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THE HYBRID TRACTION - THE WAY OF FUEL UTILIZATION IMPROVEMENT

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Daniel Kalinčák, Ľuboš Bartík, Juraj Grenčík

Department of Transport and Handling Machines, Faculty of Mechanical Engineering,
University of Žilina, Slovakia
Email: daniel.kalincak@fstroj.uniza.sk

Abstract. *The utilization of the installed power capacity of internal combustion engines (ICE) in motive power units (especially in shunting locomotives and locomotives for industrial transport) is very low. The ICE mean power in this operational mode is about 15 – 20 % of its installed one. The result is that during most of its operational time the internal combustion engine works in the regimes that are far from optimum mode. It means that the specific fuel consumption is high. Some examples of the measured operational regimes of locomotives in shunting operation and other motive power units are given in the paper. Kinetic energy of a classic diesel locomotive as well as the DMUs and trains is transformed into thermal energy during the 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 future uses. The improvement can be achieved by using the rail vehicles' unconventional traction drive. One of possible ways is the use of a hybrid traction drive. The hybrid drive includes ICE and an energy storage device. In this case, the ICE power can be substantially lower than in the classic traction. The parameters of such traction drive must be based on the analysis of the vehicles' real operational regimes. These parameters are the following: ICE power, power of traction motors, capacity and power of energy storage devices (accumulators). There are other ways of improving fuel utilization at railway vehicles, e.g. by better utilization of heat released from the fuel.*

Key Words: *Hybrid Traction Drive of Rail Vehicles, Utilization of ICE Power, Fuel Utilization, Energy Accumulation*

1. INTRODUCTION

The problem with fuel and energy savings and air pollution in the rail transport should be solved at present [2]. A significant number of diesel locomotives with various in-stalled power and age are in operation in the industrial transport and in shunting service on railways.

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It is known that the use of the installed power capacity of ICE in motive power units (especially in shunting locomotives and locomotives for industrial transport) is very low. The average usage of engine power is usually less than 20 % of the installed power capacity and the nominal engine performance is used only during minimal period of the total time of the engine operation (at the level of approx. 1%). This leads to the fact that during most of its operational time the internal combustion engine works in the 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 the engine regimes occur, which results in increased fuel consumption and imperfect fuel combustion with an increased quantity of harmful emissions.

The kinetic energy of a classic diesel locomotive as well as the DMUs and trains is transformed into thermal energy during the 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 future uses.

Even if a vehicle or a train is at standstill it happens very often that the engine continues working. The reasons for this are various, but mostly they are related to the continuous operation of auxiliary equipment (braking compressor, lighting, preheating etc.).

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

Presently the motive power units operating under the normal regime almost do not use alternative fuels, with exception of natural gas or biogas but this also happens in very rare cases. Economically not acceptable concepts of engines operating on classic fuels prevail and alternative solutions are considerably neglected. Thus the 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 are published, for example in [3, 4, 5] etc.

2. OPERATIONAL UTILIZATION OF THE ENGINE POWER

2.1. Industrial and shunting locomotives

The characters of utilization of the installed engine power in the industrial and in the shunting locomotives are similar. It has been 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. Some results of such measurements are shown in the following.

The distribution of engine power on locomotive class T 419.0 (ČKD) at shunting service in the company NH a. s. Ostrava is shown in Fig. 1 [6]. In this case the engine idling does not comprise idling during the locomotive standstill.

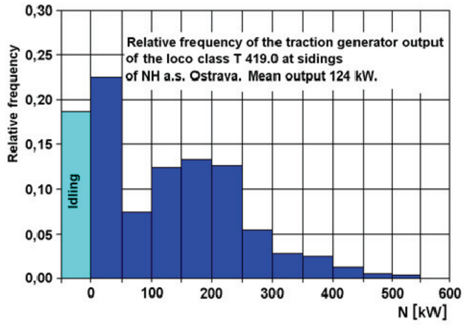

Fig. 1 Distribution of the traction generator output of locomotive class T 419.0 at shunting operation at sidings of NH a. s. Ostrava

The mean engine output is 124 kW in this case. The nominal output of this locomotive is 600 kW. The mean engine output is almost 21 % of the nominal output of locomotive. This is relatively a great value and it is caused by a relatively smaller output of the engine. Usually idling represents more than 70% of the total time of engine action in similar cases of operation.

