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To Increase the Efficiency of CNG Engine through Various Techniques

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A B S T R A C T

Natural gas is promising alternative fuel to meet strict engine emission regulations in many countries. Compressed natural gas (CNG) has long been used in stationary engines, but the application of CNG as a transport engines fuel has been considerably advanced over the last decade by the development of lightweight high-pressure storage cylinders. Engine conversion technology is well established and suitable conversion equipment is readily available. For spark ignition engines there are two options, a bi-fuel conversion and use a dedicated to CNG engine. The results showthat the replacement of CNG fuel with high-emission fuels can have a significant effect on reducing CO2 emissions. In the synthetic scenario, CO2 emission will be decreased by 11.42% in 2030, as compared to the business as usual (BAU) scenario in this year. According to Iran's commitment to the Paris Agreement, the emission of CO2 in Iran should normally be reduced by 4% in 2030, as compared to its amount in the BAU scenario. Therefore, Iran can easily full fill its obligations in the urban transport sector only by replacing gasoline and diesel fuel with CNG.

Keywords: CNG Engine ,Efficiency of Engine, Performance and brake power of Engine, Indicated power of Engine.

1. Introduction

Multifarious studies have been conducted on the market penetration of AFVs. These studies investigated the effects of various factors, such as government subsidies , individual preferences—including neighbours, family and co-workers—to use AFVs, cost savings and infrastructure development and age of consumers in the choice of AFVs. Using the survey method, Johnson et al. examined the acceptability of AFV policies. Shin et al. compared the electric vehicles and hydrogen fuel cell vehicles in terms of market penetration and consumer choice. Leaver and Gillingham examined the economic impact of different technologies, including hydrogen fuel cell, hydrogen internal combustion and battery electric technologies. Some researchers have also focused on creating the right infrastructure to implement AFV policy in the transport fleet. For example, Hong and Kubi discussed the importance of having adequate infrastructure and alternative fuel supply stations to change the transportation system to the low-carbon urban transport fleet and Bruglieri et al. examined the effect of fuel stations on the replacement of AFVs .[4]

Natural gas is safer than gasoline in many respects. The ignition temperature for natural gas is higher than gasoline and diesel fuel Additionally, natural gas is lighter than air and will dissipate upward rapidly if a rupture occurs. Gasoline and diesel will pool on the ground, increasing the danger of fire. Compressed natural gas is non-toxic and will not contaminate groundwater if spilled. Advanced compressed natural gas engines guarantee considerable advantages over conventional gasoline and diesel engines. Compressed natural gas is a largely available form of fossil energy and therefore non renewable. However, CNG has some advantages compared to gasoline and diesel from an environmental perspective. It is a cleaner fuel than either gasoline or diesel as far as emissions are concerned.[2]

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Concern over fuel security and the emissions of petrol and diesel vehicles has led to a search for replacement fuels and vehicle technologies. Natural gas has become an attractive option due to its availability; diverse sources lower emissions of local air pollutants, especially nitrogen oxides (NOx), Carbon Monoxide (CO) and particulate matter, and its suitability for heavy-duty vehicles. In Armenia, Bangladesh and Pakistan over half the fleet is powered by natural gas.

1.1. Methodology

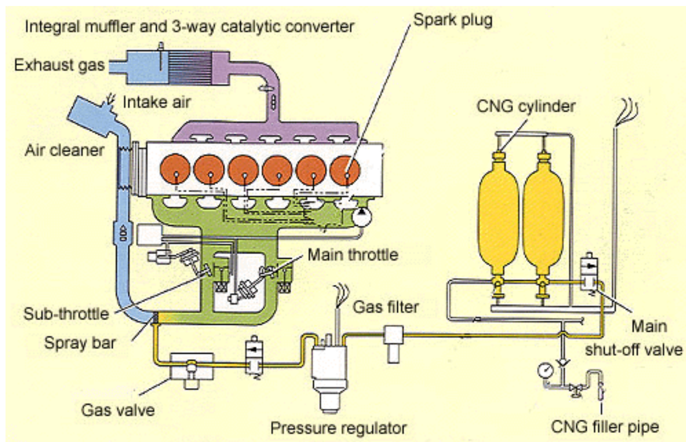

Fig 1 Flow of CNG through Engine[1]

