# Readers' Forum

## The Mach Reflection Phenomenon: A Suggestion for an International Nomenclature

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### Introduction

THE Mach- reflection phenomenon, first reported more than one hundred years ago by Ernst Mach, continues to be studied by many investigators throughout the world. As a result of this activity, a series of symposia devoted entirely to the subject of shock-wave reflection has been held in recent years in Canada, Australia, Germany, and Japan. Future symposia are planned in the United States and Israel.

One of the recommendations generated at these symposia was that a common nomenclature be used to describe the various shock reflection phenomena in order to improve communication between the various investigators. It became apparent that some confusion has occurred as a result of workers using similar, but not identical, nomenclature and that the goal of encouraging investigators from various institutions to undertake collaborative research involving different approaches, such as analysis, numerical simulation, and experiment, could be better achieved using a common set of descriptions.

The following suggestions are based on discussions held during the first three symposia. They are planned principally for pseudosteady flows. However, owing to the similarity between the phenomenon in steady, pseudosteady, and truly unsteady flows, it is believed that the suggested nomenclature will also cover these types of flow.

### Suggested Nomenclature

The shock-wave reflection phenomenon can be divided into two basic categories: RR—regular reflection, and MR—Mach reflection. Three categories of Mach reflection are recognized: SMR—single-Mach reflection; CMR—complex-Mach reflection; and DMR—double-Mach reflection.

Typical configurations of RR, SMR, CMR, and DMR are shown in Figs. 1, 2, 3, and 4, respectively. It is suggested that whenever possible the incident shock wave be drawn as moving from left to right. This simplifies comparisons with numerical simulations using Cartesian coordinates.

While the RR consists of two discontinuities, an incident shock and a reflected shock, the MR consists of four discontinuities, an incident shock, a reflected shock, a Mach stem, and a slipstream.

It is suggested that these four discontinuities be identified as follows: $i$, incident shock; $r$, reflected shock; $m$, Mach stem; and $s$, slipstream.

In the case of a DMR, illustrated in Fig. 4, there are two additional discontinuities arising from the second triple point, and it is suggested that these be identified as $m_1$, the second Mach stem shock, and $s_1$, the second slipstream. Further, if it is necessary, the reflected shock behind the second triple point may be identified as $r_1$.

For a nonsteady Mach reflection it is important to define the angle between the wedge surface and the triple point trajectory. We suggest $\chi$, triple point trajectory angle. In the case of a steady flow, $\chi$ is meaningless and should be replaced by $\lambda$, the length of the Mach stem. The trajectory angle of the second triple point in a DMR may be designated as $\chi_1$.

A number of points associated with the various reflections also need to be defined:

$G$, the point of reflection on the wedge surface. In the case of a RR this is also the point where $i$ and $r$ meet. In the case of a MR this is the point where the foot of the Mach stem touches the wedge surface.

$T$, the triple point, where $i$, $r$, $m$, and $s$ meet in a MR.

$T_1$, the second triple point, where $r$, $m_1$, $s_1$, and $r_1$ meet in a DMR.

$K$, the location of the kink in the reflected shock wave in a CMR.

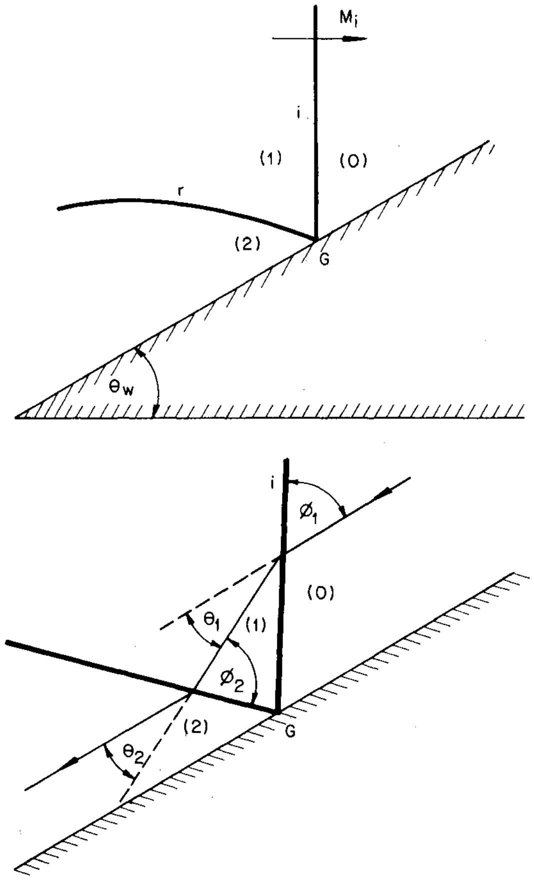


**Fig. 1 Regular oblique reflection of a plane shock (RR). Top: unsteady case in which the incident shock moves with Mach number $M_i$. Bottom: same reflection, but shock configuration has been made pseudosteady by superposing on the flowfield a velocity equal and opposite to that of reflection point $G$.**

