Effect of Conditioner Design and Polisher Kinematics on Fluid Flow Characteristics during CMP

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Problem Statement and Objective

- **Fluid dynamics in CMP is really complicated – Too many rotating and oscillating parts – And groove designs.**
- **This complexity gets exacerbated with in-situ conditioning.**
- **This complexity gets further exacerbated when discs of varying designs are employed.**
- **Current CFD and other numerical simulation capabilities are woefully inadequate for capturing various nuances in flow patterns.**
- **Today we will introduce a new experimental method based on fluorescence to help quantify flow patterns during conditioning**
- **We will focus on several case studies and explain our observations trends qualitatively and quantitatively:**

  - ✓ **Various CVD diamond disc working face designs**
  - ✓ **Platen velocities**

✓ **Further work is ongoing!**

Mechanisms of Fluid Transport in CMP

- **Pad grooves, pad pores and land-area micro-texture**
- **Oscillatory and rotary motions of the conditioner (and the carrier head)**

    - ❖ **Bow wave and boundary layer around the disc (and the retaining ring)**
    - ❖ **Movement of fluid in and out of the disc-pad (and wafer-pad) interface**

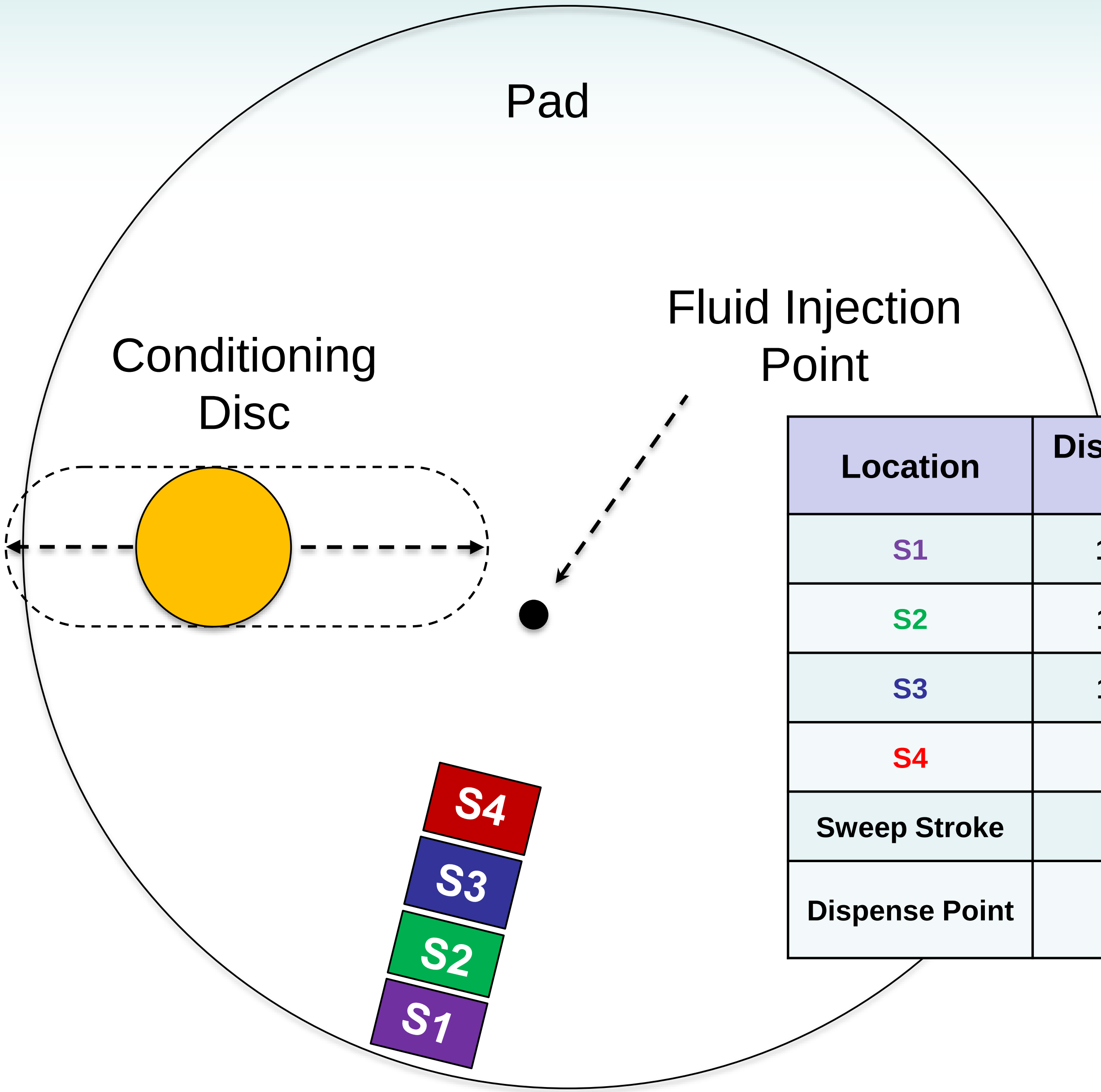
- **Advection in the radial direction**
- **Centrifugal forces**
- **Centripetal forces mainly due to drag between pad and fluid**
- **Back-flow**

    - ❖ **Fluid build-up caused by surface tension at the edge of the pad**
    - ❖ **Conditioner (and wafer carrier) motion**

Experimental Conditions

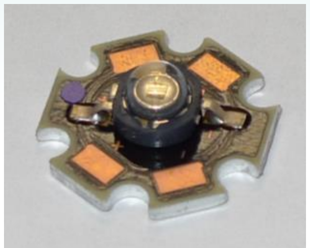
- **Pad**
  - ❖ **DowDupont Politex – Rotating CCW at 50 or 100 RPM.**
  - ❖ **Break-in – 3M PB32A brush for 30 minutes at 95 RPM with platen at 50 RPM.**
- **Fluorescent fluid (UPW with 0.5 g/l of 4-methyl-umbelliferone) flowing at 250 cc/min with LED UV illumination**
- **UPW rinse at 2,000 cc/min for 30 seconds at RT between each test.**
- **No wafers were polished – Carrier head was disengaged**
- **CVD Conditioners**
  - ❖ **MGAM – 4S**
  - ❖ **MGAM – 43**
  - ❖ **CCW rotation at 95 RPM**
  - ❖ **3-pound down-force**
  - ❖ **11 sweeps per min**
  - ❖ **72 seconds of conditioning**
- **All runs were repeated once – Differences in results were less than 4 percent in all cases!**

Details on Various Sections Tested



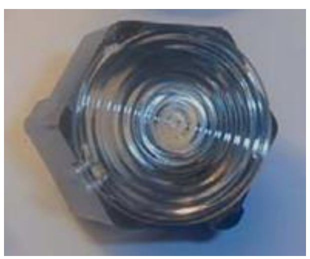
Location	Distance from Pad Center (")
S1	13.125 – 14.375
S2	11.875 – 13.125
S3	10.375 – 11.875
S4	8.000 – 10.375
Sweep Stroke	2.60 – 14.21
Dispense Point	3.5

