

Stribeck Curve Improvements for Cu and W CMP on Hard and Soft Pads

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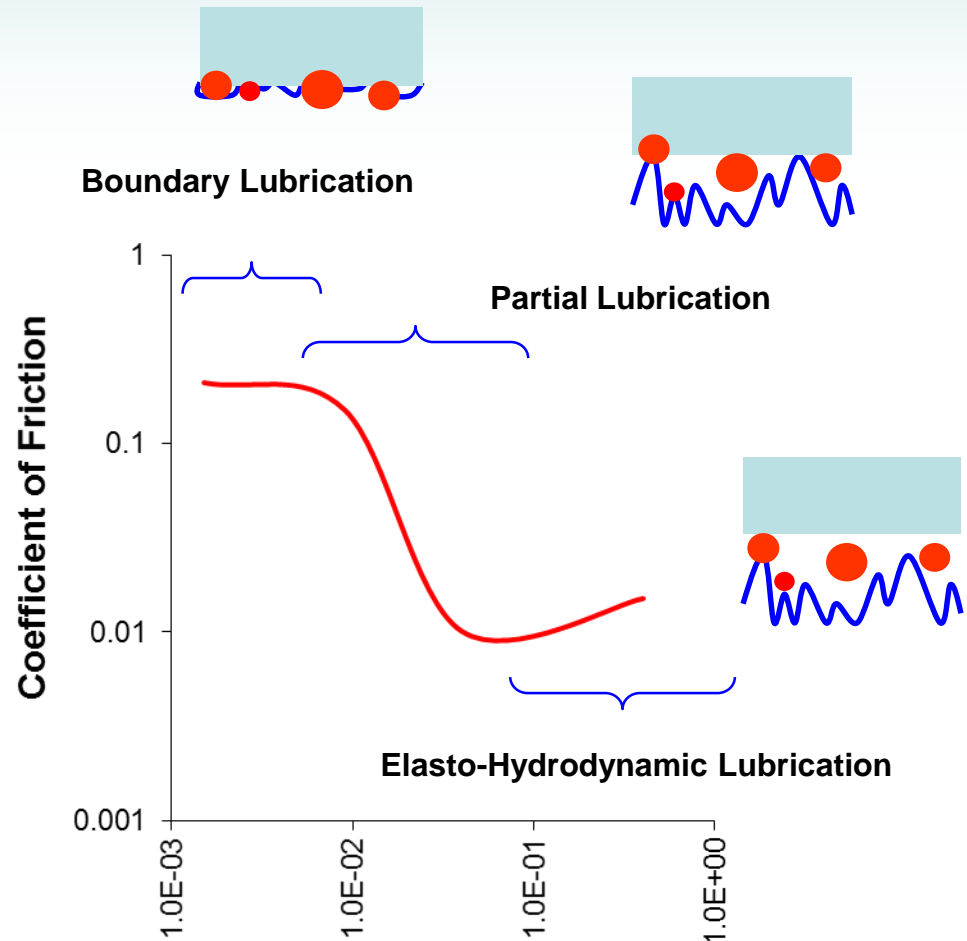


Outline

- **Background and Motivation**
- **Objective**
- **Polishing Apparatus**
- **Improving Traditional Stribeck Curves**
- **The Stribeck+ Curve**
- **Selected Cases Studies**
 - ❖ **Copper CMP on HARD pads**
 - ❖ **Copper and Tungsten CMP on SOFT pads**
 - ❖ **ILD CMP (ceria slurry) on HARD pads (time permitting)!**
- **Temperature Studies**
- **Summary**

Background

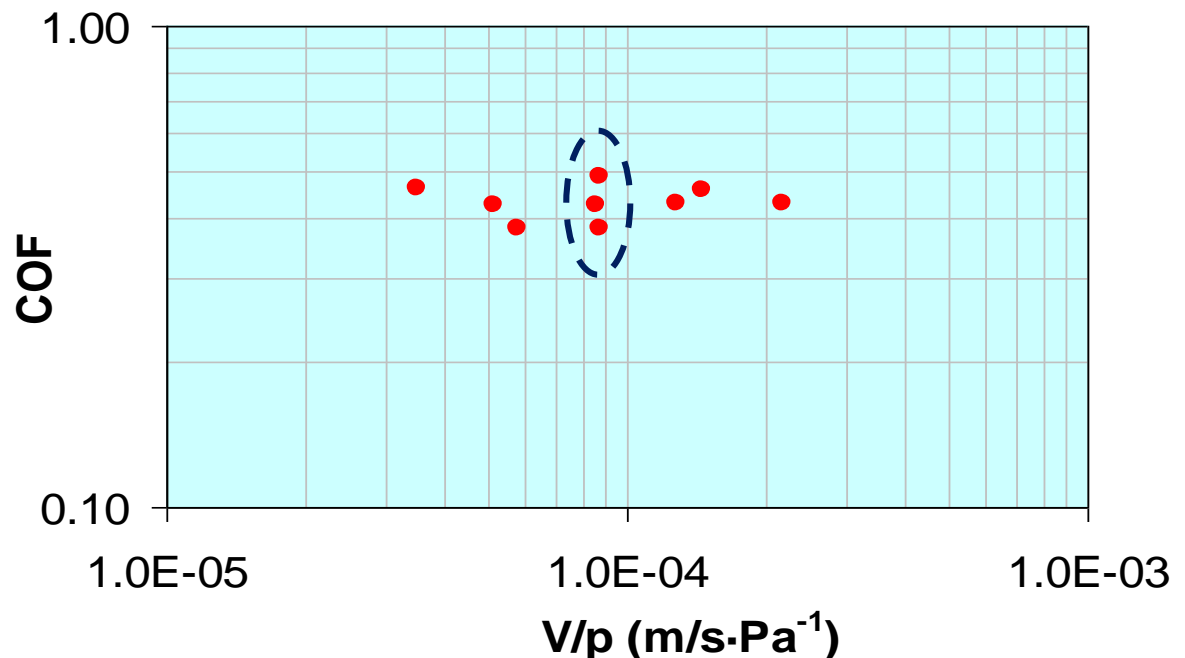
- As a 1st approximation, the Stribeck curve helps provide evidence of the extent of contact among wafer, pad and abrasive particles where 3 major lubrication modes can be distinguished.
- Additionally, it helps screen certain consumable sets by determining if and how they contact one another during CMP.
- This can help determine optimal polishing parameters, predict EOL for pads and avoid certain polishing conditions.



