Flow Visualization Using Tufts Final Copy and Review

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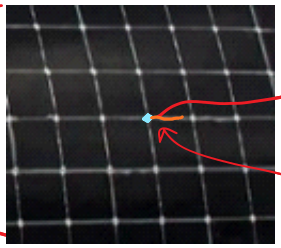
String Specifications:
- Cotton
- Not much shedding (Hopefully not much cleaning array)
- ~2mm diameter (tape will hold enough in solar area assuming laminar flow)
- Orange for high visibility against black/blue solar cells and white body

Tape:
- Regular Masking Tape (Scotch)
- Backup Freezer Tape in case masking fails in cold weather

Overall Needed Materials:
-Masking Tape
-Freezer Tape (Backup for Cold Weather)
-Duct Tape
-Epoxy
-Blue Nitrile Gloves
-String
-Sharp scissors
-String Cutting Dowel
-GoPro Hero 7 + Mount + Charging Cable
-Canon T3i
-iPhone 13 Pro

Outline for Project:
- Only need data from one half of car. Top and driver's left side will suffice.

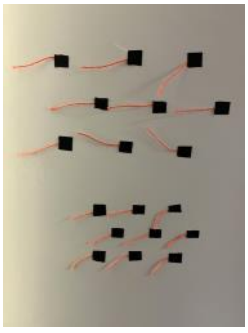


Places of Particular Interest:
- Underside of Back
- Curved areas of top edge
- Canopy(Front and Back)

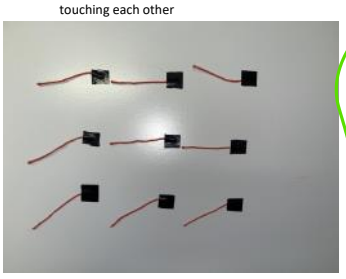
String Placement on Array:
- String will be 80 mm long here (125mm solar cell edges)
- Will be taped to 12mmx12mm white squares with 12mmx12mm masking tape squares to avoid covering/touching functional cell area
- Small amount of tape sufficient because flow here should be pretty laminar
- For actual application make sure taping edge of string isn't frayed for best hold
- MUST WEAR BLUE NITRILE GLOVES WHEN APPLYING

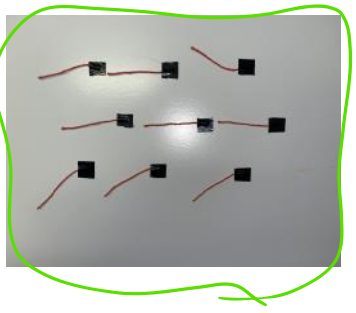
Length of String Testing (60 mm and 100 mm):
- Shorter Strings (60mm in this test seem more responsive, less whippy, but might limit range of motion if turbulent)
- Middle ground between these is best --> 80mm

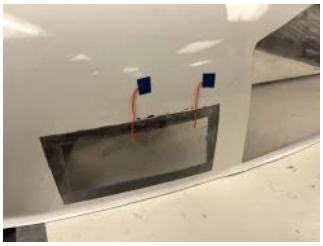
Test video:
https://drive.google.com/file/d/13xT4FYIrSahB7UgaCrTHyDkSwy1Adv41/view?usp=sharing



String Placement on Non-Array area (Canopy and Drivers left-hand side):
- Tufts 80 mm long
- Attached with square of tape, full width of tape (24mm)
- Hexagonal Pattern (more density than basic square application) with tufts not touching each other







Tufts on Canopy for Size Reference

Photo taken on iPhone 13 for ~5 meters away zoomed in
Note: Tufts will be placed on opposite side

Actual Application Process:
Application will be divided in two sessions: one before leaving for Grand Bend, one after. All low traffic areas on the car will be tufted beforehand. This is everywhere not around the seams of the car (where the top aero body folds over and the canopy is placed. These instructions apply for both sessions.

