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Teodozii Myskiv[1], Oleg Sorokivskyi[2]

[1] Department of motor vehicle transport, Lviv Polytechnic National University, 12, S. Bandery Str., Lviv, Ukraine, E-mail: teodozii.h.myskiv@lpnu.ua
[2] Department of motor vehicle transport, Lviv Polytechnic National University, 12, S. Bandery Str., Lviv, Ukraine, e-mail: oleg.i.sorokivskyi @lpnu.ua, ORCID 0000-0002-5685-1440

ANALYSIS OF VEHICLES DRIVE WITH DIFFERENT CHARACTERISTICS OF POWER SUPPLY

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Abstract. The characteristics of internal combustion engines (hereinafter referred to as ICE) have the following disadvantages: there is a gap between zero and minimum angular velocity, so it is impossible to move out of a state of rest; the dependence of torque on angular velocity is not ideal. They are corrected by the following converters: the first by a clutch or torque converter, and the second by a gearbox or variator. In addition, the ICE characteristics can be partially close themselves to ideal.

Electric motors (here in after referred to as motors) of electric vehicles have an ideal characteristic that starts from scratch and has a large zone with a sustainable maximum power. The addition of the drive with the ICE motor in hybrid electric cars solves these problems.

The different characteristics of ICE, motors and converters increase the number of possible configurations that affect the characteristics of the supply of power to the wheels.

According to the traction characteristics of the car, the indicators of the traction and speed properties of the car are determined: the ability to overcome climbs, maximum acceleration, maximum speed on a horizontal road, acceleration time to a given speed, etc. The last two indicators depend primarily on the maximum power of ice or motor and are important for supercars, while for conventional cars or electric vehicles with close values of maximum speed and acceleration time to a given speed, they mean nothing.

The authors propose to evaluate the efficiency of the drive during acceleration with maximum acceleration of the power utilization factor $k_{N\ 0\text{–}100}$ – the particles from the division of the average value of the realized power on the wheels in the interval of speeds (0; 100) km/h by the maximum power value on the wheels.

The characteristics of ICE and motors are given, traction characteristics in power coordinates are calculated – the speed of movement of cars with typical drive configurations, their power utilization coefficients are determined and appropriate conclusions are made. In the future, it is planned to investigate the use of power in more complex drive systems of hybrid cars with the recovery of braking energy.

Keywords: engines, characteristics of power supply, traction characteristics, power use

Introduction

The traction and speed properties of the car depend on two factors: the maximum torque on the wheels and the maximum traction force on them. The first depends on the characteristics of the engine and transmission parameters, and the second – on the coefficient of adhesion in the contact of the tire with the road. In addition, the strength of air resistance depends on the speed to the second power, so the maximum engine power is associated with maximum speed on a horizontal road.

During the acceleration of the car, most of the engine power is initially spent on creating maximum acceleration, and with increasing speed – on overcoming air resistance, which progressively increases. Given the affected properties of the wheels in the initial phase of acceleration, power must be limited, especially in cars with powerful engines. Using power during acceleration to a certain speed in cars with different drive configurations can be a criterion for drive efficiency.

Problem Statement

Comparing the drive of modern cars according to the existing indicators of traction and speed properties is not simple. Most manufacturers try to achieve the appropriate values of these indicators, which do not mean the same technical level. The modernized characteristics of ICE and motors, different converters of these characteristics and different types of drive complicate comparative analysis, so there is a need for an integral indicator of drive perfection.

The aim of the work is to analyze the drive of vehicles with different characteristics of power supply and assess its efficiency using the implemented indicator – the coefficient of power use.

Review of Modern Information Sources on the Subject of the Paper

Analysis of the drive of the car is to determine its traction and speed properties: speeds, accelerations and marginal road conditions in which it is possible to move the car with specified design parameters. Indicators of traction-speed properties (maximum speed on a horizontal road, acceleration time to a certain speed, acceleration during acceleration, etc.) are determined experimentally and analytically. Methods for assessing traction-speed properties have long been known [1–3]. An example of a calculation and analytical method is given in [4].

Main Material Presentation

For justification, the following vehicles have been introduced on the power utilization factor: electric vehicles: Porsche Taycan Turbo S (2022), Honda e (2022), Opel Mokka-e (2022) and cars with ICE: BMW 118i (2022), Opel Mokka 1.2 Turbo 130 (2022), Honda Fit RS MT (2019).According to technical data [5] – [10] Figs. 1–6 built characteristics of their motors and ICE.