$$So = \frac{(u) \times (\mu)}{(P) \times (\delta_{eff})}$$

Motivation

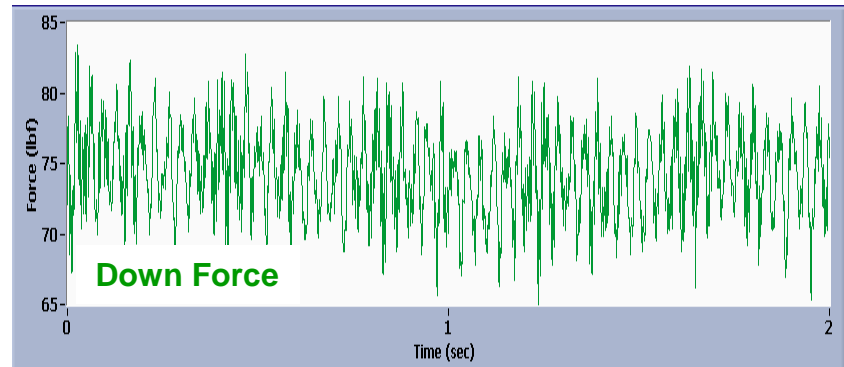
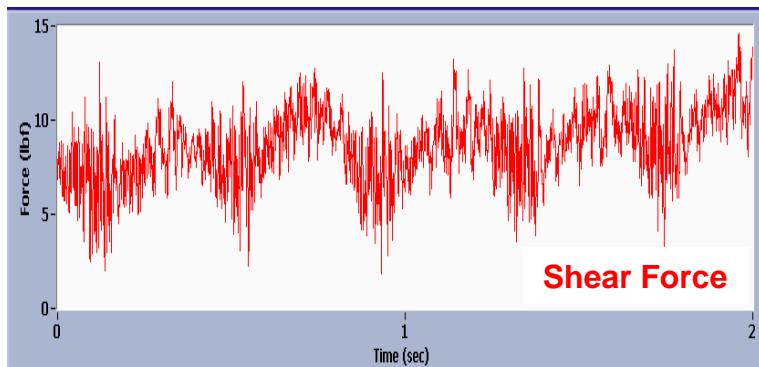
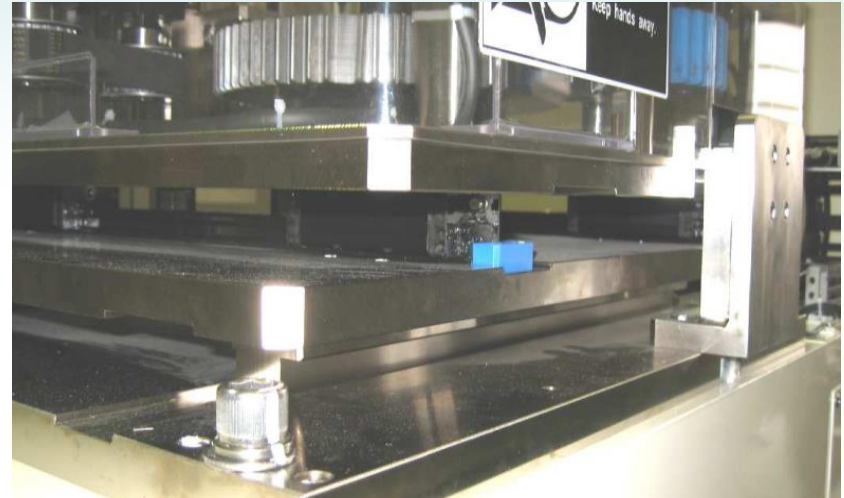
- When it comes to a “typical” Stribeck curve:
 - ❖ Many wafers need to be polished at various pressures and sliding velocities. This is costly and time consuming!
 - ❖ Generally, only average COF is plotted.
 - ❖ COF is measured assuming a constant downforce (e.g. pressure set-point in the polisher)!
 - ❖ V and P are lumped in the Sommerfeld number. Their ratio is what seems to count; not their individual values.



