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ON CERTAIN PECULIARITIES OF THE SHOCK WAVE REFLECTION

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The present paper discusses the results, both theoretical and experimental, in author's opinion most important for understanding the formation of a quasi-stationary reflection of a plane shock wave at a wedge. The peculiarities of the behaviour of the shock wave in close vicinity of the leading edge of the wedge are reported. The differences between the stationary shock reflection in the wind tunnel, and the quasi-stationary one in a shock tube, are specified. It is concluded that these two kinds of reflection can be equivalent only in the case of strong shocks.

1. Introduction

The phenomenon of shock wave reflection has been known to the scientific community nearly as long as the shock wave itself. It was the year 1878 when Ernst Mach announced the discovery of the irregular type of reflection, called thereafter "the Mach reflection" [1]. Still, not all peculiarities of this phenomenon are fully understood even now.

Recently quite a lot of research work has been undertaken in this area (see [2] and the papers quoted there). The aim of the present paper is to clarify certain points on the basis of the most recent, and also some older, experimental and theoretical results.

Of course, all problems of shock reflection would largely exceed the scope of this paper. We shall confine ourselves mainly to quasi-stationary reflections: of weak shock in general, and of strong shocks in the vicinity of the leading edge of the reflecting wedge. We shall not discuss the double and multiple Mach reflections, truly nonstationary reflections from curved surfaces and other problems of similar type.

2. Shock wave reflection – stationary case

Shock wave is a wave of a very particular nature. For its existence some dependence of sound speed on other properties of the medium is required. Small disturbances, e.g. weak compression waves, can increase the sound speed and, in consequence, overtake each other to form a finite, sometimes very large jump of parameters. This jump, the "shock wave", occurs in a narrow region, whose thickness is of the order of a few mean free paths of the gas particles at its low-pressure side.

The shock wave in air at normal conditions is about 0.1 μm thick and it is frequently treated as a discontinuity. However, in certain situations, like e.g. high altitude flights, the shock thickness may be comparable with the dimensions of the flying object, and then, of course, cannot be neglected.

The distributions of the gas parameters inside the shock wave (commonly called "the shock wave structure") can be described with a functional dependence, close to the hyperbolic tangent. In fact, the hyperbolic tangent describes exactly the structure of a very weak shock [3].

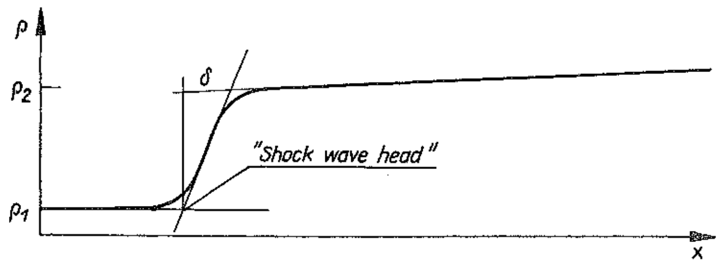

FIG. 1. Density distribution in a plane shock wave.

As the hyperbolic tangent extends from minus to plus infinity, a simple definition, attributed to Ludwig Prandtl, of the so-called "maximum slope shock thickness" has been introduced, as shown in Fig. 1.

The reader interested in the structure of the plane shock waves can be referred e.g. to the survey paper [4].

If the flow containing a shock wave encounters a solid wall, it may happen that one or more new shocks are produced because of interaction of the existing ("incident") one with the wall. This is called "shock reflection".

Consider the situation sketched in Fig. 2a. At the right-hand side of the flow field the gas is moving at a supersonic speed along a horizontal plane wall. A wedge, placed above the wall, produces an "incident", oblique shock

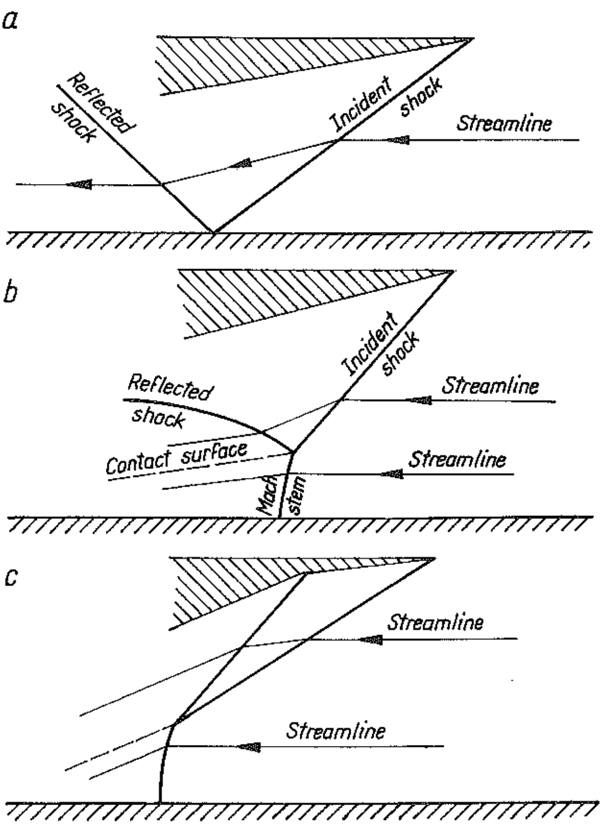

FIG. 2. Stationary case: a) regular reflection of an oblique shock wave, b) irregular reflection of an oblique shock wave, c) interaction of two oblique shock waves.