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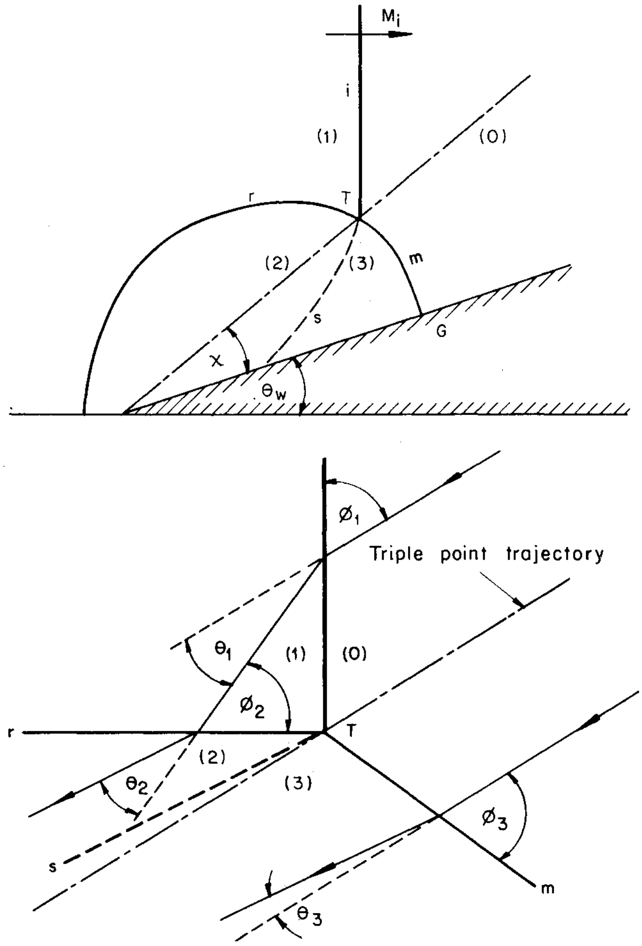


Fig. 2 Single Mach reflection of a plane shock (SMR). Top: unsteady case with a moving incident shock. Bottom: the pseudosteady flowfield in the region of the triple point $T$ produced by superposing a velocity equal and opposite to that of the triple point.

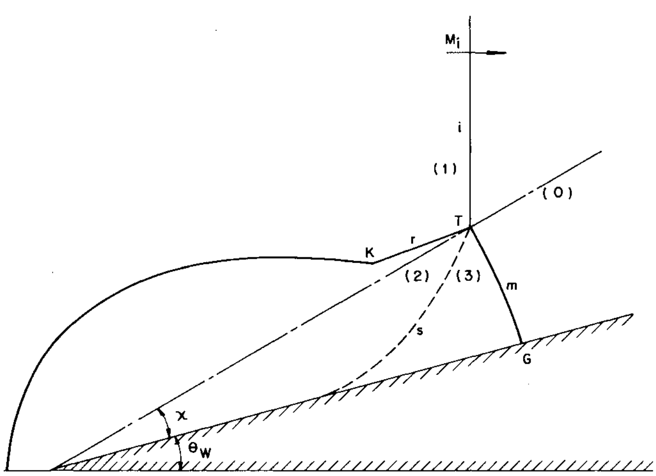


Fig. 3 Complex Mach reflection of a plane shock (CMR). With the appropriate values of the incident shock Mach number $M_i$ and wedge angle $\theta_w$, the reflected shock develops a discontinuity or kink at $K$, but the flow in region 2 has no discontinuities.

For the flow regions between the various discontinuities, it is suggested to use:

state (0), ahead of the incident shock wave.

state (1), behind the incident shock wave.

state (2), behind the reflected shock wave.

state (3), behind the Mach stem.

state (4), between the reflected shock and the second slipstream of a DMR.

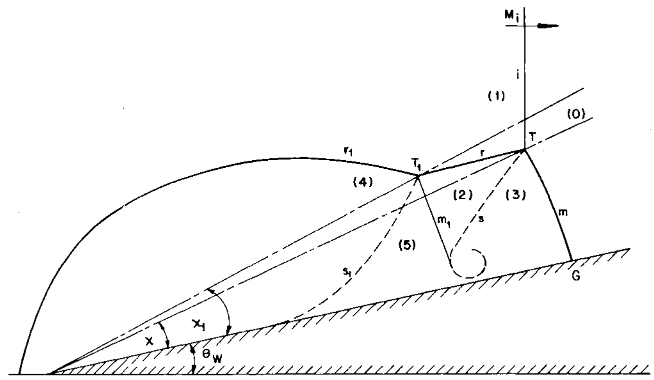


Fig. 4 Double Mach reflection of a plane shock (DMR). With appropriate values of incident shock Mach number $M_i$ and wedge angle $\theta_w$, a second Mach stem shock $m_1$ is formed, meeting the reflected shocks $r$ and $r_1$ at $T_1$. The second slipstream $s_1$ separates regions 4 and 5. The two triple points $T$ and $T_1$ have separate trajectories at angles $\chi$ and $\chi_1$, respectively, to the wedge surface.

