A ORIGINAL REVISE ON HYPO SONIC TO HYPERSONIC FLOW REGIONS AND THE EFFECT OF SHOW WAVES

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ABSTRACT:

This paper furnish and discuss about a detailed knowledge sharing about Mach number regions of sound , flow regions and parameters, basic of hypervelocity flow and basic shock layer, escape velocity. and elements associated with flow range . Which also discuss about the parameters of space elements and possibllities of shock formation and radiative shock transfer concepts . this paper would give a crystal idea about shock wave environment about the various flow and will be helpful for the researchers and students in the world of art science and engineering

Key words : shock layer , shock wave , flow properties , flow ranges

INTRODUCTION

International Standard Atmosphere, solar system, Kepler's Laws,Asteroids and Meteoroids, Early air vehicles and classifications, concept of biplanes and monoplanes, Mach number regions of sound , flow regions and parameters, basic of hypervelocity flow and basic shock layer, escape velocity.

MACH NUMBER REGIONS OF SOUND

As an aircraft moves through the air, the air molecules near the aircraft are disturbed and move around the aircraft. If the aircraft passes at a low speed, typically less than 250 mph, the density of the air remains constant. But for higher speeds, some of the energy of the aircraft goes into compressing the air and locally changing the density of the air. This compressibility effect alters the amount of resulting force on the aircraft. The effect becomes more important as speed increases. Near and beyond the speed of sound, about 330 m/s or 760 mph, small disturbances in the flow are transmitted to other locations isentropically or with constant entropy. But a sharp disturbance generates a shock wave that affects both the lift and drag of an aircraft.

The ratio of the speed of the aircraft to the speed of sound in the gas determines the magnitude of many of the compressibility effects. Because of the importance of this speed ratio, aerodynamicists have designated it with a special parameter called the **Mach number** in honor of **Ernst Mach**, a late 19th century physicist who studied gas dynamics. The Mach number **M** allows us to define flight regimes in which compressibility effects vary.

1. Subsonic conditions occur for Mach numbers less than one, **M <1** . For the lowest subsonic conditions, compressibility can be ignored.
2. As the speed of the object approaches the speed of sound, the flight Mach number is nearly equal to one, **M = 1**, and the flow is said to be sonic. At some places on the object, the local speed exceeds the speed of sound. Compressibility effects are most important in transonic flows and lead to the early belief in a **sound barrier**. Flight faster than sound was thought to be impossible. In fact, the sound barrier was only an increase in the drag near sonic conditions because of compressibility effects. Because of the high drag associated with compressibility effects, aircraft do not cruise near Mach 1.
3. Supersonic conditions occur for Mach numbers greater than one, **1 < M < 3**. Compressibility effects are important for supersonic aircraft, and shock waves are generated by the surface of the object. For high supersonic speeds, **3 < M < 5**, aerodynamic heating also becomes very important for aircraft design.
4. For speeds greater than five times the speed of sound, **M > 5**, the flow is said to be hypersonic. At these speeds, some of the energy of the object now goes into exciting the chemical bonds which hold together the nitrogen and oxygen molecules of the air. At hypersonic speeds, the chemistry of the air must be considered when determining forces on the object. The Space Shuttle re-enters the atmosphere at high hypersonic speeds, **M ~ 25**. Under these conditions, the heated air becomes an ionized plasma of gas and the spacecraft must be insulated from the high temperatures.

For supersonic and hypersonic flows, small disturbances are transmitted downstream within a cone. The trigonometric sineof the cone angle **b** is equal to the inverse of the Mach number **M** and the angle is therefore called the Mach angle.

$$\sin(b) = 1 / M$$

There is no upstream influence in a supersonic flow; disturbances are only transmitted downstream.

The Mach number appears as a similarity parameter in many of the equations for compressible flows, shock waves, andexpansions. When wind tunnel testing, you must closely match the Mach number between the experiment and flight conditions. It is completely incorrect to measure a drag coefficient at some low speed (say 200 mph) and apply that drag coefficient at twice the speed of sound (approximately 1400 mph, Mach = 2.0). The compressibility of the air alters the important physics between these two cases.

The Mach number depends on the speed of sound in the gas and the speed of sound depends on the type of gas and the temperature of the gas. The speed of sound varies from planet to planet. On Earth, the atmosphere is composed of mostly diatomic nitrogen and oxygen, and the temperature depends on the altitude in a rather complex way. Scientists and engineers have created a mathematical model of the atmosphere to help them account for the changing effects of temperature with altitude. Mars also has an atmosphere composed of mostly carbon dioxide.

