Vintage Motorcycle Electric Conversion

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Introduction

This applied research paper outlines a comprehensive senior design capstone project focusing on the electric conversion of a classic 1972 Honda CB-500 motorcycle completed in an Engineering Technology program at Sam Houston State University. The project's core objectives are multifaceted. First, it seeks to promote sustainability by reducing waste through the reuse of existing motorcycle components and minimizing the need for new materials. Second, it aims to preserve the heritage and iconic styling of the CB-500, while adding some custom flair and updates to the platform, all while meeting or exceeding the original motorcycle's performance. Third, a key goal is to develop an outline for modular, drop-in conversion kits that can be adapted for use with various other vintage motorcycle models, thereby fostering a more accessible and sustainable electric vehicle market. Finally, the project aims to contribute to the ongoing development of electric powertrains specifically designed for motorcycles. The project encompasses a comprehensive design process, including a thorough vehicle assessment, careful selection of an electric powertrain, the outline for modular conversions, rigorous safety considerations, and meticulous performance optimization to balance range, power, and handling. This initiative is driven by a desire to promote sustainable transportation, preserve motorcycle heritage, contribute to the advancement of electric vehicle technology, and create a more accessible market for electric conversions.

Problem Definition

In the current environment, the need for sustainable transportation is greater than ever, and many companies are leading the charge in creating electric sustainable vehicles. The one downside to these new electric vehicles is that they still require the same number of raw resources as conventional vehicles. Electric conversions re-use many of the components that already exist and allow for sustainable transportation to be built for a greatly reduced cost. Incorporating electric motorcycles offers a compelling solution to reduce urban congestion and pollution, particularly in densely populated areas where motorcycles and scooters are prevalent. Their smaller size and maneuverability, combined with zero tailpipe emissions, make them ideal for navigating city streets while minimizing their environmental impact. Additionally, the instant torque of electric motors provides a responsive and exciting riding experience, further enhancing their appeal as a sustainable transportation option.

For this project the central challenge lies in seamlessly integrating a modern electric powertrain into a vintage motorcycle designed for an internal combustion engine, all while ensuring a custom vintage aesthetic, good performance characteristics, and ensuring the design's adaptability to other platforms. The current electric motorcycle market presents a dichotomy: commercially available products often suffer from either underperformance or exorbitant prices.

Literature Review

Electric motorcycle (EM) technology is on the rise with many companies producing commercially available products, most of these companies are independent and only produce such products, although larger manufacturers are slowly gaining traction in the market. The front runner of these independent companies is Zero Motorcycles that offer three models with varying sub-models, and each is at the cutting edge of electric motorcycle technology [1]. The three models have vastly different performance specifications, but each carries a price tag between $12,000 and $25,000. These prices are high, and the average motorcycle cost for the last 4 years was around $12,000 [2]. Much lower cost alternatives are available from Chinese manufacturers but the performance of these products is similar to a standard E-bicycle with top speeds between 30-40 mph and very limited range. The disparity between these two levels of products leaves a hole in the market where a middle ground product would be very viable, and the ability for customers to convert their currently owned vintage motorcycle would be a major challenge.

Motorcycles are used as a main mode of transportation in many countries around the world, especially in Asian countries. Many of these countries are currently pushing for an increase in EM's due to emissions and traffic congestion problems, especially among ride sharing companies [3]. These companies have realized that even though the upfront cost for new EMs is higher than a conventional gas option, the savings on fuel costs quickly outweigh that cost [4]. Implementation of an affordable and easy to install electric conversion kit would cut the initial cost of owning an EM and would decrease the amount of resources needed to provide viable transportation.

The proper selection of components for this motorcycle conversion are paramount to the overall success of the build. The two major components for consideration at this stage of the project are the motor/ controller, and the battery. When selecting a motor and controller it is important to consider properties such as: dimension, weight, output power, longevity, and voltage rating, as these will determine the final performance specs of the motorcycle. It is also important to consider the type of motor to use. The most common type of motor used in EMs is permanent magnet synchronous motors (PMSM) [5]. Another common name for this type of motor is brushless DC motor (BLDC), although BLDC can refer to a wide range of similar style motors. The PMSM consists of 3 phase stator windings, a permanent magnet rotor, and electronically controlled commutation. These motors are generally chosen because of their high efficiency, wide speed range, and precise control features [5]. The other consideration when choosing a motor for an EM or other EV is the rated or nominal output power. A motor with the proper output power and torque characteristics must be selected for the vehicle to perform as intended.

Batteries are the other major component to consider when building an EM. Many different types and configurations exist but currently the industry standard for EV batteries is Lithium type batteries, because of their high energy density and increasing affordability [6]. Even within the category of lithium batteries many subtypes are available such as: $LiFePO_4$, NMC, and Li-polymer just to name a few. Each subtype has its own pros and cons when it comes to discharge rate, capacity, and thermal properties. The most common type used in current EVs and EMs is Lithium-ion Nickel Manganese Cobalt Oxide (NMC) due to its high energy density, long life cycle, and better thermal properties.

