UTILIZATION POSSIBILITIES OF THE HYBRID DRIVE IN LAND TRANSPORT

MOŽNOSTI VYUŽITÍ HYBRIDNÍHO POHONU V POZEMNÍ DOPRAVĚ

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Summary: Utilization possibilities of hybrid drive in land transport in this paper will be described.

Key words: hybrid drive, hybrid vehicle, rail transport, road transport, power transmission

Anotace: Článek se zabývá možnostmi využití hybridních pohonů v pozemní dopravě.

Klíčová slova: hybridní pohon, hybridní vozidlo, železniční doprava, silniční doprava, přenos výkonu

INTRODUCTION

A lot of activities on the field of road and railway transport lead towards the reduction of fuel and energy consumption and finding better energy efficiency. Progress of the advanced technologies in last few years allows implementation of new power units combinations schemas for vehicles. Utilization possibilities of hybrid drive, which is based on combustion engine and electric motor (generator) combination, in road and railway transport in this paper will be described. We can find some similar conditions analyzing urban transport mode for road vehicles and shunt mode for railway vehicles.

1. THE PRINCIPLE OF TECHNICAL SOLUTIONS OF HYBRID DRIVE

In this chapter are generally described various possible technical solutions to the hybrid drive and established the basic reasons, why it is best to deal with this drive concept for the specific use of land transport vehicles.

1.1 Using of hybrid drive

The energy consumption of any vehicle equipped with an internal combustion engine can reduce a wide range of technical solutions. Reasons to use just the hybrid drive are: Snižování celkových nákladů dopravy

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- Reducing consumption of fossil fuels
- Design of combustion engine
- Taking advantage of electric power transmission
- Reducing the negative impacts on the environment
- Reducing emissions under the Kyoto Protocol for internal combustion engines of railway vehicles (Stage III A, III B)
- EURO standards for road vehicles

1.2 Type of hybrid drive

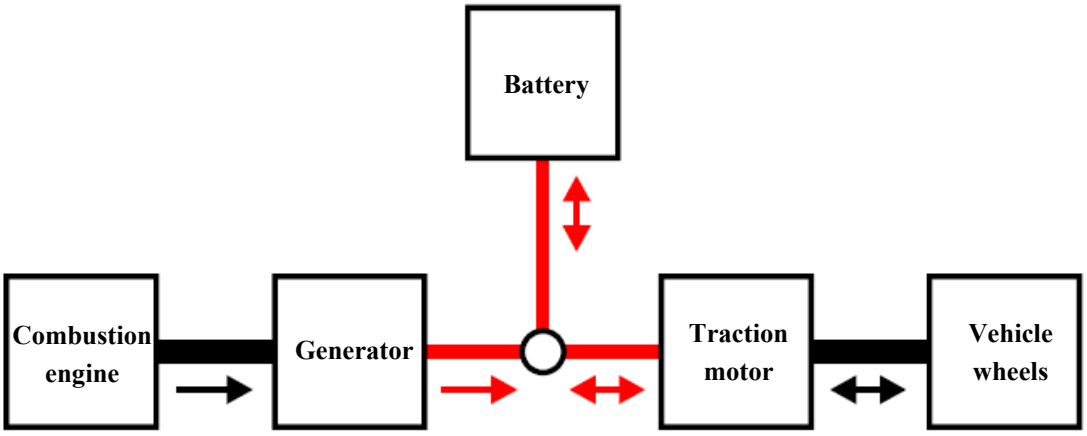
Hybrid drives using primary and secondary sources. By function, which takes the secondary source, hybrid drives are divided into:

- Micro hybrid
  - Primary source: drive of vehicle
  - Secondary source: powered auxiliary drive (equipment)
- Mild hybrid
  - Primary source: drive of vehicle
  - Secondary source: allows for energy recuperation, powered auxiliary drive, improving vehicle power
- Full hybrid
  - Both of the sources used to drive a vehicle, alone or in conjunction

Next, the hybrid drive can also be divided according to hybrid drive arrangement of individual parts:

1.2.1 Series hybrid drive

This type of hybrid drive can be used especially in the rail transport, because it´s very similar to the electric power transmission used for the diesel locomotives. The combustion engine is connected with the generator which produces electric energy for traction motor driving the wheels. The difference between standard electric power transmissions and the series hybrid drive is addend with the secondary source of the power. There is no mechanical connecting between the combustion engine and the wheels. The combustion engine speed does not depend on the vehicle speed, but there are high losses in electric machines.



