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**Control and simulation of thermoacoustic instabilities**[1]

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Combustion instabilities (CI), due to thermoacoustic coupling between acoustic waves and chemical reaction, constitute a major danger for all combustion systems. They can drive the system to unstable states where the whole combustor can oscillate, vibrate, quench or in extreme cases explode or burn. Such phenomena are commonly observed in the final phases of development programs, leading to major difficulties and significant additional costs. One of the most famous examples of combustion instabilities is the F1 engine of the Apollo program which required more than 1000 engine tests to obtain a stable regime satisfying all other constraints (performance, ignition, etc). CIs constitute one of the most challenging problems in fluid mechanics: they combine turbulence, acoustics, chemistry, unsteady two-phase flow in complex geometries. Since combustion instabilities have been identified (more than hundred years ago), the combustion community has followed two paths: (1) improve our understanding of the phenomena controlling stability to build engines which would be "stable by design" and (2) give up on a detailed understanding of mechanisms and add control systems either in open or closed loop devices to inhibit unstable modes. Of course, understanding phenomena driving combustion instabilities to suppress them would be the most satisfying approach but there is no fully reliable theory or numerical method today which can predict whether a combustor will be stable or not before it is fired. This talk will present an overview of combustion instabilities phenomenology before focusing on: (1) active control methods for combustion instabilities and (2) recent methods to predict unstable modes in combustors. These methods are based on recent Large Eddy Simulation codes for compressible reacting flows on HPC systems but we will also describe recent fully analytical methods which provide new insights into unstable modes in annular combustion chambers.

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