and reliability.

Once the conceptual design is complete, the process advances to the detailed design stage. At this stage, precise 3D modelling and specifications are created using CAD software. Every component, such as the frame, scissor arms, hydraulic or mechanical lifting system, wheels, handle assembly, and brake system, is designed with attention to material selection and stress analysis. Finite Element Analysis (FEA) is conducted to simulate structural performance under static and dynamic loads, focusing particularly on critical stress points, center of gravity management, and stability during lifting and transportation. This ensures that the cart design is capable of safely handling the heavy loads associated with the EV accumulator.

For the frame, materials such as aluminum alloys are commonly chosen for their light weight, high strength-to-weight ratio, and resistance to corrosion. Steel may be considered in certain cases to provide extra strength, though it will increase the overall weight. For wheel selection, polyurethane is a popular choice due to its durability and smooth rolling characteristics, making it suitable for various surfaces like asphalt or concrete commonly found in pit areas. Proper wheel sizing is crucial for ensuring stability and ease of movement. For the handle, lightweight yet strong materials like carbon fiber or aluminum are preferred, as they help maintain a low weight while still offering the necessary strength. Finally, stainless steel or high-grade aluminum fasteners are recommended for their corrosion resistance, ensuring the cart remains secure under load.

3. RESULTS AND DISCUSSION

The accumulator hand cart for the FSAE Electric Vehicle was designed to provide a safe, ergonomic, and efficient solution for transporting the heavy and delicate accumulator. By referring to Figures 1 and 2, the hand cart was designed to support the weight of the accumulator, which ranges from 20kg to 100kg depending on the battery configuration. The handle is designed to be adjustable, allowing the user to choose the most comfortable grip based on their height, hence reducing strain during transport. The design also optimized maneuverability, allowing one or two team members to easily transport the accumulator without strain. The lift jack is designed efficiently to raise the accumulator from the floor or storage rack and place the accumulator precisely into the accumulator compartment of the vehicle during installation or replacement (Figures 3 and 4).

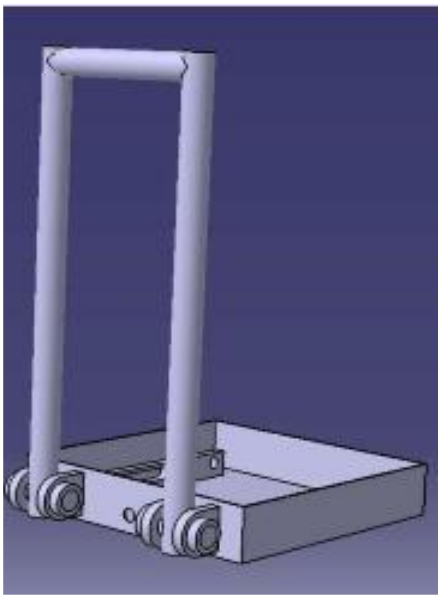

FIGURE 1: Main frame

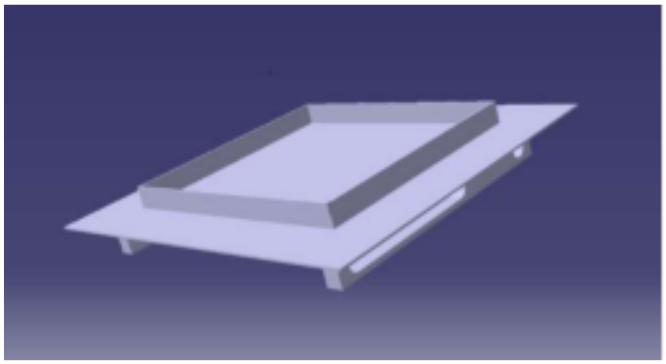

FIGURE 2: Battery platform

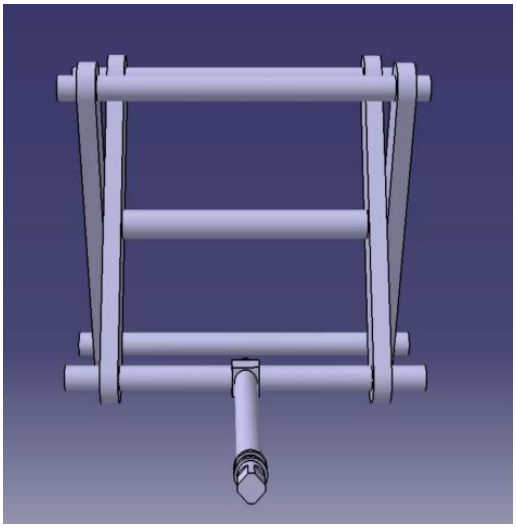

FIGURE 3: Lift jack

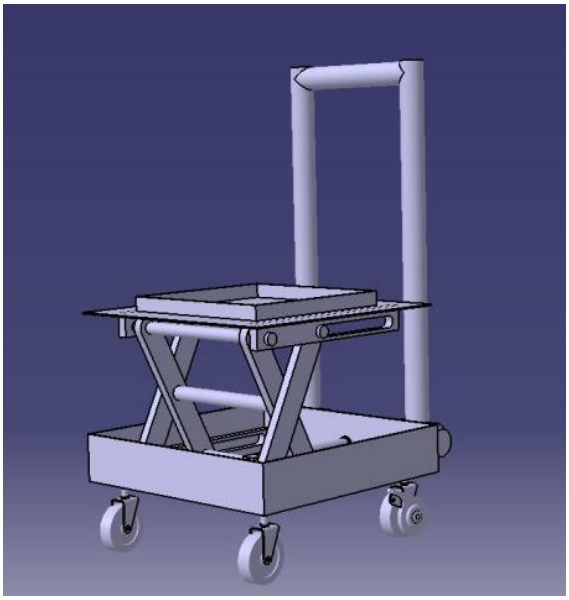

FIGURE 4: Accumulator hand cart

4. CONCLUSION

In conclusion, the design of the accumulator hand cart focuses on defining clear specifications and enhancing safety before the development phase. The integration of a dead-man braking system, along with ergonomic features such as a flexible handle and an appropriately sized platform, provides a comprehensive and reliable solution for the safe and efficient handling of EV accumulators.

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