Powering Internal Combustion Engines Using Cost Effective SYNGAS Driven from Biomass

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ABSTRACT:

Recent concerns over the security and reliability of the world's energy supply has caused a flux in the research and development of renewable sources. A leading renewable source has been found in the biomass gasification of biological materials derived from organic matters such as wood chips, forest debris, and farm waste that are found in abundance in the USA. There is a very strong interest worldwide in the development of technologies that allow the coupling of biomass gasification and fuel cell systems to produce high-energy efficiency, clean environmental performance and near-zero greenhouse gas emissions. Biomass gasification is a process which produces synthesis gas (syngas) that contains hydrogen and carbon monoxide from organic matter.

It has been proven that syngas produced from biomass is both environmentally friendly and economically viable. Syngas is the end-product of heating hydrocarbon materials / biomass in a starved environment of oxygen using a gasification process. Syngas is another form of fuel that could be developed as an alternative for gasoline. It is well known that gasoline is made with fossil fuels, which are considered a pollutant to the environment and is a resource which is rapidly depleting worldwide. Accordingly, researchers around the world are currently working on the development of different alternatives to reduce or eliminate the dependency on fossil fuels now and in the future. Due to the abundance of biomass material around the world and in the US, vast research work is being performed to gasify biomass into a possible replacement to fossil fuel. This paper shows the development of Internal Combustion Engine (ICE) operation on flex fuel using syngas and propane.

A major objective of this project is to enhance the educational experiences for engineering technology students while working on a team project resembling a realistic work environment similar to that of an industrial setting. The outcome of such learning experiences from this effort will be the design, implementation, theoretical analysis, model development and experimental application in the near future of an interdisciplinary project- oriented course for our students. This course will involve concepts from fluid mechanics, heat transfer, instrumentation, and data acquisition/analysis.

INTRODUCTION:

In the ever-fluctuating global atmosphere and oil prices, fossil energy supply is possibly the most prominent issue to have an influence on our environment and economy. An increasingly turbulent climate that reigns over this earth has interests vested deep in the market of energy supply. The real issue lies within the non-renewable sources of energy that reign today. The United States gets about 84% of its total energy supply through the consumption of Oil, Coal, and Natural Gas, all of which are fossil fuels and are non-renewable. [1] Biomass energy production is becoming an increasingly prominent alternative energy. Advancements in Biomass gasification would not only push further boundaries in research and engineering, but it would also help to stabilize the inherently unstable energy market that exists today.

Biomass energy is a process where in organic matter is consumed during a process to yield an array of by-products. The desirable synthesis gas, as previously stated, consists of 19% hydrogen and 20% carbon monoxide. [2] Recent research and work aimed to further the development and optimization of the biomass process to increase extraction of hydrogen from the synthetic gas driven from the biomass process.