wave. The flow behind this wave is directed downwards. As the velocity at the wall must be parallel to it, the flow is then turned back to the horizontal direction. In the case of a supersonic speed this can be done only in the second shock wave – the "reflected" one. The described situation is usually called "the regular reflection of the oblique shock wave".

If the flow Mach number behind the incident shock is not high enough, or the angle between the shock and the wall is too large, it may not be possible to turn the flow back to the horizontal direction in a single reflected shock. The "reflection point" (where the incident and reflected shocks meet) moves upwards and a third shock ("Mach stem") is generated to connect the reflection point (now the "triple point") with the wall. (Fig. 2b). Behind the "triple point" an additional discontinuity, the "contact surface" appears, since the parameters of gas, which passed two shock waves are different from those for the gas, which passed only one. Such a flow configuration is commonly called "irregular"or "Mach-type" reflection of the shock wave.

The shock wave reflection has been a subject of the work of many investigators, both theoreticians and experimentalists. The most recent description of the "state of art" in understanding the problem was given by H.Hornung in an excellent review, published in 1986 [2].

3. Von Neumann's theory of shock reflection and its consequences

Assume, that all shocks (the incident, reflected and, possibly, the Mach stem) and also the contact surface, if present, are plane and of zero thickness. Assume that all parts of the flow field, separated by the shocks and the contact surface, are uniform. The Rankine–Hugoniot conditions, written for all the shocks, constitute then a set of equations, describing the phenomenon. For the Mach reflection this set is not closed. To close it one should simply note, that at both sides of the contact surface the pressures are equal and the velocities are parallel.

The resulting equations will not be presented here. They can be found e.g. in the paper by Ben-Dor [5]. The whole description of the problem is commonly called "the von Neumann's theory", as J. von Neumann was one of the first, who formulated it [6].

To show certain consequences of the von Neumann's theory, the "shock polar" diagram $p = p(\theta)$ (Fig. 3) will be used. Here p is the pressure behind the shock, θ – the flow deflection angle. This diagram is particularly well suited for illustrating both the regular and the Mach reflections:

Regular reflection (Fig. 3a): the point R, where the reflected shock polar intersects the vertical axis, corresponds to the region behind the reflected shock – the net deflection of the flow behind the two shocks (the incident and the reflected) is zero, as expected for the neighbourhood of the plane wall.

Mach reflection (Fig. 3b): the condition at the wall cannot be fulfilled, as the reflected shock polar does not intersect the vertical axis. The point of intersection of the shock polars (M or F in Fig. 3b) corresponds to the region behind the reflected shock as well as behind the Mach-stem shock, since at this point the pressures and the deflection angles in both regions are the same.

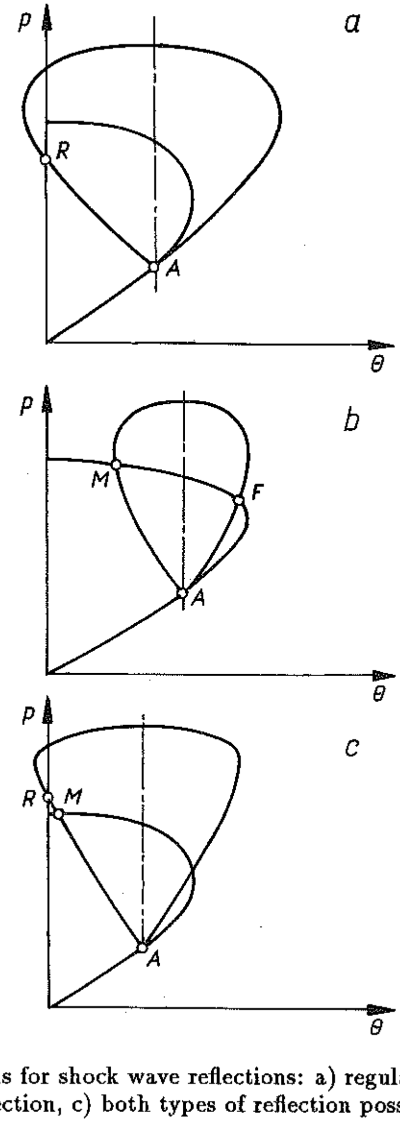

FIG. 3. Polar diagrams for shock wave reflections: a) regular reflection, b) irregular reflection, c) both types of reflection possible.

