APPLICATION OF COMPRESSED IGNITED ENGINES TO THE MUNICIPAL FLEET IN THE UNITED STATES: EXAMPLE OF DEPARTMENT OF THE ENVIRONMENT, CITY OF CHICAGO

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Abstract

The direction of combustion engines development demonstrates that the next decade will belong to Compressed Ignited Engines, applied both to the heavy duty (over 8,500 lbs GVW)and passenger vehicles. Currently in North American market only Volkswagen sells Diesel powered passenger cars (8.3 % of its total sales). In 2004 however, Daimler – Chrysler will return with its E class sedan and Jeep Liberty will introduce 5000 Diesel - pilot program - first time in North America. Also Volkswagen will expand its offer in 2004, bringing Passat 2.0 TDI and new Touareg and Phaeton V10 TDI. All the domestically designed and built heavy duty trucks are currently available with optional Diesel engine. GM offers its jointly designed with Isuzu Duramax 6.6 liter. Dodge has 5.9 Cummins, and Ford just recently brought the new 6.0 Power Stroke Diesel. All these engines found their application in the commercial heavy duty fleet, like ambulances, service and utility trucks, etc.

Historically, the diesel powered vehicles gradually were loosing their hegemony in the late eighties in the USA, when Diesel fuel became more expensive than gasoline. During the fuel crisis in mid seventies GM tried to design and produce large supplement of the Diesel engines. The effects were not satisfactory. 6.2 liter big block V8 adapted engines from its gasoline version could not handle the different requirements and operation conditions. Reliability of these engines was poor and they had problems during cold weather start. The negative image of the diesel engines remains unchanged till now in America.

The authors in this paper will try to demonstrate the advantages of Diesel fueled fleet vehicles. The authors will analyze and compare emissions of traditional spark ignited engines and compressed ignited engines. The paper will describe advantages and disadvantages of Compressed Ignited Engine vehicles in DOE City of Chicago conditions.

Introduction

The development of modern automotive industry shows continuous increase of the amount of utilized mechanical vehicles, mainly passenger vehicles, including SUV. This tendency is especially noticeable in the United States of America. The modern vehicles characterizes with the increased fuel consumption in comparison to the previous car generations. The increase of the fuel consumption is mainly caused by

the increased demands related to performance. In spite of the application of the newest vehicle production technologies continuous increase of performance and dimensions results in the increased fuel consumption.
The direct consequence of this trend is growing-up emission of harmful chemical compounds to the atmosphere. This process affects also soil and water. As recently demonstrated, the increased emission of the harmful compounds contained in the exhaust fumes particularly influences the global warming. The gases responsible for the green house effect are: manly carbon dioxide (CO2) and carbon monoxide hydrocarbons (HC), nitrous oxides (NOx), particulates (PM) (1).
The mentioned above chemical compounds also enlarge the problem with the ozone layer in the atmosphere.
The City of Chicago has always been a leading agency making an attempt to reduce the contamination of the environment. The crucial role in this field is held by the Department of Environment (DOE). The possibility of the harmful chemical compound emission reduction by the common application of the compressed ignited engine powered vehicles was perceived just in this Department. As the first step in this direction, The DOE has evaluated the plan of replacement of its own fleet. The plan proposes the exchange of the spark ignited engines for the compressed ignited engines.

Research

The vehicle fleet of the DOE includes 20 units (Tab. 1), at this moment. However, in the future the fleet is going to be expanded. All the vehicles are powered by the gasoline engines, consuming 87 octane fuel. The vehicles are mostly equipped with four – speed automatic transmissions with overdrive and traditional two – valve per cylinder, push rod engines with displacement range 3.0 V6 – 4.6 V8. These traditional engine design characterizes with huge displacement, big torque, relatively low horse power output and low fuel efficiency.
The fuel efficiency varies from 13 to 23 mpg (miles per gallon). The average fleet fuel efficiency equals 19.9 mpg. The fuel efficiency data presented in table 2 were obtained according to the Environmental Protection Agency (EPA) procedures (2). The figures were calculated for 55 % City and 45 % Highway driving cycle for the annual 15,000 mileage. The fuel used in the test contained up to 10 % of alcohol, which is in within standards with the US regulations.
The low fuel efficiency influences the high level of environmentally harmful compounds, including CO_2 emission. In the paper, only CO_2 emission was taken under consideration because only this gas can be objective source for comparison of the two engines: spark plug and compressed ignited engines. The reason is that diesel fuel contains raised amount of contaminations (mainly sulphur) comparing to regular gasoline.
Carbon dioxide emission is measured in grams per mile (g/mile). The unit means, how many grams of the compound is emitted during 1 mile driving distance.
The CO_2 emission level (tab. 1) ranges from 333 to 453 g/mile. The biggest CO_2 emission source In the fleet has Dodge Ram. The average emission for the fleet was equal to 384.1 g/mile.
The selection key of the alternative fleet was based on replacing existing vehicles for similar functionality vehicles. The selected vehicles are currently (or will be in short future) available on American market. The vehicle size and capacity, engine