The Araca UVIZ-100 System

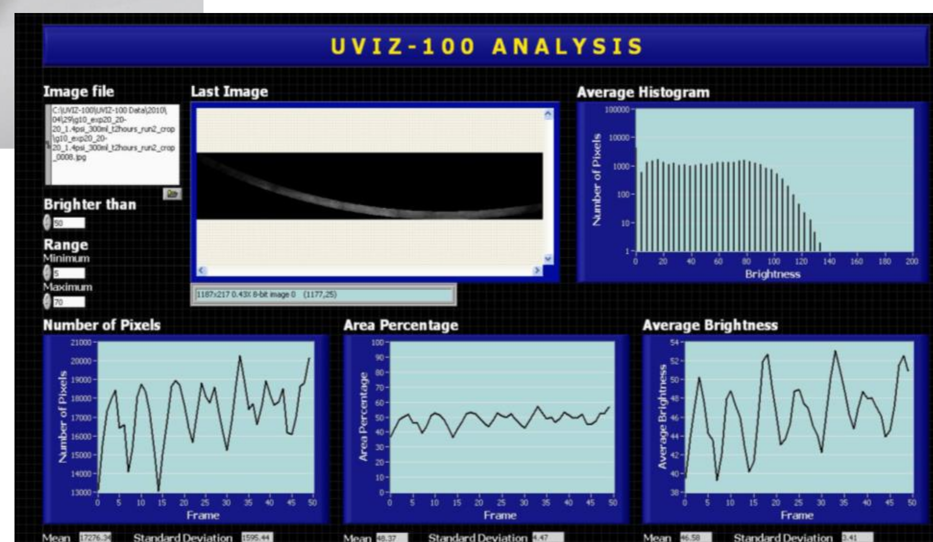


UV – LED

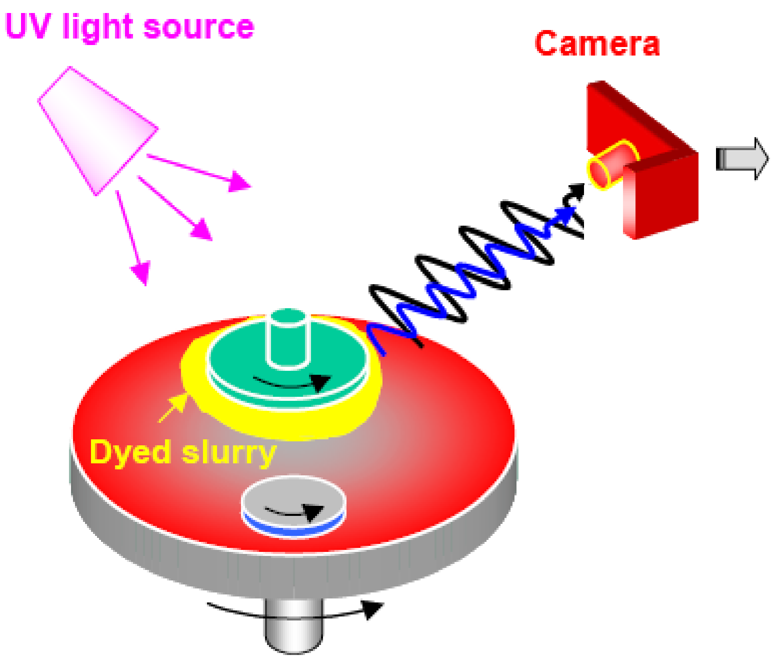
High Resolution
CCD Camera

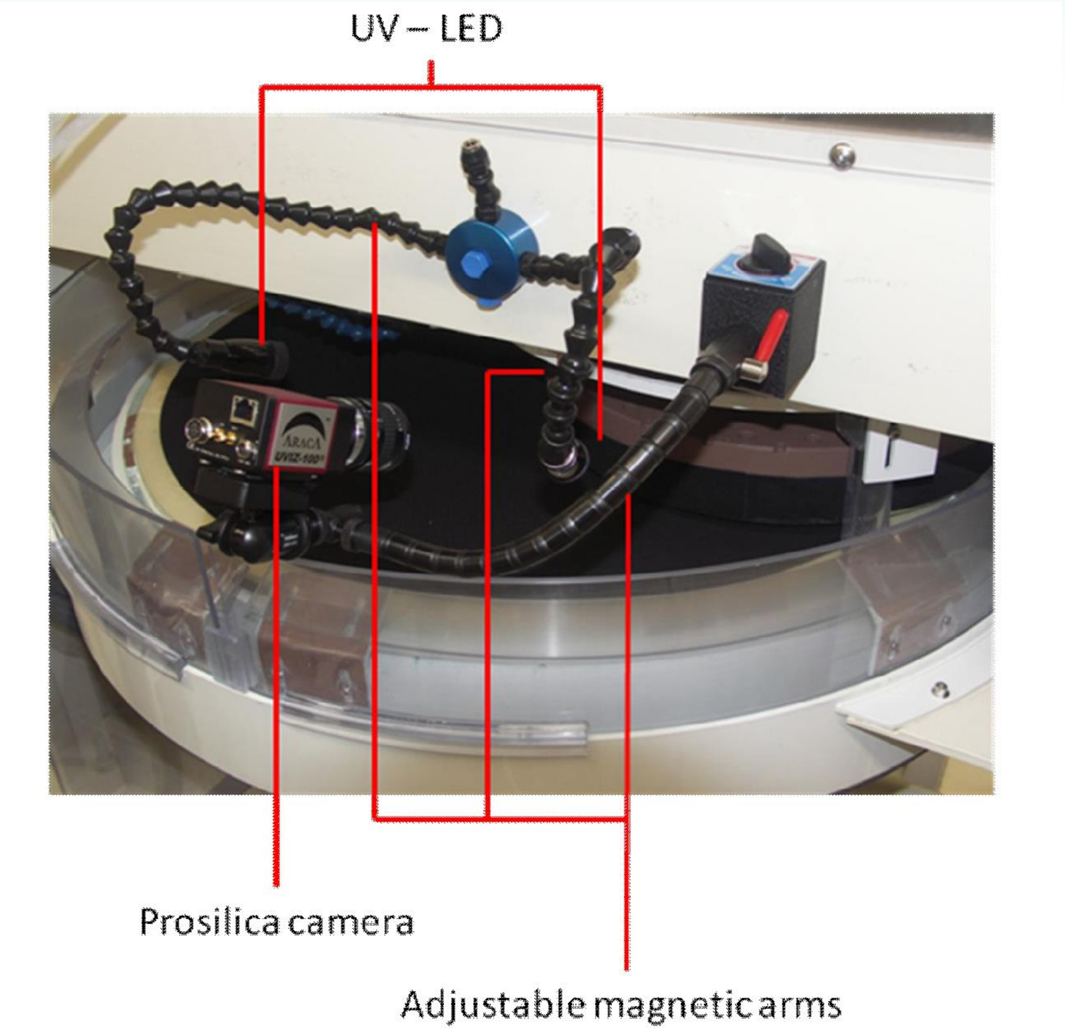


UV – LED cover



The UVIZ-100 on our APD-800 Polisher





CVD Discs and Procedure

4S

43

Break-in the pad with a bristle brush for 30 minutes

↓

Perform UVIZ test on the MGAM 4S disc with platen rotating at 100 RPM – Repeat at 50 RPM.

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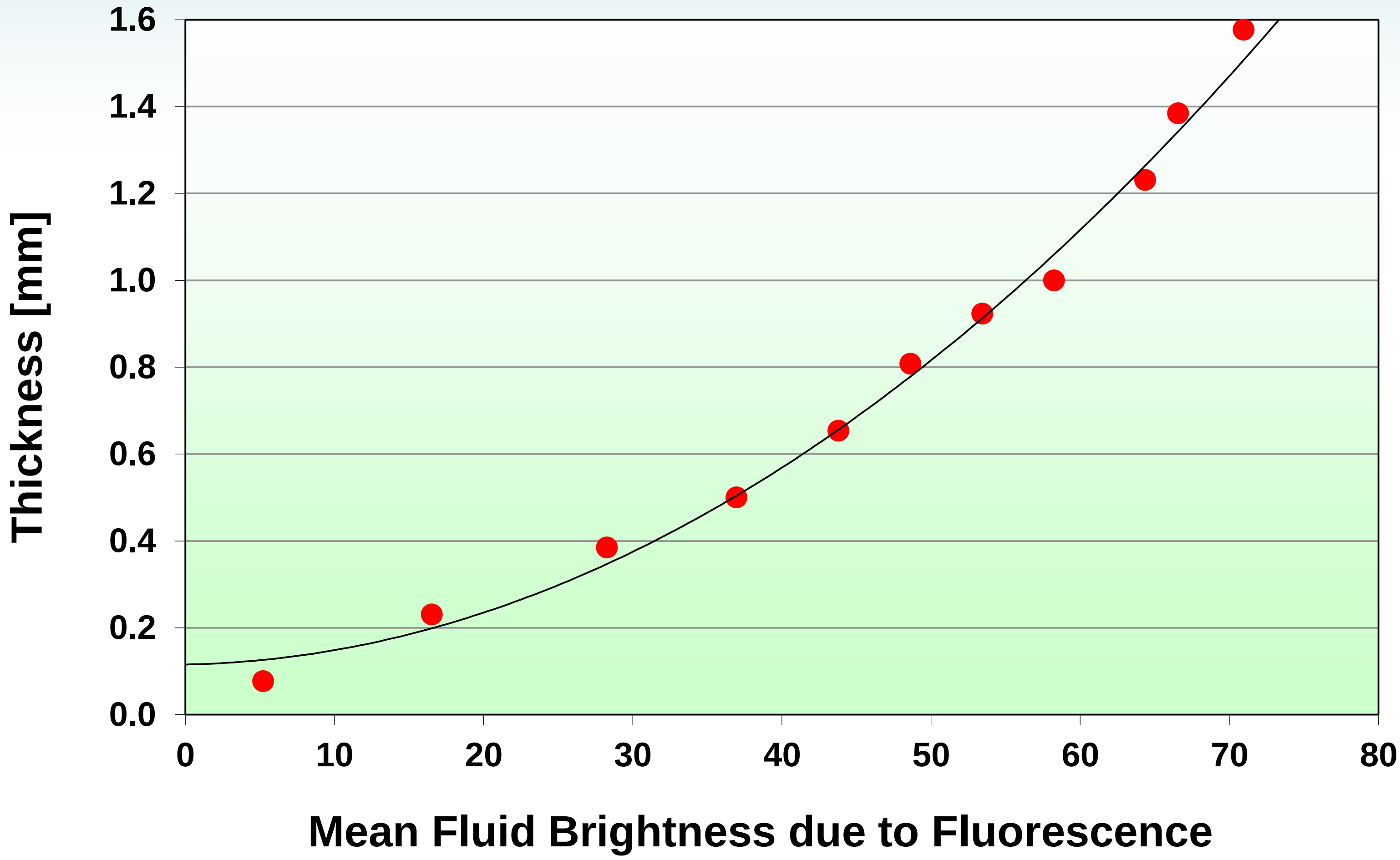
Repeat with the MGAM 43 disc

↓

Perform fluid thickness calibration (see next page)

Thickness-to-Brightness Calibration Curve



All flow visualization experiments and calibrations tests were done in a darkened room – And in 1 day so as to minimize the effect of time-dependent photobleaching.

