AN ECONOMIC AND ENVIRONMENTAL ASSESSMENT OF THE USE OF ALTERNATIVE FUELS IN A METALLURGICAL ENTERPRISE'S TRANSPORTATION SYSTEM

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Abstract

Efforts to use alternative fuels to power vehicles are not a recent phenomenon. There are three main reasons for finding new ways to power motor vehicles: the thinning reserves of fossil fuels, the fuel economy of vehicles and environmental impacts.

This paper aims to find a possible use of alternative fuels as a tool for growth in a metallurgical enterprise. The current state and possibilities of using alternative fuels led to two basic areas of research: the first one looked at vehicles that could be used in the operations of a metallurgical enterprises and could make use of alternative fuels and the second one looked at the further development of the use of alternative fuels in the automotive industry, which subsequently represents a tool for growth in metallurgical enterprises.

The conclusion evaluates the economic and ecological aspects of the use of vehicles with alternative drives/fuels in a metallurgical enterprise, as well as growth opportunities in terms of production programs in a metallurgical enterprise.

Keywords: Alternative fuels, alternative transportation

1. INTRODUCTION

The economics and ecology of using motor vehicles are frequently-discussed questions and the answers are usually not or indeed may not be entirely clear. There are many aspects that significantly affect the costs of operating motor vehicles and that affect the environment. In the case of vehicles with alternative fuels, these include various modifications to vehicles powered by conventional internal combustion engines (ignition engines - petrol, diesels) that have been modified to burn alternative fuels such as biodiesel (FAME), bio ethanol (E85), propane - butane (LPG), natural gas (CNG, LNG), hydrogen (H_2) or other fuels. Another possibility that can today be often found in motor vehicles is the use of electric motors, whether in hybrid vehicles or electric vehicles. Rapid development is expected in this particular field.

Divided by the type of fuel used and the construction design, each of the above groups of motor vehicles has its own advantages and disadvantages. This article is especially focused on the specific economic and ecological aspects in the use of individual alternative vehicles within a metallurgical enterprise [2].

2. SPECIFICATIONS OF VEHICLES USED IN AN INDUSTRIAL ENTERPRISE IN TERMS OF THE POTENTIAL USE OF ALTERNATIVE FUELS

It can now be stated that the use of alternative fuels within an industrial enterprise has almost unlimited possibilities and the use always depends only on a decision to use them being made by a company's management.

Multiple factors need to be considered when deciding to use alternative fuels. These factors are:

- the focus of the company,
- the size of the company's facility and the extent of material handling within this area,

- the need for transportation outside of the company's premises, including traffic volume and average daily driving radius of the vehicles,
- the types and number of vehicles, their age and planned investment in the acquisition of new vehicles,
- the availability of alternative fuels.

Not only private individuals, but industrial enterprises have begun to use alternative fuels more often to power their vehicles. This is due to the easy availability on the car market where most of the world's manufacturers offer vehicles with various types of "ecological" drives. Another fact is the wide range of options to modify cars to use compressed gas, which is today very popular. The advantage in using "gas" vehicles is the already insignificant difference in purchase prices between them and vehicles solely powered by petrol (BA) or diesel (NM), as well as the rapidly increasing number of public filling stations that allow for refuelling alternative fuels (mainly LPG and CNG). Recently, we have also observed a rapidly increasing number of electric vehicles, where aside from the high purchase price, the low driving range of the vehicle on one charge is a major limiting factor. This is directly linked to the low number of public recharging stations. The largest domestic car manufacturer has reacted to current market demands and offers the Škoda Octavia G-TEC, a car powered by petrol and CNG with a total range of up to 1,330 km when using both types of fuel.

Another type of vehicle that can be placed into the same category is delivery trucks that are used to transport small individual packages at shorter distances, especially in urban areas. There is already a wide range of vehicles produced by auto manufactures in this category and it is possible to choose from among several types of alternative fuels.

A completely different situation currently exists in the freight sector, where the choice of a suitable alternative to conventional drives is very limited. Alone or in combination with conventional fuels, biodiesel, ethanol, natural gas and propane-butane are to a greater or lesser extent mainly used.

