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OPERATIONAL UTILIZATION OF THE INTERNAL COMBUSTION ENGINES AT THE MOTIVE POWER UNITS AND HYBRID TRACTION DRIVES

The utilization of installed power capacity of internal combustion engines in motive power units (especially shunting locomotives and locomotives for industrial transport) is low. The result is that most of the time internal combustion engine works in regimes that are far from optimum mode. It means that specific fuel consumption is high. Some examples of measured operational regimes of locomotives in shunting operation and other motive power units are given in the paper. The improvement can be achieved by using of the unconventional traction drive of rail vehicles. One of possible ways is using of the hybrid traction drive. The hybrid drive includes the ICE and the energy storage device. The parameters of such traction drive must be based on analysis of real operational regimes of vehicles.

PREVÁDZKOVÉ VYUŽITIE SPAĽOVACÍCH MOTOROV NA HNACÍCH VOZIDLÁCH A HYBRIDNÉ POHONY

Prevádzkové využitie výkonu spaľovacích motorov hnacích koľajových vozidiel (zvlášť posunovacích rušňov a rušňov pre priemyselnú dopravu) je veľmi nízke. Výsledkom tohoto je, že väčšinu času spaľovací motor pracuje ďaleko od optimálneho režimu. To znamená, že jeho merná spotreba je vysoká. Niektoré príklady nameraných prevádzkových režimov v posunovacej prevádzke, ale aj iných hnacích vozidiel sú uvedené v tomto príspevku. Zlepšenie môže byť dosiahnuté použitím nekonvenčného pohonu. Jeden z možných spôsobov je použitie hybridného pohonu. Hybridný pohon zahŕňa spaľovací motor a zariadenie na uloženie energie.Parametre takéhoto trakčného pohonu musia byť založené na analýze reálnych prevádzkových režimov.

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1. INTRODUCTION

Problem with fuel savings and air pollution in the railway transport have to be solved at the present time. A significant number of diesel motive power units with various installed power and age are in operation in the industrial transport and in shunting service on railways.

It is well known that the use of installed power capacity of internal combustion engine in motive power units (especially in shunting locomotives and locomotives for industrial transport) is very low. Average usage of engine power is usually less than 20 % of the installed power capacity and nominal engine performance is used only during minimal period of the total time of engine operation (at the level of approx. 1%). The result of this is that most of the time the internal combustion engine works in regimes that are far from optimum mode. It means that specific fuel consumption is high. At this type of locomotives operation the frequent and fast changes of engine regimes occur, which result in increased fuel consumption and insufficient fuel combustion. Thus increased quantity of harmful emissions is produced.

Kinetic energy of a classic diesel locomotive as well as the DMUs and trains is transformed into thermal energy during braking process. Normally it is not possible to utilize this kinetic energy in a reasonable way. The kinetic energy should be transformed into a suitable form and stored for following use.

If a vehicle or a train is at standstill very often the engine continues working. The reasons are various, but mostly it is the continuous operation of peripheral equipment (braking compressor, lighting, preheating etc.).

Besides mechanical energy (approx. 40% of the energy released from the fuel in optimum regime of the engine operation) internal combustion engine produces considerable amount of thermal energy, utilization of which is poor. Possibility of utilization of this waste thermal energy is limited also because of its varying quantity during engine operation.

Presently the motive power units operating under normal regime almost do not use alternative fuels, with exception of natural gas or biogas, but it also happens in very rare cases. Economically not acceptable concepts of engines operating on classic fuels prevail and alternative solutions are considerably neglected. Thus increased production of harmful emissions continues.

The improvement of the present state can be achieved by unconventional traction drive of rail vehicles. Such unconventional traction drive can be a hybrid drive.

We have been studying these problems for a long time and some results were published for example in [1, 2, 3] etc.

2. OPERATIONAL UTILIZATION OF THE ENGINE POWER

2.1 Industrial and shunting locomotives

The character of utilization of installed engine power in the industrial and shunting locomotives are similar. It was shown in many measurements in different times and at different locomotives. Since the operational conditions may significantly vary in different cases, the results of measurements can vary as well. We will show some results of such measurements.

