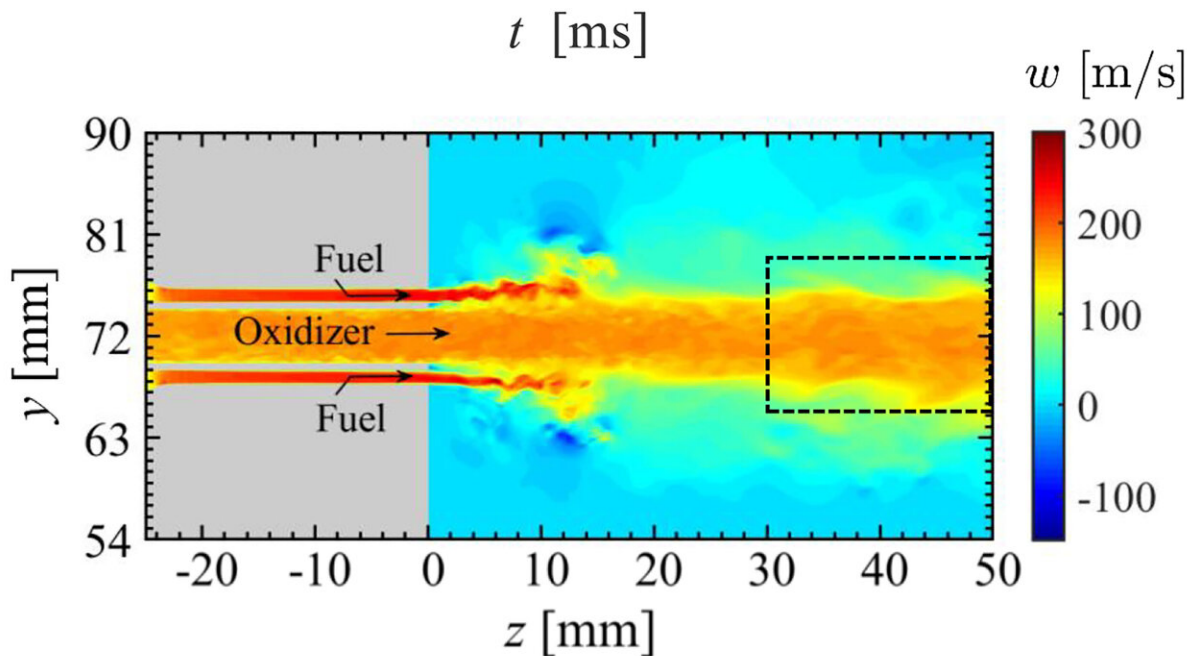


Fuel flow, heat fluctuations drive dangerous oscillations in rocket engines

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Combustion chamber during combustion oscillations in a model rocket engine.
Credit: Hiroshi Gotoda

Combustion engines can develop high frequency oscillations, leading to structural damage to the engines and unsafe operating conditions. A detailed understanding of the physical mechanism that causes these oscillations is required but has been lacking until now.

In *Physics of Fluids*, research from the Tokyo University of Science and the Japan Aerospace Exploration Agency clarifies the feedback processes that give rise to these oscillations in rocket engines.

The investigators studied simulated [combustion](#) events in a computational model of a rocket combustor. Their analysis involved sophisticated techniques, including symbolic dynamics and the use of complex networks to understand the transition into oscillatory behavior.

The symbolic dynamics techniques allowed the scientists to determine similarities in behavior between two variables that characterize the combustion event. They found a relationship between fluctuations in the flow velocity of the fuel injector and fluctuations in the heat release rate of the combustor.

A rocket engine uses injectors to deliver a fuel, typically hydrogen gas, H_2 , and an oxidizer, oxygen gas, O_2 , to a [combustion chamber](#) where ignition and subsequent combustion of the fuel occurs.

"Periodic contact of the unburnt H_2/O_2 mixture with high-temperature products of the H_2 [and] air flame gives rise to significant fluctuations in the ignition location," said author Hiroshi Gotoda.

Fluctuations in the ignition location produce fluctuations in the heat release rate, which affects pressure fluctuations in the combustor.

"We found that the heat release fluctuations and pressure fluctuations synchronize to each other," said Gotoda.

The product of the pressure and the heat release rate fluctuations in the combustor is an important physical quantity for understanding the origin of combustion oscillations. Regions where this product is greater than zero correspond to acoustic power sources that drive the oscillations.

The investigators discovered power sources in the shear layer near the injector rim. These power sources would suddenly collapse and reemerge upstream in a periodic fashion, leading to oscillations in combustion.

"The repetition of the formation and collapse of thermoacoustic source clusters in the hydrodynamic shear layer region between the inner oxidizer and outer fuel jets plays an important role in driving combustion oscillations," said Gotoda.

The investigators believe their analysis method will lead to a better understanding of the dangerous oscillations that sometimes arise in [rocket engines](#) and other combustors.

More information: "Formation mechanism of high-frequency combustion oscillations in a model rocket engine combustor" *Physics of Fluids*, aip.scitation.org/doi/full/10.1063/5.0048785

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