Specifically, natural gas is starting to be an increasingly used variant of alternative fuel in freight. This is mainly due to the fact that there are no problems with its production or storage, while its combustion produces significantly less pollution than diesel fuel. Using vehicles powered by natural gas is safe and economically advantageous for the operator. The size and weight of the tanks is the deciding factor in which way the natural gas is stored and for which types of transport it is suitable. The use of compressed natural gas (CNG) is more recommended for public utility vehicles in urban and suburban traffic, while using liquefied natural gas (LNG) is more suitable for long-distance transport.

In trucks, tractors and other industrial machines, Diesel Gas motors, namely Diesel Gas LPG or Diesel Gas CNG, cannot be neglected. This is not an alternative fuel in the true sense of the word, but this solution is economically attractive for the owners and the emissions are lower than when burning diesel only. In essence, this method adds gas to the intake air, which in combination with the injected diesel creates a mixture that is able to ignite faster and burn more completely. The amount of injected gas differs depending on the operating parameters and can be up to 70% at the same power and torque.

Industrial companies are using alternative fuels quite extensively in their internal transportation. The companies mainly use special-purpose vehicles, handling and forklift trucks and traction vehicles on railways. In the past when the impact of vehicles on the environment was not addressed, handling and forklift trucks were normally powered by electric batteries. This technology, of course, also still exists in handling equipment today; however, this entire group of "trucks" is increasingly being powered by natural gas [4].

Similarly, in railways where there is no possibility for a traction vehicle with an electric drive or where the vehicle needs to be operated outside the company's premises, natural gas is starting to be used more often. A pre-condition for this, of course, is the availability of a filling facility. An example of this is the modification of the original diesel locomotive 703.8, which has been recently equipped with a TEDOM TG 250 gas ignition engine and pressurised gas cylinders.

3. THE POSSIBILITIES OF DEVELOPMENT AND THE USE OF ALTERNATIVE FUELS WITHIN A COMPANY'S TRANSPORTATION SYSTEM AS A MEANS FOR FURTHER GROWTH IN A METALLURGICAL COMPANY

When considering what might be brought about by the current development of the use of alternative fuels in traffic and especially the use of CNG or LNG in business transportation, as well as in the respective company's production (in this case, metallurgical production), our interest must be directed at two main areas. The first is the company's production programme and possibilities to quickly react to new market demands; the second is the application itself of new emerging technologies in business operations, in this case, the transportation system.

3.1. Growth potential in terms of the production programme of the company

Each metallurgical, or each production company in general, tries to increase value to purchased raw material by delivering an added value to it and not just selling material without any further thought.

In the case of a metallurgical company that is successfully engaged in the production of gas cylinders and pipes, the possibility to further expand the production programme exists. This is clearly due to the fact that gas cylinders that must meet high safety standards are used throughout the entire process of using natural gas in transportation, i.e. from their storage and transportation, to their storage in vehicles.

The production of such cylinders is then the first and most basic area to look at for the further expansion of a metallurgical company in connection with the use of CNG in transport. According to the construction, work pressure, outer diameter, length and capacity (i.e. water volume), gas cylinders can be divided into three groups:

- for installation in cars delivered directly to car manufacturers or to individual conversion companies,
- for installation in trucks, buses and other larger vehicles (i.e. locomotives),
- for the transport and storage of CNG (LNG).

The second major area to look at for the further development of a metallurgical enterprise or for the expansion of its production programme is linked to the actual operation of vehicles equipped with a CNG drive. This is a part of the distribution, storage and filling of gas cylinders for vehicles. In practice, this means:

- the production of stationary or mobile gas tanks (volumes from about 200 Nm^3 up to 1,500 Nm^3) - tanks of small volumes,
- the production of stationary or mobile gas tanks (volumes from about 2,500 Nm^3 up to 5,200 Nm^3) - to supply larger areas,
- the production of trailer gas tanks (volumes from about 2,500 Nm^3 up to 5,200 Nm^3) - to supply larger areas,
- building larger filling stations with outputs from 20 $Nm^3/hour^{-1}$ to thousands of Nm3/hour-1 and output pressure of 250 bar - CNG filling at businesses, transport companies and public commercial CNG filling stations with fuel dispensers.

