Optimization of Thermoelectric Energy Harvesting Device for Rail Service

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1. INTRODUCTION

The Federal Railroad Administration (FRA) reported that 65% of axle/bearing related accidents in 2010 to 2020 were caused by overheated or defective bearings. At the University Transportation Center for Railway Safety (UTCRS), researchers developed a wireless monitoring device to gauge the health of freight railcar rolling stock to allow for preventive care and enhance the safety of passengers and cargo. To extend the battery life on the device, an energy harvester prototype was designed using Thermoelectric Generators (TEGs), heat sinks, and a battery management chip (BMC). Currently, the prototype is in it's second iteration with optimization of the prototype including a new mounting type that will be used for more industry-viable testing and will offer an improvement by minimizing the thermal difference required to charge the battery.

2. METHODOLOGY

To obtain the best thermoelectric generator performance, several tests were conducted on a four bearing dynamic tester with a controlled temperature and airflow environment. From the previous circuit, the boost converter and battery management chip were replaced by an e-peas thermal energy harvesting component to minimize maintenance.

One of the tests executed evaluated the relationship between the position of the TEG around an AAR Class F railcar bearing adapter and the power produced. The positions evaluated were the leading or upstream face, the trailing or downstream face, the outboard face on the upstream side, and the outboard face on the downstream side of the adapter.