Characteristics of electric vehicle engines see Figs. 1–3 are ideal due to the large zone of sustainable maximum power of N_{max}. With a decrease in angular speed caused by an increase in load, the torque in this zone increases hyperbolically, that is, the engine automatically adapts to the load.

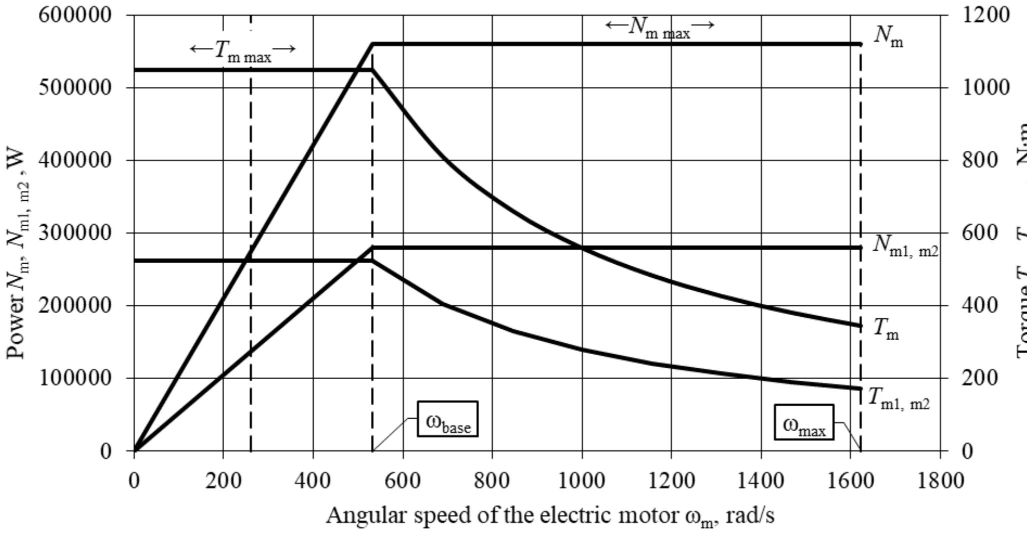

Fig. 1. Characteristics of electric motors of the Porsche Taycan Turbo S (2022) drive