Data Analysis Flow Chart

Plot raw fluid thickness data for each section analyzed and reset the data to the origin

↓

Fit a curve in each section using the following equation:

$$y = a - b \times e^{(-c \times t^{n})}$$

y = fluid thickness (mm)
t = time (s)
Constants a, b, c and n are fitting parameters

↓

Calculate the hypothetical film thickness after 10 minutes (defined as MAFT which stands for "maximum attainable fluid thickness")

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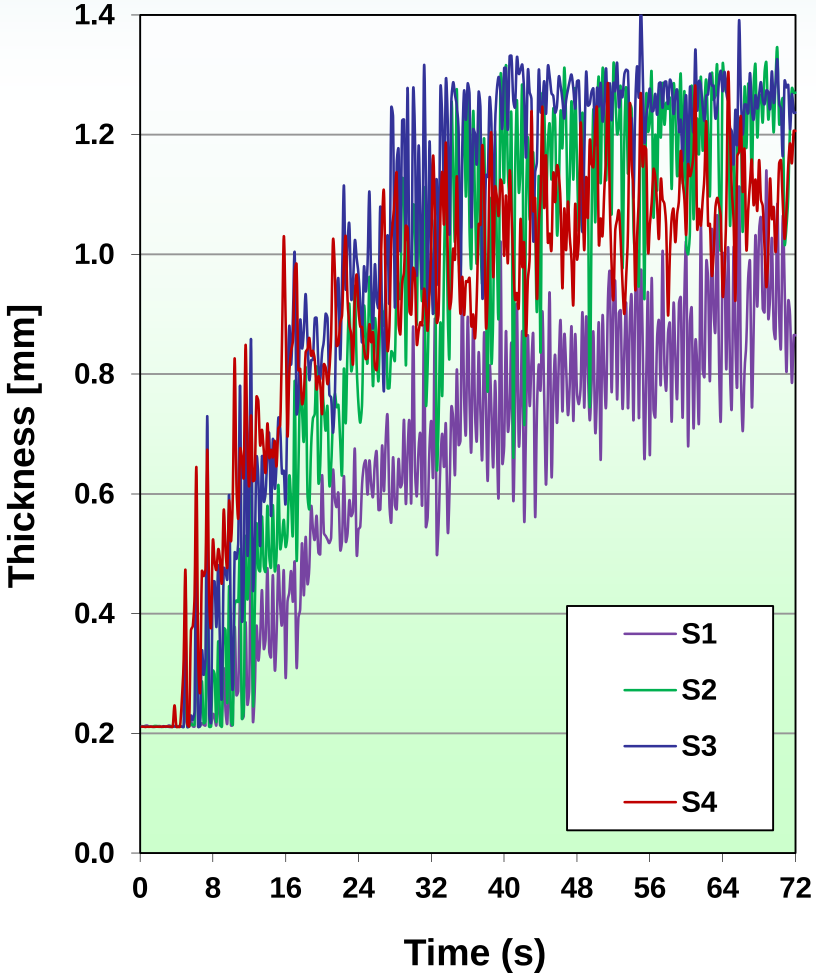
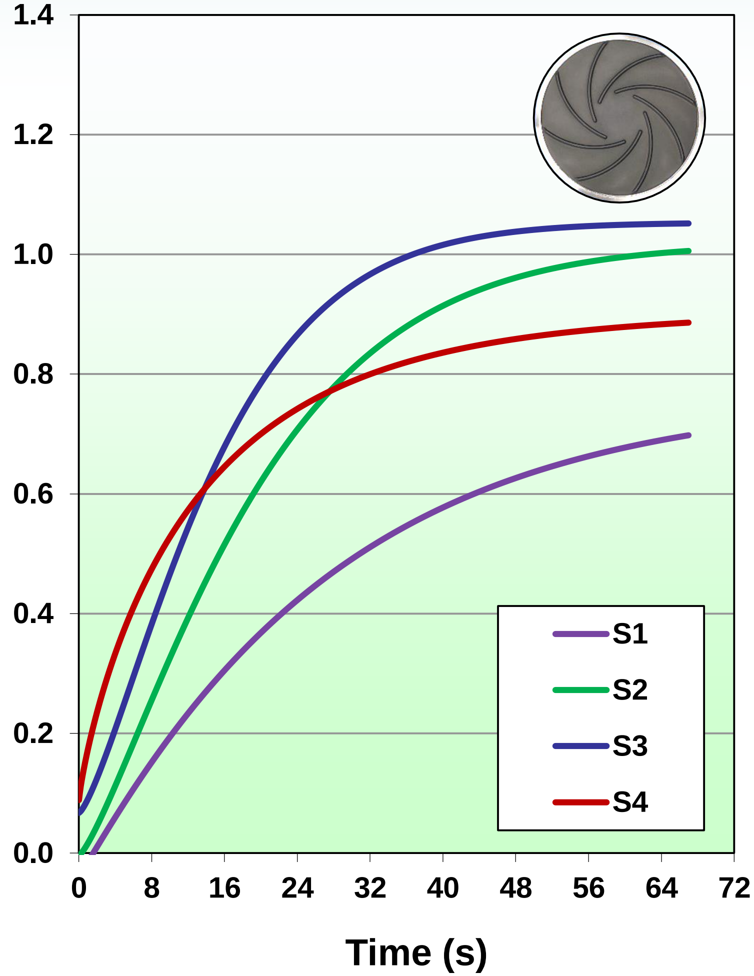
Calculate the time needed to reach 90% of the MAFT (defined as TTRSS which stands for "time to reach steady-state")

