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Assessment of the Powertrain Electrification for a Heavy-Duty Class 8 Truck for Two Different Electric Drives

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Abstract

Electrification is one of the main solutions for the decarbonization of the transport system. It is employed widely by the automotive industry in light- and medium-duty vehicles and recently started to be considered in heavy-duty applications. However, powertrain electrification of heavy-duty vehicles, especially for Class 8 trucks, is very challenging. In this study, the battery-electric powertrain energy and technical performance of a DAF 44 tones truck are compared for two different electric drives. The case study truck is modeled in AVL CRUISE M software and the battery electric powertrain is evaluated for long haul driving cycle. The minimum number of battery packs is determined by defining the lowest energy consumption of the powertrain designed for the proposed drive cycle. Also, a transient analysis is accomplished to investigate the impact of various electric drives on energy consumption and performance of the proposed electric powertrain. From the results, 5 battery packs with 176 cells each and 94 Ah capacity, are required for a Class 8 heavy-duty trucks in long haul driving cycle. Furthermore, the truck conversion of the diesel propulsion system to the battery-electric propulsion system with INVO electric drive has resulted in improvement of the powertrain total efficiency, energy consumption and regenerative brake energy recovery up to 0.79%, 6.37% and 53.72%, respectively.

Introduction

The rise of the average global temperature known as a global warming can cause catastrophic events in several countries in recent years [1, 2] The emission of greenhouse gases (GHG) such as CO_2 is the main reason for the temperature rise. The transportation industry utilizing internal combustion engines (ICEs) produces more than 26% of the CO_2 emissions around the world with the heavy-duty transport sector being responsible for a high share of the GHG emissions due to the volume and distance of the transported goods [3, 4]. Not only that, but also ICEs emit various other harmful gases and pollutants such as nitrogen oxides and particulate matter [5, 6].

This is why the decarbonization of the heavy-duty transport sector should be a priority for heavy-duty vehicles manufacturers [7, 8]. However, decarbonizing heavy-duty vehicles has proven to be more challenging compared to other types due to the higher power density and weight requirements [9, 10]. Also, the existing electrical powertrain components are more suitable for light-duty passenger vehicles and it is challenging when scaling them to fit heavy-duty powertrain requirements.

The literature is relatively lean for the electric powertrain design of heavy-duty vehicles. A recent study was performed by Wolff et al [11] on assessing the energy consumption of a battery-electric heavy-duty truck focused on the powertrain components such as the electric drive. The energy consumption of the proposed powertrain for the heavy-duty battery electric truck was simulated in four driving cycles including Truckerrunde (which was based on a real driving profile), long haul, regional delivery and T2030. DAF, E-Force, Nikola, Tesla and ZF electric drives' performance was compared during the recovery by 6.37% and 53.72%, respectively. Furthermore, the powertrain total efficiency increased by 0.79%, while the specific energy consumption of the truck decreased by 11.52 kWh/100km when INVO is used as the electric drive in the proposed battery-electric truck.

Conclusions

In this study, the energy assessment of a heavy-duty 44 tones truck with two different electric drives is performed. First, the powertrain of the proposed truck is modelled in AVL CRUISE M software. Then, the truck's powertrain is run in long-haul driving cycle by employing two different electric drives. The battery sizing of the proposed powertrain is also accomplished using the final SOC parameter. The main conclusions drawn from this work can be listed as:

- Employment of INVO electric drive unit leads to enhancement of battery packs depth of discharge by 4.41%.
- The electric motor peak output power decreased significantly by using INVO electric drive unit
- With INVO electric drive unit, the powertrain total efficiency, energy consumption and regenerative brake energy recovery are improved by 0.79%, 6.37% and 53.72%, consecutively. Moreover, the specific energy consumption of the powertrain increased by 11.52 kWh/100km when INVO electric drive is used.

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Definitions/Abbreviations

AMT - Automated manual transmission

CVT - Continuously variable transmission