A Review on Mach Probes

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A typical MP is composed of two directional electric probes located at opposite sides of an insulator, which is mostly used as a parallel MP to deduce the plasma flow velocity from the ratio of the ion saturation currents. However, there are other MP's such as perpendicular MP (PMP), Gundestrup probe (GP), and visco-MP (VMP), depending upon the shape of the probe holder, location of different probes, or the way of collecting ions. For the parallel MP (to be called an MP), the relation between the ratio of the upstream ion saturation current density (J_{up}) to the downstream (J_{dn}) and the normalized drift velocity ($M_\infty = v_d/\sqrt{T_e/m_i}$) of plasma has generally been fitted into an exponential form ($R = J_{up}/J_{dn} \approx \exp[KM_\infty]$). For the GP and RP, with oblique ion collection, $R = \exp[K(M_\parallel - M_\perp \cot\theta)]$, where $K \simeq 2.3 \sim 2.5$, $M_\parallel = M_\infty$, $M_\perp$ is normalized perpendicular flow to the magnetic field, and θ is the angle between the magnetic field and probe surface. Normalized drift velocity of the flowing plasmas is deduced from the ratio (R_m) measured by an MP as $M_\infty = \ln [R_m]/K$, where K is a calibration factor depending upon the magnetic flux density, collisionality of charged particles and neutrals, viscosity of plasmas, and ion temperature, etc. Existing theories of Mach probes in un-magnetized and magnetized flowing plasmas are also introduced in terms of kinetic, fluid and particle-in-cell models or self-consistent and self-similar methods along with key physics and comments. Experimental evidences of relevant models are shown along with validity of related theories. Collisions of ion/electron/neutrals, asymmetries of ion temperatures and existence of hyperthermal electrons, existence of ion beam, supersonic flow and negative ions can affect the deduction of the flow velocities by MP.