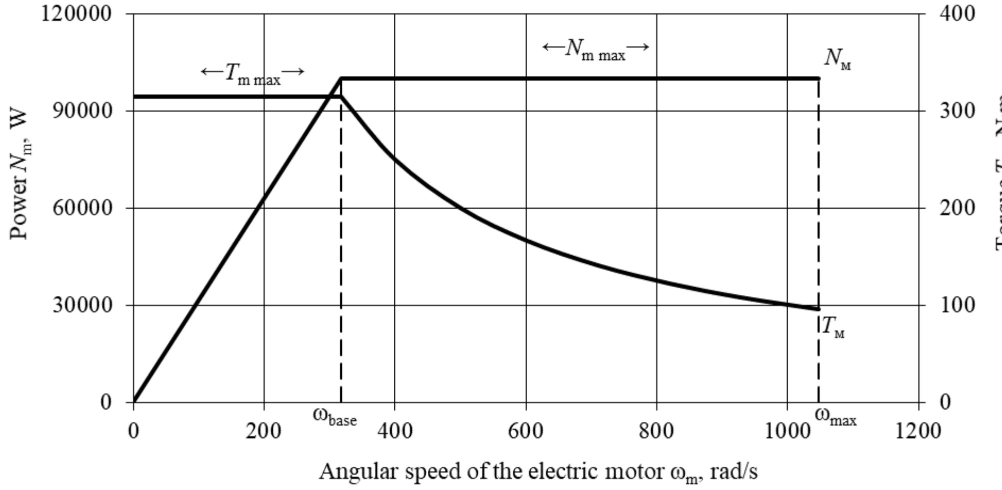

Fig. 2. Characteristics of electric motors of the Hondae (2022) drive

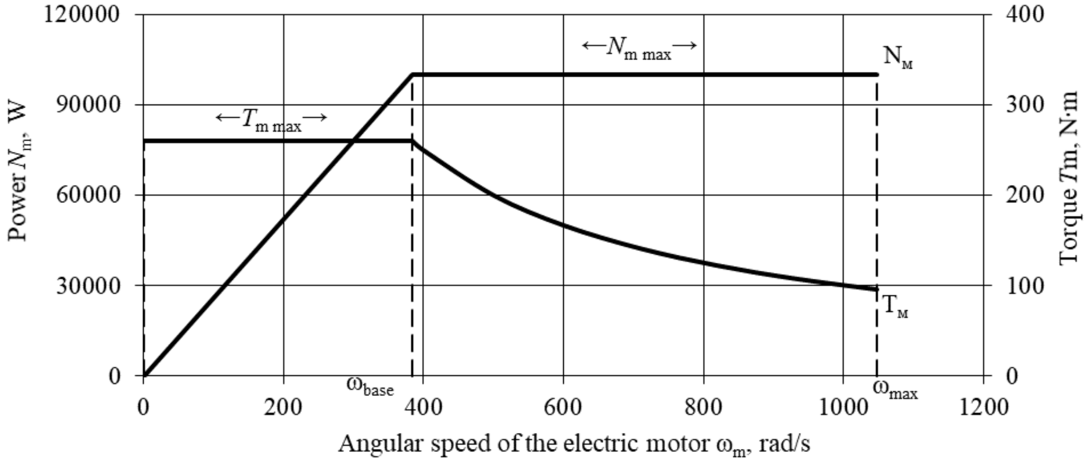

Fig. 3. Characteristics of electric motors of the Opel Mokka-e (2022) drive

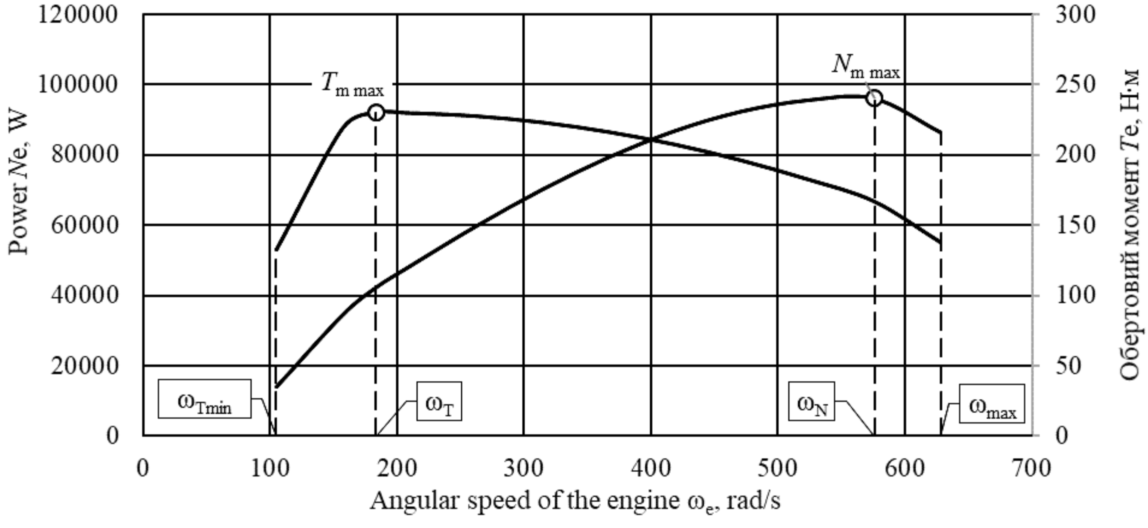

Fig. 5. Characteristics of ICE of the Opel Mokka 1.2 Turbo 130 (2022) drive

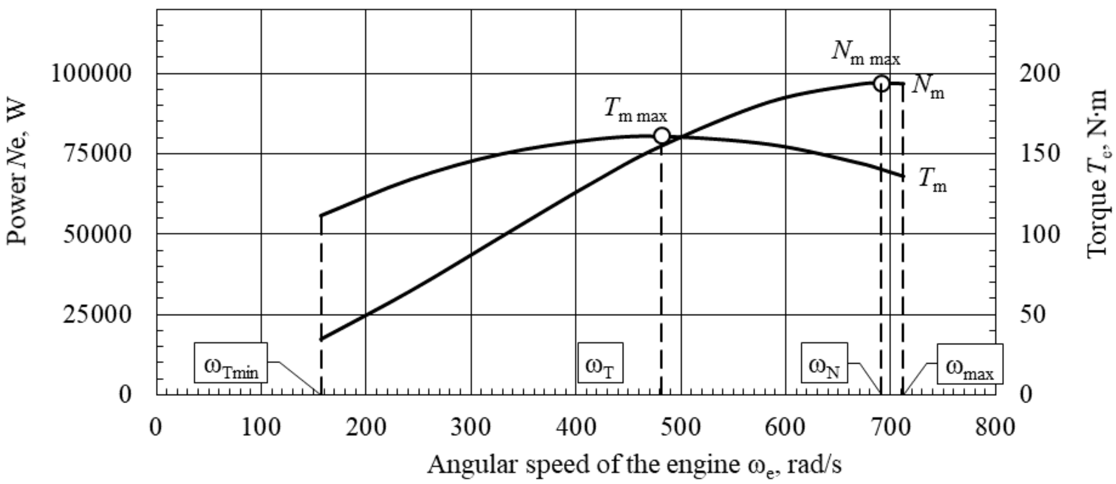

Fig. 6. Characteristics of ICE of the Honda Fit RS MT (2019) drive

Partially close to ideal is the characteristic on Fig. 4, where there is also a zone of sustainable maximum power.

In the character of ICE on Fig. 5 T_{max} is located at the beginningof the working zone of angular speeds, that is, there is a margin of torque.

The traditional ICE characteristic is shown on Fig. 6, where T_{max} is roughly in the middle of the working area of angular velocities.

