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Surface Pressure Distribution in High-Speed Aerodynamics: A Critical Review of Theory, Computation, Experiments, and Design Implications

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Abstract

Surface pressure distribution is one of the primary factors governing the aerodynamic performance, stability, controllability, and structural loading of high-speed aerospace vehicles. Accurate prediction of surface pressure is therefore essential for the design, optimization, and safe operation of flight systems ranging from supersonic aircraft to hypersonic vehicles and atmospheric re-entry platforms. Over the past several decades, extensive theoretical, computational, and experimental research has sought to characterize pressure distributions over canonical configurations, including wedges, cones, and delta wings, across a broad spectrum of flow conditions. This review provides a critical and comprehensive assessment of the current state of knowledge on surface-pressure prediction in these cases. Particular attention is devoted to the influence of Mach number, angle of

attack, geometric characteristics, shock-wave structure, and viscous effects on pressure-distribution behaviour. Classical analytical approaches, including shock-expansion theory, Newtonian theory, hypersonic similitude, and piston theory, are examined alongside modern Computational Fluid Dynamics (CFD) techniques and experimental investigations. Their assumptions, domains of applicability, strengths, and limitations are critically evaluated and compared across different flow regimes. The review further examines the impact of shock-wave/boundary-layer interactions, aerodynamic stability derivatives, unsteady flow phenomena, and active and passive flow-control strategies on surface-pressure characteristics. By synthesizing results from a broad body of literature, it identifies consistent physical trends, reconciles apparent discrepancies among previous studies, and highlights the principal sources of uncertainty that continue to limit predictive accuracy. The analysis demonstrates that reliable aerodynamic assessment increasingly relies on an integrated framework combining analytical methods, high-fidelity numerical simulations, and carefully validated experimental measurements. Finally, the review outlines promising directions for future research, with particular emphasis on high-Mach-number aerodynamics, real-gas and thermochemical nonequilibrium effects, uncertainty quantification, data-driven modelling, and advanced predictive methodologies. Copyright © 2026 The Authors. Published by Tech Science Press. This work is licensed under a Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Author keywords

CFD analysis; High-speed aerodynamics; Mach number; Supersonic; Surface pressure; Wedge angle

Indexed keywords

Engineering controlled terms

Aerodynamic stability; Aerospace vehicles; Computation theory; Computational fluid dynamics; Delta wing aircraft; Fighter aircraft; Flight control systems; Flow control; Hypersonic aerodynamics; Hypersonic vehicles; Pressure distribution; Shock waves; Supersonic aerodynamics; Supersonic aircraft; Wings

Engineering uncontrolled terms

Computational fluid dynamics analysis (CFD); Critical review; Design implications; High speed aerodynamics; Supersonic; Surface pressure distribution; Surface pressures; Theory computation; Theory designs; Wedge angle

Engineering main heading

Mach number

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