Source: [3]

Fig. 1 – Example of series hybrid drive

1.2.2 Parallel hybrid drive

This is the sort of combustion engine, gear box and vehicles wheels in line. The secondary source of transmission is connected parallel to this line. The electrical energy in the secondary source is changed to mechanical energy by the generator. The advantage of the parallel system is effective for direct mechanical connection of the combustion engine and gearbox.

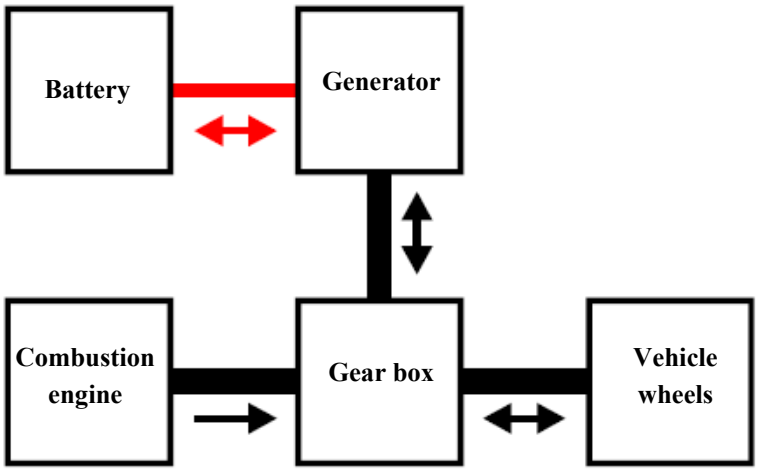


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Fig. 2 – Example of parallel hybrid drive

1.2.3 Combined hybrid drive

This system includes both types of hybrid drive. The system is perhaps the mechanical connection between the electrical machines. The system can work in parallel mode the same as a true series hybrid drive.

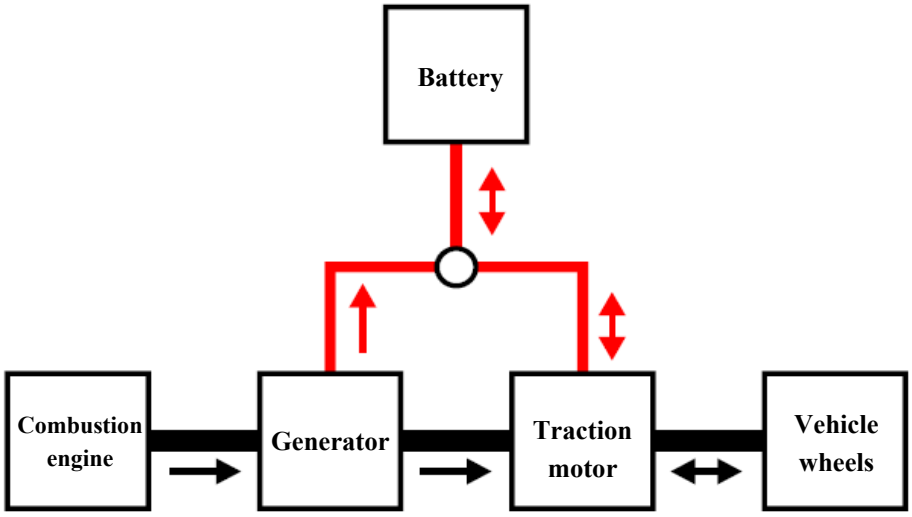

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Fig. 3 - Example of combined hybrid drive

2. ROAD TRAFFIC OPERATION MODE ANALYSIS

Application of hybrid drive is a few years known on the field of road traffic. Personal vehicles, as Honda Insight and Toyota Prius, or light truck Iveco Daily Hybrid are using the hybrid technology and sometimes we can meet these vehicles in standard operation. The question is what operation mode is the most suitable for this drive type at this moment and how can be these operation modes generalized. Some basic studies of hybrid drive utilization possibilities by our department have been realized. Standard operation modes of the hybrid driven vehicle we can specify in the following articles.