Engineering Approach

The path to solving an engineering design problem can take many different routes and is almost always different for each project. The key to success is to have a well-defined plan, do in depth research on the problem and possible solutions, evaluate the solutions for viability, and then test and prototype those solutions until the result is acceptable. This project contains many different design challenges along with a numerous of solutions. By breaking down the project into categories and subcategories, the individual solutions can be analyzed for viability and the best solution can be selected. The functional block diagram in Figure 1 shows the EM project broken down into major phases and how those systems interact with each other. The arrows represent what type of interaction takes place and in which direction the power or information flows. This is a surface level representation of the entire system but serves to identify the individual systems that will need to be analyzed and constructed.

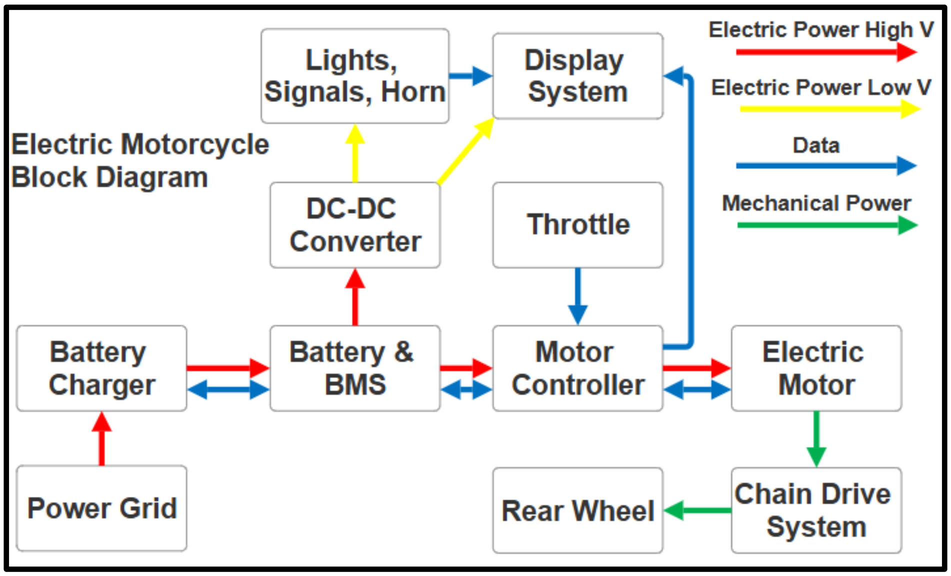


Figure 1. Simplified functional block diagram of electric motorcycle (EM)

Motor and Controller

For this project the motor and controller are being considered together instead of as separate entities. This is because in today's market most electric motors that would be considered for this type of project come with manufacturer-recommended controllers for specific purposes. To properly select a motor for any EV project certain metrics must be known to ensure the system to perform as desired. The key considerations are power output, weight, and space. The theoretical minimum power to achieve the 0-60 mph acceleration of the original motorcycle can be found using the formula in Figure 2.

P = Power	
M = mass	M= 250 Kg V= 26.8 m/s T= 6 sec
A = acceleration	A= V/T = 4.5 m/s2
V =velocity	F= M*A = 1125 N
F = force	P=F*V = 30 Kw
T= time	

Figure 2. Basic formula for calculating minimum power to achieve a speed of 0-60 mph in 6 s

After considering the minimum required power of 30 kW, as well as weight and space constraints within the motorcycle frame, the Motenergy ME-1905, as seen in Figure 3, was chosen as the optimal motor.

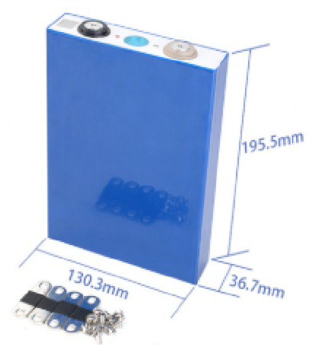
ME-1905 Motor Specs:
Power Output: 18 KW Nominal 47 KW Maximum
Input Voltage: 48 -120 V
Torque: 44 Nm Nominal 134 Nm Maximum
RPM: 4500 RPM Nominal 8000 RPM Maximum
Weight: 22 KG
Phase Current: 220A Nominal 550 A Maximum

Figure 3. ME-1905 motor and specifications

This motor has a high output power and a relatively small footprint which makes it an excellent candidate for this project. The maximum output power exceeds that of the original gas engine in the motorcycle which aligns with the goal of the electric conversion meeting or exceeding the original performance specifications. The controller recommended for this motor is a Sevcon size 4, this controller is highly configurable and has a small footprint. This controller is also specifically designed for PMSM type motors. The focus of this project is the integration of the electric drivetrain to the vintage motorcycle chassis; therefore, the motor and controller were purchased as a turnkey kit that includes the motor, controller, fuses, junction box, contactor, throttle, and key switch.