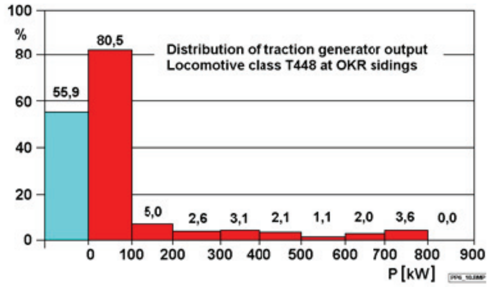

Fig. 2 Distribution of the traction generator output of locomotive T 448.0 at shunting operation at sidings of OKR a. s. Ostrava

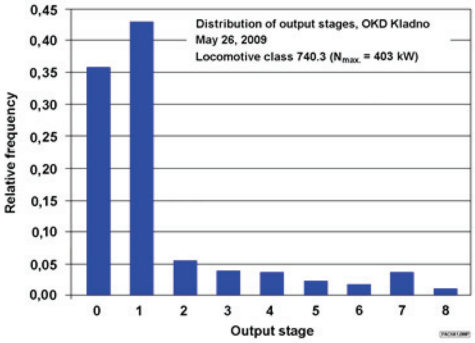

Fig. 3 Distribution of engine output stages at the sidings of OKD in Kladno

Another example is from measurements at the OKR sidings in Ostrava. The measurements are 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 in Fig. 2 [8]. In the graph several various regimes of locomotive work are included. The left column (55.9 %) shows relative duration of idling run. About 7.1 % is an idling run with consumption of power by auxiliaries (braking compressor and/or fans of cooler). The mean value of the traction generator output is in this case approx. 121 kW, which is about 14 % of maximum output of locomotive. It is evident that in this case the utilization of the maximum engine output is worse than in the previous one.

The part of results of measurements on locomotives class 740.3 at sidings of OKD Kladno is shown in Fig. 3 [11]. 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 is about 95 kW which is about 23 % of the maximum locomotive output.

We can also find similar engine distribution output in the 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 Fig. 4 [7]. 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

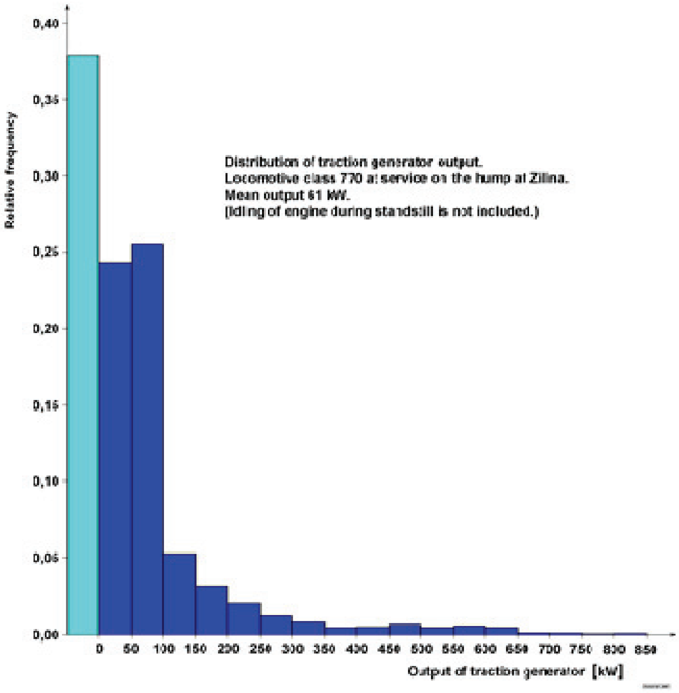

Fig. 4 The distribution of traction generator output of locomotive class 770 at service on the hump at Žilina

Another example of locomotive operational regimes is taken from railway station Trencianska Tepla. The measurements are carried out on the locomotive class 742 (ČKD) [12]. This class of locomotives has nominal output of 883 kW. The distribution of traction generator output is in Fig. 5. The mean output of traction generator is only about 102 kW, which represents about 11.5 % of nominal output.

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

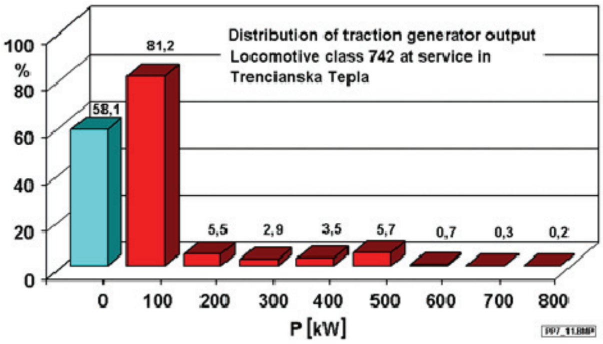

Fig. 5 The distribution of traction generator output of locomotive class 742 in the shunting service at Trencianska Tepla

In Fig. 6 an example of time behaviour of output power measured on locomotive class 740 is shown [12]. The measurement comprises shunting of empty wagons at the Trencianska Tepla railway station. In this case, the mean value of output is about 80 kW.

