HYPERSONIC BOUNDARY LAYER TURBULENCE

by

SEAN CRANFORD

BS Mechanical Engineering
BS Mathematics

A FINAL HONORS PROJECT

submitted in accordance with the University Honors Program requirements

Mechanical Engineering
College of Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

December 2021

Approved by:

Dr. Kevin Wanklyn

Abstract

Hypersonic flow involves an extremely complex flow system. The parameters that affect laminar to turbulent flow, especially at hypersonic speeds, play a large role in developing accurate predictions of drag and heating. Transition from laminar to turbulent flow involves a multifaceted scheme consisting of a variety of mechanisms. The study of these conditions has yielded a reliable understanding of their role pertaining to planar bodies or axisymmetric shapes. The Boundary Layer Transition (BOLT1) flight experiment was developed to stimulate the advancement of transition predictions and assess experimental capabilities by introducing a more geometrically complex surface. The new geometry includes a concave surface; however, its most prominent features are the leading edges. BOLT is a collaborative effort spanning multiple organizations whose purpose is to establish new flow predictions and collect experimental data for the complex surface. This project includes the Air Force Office of Scientific Research (AFOSR), Air Force Research Lab (AFRL), Purdue University, Texas A&M University (TAMU), University of Minnesota, John Hopkins University Applied Physics Laboratory (JUAPL), and NASA-Langley. Hypersonic flow measurements for BOLT1 were taken by utilizing the advanced wind tunnel facilities housed at TAMU, NASA, and Purdue. Each facility tested the scale model and data was collected and compared to the computational fluid dynamics (CFD) analysis and predictions performed by Minnesota and TAMU. The new studies conducted are on Boundary Layer Turbulence (BOLT2). BOLT2 is an extended geometry of BOLT1 and focuses more on the effects of turbulent flow on the model. BOLT2 IR thermography was conducted in TAMU's Mach 6 Quiet Tunnel (M6QT) and the Actively Controlled Expansion (ACE) hypersonic tunnel. Measurements and CFD conducted on BOLT2 will yield a better understanding of the turbulent flow and boundary layer transition.

Student Responsibilities

Poster presented at Texas A&M University College of Engineering Undergraduate Summer Research Program Symposium on August 2, 2019

Student Responsibilities

- Submit project proposal to Texas A&M REU program coordinator
- Present initial and final project briefings to Texas A&M Propulsion and Energy REU Program
- Assist with designing BOLT2 in SolidWorks
- Learn about Computational Fluid Dynamics (CDF)
- Perform maintenance on Hypervelocity Expansion Tunnel (HXT), Actively Controlled Expansion Tunnel (ACE), and NASA Langley Mach 6 Quiet Tunnel (M6QT)
- Operate and calibrate FLIR SC-8000 IR camera
- Fabricate 20% and 25% scale model of BOLT2 out of polycarbonate
- Machine and order parts necessary for new metal thread inserts
- Install thread inserts in models
- Mount models in wind tunnels
- Perform IR data collection runs in ACE and M6QT
- Create MATLAB program to output temperature maps and temperature difference
- Compare IR data with CFD and BOLT1 runs