Battery, BMS, and Charger

When choosing a battery setup for an EM it is critical to consider the motor and controller requirements as well as the desired quantitative results of the vehicle. A battery system cannot be selected until the requirements of the drive system and the desired range are known. For this project individual EVE LF-105 lithium cells will be used to construct a battery pack with a nominal voltage of 96V and 105 Ah capacity. This battery, as seen in Figure 4, is a prismatic style cell that has an aluminum case and threaded connection posts.



EVE LF-105 Prismatic Cell Specs:

Nominal Voltage- 3.2 V

Voltage Range- 2.5 V - 3.65 V

Capacity- 105 AH

Cycle Life- 4000

Weight- 4.4 LB

Figure 4. Specifications of EVE LF-105 prismatic cell battery

This style was chosen for several reasons including increased protection for each cell, more options for mounting, and reduced need for soldered connections. Each cell is 3.2 V rated, and a 30 series (30S) configuration will be required to achieve 96 V. The battery enclosure will consist of aluminum plates, 3D printed components, and m6 threaded rods. The design is covered in depth in the battery assembly section of this report. The battery management system (BMS) is an off the shelf solution from ANT BMS. It is a 7S-32S system that employs bluetooth connection, over discharge/ charge protection, temperature sensing, and short circuit protection. The function of the BMS is to monitor charging and discharging operations and ensure balance within the series connected batteries. The charging system is also an off the shelf solution, the selected charger is dual voltage accepting 120/ 220 V AC input and outputting 10A and 20A respectively at 96V DC. This charger allows flexibility in charging when a 220V outlet is not available.

Chain Drive System

The existing chain drive system will be modified to link the new electric motor to the existing rear hub to supply power to the rear wheel of the EM. The front and rear sprockets can be exchanged for ones with teeth to adjust the gear ratio. The gear ratio will directly affect the top speed, acceleration, and torque delivery of the vehicle. Online calculators have been used to select an initial gear ratio of 1:3. Electric motors generally yield very high and instant torque, and a low gear ratio is usually selected for these applications. Custom sprockets are generally inexpensive therefore additional ones can be purchased if the first set does not achieve acceptable results.

Weight

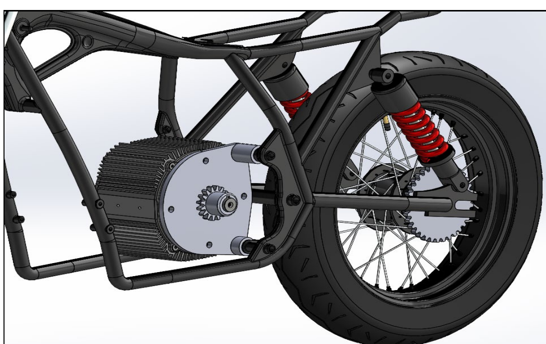
Weight is a critical factor in the design of any vehicle, particularly electric vehicles, where efficiency and aerodynamics are paramount. The integration of batteries, motors, and ancillary components will inevitably increase the motorcycle's weight. However, the removal of the original engine and fuel tank will offset some of this additional weight. The objective is to carefully balance these weight changes, ideally resulting in a final curb weight that is equal to or less than the original. Table 1 shows the comparison of the original wet weight (weight includes all fluids and a full tank of fuel) of the motorcycle and the estimated weight of the electric conversion.

Table 1. Weight comparison of original motorcycle and electric conversion

Original 1972 CB-500K weight		Electric conversion weight (estimated)	
Total wet weight	445 lbs	Modified frame (wheels, brakes, and handlebars included)	155 lbs
		Motor, controller, and wiring	65 lbs
		Battery assembly	150 lbs
		Bodywork, seat, and electrical system	35 lbs
Total weight	445 lbs	Estimated final weight	405 lbs

Frame Modifications

The motorcycle frame will need extensive modifications to account for the electric components and to achieve the custom styling that is desired. A model of the stock frame was sourced and used as a starting point for the modification modeling. The rear subframe area was removed from the stock model and rebuilt with a sleek tube design with a more aggressive shock mounting angle and a motor mounting plate was designed to mount to the original frame, as seen in Figure 5. The increased angle of the rear shock will assist the suspension with handling the larger load of the electric components. The new design will not only enhance the motorcycle's performance but also give it a distinctive, vintage look, setting it apart from traditional electric motorcycles.