The octane rating of natural gas is about 130,meaning that engines could operate at compression ratio of up to 16:1 without "knock" or detonation. Many of the automotive makers already built transportation with a natural gas fuelling system and consumer does not have to pay for the cost of conversion kits and required accessories. Most importantly, natural gas significantly reduces CO2 emissions by 20-25% compare to gasoline because simple chemical structures of natural gas (primarily methane – CH4) contain one Carbon compare to diesel (C15H32) and gasoline (C8H18). Like methane and hydrogen is a lighter than air type of gas and can be blended to reduce vehicle emission by an extra 50%. Natural gas composition varies considerably over time and from location to location. Methane content is typically 70-90% with the reminder primarily ethane, propane and carbon dioxide.

As has been observed in this research, the system dynamics method has been used to study the reduction of energy consumption and CO2 emissions. Therefore, system dynamics modeling is a common method to study the complex systems, such as urban transportation systems. However, none of these studies have discussed natural gas as an alternative fuel in urban transport and its impact on reducing CO2 emissions as a fuel for the transition from high emission fuels to low emission fuels. In these studies, natural gas fuel is not seen as a separate subsystem. The basic concept of system dynamics was presented by Forrester System dynamics is the study of the policies and decision making on system control as well as the structural characteristics of the systems, on the basis of several unique features in the methodology. Firstly, system dynamics considers the dynamic behaviour of the systems, more particularly the changes in the system behavior according to the time. Secondly, system dynamics seeks the root causes of the dynamic changes in its feedback structure.

1.2 CNG Vehicle system

CNG fuel characteristics[10]

Vapour density= 0.68 , Auto Ignition =700°C , Octane rating =130
Boiling point (Atm. Press) =162°C Air-Fuel Ratio (Weight)= 17.24

Chemical Reaction With Rubber No : Storage Pressure =20.6Mpa

Fuel Air Mixture Quality Good

Pollution CO-HC-NOx Very Low	Flame Speed m per sec =0.63	Combust. ability with air= 4-14%

According to Poulton that natural gas has a high octane rating, for pure methane the RON=130 and enabling a dedicated engine to use a higher compression ratio to improve thermal efficiency by about 10 percent above that for a petrol engine, although it has been suggested that optimized CNG engine should be up to 20 percent more efficient, although this has yet to be demonstrated. Compressed natural gas therefore can be easily employed in spark ignited internal combustion engines. It has also a wider flammability range than gasoline and diesel oil Optimum efficiency from natural gas is obtained when burnt in a lean mixture in the range A=1.3 to 1.5, although this leads to a loss in power, which is maximized slightly rich of the stoichiometric air/gas mixture. Additionally, the use of natural gas improves engine warm-up efficiency, and together with improved engine thermal efficiency more than compensate for the fuel penalty caused by heavier storage tanks. Natural gas must be in a concentration of 5% to 15% in order to ignite, making ignition in the open environment unlikely. The last and most often cited advantages have to do with pollution. The percentages vary depending upon the source, but vehicles burning natural gas emit substantially lesser amounts of pollutants than petroleum powered vehicles. Non-methane hydrocarbons are reduced by approximately 50%, NOx by 50-87%, CO_2 by 20-30%, CO by 70-95%, and the combustion of natural gas produces almost no particulate matter. Natural gas powered vehicles emit no benzene and 1,3-butadiene which are toxins emitted by diesel powered vehicles. The use of natural gas as a vehicle fuel is claimed to provide several benefits to engine components and effectively reduce maintenance requirements. It does not mix with or dilute the lubricating oil and will not cause deposits in combustion chambers and on spark plugs to the extent that the use of petrol does, thereby generally extending the piston ring and spark plug life. In diesel dual-fuel operation evidence of reduced engine wear is reported, leading to expected longer engine life. The use of natural gas in a diesel spark-ignition (SI) conversion is expected to allow engine life at least as good as that of the original diesel engine. Because of its very low energy density at atmospheric pressure and room temperature, natural gas must be compressed and stored on the vehicle at high pressure - typically 20 MPa, 200 bar or 2,900 psi.