Slow standing start	-	only electric motor up to 50 km/h, energy for electric motor comes only from accumulator
Quick standing start	-	combination of electric motor and combustion engine, energy for electric motor comes from accumulator and generator
Normal drive	-	only combustion engine, generator charge accumulator
Acceleration	-	combination of electric motor and combustion engine, energy for electric motor comes from accumulator and generator
Uphill driving	-	combination of electric motor and combustion engine, energy for electric motor comes from accumulator and generator
Downhill driving	-	generator charge accumulator
Deceleration	-	generator charge accumulator
Braking	-	generator charge accumulator

The combustion engine supplies the most part of power in vehicle operation and electric motor is active only in acceleration. Slow standing start is unique mode when the vehicle is electric driven. In the situation, when the combustion engine power is sopped, vehicle wheels change a kinetic energy in generator and accumulators are charged. In the situation, when the combustion engine works with power reserve, the power is splitted between wheels and generator.

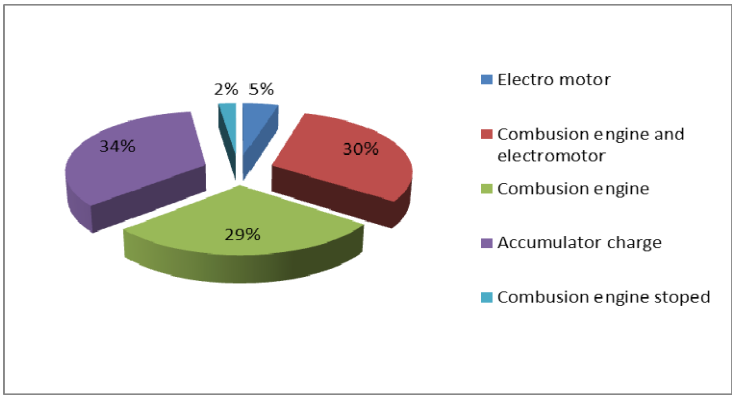
The power on vehicle wheels in combined mode (combustion engine and electric motor) is following:

$$P_k = \frac{F_k \cdot V}{3600} = \left(\frac{M_t \cdot i_c^{\,m}}{r} \cdot \frac{V}{3600} + \frac{M_{em} \cdot i_c^{\,em}}{r} \cdot \frac{V}{3600} \right) \cdot \eta_c \qquad (1)$$

The analysis for vehicle category N_1 in four following situations has been simulated. The first situation assumed that the electro motor will be used up to 20 km/h in urban operation, second situation assumed that the electro motor will be used up to 50 km/h in urban operation, third situation assumed that the electro motor will be used up to 50 km/h according directive 93/116/EU for urban cycle and fourth situation assumed that the electro motor will be used up to 20 km/h in non-city operation.

Results for the first situation assumed that the electro motor will be used up to 20 km/h in urban operation are showed below (see fig. 4 and fig. 5).

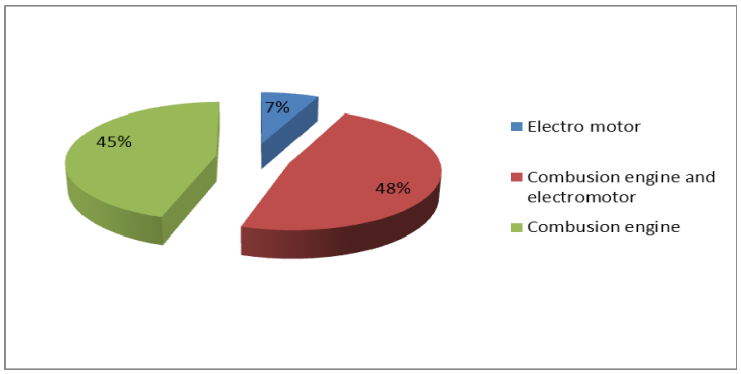
Utilization of electro motor is about 5 %, accumulator charge 34 %, combustion engine 29 %, combination of electro motor and combustion engine 30 % and combustion engine stopped 2%.