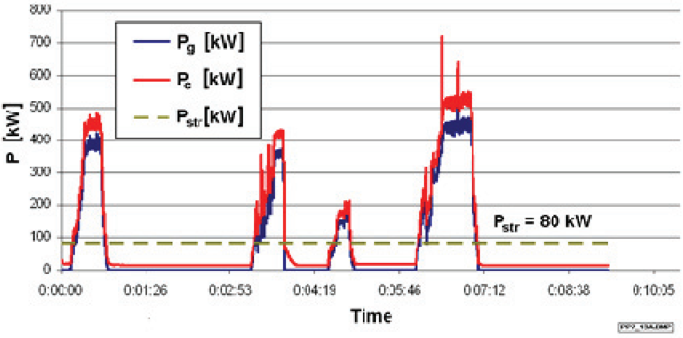

Fig. 6 Output power of locomotive class 740 on shunting operation at Trencianska Tepla

2.2. Diesel multiple units

The character of operational usage of the 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 Fig. 7 [13]. The peak output at driving wheelsets is 250 kW in this case. The mean output is about 105 kW without idling at the stops.

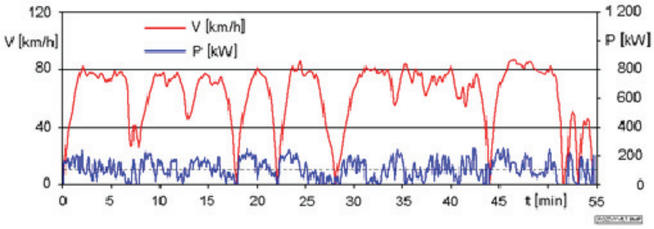

Fig. 7 The course of power on wheelsets and velocity of DMU at the railways VLTJ

4. HYBRID TRACTION DRIVE

As above mentioned, one of possible ways is the usage of a hybrid traction drive. This system comprises 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 next 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 fuel consumption and emissions point of view,
- 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.

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

The possibility of a significantly smaller engine usage brings about fuel consumption reduction while idling and this is of importance when it comes to the vase of industrial locomotives and locomotives for shunting operation. As shown, idling takes about 60 - 80% of total time of engine operation in cases of industrial and shunting locomotives.

The energy stored in accumulators can be used for acceleration in the case of multiple diesel units. The requirements laid on the energy storage device in the case of locomotives and diesel multiple units are different. Greater importance is laid on the power of energy storage device than on its capacity in the case of diesel multiple units.

Another possibility for hybrid drive is utilization of solar energy [1] using the moving and stationary photovoltaic panels.

4. CONCLUSION

At some types of motive power units the utilization of the output of internal combustion engines is very poor. As is shown, the mean output in many cases is below 15 % of installed output. This leads to an uneconomical operation. One of the possible ways of solving the problem is by using the hybrid traction drive. The knowledge of operational regimes of locomotives is necessary for the 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. This is proved by measurements at the first hybrid locomotive class TA 436 in the former Czechoslovakia [9]. This locomotive has engine output 189 kW instead of 600 kW of compared locomotive.

Another way for better utilization of fuel is to use the SteamTrac technology [10]. This technology is based on waste heat recovery from exhaust gases. It can bring about 5-9 % fuel savings.

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HIBRIDNI POGON - NAČIN ZA UNAPREĐENJE ISKORIŠĆENOSTI GORIVA

Daniel Kalinčak, Luboš Bartik, Juraj Grenčik

Iskorišćenje instalisane snage motora sa unutrašnjim sagorevanjem (SUS) u pogonskim jedinicama (posebno u lokomotivama za manevrisanje i industrijski prevoz) je veoma nisko. Srednja snaga motora SUS u ovom operativnom režimu je oko 15 - 20% od njihove instalisane snage. Rezultat toga je da najveći deo vremena motor sa unutrašnjim sagorevanjem radi u režimima koji su daleko od optimalnog. To znači da je specifična potrošnja goriva visoka. Neki primeri merenja operativnih režima rada lokomotiva u manevrisanju i drugih pogonskih jedinica dati su u radu. Tokom kočenja, kinetička energija klasične dizel lokomotive, kao i DMUs i vozova se pretvara u toplotnu energiju. Najčešće nije moguće iskoristiti ovu kinetičku energiju na racionalan način. Kinetičku energiju je potrebno transformisati u odgovarajući oblik i čuvati je za kasniju upotrebu. Poboljšanje se može postići upotrebom nekonvencionalnog pogona šinskih vozila. Jedan od mogućih načina je korišćenje hibridnog pogona. Hibridni pogon obuhvata motor SUS i uređaj za skladištenje energije. U tom slučaju snaga motora SUS može biti znatno niža nego kod klasične vuče. Parametri takvog pogona moraju biti zasnovani na analizi realnih operativnih režima vozila. Ovi parametri su: snaga motora SUS, snaga vučnih motora, kapacitet i snaga uređaja za skladištenje energije (akumulatora). Postoje i drugi načini kako da se poboljša iskorišćenje goriva kod železničkih vozila, kao što je npr. bolje korišćenje toplote oslobođene iz goriva.

Ključne reči: *hibridni pogon šinskih vozila, korišćenje snage motora SUS, potrošnja goriva, akumulacija energije*