Table 1: Comparison of the technical data of the used and substitute vehicles in the DOE City of Chicago

Vehicles In Use	Year	Fuel Economy (gasoline) [mpg] [1]	CO_2 [g/mile]	Alternative Vehicles	Year	Fuel Economy (diesel) [mpg] [1]	Fuel Economy (hydrocrack motor oil)) [mpg] [1]	CO_2 [g/mile] [3]
Ford Aero Van 3.0 V6	1993	19	430	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
Dodge Caravan 3.0 V6	1994	20	381	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
Ford Crown Victoria 4.6 V8	1996	20	375	Mercedes E class 3.2 CDI automatic	2004	32	34.56	310
Ford Aero Van 3.0 V6	1997	19	401	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
CNG Crown Victoria 4.6 V8	1997	20	375	Mercedes E class 3.2 CDI automatic	2004	32	34.56	310
Ford Crown Victoria 4.6 V8	1997	20	375	Mercedes E class 3.2 CDI auto	2004	32	34.56	310
Ford Taurus 3.0 V6	1997	23	333	VW Passat 2.0 TDI 5 speed tiptronic	2004	33	35.64	309
Plymouth Voyager 3.3 V6	1999	20	352	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
Plymouth Voyager 3.3 V6	1999	20	352	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
Plymouth Voyager 3.3 V6	2000	20	363	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
Plymouth Voyager 3.3 V6	2000	20	363	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
Dodge Ram 12 – passenger Van 3.9 V8	2000	13	453	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
Ford Taurus 3.0 FFV [2]	2001	22	362	VW Passat 2.0 TDI 5 speed tiptronic	2004	33	35.64	260
Ford Taurus 3.0 FFV [2]	2001	22	362	VW Passat 2.0 TDI 5 speed tiptronic	2004	33	35.64	260
Ford Taurus 3.0 FFV [2]	2001	22	362	VW Passat 2.0 TDI 5 speed tiptronic	2004	33	35.64	260
Ford Taurus 3.0 FFV [2]	2001	22	362	VW Passat 2.0 TDI 5 speed tiptronic	2004	33	35.64	260
Dodge Caravan 3.0 V6	2003	22	379	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
GMC Safari minivan 4.3 V6	2003	18	434	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
GMC Safari minivan 4.3 V6	2003	18	434	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410
GMC Safari minivan 4.3 V6	2003	18	434	Dodge Sprinter CDI 2800 automatic	2003	27	29.16	410

1) Average fuel consumption

2) leased cars

3) CO_2 emission level obtained for regular motor oil

performance were taken into consideration. All the alternative vehicles are powered by the compressed ignited engines, which provide higher torque and its availability at lower rotational speed (rpm). The vehicles are provided with a five speed automatic transmission with manual override function. These transmission enable more efficient operation and lower fuel consumption comparing to conventional type of transmissions. All the diesel engines are modern design, with four valves per cylinder, common rail second generation injection and patented by VW pump injectors.
The modern engine design enables decreased fuel consumption and lower CO_2 emission. The average fuel efficiency (tab. 1) ranges from 27 to 33 mpg. The average CO_2 emission equals 359.9 g/mile and ranges from 309 to 410 g/mile.
As presented in the fig. 1, the application of the compressed ignited engines could increase the fuel efficiency by almost 10 mpg, which would decrease the fuel consumption in the fleet by nearly 5,000 gallons a year.

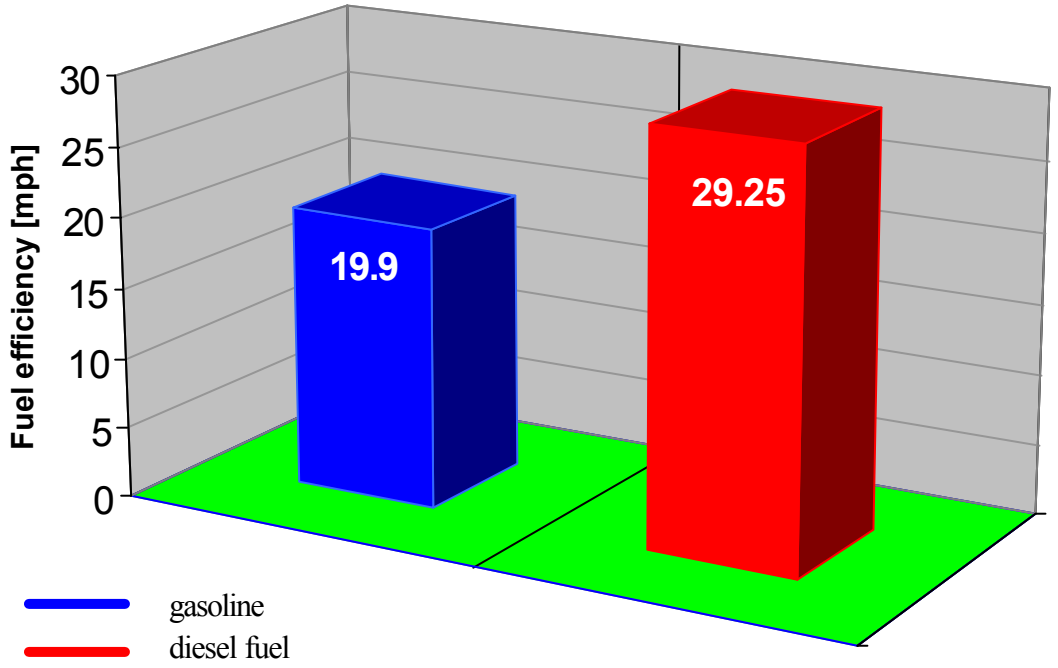

Fig. 1: Comparison of fuel efficiency for spark plug and compressed ignited engines of the fleet

