Team508: Structural and Thermal Management of an Automotive Battery

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Targets and Metrics

Each fundamental function of the battery enclosure is illustrated in Table 1, highlighting the necessary targets and metrics that will be met in the design process. These targets and metrics were obtained through analysis of the SAE Formula Hybrid Competition rules and regulations, customer needs, and research of battery systems.

**Testing Methods**

Testing Methods for the critical functions may be dependent on the amount of budget that is available. For a low-cost way to test the G-forces and impact forces a CAD simulation utilizing Solidworks or ProE would be ideal for these tests in the initial design phase, this testing is also useful in finding integrity of the design with relation to wear and tear. Physical testing using a shaker machine would be an optimal way to test the structural integrity of the battery box design in the prototyping phase for tests of the vibrational damping of the box. Testing the ability for the battery box to withstand impact in a real-world test would be destructive and would dig into budget constraints. Testing of battery cell temperatures, discharge rates, and power output can be tested with a battery cycler, temperature probes will be applied to the battery during this test to determine the thermal output of the battery at peak loads. Testing the sealing of the battery box is basic test of showering the box to test the water tightness, this test is specified in the SAE formula hybrid rule book.

**Derivation of Critical Targets and Metrics**

The battery enclosure is required to accomplish critical targets in order to fulfill the general functions of securing the battery system structurally and thermally. These critical functions were established in the functional decomposition of the battery enclosure, paying close attention to the necessary actions and outcomes of its performance. The critical functions consist of maintaining operating temperature, withstanding impact, and seal the container.

**Operating Temperature**

One of the critical functions needed in order for the battery enclosure to thermally manage the system is to stay within the operating temperature. This entails heating and/or cooling the components in order to maintain a temperature of less than 60 degrees Celsius. The numerical target was determined based on the rules and regulations for the SAE Formula Hybrid Competition. This function is critical in keeping a safe operating environment, so that the battery does not overheat and fail. On the other hand, if the battery is too cold, the internal resistance will increase and the charge capacity will decrease to the point where the battery will not operate. The critical target of maintaining the operating temperature will be assessed through implementing heating and cooling components into the enclosure. The current battery will be tested in order to gain an initial thermal analysis of the system. With the current thermal performance, necessary designs can be carried out to obtain and control the needed operating temperature.

**Withstand Impact**

The battery enclosure’s ability to withstand impact is another critical target that needs to be addressed. The enclosure will be responsible for maintaining structural integrity throughout the course of its life time. This includes surviving the impact from external forces and dampening mechanical vibrations. Throughout the course of the race, the battery will be exposed to vibrations due to the dynamic forces of the vehicle and interaction with the vehicle components and environment. Similarly, the battery will be connected to the vehicle and is subject to experience large forces if the vehicle undergoes an impact. The numerical targets for this critical function were determined mathematically using the maximum velocity, as presented in the race track velocity profile, and existing vehicle parameters. These targets will guide the design of the structure, and then mechanical testing and analysis will be carried out to ensure the necessary targets are met.

**Sealing Battery Box**

Sealing the battery box from the outside environment is a critical target in the effective operation and performance of the battery. During the operation of the vehicle, the battery will be low to the ground and exposed to dirt, water, and other debris. The contamination of the battery system by the environment can destroy the system and can cause failure in addition to irreversible damage to the internal components. The target for this function was determined based on an anticipated efficiency for the performance of the battery system. Designs will be carried out with the intention of sealing the battery from any wet or dry environmental debris.

**Conclusion**

The necessary targets and metrics for the completion of a structurally and thermally secure battery were discussed and analyzed. Some critical functions for the enclosure were determined, as vital requirements for the operation of the battery system. Targets were gathered using SAE Formula Hybrid Competition rules and other external resources. Verification of the targets will be conducted via the various testing methods discussed. Ultimately, all critical and presented targets will guide the next steps of the design process, particularly in the generation of concepts.

References

2019 Formula Hybrid Rules. (2018). SAE Formula Hybrid.

Tables

Table 1

Targets and Metrics

|  |  |  |
| --- | --- | --- |
| **Functions** | **Targets** | **Metrics** |
| Power output | 28.77 kW | Peak power |
| Withstand impact | 59.73 kJ | Impact Energy |
| Dampen Vibrations | 10 Hz | Peak Vibration |
| Insulated from moisture? | <1% RH | Maximum Relative Humidity |
| Structural Dimensions to Fit Chassis | 2 ft x 1 ft x 3 ft | Volume |
| Lightweight Structure | 50 lbs | Max Weight |
| Limit External Debris | 50,000 particles/mL | 95% efficiency |
| Spacing of the Components | 1 cm between all parts | Minimum spacing |
| Maintain Operating Temperature | 60° C | Temperature |
| Maintain Module Temperature | 50° C | Temperature |
| Electrical insulation  -minimum thickness  -minimum temperature | 0.25 mm  150° C | Thickness  Temperature |
| Timeframe\* | 6 months | time |
| Lifetime\* | 5 years | Minimum years of use |
| Recyclability | 60% | recyclable: percent by weight |

*\* Identifies nonfunctions that are still relevant to the project*