MACH WAVES

Consider an aerodynamic body moving with certain velocity (V) in a still air. When the pressure at the surface of the body is greater than that of the surrounding air, it results an infinitesimal compression wave that moves at speed of sound (a). These disturbances in the medium spread out from the body and become progressively weaker away from the body. If the air has to pass smoothly over the surface of the body, the disturbances must 'warn' the still air, about the approach of the body.

Now analyze two situations:

(a) the body is moving at subsonic speed $(V < a; M < 1)$;

(b) the body is moving at supersonic speed $(V > a; M > 1)$

Case I : During the motion of the body, the sound waves are generated at different time intervals (t).

The distance covered by the sound waves can be represented by the circle of radius $(at, 2at, 3at......\text{so on})$.

During same time intervals (t), the body will cover distances represented by, $Vt,\ 2Vt,\ 3Vt......\text{so on}$.

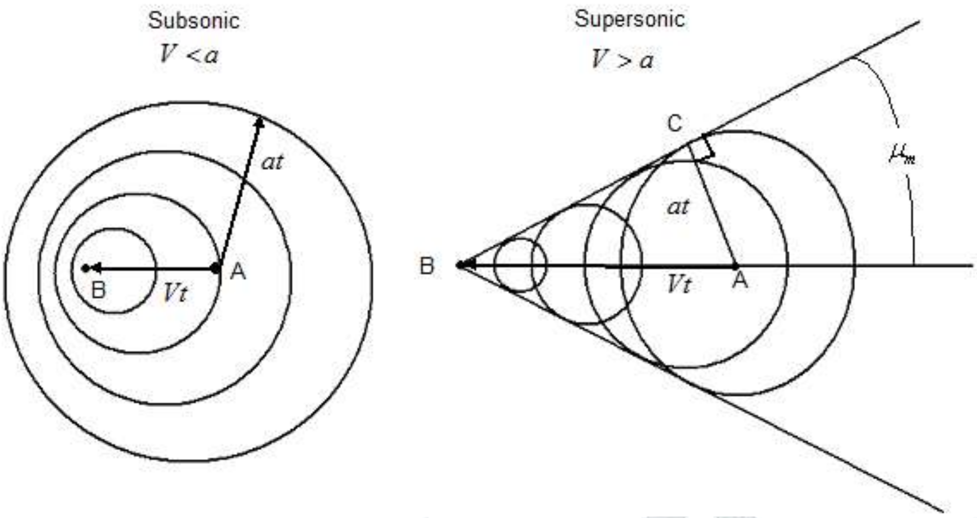
At subsonic speeds $(V < a; M < 1)$, the body will always remain inside the family of circular sound waves. In other words, the information is propagated through the sound wave in all directions. Thus, the surrounding still air becomes aware of the presence of the body due to the disturbances induced in the medium. Hence, the flow adjusts itself very much before it approaches the body.

Case II: Consider the case, when the body is moving at supersonic speed $(V > a; M > 1)$.

With a similar manner, the sound waves are represented by circle of radius $(at, 2at, 3at......\text{so on})$ after different time (t) intervals.

By this time, the body would have moved to a different location much faster from its initial position. At any point of time, the location of the body is always outside the family of circles of sound waves. The pressure disturbances created by the body always lags behind the body that created the disturbances. In other words, the information reaches the surrounding air much later because the disturbances cannot overtake the body. Hence, the flow cannot adjust itself when it approaches the body. The nature induces a wave across which the flow properties have to change and this line of disturbance is known as "Mach wave".

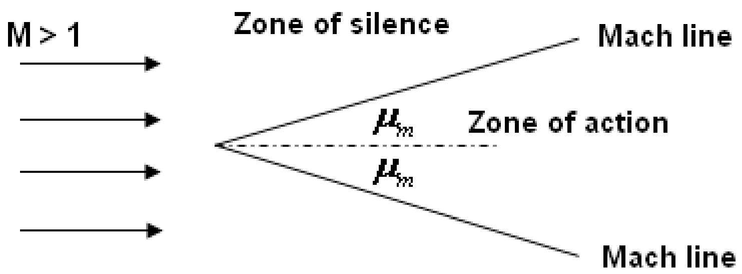
These mach waves are initiated when the speed of the body approaches the speed of sound $(V = a; M = 1)$. They become progressively stronger with increase in the Mach number.



