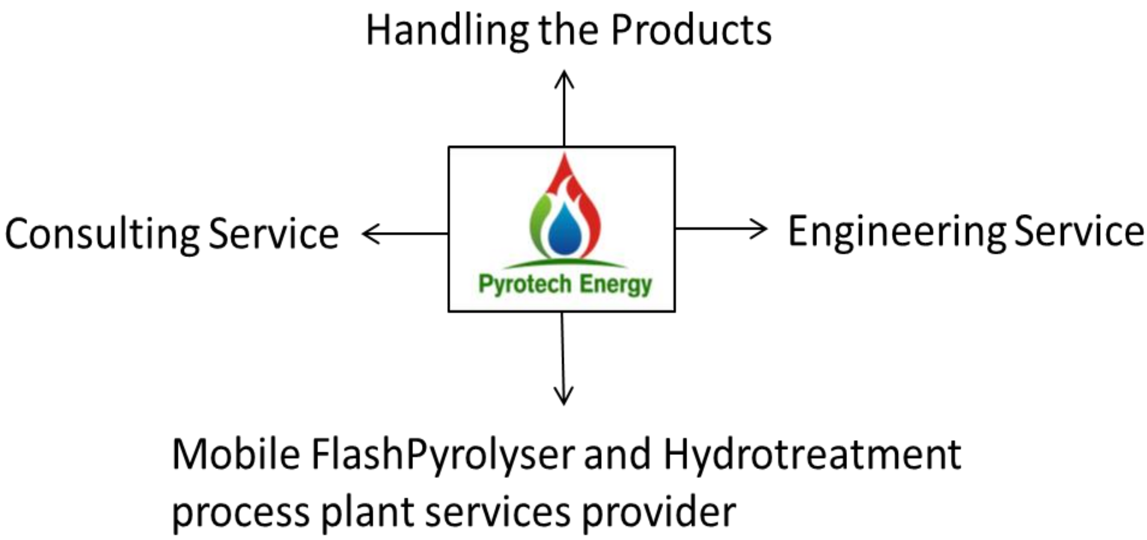
Address: Level 13/114 William St, Melbourne VIC 3000, Australia

Phone: 1300 714 305

Email: info@pyrotechenergy.com

Pyrolysis of Biomass to Produce Marine and Aviation Fuels



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1. Introduction

1.1. Marine and aviation fuels

Fossil fuel depletion and also green gas emission is boosting the research on new sources of energy. Marine and aviation fuels are between the most consumed fossil based fuels. As a result, they should be replaced by other fuels in the near future.

Recently, biomass-derived fuel has become a key element to replace the aviation and marine fuels because of being renewable and also reducing the costs and environmental impacts. For this aim, pyrolysis was selected as a preferred process to convert thermochemically the biomass into bio-marine and bio-aviation fuels.

1.2. Biomass pyrolysis

Pyrolysis is the thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen. It typically occurs at operating temperatures above 350°C. Pyrolysis is categorized to slow, fast and flash types. The fast and flash ones are currently the most widely used pyrolysis systems because the slow process takes several hours to complete and results in bio-char as the main product. On the other hand, fast and flash pyrolysis yields high content of bio-oil and flammable gas. In addition, it takes a very short time to complete the fast and flash pyrolysis.

Bio-oil is an attractive alternative energy source for many reasons. Most notably, it is completely renewable and easily created from common waste products. Using biomass feedstock such as wood, the pyrolysis process results in “net zero” carbon dioxide emissions. In the short term, bio-oil can be used in place of traditional fuel oil in conventional home furnaces and boilers with little modification. However, comparing its fuel properties with marine and aviation fuels, it requires further upgrading.

As can be seen from Table 1, typical bio-oil fuel properties are far from the fuel properties of marine and aviation fuels. High acidity, low heating value and instability of the bio-oil are the major problems hindering their supply in sheep and planes.

Table 1. The typical fuel properties of woody biomass bio-oil, marine and aviation fuels.