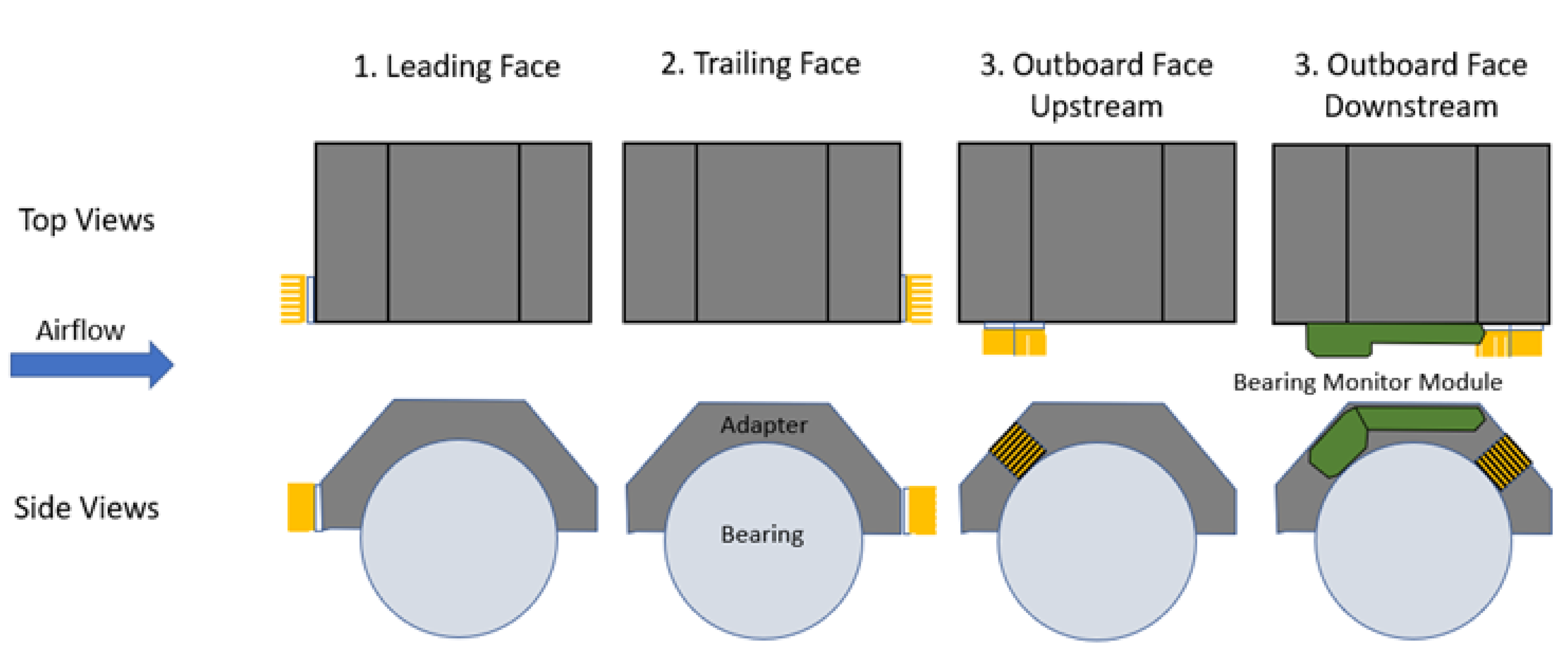

Figure 1: Positions for the Thermoelectric Module and Heat Sink

The TEG module was mounted to the railcar bearing adapter with a pressure mounting system using a thermal compound in between components. The thermal compound has a thermal conductivity of 1.93 W/mk. The surface of the bearing adapter was faced, or machined until smooth, to reduce thermal contact resistance and enhance heat transfer performance. As seen in **Figure 2**, the heat sink extends beyond the TEG module to allow for the fastening of the system to the bearing adapter.

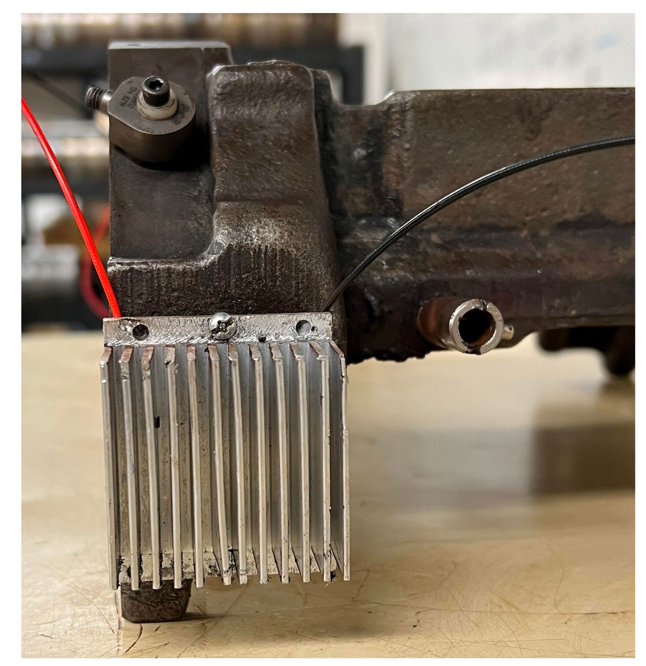

Figure 2: Mounting for the Thermoelectric Module and Heat Sink

3. RESULTS AND DISCUSSION

Compared to the previous energy harvester project, the mounting system improved maintenance by removing the need for thermal adhesive to be used. This eliminated factors like curing time and component replacement. The values provided in Table I show the performance in each position, averaged over six readings taken during a one-hour test for each case.

Position	T_{ad} [ºC]	T_{am} [ºC]	ΔT [ºC]	V_b [V]	I_b [mA]	P_b [mW]	P_{nc}
1. Leading Face	69.7	22.6	47.1	3.508	2.262	7.935	**1.00**
2. Trailing Face	66.8	22.7	44.1	3.515	1.365	4.798	**0.69**
3. Outboard Upstream	68.7	22.5	46.2	3.313	2.022	6.699	**0.88**
4. Outboard Downstream	60.2	23.8	36.4	3.275	0.781	2.558	**0.54**

Table 1: TEG System performance versus mounting location

Since the adapter temperature (T_{ad}) could not be made the same in all four cases, the power (P_b) values do not provide a fair head-to-head comparison. Since low ΔT available power in TEGs varies with $(\Delta T)^2$, a more direct comparison can be obtained by dividing each P_b by its associated $(\Delta T)^2$ and then normalizing to the value for the leading face.

