Development of Jet Fuel Production System from Woody Biomass

TAKASHI YAMAMOTO[*1] ATSUSHI FUJII[*2]

MASASHI HISHIDA[*3] KATSUHIKO SHINODA[*4]

BTL (Biomass to Liquid) is a technology for synthesizing biomass into liquid fuel that has been attracting attention as a method to produce clean and environmentally-friendly fuel. Through this research and development, a partial oxidation-type entrained bed biomass gasifier suitable for scaling up for future mass production was developed. Mitsubishi Heavy Industries, Ltd. (MHI) also implemented integration test of a biomass gasification and FT (Fischer-Tropsch) synthesis that actually combined the developed biomass gasifier with a highly selective Anti-ASF-type FT synthesis catalyst/process to verify the realizability of a system for producing bio jet fuel from various types of woody biomass.

1. Introduction

For the practical application of BTL (Biomass to Liquid), the optimization of the entire process is required. On this occasion, we carried out research and development for a high value-added total bio jet fuel production system in cooperation with the University of Toyama, which has achievements in the research and development of a liquid fuel synthesis catalyst.

The International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA) have been working on the reduction of CO_2 emissions from aircraft and aim to set an upper limit for CO_2 emissions in 2020. To achieve this goal, the introduction of bio fuel is essential.

One of the widely-known liquid bio fuels is alcohol fuel such as bio ethanol. However, the heat value per unit mass of alcohol fuel is small and it is not suitable for jet fuel (aviation fuel). Accordingly, the use of animal and vegetable oils or BTL with FT (Fischer-Tropsch) synthesis is under consideration for bio jet fuel. To realize the use of animal and vegetable oils, projects for the development of bio jet fuel originating from algae are progressing. However, there are various issues for supply in a large amount such as large-scale cultivation and enhancement in the efficiency of the refining process. On the other hand, jet fuel production with BTL is easy to scale up, and thus is expected to be a production technology that enables mass production in response to increased demand.

2. Development of bio jet fuel production process

Figure 1 shows a bio jet fuel production process using FT synthesis. Woody biomass in a pulverized state is put into the gasifier and then becomes syngas consisting mainly of H_2 and CO. The gas generated in the gasifier is supplied through cooling and clean up processes to the liquid fuel synthesis process. Before being supplied to the synthesis process, the gas is pressurized from normal pressure by the pressure boosting device, so that the partial pressure of H_2 and CO becomes high in order to accelerate the FT synthesis reaction. CO_2, which does not contribute to the

*1 Chief Staff Manager, Heat Transfer Research Department, Research & Innovation Center
*2 Heat Transfer Research Department, Research & Innovation Center
*3 General Manager, Boiler Technology Development Department, Boiler Products Headquarters, Mitsubishi Hitachi Power Systems,Ltd.
*4 Senior Manager, Boiler Technology Development Department, Boiler Products Headquarters, Mitsubishi Hitachi Power Systems,Ltd.

reaction, is recovered by decarbonation after pressurization. Hydrogen is then added to the hydrocarbon generated by FT synthesis. Through the isomerization process that generates isoparaffin and the distillation process, products such as light oil, jet fuel, and wax are recovered.

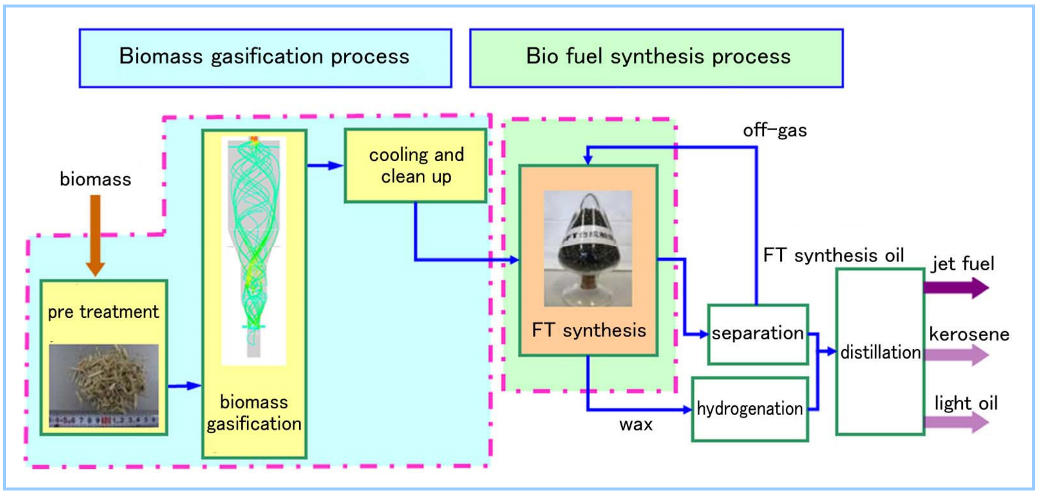

Figure 1 Bio jet fuel production process

2.1 Development of biomass gasifier

For the biomass gasification process, an entrained bed gasifier is adopted. The entrained bed gasifier is suitable for synthesizing bio fuel because the size is relatively compact and the capacity can be easily enhanced due to high-speed gasification, and the amount of tar generated can be reduced by high-temperature gasification.