A – state behind the incident shock, R – point corresponding to regular reflection, M – point corresponding to irregular reflection, F – point corresponding to Fig. 2c.

For all real shock reflections the interaction point of the polars stays always between the axis of symmetry of the reflected shock polar and the p-axis (point M). If such a point exists, the reflection is called "strong Mach reflection". If not, we have the "weak Mach reflection" and the presented theory does not correspond to the real flow, encountered in the experiment. Other intersection points, like point F in Fig. 3b, either correspond to some special flow cases (e.g. Fig. 2c) or have no physical meaning at all.

The polar diagram shown in Fig. 3c may correspond to both, the regular and the Mach reflections. The choice depends on the whole flow field. The situation is described best by the "information condition", as first formulated by HORNUNG *et al.* [7]. As the distance from the triple point to the wall constitutes a length scale depending on the geometry of the walls, the Mach reflection occurs when this length scale can be communicated from the walls to the triple point. If this is not possible, the regular reflection takes place.

4. QUASI-STATIONARY SHOCK REFLECTION AT A WEDGE

In the preceding chapters only the stationary shock reflections were considered. The shocks were motionless in the laboratory frame of reference and the gas was moving at a supersonic speed. It happens often that shock wave, travelling in a quiescent gas, encounters on its way an obstacle – a reflecting wedge (Fig. 4). It is commonly considered that this case is equivalent to the former one, provided that the shock is plane, moves at constant velocity and the reflecting surface of the wedge is also plane. If this is fulfilled, a Galilean transformation exists, which transforms the phenomena, nonstationary in the laboratory frame of reference, into quasi-stationary, in the frame of reference connected with the reflection point.

The quasi-stationary reflection, as described here, is however not always fully equivalent to the stationary one. In the two cases, the shapes of the flow boundaries are different. In addition to that, the stationary and nonstationary boundary layers are of different character. The two cases are therefore equivalent only if the flow behind the reflected shock is supersonic relative to the reflection point. If this is fulfilled, the information from the boundary cannot reach the reflected wave, so it is irrelevant to the reflection process.

It should be noticed here too that, in order to produce the stationary shock reflection, the suitable supersonic flow is generated in a wind tunnel

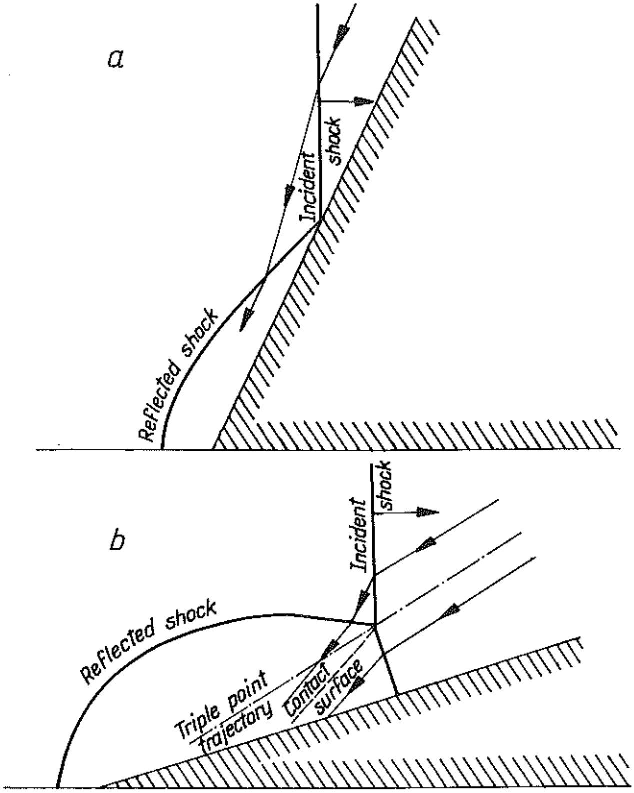

FIG. 4. Reflection of a moving shock wave from a wedge: a) regular, b) irregular.

of some kind. The incident shock results from interaction of the flow with the wedge, immersed in it. For flows which are only weakly supersonic, the wind tunnel may "choke" because of the presence of the wedge, and the expected incident shock may not appear.

Nothing of this kind can happen at the reflection of the moving shock. In the quiescent gas a shock wave of any strength can be produced with relative ease. It is also possible to place on its way a wedge of arbitrary shape. The experiments [8–10] indicate, that in such a case the reflected shock appears always, no matter whether and where the shock polars intersect each other.

It should be noted, however, that if the shocks are weak, the wave reflected irregularly is always curved and the flow behind it is nonuniform, which is contrary to the assumptions of the von Neumann's theory. It is not surprising then, that the experimental results, obtained mainly in shock tube flows (with incident waves moving in a quiescent gas), for weak shocks disagree with predictions of this theory.