Source: [2]

Fig. 4 - Utilization of hybrid drive modes (urban operation, electromotor up to 20 km/h)

Summary percentage utilization of electro motor is about 7 %, combustion engine 45 %, combination of electro motor and combustion engine 48 %.



Source: [2]

Fig. 5 - Percentage utilization of drives (urban operation, electromotor up to 20 km/h)

Results for the second situation assumed that the electro motor will be used up to 50 km/h in urban operation are showed below (see fig. 6 and fig. 7).

Utilization of electro motor is about 37 %, accumulator charge 29 %, combustion engine 16 %, combination of electro motor and combustion engine 16 % and combustion engine stopped 2%.

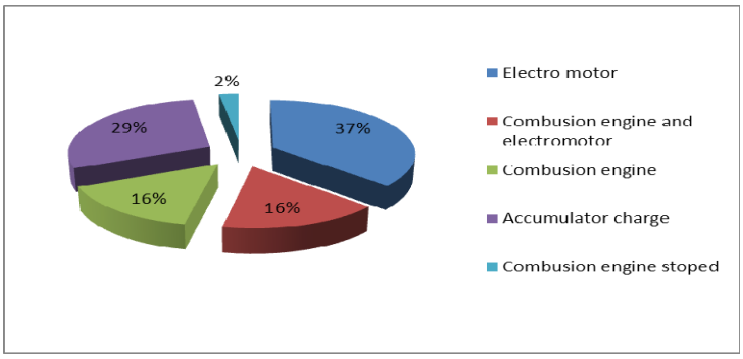


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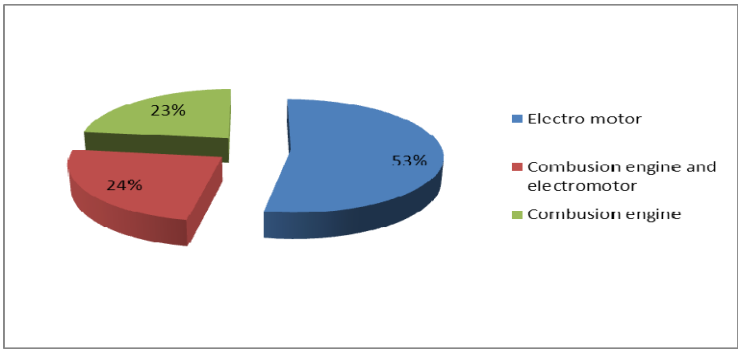
Fig. 6 Utilization of hybrid drive modes (urban operation, electromotor up to 50 km/h)

Summary percentage utilization of electro motor is about 53 %, combustion engine 23 %, combination of electro motor and combustion engine 24 %.



Source: [2]

Fig. 7 Percentage utilization of drives (urban operation, electromotor up to 50 km/h)

The analysis for vehicle category N_1, comes from assumptions of directive 93/116/EU for urban cycle (fig. 8) and then vehicle is driven by electro motor up to 50 km/h, show following results [2].

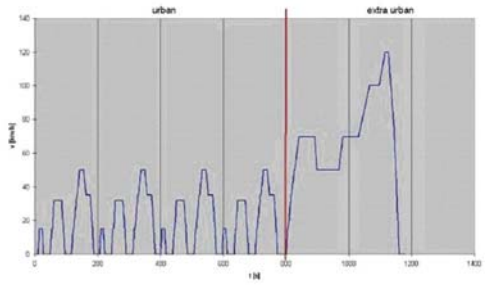


Fig. 8 - European directive 93/116/EU

Hybrid drive mode	Utilisation	Energy flow
Electro motor	96	from accu.
Combustion engine and electromotor	24	from accu.
Combustion engine	48	to accu.
Accumulator charge	80	to accu.
Combustion engine stoped	12	

Fig. 9 - Hybrid drive modes utilization (urban operation)

From the fig. 9 comes percentage expression (see fig. 10). Utilization of electro motor is about 37 %, accumulator charge 31 %, combustion engine 18 %, combination of electro motor and combustion engine 9 % and combustion engine stopped 5%.