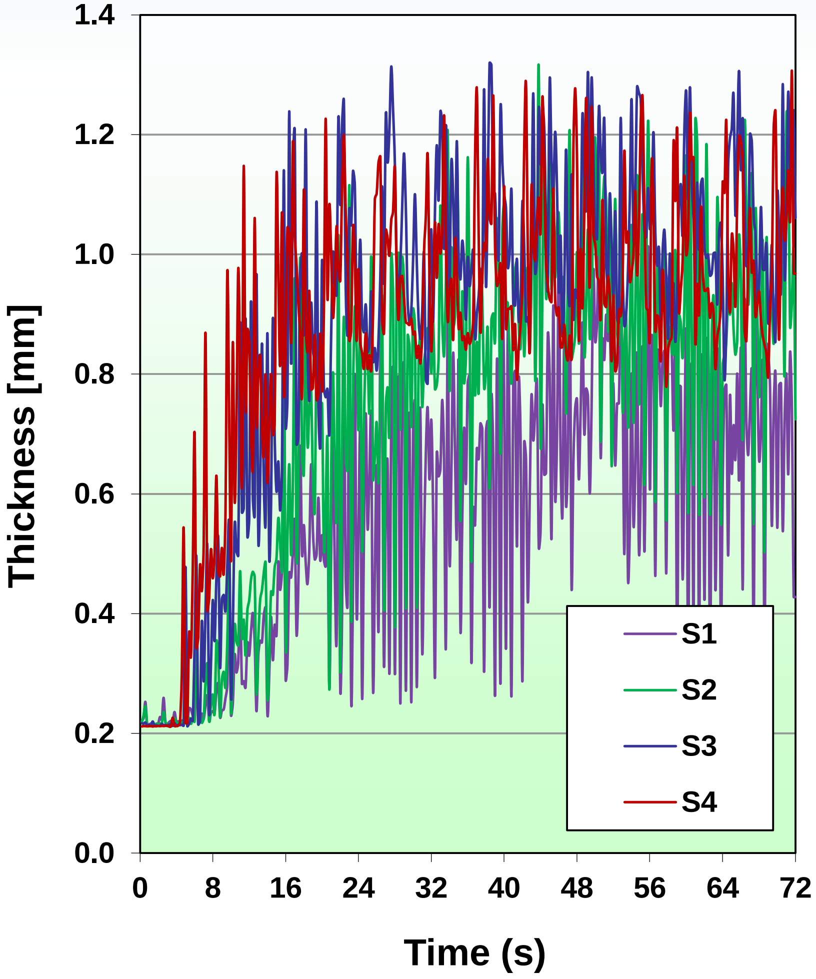
Data Analysis – 4S at 100 RPM

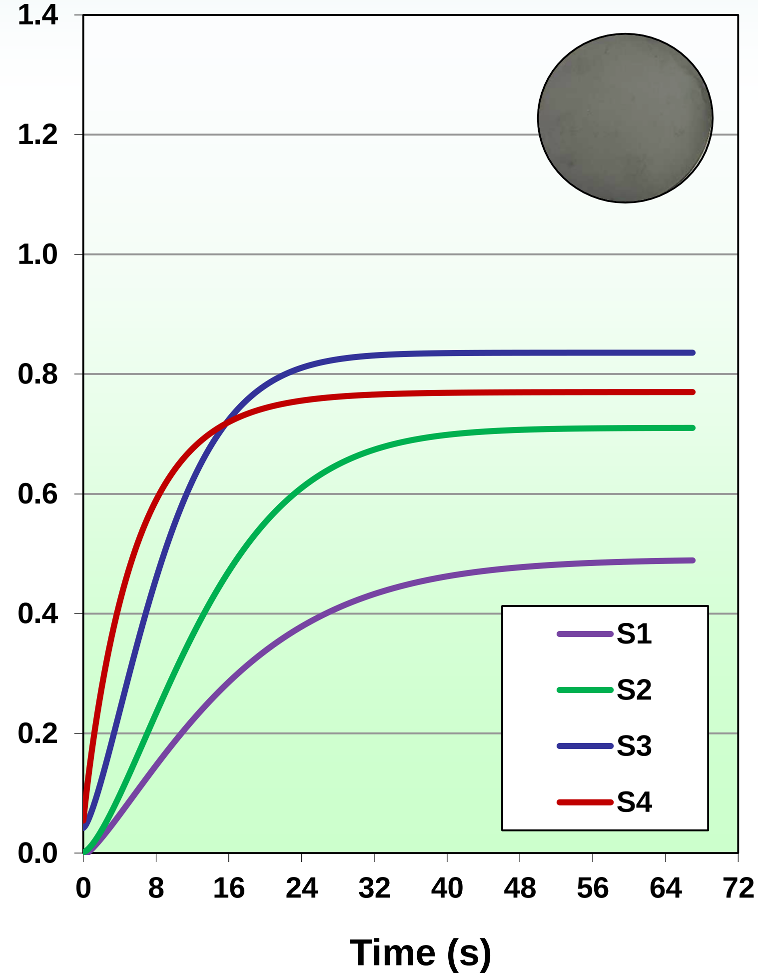
Raw Data and Fitted Curves



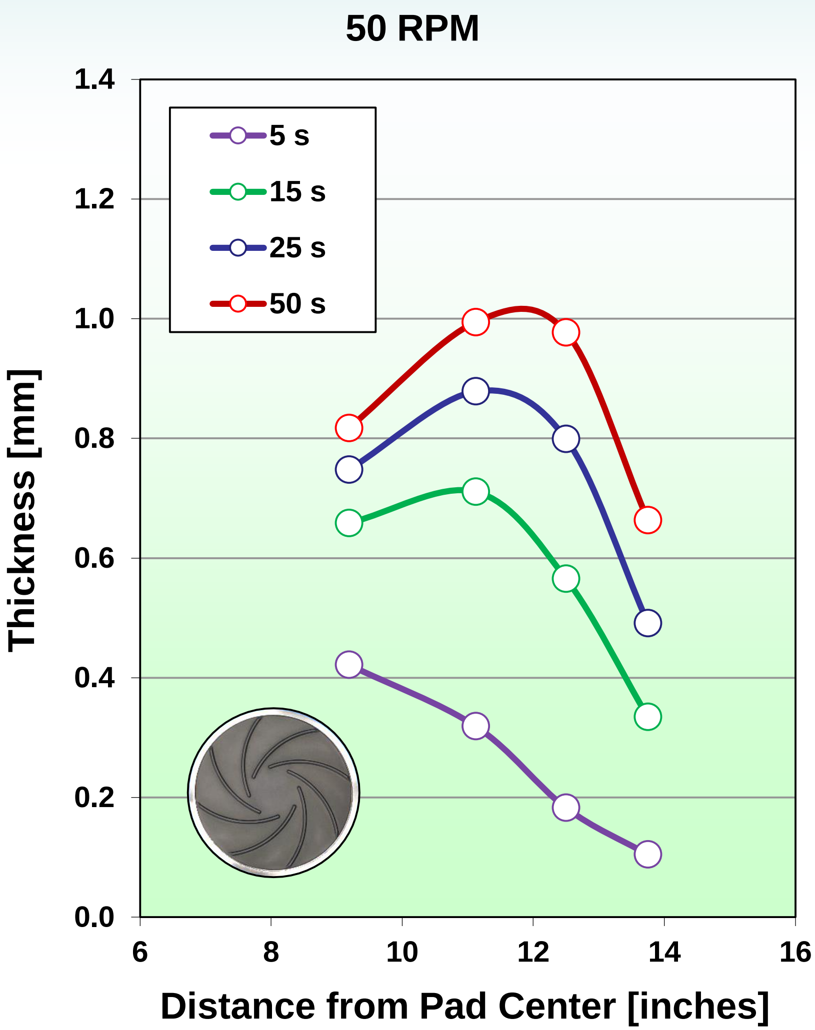


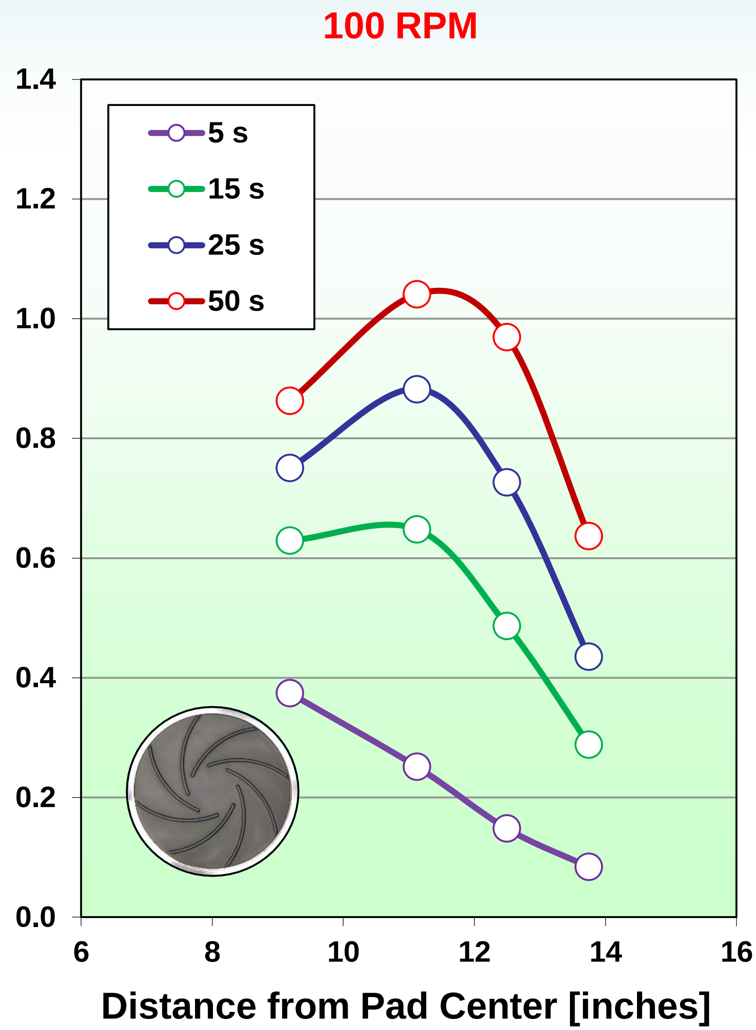
Data Analysis – 43 at 100 RPM
Raw Data and Fitted Curves





Disc 4S – Film Thickness vs. Distance





Trend Analysis

- At the shortest time, section closest to pad center has the thickest film because fresh fluid is dispensed near that region.