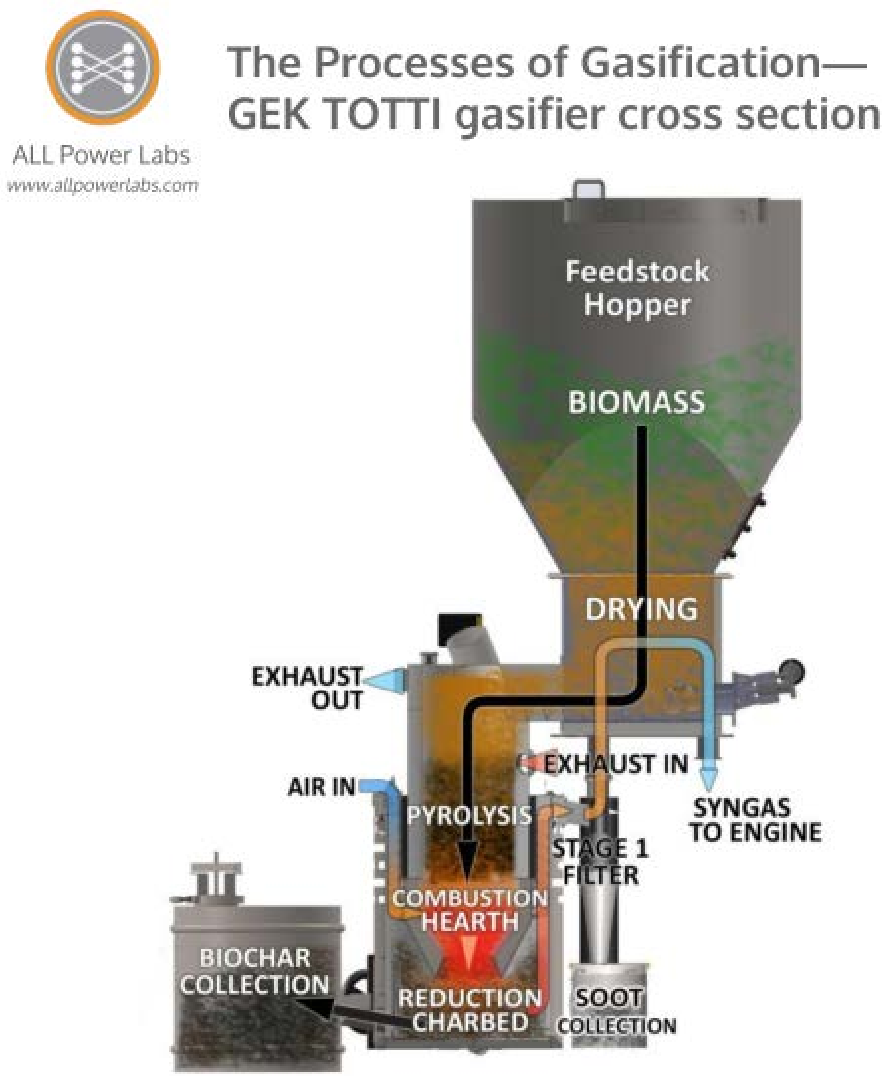

Figure (1) Downdraft Gasifier

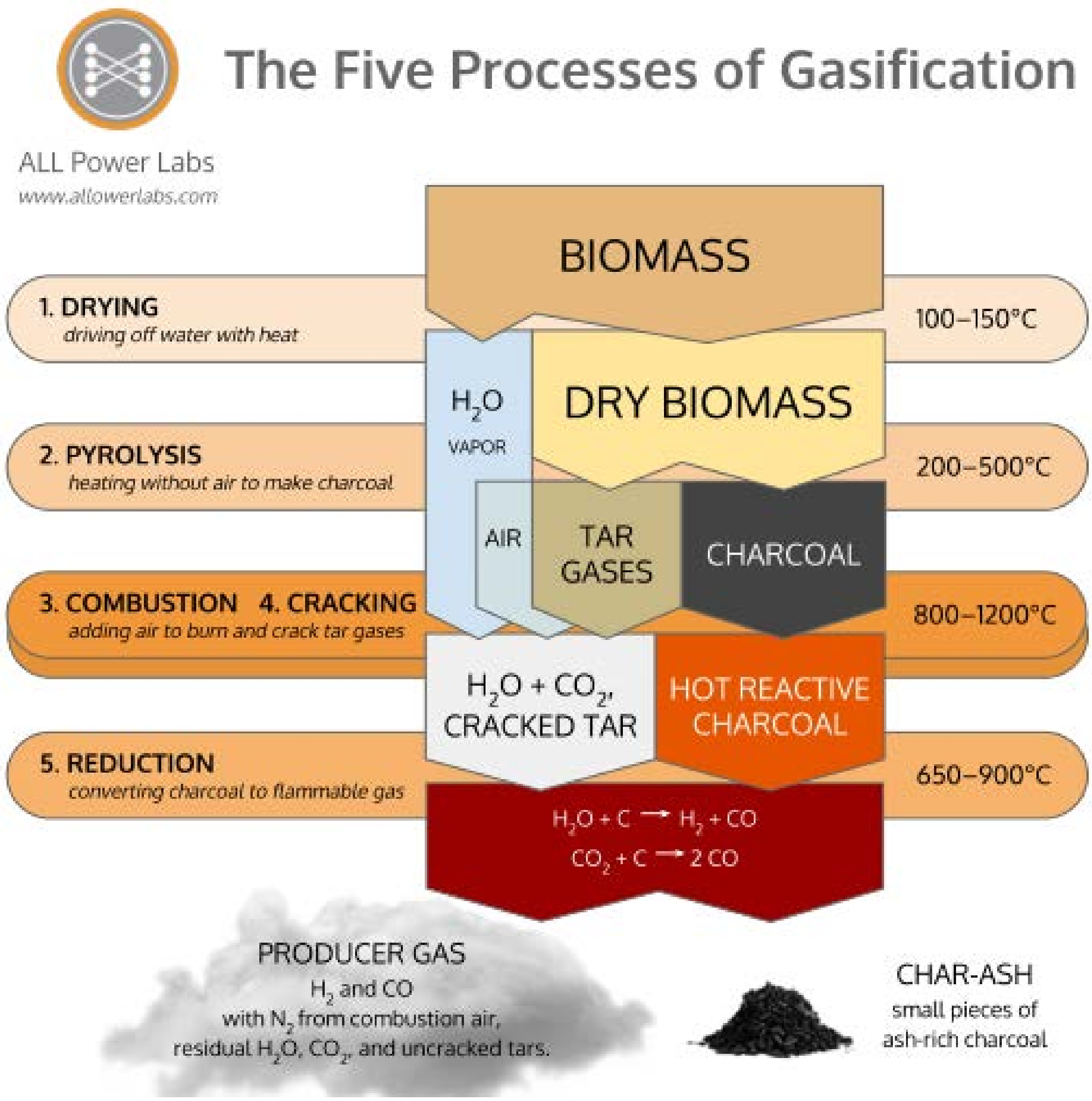

Figure (2) Downdraft Gasifier

Gasification involves turning organic fuels (such as biomass resources) into gaseous compounds (producer gas or syngas) by supplying less oxygen than is needed for complete combustion of the fuel. Gasification occurs at temperatures between 1112º and 2732º F and produces a low- to medium-energy gas depending upon the process type and operating conditions. Gasification is a thermo chemical process that produces mainly hydrogen H_2 and carbon monoxide CO but also contains smaller amounts of Carbon dioxide CO_2, Methane CH_4, and larger amount Nitrogen N_2 from air. Gasification has four different stages; drying, pyrolysis, oxidation, and reduction. In the oxidation stage, the heat helps to dry out the fuel in the drying stage, removing the combustible gas in the pyrolysis stage and producing syngas in the reduction stage as the downdraft gasifier Figure (1) depicts [3]. However, there are a few factors that could affect the gasification process;

namely: temperature and residence time in each stage. These two factors, temperature and residence time (about 15 to 30 seconds) of each stage inside the gasifier, determine the fractions of the chemical products of syngas. The temperature needed for each stage increases from the drying stage to reduction stage as Figure (2) depicts [3]. During the gasification of biomass there are some contaminants such as ash, sand, char and tar are produced. When running syngas in an internal combustion engine, tar is a major problem since it tends to stick the valves to their seats and block pores in filters as well as other internal components. However, Biochar has a lot of advantages and various useful applications such as lakes and rivers purification as well as roads coverage and improvement, The Imbert gasifier is a downdraft gasifier that incorporates a restriction below the air intake in the combustion zone and above the reaction or gasification zone.

Although syngas composition varies depending on biomass type and gasifier operating conditions, there are still general ranges for syngas composition. Syngas produced by a gasifier using air as an oxidizer is composed of the following by volume:

- H_2 – 18%-20%
- CO – 18% - 20%
- CH_4 – 2%
- CO_2 – 11% - 13%

N_2 – 47% -51%

Most of the energy in the syngas that is usable in an internal combustion engine is generated from hydrogen and carbon monoxide. Any process that generates syngas aims at maximizing the amount of carbon monoxide and hydrogen expressed by volume and the molar ratio of hydrogen to carbon monoxide in order to achieve a gas with as high as possible energy content.