The distribution of engine power on locomotive class T 419.0 (ČKD) at shunting service in the company NH a. s. Ostrava is shown on the Fig. 1 [4]. In this case idling of engine does not comprise idling during standstill of locomotive. Mean output of the engine is 124 kW in this case. Nominal output of this locomotive is 600 kW. The mean output of the engine is almost 21 % of the nominal output of locomotive. This is relatively great value and it is caused by relatively smaller output of the engine. Usually idling represents more than 70% of the total time of engine activity in similar cases of operation.

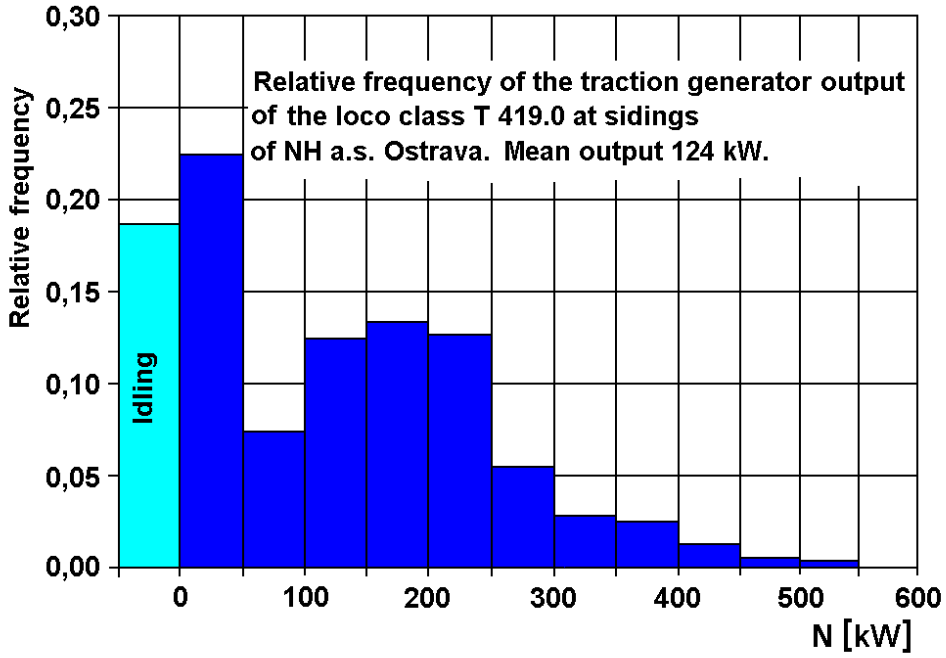

Fig. 1. The distribution of the traction generator output of locomotive T 419.0 at shunting operation at sidings of NH a. s. Ostrava

Another example is from measurements at the OKR sidings in Ostrava. The measurements were carried out on the locomotive class T448 (ČKD). This locomotive has maximum output of internal combustion engine 883 kW. The distribution of traction generator output is shown on the Fig. 2 [6]. In the graph several various regimes of locomotive work were included. The left column (55.9 %) shows relative duration of idling run. About 7.1 % was idling run with consumption of power by auxiliaries (braking compressor and/or fans of cooler). The mean value of the traction generator output was in this case approx. 121 kW, which is about 14 % of maximum output of locomotive. It is evident that in this case utilization of maximum engine output is worse than in the previous one.