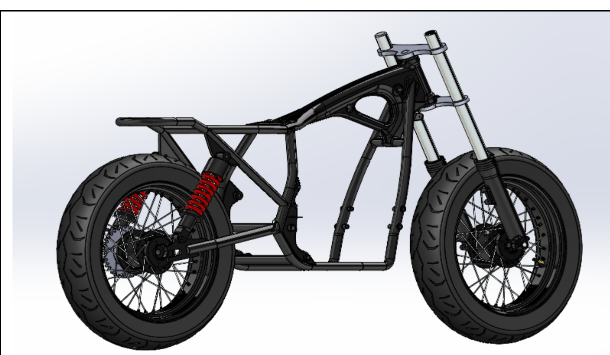


Figure 5. SolidWorks model of modified CB-500 frame

In addition to the modifications to the frame, a custom set of aero-dynamic fairings will be constructed using fiberglass laid over a high-density foam mold. The fairings will increase the overall efficiency of the EM and provide desired aesthetic visuals. This design will incorporate a fixed headlight housing that will be purchased separately and will be molded into the side fairings. This housing is fixed which will require an adjustable headlight mount to be designed and constructed so the headlight angle can be adjusted to fit the new angle of the motorcycle as seen in Figure 6.

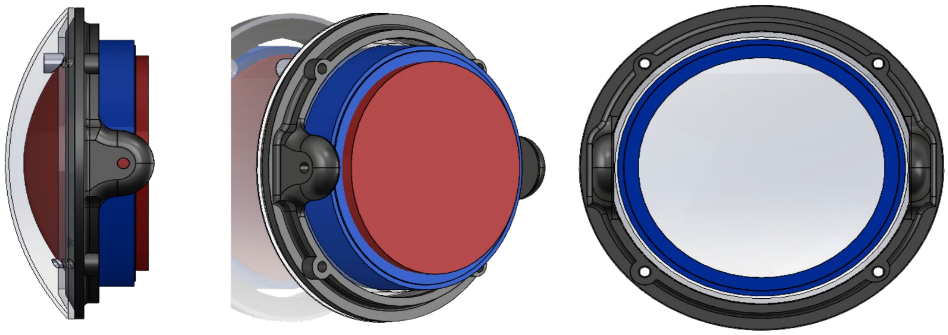


Figure 6. Solid works model of adjustable headlight fixture

Battery Assembly

The battery enclosure has been designed to house 30 of the LF-105 3.2 V prismatic cell batteries, as seen in Figure 7. The enclosure has a 6 mm aluminum plate for the base that the other components will be mechanically attached to. The corners and top pieces will be 3D printed using highly heat resistant carbon fiber reinforced polyethylene terephthalate glycol filament (PETG-CF). Threaded rods and stainless hardware will be used for the mechanical connections of the assembly. The PETG-CF used for the enclosure parts has a heat deflection temperature of 70ºC which makes it ideal since the batteries being used have a maximum operating temperature of around 60ºC.