5. Theoretical solutions for Mach reflection of weak shocks

Because of inapplicability of the von Neumann's theory to weak shocks, the theoreticians attempted at finding some other solutions, valid in this case. Among the first solutions of this type the best known ones are due to GUDERLEY [11] and SAKURAI [12], although other attempts should also be recognized.

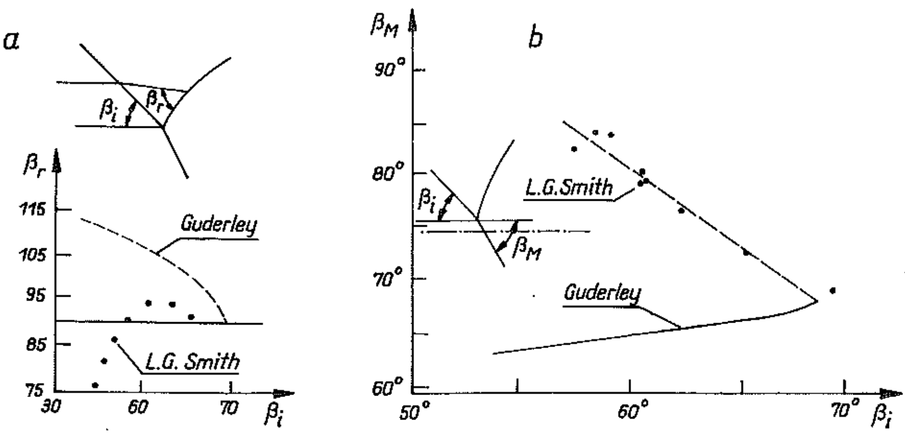

FIG. 5. Comparison of Guderley's theory and experiment for shock wave angles at the triple point. Air; Ms = 1.102; a) reflected shock, b) Mach stem. Reproduced from STERNBERG [13].

The Guderley's solution was supposed to explain the existence of the Mach reflection of weak shocks, as reported by the experimentalists, when the shock polars did not intersect. It assumed that the pressures at both sides of the contact surface behind the triple point were equalized by an additional rarefaction wave. However, no experiment confirmed the existence of such a wave. Besides this, as shown e.g. by STERNBERG [13], the angles between the shocks predicted by this solution differed very strongly from those obtained experimentally (Fig. 5).

The protagonists of the Guderley's solution argued, that the rarefaction wave is invisible with the usual optical methods (shadow, schlieren, interferometry), because it occupies very small area and the spatial resolution is not sufficient to detect it. Besides this, both the reflected and Mach waves are strongly curved in the neighbourhood of the triple point, therefore the angles are never measured at the proper location. The argument was not solvable as long as only the optical methods, requiring relatively high gas densities, were available. We shall return to the problem later, when discussing the recent experimental results.

STERNBERG [13] was perhaps the first who proposed to relax the von Neumann's conditions at the contact surface. In his extensive study, published in 1959, he argued that viscosity transforms the contact surface into a broad zone, which can support a finite pressure difference and have different velocity directions at both sides. As this required new conditions to close the system of equations, he argued that the flow in the whole region behind the shocks should be solved. Sternberg's argument was based on the order-of-magnitude estimation of the possible influences, therefore it required future confirmation.

Akira SAKURAI in the paper published in 1964 [12] solved the flow equations locally, between the reflected and the Mach shocks, in close neighbourhood of the triple point. He took into account viscosity and thermal conductivity of the medium; however, the shocks were assumed to be infinitely thin. Their inclination angles were calculated from the Rankine–Hugoniot relations.

Sakurai's solution agreed well with experiment for the weakest measurable shocks. The agreement became worse at increasing strength. With the present understanding of the phenomenon such a behaviour seems to be easy to explain. Sakurai's solution does not take into account the conditions at the boundaries. Therefore, if the flow behind the reflected shock is subsonic and the conditions at the boundaries are important, this solution cannot be correct. However, in the limit of infinitely weak waves, the shocks are actually sound waves, subject to the laws of acoustics. The influence of the walls is then of no importance, and it is not surprising that the agreement with experiment is good.

Sakurai's paper made it possible to understand that, even if viscosity and thermal conductivity are taken into account, the local solutions cannot describe properly the irregular reflection of the shock wave when the flow behind the reflected shock is subsonic. In this case the Sternberg's idea of solving the whole flow field should be applied.