Objective

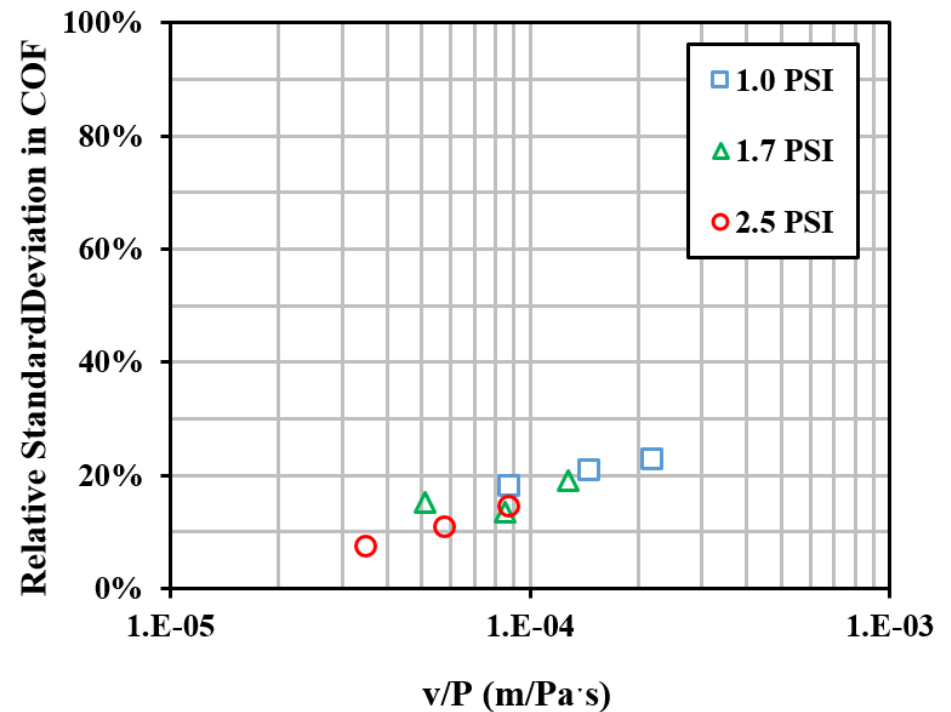
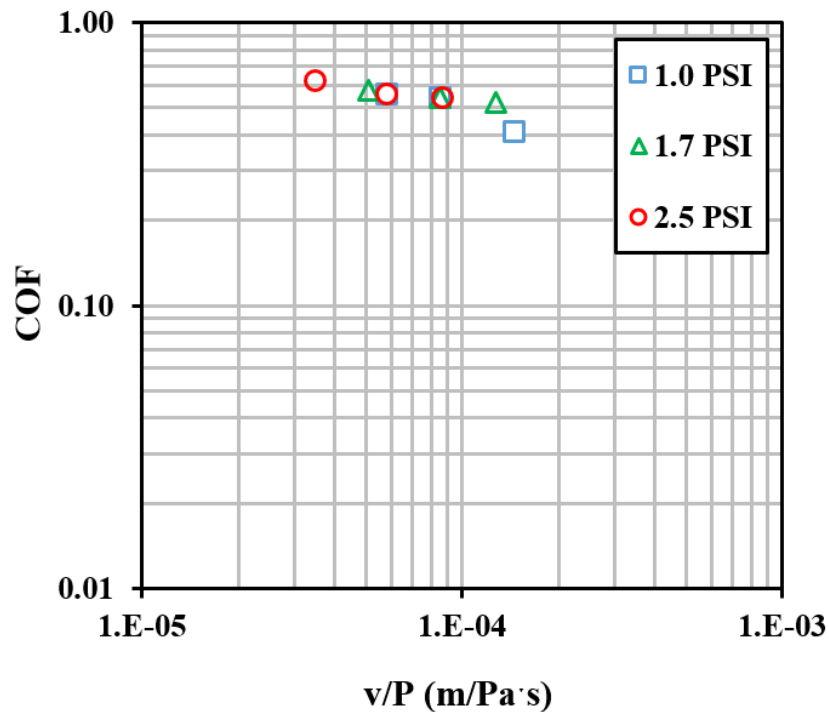
- Show that Stribeck curves based on average COF can be misleading!
- Show that the measure of COF in Stribeck curves should really be based on accurate measurements of not just shear force, but also downforce.
- Introduce a new method for obtaining the Stribeck curve corresponding to a set of consumables in CMP by only performing **ONE** wafer polish.
- Compare and contrast several Stribeck and **Stribeck+** curves resulting from polishing 300 mm blanket Cu and ILD wafers using different types of hard pads and slurries.
- Show how **Stribeck+** curves differ for Cu and W applications on soft pads.
- Supplement **Stribeck+** curves with real-time pad surface temperature measurements and discuss certain thermal ramifications!