2. Combustion System of CNG Engine

One of the major advantages of CNG is that it offers a cheap source of energy. As the world continues to run with expensive fuels such as and gasoline and diesel, the low-cost CNG offers a glimmer of hope. Although emission reduction using natural gas was the main focus of CNG application as a transportation fuel, especially in metropolitan regions, in recent days, with a sharp rise in oil prices. One of the important factors for comparing the economic aspect of automotive technology is the associated maintenance cost. Although a review of the literature found no previous empirical work that has examined the issue of maintenance cost competitiveness of latest NGV or diesel technologies based on total life- cycle costs. However, there are few studies which examined the operating cost associated with natural gas vehicles. Nearly all of the countries where CNG infrastructure has been developed; incentive programs offered to investors such as loans, subsidies, exemptions from import duties and the lowering or elimination of import tariffs on machinery, equipment, and kits (price-supplier); and exemption from sales taxes for the construction and operation of refueling stations. Once subsidies for fuelling stations and NGV customers run out The most observable social advantage associated with operating vehicles with CNG pertains to the environmental advantage of natural gas. As previously discussed in Section 8, compared to oil, natural gas releases lower levels of carbon dioxide, sulphur, nitrogen oxides, and ash. By emitting fewer harmful chemicals into the air, natural gas can help alleviate different environmental problems. Compared to oil, natural gas releases lower levels of carbon dioxide, sulphured , nitrogen oxides, and ash. By emitting fewer harmful Topics handled in this section: comparative economics of CNG; cost-effectiveness evaluation of diesel vs. CNG for buses; commercializing CNG as a fuel; potential of CNG transport; policy development for marketing CNG; CNG vehicles energy consumption life-cycle analyses; empirical analysis on the adoption of CNG; global opportunities for CNG as a transportation fuel; fuel consumption of CNG vehicles.

3. CNG/Diesel Dual fuel method work

Diesel engines were traditionally preferred due to its lower running cost and better torque characteristics; however, during the past decade, stringent emissions norms have mandated the use of several advanced combustion and after-treatment technol- ogies, which in turn have made the diesel engine power train expensive and complex. In recent years, a concern over the emissions of a greenhouse gas like CO2 and particulate matter PM has further posed an additional challenge to the development of diesel engines. One way to overcome these problems is by em- ploying dual fuel technology in which part of diesel fuel is supplemented by natural gas which is fumigated in the intake manifold.

performance of a diesel/CNG dual-fuel engine; effect of engine parameters on the performance of dual-fuel engines; performance characteristics of a turbo- charged dual fuel engines; combustion simulation of dual fuel engines; knock characteristics of dual-fuel combustion; NOx reduction from a dual-fuel engines; numerical study of the pollution formation in dual-fuel engine; after treatment system for dual-fuel operation; emission characteristic of dual-fuel engine; effects of natural gas percentage on performance of dual-fuel engine.

As discussed 5–10% power loss occurs in CNG-fuelled engines due to the low flame propagation speed of natural gas. Bi-fuel vehicle can run on either natural gas or gasoline. The engine type they used is a regular gasoline IC engine. The driver can select what fuel to burn by simply flipping a switch on the dashboard. Any existing gasoline vehicle can be converted to a bi-fuel vehicle. Most of the CNG vehicles operated today are retrofitted from the gasoline engine In Pakistan, the 2nd largest consumer of CNG almost the entire NGV fleet comes under bi-fuel vehicle category.