6. Contemporary numerical solutions for flows with shock wave reflections

Rapid development of fast computers made it possible to calculate many complex flows. The shock wave reflection, being relatively simple, and not very difficult for experimental investigation, was often used as a test case for numerical codes. Quite recently a series of papers presented numerical solutions to the Euler equations for irregular shock wave reflections at vari-

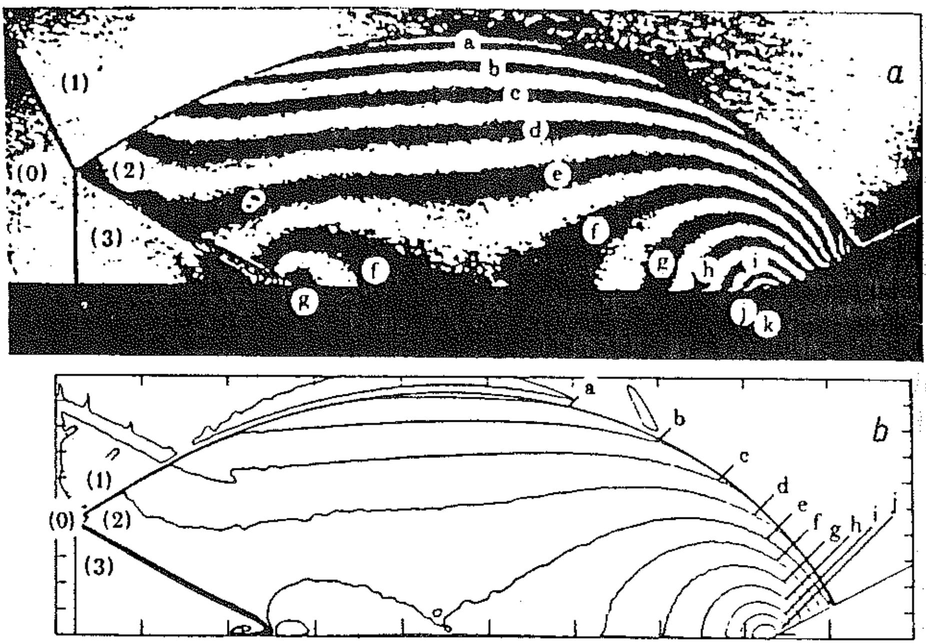

FIG. 6. Single Mach reflection: Air; Ms = 2.03; wedge angle $\theta_w = 27°$; Initial conditions: $p_1 = 33.3\,\mathrm{kPa}$; $T_1 = 299.2\,\mathrm{K}$; a) infinite fringe interferogram showing lines of constant density, b) numerical simulation.

Reproduced from GLAZ *et al.* [14].

ous Mach numbers [14, 15]. These solutions agree surprisingly well with shock-tube experiments made at high densities (Fig. 6). Such an agreement supports the previously expressed opinion, that transport phenomena are generally of little importance for the shock reflection, except, perhaps, for some special situations.

One of such special situations occurs when the moving shock wave is close to the leading edge of the reflecting wedge. Certainly, in this area neither Euler's nor even Navier–Stokes equations can be used. What remains is the Boltzmann's equation or the Direct Simulation Monte Carlo (DSMC) method.

Neither theoretical, nor experimental investigation of the leading edge region has been brought to such a stage as that for high densities (which is equivalent to large distances from the leading edge, as measured in mean free paths of the molecules). However, a lot of work is presently being done and one may hope that satisfactory results will appear soon.

7. Recent results for the vicinity of the leading edge of the reflecting wedge

7.1. General remarks

As already mentioned, the region close to the leading edge of the wedge, reflecting the moving shock, is not sufficiently understood yet. The present chapter describes mainly the experimental results, obtained recently in this area. They give some information about the behaviour of the shocks and create the basis for the future research.

In order to resolve the peculiarities of the flow in the leading edge region, it was necessary to expand the linear scale of the phenomenon. It could be achieved by decreasing the initial gas density. This however, in turn, required experimental techniques, suitable for nonstationary, rarefied gas flows. The electron beam attenuation technique [16] and laser differential interferometry [17] could only be used to obtain the results. Unfortunately, these techniques in a single experiment can only register the variation of gas density in one or, at the most, few points in the physical space. To obtain the information on the whole flow field it was necessary to perform a number of test runs under the same flow conditions and different positions of the measuring device, and then superimpose the data upon one picture. This procedure gives meaningful results, provided that repeatability of the runs is good.

7.2. Development of the regular reflection of an oblique shock wave

Quite recently Fuchs and Schmidt [18] presented a series of results (obtained with a laser differential interferometer [17]) for the density field at the leading edge of a 60 degree wedge in argon. The incident shock Mach number was close to the value Ms = 3.88. The maximum distance between the leading edge and the centre of the incident shock, measured along the reflecting surface, was equal to about 30 mean free paths of the gas particles in front of the incident shock.