Part of the production programme of a metallurgical company in the transport, storage and dispensing of CNG is shown in **Fig. 1**.

Converting vehicles to a CNG drive, producing CNG conversion kits and providing related services, including modifications to pressure vessels or building and running public CNG filling stations can be a suitable complementary programme for the company [1]. .

Fig. 1 The production programme of a metallurgical company in the transport, storage and dispensing of CNG (from the left: 2 trailers, a filling station, a container and gas cylinders with CNG) [1]

3.2. The ecological aspects of the use of alternative fuels in a company's vehicle fleet

Since 1 January 2014, the European Union has begun to apply a new law to reduce emissions by commercial vehicles. Due to the new Euro 6 emission standard (effective since September 2014), the allowable emission levels of trucks and buses have been significantly lowered. When compared to the Euro 5 standard, the permitted amount of solid particulates is reduced by 66% and the amount of nitrogen oxides (NOx) by 80%; the value of carbon dioxide (CO) was not changed [3].

For carriers and companies with their own transport, this means further investments into the acquisition of vehicles that meet the given legislation requirements. Standard equipment includes new vehicles with diesel engines that meet the Euro 6 specification, while suitable alternatives are vehicles with natural gas drives (CNG, LNG).

The advantage of using natural gas as a fuel is its composition because it is approximately 98% composed of methane CH_4. This ensures zero production of sulphur dioxide (SO_2), significantly lower emissions of solid particulates, a substantial reduction of hydrocarbons (HxCx), carbon monoxide (CO), nitrogen oxide (NO_x) and carbon dioxide (CO_2), which is a major contributor to the creation of the greenhouse effect. It can be stated that in terms of pollutant emissions, vehicles with natural gas drives meet the strict emission standards of Euro 6 by a sufficient margin.

In terms of ecology, the other advantages of using natural gas include:

- When burning natural gas, motors are quieter (up to 50%),
- it is not necessary to add additives or other substances to natural gas,
- natural gas does not leak into the air during refuelling (petrol and diesel require vapour suction), and because of this the air is cleaner indoors than is the case with leaking petrol or diesel,
- it is impossibility to contaminate the soil due to a leakage of natural gas.

3.3. The economic aspects of using alternative fuels in a company's vehicle fleet

In larger companies, among which a metallurgical company certainly belongs, the costs for purchasing or renting vehicles, as well as for purchasing energies required for their operation, make up a very significant part of cost side of the budget. Although it is today very difficult or even impossible to predict price changes in conventional fossil fuels (petrol and diesel) on the world markets, it is fairly clear that at the current prices of natural gas, which have long been relatively constant, the use of CNG or LNG as a fuel for vehicles is suitable not only in terms of ecology, but also in terms of economy.

As previously mentioned, in the case of a metallurgical company, the possibilities for using natural gas in transportation are very wide. CNG or LNG is used in cars and light commercial vehicles, trucks and municipal vehicles, as well as in internal transport, which mainly includes handling forklifts, trucks and other special-purpose vehicles. An interesting possibility for using CNG that is not mentioned very often is the operation of locomotives.

Determining the economic advantages of using natural gas (CNG or LNG) as an alternative fuel in vehicles is not easy, especially when the outcome is affected by many factors and we are not able to influence some of them. However, when a company is considering using CNG in transport, it is necessary to bear in mind the return on investment and expected savings when calculating, especially [6].:

- the price difference between the acquisition price of a vehicle with a conventional fuel drive and a vehicle with alternative fuel, or the price of conversion.
- the average consumption of a vehicle when driven by petrol or diesel (L/100 km) and the consumption of natural gas (kg/100 km or m3/100 km),
- the purchase prices of conventional fuel (petrol and diesel) and alternative fuel (CNG, LNG),
- the average annual mileage of monitored vehicles, including necessary trips to the closest filling station, including the average mileage travelled outside the company's premises, thus without the possibility of refuelling at the company's own filling station or the need to drive with conventional fuel,
- the price difference between servicing, spare parts and operating fluids for vehicles with different drives according to the frequency of service checks, including the price of changing out gas cylinders,
- other factors resulting from the current valid and future legislation that affect the price of natural gas in transport (CNG, LNG) according to taxes, road tax, etc.