The combustion properties of natural gas are significantly different from regular fuel i.e. diesel and gasoline. As compared to diesel and gasoline CNG has a longer ignition delay time due to low flame propagation speed. Thus using the same gasoline fuelled engine for CNG, the combustion duration becomes relatively longer and it requires more advance spark timing. Hence, retrofitting is necessary for conventional gasoline fueled engine to run with

CNG. The bi-fuel engines are generally optimized for natural gas, with the ignition timing rather advanced to accommodate the slower burning rate of methane. Depicts a schematic of conventional retrofitted bi-fuel CNG vehicle.

Dual-fuel vehicle are based on CI engine technology. They run either on diesel only or utilize a mixture of natural gas and diesel, with the natural gas/air mixture ignited by a diesel "pilot". During the idle condition these engines tend to operate only on diesel. As the vehicle starts to pick the load, the natural gas substitutes the diesel fuel up to 60–90%. However, like bi-fuel vehicle direct conversion is not possible due to the very low cetane number of natural gas as a result of its very high auto ignition temperature which necessitates either conversion to spark-ignition or adoption of a dual-fuel system. Due to high ignition temperature of natural gas, it needs very high compression ratio for auto ignition i.e. about 38:1. Owing to this, it should be ignited with another fuel (diesel)—pilot injection. The diesel fuel is introduced directly into combustion chamber, while gas is injected into air intake by carburetion. The gaseous fuel is then compressed in the compression stroke of the engine. Diesel fuel is then injected near the end of compression stroke. With a short ignition delay the combustion of diesel fuel happens first, resulting in the ignition the natural gas and instigation of flame propagation. An important factor for the dual fuel operation is the replacement rate, which is defined as the portion of energy content of the fuel which is supplied by natural gas. The replacement rates vary depending on the engine load. A maximum replacement rate up to 90% can be obtained with the currently available dual-fuel engines. Substitution rate affect both engine performance and emission. Egúsquiza et al.found that brake specific fuel consumption increased as the percentage of substitution increased. They also observed that at higher loads and with the increase of substitution ratio, the hydrocarbons concentrations showed a tendency to increase while CO concentration first increased up to substitution rate of 70% and then decreased. NOx were the only emission factor which showed decreasing trend with the corresponding increase in substitution ratio. Dual-fuel vehicle provides 30–40% higher engine efficiency which subsequently reduces the fuel consumption by 25% .In both cases, there is an incremental cost relative to conventional diesel and gasoline vehicles and this extra cost to be reimbursed by the saving in operating cost due to fuel cost

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4. Opportunities and Constraints

Within an industry built on the use of petrol and diesel for a variety of operations, breaking into the market in a substantial way is proving challenging for all alternatives. We now map the interview findings against Cooper's (1994) framework of product superiority, Clearly for the van market the barriers outweigh the growth incentives. This is particularly true with respect to value for money and visible and perceived benefits. CNG vans available in the UK carry a price premium, here we consider how the lower operating costs might offset this. an operating cost comparison between the VW Caddy Ecofuel (CNG) and the equivalent diesel version based on manufacturer data.[3]

In a small number of gas van trials in 2012 actual diesel consumption (in the trial companies existing vehicle) was found to be reasonably close to the manufacturer specification giving confidence in these estimates (unfortunately we were unable to accurately monitor CNG consumption in these trials). It the initial additional cost of a CNG van would be recovered after about 27,000 miles. However, this assumes access to a public refuelling station. Given the lack of CNG refuelling points in the UK, any company wishing to use CNG vehicles would have to invest in or hire refuelling infrastructure. As mentioned in the Results section a refuelling station may require an investment of about £150,000 to £200,000, and a portable refuelling station about £100 per week to hire (personal communication, Tony King, the Hardstaff Group – 31.08.12) to which transport costs for refilling the station would be added. For small fleets this would clearly offset any fuel cost saving. Larger companies might invest in a station primarily for HGV operation, giving an option to run smaller vehicles as well. Some intervention is clearly required to enable the take up of CNG in this sector.[6]