The gasifier has a structure where the shape is changed gradually as shown in **Figure 2**, and the cross section area of the lower part of the gasifier is smaller than that of the upper part. As a result of this shape, the gas ascending flow speed (superficial velocity) is high at the lower part and low at the upper part. Figure 2 collectively shows the biomass particle behavior in the gasifier estimated by CFD. At the lower part of the gasifier, the gas flow speed is high and thus large particles are prevented from falling down to the bottom, while at the higher part of the gasifier, the gas flow speed is low and thus characteristically, only small particles accompany the gas flow. Unreacted large particles and raw materials that take time to completely react circulate and stay in the gasifier until the completion of the reaction, and are discharged after a sufficient decrease in their size. Therefore, a high carbon conversion rate can be obtained for biomass raw materials with various characteristics.

Figure 3 shows the carbon conversion rate of various biomass raw materials in large particle. A carbon conversion rate as high as 95% or higher is attained regardless of the material types and the operational conditions of the gasifier (O_2/C).

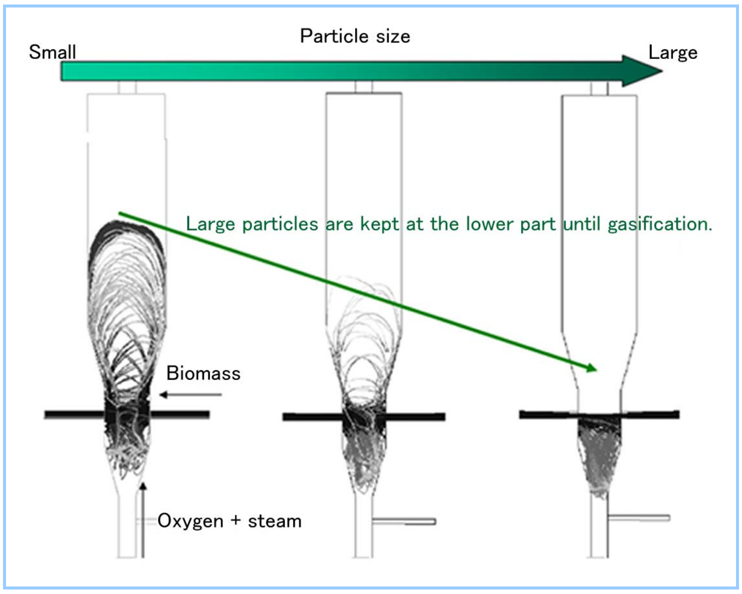

Figure 2 Biomass particle behavior in a gasifier

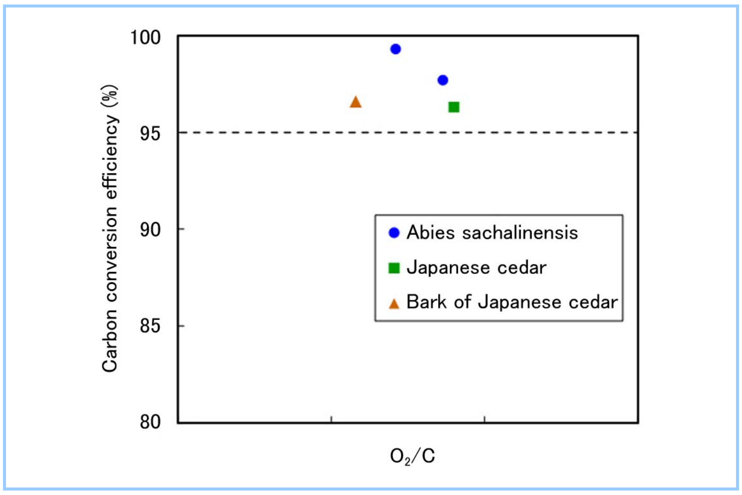

Figure 3 Carbon conversion rate of various types of biomass

2.2 Development of FT synthesis catalyst/process

FT synthesis is a polymerization reaction of carbene (CH_2) and the obtained hydrocarbon has a mountain-like distribution in which the maximum value exists in the vicinity of C6-C8 according to the ASF (Anderson Schultz Flory) rule. The main fraction of jet fuel is C8-C16, and therefore maximizing the selectivity requires breaking the ASF distribution. Professor Tsubaki of the University of Toyama et al.[(2)], collaborators in this project, developed the world's first FT synthesis catalyst/process that realizes Anti-ASF distribution by adding a small amount of 1-olefin to the raw material synthesis gas and the use of a catalyst with even higher selectivity.