The Araca APD – 800 Polisher & Tribometer



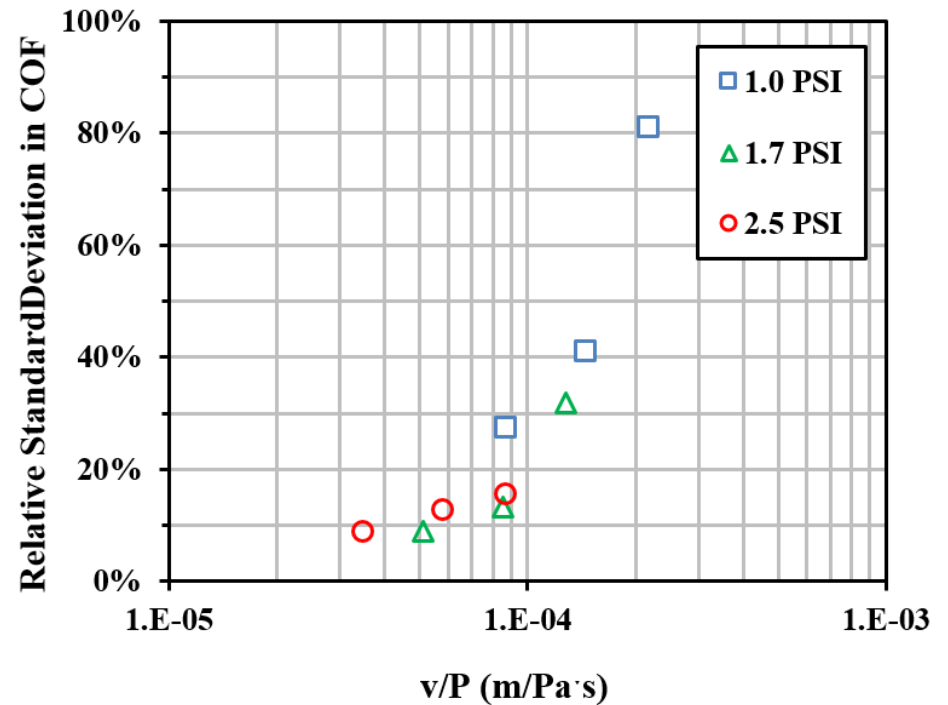
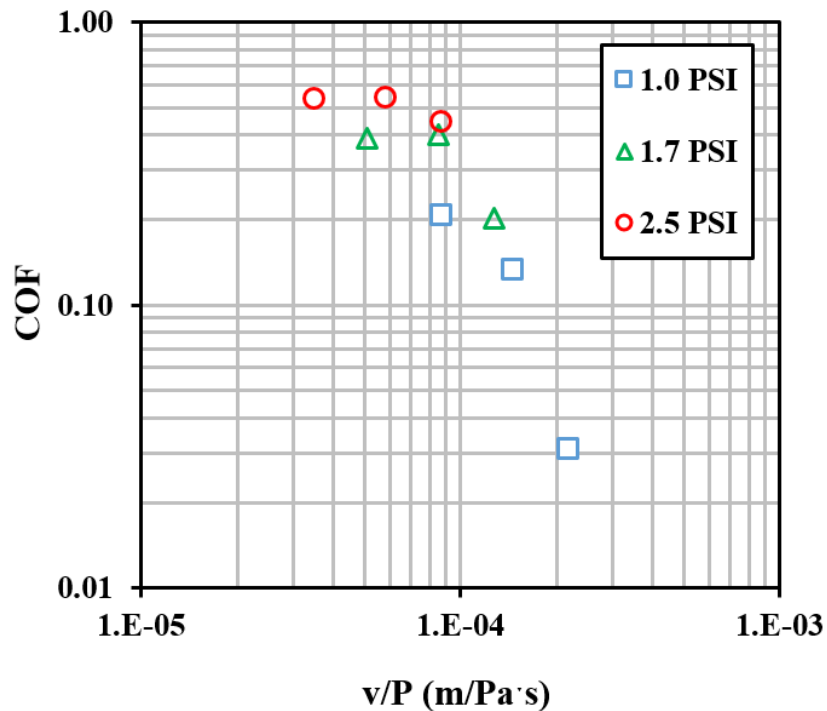
Traditional Stribeck Curve