Based on the characteristics of motors, ICE and transmission parameters according to the method [4] calculated and constructed traction characteristics in the coordinates tractive power on wheels – vehicle speed for selected vehicles (Figs. 7–12).

A feature of the four-wheel drive of an electric car on Fig. 7 is a two-speed gear in the rear wheel drive, so that the traction force in the initial acceleration phase on the first gear can be increased by about a third.Then in the interval of speeds (0; v_{base2}) power is growing faster – lines $N_{w1.1}$ and $N_{w1.2}$, as opposed to overclocking on second gear – the $N_{w2.1}$ line.

By comparison Figs. 8 and 9 can be seen that with the same N_{wmax} due to the drive of the rear wheels, power growth in the speed interval (0; v_{base}) more in Honda e (2022).

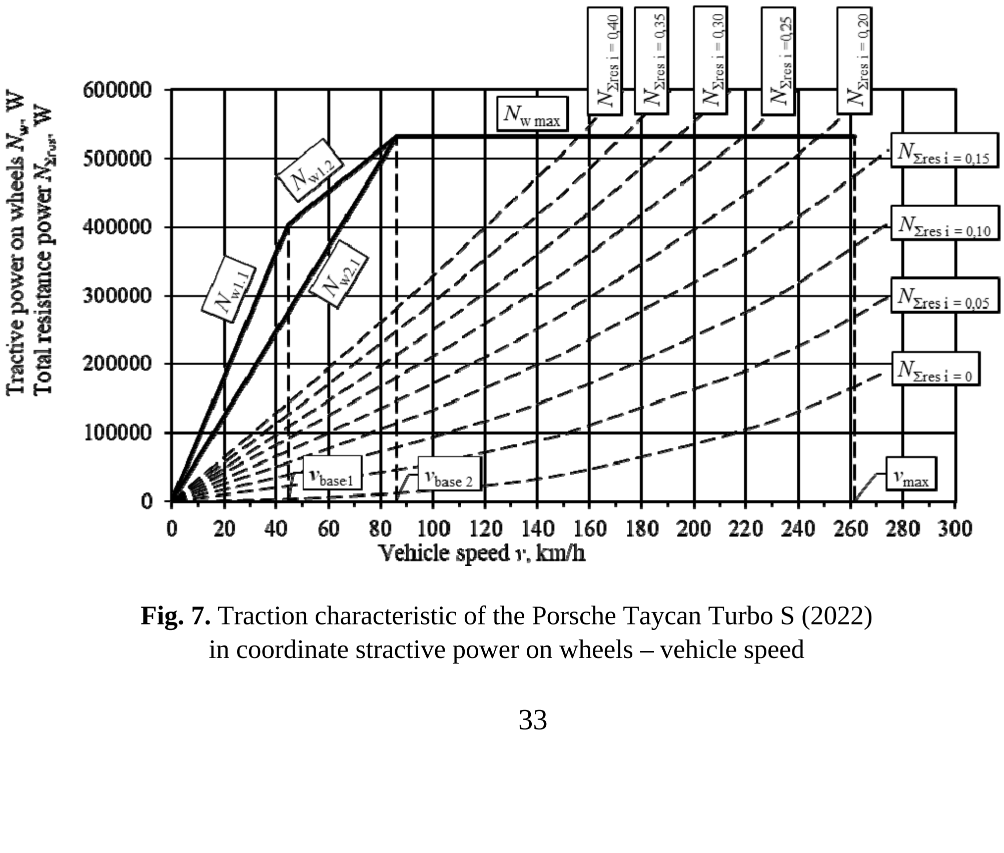

Fig. 7. Traction characteristic of the Porsche Taycan Turbo S (2022)
in coordinate stractive power on wheels – vehicle speed