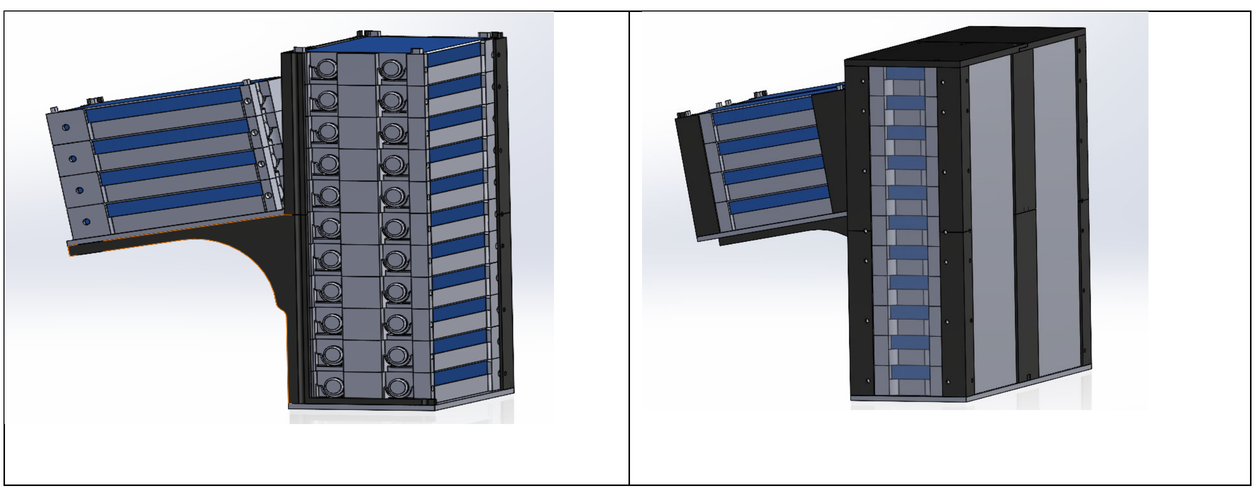


Figure 7. SolidWorks model of 30S Lithium battery enclosure

Construction

Construction of the electric conversion started with stripping down all the unneeded components from the 1972 Honda CB-500 including the engine, exhaust, display components, seat, headlight, and all of the original wiring. The next stage of the build involved cutting away the rear subframe and all of the unnecessary mounting tabs as well as grinding down the original paint where welding would take place. Once the frame was prepped the new subframe assembly could be constructed using pre-bent ⅞ tubing for the seat section and straight tubing for the support bars. The rear shock mount locations were fabricated from ¼ steel plate and fitted using the new 14-inch rear shocks as a guide for placement. The font lower portion of the frame was also modified to accept the battery pack by squaring off the upper and lower tubes. The new joints on the frame will have gussets and extra support material and the existing joints will be inspected and reinforced as necessary. Figure 8 shows the unmodified 1972 CB-500, the stripped-down frame, and the modified version.

Figure 8. CB-500 electric conversion frame modification progress

The battery pack construction started with printing all the required components and ordering the aluminum plates for the lower supports. All 30 of the support trays and most of the structure components have currently been printed and inspected for defects. Each tray receives 6 heat insert threaded barrels which allow the surrounding structures to be bolted firmly to them. Initial assembly of the battery pack has been completed so that it can be used to create the mounting structure to the motorcycle frame, as seen in Figure 9.

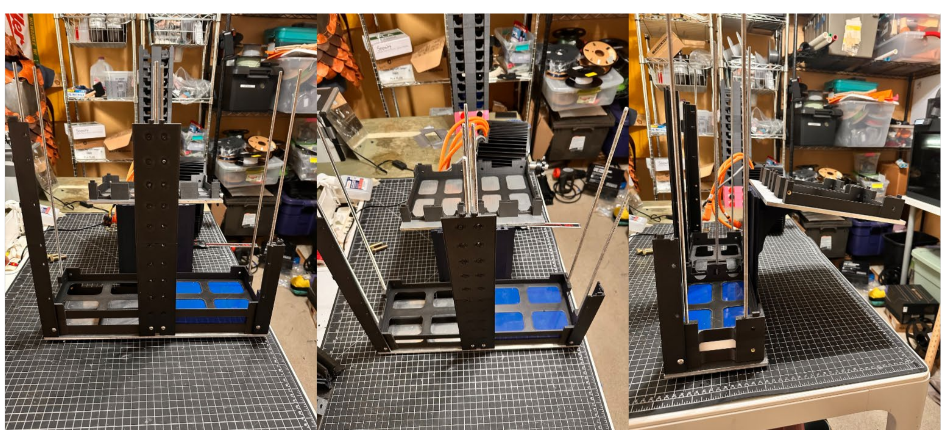


Figure 9. Initial assembly of battery enclosure components

All of the mounting locations for the electric components were built and finalized during the initial modifications to the frame. The solid works designs created in the early stages of the project ensured proper fitment of the major components during this stage. The smaller components were fitted around them using the space allowed while still considering security and heat dissipation of the components. At the conclusion of all of the custom fabrication the frame was sanded down and painted with a highly corrosion resistant stainless steel paint and a few layers of clear coat. A custom seat pan was constructed using fiberglass and a seat cover was sewn using outdoor grade faux leather vinyl. A custom headlight fairing was added in addition to fiberglass side covers and a fiberglass shell to cover the electrical components in the design of a motorcycle fuel tank. Figure 10 shows the stages of the final assembly.

Figure 10. Assembly stages of vintage electric motorcycle.

The final assembly of the EM was completed on schedule to allow testing time before the final presentation. Figure 11 shows the finished product with a graphical component breakdown

