Performance Analysis of Continuously Varying Transmission System for Electric Vehicles

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Abstract—Electric Vehicles have zero emissions and are hence green and environmentally friendly. A lot of research is being done considering such vehicles at the system level. One of the systems being worked on is CVT (Continuously Varying Transmission). It is observed that coupling the motor with a (CVT) transmission system in such vehicles allow the motor to operate at high efficiency levels and hence bring down the power consumption. The data taken for the motor is from the specifications of 800W BLDC hub motor and has been used to choose a suitable CVT system. Furthermore, numerical analysis of the system has been carried out to understand its behavior. Lower power consumption means less power of battery required. This, in turn, is expected to further make the vehicle lighter, more efficient and more environmentally friendly. Also, these power savings make electric vehicle more economical and accessible to everyone.

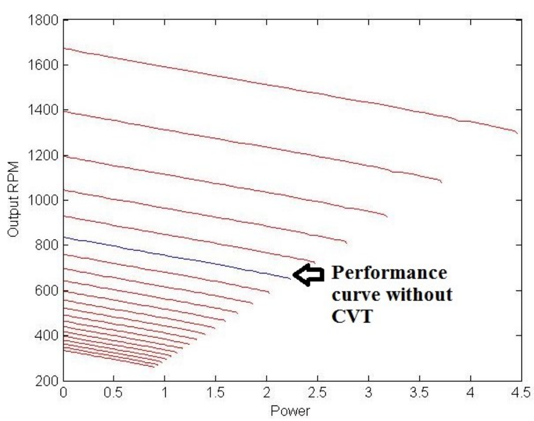

Figure 1: Output Speed (rpm) v/s Power Consumption (kW) Curve highlighted for without CVT;

Usually, electric vehicles (EV) utilize a direct-drive configuration where the motor is directly connected to the wheel with a fixed gear ratio. This is a simple drive configuration which has no variable ratios. But, the single drive configuration would not be able to accommodate real world scenarios as it can result in a jerky ride. Another major drawback of using a direct drive transmission is that the motor operates at very low efficiencies during low-speed maneuvers. The advantage of using a CVT system with electric vehicles is that it allows the motor to continuously operate in its highest efficiency region while supplying the necessary torque and rpm at the wheel end as per the requirements of the drive. This results in power savings within the system and hence extends the range of the electric vehicle.

The current paper incorporates a continuously varying transmission system for electric vehicles to check its performances with respect to varying torque and speed based on road conditions. Due to ease of availability and being inexpensive, the planetary type and pulley type CVT's are considered for the study.

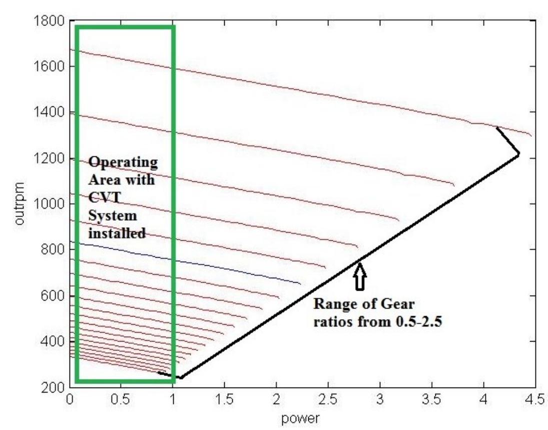

Figure 2: Output Speed (rpm) v/s Power Consumption (kW) Operating Area highlighted for with CVT.

Noise levels of systems using a CVT are expected to be much below the noise levels observed in vehicles using epicyclic gear train transmissions. Hence, this would also result in lesser noise pollution of the environment. The scope of this paper is to present the results from a numerical study of coupling motor with the CVT.