When comparing syngas to ethanol and propane as fuel in an internal combustion engine, it is important to compare the energy density property of each fuel. Energy density is defined by the amount of energy per unit weight or volume. With the energy density of the fuels in question are as follows Ethanol e100- 11565btu/lb, Syngas- 6880btu/lb, Propane-20059.5btu/lb, H2-51585btu/lb obtained from the U.S department of energy website we can compare the gasses efficiency. With these results we can conclude that ethanol contains more energy than syngas. Since Ethanol is considered as a renewable fuel and is already been used regularly to power internal combustion engines, it is important to compare to syngas when discussing future substitution of gasoline (4).

Since syngas contains approximately 20% hydrogen in its gasified state, the water gas shift process has been utilized to almost double up the hydrogen content. Increasing the hydrogen content will greatly enhance the energy output. This was achieved by using a copper zinc oxide alumina-based catalyst with injecting steam and syngas into a reactor at 1472^{o}F, and we were able to transfer the oxygen in the steam and combining it with the carbon monoxide to form carbon dioxide. This process can almost double the hydrogen content which has a relatively high energy density and reduce the undesirable carbon monoxide gas in the syngas system. After the water gas shift the syngas with extra hydrogen may equate or even exceeds the ethanol in the energy content.

EXPERIMENTAL WORK:

Syngas has been tested and found to function better in a spark ignition engine shown in Figure (3) since syngas has relatively high ignition temperature as compared to gasoline. This means that a higher compression ratio can be used in ICE engines powered by syngas because of the possible knock characteristics of the combination of CO, H_2, and CH_4 resulting in inhomogeneous ignition. Since syngas has a low flame propagation speed, this explains the knocking tendencies of the engine while also requiring increased cylinder temperature and pressure to counteract this phenomenon. Therefore, engines that are manufactured to operate on gasoline will require modifications in the fuel system if syngas is utilized to power the engine that necessitate at least doubling the amount of hydrogen.

Figure (3) One-cylinder Gasoline engine Predator 212cc engine conversion kit

One-cylinder Gasoline engine Predator 212cc engine conversion kit was also installed to convert this engine to run on gases such as syngas and propane. [5]

In the present research project, propane has also been tested as a fuel to operate the same engine shown in Fig (3) and was measured to have a higher stoichiometric air/fuel ratio 15.5:1

compared to gasoline 14.7: 1. Propane also has slower burning properties compared to gasoline, so the motors require more initial spark advance and a faster advancing flame. The ideal compression ratio that has been tested to give the optimal performance is from 10:1 to 10.5:1. At this ratio and a fully optimized propane set up, this can give the most power and the most mileage out of this fuel.