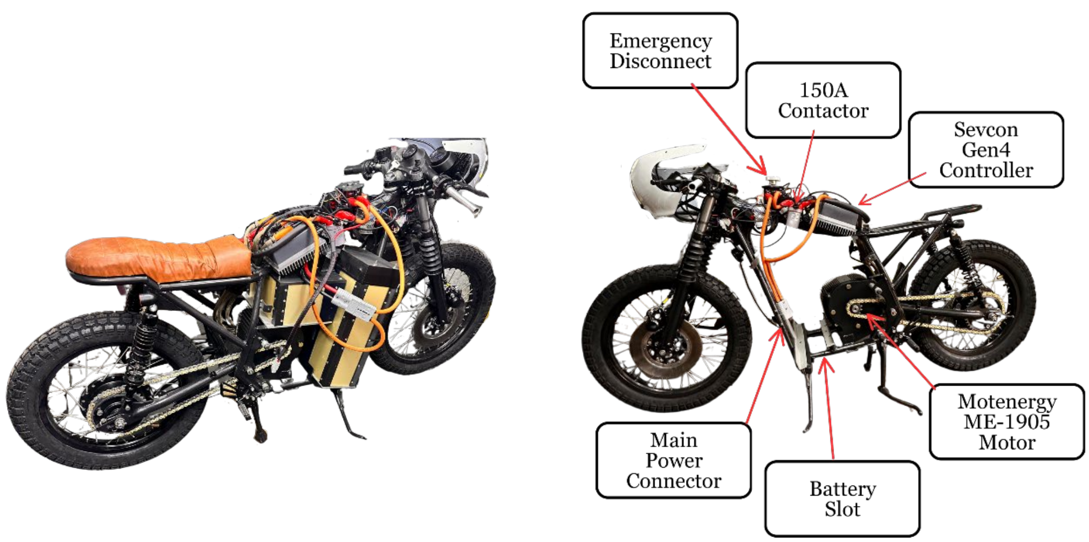


Figure 11. Finished product with graphical components.

Test Data

The EM was tested at 10 miles distance in 2 miles increments to collect the battery performance data. Figure 12 shows the test data of the EM for starting battery V, ending battery V, and average motor temperature in two separate trials. The average outdoor temperature during the testing was 88 ºF. According to the data collected, the battery total voltage drop was 1.56 V after 10 miles of distance which was equivalent to 7.2% of the total battery usable capacity. The estimated total range was calculated as 138 miles. Future work will include longer range testing to compare efficiency at lower voltages in addition to monitoring battery cell degradation.

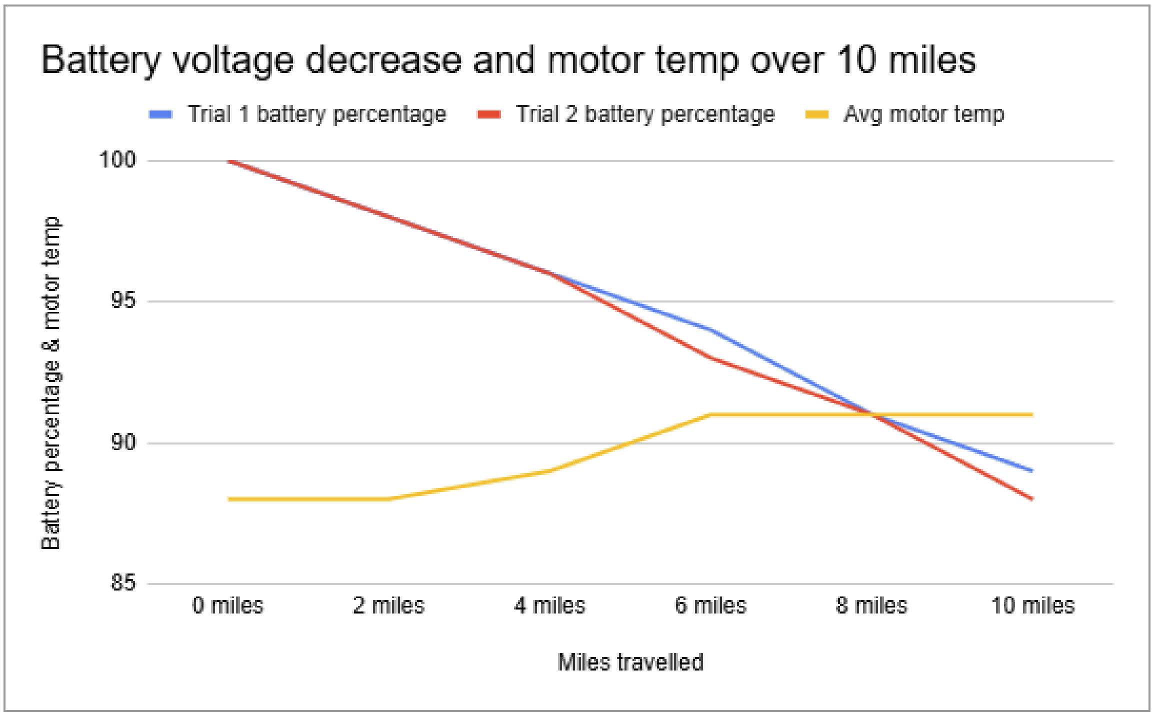


Figure 12. EM test data for 10 miles of distance.

Budget

One of the main objectives of this project is to keep the cost as low as possible thus making this an affordable option for sustainable transportation. The initial budget for the project was $7500 and with over 80% of components being purchased already the project is on track to come in at or below that number. Table 2 exhibits the budget by category and the amount spent.

