# An experimental study of shock wave boundary layer interactions over curved surfaces of supersonic turbine cascades

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Shock wave boundary layer interaction (SBLI) is a critical phenomenon that can significantly impact aircraft performance by inducing flow separation and reducing aerodynamic efficiency. SBLI occurs on various curved aerodynamic surfaces, including airfoils found in airplane wings, compressor inlets for ramjets, vertical stabilizers, and control surfaces. Decades of research have demonstrated that SBLI can lead to adverse effects, necessitating further experimental and computational studies.

This study experimentally explores SBLI in a blade cascade configuration commonly used in ramjet inlets. While SBLI is inherently a three-dimensional interaction, this work primarily focuses on its two-dimensional aspects due to the constraints of the geometry. The study was influenced by previous simulations conducted by Lui et al. [2024] using Large Eddy Simulation (LES). The experimental setup consists of a two-cambered blade cascade with a chord length of 35 mm and an angle of attack of 10 degrees. Testing was conducted in the Variable Mach Number Link Supersonic Tunnel at Syracuse University at five distinct Mach numbers, selected to match the simulation conditions.

To distinguish the effects of SBLI from those induced by geometry and angle of attack, additional experiments were performed using a single blade under identical flow conditions. The models were fabricated using selective laser sintering (SLS) in stainless steel with a sandblasted finish. They were subsequently 3D scanned with a Creality Raptor blue laser scanner and compared against the original CAD models to verify dimensional accuracy.

Flow visualization was performed using a Z-type shadowgraph system in conjunction with a Phantom T-2410 high-speed camera operating at 50,000 frames per second. On the concave side, normal shock reflection was observed due to the inability of the flow to conform to the surface curvature. On the convex surface, flow separation consistently occurred at the location of SBLI regardless of Mach number.

A bi-stable behavior of the flow was observed, where different experimental runs under seemingly identical conditions resulted in either an attached or separated flow state. This phenomenon is hypothesized to be influenced by the tunnel start-up process, where the flow stabilizes into one of the two possible states.

To further investigate flow unsteadiness, time-resolved image analysis of the shock foot location was performed to identify oscillation frequencies. The results revealed characteristic peaks consistent with those found in flat plate SBLI studies. Overall, this study provides insights into the unsteady nature of separation bubbles and shock structures across varying Mach numbers, comparing experimental results with flat plate models and computational fluid dynamics simulations.

## References

Hugo F.S. Lui, William R. Wolf, Tulio R. Ricciardi, and Datta V. Gaitonde. Mach number effects on shock-boundary layer interactions over curved surfaces of supersonic turbine cascades. *Theoretical and Computational Fluid Dynamics*, 8 2024. ISSN 14322250. doi: 10.1007/s00162-024-00712-2.

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