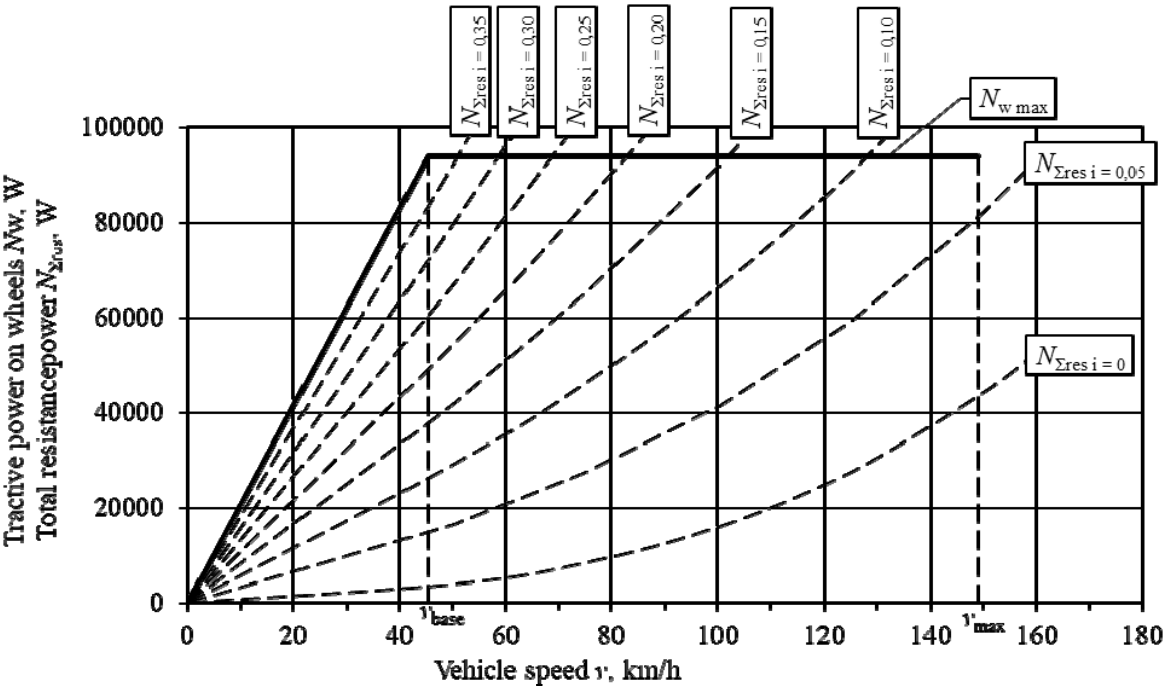

Fig. 8. Traction characteristic of the Honda e (2022)in coordinate stractive power on wheels – vehicle speed

In order to save battery power, the maximum speed of electric vehicles is limited, while the traction characteristics on Figs. 7–9 show that it could be higher.

The six-speed gearbox and, partially close to the ideal, ICE characteristic of the BMW 118i (2022) contribute to the rapid growth of power in the speed interval (0; v_{base}) (Fig. 10).