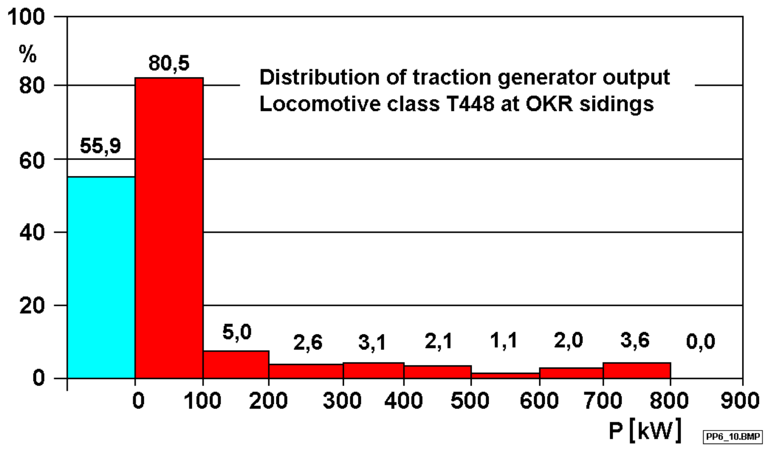

Fig. 2. The distribution of the traction generator output of locomotive T 448.0 at shunting operation at sidings of OKR a. s. Ostrava

The part of results of measurements on locomotives class 740.3 at sidings of OKD Kladno is shown at the Fig. 3 [7]. The class 740.3 (CZ LOKO) is refurbished locomotive class 740 (ČKD) with engine Caterpillar C15 with half output (403 kW). The mean output of engine was about 95 kW, what is about 23 % of maximum output of locomotive.

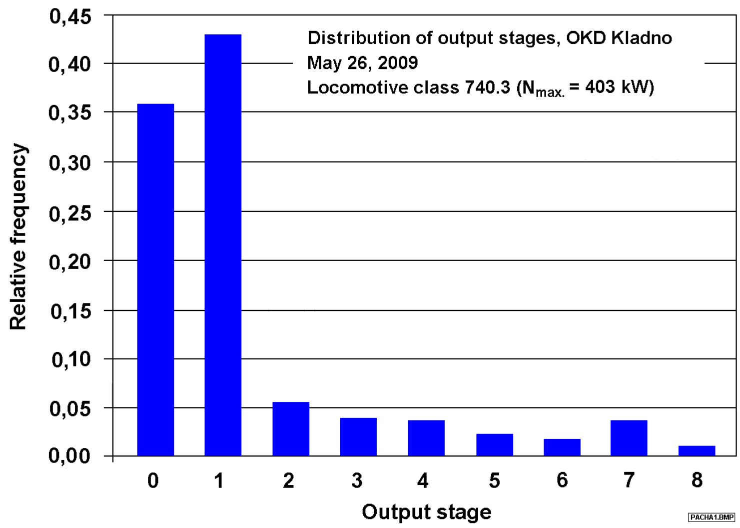

Fig. 3. The distribution of engine output stages at the sidings of OKD in Kladno

We can find similar distribution of engine output also in case of railway shunting locomotives. An example of output distribution of locomotive class 770 (ČKD) during shunting operation on hump in railway station in Žilina is shown in the Fig. 4 [5]. The mean output of the locomotive with nominal rating of 993 kW was only 61 kW in this case, what represents only 6 % of nominal output.