Table 2. Project budget by category and total spent

Component Category	Budgeted amount	Total spent
Motor and Controller Components	$3,500	$3602
Battery Components	$1800	$1826

Fabrication Materials	$800	$683
Motorcycle components	$1400	$1895
Finishing	$500	$390
Total Expected Budget	$8000	$8397

Student Assessment

ETEC 4199 Senior Design I and ETEC 4399 Senior Design II courses at Sam Houston State University include all the student learning outcomes (SLOs) developed in the Electronics and Computer Engineering Technology and Mechanical Engineering Technology programs. The SLO3 requires students to function effectively as a member as well as a leader on technical teams. The corresponding Performance Indicators (PIs) for SLO3 is (a) Use appropriate context, conventions, and mechanics, (b) Use credible sources, evidence, and structure, and (c) Demonstrate oral presentation skills. The senior design project presented in this paper is one of the eleven capstone projects completed in the 2024-2025 academic year for ETEC 4199-01. We also had ETEC 4199-02 and ETEC 4199-03 sections with several other capstone projects. Out of eleven senior design projects in this section, only this project included a special case; one senior student who is working full-time and having family and a child that made him as only one person working in the project. He is also responsible for all the cost of the project as he did a very successful fundraising and secured almost 85% of the entire cost. Three in-class presentations in Senior Design I provided valuable feedback from other student teams and faculty to the project design and implementation. The student also met with both faculty advisors weekly face-to-face or via Zoom meetings outside of regular class hours for progress and resolving design challenges. Engineering Technology programs contain five Student Learning Outcomes (SLOs) and their corresponding fourteen Key Performance Indicators (KPIs) that are all measured for completed capstone projects. Out of five SLOs, assessment results for SLO3 entitled as "Apply written, oral, and graphical communication in broadly defined technical and non-technical environments; and an ability to identify and use appropriate technical literature " is shown on Table 3. The full and completed assessment for all SLOs will be available after ETEC 4399 at the end of Spring 2025 semester.

Table 3. Sample assessment selected for SLO3

Key Performance Indicators	**Unsatisfactory < 60%**	**Developing 60-69%**	**Satisfactory 70-79%**	**Exemplar y ≥ 80%**
a) Use appropriate context, conventions, and mechanics (Pre-	0%	0%	0%	100%

Proposal + Mid-Report)				
b) Use credible sources, evidence, and structure (Final Technical Report)	0%	0%	0%	100%
c) Demonstrate oral presentation skills (Final + Mid Presentation)	3.3%	0%	0%	96.7%

Conclusion

This paper outlines a promising senior design project focused on converting a 1972 Honda CB-500 from gas to electric power. As of May 1, 2025, this project was completed and tested with the performance data provided. The project addresses the growing need for sustainable transportation solutions, particularly in urban environments, by exploring the viability of electric motorcycle conversions. By reusing existing components and developing a modular conversion approach, this project aims to offer a more accessible and cost-effective alternative to purchasing new electric motorcycles.

The work completed thus far demonstrates a strong foundation for achieving these goals. The detailed literature review effectively establishes the context of the project within the current electric vehicle market, highlighting the gap between expensive, high-performance models and cheaper, underperforming alternatives. The selection of the Motenergy ME-1905 motor, coupled with the Sevcon controller, indicates a focus on achieving performance comparable to, or exceeding, the original motorcycle. The choice of EVE LF-105 prismatic cells and the ANT BMS demonstrates careful consideration of battery technology and safety. The weight analysis, while still an estimate, suggests that the conversion can be achieved without significantly increasing the overall weight of the motorcycle. Furthermore, the detailed descriptions of the frame modifications, battery enclosure design, and progress on physical construction showcase the practical application of engineering principles and the commitment to realizing the project's objectives.

The meticulous approach to component selection, design, and construction, coupled with the focus on sustainability and cost-effectiveness, positions this project as a valuable contribution to the field of electric vehicle conversions. Future work will focus on completing the physical assembly, thoroughly testing the performance and safety of the converted motorcycle and refining the design for potential modular conversion kits. This applied research project completed in a B.S. degree provides valuable insights into the feasibility and benefits of vintage motorcycle electric conversions, contributing to a more sustainable transportation future and offering a compelling option for motorcycle enthusiasts seeking a blend of classic aesthetics and modern technology.

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Appendix

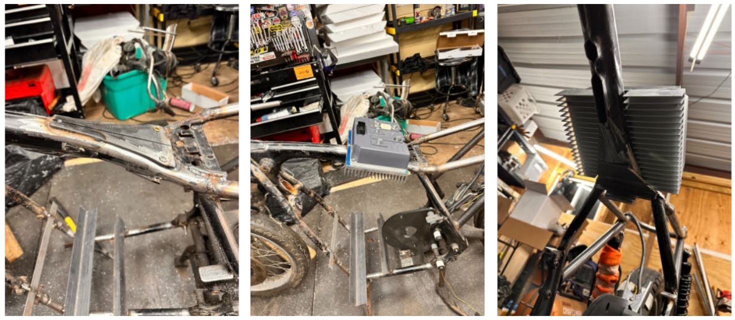
The appendix contains additional construction and assembly photos of the vintage motorcycle electric conversion.