2.3 Biomass gasification and FT synthesis integration test

We combined the gasifier and the FT synthesis catalyst/process that were developed through this research to implement a biomass gasification and FT synthesis integration test. The biomass gasification and FT synthesis integration test was performed four times in total in fiscal 2012 to 2015 using the biomass gasification and FT synthesis test facility (**Figure 4** and **Table 1**) installed at MHI Research & Innovation Center (Nagasaki District).

Figure 5 shows an example of FT synthesis oil and its carbon number distribution obtained in the integration test. Through this process, a high yield (approximately 70%) of jet fuel fraction (C8-C16) was confirmed. In addition, gasification and FT synthesis integration operation using actual gas for approximately 100 hours was performed, and it was confirmed that there was no deterioration tendency of the catalyst performance.

Figure 4 Biomass gasification and FT synthesis integration test facility

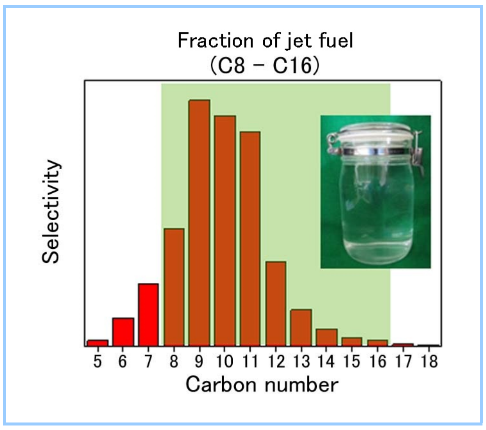

Figure 5 Carbon number distribution of FT synthesis oil

Table 1 Specifications of biomass gasification and FT synthesis integration test facility

Gasifier	Biomass processing amount of capacity	240 kg/day
	Method	Entrained bed
	Gasification agent	Oxygen and steam
FT synthesizing equipment	Method	Slurry bed catalyst method

2.4 Consideration of bio jet fuel production process

By reflecting the results of the aforementioned research and development, we established a bio jet fuel production process model including an FT synthesis oil refining system using a process simulator, and evaluated the material balance on a verification scale (biomass processing amounting to 20 tons per a day). **Figure 6** shows the heat balance of the process (based on the input biomass chemical heat). This process converts 37% of the biomass heat value into bio fuel (jet fuel, wax and light oil). Moreover, when off-gas (consisting mainly of CH_4 and CO) is utilized effectively, 55% of the biomass heat value can be recovered.

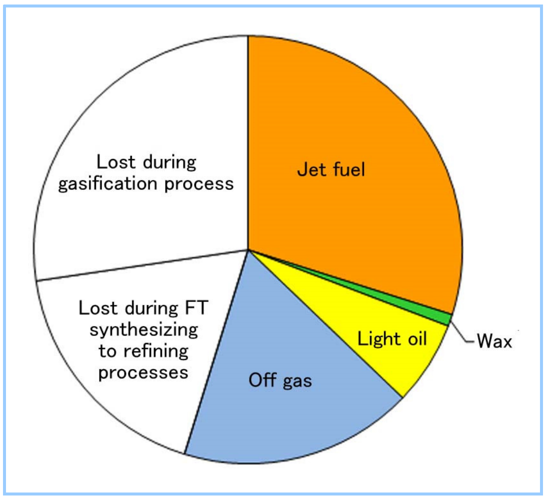

Figure 6 Bio jet fuel production process Heat balance

3. Conclusion

MHI and Mitsubishi Hitachi Power Systems, Ltd. have been working on the development of a technology for producing liquid fuel from biomass (BTL) as a technology for the production of third-generation bio fuel that does not compete with food production. On this occasion, the realizability of the technology for producing jet fuel from woody bio mass was confirmed by an integration test that combined a gasification process and an FT synthesis process.

It is expected that the securement of alternative bio aviation fuel will be important, particularly in 2020 and later. The Ministry of Economy, Trade and Industry organized the "Committee for the Study of a Process Leading to Introduction of Bio Jet Fuel for the 2020 Summer Olympic Games and Paralympic Games in Tokyo" and the momentum toward the introduction of made-in-Japan bio fuel has been accelerated.

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References

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