THESE

Characterization of unsteady flow behavior by linear stability analysis

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Linear stability theory has been intensively used over the past decades for the characterization of unsteady flow behaviors. Unfortunately, none of the numerous existing approaches has the ability to address any general flow, and clear validity conditions for these techniques are often missing. In this thesis, this is addressed by first considering the classical base flow stability approach, which focuses on small disturbances about a steady solution of the Navier-Stokes equations.

To this end, underexpanded screeching jets are studied, and their nonlinear dynamics is found to be well-predicted by a linear base flow stability analysis. A confrontation with other similar analyses from the literature shows that such a satisfactory result is not always observed. However, when a self-sustained oscillating flow is driven by an acoustic feedback loop, as it is the case for the screech phenomenon, then the impact of nonlinearities on the frequency selection process seems weak, explaining the ability of a linear analysis to characterize the flow.

Another alternative approach, based on a linearization about the mean flow, is known to be successful in some cases where a base flow analysis fails. This observation from the literature is explained in this thesis by outlining the role of the resolvent operator, arising from a linearization about the mean flow, in the dynamics of a flow. The main finding is that if this operator displays a clear separation of singular values, which relates to the existence of one strong convective instability mechanism, then the Fourier modes are proportional to the first resolvent modes. This provides mathematical and physical conditions for the use and meaning of several mean flow stability techniques. Moreover, it leads to a predictive model for the frequency spectrum of a flow field at any arbitrary location, from the sole knowledge of the mean flow and the frequency spectrum at one or more points. This is proven useful in some experimental applications, in order to reconstruct an unsteady flow without the need of time-resolved Particle Image Velocimetry.

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Composition du jury

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