Ammonia direct combustion

Thermal power generation using carbon-free fuel

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Gas turbine power generation using ammonia as a fuel

Since ammonia does not emit carbon dioxide during combustion, it is expected to reduce carbon dioxide emissions significantly by replacing coal and natural gas used in thermal power plants. Currently, ammonia is produced using fossil fuels as a raw material, but in recent years attempts have also been made to produce ammonia using renewable energy such as solar power. If this can be put into practical use, ammonia can become a carbon-free fuel. If this fuel is in turn used in thermal power plants, it will also become possible to obtain power without emitting carbon dioxide.

The Cross-ministerial Strategic Innovation Promotion Program (SIP) is a national project implemented by the Council for Science, Technology and Innovation of the Cabinet Office. " Energy Carriers" is one of 11 programs and the Japan Science and Technology Agency (JST) serves as the management agency. " Ammonia direct combustion" is one of the research and development topics. Professor Hideaki Kobayashi, team leader, has been working on the development of basic technologies for direct combustion of ammonia, and has been embarking on the challenge of developing a combustion method that burns ammonia stably and efficiently. In August 2014, in collaboration with the National Institute of Advanced Industrial Science and Technology (AIST), his research group succeeded in demonstrating gas turbine power generation using ammonia as a fuel for the first time in the world.

How to burn ammonia

By burning ammonia, the turbine is rotated to generate electricity. (* Turbine: an engine in which a wheel of special blades is driven around at high speed by heated burnt gases, producing a lot of power.) However, there are some issues to be solved. For example, the range of flame stability of ammonia combustion is narrow compared with hydrocarbon fuels such as methane, which is the main component of natural gas. The burning velocity of ammonia-air mixture is very low, only one-fifth of that of methane-air mixture, meaning that combustibility of ammonia is significantly low and ignition and flame stabilization are difficult in many cases.

As solutions to these problems, Professor Kobayashi came up with the idea that using a swirling flow in a burner could control the flow of the mixture of ammonia and air for stable combustion. First, the stabilization of ammonia flame was realized by changing flow rotation speed in a swirl flow combustor and changing the strength and winding direction of the gas flow inside. Next, by establishing a three-dimensional numerical analysis method, it became possible to theoretically verify the combustion condition that reduces nitrogen oxides (NOx) and unburned ammonia by changing the supply ratio of ammonia and air, supply speed, etc. Research is now underway on clarifying the combustion mechanism of ammonia. In addition, experiments are being conducted in an environment that realizes operating conditions of actual gas turbine power generation in search of practical combustion methods.

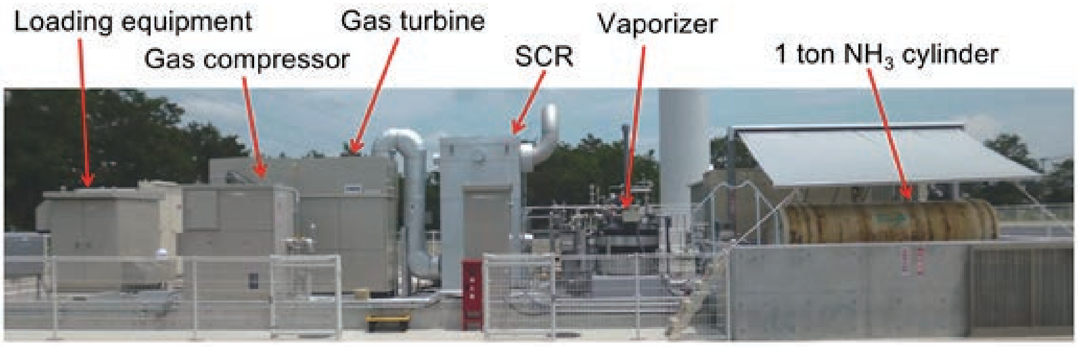
Development of power plant fueled by ammonia

This system can generate electricity by supplying high-temperature and high-pressure gas to the turbine by direct combustion of ammonia.