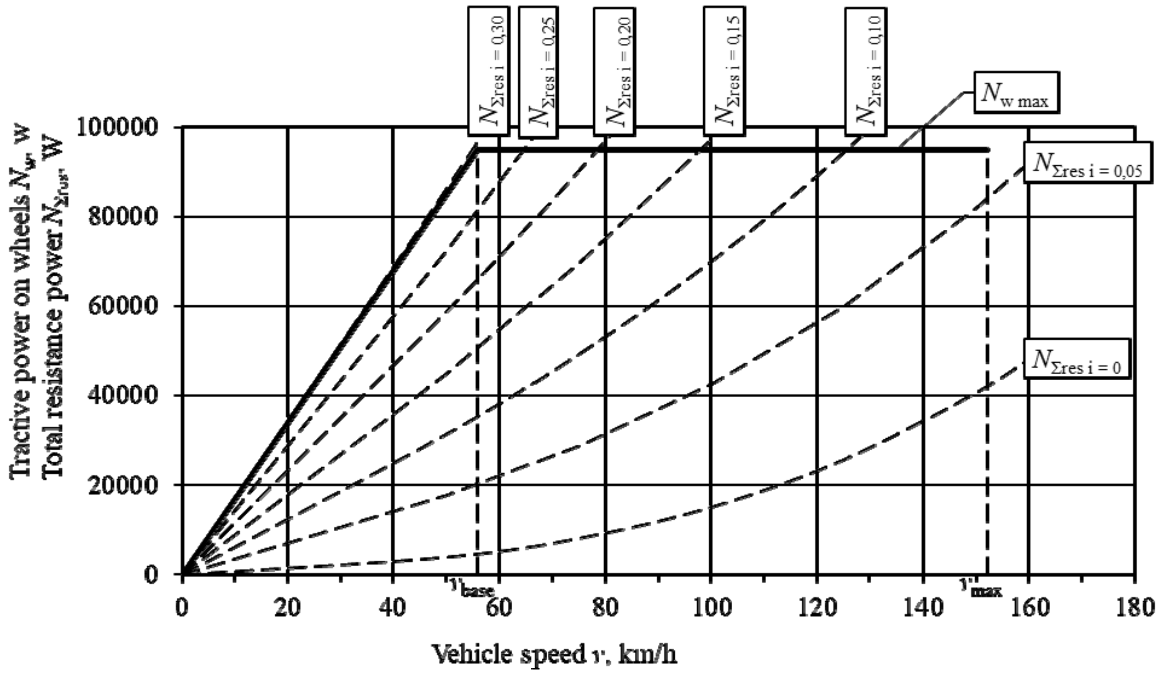

Fig. 9. Traction characteristic of the Opel Mokka-e (2022) in coordinate stractive power on wheels – vehicle speed

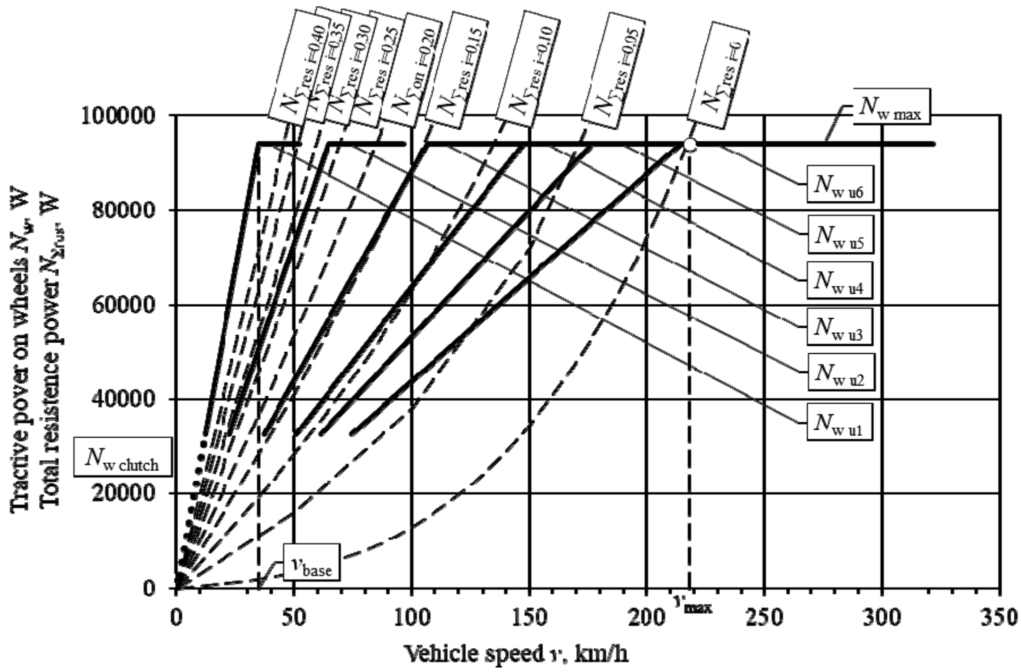

Fig. 10. Traction characteristic of the BMW 118i (2022)
in coordinate stractive power on wheels – vehicle speed

A similar effect is achieved (Fig. 11) when the T_{max} characteristics of ICE are at the beginning of the working zone of angular speeds.

