Stability and Transition: Theory and Application

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Laminar-turbulent transition prediction is an important element of aerodynamic design because it has a strong impact on aerodynamic drag prediction, thermal protection requirements, and the performance of air-breathing engines. Despite progress in the understanding of the underlying mechanisms of the transition phenomenon, there are still many unanswered questions that limit the value of any given method of transition prediction. Therefore, designers need to understand the foundation of prediction methods, as well as their limitations.

The available methods of transition prediction include a number of correlation methods and the most "rigorous" one—the e^N method—is based on the stability analysis of boundary-layer flows, accompanied by an evaluation of possible amplitude growth factors, and on the correlation of the N value to a variety of experimental conditions. Currently the e^N method is applied to two- and three-dimensional flows and encompasses the entire range of speeds. Owing to the complexity of the underlying processes responsible for laminar-turbulent transition, applications of the method have to be based on a good understanding of possible transition scenarios. The book is devoted mainly to the e^N method.

One can expect from the title that the book addresses the theoretical and practical aspects of transition prediction and that it aims to provide guidance in industrial applications. To proceed with the review, I would like to delineate the scope of the book with a citation from the preface (pp. v, vi): "The main concern is transition of wall boundary layers, although one chapter is devoted to an approach based on the Navier–Stokes equations. The first three chapters summarize physical knowledge of the transition process...." After reading the first three chapters, I still did not understand what this "physical knowledge" means. The book is also not as timely as one would expect; for example, of the references in the book, only eight (except four books and two papers by the author) are dated from the 1990s. The others are dated from the 1980s or earlier. The reader cannot find a contemporary understanding of the receptivity (I could not even find the word in the text) problem and of transition scenarios. Consequently, the reader will not understand from this book what the limitations of the e^N method are.

This lack of currency is the probable cause of the confusion between the temporal and the spatial stability theories as evidenced by this extract (p. 33 and the same statement on p. 29): "The spatial amplification theory is preferred since the amplitude change of the disturbance with distance can be measured in a steady mean flow. The amplitude at a fixed point is independent of time and the spatial theory gives the amplitude change in a more direct manner than does the temporal theory." Today, we know that these two formulations of the linear stability problem represent two different physical problems. The first one may be referred to as an initial-value problem (wave packet).[1] The second one may be illustrated as the signaling problem (wave train).[2,3] In the first case, the solution might be represented by the modes of discrete and continuous spectra of the temporal theory, whereas the solution of the second problem is associated with the modes of discrete and continuous spectra of the spatial theory.

In addition to jargon such as "eigenvalue procedure for transition," the reader encounters an incorrect interpretation of the quasi-parallel approximation. For example, the author finds justification of the quasi-parallel approximation in that "the mean flow changes more slowly in the streamwise direction than in the wall-normal direction" (p. 185). Actually, this is a justification of the boundary-layer approximation for the mean flow only. For quasi-parallel approximation in stability analysis, we require that the characteristic scale of the perturbation in the streamwise direction be much smaller than the characteristic scale of the mean flow.

To summarize, the "Theory" presented in the book is too outdated to be used confidently today. If the reader is going to use the e^N method, I recommend reviews,[4–6] which contain a brief outline of the problem, a discussion of the method's background, and an analysis of possible pitfalls.

The other part of the book ("Application") deals with the description of numerical codes and numerical methods designed for solving the stability equations for two- and three-dimensional compressible and incompressible flows. A reader working on the development of stability codes could probably find this part useful because it presents the author's experience in computation of aerodynamic flows. However, in this part, too, the reader can find a number of flaws. Particularly, the author makes statements that are not supported by proof or by an appropriate reference that would explain the subject to the reader. For example, in Chapter 8, which is devoted to parabolized stability equations, we find the following statement (p. 191): "It has been shown that this system of equations is ill-posed as an initial value problem, but stable marching solutions can be derived if one of the following restrictions are [*sic*] observed...." The text does not provide a reference relevant to this statement. At this point, the reader should be directed, for example, to Refs. 7–9. Moreover, in this chapter, the book does not have a reference to the review by Herbert.[10] The reference would be especially helpful to the reader because the fundamental idea to separate "fast" and "slow" scales is not outlined properly in the book (the latter also caused the confusion about the quasi-parallel flow approximation). In addition, the "Application" part does not provide references to modern, state-of-the-art methods, and the reader will not encounter descriptions of developments during the past decade in academic and government aerospace institutions (see, for example, Ref. 11).

To conclude, I do not expect the book to appeal to readers in the academic community, and I am doubtful that it will be of substantial help to aerospace engineers looking for guidance on how to predict laminar-turbulent transition.

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