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Technical review on jet fuel production

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ABSTRACT

In present study, we investigated jet fuel production process, including the crude oil-based conventional process, unconventional oil sources-based process, Fischer–Tropsch synthesis (F–T) process and renewable jet fuel process and analyzed the details of each jet fuel production process. Among these jet fuel production technologies, the F–T synthesis and renewable jet fuel process supply alternative fuels with potential environmental benefit of reduced life cycle greenhouse gas (GHG) emissions and the economic benefits associated with increased fuel availability and lower fuel costs. The F–T synthesis has a major advantage with the possibility of accepting any carbon-based input, which makes it suitable for using a variety of sources such as coal, natural gas and 2nd generation biomass as feedstocks. The renewable jet fuel process such as Bio-Synfining™ (Syntroleum) and Ecofining™ (UOP) as well as C-L™ (Tianjin University) is a low capital cost process of producing high quality synthetic paraffinic kerosene (SPK) from bio-renewable feeds like vegetable oils/fats and waste cooking oils/fats, greases, energy plants of jatropha and algal. The SPK has superior fuel properties to other options available today, with higher cetane number, lower cloud point and lower emissions

Contents

1. Introduction

The world is changing and so is the aviation industry [1–4]. Now with declining petroleum resources and shocking surge in the price of fuel, combined with the increase in political and environmental concern and the current economic downturn, it is imperative to develop renewably clean and energy-efficient technologies for producing sustainable products of fuels [2,5–7]. Aviation is powered by liquid petroleum fuel especially liquid jet fuel, which requires higher energy contents per unit volume than gases, and is easier to handle and distribute than solids [8–10]. The consumption of jet fuel has been declining from 191.1 million gallons per day in 2000 to 189.1 million gallons per day in 2001, growing up to 198.3 million gallons per day in 2008. However, the United States is the largest single market around the world, consuming about 37% of the worldwide total [11]. Statistically, fuel has represented about 10–15% of airline operating cost. The large fluctuation in the cost of fuel has promoted a strong incentive for airlines to shift to use of alternative sources of fuel. According to previous studies, the fatty acid methyl esters (FAME),

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synthetic alcohols (bio-ethanol or bio-methanol), synthetic hydrocarbons from sugars, dimethyl ether (DME) and hydrogen could be possibly used as aviation gas turbine alternative fuels. However, the high quality requirements for the commercial aviation fuels strictly limit the wide application of these alternative fuels for all exiting aircrafts [12,13].

According to the International Energy Agency (IEA), transportation system contributes about 23% of energy-related carbon dioxide emissions (CO_2) all over the world, and this share will likely rise in the future [14]. Aviation contributes approximately 2~3% of the world's anthropogenic carbon dioxide emissions, but has received considerable attention regarding these emissions [15–17]. In 2007, the European Parliament voted to bring aviation into the European GHG-emission trading system (EU-ETS) [18,19]. This legislation would require all airlines flying within or into Europe region decrease their GHG emissions by 10% or buy CO_2 allowances on the open market after it takes effect in 2012 [20–22]. The aviation industry is facing billions of dollars of cost increase from their prospective, requiring carbon credit purchases via their entry into the EU's emissions trading scheme [6,23,24]. In order to deal with this issue, aviation industries have explored several improvements on engine & airframe technology, operation & fleet management and other measures [19,22,24–28]. Moreover, alternative fuel is an imminent part of the aviation industry's future [15,29]. Renewable jet fuels could significantly lower GHG emissions and provide a long-term sustainable alternative to petroleum jet fuel [30,31]. Following the first successful biofuel flight of a Virgin Atlantic Airways 747-400, more commercial airlines conducted successful in-flight tests using sustainable alternative jet fuel. The fuel was produced from second generation of biomass sources, including camelina, jatropha and algae, reducing the fuel's carbon footprint by 80% relative to jet fuel without competing for resources with food production [32].

