International Refereed Journal of Engineering and Science (IRJES)
ISSN (Online) 2319-183X, (Print) 2319-1821
Volume 13, Issue 2 (Mar.-Apr. 2024), PP. 56-60

Geographical Disparities in Worldwide Harmonized Light Vehicles Test Procedure (WLTP) Emissions: A Comparative Analysis between Flat and Mountainous Regions

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Abstract:
This paper presents a comprehensive examination of how geographical terrains impact vehicle emissions testing. Through a comparative analysis of emissions data obtained from flat and mountainous regions using the WLTP methodology and measurements, the paper uncovers significant insights into the variations in fuel consumption based on terrain characteristics. The research highlights the opportunities in assessing emissions in diverse geographical settings, emphasizing the need for tailored testing protocols to accurately reflect real-world driving conditions. By comparing an electric vehicle with an internal combustion vehicle, the paper shows the difference in efficiency of both drive concepts.
Keywords: *EV, ICE, car technology, efficiency, fuel consumption, recuperation*

Date of Submission: 15-03-2024 Date of acceptance: 30-03-2024

I. OBJECTIVE

The Worldwide Harmonized Light Vehicles Test Procedure (WLTP) represents a globally recognized standard for evaluating the emissions and fuel consumption of light vehicles. Developed collaboratively by regulatory authorities and industry experts, the WLTP aims to provide a more accurate representation of real-world driving conditions compared to its predecessor, the New European Driving Cycle (NEDC). By incorporating a wider range of driving scenarios, including higher speeds and more dynamic acceleration patterns, the WLTP seeks to address criticisms leveled against the NEDC, which was deemed outdated and unrealistic in capturing actual driving behaviors. The WLTP's methodology involves a series of standardized driving cycles, including urban, suburban, and extra-urban segments, designed to mimic typical driving conditions worldwide. These cycles are characterized by specific parameters such as speed, acceleration, and deceleration profiles, aiming to simulate real-world driving more accurately. But what happens if we look at a geographical topology which is not flat like the WLTP cycle? Are electric cars superior compared to ICE (internal combustion engine) cars when the driven route is not flat? This Paper compares the two concepts in hindsight of their real-world energy consumption.

II. WHAT IS THE WLTP CYCLE?

The WLTP got introduced in 2015 replacing the NEDC because of too big emission differences between test and reality. The main differences between the two measurement methods are the testing sequences and the duration of the test in which the WLTP gets a more accurate real world usage result.

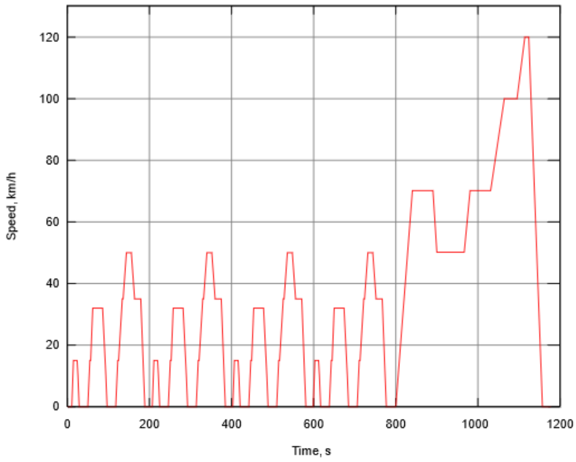

Figure 1: NEDC testing procedure [6]

In the NEDC method (figure 1) [1] the test gets split into two parts. At first the urban driving cycle [2] gets repeated 4 times (Figure 1, second 0-800) then gets followed by the extra urban driving cycle [3] (Figure 1, second 800-1200).