Average COF and RSD – Copper – CMC 600Y-75 – D100

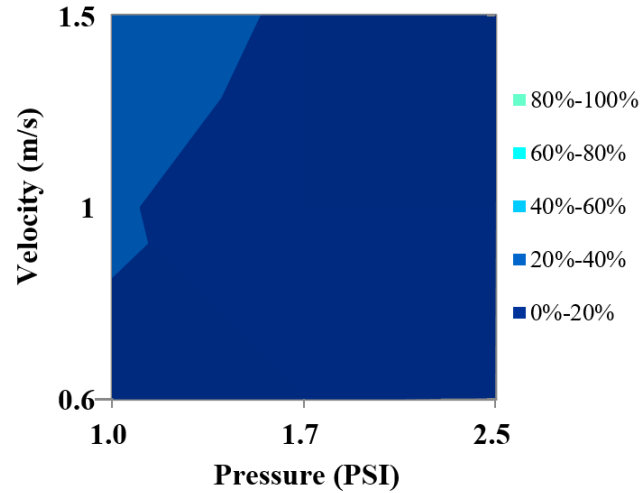
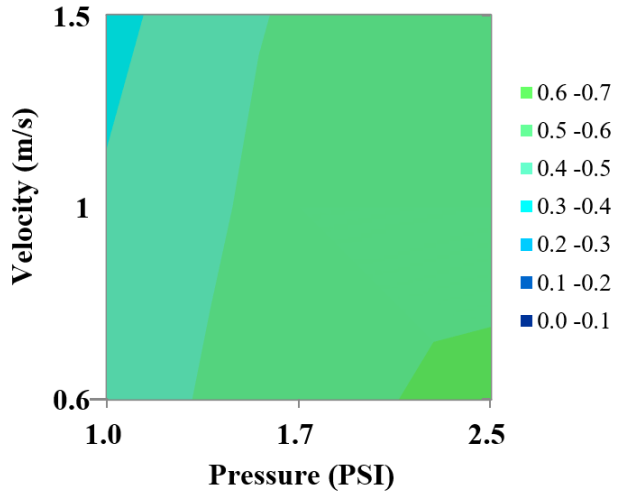


Traditional Stribeck Curve

Average COF and RSD – Copper – CMC 600Y-75 – IC1000 K

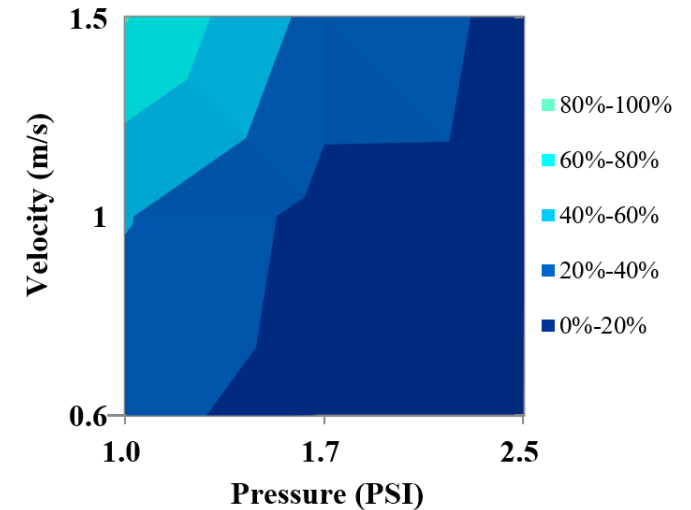
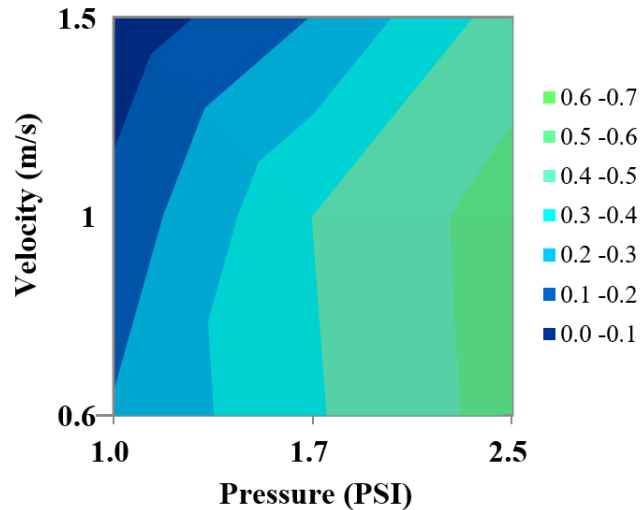


