Enhancing and Characterizing Fast-Response Temperature Sensitive Paint

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Introduction

PURPOSE OF TSP

- Skin friction dictates behavior of wall-bounded and separated flows but is difficult to measure.
- Temperature Sensitive Paint (TSP) emits light at **decreasing intensity** with **increasing temperature**

TSP ANALYSIS PROCESS

Flow Structures (e.g., vorticies) over heated target TSP painted surface causes heat transfer gradients

Visualization of convecting structures as an intensity gradient map

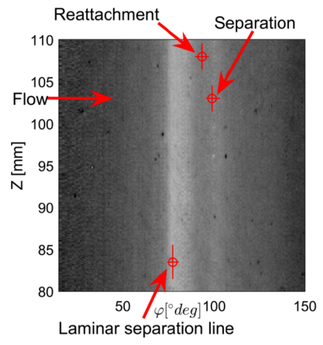

Figure 1: Time Averaged Temperature Map [1]

Optical flow algorithm allows for deduction of **skin-friction vector field**

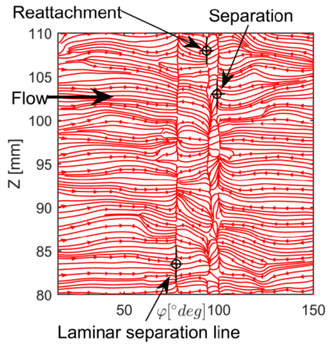

Figure 2: Associated Skin Friction Lines [1]

TSP provides a **time-resolved evolution of the skin-friction streamlines** but this requires the TSP to respond quick enough to respond to the flow structures

This study aims to characterize the TSP's frequency response capabilities and the parameters that affect the response time on different materials

Method

COUPON PREPARATION

This study is focused on TSP responses on **aluminum** and **Corian** coupons. Each coupon is prepared with:

- Two layers of enamel-based white paint
- 3M white vinyl film
- Markers for image tracking
- Ruthenium-based paint of 3 varying thicknesses

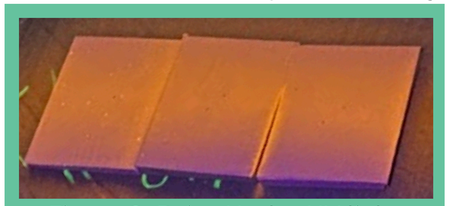

Figure 3: Paint Under UV light

The homogeneity of paint layers is important for thickness comparison. Coupons are inspected with UV light to ensure **even paint layers.**

- Thinner paint responds faster than thicker paint layers
- Thicker paint has higher signal to noise ratio
- One paint layer is expected to be less than 2 microns thick

EXPERIMENTAL SET-UP

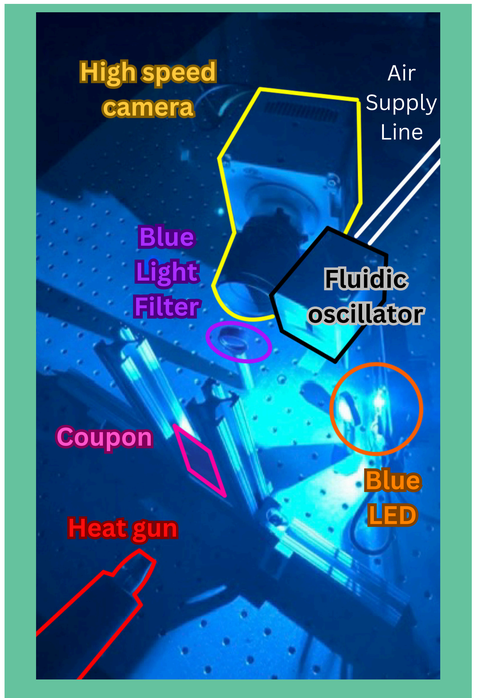

Figure 4: Experimental Set-Up

Blue LED: Ruthenium based paint molecules are excited by blue light, the Ruthenium based paint molecules absorb the blue light and emit a red-orange light

Heat Gun: TSP requires some initial heating for intensity changes due to flow structures, every coupon was tested with two different heat settings: heat off and heat on during the test

Blue light filter: filters out excitation light to isolate response from TSP for camera

High speed camera: captures intensity maps. Set to 6400 fps for highest frequency tests.

Fluidic oscillator: creates periodic sweeping jet stream to create flow structures on coupon at 3KHz for this test. The goal is for the TSP to respond to this frequency of flow changes.

Findings

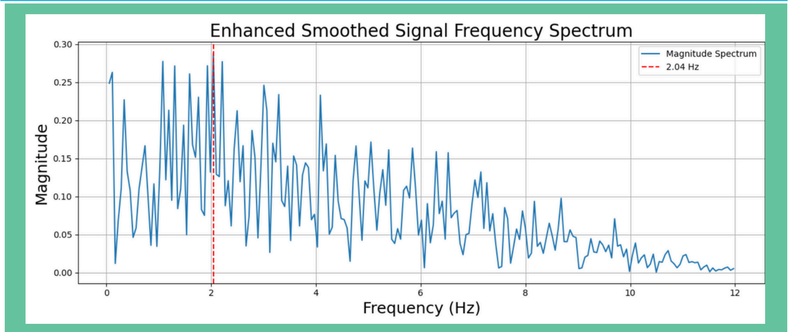

Figure 5: Frequency Response to ~ 2 Hz frequency input

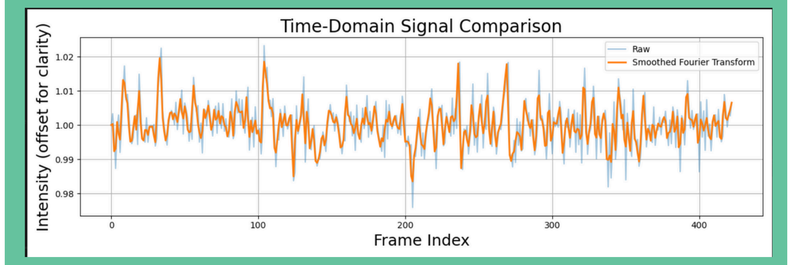

Figure 6: Intensity response & Smoothed response curve

- Preliminary Testing including inducing ~2 Hz oscillation
- Image Processing:
  - Marker tracking is used to stabilize images to account for coupon deflection due to unsteady jet stream
  - Intensity normalized to rolling average of video sequence
- Fourier Analysis conducted to analyze frequency response to input

Able to Resolve structures at maximum 50Hz

- Ability to resolve structures is a success however the goal is to resolve frequencies at 3KHz

To resolve higher frequencies more LED lighting is required to increase fps but higher signal to noise ratio

Future Study

- Comparison of different paint layer thicknesses (2,4,and 6 microns)
- Aluminum coupon testing
- Frequency tests with 800 Hz oscillator
- Higher FPS testing with stronger LED
- 'Small Bump' Test - small three dimensional structure test

References

[1] Massimo Miozzi, Alessandro Capone, Fabio Di Felice, Christian Klein, Tianshu Liu; Global and local skin friction diagnostics from TSP surface patterns on an underwater cylinder in crossflow. Physics of Fluids 1 December 2016; 28 (12): 124101.