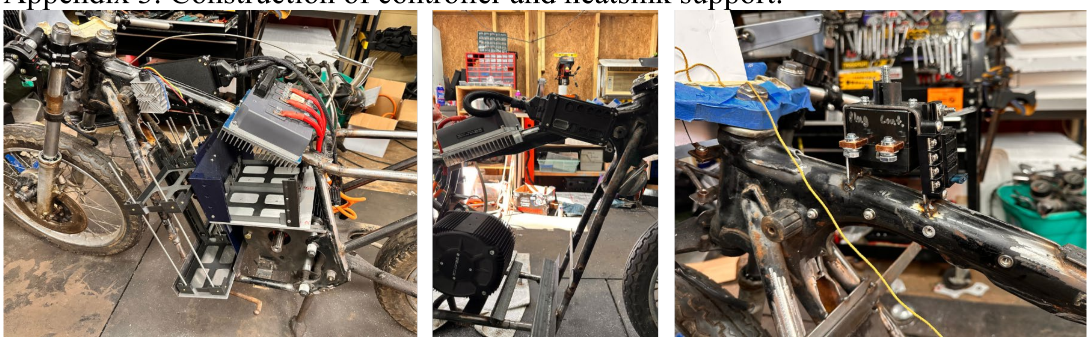
Appendix 1. Construction of battery supports.



Appendix 2. Construction of custom subframe assembly.

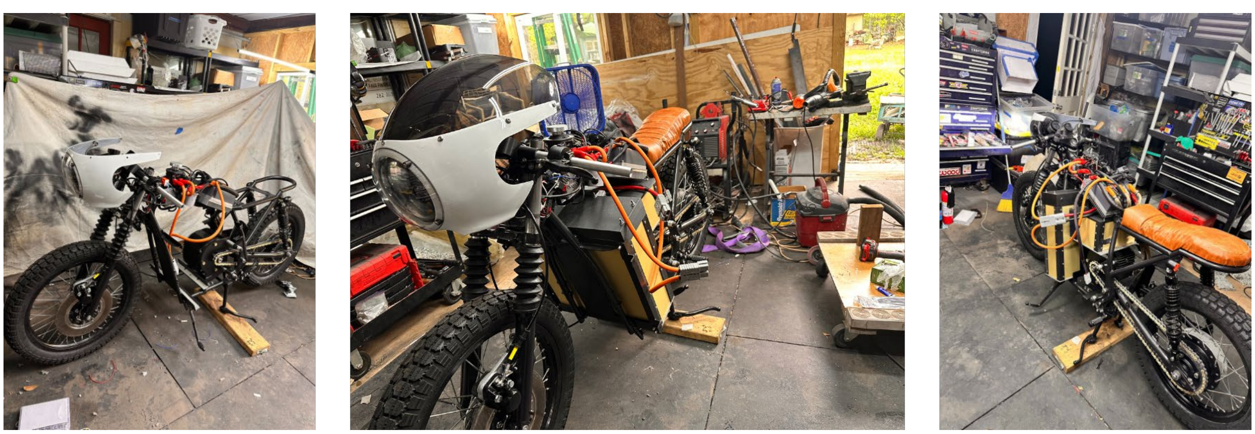


Appendix 3. Construction of controller and heatsink support.

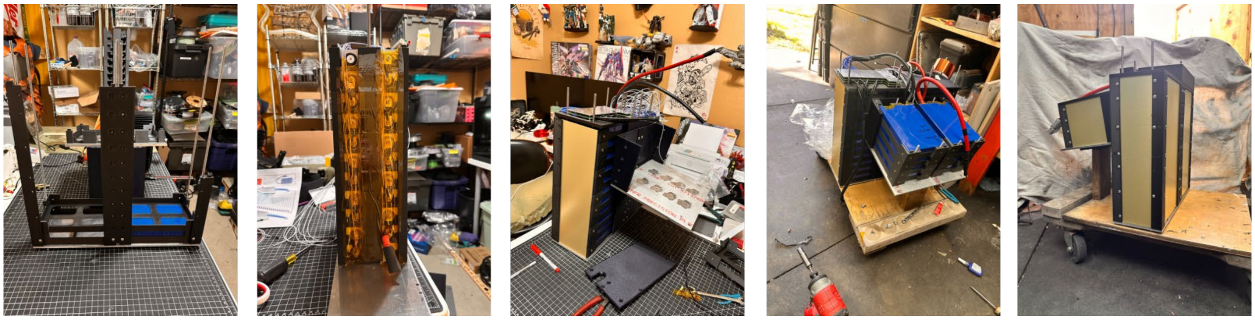


Appendix 4. Placement of various electronics components.

Appendix 5. Frame preparation and paint application.



Appendix 6. Final assembly.



Appendix 7. Battery enclosure and wiring.

Appendix 8. Fairing and tank construction.

Appendix 9. Seat construction.