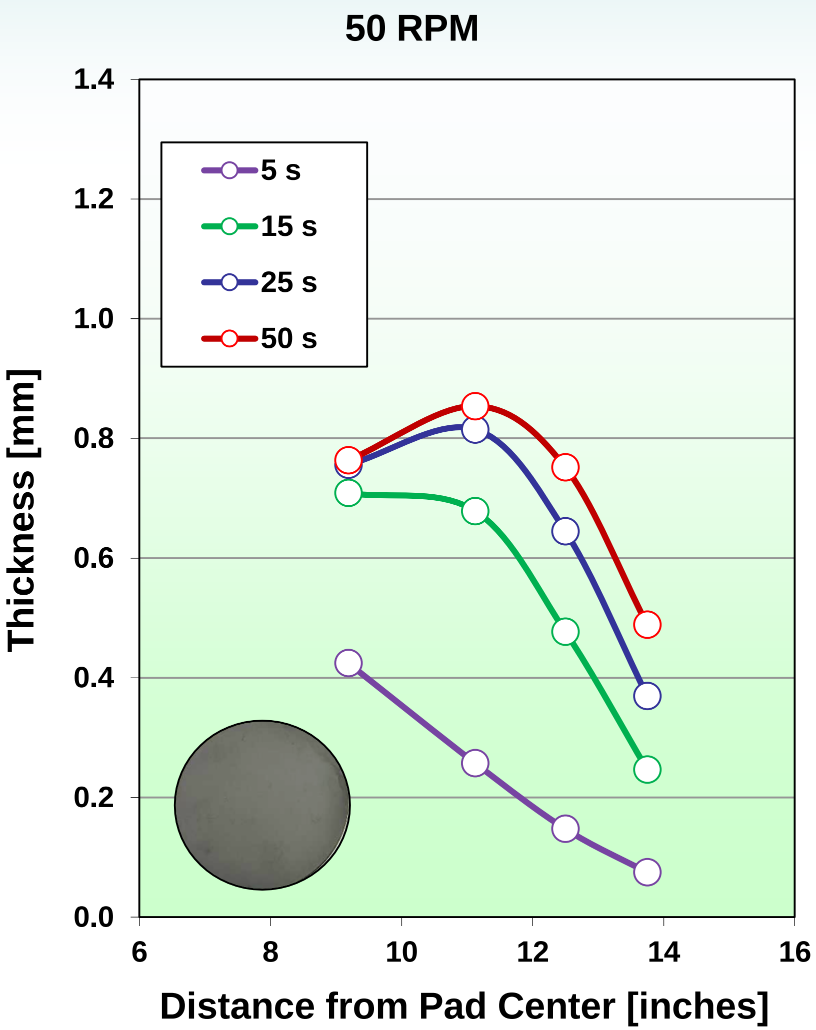
- At longer times, film thicknesses:

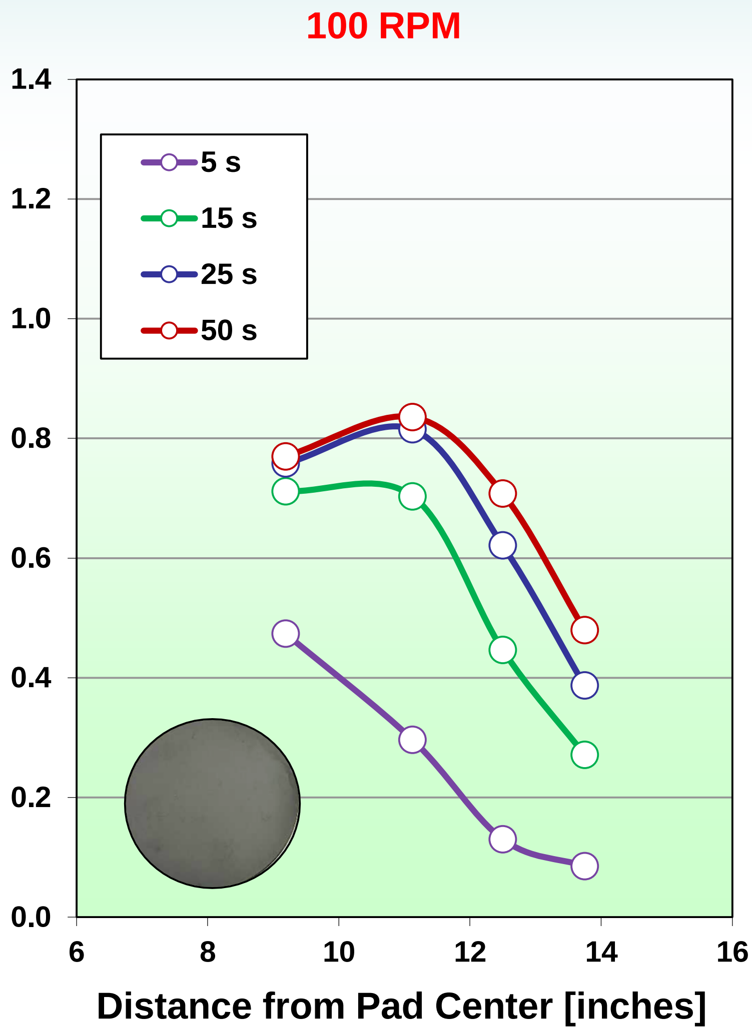
  - ✓ Closest to pad center, increase (by up to 2X) – Then they level off rapidly.
  - ✓ In regions away from pad center, keep on increasing (by up to 3X) – Then they level off at a slower rate. This is due to the conditioner's ability to draw fresh fluid from the center and carry it further out as it moves away.
  - ✓ Near the edge, keep on increasing (by 5X) – Then they level off at a slower rate.

- Thicknesses near pad edge are lowest because fluid is removed from the surface as the conditioner moves over the edge.

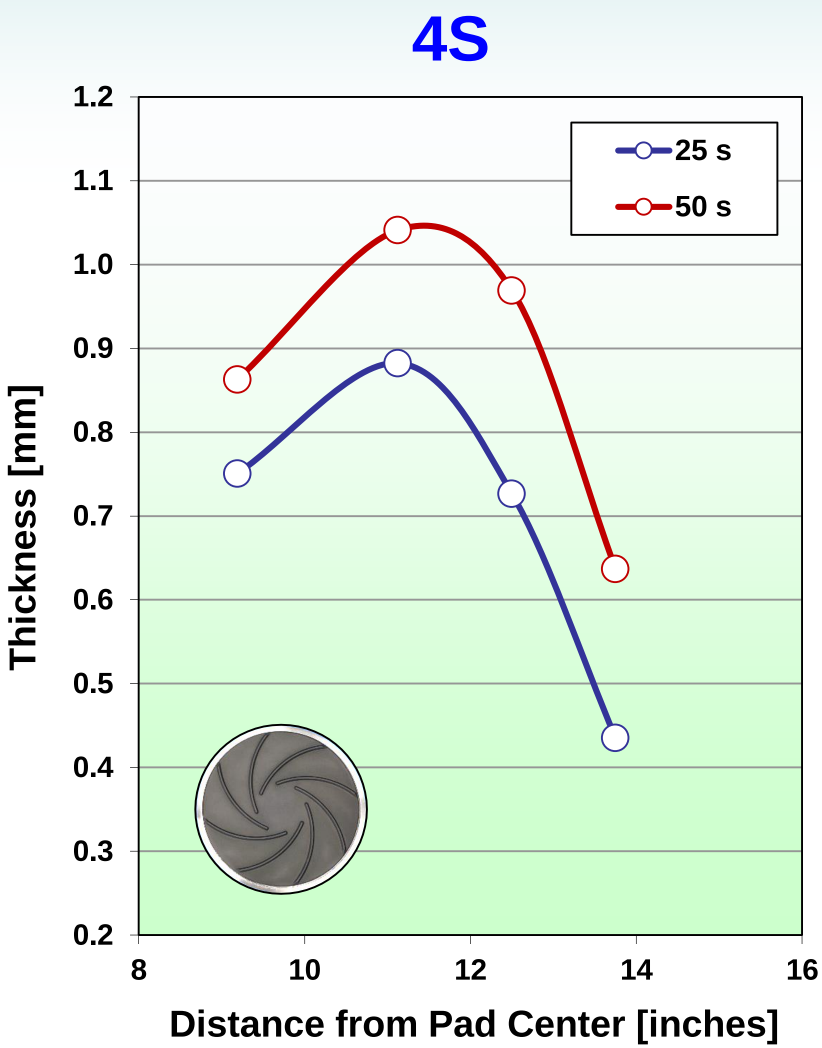
- Higher pad angular velocity causes films near the edge to get thinner (due larger centrifugal forces) – No angular velocity dependence near the center.