Average COF and RSD Lim-Ashby Plots



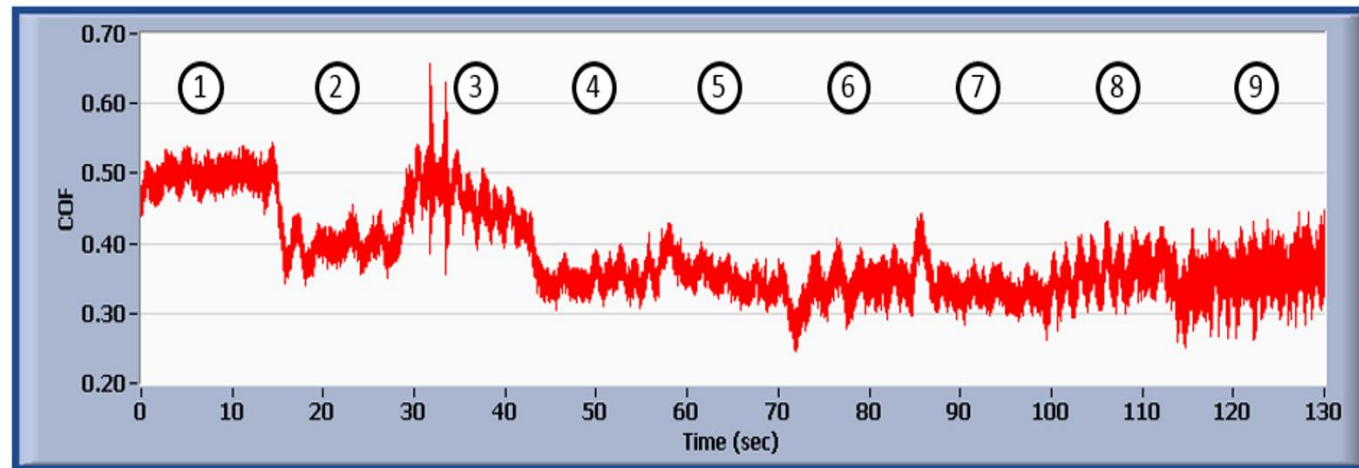
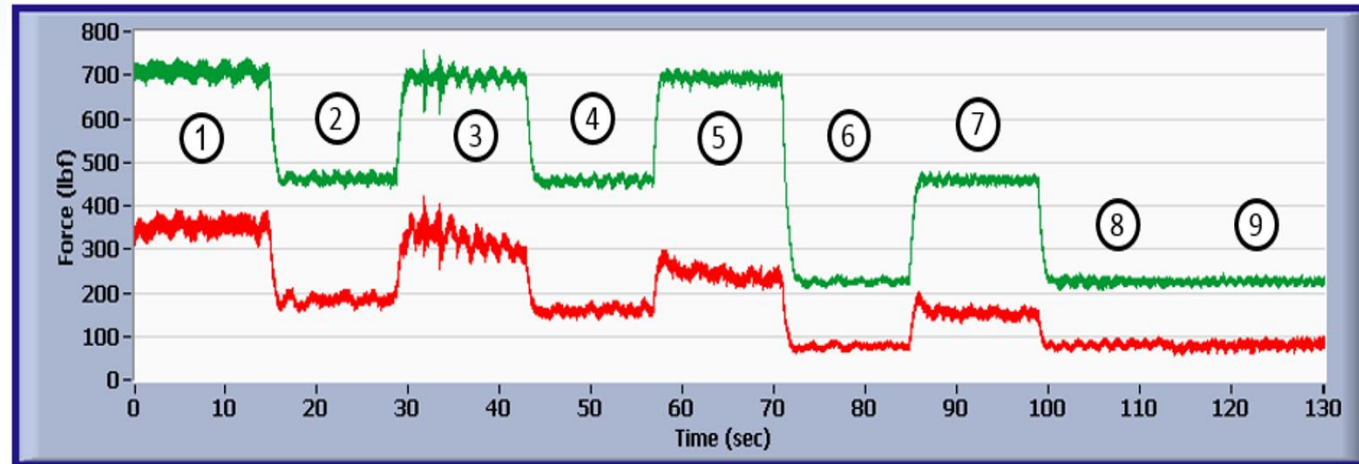
←
CMC D100