By comparison Figs. 10–12 shows that the slowest power growth rate during the acceleration of cars with six-speed gearboxes and ICE is approximately the same power in the Honda Fit RS MT (2019), where the T_{max} characteristics of ICE is approximately in the middle of the working zone of angular speeds.

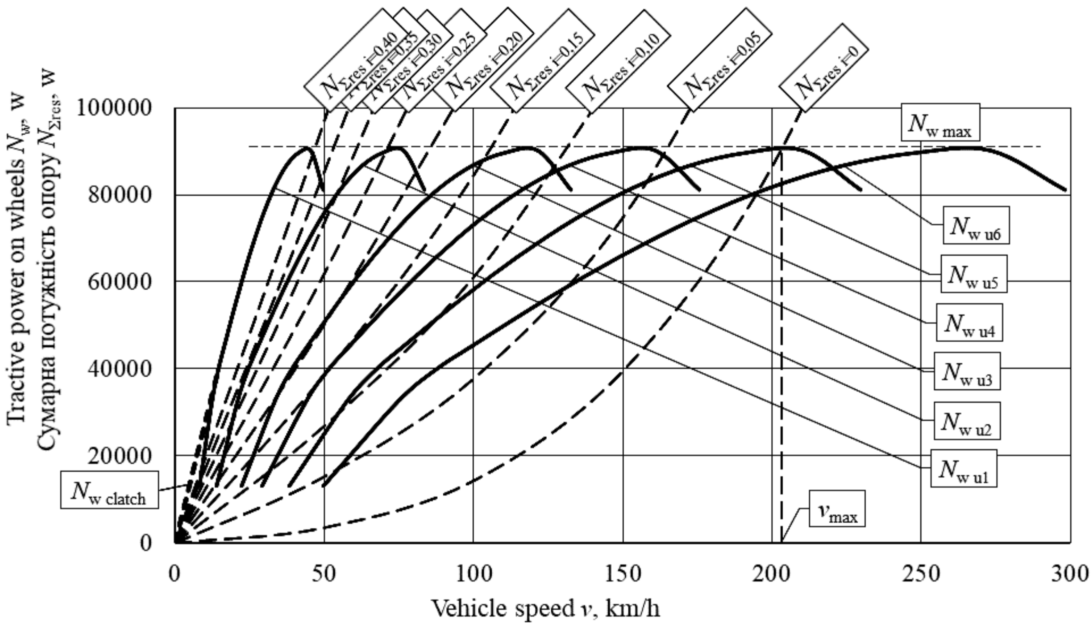

Fig. 11. Traction characteristic of the Opel Mokka 1.2 Turbo 130 (2022)
in coordinate stractive power on wheels – vehicle speed