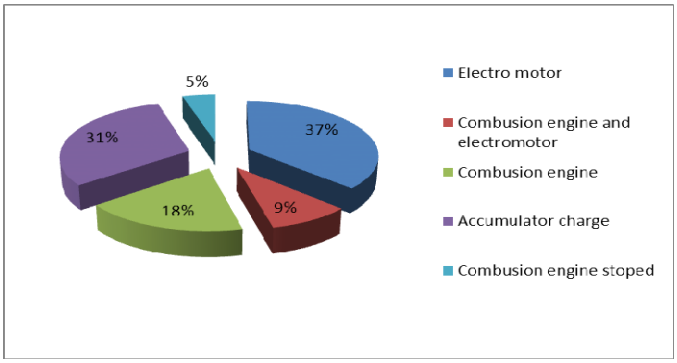


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Fig. 10 - Utilization of hybrid drive modes (directive 93/116/EU, urban operation)

Summary percentage utilization of electro motor is about 57 %, combustion engine 29 %, combination of electro motor and combustion engine 14 %.

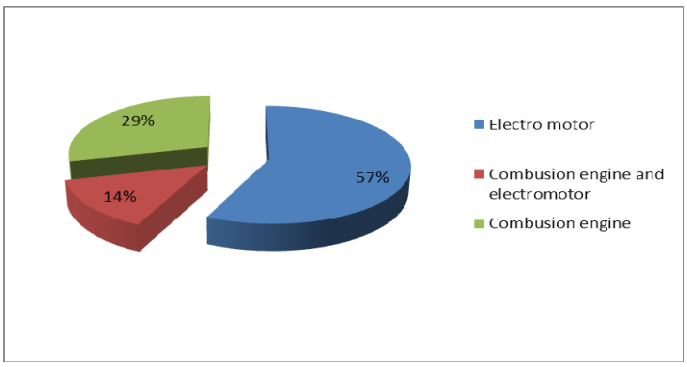

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Fig. 11 - Percentage utilization of drives (directive 93/116/EU, urban operation)

Results for the fourth situation assumed that the electro motor will be used up to 20 km/h in non-city operation are showed below (see fig. 12 and fig. 13).

Utilization of electro motor is about 3 %, accumulator charge 35 %, combustion engine 22 %, combination of electro motor and combustion engine 38 % and combustion engine stopped 2%.

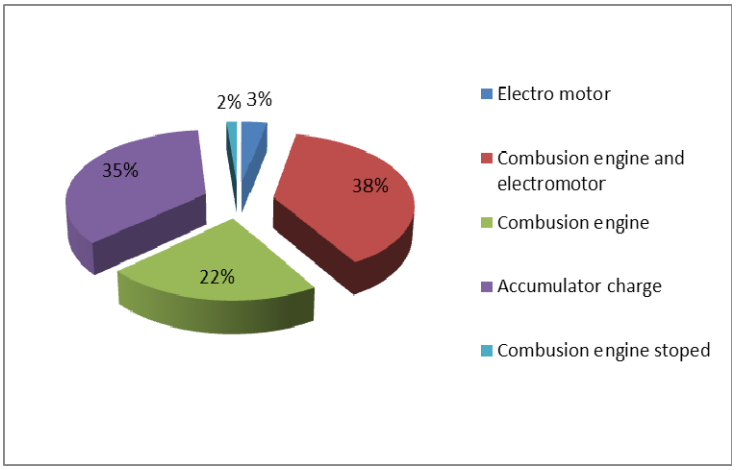

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Fig. 12 - Utilization of hybrid drive modes (non-city operation, electromotor up to 20 km/h)

Summary percentage utilization of electro motor is about 5 %, combustion engine 35 %, combination of electro motor and combustion engine 60 %.

