

Compressorless Gas Turbine

Detonation Burner Increases Efficiency of Energy Conversion with Hydrogen

An innovative compressorless gas turbine sets new standards in the use of hydrogen for energy supply. It is based on pressure-gain combustion: Detonation waves inside the combustion chamber generate the high pressure required. This saves energy, increases efficiency, and reduces the number of moving parts. The technology is not limited to hydrogen. However, hydrogen is particularly well suited. Unlike natural gas, hydrogen can be produced from renewable energy sources. The compressorless gas turbine, hence, marks a breakthrough in green electricity generation with hydrogen.

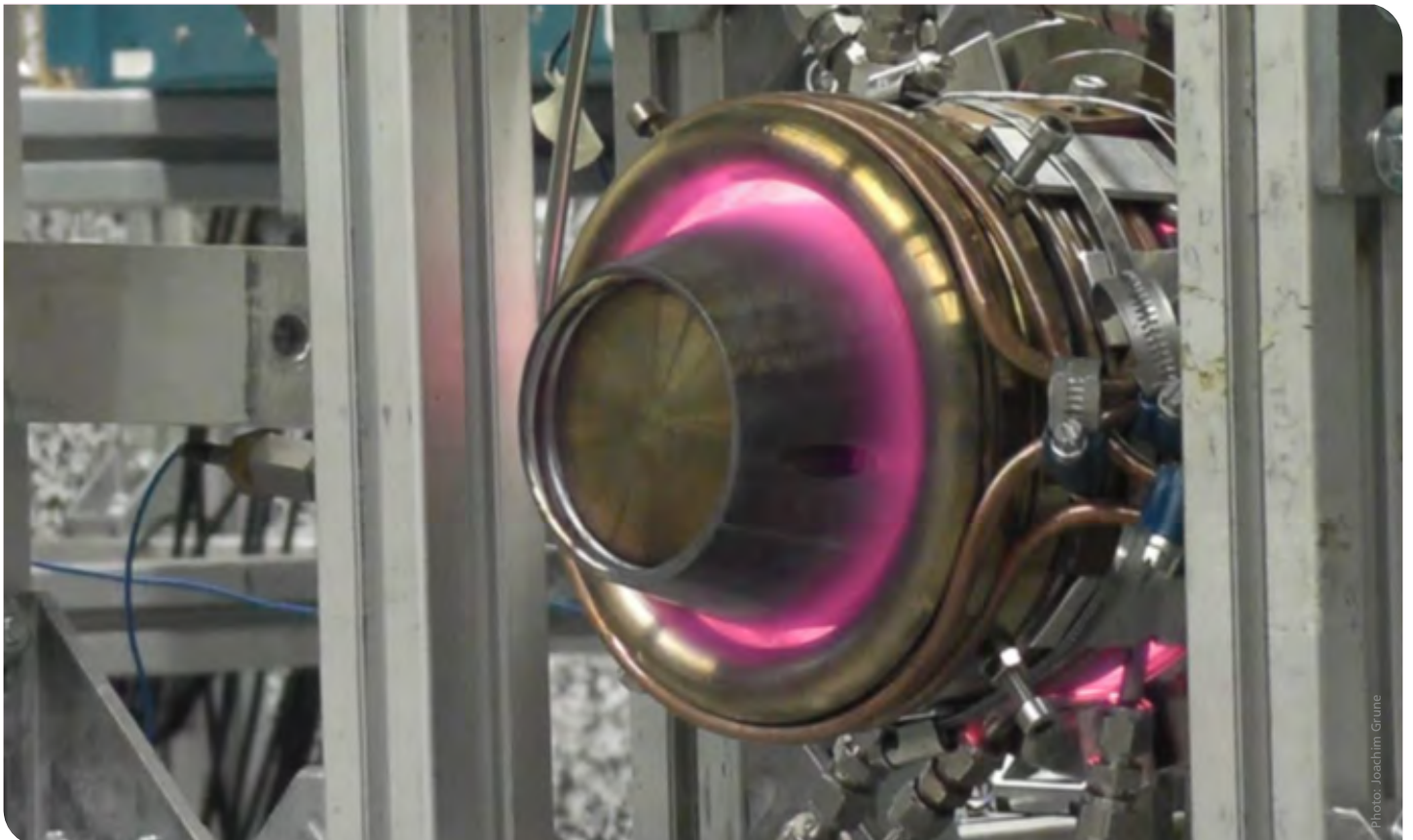
Higher Energy Efficiency – Reduced Plant Complexity

Pressure-gain combustion has been subject of intense international research for some time already. In the innovative combustion processes studied, the high pressure needed for thermodynamically

efficient combustion is generated by detonation waves. This means that energy-consuming and technologically complex compression with mechanical compressors is no longer required.