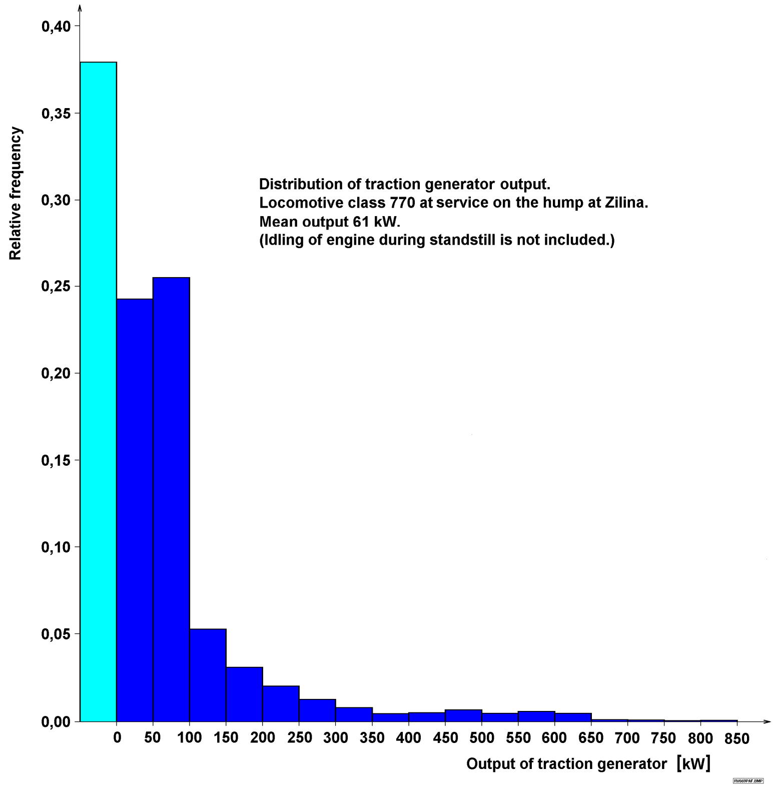

Fig. 4. The distribution of traction generator output of locomotive class 770 at service on the hump at Žilina

Another example of locomotive operational regimes is taken from railway station Trencianska Tepla. The measurements were carried out on the locomotive class 742 (ČKD) [8]. This class of locomotives has nominal output of 883 kW. The distribution of traction generator output is in the Fig. 5. The mean output of traction generator was only about 102 kW, which represents about 11.5 % of nominal output.

From demonstrated examples we can conclude that the greater is nominal output of locomotive the poorer is using of installed power. This observation is valid only for locomotives designated for shunting operations in railways and for using in industrial transport.

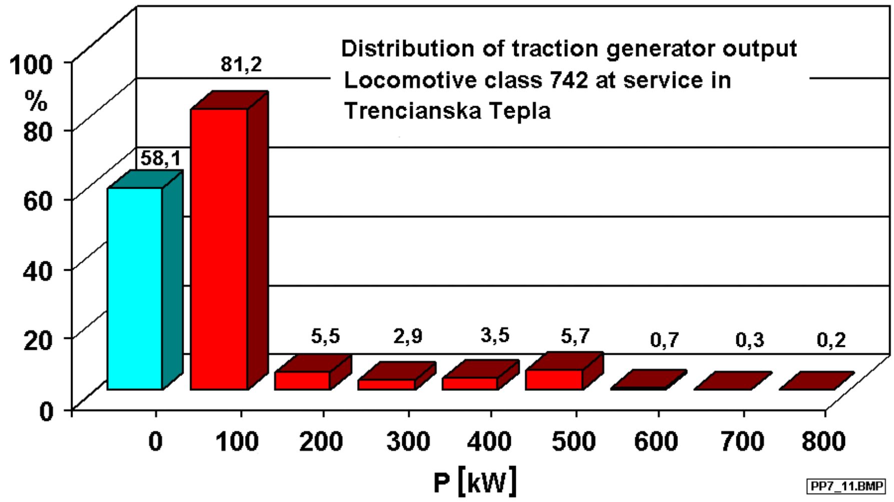

Fig. 5. The distribution of traction generator output of locomotive class 742 in the shunting service at Trencianska Tepla

In the Fig. 6 an example of time behaviour of output power measured on locomotive class 740 is shown [8]. The measurement comprises shunting of empty wagons at the Trencianska Tepla railway station. The mean value of output was about 80 kW in this case.

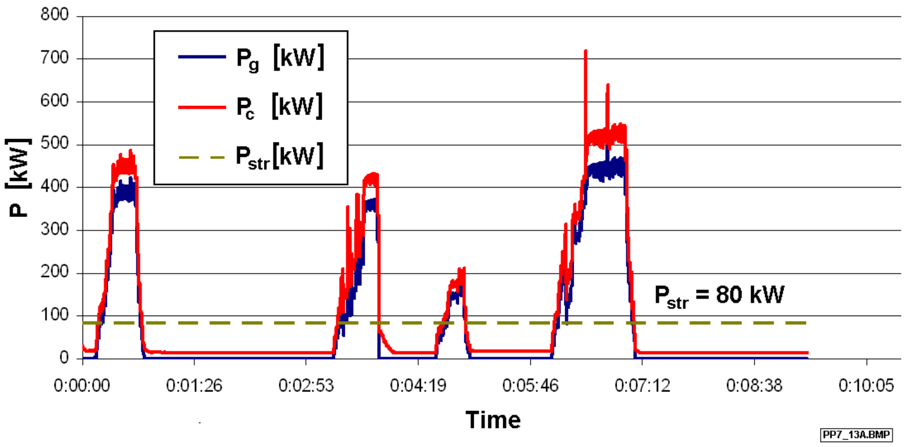

Fig. 6. Output power of locomotive class 740 on shunting operation at Trencianska Tepla