Dow IC1000

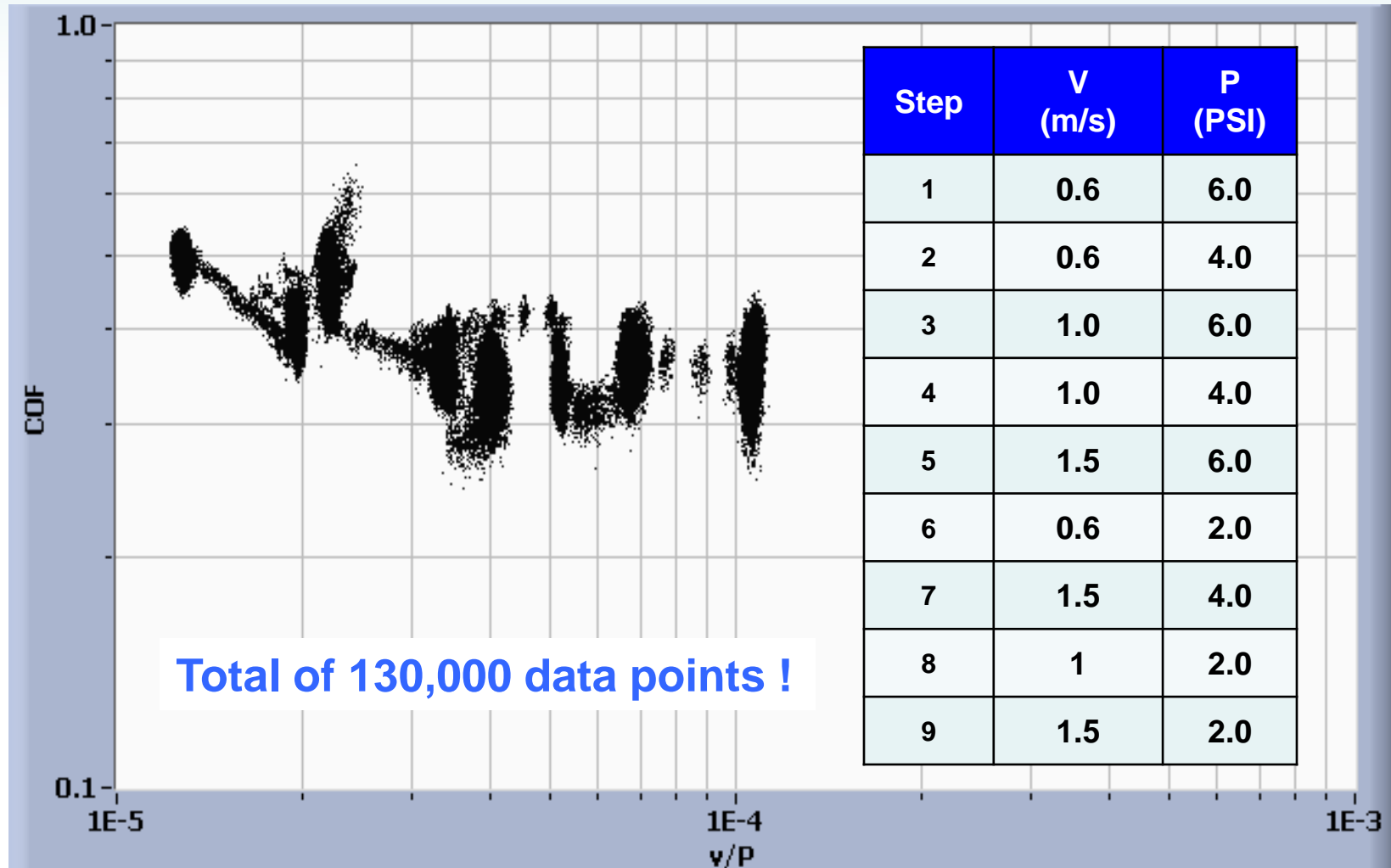


A Continuous Run Through 9 Conditions

Step	V (m/s)	P (PSI)
1	0.6	6.0
2	0.6	4.0
3	1.0	6.0
4	1.0	4.0
5	1.5	6.0
6	0.6	2.0
7	1.5	4.0
8	1	2.0
9	1.5	2.0