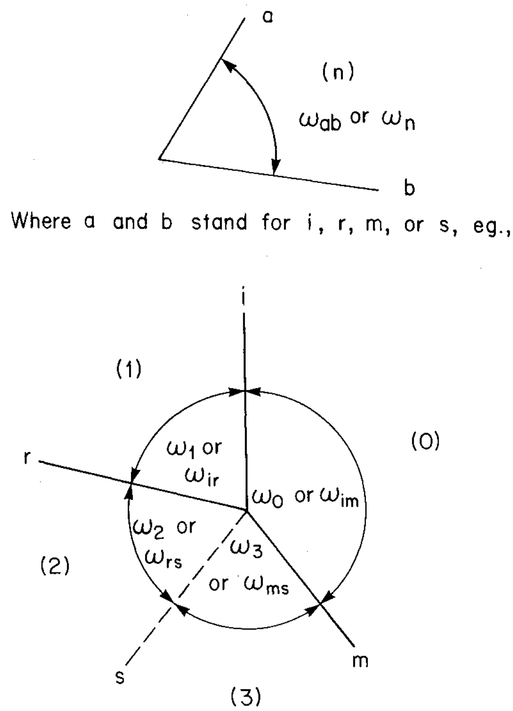


Fig. 5 Angles between shocks or slipstreams at a triple point designated using the subscript of the region in which they lie, or the double subscript of the bounding discontinuities if there are ambiguities such as may occur in region 2 of DMR.

state (5), between the second Mach stem and slipstream of a DMR.

In order to define angles between the various discontinuities, it is suggested to reserve $\omega$ and use it in one of the following ways. In the cases of RR, SMR and CMR, there is no ambiguity if $\omega$ is subscripted by the number of the region in which it lies, as shown in Fig. 5. For DMR such a nomenclature leads to ambiguities in region 2, and it is suggested that $\omega$ then be subscripted by the symbols associated with the bounding discontinuities, e.g., $\omega_{rs}$, $\omega_{rm_1}$, and $\omega_{m_1s}$.

Other important angles associated with the reflection phenomenon are the wedge angle, the angle of incidence in a pseudosteady frame between the oncoming flow and the shock wave it passes through, and the angle by which this flow is deflected while passing through the shock.

We suggest: $\theta_w$, the reflecting wedge angle; $\phi$, the angle of incidence; and $\theta$, the angle of deflection.

Angles of incidence and deflection are associated with each shock wave, and in order to avoid ambiguity, it is suggested that they be subscripted according to the region behind the shock, as illustrated in Figs. 1 and 2.

It is suggested that $V$ and $M$, with the appropriate subscript, be used for the velocity and Mach number, respectively, of shock fronts and points. For example:

$M_i$, Mach number of the incident shock.

$M_m$, Mach number of the Mach stem shock.

$V_G$, velocity of the foot of the Mach stem along the wedge surface.

$V_{T_l}$, velocity of the second triple point.

Particle velocities may be designated by $U$, subscripted according to the appropriate region, for example, $U_2$, particle velocity behind the reflected shock.

It is important to note that the second triple point $T_l$ is moving with respect to the first triple point $T$. Consequently, it is suggested that dynamic flow properties, such as velocities, be marked by a superscript $T$, $T_l$, or $G$ to identify the frame of reference to which they are related. For example, the flow velocity in state 2 behind the reflected shock wave $r$ is $U_2^T$, with respect to the first triple point ($T$) and $U_2^{T_l}$, with respect to the second triple point ($T_l$). Using this notation, one can write

$$U_2^T = U_2^{T_l} + V_{T_l}^T$$

where $V_{T_l}^T$ indicates the velocity vector of the second triple point ($T_l$) with respect to the first triple point ($T$).

It is furthermore suggested to define $\theta_T = \theta_W + \chi$ and $\theta_{T_l} = \theta_W + \chi_l$.

## Conclusions

The foregoing suggestion of an international nomenclature for the description of Mach reflection basically covers the phenomenon in steady, pseudosteady, and truly unsteady flows. Although there may be circumstances in which its use would be inappropriate, adoption would make it easier for scientists to understand each other's works and to compare analytical, numerical, and experimental results obtained by different investigators.

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