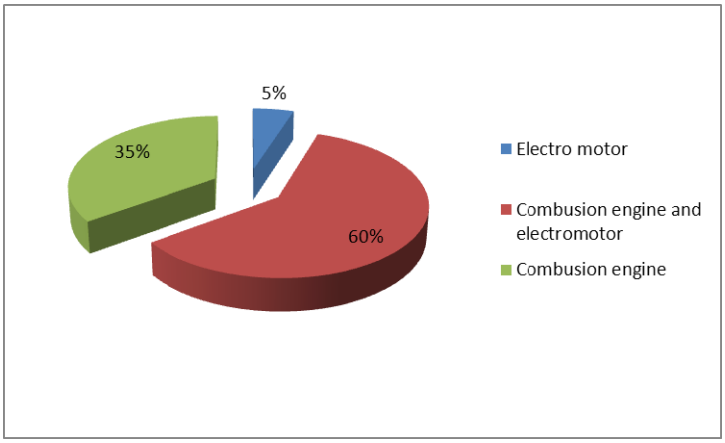

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Fig. 13 - Percentage utilization of drives (non-city operation, electromotor up to 20 km/h)

Simulated situation shows that the hybrid drive is very suitable for traffic conditions in small velocities (up to 50 km/h) and for frequent start – stop modes. This is typical for urban transport mode.

3. APPLICATIONS EXPERIENCE IN THE FIELD OF RAILWAY TRANSPORT

Operating modes of rail transport is fundamentally different from the operating modes used in road transport. Railway vehicles tractions are constructed differently adapted to the requirements imposed on different types of operating modes. Operating modes can be classified according to Table 1. The criteria, in which these modes of operation are different, include the weight of the load and operating speed.

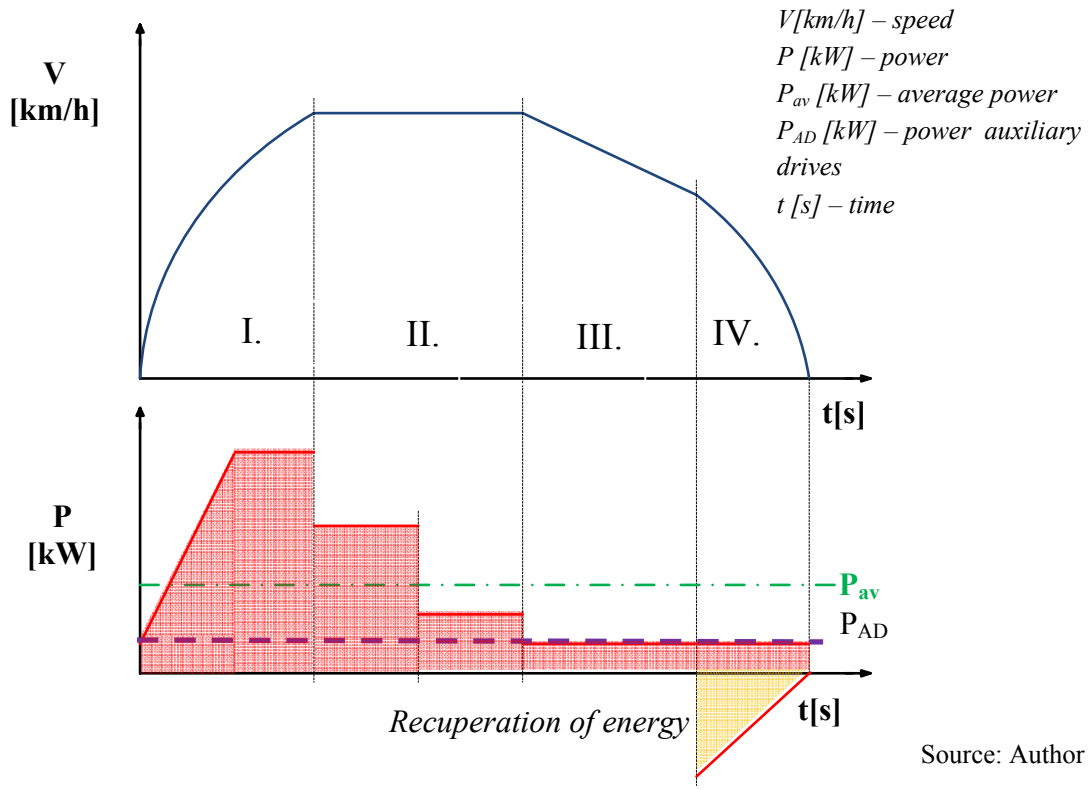
Operating modes	Speed requirements	Weight of the load
Transportation passanger: regional	variable	low
Transportation passanger: high-speed	high (max. line speed)	low - medium
Cargo transportation	limited (120km/h)	high
Shunt to rail	low (to 40 km/h)	variable