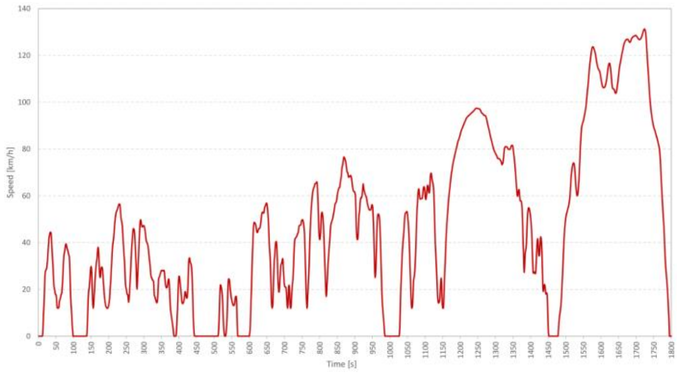

Figure 2: WLTP Class 3 testing procedure [6]

For Vehicles with a top speed over 90km/h the WLTP class 3 test cycle is used which consists out of four parts [4]. The segments of Table 1 simulate a more diverse driving profile to get closer to the real-world fuel consumption and CO2 output.

Load	Time [s]	Absolute time [s]	Max. reached speed [km/h]
Low	589	589	56,6
Medium	433	1022	76,6
High	455	1477	97,4
Extra High	323	1800	131,3

Table 1: WLTP Class 3 load cycles

III. WLTP COMPARED TO THE REAL WORLD

Firstly, the WLTP cycle operates under controlled laboratory conditions, where factors such as road surface, weather conditions, and traffic congestion are not replicated accurately. Real-world driving involves a multitude of unpredictable variables that can significantly influence vehicle performance and emissions, including traffic patterns, driver behavior and road gradients. These dynamic elements are difficult to replicate in laboratory settings, leading to discrepancies between WLTP test results and actual on-road performance.

Furthermore, the WLTP cycle consists of predefined driving cycles that may not fully capture the diverse range of driving conditions experienced in everyday life. For example, the cycle's speed profiles, and acceleration patterns may not accurately reflect the driving behavior of individual drivers or specific geographical regions. As a result, vehicles tested under the WLTP may exhibit different fuel consumption and emissions profiles when subjected to real-world driving conditions.

Additionally, advancements in automotive technology, such as hybrid powertrains and regenerative braking systems, can further complicate the applicability of the WLTP cycle to real-world scenarios. These technologies may operate differently in laboratory conditions compared to actual driving, leading to discrepancies in fuel consumption and emissions measurements.

IV. TEST SETUP

For the measurements it was important to find a route which represents has a mixed topology with high altitude changes to get good results. The cars used for the test were a KIA EV6 (EV) and a VW Tiguan (ICE). Both cars were driven at a course of 59,2km which consisted out of a combination of highway, city, and federal roads with a mixed load profile for the vehicles. The temperature was 18°C (641m over sea level) and 16°C (1264m above sea level) which is mostly affecting the EV due to the energy consumption for the thermal management of the battery and the driver. The ICE uses the excess heat of the engine. Due to those circumstances the tests cannot be compared to a real WLTP test cycle but it is possible to calculate the difference to the given WLTP values of the vehicles to see which drive type is more efficient in areas with topological changes.

Vehicle	KIA EV6	VW Tiguan
Type	EV6	5N
Drive type	Electric	ICE (Diesel)
Motor/Engine	Dual synchronous motors	2.0 Tdi
Power	81kW (30 min continuous power)	85kW
Weight [kg]	2050	1650
WLTP	18kWh/100km	4,7l/100km ≙ 48,9kWh/100km

Table 2: Specifications of the used vehicles

To measure the consumption of energy the driven route gets divided into six checkpoints. For each distance between those checkpoints the absolute energy consumption is calculated (Table 4). The checkpoints and the topology change can be seen in Figure 3.

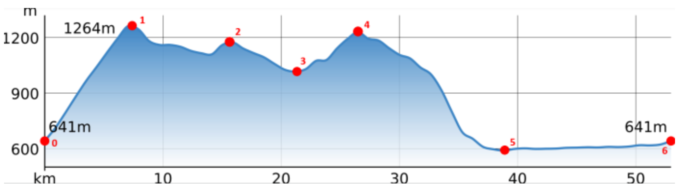

Figure 3: Elevation profile of the test route [7]

Checkpoint	Height [m]	Distance [km]
0	641	0
1	1264	6,8
2	1197	15,7
3	1004	21,5
4	1224	27,3
5	598	38,2
6	641	59,2

Table 3: Absolute height for Figure 1 checkpoints

The route starts at 641m above sea level and is divided into 6 parts. It starts with a steep ascent with a length of 6,8km and a vertical change of 623m (Figure 3, Point 1). At the plateau (see Figure 3, Point 1-4) the driving profile is mixed and consists out of city and overland driving. Between checkpoint four and five there is a 626m descent (Table 3, 4-5). To end the test route, checkpoint five to six was driven on the highway with a speed of 120km/h. The average speed of both cars was 51km/h on the course of 59,2km.