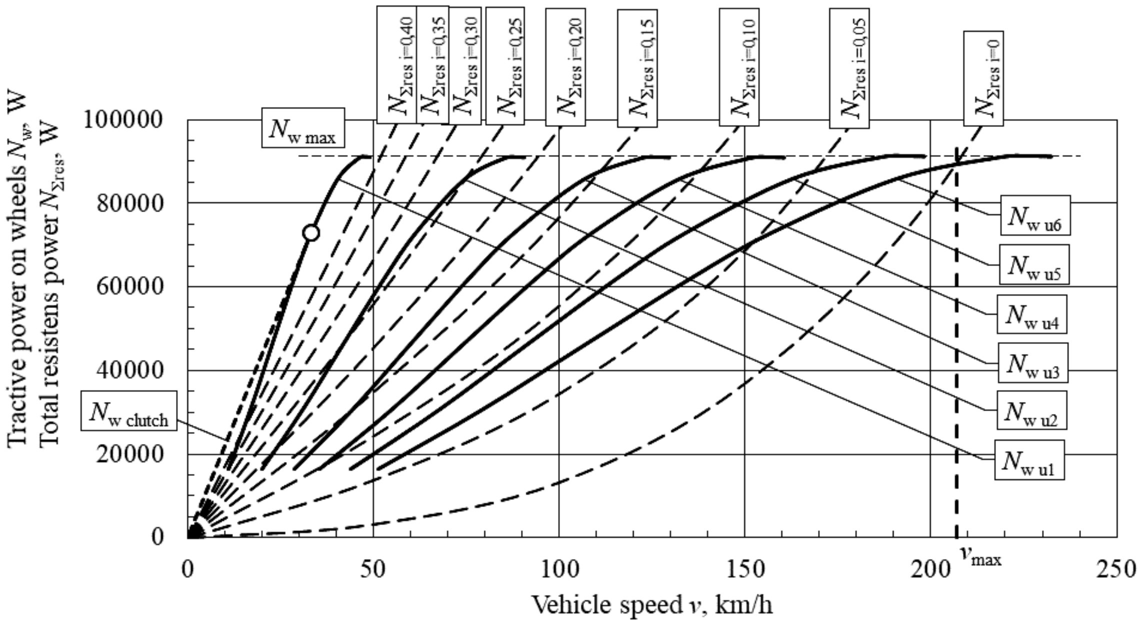

Fig. 12. Traction characteristic of the Honda Fit RS MT (2019)
in coordinatestractive power on wheels – vehicle speed

The efficiency of the drive of vehicles with close standard indicators of traction and speed properties is proposed to be estimated by the power utilization factor $k_{N\ 0\text{-}100}$.

$$K_{NO-100} = N_{w\ average} / (\eta \cdot N_{m\ \max}), \tag{1}$$

where $N_{w\ average}$ is the average realized power on wheels; is the efficiency of the driveline from the motor to the driven wheels ($\eta = 0.94$); $N_{m\ \max}$ is the maximum power of motor ($N_{m\ \max} = 560000W$).

For example, in Fig. 7 $N_{w\ average}$ is

$$N_{w\ average} = \begin{bmatrix} N_{w1.1\max} \cdot v_{base1} / 2 + (N_{w1.1\max} + N_{w1.2\max}) \cdot (v_{base2} + v_{base1}) / 2 \\ + N_{w1.2\max} \cdot (100 - v_{base2}) \end{bmatrix} / 100 =$$

$$= [404148 \cdot 44.61 / 2 + (404148 + 532000) \cdot (85.90 - 44.61) / 2 +$$

$$+ 532000 \cdot (100 - 85.90)] / 100 = 358425W.$$

Using the (Eq. 1), we have:

$$K_{NO-100} = 358425 / (0.94 \cdot 560000) = 0.681.$$

Table 1 contains indicators of traction-speed properties of vehicles selected for analysis, as well as determining the power utilization factor $k_{N\ 0\text{-}100}$.

Table 1

Indicators of traction and speed properties

No.	Vehicle models	Traction	Engine type	N_{max}, kW	v_{max}, km/h	$t_{0\text{-}100}$, s	$k_{N\ 0\text{-}100}$
1	Porsche Taycan Turbo S (2022)	four-wheel	electric motor	560	260	2.8	0.681
2	Honda e (2022)	rear-wheel	electric motor	100	145	9	0.775
3	Opel Mokka-e (2022)	front-wheel	electric motor	100	150	9	0.728
4	BMW 118i (2022)	front-wheel	spark-ignition	100	213	8.9	0.812
5	Opel Mokka 1.2 Turbo 130 (2022)	front-wheel	spark-ignition	96	202	9.1	0.799
6	Honda Fit RS MT (2019)	front-wheel	spark-ignition	97	201	9.1	0.723

Conclusions

The proposed power utilization factor allows you to assess the perfection of the drive of vehicles with the same standard indicators of traction and speed properties.

As we can see, (Table 1) for two electric vehicles Honda e (2022) and Opel Mokka-e (2022) with almost the same *Nmax*, *vmax*, $t_{0\text{-}100}$ – $K_{N\ 0\text{-}100}$ higher in the first thanks to the rear drive.

From the same comparison of the following three cars, it is clear that the leaders are: BMW 118i (2022) and Opel Mokka 1.2 Turbo 130 (2022) due to the characteristics of the engine: the first – partially close to the ideal, and the second – with $T_{\max}$ at the beginning of the characteristic. The Honda Fit RS MT (2019) with the traditional engine characteristic – with *the* $T_{\max}$ in the middle of the characteristic – has the lowest $k_{N\ 0\text{-}100}$.

On the other hand, the executive electric car Porsche Taycan Turbo S (2022) with four-wheel drive and the highest traditional $v_{\max}$ = 260 km/h and $t_{0\text{-}100}$ =2/8 s due to the high power $N_{\max}$ = 560 kW has the lowest $k_{N\ 0\text{-}100}$.

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