Table 1 A comparison of basic vehicle parameters (petrol, diesel, CNG)

Fuel	Motor	Power [kW]	Combined consumption [x/100 km]	CO2 emissions [g/km]	Price [CZK]
Car - Škoda Octavia Active					
Diesel	1.6 TDI	81	3.8 l	99	445,900
CNG	1.4 TSI G-TEC	81	5.4 m^3 (3.6 kg)	94	441,900
Light utility - Mercedes Benz Sprinter KAWA					
Petrol	316	115	12.7 l	303	859,705
Diesel	316 CDI	120	6.8	171	923,230
CNG	316 NGT	115	11.8 m^3 (8.1 kg)	211	1,011,560
Truck - Iveco Stralis, 3-sided tipper					
Diesel	Cursor 8	228	35 l	Not available	1,872,000
CNG	Cursor 8-CNG	220	43 m^3 (29.5 kg)	Not available	2,392,000

Table 2 Changes in fuel prices in the Czech Republic (petrol, diesel, CNG) in 2010 - 2015

Period	Average annual fuel price			Price ratio	
	petrol [CZK/l]	diesel [CZK/l]	CNG [CZK/kg]	fuel - CNG	diesel - CNG
January 2010	30.44	29.03	22.59	1.35	1.29
January 2011	33.47	32.72	23.38	1.43	1.40
January 2012	35.72	36.32	24.86	1.43	1.46
January 2013	35.16	35.67	24.98	1.41	1.43
January 2014	37.88	37.19	25.43	1.48	1.46
January 2015	31.07	31.89	26.13	1.19	1.22
September 2015	31.26	29.60	26.27	1.18	1.12

Based on the information contained in **Tables 1 and 2**, it is apparent that determining the degree of convenience of the use of natural gas in transport in terms of economy is very difficult. The advantages, or more precisely savings from using alternative fuels, varies over time and depends mainly on the difference in the market prices between the conventional fuels (petrol and diesel) and the alternative fuels (CNG, LNG).

To compare the operating costs of vehicles with different types of fuel, the information on the energy contents of fuels can be used (BA - 8.6 $kWh.l^{-1}$, NM - 9.9 $kWh.l^{-1}$, CNG - 13.3 $kWh.kg^{-1}$). Therefore, in general, there is as much energy in 1 kg of CNG as in 1.5 litres of petrol or 1.3 litres of diesel. Statements that using CNG can save up to 50% of the cost of fuel when compared to petrol or 35% when compared to diesel are often made. However, it is clear that with the currently decreasing price of conventional fuels and the increasing price of CNG (also due to reduced state backing), these differences no longer apply.

4. CONCLUSION

The use of alternative fuels is no longer just a trendy topic and there are several reasons for finding new methods to drive vehicles, whether this is due to the diminishing supplies of fossil fuels, due to the costs of operating vehicles or due to the environment. All these aspects lead us to find new possibilities for using alternative fuels as an instrument for expanding an industrial (metallurgical) enterprise. There are several views on this expansion. The first view is the possibility of growth potential in terms of the company's production programme where metallurgical companies may consider subcontracts for automakers for car or truck installation or individual conversion, or the production of stationary or mobile gas tanks, gas containers, trailers or even building filling stations. Another view is the use of alternative fuels in internal transport where the acquisition or rental costs play a significant role in the budget. There is a need to find the optimal solution due to factors such as the acquisition prices of the vehicles, their average fuel consumption, the prices of fuels, annual mileage, etc. The ecological aspect is the fact that the operation of a vehicle fleet must comply with the currently valid legislation, which is either met or exceeded by vehicles with alternative drives. This comes with other benefits such as quieter engines, no need for additives (compared to petrol), no fuel leakage into the air, etc. To determine the level of benefits of using natural gas in transport in terms of economics is very difficult. The advantages, or more precisely savings from using alternative fuels, varies over time and depends mainly on the difference in the market prices between conventional fuels (petrol and diesel) and alternative fuels (CNG, LNG) [5].

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