Acoustic receptivity of the supersonic boundary layer subject to spanwise-periodic surface heating

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We investigate the receptivity to free-stream acoustic waves of a supersonic boundary layer that is subjected to streamwise-elongated, spanwise-periodic surface heating. Attention is focused on the generation and evolution of the lower-branch viscous instability modes which acquire a triple-deck structure. Due to the presence of intense surface heating, three-dimensional velocity and thermal streaks are induced in the boundary layer and acquire an $O(1)$ magnitude. The incident sound wave interacts with the streaky flow to produce harmonics with different spanwise wavenumbers in the reflected waves and the boundary-layer response, which are calculated using the triple-deck formalism and Floquet theory. A typical result is shown in Figure 1. The reflected sound is very strong in narrow strips in the $\alpha - \omega$ plane (Figure 1b). Moreover, for certain frequencies and wavenumbers of the sound wave, the forced response has the same temporal and spatial scales as those of the neutral instability mode of the streaky flow, leading to a resonance of the incident sound wave with the instability mode. The latter is thereby excited near the lower branch of the neutral curve. Through asymptotic analysis of the resonance region, the amplitude of the excited instability mode is derived which allows us to determine the coupling coefficient. A distinctive feature of strong streaky flow is that the instability mode generated is much stronger than the impinging wave, indicating that the receptivity mechanism is particularly efficient.

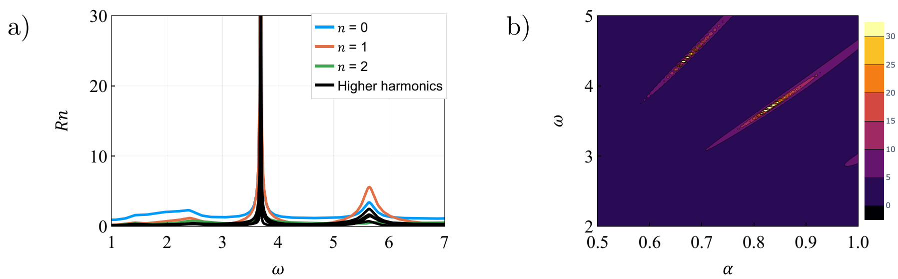

Figure 1: Boundary-layer response to free-stream acoustic waves. (a) normalised amplitudes of reflected waves with different spanwise wavenumbers $n\beta_s$ for $\alpha = 0.83$, where $\beta_s = 1$ is the wavenumber of the streaks. (b) contours of R_1, the normalised amplitude of the first oblique component, in the $\alpha - \omega$ plane, where α and ω are wavenumber and frequency of the incident sound wave.

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