Abstract

This study focuses on the development of control systems of a hybrid propulsion system (IC Engine and Electric Motor) for a heavy tracked vehicle and the assessment of performance such as power, torque, energy efficiency, emissions and costs. Advances in automobile technology have led to the widespread adoption of hybrid drivetrains in passenger vehicles as a promising alternative to traditional Internal Combustion Engines (ICE) presenting significant advances toward a more sustainable and energy-efficient future for passenger transportation. However, hybrid technology in tracked vehicles is still in its nascent stages, with considerable potential for development and practical benefits. Tracked vehicles' unique design features a drivetrain with a continuous track system that distributes weight evenly offering superior traction and stability on rough, uneven terrain, which is vital in military, farming, construction and mining operations.

In this study, a tracked military vehicle, with a diesel Internal Combustion Engine (ICE) of 221 kW, was virtually substituted by a hybrid propulsion system with 68.5 kW IC Engine and 112 kW Electric Motor (EM) in parallel configuration (62% Degree of Hybridisation) in MATLAB Simulink. The parameters of IC Engine, Motor, target vehicle, Modified Indian Drive Cycle (MIDC), and battery characteristics were provided as inputs to the MATLAB Simulink for operation of the hybrid system. The control systems incorporate tailor-made algorithms while facilitating peculiar tracked vehicle functions like braking, clutching, turning, and gear shifting. The novelty of this research lies in the development, integration, and validation of an optimised hybrid control strategy for heavy tracked vehicles. A supporting contribution is the novel assessment methodology, which systematically quantifies performance, energy efficiency, fuel consumption, energy recovery from regenerative braking, range enhancement, CO_2 emission, carbon penalty from cradle-to-gate and running costs.

The developed hybrid system with 180.5 kW could provide the performance (power and torque

with respect to speed) equivalent of 221 kW IC Engine under MIDC conditions and satisfactorily maintained the velocity profile of the MIDC within a mean variance of 1.28 km/h with braking, gear shifting, clutching, and turning functions as required. The developed hybrid system could achieve a regenerative efficiency of 14.24% and a 14.44% theoretical increase in range compared to the IC engine. Range analysis suggests IC engines and hybrids suit heavier highway vehicles, while grid-based EVs are better for lighter, urban, short-distance driving. The carbon footprint of the IC engine was the highest, at 1.33 times that of the electric system and 1.22 times that of the hybrid system. Cumulative running cost (including carbon price) of the hybrid and electric power sources was lower than the IC engine, with cost savings of 72% for the hybrid source and 86% for the electric, electric power source being the lowest.

Notable conclusions that emerged from this study suggest that a hybrid propulsion system with 62% Degree of Hybridisation (62% Electric, 38% IC Engine) is suitable for heavy tracked vehicles operating on Modified Indian Drive Cycle (MIDC), based on power density, velocity, driving range, energy consumption, regenerative efficiency, decrease in carbon footprint and reduced operating costs. The development of a hybrid propulsion system with a control strategy including the performance and cost analysis performed in this study, advances the development of scalable hybrid propulsion systems as credible alternatives to conventional IC engines for heavy tracked vehicles.