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On the Possibilities of Using Alternative Fuels in ICE Powered Lawn Mowers and Tractors to Meet Phase III Emissions Standards

Etim U Ubong[1,2*]

I.C. Engines/Alternative Fuels and PEM Fuel Cells, USA
PEM Fuel Cell Program, Kettering University, USA

Abstract

There is a need to use alternative fuels in Internal Combustion Engines (ICE) powered lawn care equipment used around residential, office and reserved areas. This will enable this equipment to meet Phase III emissions standards set by the Environmental Protection Agency. One method of reducing emissions from trimmers, lawn mowers, tractors and blowers is to use alcohol fuels in the next generation of ICE powered devices and also, to make it adaptable to operate on flex-fuels. These devices are not only a great source of noise pollution, they are also a major source of hydrocarbon, NOx and CO emissions in the residential neighbourhood from spring to the fall seasons, hence, the need to mandate the use of alcohol and flex fuels to lowers emissions. These changes will require a slight modification of the engine, by way of increasing the compression ratio on one hand, and modifying the fuel system: tank, fuel lines, and fuel dispensing system (carburetor) to meet flex-fuel requirements. This proposed engine modification will meet Phase 3 emissions standards as alcohol fuels possess superior combustion characteristics and lower emissions.

Keywords: Environmental pollution; Alternative fuels; Lawn mowers and tractors; Phase III emissions standards

Introduction

Environmental pollution is an issue of concern to the community and a challenge to the engineering society. A review of fuels used in automobiles or in rotating or reciprocating utility devices show that alternative fuels produce lower environmental emissions than conventional fossil fuels. Hence, a need to introduce alternative fuels into utility-power producing devices, such as lawn mowers, tractors, trimmers, blowers, etc. This in-turn, will require slight modification of the power system to use these fuels. Gaseous fuels produce lower emissions but require larger storage tanks for a comparative operating time as gasoline. Alcohol fuels (methanol and ethanol) require 2.0 and 1.6 times by volume respectively, as one volume of gasoline. Since these utility devices use carburettors, the modification to the fuel system is simplified. However, there are few concerns with the lubrication of the engine components. There is also a need to use a special grade of lubricating oil that will not be degraded in the presence of alcohol fuel, when it blows-by, into the crank case [1].

Environmental Protection Agency – EPA in 1997, for the first time, regulated out-door lawn care devices (tractors, mowers, blowers, trimmers), etc. This was Phase 1 of emissions regulations for tractors and lawn mowers. Table 1 shows Phases 1-3 of emissions standards from then to date [2]. However, the Agency has not considered the use of alcohol fuels, which have lower emissions than gasoline fuels, hence, the justification for this proposition. The table also shows evaporative losses from gasoline powered devices. Alcohol fuels have less evaporative emissions losses than its gasoline counterpart for the following reasons. The flash point of methanol is 11°C, for ethanol, it is 13°C and for gasoline -43°C [3]. The heats of vaporization of M100 and E100 are 1178 kJ/kg and 923 kJ/kg respectively versus 349 kJ/kg for gasoline. The implication is that the amount of heat required to change from liquid to vapor for ME100 is 3.4 times, and that for E100 is 2.6 times compared with the conventional gasoline fuel. As such, when alcohol fuels are introduced into the cylinder, the cylinder charge temperature decreases. This in turn reduces the cycle temperature and hence, NOx emissions [4].

A mower is a generic term for lawn care-ICE powered devices. They are either push type or walk-behind mowers – (CLASS 1) and the tractor types (CLASS 2). The implication of Table 1 is that the next generation of lawn mowers and tractors needs to be re-engineered to comply with the stringent current emissions' standards. A review of pollution studies (EPA statistics) for lawn care equipment shows that 5% of air pollution in the USA come from lawn mowing [2]. Also from EPA statistics, in excess of fifty–four million lawn mowers are in use in America, and an over 80 million gallons of gasoline are burnt/year [5]. Over five million mowers are sold each year. One new lawn mower produces Volatile Organic Compounds (VOCs) and NOx in one hour as eleven new cars driven in one hour [6,7]. Another source of pollution is from spilling and evaporative losses. An estimated seventeen million gallons of gasoline is spilled each year during refueling [6]. A lawn mower releases about 40 kg [88 Ibs] of CO_2 (a Greenhouse Gas) and 15.4 kg [34 Ibs] of other pollutants per year. The consequences of these lead to massive environmental pollution: destroying of vegetation, contamination of ground water, etc., while the VOCs contribute to air-borne environmental sicknesses.

