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COMMENTARY

Notes on the hypersonic boundary layer transition

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Abstract

A brief discussion is given in this note to clarify the transition path of the hypersonic boundary layer. The first mode plays an important role in the hypersonic boundary layer transition and should not be ignored. The second mode may enhance the boundary layer transition, but it is not the decisive factor affecting the transition.

Keywords: Boundary layer, Hypersonic, Transition

1 Main text

We note a recent publication by Zhao et al. [1] in Advances in Aerodynamics. The citation of our work (Reference 5 in the article by Zhao et al. [1]) is stated as "The first mode is dominant at low Mach numbers, but as the Mach number increases, the Mack second mode leads to the transition". We feel the need to clarify our views and have a benifical discussion in the future. In fact, the research group at Peking University believes that the first mode plays a dominant role in the boundary layer transition at both low and high Mach numbers [2, 3].

The Mack second mode belongs to the family of trapped acoustic waves, propagating between the relative sonic line and the wall [4]. At high Mach numbers, the second mode grows rapidly due to the existence of a relatively supersonic region within the boundary layer. The research group at Peking University identified that the first mode leads to the transition directly in the hypersonic boundary layer, and the second mode decays before transition, although it obtains a high amplitude. The boundary layer transition is closely related to the first mode, which has also been observed in previous experiments [5, 6] and numerical simulations [7].

Transition refers to the process in which the flow changes from regular laminar flow to disorderly turbulent flow. A notable feature of this process is the significant growth of nonlinear disturbances, and the flow becomes three-dimensional. In the hypersonic wind tunnel experiments, the research group at Peking University showed that the second mode grows, saturates and decays before the transition, while the first mode keeps growing in the hypersonic boundary layer [8, 9]. Theoretical results show that the rapid growth of the low-frequency mode is due to the rapid growth of linear terms from the meanflow, rather than being caused by the second mode directly. The second mode only enhances the ability of low-frequency modes to obtain energy from the meanflow by changing their perturbation profile [10]. Further analysis showed that the first mode is related to the viscous force and inertial force and the shear of the fluid; the second mode in the hypersonic boundary layer is related to the compression and expansion of the fluid [11, 12]. It was shown that heat generation within the hypersonic boundary layer is comprised of dilatation and shear processes. Dilatation heating, due to pressure, dominates the early transitional high-temperature region. Shear-induced heating is the dominant process creating the latter hightemperature region, where the transition is almost complete [13].

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Author's contributions
Wenkai Zhu contributes all the contents in this paper. The author read and approved the final manuscript.

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Availability of data and materials
All the datasets are available upon request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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