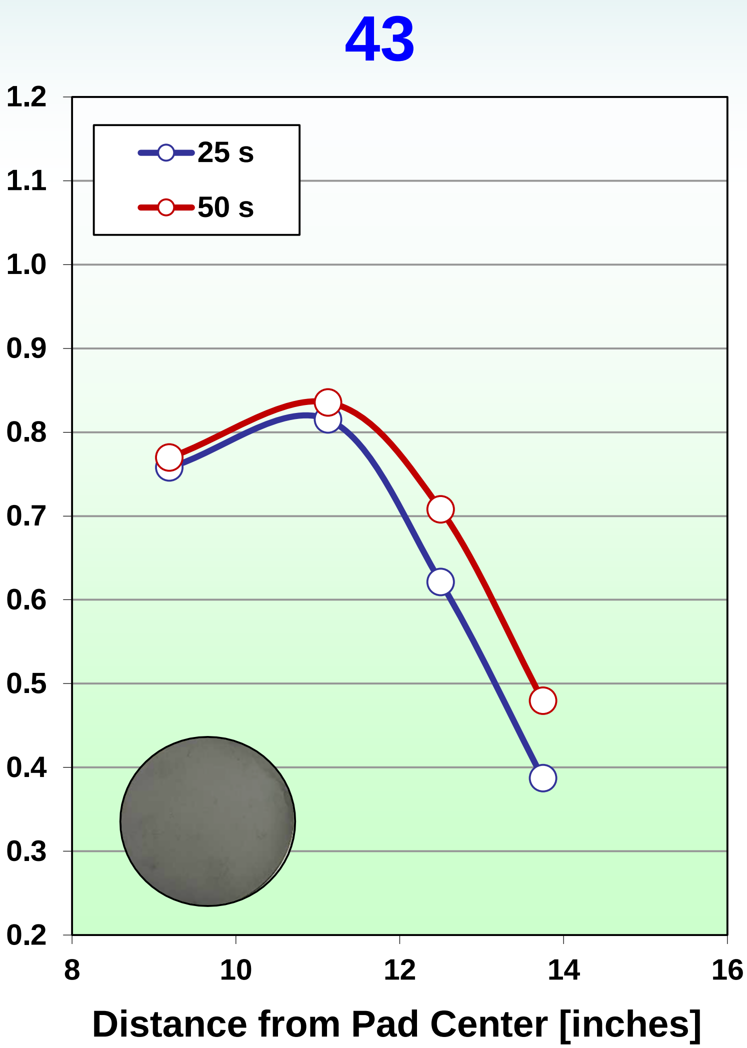
Disc 43 – Film Thickness vs. Distance





Disc Comparison (4S vs. 43) at 100 RPM





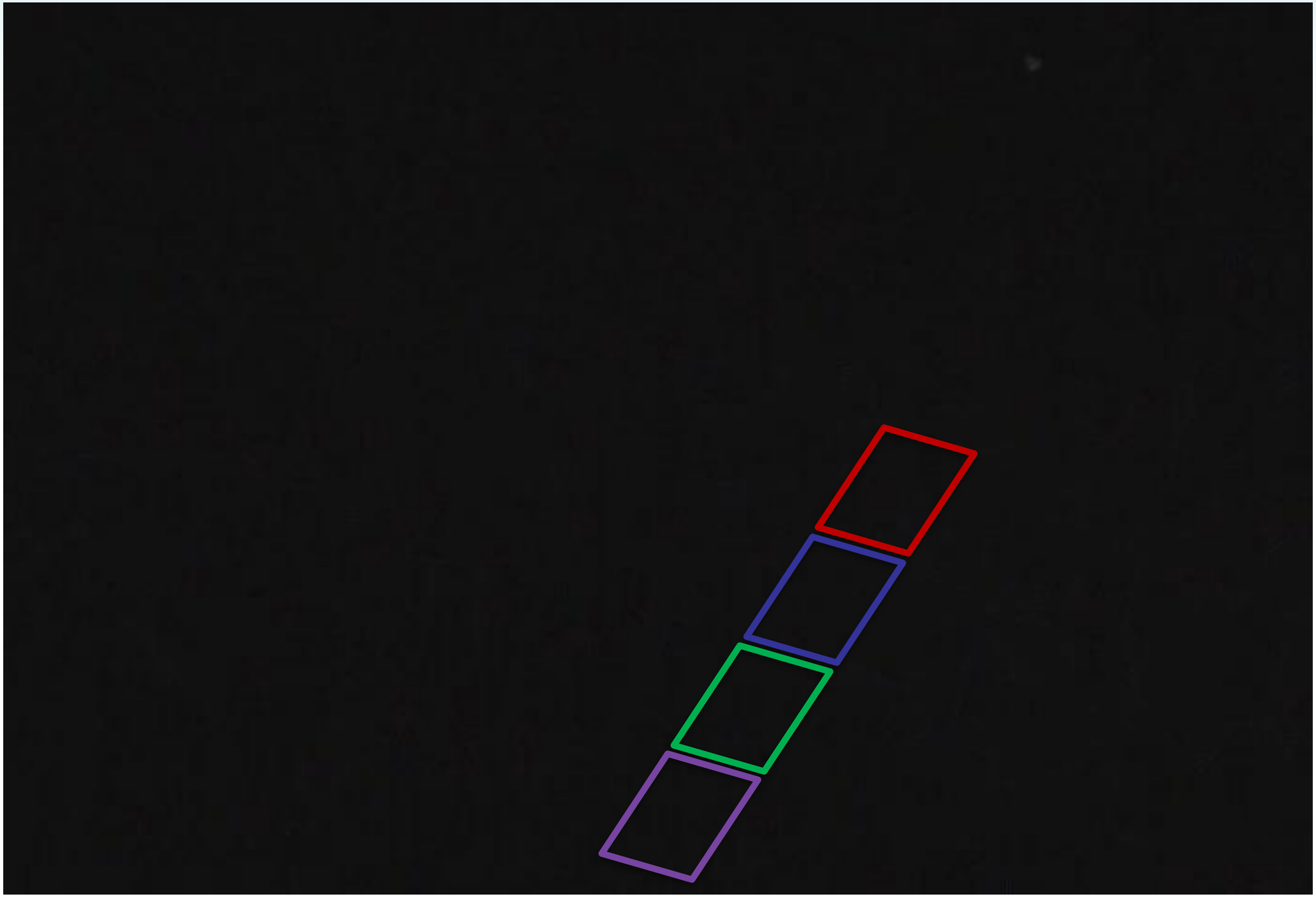
Trend Analysis

- **Same general trends discussed for the 4S are apparent with the 43.**

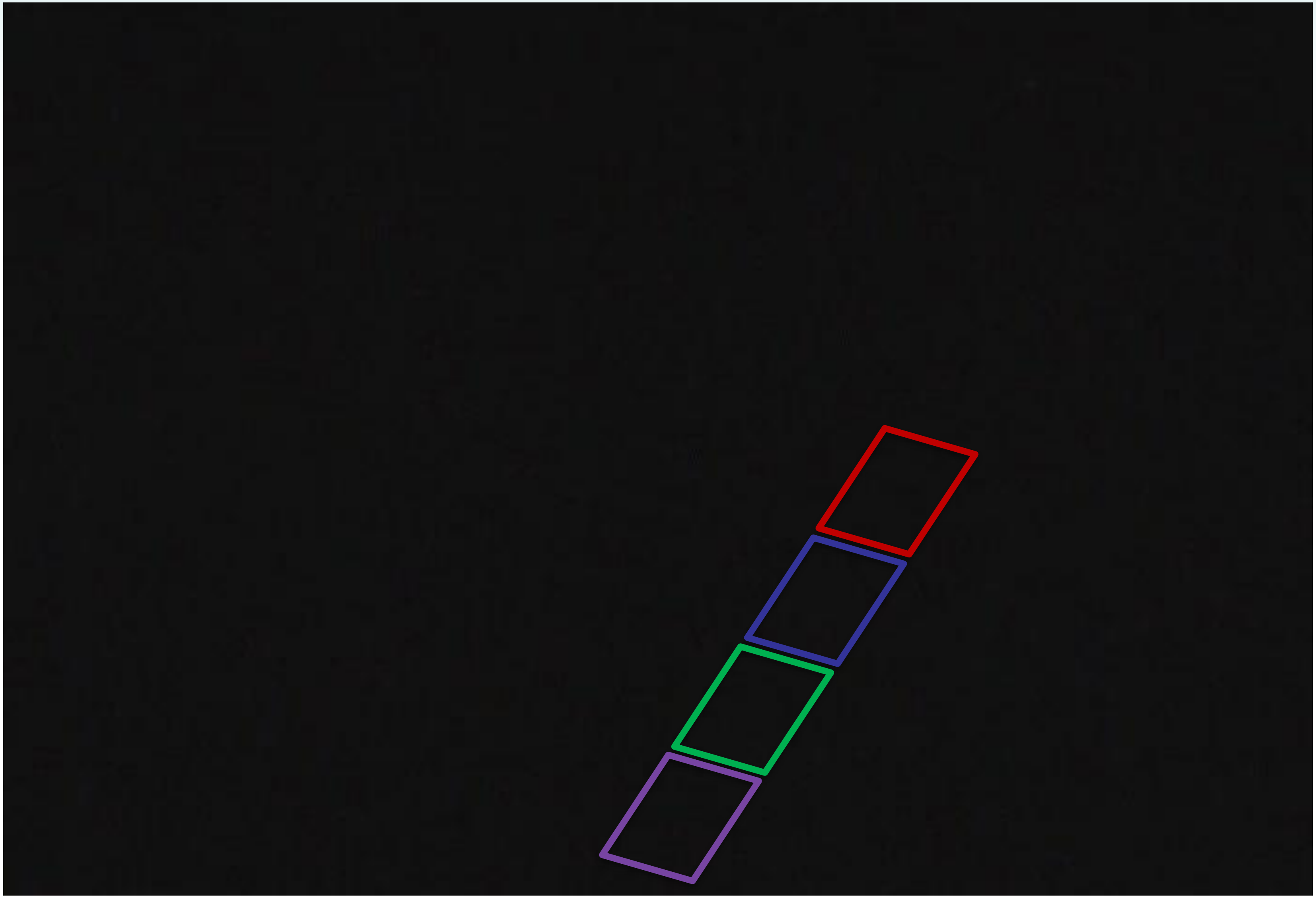
- **However:**

  - ✓ **Full-face conditioner (43) has lower overall film thicknesses because it does not entrain fluid as effectively as the 4S which has vanes.**
  - ✓ **43 tends to impart more of a squeegeeing effect and as it moves over the edge, more fluid is expelled away.**
  - ✓ **Due to its fluid retention characteristics, 4S generates more back-flow.**
  - ✓ **This effect is more pronounced at 100 RPM likely because disc rotation (95 RPM) and platen rotation (100 RPM) are nearly matched.**