The coupled compression and combustion process achieved through the detonation wave may take place in the pulsed mode (pulsed detonation engine – PDE) or in an annular gap in the circular mode (rotating detonation engine – RDE).

So far, the corresponding technologies have primarily been studied for applications in the aircraft and space sector. Still, they also have major advantages in stationary uses, such as gas power plants, because they improve energy efficiency and reduce the complexity of the plants.



Outlet nozzle of the detonation burning chamber operated with a hydrogen-air mix.

Breakthrough for Green Electricity Generation with Hydrogen

Thanks to its research into safety technologies, the Hydrogen Department of KIT's Institute for Thermal Energy Technology and Safety (ITES) possesses outstanding expertise and know-how in the area of gas dynamics processes. Gas dynamics processes are associated with complex transient combustion phenomena, mainly detonations. Based on this expertise, the researchers set up a unique RDE experiment and demonstrator.

Characteristic features are a special geometrical design of the pre-mixing zone, the ignition mechanism, and water cooling coupled with steam injection.

With this machine, KIT researchers reached a runtime record: The burner, featuring the revolutionary pressure-gain combustion technology, operated for 303 seconds. This surpasses NASA's previous record of 250 seconds. Earlier this year, KIT researchers succeeded for the first time in generating electricity with a hydrogen gas turbine without a mechanical compressor.

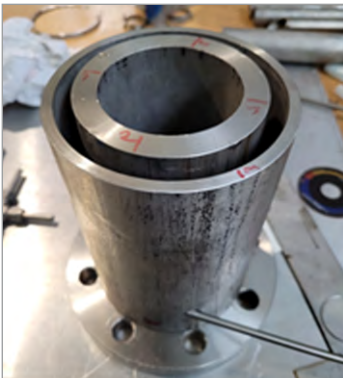
Efficiencies in Comparison

The compressorless gas turbine is based on pressure-gain combustion. Contrary to classical gas turbines (Brayton cycle), which require half of their output for air compression, detonation waves generate

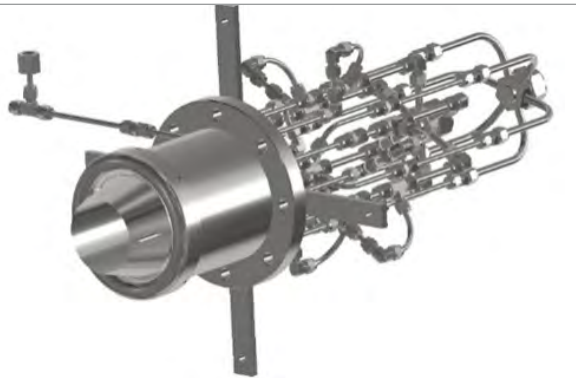
the high pressure required in the burning chamber (Fickett-Jacobs cycle). These waves are produced by combustion that is initiated by a shock wave. The energy released by combustion continues to power the shock wave. As a result, nominal efficiency can be nearly doubled compared to a conventional gas turbine operated with natural gas.

From the Component to the System

At KIT, development work has advanced to the demonstration phase. Researchers have meanwhile developed the third generation of detonation burning chambers. Development work is accompanied by numerical simulations using KIT's own CFD software and detailed measurement campaigns. Thanks to intense scientific support, KIT has reached leadership in RDE technology within three years only. In particular, coupling of the burning chamber with a turbine posed a technical challenge. The very fast and intense, but unstable combustion processes in the burning chamber made stable energy transfer to the turbine challenging. The KIT team analyzed various influencing factors and, in late 2025, succeeded for the first time in operating such a turbine and generating electricity.



Detonation burning chamber of the first generation: Without cooling, for tests of various fuel mixtures.



Detonation burning chamber of the second generation: With cooling and improved flow control (see exhibit).



Detonation burning chamber of the third generation: With improved cooling and steam injection for coupling with a turbine. (Photos: Joachim Grune / KIT)

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