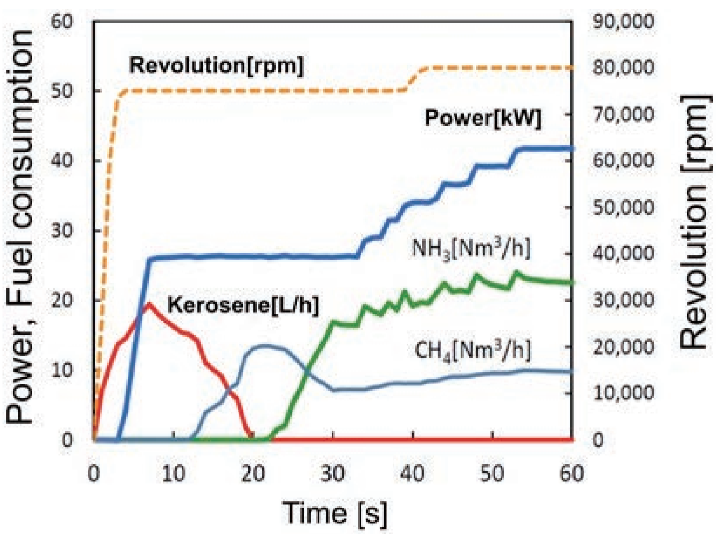
In August 2014 at AIST, using the maximum power output 50 kW ammonia-fueled gas turbine, stable power output of 21 kW was generated for the first time in the world. The combustion heat ratio was 30% ammonia with 70% kerosene.

In September 2015, gas turbine power generation was also conducted successfully with a mixed gas of methane and ammonia, and single fuel with 100% ammonia. In all cases the power output achieved 41.8 kW, showing that it may be possible to use ammonia as a fuel for thermal power plants. However, further research and development are necessary, such as on upsizing of the system to a practical stage.

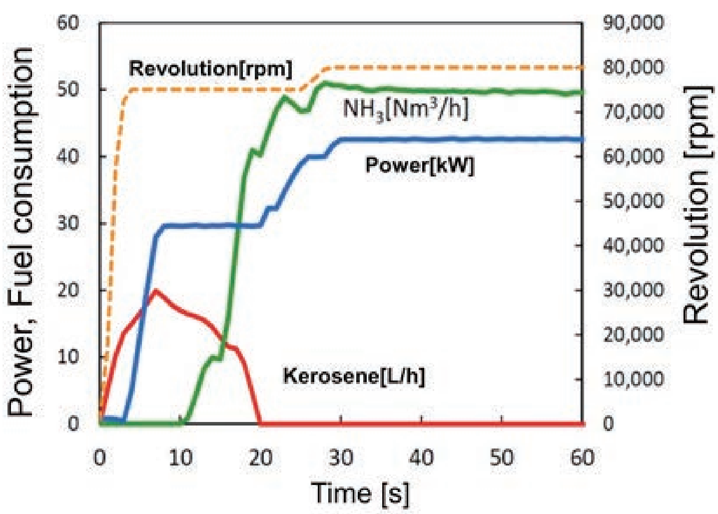
During the combustion of ammonia, there is concern about the formation of NOx that cause air pollution such as acid rain. Although NOx reduction equipment using catalyst have already been established, it is necessary to devise measures to minimize the amount of NOx produced by combustion. Professor Kobayashi's efforts will continue.



NH3 gas-turbine test facility in AIST



NH3/CH4/air fueled operation (Power generation: 41.8 kW)



NH3/air fueled operation (Power generation: 41.8 kW)

There are some advantages to ammonia besides combustion.

The most important point is that the supply chain is already established. Currently, ammonia is widely used as fertilizer and chemical raw material all over the world, and mass transportation system by tankers is already set up. Therefore, carbon-free ammonia produced overseas could be transported and stored with existing technology. Ammonia is essential for a thermal power plant to remove NOx by reacting with the catalyst. There is an ammonia tank, and the operator is accustomed to handling ammonia. Thus, it is not difficult to use ammonia as a fuel for a thermal power plant.

Professor Kobayashi and colleagues have first attempted to raise the combustion efficiency of the ammonia-fueled gas turbine to the same level as natural gas. And in the near future, they will aim to commercialize the ammonia-fueled gas turbines. They will also conduct technical development and demonstration tests based on fundamental combustion characteristics with regard to the application of ammonia reciprocal engines for transportation and heat utilization in industrial furnaces using ammonia as a fuel.