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Analysis of Energy Flow in the Hybrid Power-Split (PS) System of SUV Vehicle in Real Driving Conditions (RDC)

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Abstract

Hybrid powertrains are replacing conventional combustion drives at an accelerating rate, while offering a reduction in fuel consumption and toxic exhaust emissions. The large share of hybrid solutions in engine vehicles has been observed for the compact class and in SUVs. The Authors of this study proposed an energy flow assessment in the hybrid powertrain system of an SUV in various driving conditions: urban, extra-urban and motorway. The tests were performed in accordance with the stipulations of the RDC test conditions and its requirements. The tests were carried out on a Toyota RAV4 HEV equipped with a 2.5 dm^3 engine in a hybrid drive system along with Li-Ion batteries, which had an energy capacity of 1.11 kWh (4.3 Ah). The research was carried out on an urban route in Poznan as well as in its vicinity using three drive modes of the drive system: Eco, Normal and Sport. Based on the results of energy flow tests, it was found that, regardless of the initial state of charge (SOC) of battery, the vehicle would reach constant SOC values in the second phase of the test - in the extra-urban driving phase. Such conditions stabilize after about 30 km of urban driving. The differences in the range of these SOC values were around 10%. Due to the conditions of motorway driving, the SOC changes were very small and amounted to about 3-5% while covering about 20 km (in this driving mode). The tests confirmed the slight influence that the driving mode (eco, normal, sport) had on the final measured charge values: for discharge, charging or regeneration. The share of time operating in electric mode for individual test phases was also determined, and it was approximately 65-68%, 25-30% and 5-8% in the urban, extra-urban and motorway phases, respectively.

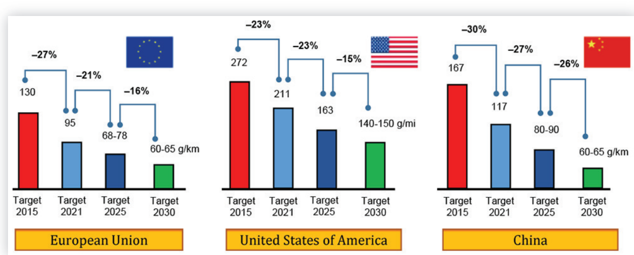
Introduction

The emission of carbon dioxide to the atmosphere depends on many factors. One of them is transport, which in 2018 was responsible for the emission of 8 billion tons. It accounted for 24% of total carbon dioxide emissions [1]. Passenger transport (including passenger cars, two-wheelers, buses and taxis) accounted for 45.1% of the share, long-haul transport - 29.4%, aviation - 11.6% (81% - passengers and 19% - goods), sea transport - 6%, rail transport - about 1%. In the European Union, transport is responsible for about 1/3 of greenhouse gas emissions (29%). A total of 3.8 Gt of carbon dioxide was emitted in 2018 [2]. Road transport accounted for 51.7% and truck transport for 17.2%.

In line with the Paris Agreement (COP21), the European Union has committed itself to achieving greenhouse gas reductions in the period 2021-2030 [3]. By 2030, this reduction is planned to reach 40% of the value recorded for 1990. The European Union has set itself the goal of achieving zero greenhouse gas emissions (net) by 2050. Evolution of CO_2 legislation remains a major driver of change in vehicle technology (e.g. [4]). The CO_2 emissions limits are being reduced in each of the automotive markets. The level of CO_2 emission limits in Europe and China is much lower than in the USA (Fig. 1). The subsequent 5-year periods of introducing emission restrictions are associated with 15-20% reductions in CO_2 emission limits [5, 6]. Target limits for CO_2 emissions in 2030 indicate uniform limit values in Europe and China. The US limits are about 20% less stringent.

Currently, stop-start systems have a very large share in traditional drive systems. The FEV company anticipates a

FIGURE 1 World and EU CO_2 exhaust emission limits for PC [6, 7, 15].



- Variations throughout the entire test drive equaled: 4 percent
- For driving in the urban section: 5 percent
- For driving in the rural section: 9 percent
- For driving in the motorway section: 5 percent

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