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Downstream flow condition effects on the RR → MR transition of asymmetric shock waves in steady flows

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In this paper, the regular reflection (RR) to Mach reflection (MR) transition of asymmetric shock waves is theoretically studied by employing the classical two- and three-shock theories. Computations are conducted to evaluate the effects of expansion fans, which are inherent flow structures in asymmetric reflection of shock waves, on the RR → MR transition. Comparison shows good agreement among the theoretical, numerical and experimental results. Some discrepancies between experiment and theory reported in previous studies are also explained based on the present theoretical analysis. The advanced RR → MR transition triggered by a transverse wave is also discussed for the interaction of a hypersonic flow and a double-wedge-like geometry.

1. Introduction

It is well known that for shock wave reflection in a steady flow at a sufficiently high Mach number, more than one global solution is compatible with the conservation laws and the applied boundary conditions. This leads to what is known as the dual solution. In the dual-solution domain, both regular and Mach reflection patterns (denoted by RR and MR) are locally stable for a given time history, as shown in figure 1. Intensive analytical, experimental and numerical investigations have contributed much to the understanding of the physics underlining shock wave reflection in the last few decades. The reflection phenomena of shock waves in steady, pseudo-steady and unsteady flows were summarized by Ben-Dor (1991). Shock polars for two-dimensional shock wave interactions are bounded and not monotonic, which may, consequently, have no intersection or more than one intersection in the graphical construction. When no intersection exists, the problem of non-existence is resolved with more complex wave patterns: either with transonic curved shocks or with composite wave patterns. The wave patterns of the former are not steady but may be pseudo-steady. Composite wave patterns, including single-Mach reflection, transitional-Mach reflection and double-Mach reflection, consist of multiple simple nodes separated by smoothly varying flows (see Henderson 1990; Henderson, Colella & Puckett 1991; Henderson & Menikoff 1998). In these cases, the time-dependent boundary conditions or downstream boundary conditions can cause a wave pattern to bifurcate or change the form. Bifurcations can be triggered by acoustic waves impacting a node or can be forced by a sudden change in geometry. The state of the

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