Properties	Bio-oil	Marine fuel	Aviation fuel
Density (kg/m^3)	1100-1300	790-910	775-840
Viscosity @ 50^{o}C (mm^2/s)	15-40	10-60	8
CCAI	---	800	---
Sulphur (wt%)	<0.05	<0.1	0.003
Flash (^{o}C)	40-110	>60	38
Hydrogen sulphide (mg/kg)	---	<2	---
Acid Number (mg KOH/g)	70-100	<0.5	<0.1
Water (v%)	20-30	0.05	<0.1
Ash (wt%)	<0.3	0.01	
High heating value (MJ/kg)	19-24	45	47.3
Low heating value (MJ/kg)	13-18	44	42.0

1.3. Bio-oil upgrading

The produced raw bio-oil from pyrolysis cannot directly be used as a marine and/or aviation fuels because of the high acidity and low heating value. The high concentration of heavy components gives it instability. These pure properties are mainly because of the presence of oxygen containing compounds in the bio-oil. One of the most promising methods to upgrade the property of crude bio-oil is hydrodeoxygenation (HDO) of bio-oil with a catalyst at high hydrogen pressure (50-200 bar) and high temperature (250-400^{o}C) to remove the oxygen in the form of water. Bio-oil hydrodeoxygenation can be performed in batch and continuous reactors. The continuous HDO is more likely used in commercial operations.

The earliest research on the hydrodeoxygenation of pyrolysis oil appeared in 1984. In these investigations, apparent similarities between hydrodesulphurization (HDS) of crude petroleum in the refinery and HDO were taken as a starting point. As a result, the commonly applied catalysts were HDS catalysts, either NiMo/Al_2O_3 or CoMo/Al_2O_3. The chosen reaction conditions were the temperature of 200-400˚C, the pressure of 100-200 bar and liquid hourly space velocity (LHSV) of bio-oil feeding varied from 0.05 up to 2. The most important findings from this work were that bio-oil could not be treated like petroleum because severe reactor blockage was observed due to charring of the bio-oil and coke formation. Then there was a need for understanding the reason of charring and coke formation, using an optimized condition of hydrotreatment and a proper catalyst to avoid reactor and pipeline blockage.

Noble metal catalysts such as Ru, Pd, Rh, Pt, CuCr, CuO, NiO, Ni supported on Mg_2O_3/SiO_2 or activated carbon were the second catalyst group which have been tested. In the continuous set-ups, the noble metal catalysts in general showed better performance than the HDS catalysts. As the price of the noble metal catalysts was much higher than the ones of HDS catalysts, some researchers endeavoured to work on HDS catalysts and use sulphur to activate them. The result of this research showed that non-sulphided form of the catalyst has less activity than the sulphided catalysts. This implies that the addition of a sulphur source is advantageous when using these catalysts. A few different methods have been applied to sulphide the catalyst using H_2S or dimethyl disulphide (DMDS) as a sulphur source. All in all, by using a proper catalyst in HDO process, depending on the process severity, bio-oil can be upgraded to biofuel, which can be used in a range of applications such as petrol, diesel, marine and aviation fuels.

The typical properties of the biofuel are shown in Table 2. Not much data are available in literature regarding the biofuel from woody biomass. However, the presented data proves the possibility of using the biofuel as an engine fuel directly.

Table 2. The typical fuel properties of woody biomass biofuel.

Properties	**Biofuel**
Density (kg/m^3)	930
Heating value (MJ/kg)	41.4
pH	6.4

2. PyroTech Energy Pty Ltd Pyrolysis Technology

2.1. PyroTech Energy pyrolyser

Pyrotech Energy is a licensor and provider of the mobile flash pyrolysis technology in Australia. Its pyrolyser can convert the woody biomass into dry bio-oil, wood vinegar (also called wood acid), biochar and wood gas. In addition, its process can separate the mixture of acids and water from the bio-oil and produce the wood vinegar and dry bio-oil separately. The typical yields of the products from the pyrolysis of the woody feedstock by PyroFlash technology considering 10 wt% water in biomass are shown in Table 3.

Table 3. The yield of the different products from the pyrolysis of woody biomass

No.	Product	wt% of feed
1	Biochar	10
2	Bio-oil*	25
3	Wood vinegar	25
4	Wood gas	40

* It should be noted that the bio-oil includes 5 and 20 wt% wet and dry oils.

The company provides the pyrolyser with two possible production capacities including 2 and 10 tonnes per day of woody biomass feeding. The most string fact is that both plants are mobile and can be taken to the farm land or the biomass source (Figure 1).

Figure 1. The mobile pyrolyser with 2 and 10 tonnes per day feeding capabilities.

Further upgrading system is also proposed by Pyrotech Energy Company to upgrade the bio-oil into biofuels.

2.2. PyroTech Energy engineering service

Pyrotech Energy Company is the engineering service provider of the all aspects of the wood waste & agriculture residue pyrolysis. The service includes consulting, design, installation and operation of pyrolysis and HDO processes.