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Comparative Analysis of Electric Motorcycle

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Abstract— In this work, a team of three mechanical engineering students performed an analysis of the Kawasaki Ninja 250R that has been converted from a gasoline-powered bike to an electric-powered bike. Using the knowledge gained from previous engineering courses, the team members had sufficient knowledge and skill to complete the project. The results of analysis determined which version of the bike is best for the environment and for the economy. The team used the data which was provided by last year's engineering students who have completed the conversion of the Kawasaki Ninja gas bike to electric motorcycle.

I. INTRODUCTION

This analysis consists of three main sections. First, the efficiency of the motorcycle was analyzed by comparing the output power with the input power. Then, the analysis of the cost and environmental impacts were performed. These analyses were completed for the existing converted electric motorcycle, the original gas-fueled motorcycle, and a commercial modern electric motorcycle.

The original gas-fueled 1996 Kawasaki Ninja 250R motorcycle is depicted in Figure 1. This model of motorcycle has gone through few redesigns through its quarter-century lifetime [1]. Figures 2 to 4 show the converted Kawasaki Ninja 250R motorcycle at WVU Tech. The converted motorcycle utilized a set lithium-ion battery.

Figure 1: Gasoline-fueled Kawasaki Ninja 250R motorcycle, third generation [2]

Figure 2: The converted Kawasaki Ninja 250R motorcycle

Figure 3: The converted Kawasaki Ninja 250R motorcycle

Figure 4: Some components of the converted motorcycle

The team used the results produced from tests on the electric motorcycle. Next, the efficiency of the motorcycle was analyzed by comparing the output power with the input power. After that, the gasoline-fuel motorcycle was analyzed to evaluate its cost and its environmental impacts. Finally, the electric motorcycle was analyzed in the same ways as the gasoline-fueled motorcycle.

II. RESULTS

i. Efficiency

After researching the gas engine on the 1996 Kawasaki 250R, the specifications for the engine were found in two separate sources [3, 4].To ensure accuracy, the two sources were compared. It was found that the sources were in congruence about the specifications of the bike. Therefore, the team felt confident proceeding to calculate the efficiency of the electric motorcycle. The team from the previous year had a goal of attaining 50-60 mph with 20-25 miles per charge. They were able to achieve 40 mph before the motorcycle was in the shop again. Using the formula for efficiency in conjunction with the results from last year the electric motor efficiency would be calculated [5] using the following equation:

$$\eta=P_{out}/P_{in}$$

Where η is the efficiency, P_{out} is the output power, and P_{in} is the input power. In this case, there was not enough information to obtain percentage efficiency; therefore, the team computed the efficiency in the form of cost per mile, cost per kWh, mile per kWh, and compared the results between all three motorcycles (gas motorcycle, experimental electric motorcycle, and commercial electric motorcycle).

ii. Gas motorcycle

The original 1996 Kawasaki GPX 250R had a liquid cooled, parallel twin cylinder, DOHC, four valve engine. This engine had a compression ratio of 12.4:1 and was capable of producing 45 hp and 2.5 kg-m of torque. The efficiency of the motorcycle was 52 mpg, and with a 4.8 gallon tank, the motorcycle had a range of 250 miles. As far as performance, it was able to reach a top speed of 94.9 mph and a standing quarter mile in 13.8 s at 82.3 mph [3]. Currently, the cost per gallon of gasoline is $3.29. Using this cost with the efficiency of the gasoline engine produces a cost of $0.07/mile. During the combustion of a single gallon of gasoline 8887 grams of CO_2 are emitted to the atmosphere. This means if the bike was to travel 100 miles it would use 1.92 gallons of gasoline which would produce 17,090.4 grams of CO_2. This equates to 170.9 g/mile [6].

iii. Electric Motorcycle

The GBS LFMP20AH lithium-ion batteries are rated to have a capacity of 20 Amp hours [7].Using the formula:

$$E= QVN$$

Where E is the energy output, Q is the Amp hours, V is the Voltage, and N is the number of batteries. The energy required for one charge was found to be 1024 Wh [8].