Some silent features of a *Mach wave* are listed below;

The series of wave fronts form a disturbance envelope given by a straight line which is tangent to the family of circles. It will be seen that all the disturbance waves lie within a cone having a *vertex/apex* at the body at time considered. The locus of all the leading surfaces of the waves of this cone is known as *Mach cone* . All disturbances confine inside the Mach cone extending downstream of the moving body is called as *zone of action* . The region outside the Mach cone and extending upstream is known as *zone of silence* . The pressure disturbances are largely concentrated in the neighborhood of the Mach cone that forms the outer limit of the zone of action . The half angle of the Mach cone is called as the Mach angle (μ_m)

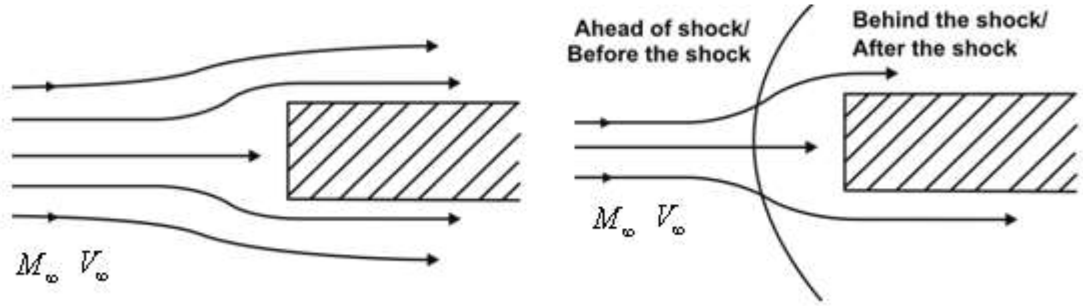
$$\sin \mu_m = \frac{at}{Vt} = \frac{a(2t)}{V(2t)} = \frac{a(3t)}{V(3t)} \ldots\ldots = \frac{a}{V} = \frac{1}{M} \Rightarrow \mu_m = \sin^{-1}\left(\frac{1}{M}\right)$$



Shock Waves

Let us consider a subsonic and supersonic flow past a body. In both the cases, the body acts as an obstruction to the flow and thus there is a change in energy and momentum of the flow. The changes in flow properties are communicated through pressure waves moving at speed of sound everywhere in the flow field (i.e. both upstream and downstream). If the incoming stream is subsonic i.e. $M_\infty < 1;\ V_\infty < a_\infty$, the sound waves propagate faster than the flow speed and warn the medium about the presence of the body. So, the streamlines approaching the body begin to adjust themselves far upstream and the flow properties change the pattern gradually in the vicinity of the body.

In contrast, when the flow is supersonic, i.e. $M_\infty > 1;\ V_\infty > a_\infty$, the sound waves overtake the speed of the body and these weak pressure waves merge themselves ahead of the body leading to compression in the vicinity of the body. In other words, the flow medium gets compressed at a very short distance ahead of the body in a very thin region that may be comparable to the mean free path of the molecules in the medium. Since, these compression waves propagate upstream, so they tend to merge as *shock wave* . Ahead of the shock wave, the flow has no idea of presence of the body and immediately behind the shock; the flow is subsonic



(a) Subsonic flow $M_\infty < 1;\ V_\infty < a_\infty$

(b) Supersonic flow $M_\infty > 1;\ V_\infty > a_\infty$

FLOW REGIONS AND PARAMETERS

Regime	(Mach number)	(m/s)	General plane characteristics
Subsonic	<0.8	<274	Most often propeller-driven and commercial turbofan aircraft with high aspect-ratio (slender) wings, and rounded features like the nose and leading edges.
Transonic	0.8–1.2	274–412	Transonic aircraft nearly always have swept wings that delay drag-divergence, and often feature designs adhering to the principles of the Whitcomb area rule.
Supersonic	1.2–5.0	412–1,715	Aircraft designed to fly at supersonic speeds show large differences in their aerodynamic design because of the radical differences in the behaviour of fluid flows above Mach 1. Sharp edges, thin airfoil-sections, and all-moving tailplane/canards are common. Modern combat aircraft must compromise in order to maintain low-speed handling; "true" supersonic designs include the F-104 Starfighter and BAC/Aérospatiale Concorde.
Hypersonic	5.0–10.0	1,715–3,430	Cooled nickel or titanium skin; highly integrated (due to domination of interference effects: non-linear behaviour means that superposition of results for separate components is invalid), small wings. eg:X-51A Waverider, HyperSoar and WU-

			14 (DF-ZF).
High-hypersonic	10.0–25.0	3,430–8,575	Thermal control becomes a dominant design consideration. Structure must either be designed to operate hot, or be protected by special silicate tiles or similar. Chemically reacting flow can also cause corrosion of the vehicle's skin, with free-atomic oxygen featuring in very high-speed flows. Examples include the 53T6 *ABM-3 Gazelle* (Mach 17) anti-ballistic missile and DF-41 (Mach 25) intercontinental ballistic missile. Hypersonic designs are often forced into blunt configurations because of the aerodynamic heating rising with a reduced radius of curvature.
Re-entry speeds	>25.0	>8,575	Ablative heat shield; small or no wings; blunt shape.