Choice of Alcohol Fuels and their Comparative Properties to Petroleum Fuels

Alcohol fuels (methanol and ethanol) are very good candidates for the flex-fuel substitution for the following reasons: they are commercially available at the gas stations, they are renewable and sustainable and the technology for their production is very mature. Alcohol fuels have been extensively introduced into petroleum fuels with great success. They do not emit particulates.

They are octane number improvers and their high heat of

***Corresponding author:** Etim U. Ubong, Associate Professor, I.C. Engines/Alternative Fuels and PEM Fuel Cells, Director, PEM Fuel Cell Program, Kettering University, USA, Tel: +1 800-955-4464; E-mail: eubong@kettering.edu

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Phases	Devices	Effective Model	HC and NOx (g/W-hr)	**NM-HC and NOx (g/kW-hr)[1]	CO (g/kW-hr)	Expected reduction in HC %)
Phase 1	Mowers	1997	16.1		519	32
	Tractors	1997	13.4			
Phase 2	Mowers	2007	16.1	14.8	610	59
	Tractors	2001-2005	12.1	11.3		
Phase 3	Mowers	2012	10	14.8	610	34
	Tractors	2011	8	11.3		

* HC and NOx (Hydrocarbon and Nitrogen oxides)
** NMHC and NOx-(Non-methane Hydrocarbons and Nitrogen oxides). [1]For devices that use natural gas as fuel

Table 1: EPA standards for lawn mowers and tractors /8/.

vaporization (chilling effect) reduces cylinder temperature which results in lower NOx emissions. On mass basis, Methanol's 3.4 times heat of vaporization compared to gasoline; and 2:1 volumetric ratio to gasoline – meaning, two gallons of methanol to a gallon of gasoline gives an overall 6.8 times effect [3]. This ultimately improves the chilling effect of the cylinder charge and improves the engine volumetric efficiency. Ethanol on the other hand, has a comparative 2.6 heat of vaporization gravimetric ratio to gasoline, and 1.6:1 volume of ethanol to one volume of gasoline. On the contrary to gasoline, both fuels do not vaporize easily, especially at very low temperatures. At 7°C, spark ignition engines modified for either methanol or ethanol fuels encounter startability problems due to their low flash points. Flash point is the minimum temperature at which a fuel forms enough vapor to produce combustible mixture. To augment for the deficiency, M85 and E-85 are widely used as flex-fuels. Both fuels have higher octane numbers than gasoline on Motor and Research measurements basis.

Methanol fuel is more environmentally friendly than gasoline fuel for use in ICE. Both methanol and gasoline are liquid fuels and can use same containers (tank) used for gasoline storage. Methanol has a characteristic faint odor that distinguishes it from water. When spilled, it is not devastating to the environment as fossil fuels. Mass storage using under-ground storage tanks is the preferred method of safe storage, and dispensing. Similar to hydrocarbon fuels, pumps are used to dispense the fuel. The fuel is not stored under pressure as in the case of gaseous fuels.

The emissions from alcohol fuels are comparatively less than its hydrocarbon counterparts in terms of photochemical reactivity. However, their by-product of combustion includes formaldehyde. The high heat of vaporization is of advantage as evaporative losses during fueling (dispensing), operation and engine shut-down are significantly reduced. Alcohol fuel contains oxygen in its molecule. The implication is that, on combustion, they produce less CO as the in-cylinder charge has sufficient oxygen in the combustion chamber. Carbon monoxide results from insufficient oxygen in the combustion chamber to enable complete combustion. All fossil fuels (gasoline, diesel, kerosene, aviation fuels, coal, natural gas, etc., contain sulfur which is a source of SOx. Oxides of Sulfur (SOx) in the presence of atmospheric moisture contribute to acid rain. Methanol and ethanol fuels do not contain sulfur [8].