VIDEO – Disc 4S at 100 RPM

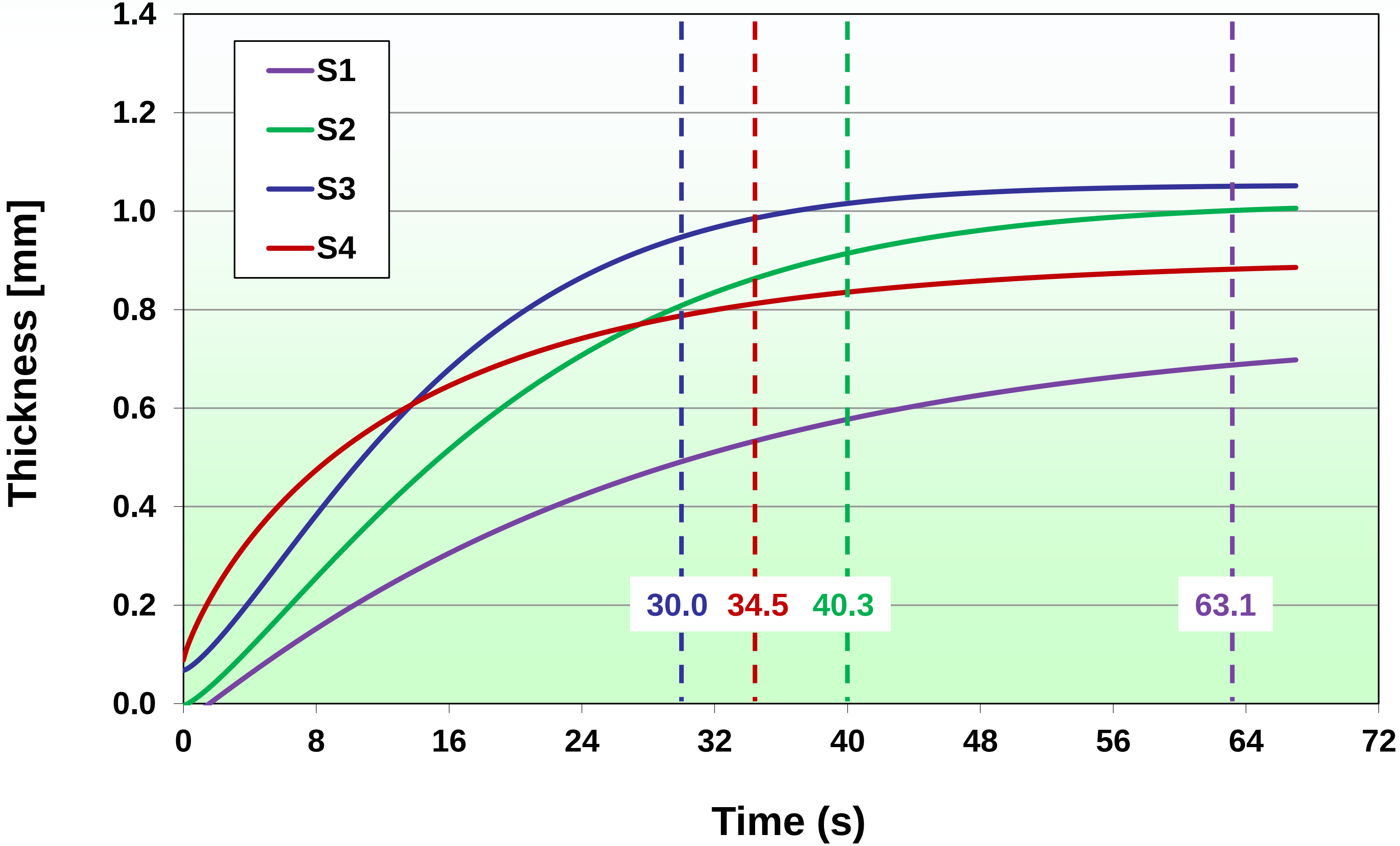


VIDEO – Disc 43 at 100 RPM

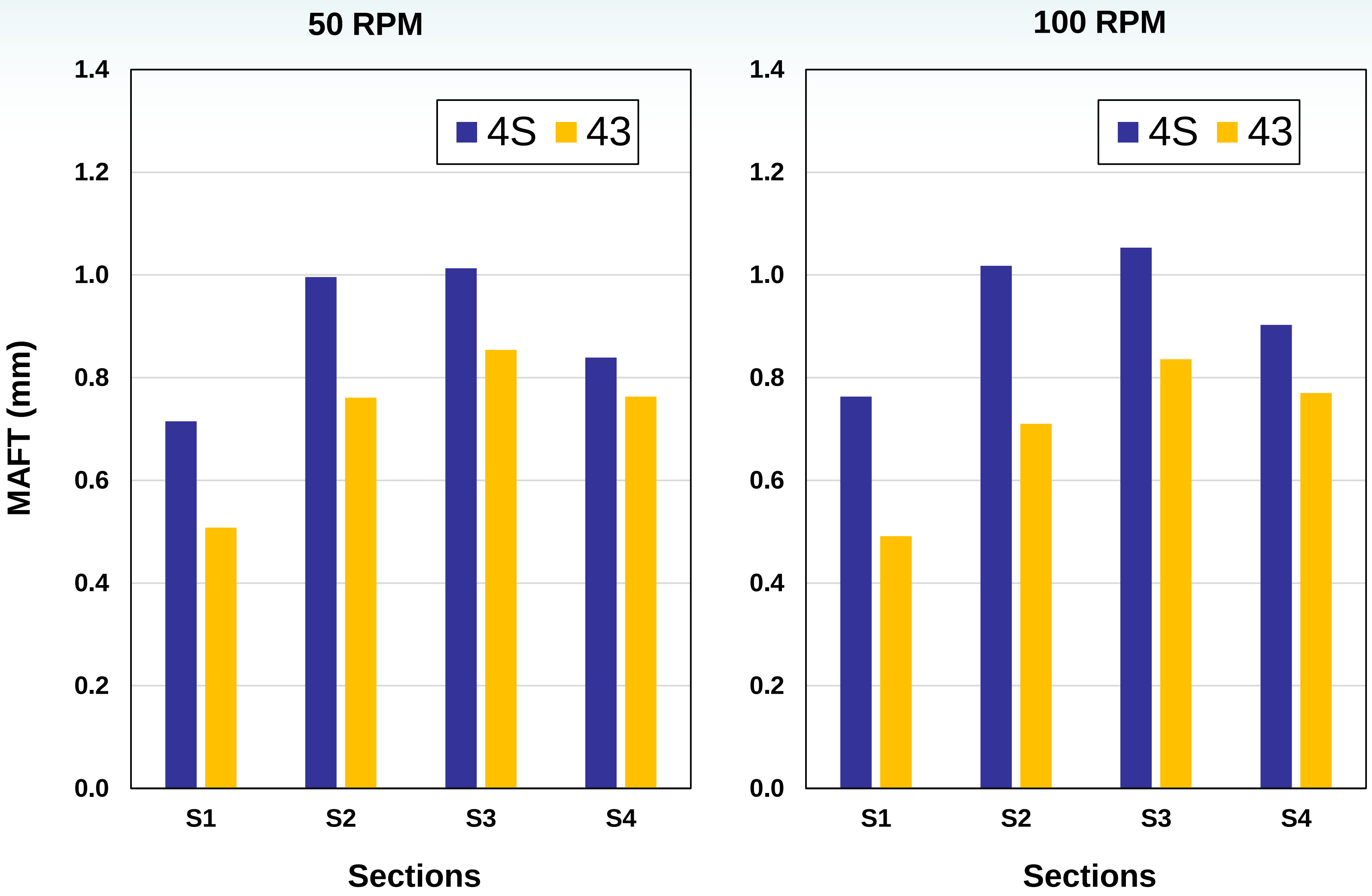


Time To Reach Steady State

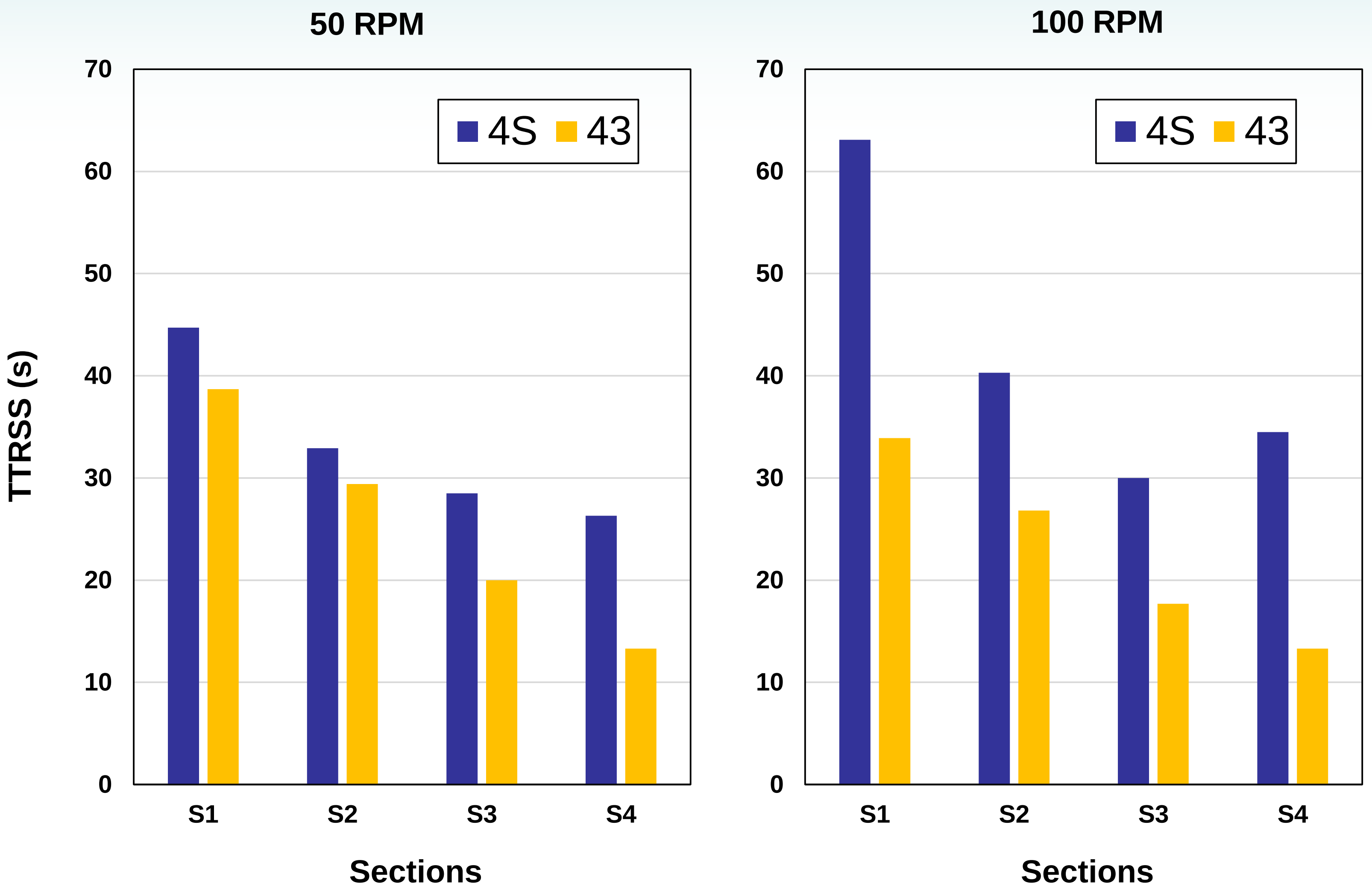
TTRSS ≡ Time needed to reach 90% of the maximum attainable fluid thickness (MAFT)



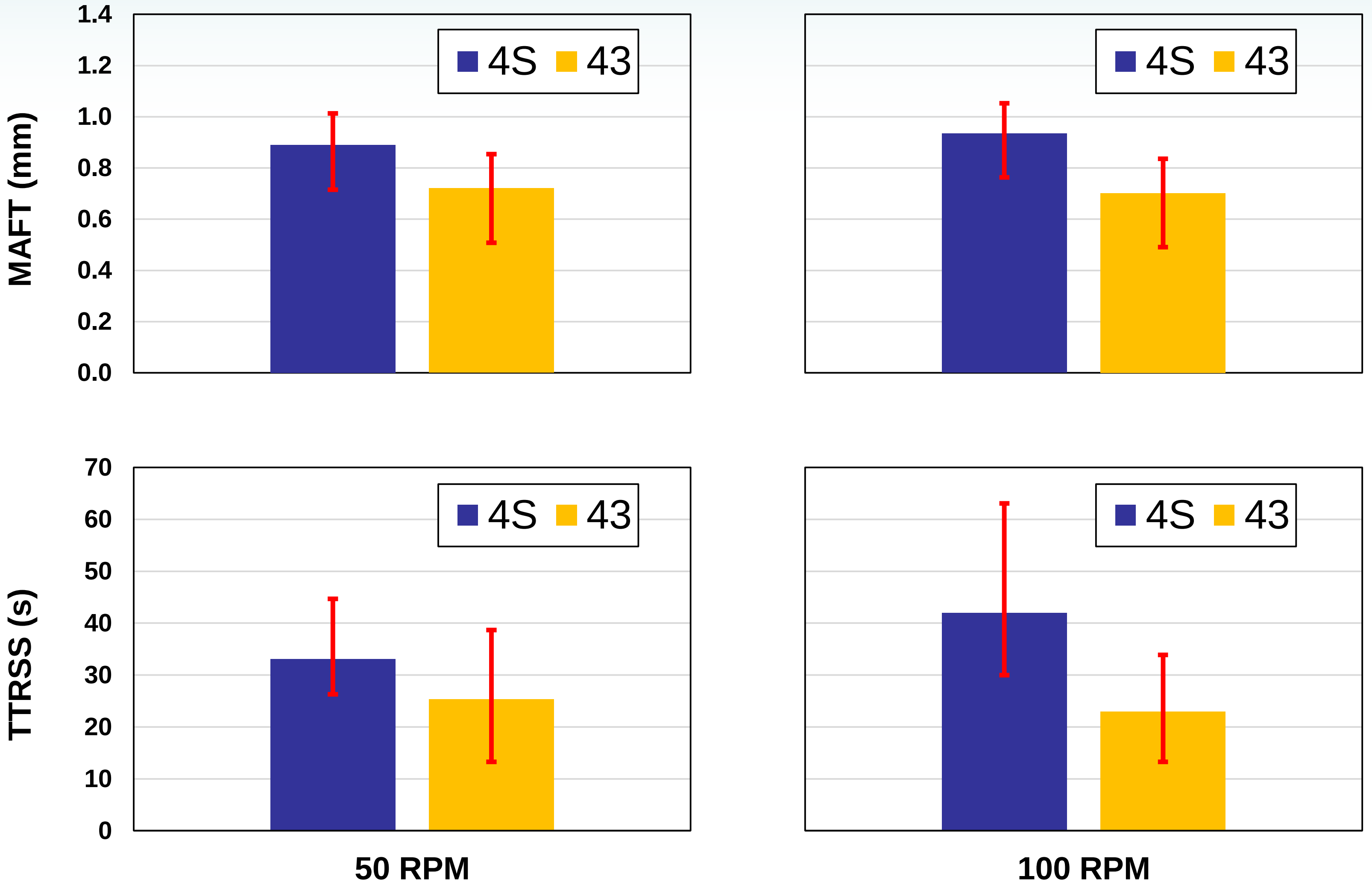
Maximum Attainable Fluid Thickness



Time To Reach Steady State



MAFT and TTRSS Means and Ranges



MAFT and TTRSS Summary

- 4S causes thicker fluid films (by 23 and 33 percent at 50 and 100 RPM, respectively) as compared to 43 – Because 4S has greater retention capabilities and generates more back-flow
- Sections near the center of the wafer track have thicker fluid
- Near the center of the pad, fluid is only slightly thinner
- Near the edge of the pad, fluid is significantly thinner
- Regarding time to reach steady-state fluid thickness conditions:

  - ✓ 4S takes longer (by 31 and 83 percent at 50 and 100 RPM, respectively) compared to 43 – Because 4S impedes and disrupts flow more effectively
  - ✓ The farther away from the pad center, the longer it takes for film thicknesses to reach SS due to the area dependence on radius (i.e. the ΠR^2 effect)!

- Further work using our novel technique is ongoing with the ultimate goal being to come up with the ideal disc face designs and process conditions!

Thank You!