Source: Autor

Fig. 14 – Operating modes

Generally describe the traction vehicle according to fig. 14. There is shown tachogram of the train and the power output. The course of vehicle drive can be divided into four phases, it can be distinguished:

I. Accelerating period - it can use the installed propulsion power source.
II. Driving a constant speed - the actual value of the required power - oriented total runnig resistance and towed vehicle weight.
III. Period without power - the power of the vehicle is used only to power auxiliary drives, the vehicle driving force of inertia.
IV. Braking - vehicle develops braking force and slowing down. It can use the energy recuperation.

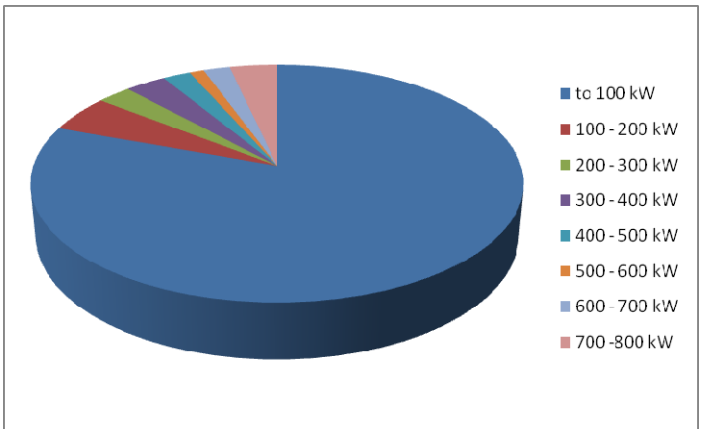


Source: Author

Fig. 15 - Theory of driving a locomotive

Based on the evaluation of operating modes of rail vehicles, use hybrid drive system particularly suitable for shunt to rail. There is a possibility to use hybrid drive under certain conditions for passenger transportation especially in regional operating mode in the high number of stops. Influencing factor in the choice of using the hybrid system is the total number of accelerations, braking, and travel time runs. Another factor is the variable weight of the load. When the weight of the load is low the result is unused the installed capacity of driving the vehicle.

For example, the use of locomotive power - locomotives series 740 is shown in fig. 16. These measurements made during the shunt on rail sidings NHKG Ostrava (now Arcelor Mittal) [3]. From these measurements show that the power output of the shift is moving at low levels. To 100 kW is 80,5 %. So in this case is a wide possibility to install a hybrid drive.



Source: [3]

Fig. 16 - Example distribution of the power to shift the locomotive no.740

To describe the mathematical solution of the hybrid drive of railways transport can be written:

$$P_W = \left(P_{CE} \cdot \sum_i \eta_{SMi} + P_A \cdot \sum_i \eta_{Ai} - \frac{P_{AD}}{\sum_i \eta_{ADi}} \right) \cdot \sum_i \eta_{Ti} \qquad (2)$$

The equation expresses the relation to overall power on the perimeter of the wheels, depending on the power of different sources. P_A component in this case is the possibility of a secondary power source provided that the battery can be used as a secondary source.

4. CONCLUSION

Hybrid drive, as an alternative to reduce fuel consumption when used in land transport, appears to be particularly suitable for certain types of operating modes. In the road transport it is best to use in urban driving mode. In the rail transport the hybrid is suitable for use in shunting locomotives.

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