BIOMASS-FUSION HYBRID WITH HIGH TEMPERATURE LIPB BLANKET

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This paper proposes an innovative power plant concept of biomass-fusion hybrid, and presents an overview of integrated conceptual design based on various experimental verifications. This concept can drastically reduces many of the difficulties in technology development, while enhances attractiveness of fusion.

Waste biomass was experimentally proved to be converted to hydrogen and carbon monoxide mixture by the endothermic reaction, $C_6H_{10}O_5+H_2O \rightarrow 6H_2 + 6CO$ -814 kJ at the efficiency above 95%. Since the endothermic chemical reaction free from the limit of thermal cycle that inevitably discards heat, high efficiency conversion of fusion heat was possible. And utilizing chemical energy contained in the biomass, total apparent energy output from fusion to the product energy as a form of gaseous fuel by this system approaches 270%, that is ten times larger than what expected for pure fusion electricity generation. This "hybrid" effect enables fusion power generation possible with Q~5 plasma to be attainable by current technology. Gaseous product of H_2-CO mixture can further be used for synthesizing artificial oil products by Fischer-Tropsch reaction, $2H_2 + CO \rightarrow -CH_2- + H_2O$ to be deployed in the current market. Taking advantage of this hybrid effect, small tokamak of major radius ~5m and 300 MW fusion power is designed[1].

High temperature LiPb blanket required to extract fusion heat at the temperature above 900 degree C is studied. Combination of SiC composite and LiPb is tested and the feasibility to obtain high temperature heat with liquid LIPb is demonstrated by LiPb/He dual coolant loop. Intermediate heat exchanger (IHX) for the transfer of the heat to biomass thermal decomposition process is also developed with SiC/SiC composite, and experimentally tested. High temperature tritium permeation through SiC material was measured to evaluate the safety and tritium economy of this blanket concept.

Tritium recovery process for LiPb system was designed and tested. With experimentally measured hydrogen diffusion data from LiPb, tritium recovery device based on vacuum sieve tray units was selected. Typically, 1mm radius droplets of LiPb can release majority of tritium within free fall of 1m, that results in compact tritium extractor satisfying the safety requirements.

By the safety analysis, the most important requirement for environmental safety was identified to be the contamination of product hydrogen to be distributed as fuel. Tritium recovery system was designed to maintain tritium concentration in the product stream far lower than the regal limit and environmental consideration. Low pressure system is another major safety advantage.

Finally socio-economic feature of this concept was evaluated. This biomass-fusion hybrid is expected to be technically possible with current technology or its realistic extension in the near future. Major product can be sold as diesel or jet fuels through existing infrastructure and market, that is far larger than electricity market. Supply chain of waste biomass is evaluated in the current Japanese society, both urban area and country side and found to have sufficient capacity at very low or negative cost because they are wastes. Substituting fossil fuel is very important and effective feature in the aspect of reduction of carbon dioxide emission, compared to the competition with renewable or fission, and suggests the attractiveness of fusion as a significant environmentally friendly energy source. Because of the relatively small scale of the plant and easy technical requirements as pulse and/or driven tokamak, this concept can be constructed at relatively small project cost in the nearer future than pure fusion electricity, while expected to eventually demonstrate net energy output.

[1] K. Ibano et al., "Design Studies of Innovatively Small Fusion Reactor Based on Biomass-Fusion Hybrid Concept:GNOME", this conference, (2010).