Checkpoint	Elevation change [m]	KIA EV6 [kWh]	VW Tiguan [l]
0-1	623	3,95	0,98
1-2	-67	1,73	0,5
2-3	-193	0,11	0,27
3-4	220	2,34	0,65
4-5	-626	-1,68	0,3
5-6	43	4,76	1,26
Sum	-	11,21	3,96

Table 4: Absolute energy consumption for each checkpoint

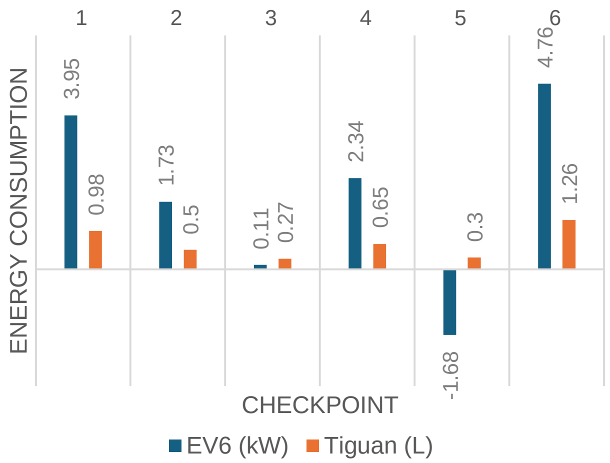

Figure 4: Energy consumption

Figure 4 shows the absolute energy consumption for the EV (kWh) and the ICE (l). Due to the ability to recuperate the EV gained on the descent between checkpoint four to five (Figure 4, 5) 1,68kWh of energy. Whilst the ICE Car needed 0,3l of diesel.

V. RESULTS AND COMPARISON BETWEEN ICE AND EV

To calculate the real efficiency, the absolute fuel consumption of the ICE car must be calculated into a metric which is comparable to the EV energy consumption. First the average consumption per 100km gets calculated.

$$Consumption = \frac{absolute\ energy\ consumption}{driven\ distance} * 100$$

Vehicle	Energy consumption
KIA EV6	18,9kWh/100km
VW Tiguan	69,7kWh/100km (6,7l/100km)

Table 5: Average energy consumption

The main advantage of the EV is the possibility to recuperate when going downhill (Table 4, Checkpoint 4-5). When comparing the results of table 5 with the given WLTP values of table 2 the difference can be calculated. The EV performed 5,5 percent worse than its given WLTP value, the ICE car performed 29.8 percent worse than its WLTP. This proves the point that an EV is more economic when driving in mountainous regions. To further proof the point the energy consumption oft the test course gets calculated. The energy cost is the average price of 2023 per kWh and per liter diesel [5] in Austria.

Vehicle	Energy cost	€/km	Total (€) for course (59,2km)
KIA EV6	0,25€/kWh	0,048	2,81
VW Tiguan	1,73€/l	0,115	6,85

Table 6: Energy cost

VI. CONCLUSION

When comparing an EV to an ICE the EV performs better in mountainous regions due to the ability to recuperate. Furthermore, the EV is more economic and therefore cost effective. The WLTP cycle does not consider terrain like that but also is not ideally suited for electric cars due to the lack of testing of the recuperation function which matters a lot in real world traffic. The possibility to one pedal drive an EV without using the brake is a huge boost in efficiency compared to an ICE which converts the braking energy into heat. This paper aims to be an impetus to further research into WLTP testing EVs.

An interesting survey would also be to determine the percentage of people who actually drive in flat areas, mountainous regions, or at least hilly areas, in order to incorporate this data into future testing procedures.

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