$$E= 20 \text{ [Ahr]} * 12.8 \text{ [V]} * 4 \text{ Batteries}$$

$$E=1.024 \text{ [kWh]}$$

The current rate for Appalachian Power is 11.140 cents/kWh [9]. This cost in conjunction with the amount of energy used per charge results in roughly $0.1141 per charge.

$$1.024 \text{ [kWh]} * 11.140 \text{ [cents/kWh]} = \$0.114$$

Since the bike is capable of 25 miles per charge, the cost per mile comes out to 0.5705 cents/mile. This was found by measuring the average distance in miles that the bike could travel according to the odometer.

$$\$0.114 / 25 \text{ [miles]} = 0.570 \text{ [cents]}$$

The average output of CO_2 per kWh is approximately 2.14 lb/kWh, which is equal to 970.69 g/kWh [10]. This means with the amount of kWh used per charging session that the amount of CO_2 emissions per charging session is 993.98 g/charge. This used in conjunction with the 25 mile per charge capability results in 49.70 g/mile of CO_2.

$$970.69 \text{ [g/kWh]} * 1.024 \text{ [kWh]} = 993.98 \text{ [g/charge]}$$

$$993.98 \text{ [g/charge]} / 25 \text{ [miles/charge]} = 49.70 \text{ [g/mile]}$$

III. Comparison and Conclusion

The cost of the modification of the bike was $2,392.22, and the cost per mile to operate the bike is $0.006; therefore, the equation for the total cost of the electric bike is:

$$C = 2{,}392.22 + 0.006 (x)$$

X is the number of miles traveled by the bike. Similarly, the cost for the gasoline bike is $0.07 per mile. So, the cost for the gas bike is:

$$C= 0.07(x)$$

In order to find out when the cost of the modification will be equal to the amount saved, (when the bike will essentially "pay for itself"), the two equations need to be set equal. This results in the total number of miles being equal to 37,207. This means for the modification to be cost effective, the electric bike needs to be driven 37,207 miles. If the bike was driven a full charge per day, this would result in a little over four years to "pay" for the modification.

$$2392.22 + 0.005705x=0.07x$$

$$X = 37{,}207 \text{ miles}$$

$$37{,}207 \text{ [miles]} / 25 \text{ [miles/day]} * 365 \text{ [days/year]} = 4.08 \text{ [years]}$$

In terms of performance the down side with the electric bike is that it can only travel 25 miles on a charge; it will then take five hours to recharge. Another down side is the top speed and the acceleration; both are much lower than that of the gas powered counterpart. The top speed of the electric bike is only 40 mph. This would not be a safe speed for use on public highways. Also, the electric bike only has 15 horsepower which meant it is very slow reaching its max speed.

In terms of the environmental impacts, the comparison is more direct. The gasoline engine produces 170.9 g/mile of CO_2, while the electricity only produces 49.70 g/mile of CO_2. This means, the gasoline engine produces a little over three times as much carbon dioxide compared to the electric equivalent. There is no disputing the fact that the electric motor has a lesser impact on the environment. As validation for the team's calculations, a comparison to a commercial electric motorcycle will be made. The comparisons are presented in Table 1.

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Table 1: Comparison of performance of three motorcycles under investigation

	Gasoline Motorcycle	Experimental Electric Motorcycle	Commercial Electric Motorcycle [11]
Initial Cost ($)	100.00	2492.22	13,000
Range (Miles)	250	25	103
Cost/Mile ($/mile)	0.07	0.005	0.009
Cost of Recharge ($)	15.79 (Fill-up Tank)	0.11	0.96
Power Consumption (mile/kWh)	N/A	24.41	12.18
CO_2/Mile (g/mile)	170.9	49.70	80.11
Power (hp)	45	15	54
Top Speed (mile/hr)	94.9	40	95

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