BASIC OF HYPERVELOCITY FLOW AND BASIC SHOCK LAYER

Hypervelocity is very high velocity, approximately over 3,000 meters per second (6,700 mph, 11,000 km/h, 10,000 ft/s, or Mach 8.8). In particular, hypervelocity is velocity so high that the strength of materials upon impact is very small compared to inertial stresses. Thus, even metals behave like fluids under hypervelocity impact. Extreme hypervelocity results in vaporization of the impactor and target. For structural metals, hypervelocity is generally considered to be over 2,500 m/s (5,600 mph, 9,000 km/h, 8,200 ft/s, or Mach 7.3). Meteorite craters are also examples of hypervelocity impacts.

"Hypervelocity" refers to velocities in the range from a few kilometers per second to some tens of kilometers per second. This is especially relevant in the field of space exploration and military use of space, where hypervelocity impacts (e.g. by space debris or an attacking projectile) can result in anything from minor component degradation to the complete destruction of a spacecraft or missile. The impactor, as well as the surface it hits, can undergo temporary liquefaction. The impact process can generate plasma discharges, which can interfere with spacecraft electronics.

While the definition of hypersonic flow can be quite vague and is generally debatable (especially due to the absence of discontinuity between supersonic and hypersonic flows), a hypersonic flow may be characterized by certain physical phenomena that can no longer be analytically discounted as in supersonic flow. The peculiarity in hypersonic flows are as follows: Shock layer, Aerodynamic heating, Entropy layer, Real gas effects, Low density effects, Independence of aerodynamic coefficients with Mach number,
Small shock stand-off distance

As a body's Mach number increases, the density behind a bow shock generated by the body also increases, which corresponds to a decrease in volume behind the shock due to conservation of mass. Consequently, the distance between the bow shock and the body decreases at higher Mach numbers.

ESCAPE VELOCITY

Escape velocity is the minimum speed needed for an object to escape from the gravitational influence of a massive body.

The escape velocity from Earth is about 11.186 km/s (6.951 mi/s; 40,270 km/h; 25,020 mph) at the surface. More generally, escape velocity is the speed at which the sum of an object's kinetic energy and its gravitational potential energy is equal to zero an object which has achieved escape velocity is neither on the surface, nor in a closed orbit (of any radius). With escape velocity in a direction pointing away from the ground of a massive body, the object will move away from the body, slowing forever and approaching, but never reaching, zero speed. Once escape velocity is achieved, no further impulse need be applied for it to continue in its escape. In other words, if given escape velocity, the object will move away from the other body, continually slowing, and will asymptotically approach zero speed as the object's distance approaches infinity, never to come back. Speeds higher than escape velocity have a positive speed at infinity. Note that the minimum escape velocity assumes that there is no friction (e.g., atmospheric drag), which would increase the required instantaneous velocity to escape the gravitational influence, and that there will be no future sources of additional velocity (e.g., thrust), which would reduce the required instantaneous velocity.

For a spherically symmetric, massive body such as a star, or planet, the escape velocity for that body, at a given distance, is calculated by the formula

$$v_e = \sqrt{\frac{2GM}{r}}$$

where G is the universal gravitational constant ($G \approx 6.67\times10^{-11}\ \mathrm{m^3 \cdot kg^{-1} \cdot s^{-2}}$), M the mass of the body to be escaped from, and r the distance from the center of mass of the body to the object. The relationship is independent of the mass of the object escaping the massive body. Conversely, a body that falls under the force of gravitational attraction of mass M, from infinity, starting with zero velocity, will strike the massive object with a velocity equal to its escape velocity given by the same formula.

Conclusion

The paper elaborate the study of shock layer its behaviour with respect to altitude and flow mach number. And could able to produce a lecture notes on flow theory from hypo sonic to hypser sonic reagion . aircraft classification also made in terms of flow mach number with examples . which gives a detailed on board understanding to the aerospace students and aerospace fertility

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