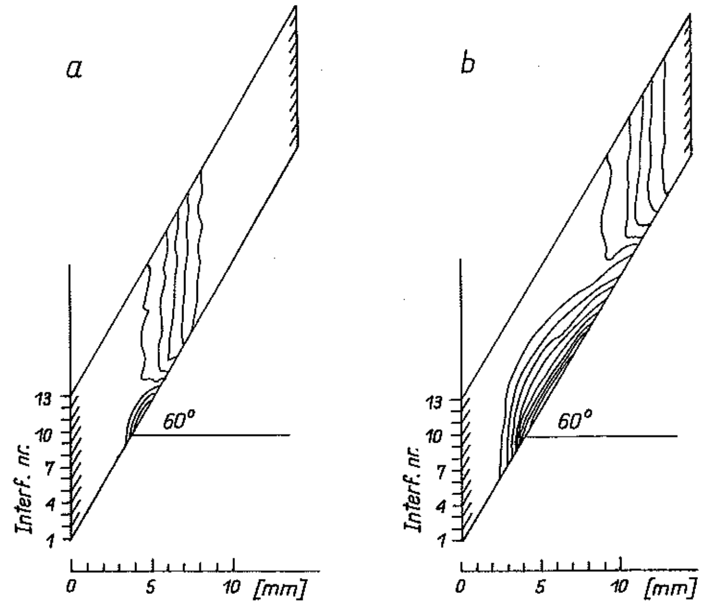

Fig. 7. Lines of constant density for regular reflection: a) incident shock $10\lambda_1$ from the leading edge, only thermal layer at the surface visible, b) incident shock $30\lambda_1$ from the leading edge, reflected shock emerges from the thermal layer. (λ_1 – initial mean free path).

Reproduced from Fuchs and Schmidt [18].

From the pictures of the constant density lines, as shown by Fuchs and Schmidt (Fig. 7), it follows that the regular reflection is probably formed with certain delay. After arrival of the incident shock, first a dense thermal layer builds up at the wall. The reflected shock emerges from it after some finite delay time.

It is difficult to judge from the pictures what the delay in formation of the reflected shock exactly is. In any case, the results of WALENTA [19], obtained with the use of an electron beam for the slightly weaker shock (Ms = 3.24), indicate that a well developed regular reflection exists when the distance from the leading edge to the incident shock is equal to about 75 mean free paths. Walenta's results show, however, an unexpectedly large difference between the inclination angle of the reflected shock, as measured and calculated assuming an inviscid flow (Fig. 8). It is believed, that this difference is due to the influence of the nonstationary boundary layer at the wedge. Such a boundary layer exhibits a strong "sucking" effect, causing the reflected wave to stay closer to the wedge surface.

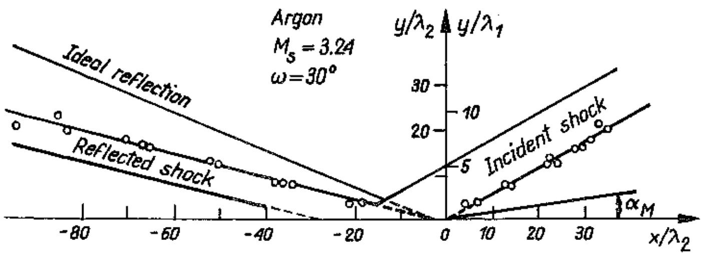

FIG. 8. Regular reflection $75\lambda_1$ from the leading edge. Points correspond to positions of the "shock wave head", as defined in Fig. 1.
Reproduced from WALENTA [19].

This effect is most pronounced when the incident shock is close behind the wedge tip. Later, for larger distances, when the boundary layer becomes relatively thinner, its influence decreases and the reflected shock should move towards the position, prescribed by the inviscid theory.

7.3. Development of the irregular reflection of a shock wave

The results obtained by WALENTA [20, 21] and FUCHS and SCHMIDT [18] in noble gases suggest, that the initial stage of formation of the Mach reflection is quite similar to that of the regular reflection. When the incident shock is close behind the leading edge, no reflected shock appears, only a dense thermal layer builds up at the wall. According to WALENTA [21], the reflected shock can be spotted for the first time when the incident one is about 15 mean free paths (i.e. about 4 incident shock thicknesses) from the leading edge. From that time on, the reflected shock propagates in all directions above the wedge from the place it first appeared, in a gas set in motion by the incident shock wave.