Sources of Alcohol Fuels

Methanol (CH_3OH) and Ethanol (C_2H_5OH)

Ethanol is produced from bio-sources, mainly from fermentation of organic products such as sugar cane (Brazil) or corn (USA). It is also achieved by chemical conversion of syngas to Methanol or Ethanol. Ethanol is credited with higher energy density than methanol. Its introduction into engine fuel cycle increases fuel availability. Methanol is commercially produced from steam methane reformation. It can also be produced via synthesis (syn) gas from biomass. Animal, municipal wastes, agricultural products are also sources of methanol fuel. This information is well documented in literature [5,6,9]. Eighty-five percent of alcohol (M-85 and E-85) and fifteen percent gasoline composition are readily available at many gas stations for smooth transition. .

Comparative Analysis with Battery–Powered Mowers

The use of battery-powered lawn mower is a known practice, but its application is limited by the size of the lawn, the terrain (flat-landscape or a slope), the region of the country (USA), the budget and battery-life, Gasoline and alcohol powered mowers work favorably during the applicable seasons. Storage of the mowers (push-type or tractor) in garages during the cold months of the year does not shorten the life of the devices. There is no requirement to connect it to a battery charger in the garage during the wintery months.

In contrast, the battery powered (cordless/corded) mowers have some limitations. The corded mower is limited to small lawns that are few meters from the residential building. Their advantages include reduced noise, almost zero emissions and absence of spills of the fuel on the lawn. For the cordless types (push -type and tractor), the demerits are: the cost and the life of the battery. The estimated life span is up to five years (based on current battery technology) and that is subject to many factors, such as the use factor, charging frequency, cold region of the country, temperature in the garage where the equipment is stored during off-season and the limitation imposed by manufacturers on charging condition and storage. For commercially used mowers, battery powered mowers are not suitable. As, such, battery powered mowers which will be less than 1% of the population is given less attention in this report.

First, the noise from an electric mower - (e-mower) on a comparative basis, is lower than that of an equivalent alcohol and ICE gasoline-powered mowers for the following reasons: there are less moving parts in the e-powered mower. The electrical energy from the battery is converted to mechanical work through an electric motor as against conversion of chemical energy of alcohol/gasoline fuel into mechanical work through the piston –connecting rod and crank shaft mechanisms. Since there is no combustion in e-mower, the noise level is lower. On the contrary, the gasoline powered mower is nosier than the alcohol counterparts. Alcohol fuels have very high heat of evaporation that results in reduced peak cylinder pressure and temperature.

The torque and power characteristics of alcohol-fueled engine are superior to the gasoline counterpart for the following reasons. Alcohol fuel has a higher-octane number, as such, it is not knock limited within the same compression ratio range as its gasoline counterpart. The alcohol fueled engine has a higher enthalpy of evaporation which improves its volumetric efficiency and makes it operate at a much higher compression ratio. It exhibits superior combustion, torque, and output power characteristics than its gasoline counterpart.

Proposed Action to Comply with Table 1

The use of alternative fuels – methanol and ethanol and also flex-fuels (which consists of M-85 and E-85) to meet EPA Phase 3 for mowers and tractors is expedient to meet future emissions standards. The flex fuels are available in many gas stations nationwide which make the transition smooth. By addition of 15% of gasoline to alcohol fuels, both flex-fuel derivatives have superior cold-start qualities and their flames are visible in broad day light unlike M100 and E100. Their energy content is also higher than pure methanol or ethanol with an approximately 1.75/1.40 by volume of ME85/E85 to one volume of gasoline. Their emissions are lower than pure gasoline fuel.

Conclusion

There is a need to regulate the amount of pollutants from over 54 million lawn mowers and tractors currently in use in USA. The emissions contribute to health complications, such as asthma and other forms of breathing complications, acid rain, and greenhouse gases, etc. The proposed use of alcohol fuels will enhance compliance with Phase 3 of emission standards with minimal retrofit to the mowers and tractors. While significant improvement will be made to air quality. Ecological damage resulting from spills will be significantly reduced. Finally, a gradual transition to alcohol fueled powered systems will be widely accepted.

The gradual diversification to other forms of energy is determined by global atmospheric and economic conditions. More than any other moment in the history of mankind, we need to use renewable and sustainable resources that are environmentally friendly and meet the societal energy needs and standards.

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