Hybridisation Potentials for Heavy Trucks Considering Route Topography

Based on dynamometer test cycles or plain motorway operation, heavy truck hybridisation must be considered as uneconomic if only the kinetic vehicle energy can be recuperated. In mountainous regions, micro hybridization by a 48V-belt generator or mild parallel hybridisation by a large high voltage electric drive can result in considerable fuel consumption savings as well as additional benefits for heavy load utility vehicles. Additional electric power and battery size are still critical design parameters as well as critical cost factors considering the limited space and depreciation time as well as the need for maximum payload. Based on vehicle model simulations, this contribution quantifies fuel consumption savings, recuperation energy harvesting and battery requirements for different truck sizes with test cycles based on realistic route topography. The main route topography parameter for the recuperation benefit is the effective incline that integrates all downhill sections that overcompensate the vehicle resistance by tire friction and air resistance. The simulation parameter studies lead to an analytical benefit estimation, based on load cycle parameters like effective velocity, effective incline as well as the vehicle parameters mass, drag coefficient and cross sectional area. Thus, the return on investment can be assessed by an analytic rule of thumb, based on tracked cycles of existing vehicles.

Analytical fuel saving potential based on load cycle data:

\[ h_{\text{eff}} = \frac{1}{T} \int_0^T \left( p_{\text{in}}(\tau) \cdot v(\tau) - p_{\text{out}}(\tau) \cdot v(\tau) \right) d\tau \]

Fuel saving potential depending on the installed electric power:

\[ h_{\text{inst}}(P_E) = \frac{P_E}{P_{E0}} \cdot \frac{1}{0.6 + \left( \frac{P_{E0}}{P_E} \right)^2} \]

Mild hybridisation rated power:

\[ P_{E0} = m \cdot g \cdot v_{\text{eff}} \]

Effective incline of the load cycle:

\[ p_{\text{eff}} = \frac{1}{x} \int_0^x \left( p_{\text{in}}(\xi) \cdot v(\xi) \right) d\xi \]

Effective velocity of the load cycle:

\[ v_{\text{eff}} = \frac{1}{T} \int_0^T v(\tau) d\tau \]

Incline limit for recuperation:

\[ p_{\text{lim}} = \frac{f_s}{2} + h_{\text{eff}} \]

Realistic test cycle:

Diesel saving potential of Truck 2 for the Stuttgart region test cycle

Diesel saving potential of Truck 2 for A81/A83 test cycle

Analytical fuel saving potential based on real urban/rural cycle in the Stuttgart region

Statistical test cycle

Incline limit for recuperation

48V High voltage

High voltage


cap. in kWh

Diesel saving potential of Truck 2 for A81/A83 test cycle

Diesel saving potential of Truck 2 for Stuttgart region test cycle

48V High voltage

High voltage

\[ p_{\text{lim}} = \frac{f_s}{2} + h_{\text{eff}} \]