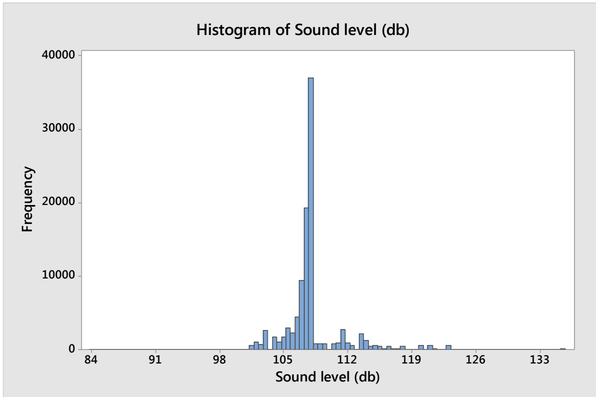

Figure 3: Sound Levels (dBA) v/s Frequency (Hz)

A simplified CAD model of the CVT is created prior to conducting the harmonic analysis in order to predict the Noise Vibration and Harshness (NVH) behavior of the system. Experimental testing is also carried out to validate the power savings and noise data obtained from numerical simulation.

A semi-empirical transfer function has been developed to predict the performance of the CVT under various loading conditions using statistical tools. The transfer function thus arrived at allows us to accurately predict the performance parameters of the CVT in a real-world scenario very easily and accurately. Furthermore, the experiments have been carried out in accordance with Design of Experiments (DOE) model. The results obtained were then utilized to improve the quality of the existing transfer function.

Transfer Function:
Current = 7.614 + 0.003297*(RPM) + 1.869*(Gear Ratio)
(R square =96.58%)

Input RPM	Gear Ratio	Measured Current	Output RPM	Predicted Current	% Difference
200	0.5	9.5	96	9.2079	3%
200	1.9	11.5	400	11.8245	-3%
667	1.9	13.6	1194	13.364199	2%
667	0.5	10.5	340	10.747599	-2%
350	0.87	10.3	200	10.39398	-1%
550	0.87	11	356	11.05338	0%
400	1.43	11.8	530	11.60547	2%

Table 1: Measured Output responses

Figure 4: an Electric vehicle mounted with CVT system.

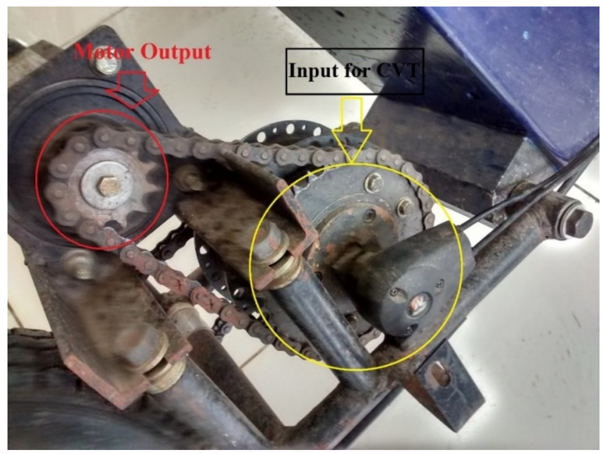

Figure 5: Motor-CVT chain drive

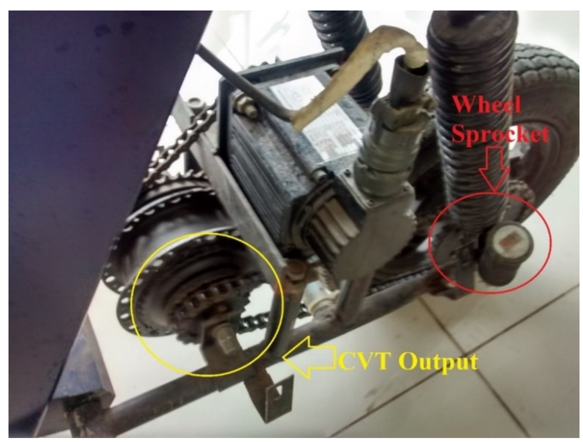

Figure 6: CVT-Wheel Chain drive.

Keywords – Electric Vehicles; Continuously Varying Transmission systems; Noise Vibration Harshness analysis; Automobiles.