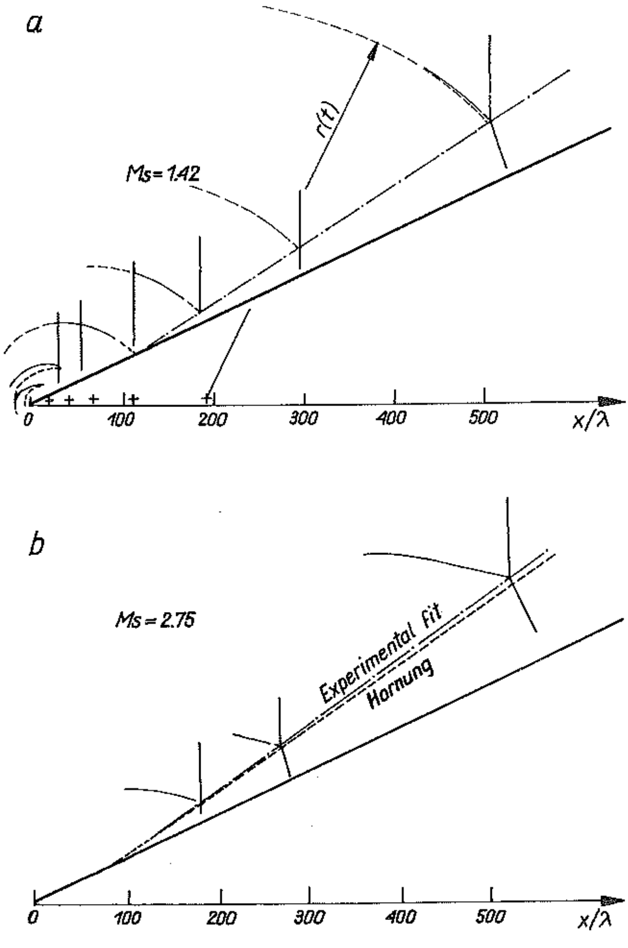

FIG. 9. Development of Mach reflection: a) weak shock case, Ms=1.42, b) strong shock case, Ms=2.75.

Reproduced from WALENTA [21].

In the case of weak shocks the speed of the reflected wave is close to the speed of sound, therefore nearly independent of the direction of motion. The shape of the reflected shock is then circularly cylindrical. For strong shocks this simple shape is distorted, particularly at the leading edge. Closer to the incident shock the approximately cylindrical shape is maintained for some time.

Because of the delay in formation, the reflected shock initially meets the incident one at the reflecting surface. The reflection is then "apparently regular". Only after a certain finite amount of time the reflected shock "overtakes" the incident one. The point, where the shocks meet, moves then away from the surface and the third shock, the Mach stem, is created.

From the described behaviour of the shocks it is clear, that the trajectory of the triple point cannot begin at the wedge tip. This was first anticipated by HENDERSON and SIEGENTHALER [22] and independently shown by WALENTA [23]. Later WALENTA made some more accurate measurements [20, 21] in noble gases, using a 25 degree wedge, at shock Mach numbers equal to 1.42 and 2.75. Under such conditions the triple point first appears about 100 mean free paths from the wedge tip (Fig. 9).

Based on the estimation of "sucking" the gas off the region behind the Mach stem by the boundary layer, HORNUNG [24] proposed a method of calculating the triple point trajectory for strong shocks. The calculated trajectory agrees very well with WALENTA'S measurements [21].

Quite recently XU, HONMA and ABE [25] calculated the formation of the Mach reflection in a gas of Maxwell molecules, using the BGK model equation. The conditions were chosen to be identical with those for the experiments reported in [21]. In the case of diffuse reflection of the molecules from the wall, an excellent qualitative agreement with experiments has been obtained. Small quantitative differences can be attributed to the strong simplifying assumptions – BGK equation and Maxwell molecules.

7.4. Further evolution of the Mach reflection

As shown by WALENTA'S measurements [21], at the initial stage of existence of the Mach reflection, the geometry of the neighbourhood of the triple point is induced by the approximately cylindrical shape of the reflected shock. The situation is physically possible, because the concept of the "contact surface" is no longer applicable here. The flow regions behind the reflected and the Mach stem shocks are separated by a thick layer of gas with varying parameters (as first suggested by STERNBERG [13] and shown experimentally by WALENTA [23]). There is no evident reason why the pressures at both sides of such a layer should be equal and velocities parallel.

As pointed out in reference [26], in the case of weak waves the whole region behind the reflected and the Mach shocks is strongly nonuniform. This nonuniformity does not seem to affect the shapes of the shocks, only the size increases with time. As a result, the circularly cylindrical shape of the reflected shock is maintained. This is evident from all weak shock experiments, at high and low gas densities [8–10, 21].

The shapes of weak reflected shocks, at positions not too close to the wedge tip, are well reproduced (Walenta [21]; compare also Fig. 9) by circles of the radii:

$$r(t) = U_r t + r_0$$

and centres at the distances from the leading edge:

$$x_c(t) = u_2 t + x_{c0}.$$

Time is specified as:

$$t = X/U$$

and the other symbols are: X – current distance of the incident shock from the leading edge, U – speed of the incident shock, U_r – speed of the reflected shock relative to the gas in the front of it, u_2 – flow velocity behind the incident shock, r_0, x_{c0} – constants, accounting for the delay in formation of the reflected shock.

At this point one remark is due in connection with the GUDERLEY'S solution for Mach reflection of a weak shock [11]. In the experiments, reported in ref. [27], WALENTA investigated very carefully the neighbourhood of the triple point, trying to find the reflection wave, postulated by Guderley. The conditions of the experiment (argon gas, 25 degree wedge, shock Mach numbers equal to 1.14 and 1.28) did not allow for the existence of the von Neumann's solution (no intersection of the shock polars), therefore the Guderley's solution should have been applicable. The result was negative. The measurements, performed under rarefied flow conditions with the use of an electron beam densitometer, indicated no trace of the rarefaction wave, although large gradients of gas parameters, as reported also in other papers [8, 26] were clearly visible.