The most widely used quality standards of conventional petroleum-derived jet fuel are the ASTM D1655 (US) and DEF STAN 91/91 (UK Ministry of Defence). A number of other specifications also exist, such as DCSEA (France) and GHOST (Russia). The specification of aviation kerosene has changed and developed in line with safety and security of supply criteria [11,33,34]. In December 2007, DEF STAN 91/91 approved 100% Sasol full-synthetic fuel, which represented the world's first fully synthetic jet fuel approved for use in all commercial and military engines [35]. Besides, The American Society for Testing and Materials (ASTM) created a new specification ASTM D7566 for blends containing synthetic jet fuel. This new specification entitled as “Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons”. This specification certifies a 50% blend of Jet-A and synthetic paraffinic kerosene (SPK) produced from biomass using an alternative process. It also provides a framework for certifying new alternative fuels as they are developed.

Aviation liquid fuels would be derived from different materials by different methods [36]. In the present study, we investigated four different typical jet fuel production technologies, which include the conventional process from crude oil, the route from unconventional oil sources, the Fischer–Tropsch synthesis (F–T) and the renewable jet fuel process. Besides, the details of each jet fuel producing technology were analyzed and the comparison between each other was made.

2. The crude oil-based conventional process

The discovery of crude oil created an inexpensive liquid fuel source that helped industrialize the world and improve living standards, while the fossil fuels have contributed to over 80% of energy expenses. Crude oil, also called petroleum, is a complex mixture of hydrocarbons. The carbon and hydrogen in crude oil are thought to have originated from the remains of microscopic marine organisms that were deposited at the bottom of seas and oceans and were transformed at high temperature and pressure into crude oil. Global oil production is approximately 81.5 million barrels per day, which is equivalent to an annual output of 3905.9 million tonnes in 2008 [37]. The International Energy Agency (IEA) has estimated that the world's total refinery production in 2006 is 3861 million tonnes. The aviation fuel accounts for 6.3% of the total amount of oil consumed. Petroleum refining is a process of separating many compounds present in crude petroleum [38]. This process is called atmospheric & vacuum fractional distillation where the crude oil is heated and compounds boil at different temperatures and change to gases. These gases are later recondensed back into liquids [39]. Fig. 1 shows the basic flow sheet of atmospheric fractional distillation.

The lowest boiling fraction, taken from the top of the distillation column, is called naphtha. It is mainly processed further to make motor gasoline. The second fraction of about 33% of the crude oil input contains the raw material for jet fuel production. This fraction is further processed in the distillate hydrotreater to become kerosene and special solvents, followed by the so-called “gas oil” or “middle distillate base oil” fraction which includes diesel fuel and heating oil. Basically, kerosene is originated as a straight-run (distilled) petroleum fraction with boiling temperature ranging from 205 °C to 260 °C. If jet fuel production was to increase, obviously the production of other products would decrease [40]. Finally, although the bottoms fractions or residual fraction can be used as heavy boiler fuel, it is usually vacuum distilled first to yield more high-value distillate [41].

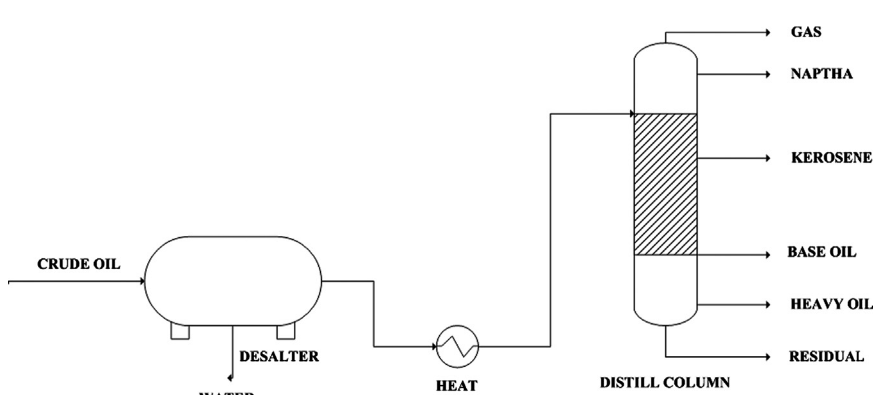

Fig. 1. The conventional route for jet fuel production from crude oil.