The 2012 Technology Strategy Board (TSB) low carbon truck competition involved a £23 million investment in the industry, including £2.4 million to support the provision of publically accessible refuelling stations (TSB, 2012). This initiative is helping to provide a strategic network of gas refuelling stations, largely on the motorway network. Although aimed at HGV operators, this will be accessible to vans and will also help to raise awareness of the fuel amongst potential users through visibility. Further support for anchor stations in more urban locations might assist the market, unfortunately the scheme that provided part of the financial costs of the Leeds and Camden stations was discontinued in 2010 due to budget cuts (CENEX, 2014). There is clearly scope to revive this type of matching funding support, perhaps through a future TSB initiative.[7]

5. Issue and Limitation of CNG Vehicles

5.1 CNG vehicles produce a large number of particles.

Particle pollution is linked to a number of serious diseases including cancer1, Alzheimer's2 and cardiovascular and respiratory illnesses3. CNG cars and vans, unlike their diesel and petrol counterparts, are not subject to a particle number emission limit. This is despite Euro 6 CNG cars and vans having been shown to emit a large number of particles; for one van model tested particle number emissions were 50% higher than permitted for diesel or petrol vans4. Heavy duty CNG vehicles are not subject to an on-road particle number limit until 20235 but have been shown to emit up to 3000 billion (3x10 12)6 particles per km which is far from negligible and buses also emit a large number of particles. The highest particle number emissions from CNG vehicles are usually measured during urban driving (i.e. low speeds, cold starts) which is particularly concerning for air quality in cities and urban areas.[7]

CNG vehicles emit especially large numbers of ultrafine particles as small as 2.5 nm7. These particles could potentially be the most harmful to human health as they have been shown to penetrate deep into the body and have been linked to an increased risk of brain cancer8. If particles as small as 2.5nm are taken into account, the total amount of particles emitted by CNG cars and vans increases by between 100-500 times9. For heavy duty CNG vehicles, extending the measurement range down to 10nm has been shown to increase the total amount of particles by 100%10 and this is likely to increase if 2.5nm particles are considered.[9]

5.2 Exhaust of Ammonia Gas

On-road testing of Euro 6 CNG cars and vans has shown that these vehicles cannemit up to 20mg/km11 and 66mg/km12 of ammonia, respectively. As 1mg of ammonia is estimated to form 1mg of particle pollution, ammonia emissions from CNG vehicles can contribute significantly to PM 2.5 (particles smaller than 2.5 microns in size) air pollution. [10] At present cars and vans are not subject to an ammonia emission limit. CNG cannot therefore be considered a clean or low emission technology. Policies or financial incentives to promote CNG in order to improve air quality are counterproductive and the only way to truly reduce air pollution from transport and achieve the 'zero pollution ambition' of the European Green Deal is to move away from vehicles with an internal combustion engine and fully embrace zero emission mobility. In order to achieve this and to limit the environmental and health impacts of CNG vehicles, T&E proposes the following policy recommendations.[5]

6. Conclusion

CNG is attractive for five reasons. It is the only fuel cheaper than gasoline or diesel. It has inherently lower air pollution emissions. It has lower greenhouse gas emissions. Its use extends petroleum supplies, and there are large quantities of the fuel available in the world. There are several major problems needed to be solved when using natural gas engines, there is the set point for the best compromise between emissions and fuel economy is not clear, the optimum air–fuel ratio changes with both operating conditions and fuel properties.

Rising concerns about the harmful effects of emissions of diesel and gasoline have made CNG a very promising alternative fuel for the road transportation. The NGV sector has shown tremendous growth over the last 15 year in most of the gas producing countries to offer a product which has behind it a tried and tested technology which guarantees the environment protection, is inexpensive and affordable. CNG is clearly a powerful weapon for the countries in the battle to replace oil in the transportation sector, to reduce air pollution and to address the challenge posed by climate change. Worldwide CNG vehicle technologies are well established and commercially available for all type of road transport vehicle. To keep the torque and brake horsepower, of CNG vehicles comparable to their diesel or gasoline counterparts, dedicated CNG engines research should be accelerated.

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