The fleet replacement would decrease the CO_2 emission by over 7 tons (fig. 2).
According to the table 1, the additional increase of the fuel efficiency could be achieved by the application of the hydrocrack motor oil (3).
The further step towards decreasing the fuel consumption would be application of additive of the biodiesel B20 (4) to conventional diesel fuel. Its application is going to improve the combustion process in the engine, which in result will increase the fuel efficiency and decrease the CO_2 emission.

Conclusions

The DOE fleet evaluation analysis presented in the paper proved that the application of the compressed ignited vehicles instead of the spark ignited ones is significant for the environmental protection:

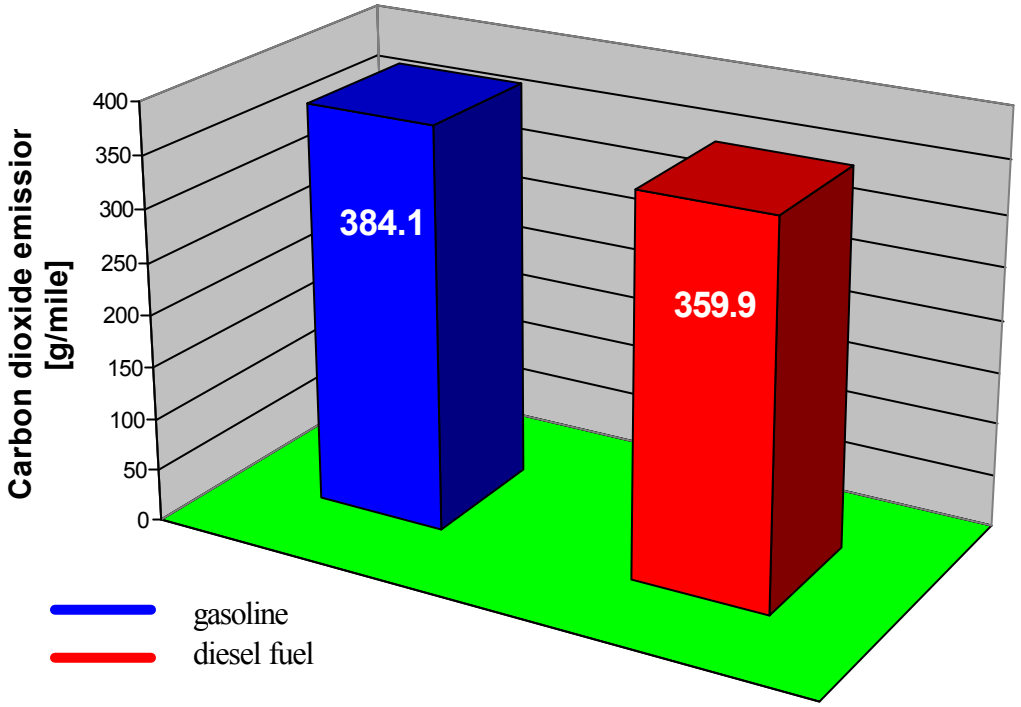

Fig. 2: Comparison of CO_2 emission for spark plug and compressed ignited engines in the fleet

1. Increasing CO_2 emission demands the decrease of fuel consumption by vehicles
2. The exchange of the current DOE fleet for compressed ignited engine driven cars might resolve the problem of increasing fuel consumption
3. Modern design of the diesel engines offers bigger potential towards environmental protection
4. It is possible to replace the existing DOE fleet with comparable diesel fueled vehicles available on American market
5. Application of diesel technology allows to:
   a. decrease annual fuel consumption by 32 %
   b. reduce annual CO_2 emission by 6.3 % (mass)
6. Decreased fuel consumption and CO_2 emission will slow down greenhouse effect
7. The additional reduction of fuel consumption and CO_2 emission of the diesel engines could be achieved by:
   a. application of the hydrocrack motor oil
   b. application of the biodiesel fuel
8. Scheduled introduction of the low sulfur diesel fuel will additionally decrease the fuel consumption and harmfulness of the exhaust gases and also extend life of engines, transmissions and exhausts

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References

(1) S. Shen, Global Warming Science and Policy, Progress 2002-2003,
(2) EPA, Office of Transportation and Air Quality (www.epa.gov/otaq)
(3) Elf, Total, Fina (www.elf.com)
(4) National Biodiesel Board (www.nbb.org)