1) Preparing String:
- Cut string efficiently with dowel with groove for scissors (diameter 1 inch = 25.4 mm so circumference is ~80 mm, length was not chosen because of this, it just happened to work out)

2) Preparing Tape and putting together:
- For Array: Tape must be cut into 12mm by 12mm squares. Since the tape is 24mm wide, we can cut the roll down the middle for a few layers for ease of cutting. String must then be attached on the diagonal of the tape and placed on the car directly or on a smooth clean surface to prepare for application.
- For Non-Array: Tape should be cut in into full 24mm by 24mm squares. String can be attached orthogonally to tape and placed on car directly or on a smooth clean surface for application

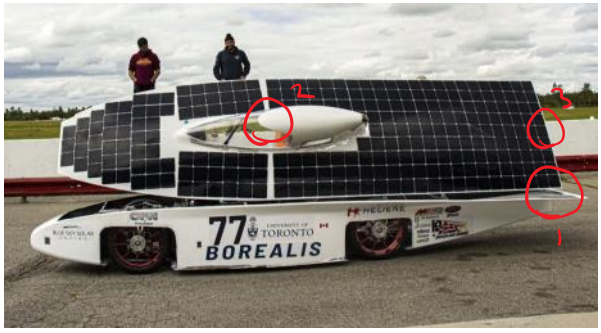
3) Application:
- For Array: Wear Blue Nitrile Gloves during application. Take tufts (prepared string and tape), and place on white squares formed by triangles on corners of the solar cells as shown above with strings pointed back.
- For Non-Array: Take tufts and apply to all surfaces on top and driver's left-side in a hexagonal pattern as shown above with strings pointed to the back.

Cutting String

Cutting Tape

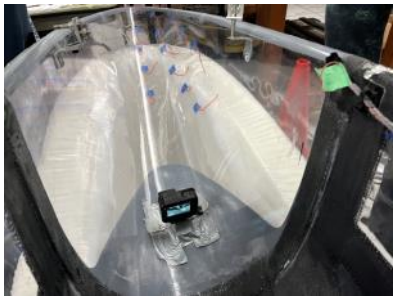
Cameras:

1) GoPro Hero 7 with sticky mount
   - 4K 60fps video
   - Will be fixed to all locations marked in red in picture below: 1) On bottom of trailing edge to capture underside. 2) On inside top of canopy to capture front of canopy. 3) On top of trailing edge to capture backside of canopy.
   - For Mounting: Sticky Mount with duct tape and possibly epoxy for inside canopy location, which can be applied on site
2) Canon T3i
   - For Still Pictures from Chase Car (Passenger seat)
   - Shutter Speed 30-1/4000 of a second (shorter shutter speed ideal for tufts, ~1000th of a second)
3) iPhone 13 Pro
   - For primarily Video from Chase Car
   - Up to 15x zoom for pictures, 9x for video
   - Capable of 60 fps

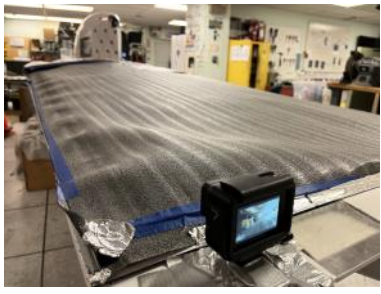


GoPro Location #1
Note: This test was on the opposite side compared to the final plan. View will be from other side.

GoPro Location #2



GoPro Location #3



Outcome Of Project:

- Canceled due to delays and inclement weather.
- Actual execution went well: this report can serve as a valid blueprint for future tests. Tuft visibility and reactivity good. Camera visibility all good. Freezer tape not necessary in ~5 degrees Celsius weather. Duct tape ok for camera mounting
- With prior cutting of string, application of tufts under main plane of aero body took 2 hours for one person with proper efficiency techniques. Application of tufts on array took 1.5 hours with two people due to necessary array safety precautions. Onsite application of tufts on canopy took ~ 20 minutes with two people. Time could be drastically decreased with multiple people.
- Points for improvement aside from weather planning: Biggest challenge was attachment of tufts to gaps in array. Surface in some spots was uneven or covered in silicon which prevented tape from sticking. Look into more generous application of tape or different types of tape with guidance from Array.