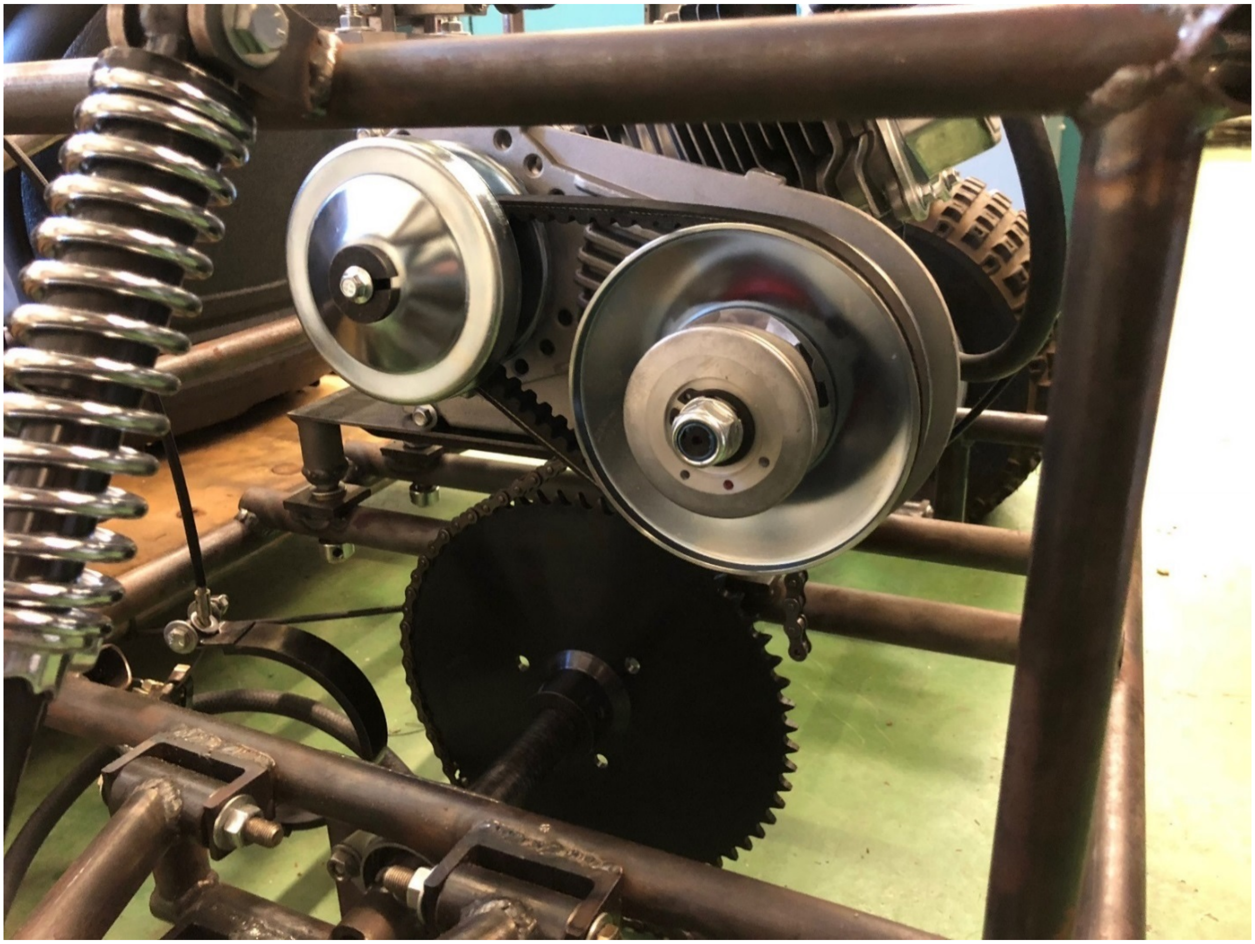

Figure (4) CVT transmission

A CVT Transmission was installed to give the engine more ratios of torque application without the addition of separate gears while also keeping the weight down as Figure (4) depicts. An inboard sprocket behind the driven gear was also added to complete the chain drive that transfers the torque to the axel.

IMPACT IN ENGINEERING TECHNOLOGY EDUCATION:

Emerging technologies such as those involving alternate forms of energy are expected to play a major role in modern engineering technology curricula. The results presented in this paper involve expertise from multidisciplinary teams in our school of engineering technology; in particular, technology of biomass, control systems, fluid mechanics, thermodynamics, and software applications. Major parts of this work were performed as student projects in the school of engineering technology. Namely the student was involved in setting up the biomass system, data acquisition, and running the experiments at Farmingdale State College supported by the Department of Energy (DOE). It is expected that this lab setup will be used in future undergraduate senior projects for students in the departments of mechanical engineering technology. In addition, interdisciplinary courses in alternate forms of energy, biomass, solar energy systems, and control mechanisms could be developed in the future as outgrowth of these experimental setups and activities.

The performance of the biomass system is influenced by many different parameters. In this paper we analyzed the optimal performance and maximum small vehicle acceleration using biomass system. There are many important parameters to maximize power output. We will continuously investigate the relationship between temperature, humidity, time for each stage of the gasifier and the output power. For real life applications, we need to develop a more sophisticated system to consider many parameters in the running of biomass system.

CONCLUSION:

The engine was installed on small vehicle chasse for preliminary testing of its performance and maximum acceleration achieved in one minute using the syngas, propane and gasoline as fuels. The torque converter was instrumental in similarly enhancing the power output for all the three tests and the results were as follows:

	Acceleration	Economics	stability	Repeatability
Syngas	0.6 feet/s2	high	high	Yes
Propane	0.6 feet/s2	medium	high	Yes
Gasoline	0.6 feet/s2	low	high	Yes

The overall conclusion of the current research work is the syngas exhibited the most cost effectiveness out the three gases tested in the current project.

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