2.2 Diesel multiple units

The character of operational using of diesel multiple units is different from shunting and industrial locomotives. Example of time behaviour of velocity and power output of light diesel unit at the regional railways VLTJ in Denmark is in the Fig. 7 [9]. The peak output at driving wheelsets was 250 kW in this case. The mean output was about 105 kW without idling at the stops.

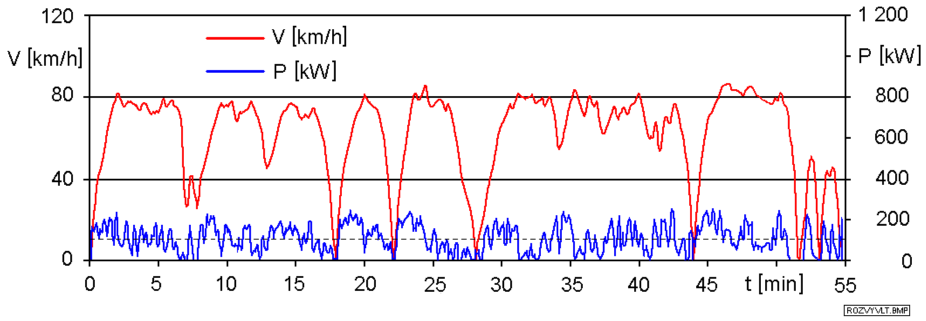

Fig. 7. The course of power on wheelsets and velocity of DMU at the railways VLTJ

3. HYBRID TRACTION DRIVE

As it was mentioned above, one of possible ways is using of a hybrid traction drive. This system comprises the ICE or fuel cells and the energy storage device (flywheel type storage device, electrochemical batteries, double layer capacitors, flow batteries etc.).

Hybrid traction drive enables:

- ► storage of energy gained by electrodynamic braking and its exploitation,
- ► installation of a primary power source with significantly lower output as in the case the of classic traction drive,
- ► operation of primary source of energy in optimum regime from the point of view of fuel consumption and emissions,
- ► utilization of accumulated energy for auxiliary systems in standstill regime of vehicle (engine not running),
- ► improvement of conditions for alternative fuels and fuel cells using.

Principle of hybrid traction drive is simple. In those regimes of operation which require smaller traction power as produces the primary source of power, the surplus energy would be accumulated at proper accumulator and on the contrary in case of higher traction power demands as primary energy source offers, missing energy would be drawn from accumulator (in such way it is also possible to use energy acquired from electrodynamic braking). Using of kinetic energy of train which can be transformed by electrodynamic braking is very important and leads to much better energy balance.

Possibility of smaller engine using brings reduction of fuel consumption while idling, what is important in case of industrial locomotives and locomotives for shunting operation. As was shown, idling takes about 70 - 80% of total time of engine operation in some cases.

4. CONCLUSION

At some types of motive power units the utilization of the output of internal combustion engines is very poor. As was shown the mean output in many cases is below 15 % of installed output. This leads to uneconomical operation. One of the possible ways how to solve the problem is using of the hybrid traction drive. Knowledge of operational regimes of locomotives is necessary for right choice of parameters of hybrid traction drive.

It is possible to gain about 15 – 20 % savings in fuel consumption of shunting locomotive by introducing hybrid traction drive. It was proved by measurements at the first hybrid locomotive class TA 436 in the former Czechoslovakia [10]. This locomotive has engine output 189 kW instead of 600 kW of compared locomotive.

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