The result, P_{nc}, provides a better measure of the relative power available, and serves as a figure-of-merit for each position.

The leading face of an adapter is the best location for thermoelectric generation. The outboard downstream location suffers from partially blocked airflow due to the bearing condition monitoring device location.

4. CONCLUSION

The optimized prototype design implements boost convertors with low self-start voltage to maximize energy harvesting at various bearing operating conditions. A circuit is being designed and will be implemented and soldered onto our UTCRS wireless monitoring device. The block diagram of this circuit is shown in **Figure 3**. A two-sided system will ensure effective operation regardless of the direction the train is traveling. A single TEG module would have reduced forced convection when mounted on the trailing side of the adapter. This optimized system will be further tested on a route simulation that was previously studied to compare results and ensure enhanced performance.

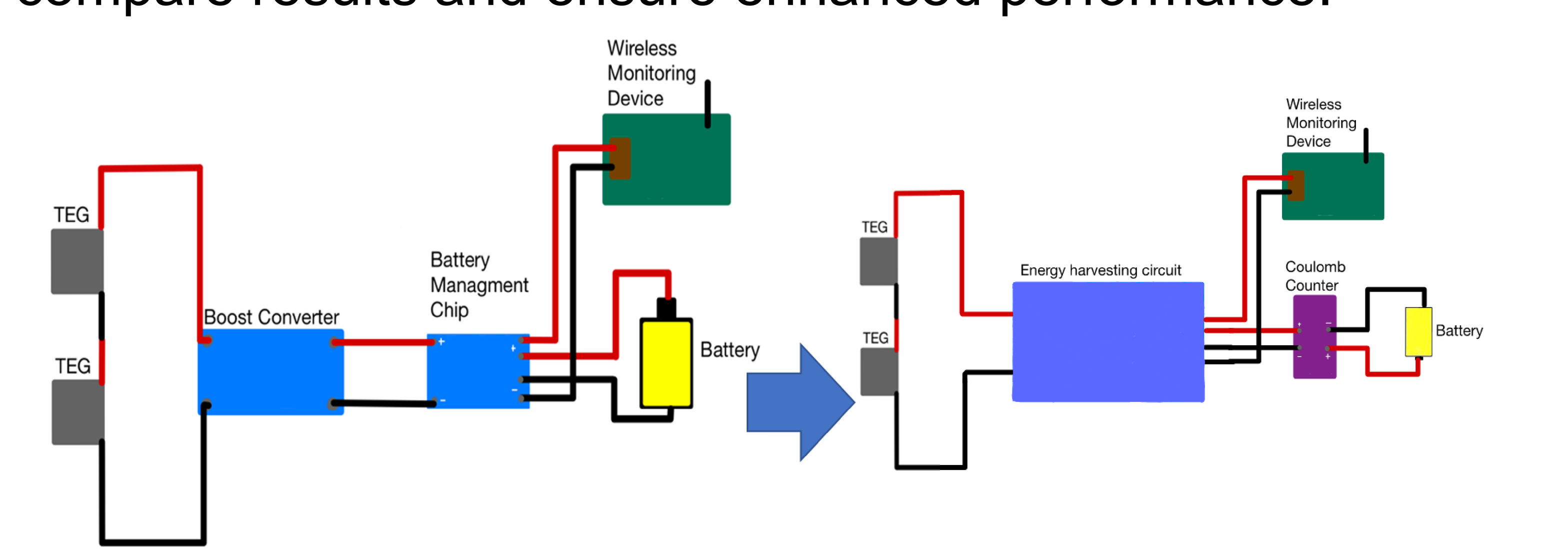

Figure 3: Optimized block diagram for the Energy Harvester circuit

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5. REFERENCES

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