In the strong shock case, the described shape of the reflected shock results in the fact, that the flow directions behind the reflected and the Mach shocks are convergent. This produces a local maximum of pressure, density, temperature and other gas parameters immediately behind the triple point. Such a maximum was anticipated, on the basis of some optical measurements, by BEN-DOR, TAKAYAMA and NEEDHAM [28] and shown directly by WALENTA [21].

Probably due to this maximum the flow evolves in such a way that, far from the leading edge, the whole pattern agrees with von Neumann's theory even if the flow behind the reflected shock is subsonic with respect to it (the case of the so-called "single Mach reflection").

If the flow is supersonic, no information from the wall can reach certain finite region behind the reflected shock. Part of the reflected shock in the neighbourhood of this region is then plane and its parameters agree with the von Neumann's solution. Close to the rear boundary of this region, a bend or a kink appears on the reflected shock, which is connected with an additional wave (compression, or shock). The whole phenomenon is then called the "complex" or "double" Mach reflection. Its existence was mentioned here for completeness, however it will not be discussed in more detail.

7.5. Mach reflection in gases with high molar specific heat

Quite recently Walenta [29] presented the results of experiments on formation of the Mach reflection in a gas of very high molar specific heat. As a test gas Perfluoro-N-Hexane (C_6F_{14}) was chosen. Its complex molecules have a very large number of vibrational degrees of freedom, resulting in its high specific heat. Moreover, the vibrational degrees of freedom can be excited nearly as fast as the translational and rotational ones. Such a substance, under rarefied flow conditions, may be treated with good accuracy as a perfect gas with adiabatic exponent close to unity.

The structure of a shock wave of moderate strength in Perfluoro-N-Hexane looks similarly to that in noble gases. All the internal degrees of freedom are excited simultaneously with translational ones and no "relaxation tail" is present.

The presented experimental results indicate, that in Perfluoro-N-Hexane both the reflected and Mach shocks are produced much faster than in noble gases. This is most probably due to the fact, that in a gas of such a high specific heat the temperature rise at the shock is more than an order of magnitude smaller than in noble gases. This results in reduction of the cooling effect by the walls, which evidently has major influence upon the phenomenon. As the flow velocity behind the shock in a gas of this kind is larger than in noble gases, the effect of momentum transfer is probably, generally, of minor importance.

8. Conclusions

1. The two cases of reflection of plane, oblique shock wave from a plane surface (the case stationary in the laboratory frame of reference and the quasi-stationary case of a shock moving at constant speed), are not equivalent, except in specified particular situations.

2. The reflection of a moving shock wave from a wedge at high gas densities (i.e. at large distances from the leading edge, as measured in molecular mean free paths) seems presently to be quite well understood. It can be described using the Euler's flow equations – without viscosity and thermal conductivity. In the case of weak shocks, the influence of all flow boundaries must be taken into account. For strong shocks the description simplifies greatly and reduces to a set of algebraic equations, following from the Rankine–Hugoniot conditions at the shocks (the von Neumann's theory).

3. Close neighbourhood of the leading edge of the wedge, which reflects the moving shock, seems to be the only region, where transport of momentum and energy (the effects of viscosity and thermal conductivity) has an essential influence upon the reflection. The experiments with gases of high molar specific heat indicate that, among these effects, the energy transport is of major importance.

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STRESZCZENIE

O PEWNYCH ZJAWISKACH ZWIĄZANYCH Z ODBICIEM FALI UDERZENIOWEJ

Niniejsza praca zawiera omówienie wyników, zarówno teoretycznych jak i eksperymentalnych, najbardziej zdaniem autora istotnych dla zrozumienia procesu formowania się quasi-stacjonarnego odbicia płaskiej fali uderzeniowej od klina. Omówiono w szczególności ostatnio opublikowane prace eksperymentalne, wykonane przy silnym rozrzedzeniu gazu, dotyczące zjawisk zachodzących w sąsiedztwie ostrza odbijającego klina. Zwrócono również uwagę na istotne jakościowe różnice między odbiciami fali w warunkach stacjonarnych i quasi-stacjonarnych, powodujące, że zjawiska te można uważać za równoważne jedynie w przypadku fal silnych.

Р е з ю м е

О НЕКОТОРЫХ ЯВЛИЕНИЯХ СВЯЗАННЫХ С ОТРАЖЕНИЕМ УДАРНОЙ ВОЛНЫ

Настоящая работа содержит обсуждение результатов, так теоретических, как и экспериментальных, наиболее по мнению автора существенных дла понимания процесса формирования квазистационарного отражения плоской ударной волны от клина. В частности обсуждены опубликованные в последнее время экспериментальные работы, проведенные при сильном разрежении газа, касающиеся явлений, происходящих в соседстве острия отражающего клина. Обращено тоже внимание на существенные качественные разницы между отражениями волны в стационарных и квазистационарных условиях, из которых следует, что эти явления можно считать эквивалентными только в случае сильных волн.

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