Example of a Stribeck+ Curve



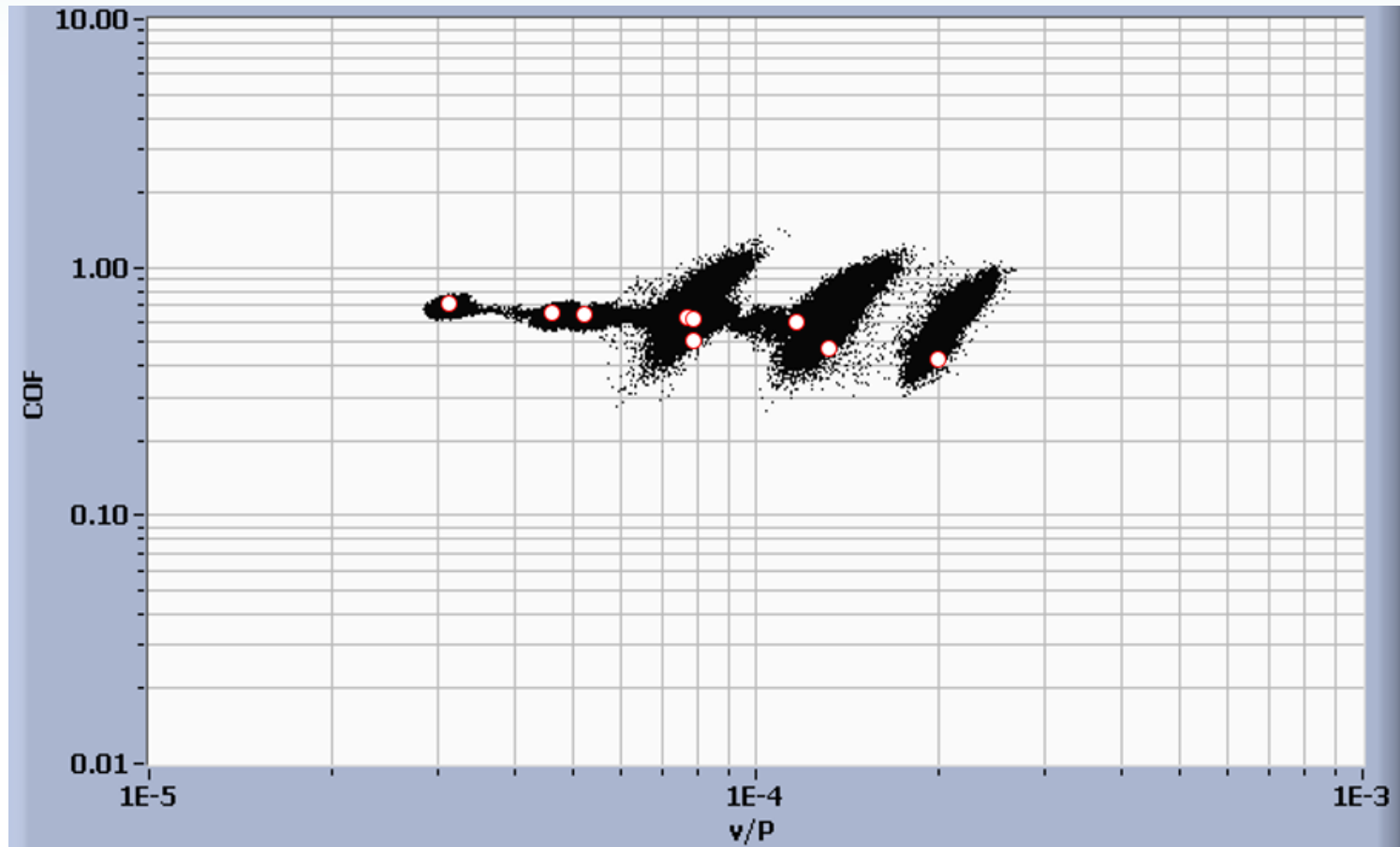
Experimental Conditions

Copper CMP

- Wafer: 300-mm blanket copper
- Wafer pressure: 1.0, 1.7 and 2.5 PSI
- Sliding velocity: 0.6, 1.0 and 1.5 m/s
- Slurry flow rate: 300 cc/min
- Slurries:
 - ❖ CMC 600Y-75
 - ❖ Hitachi Chemicals HS-2H635
 - ❖ Fujimi PL-7103
- Pads:
 - ❖ CMC D100
 - ❖ DOW IC-1000 K-groove
 - ❖ IC-1000 M-Groove
- Conditioner: 3M A165
- Conditioning downforce: 6 lb_f
- Conditioning: In-situ at 95 RPM & 10 per minute sweep frequency
- Polishing time = 130 seconds

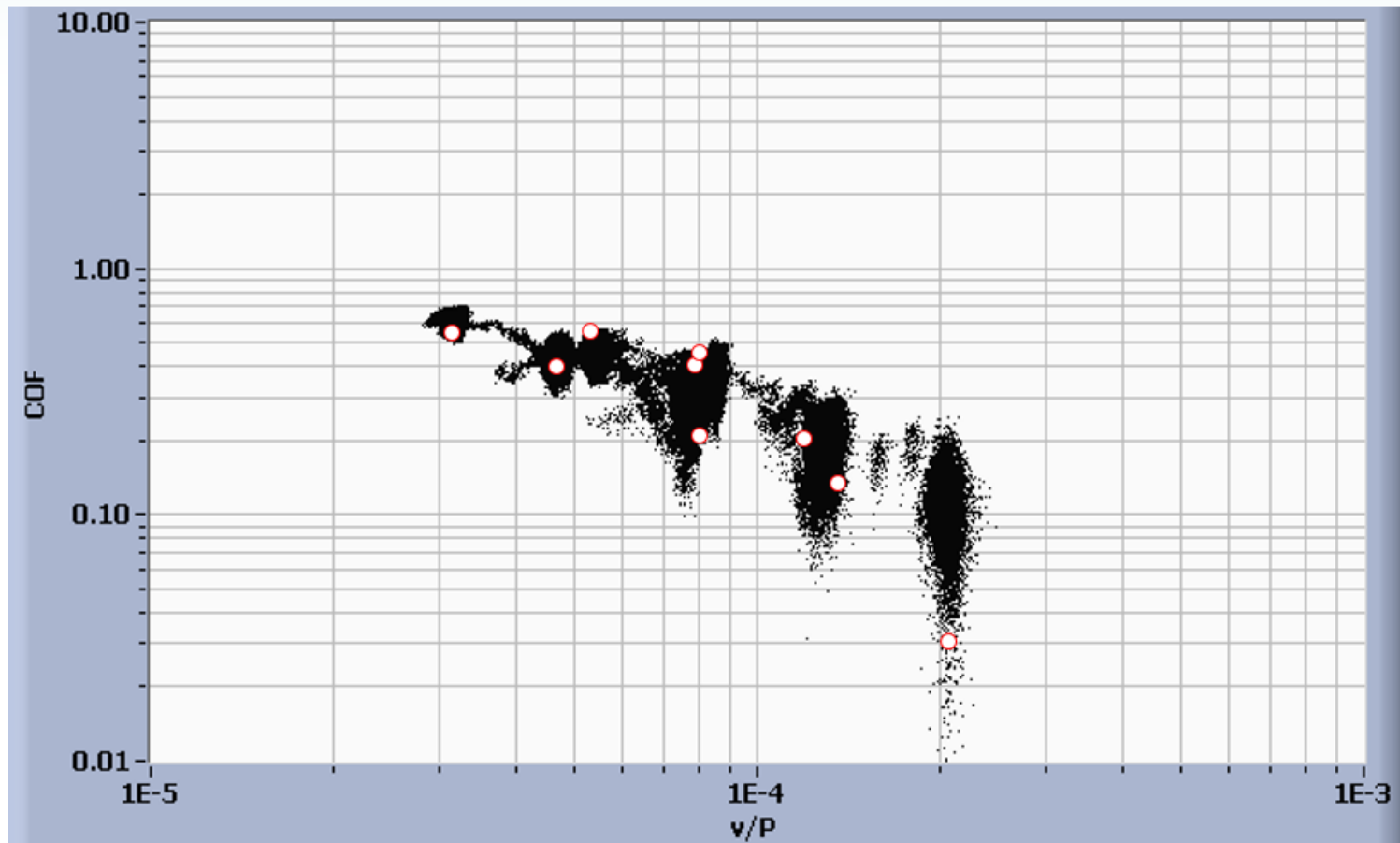
Stribeck+ Curves

Copper – D100 – CMC 600Y-75



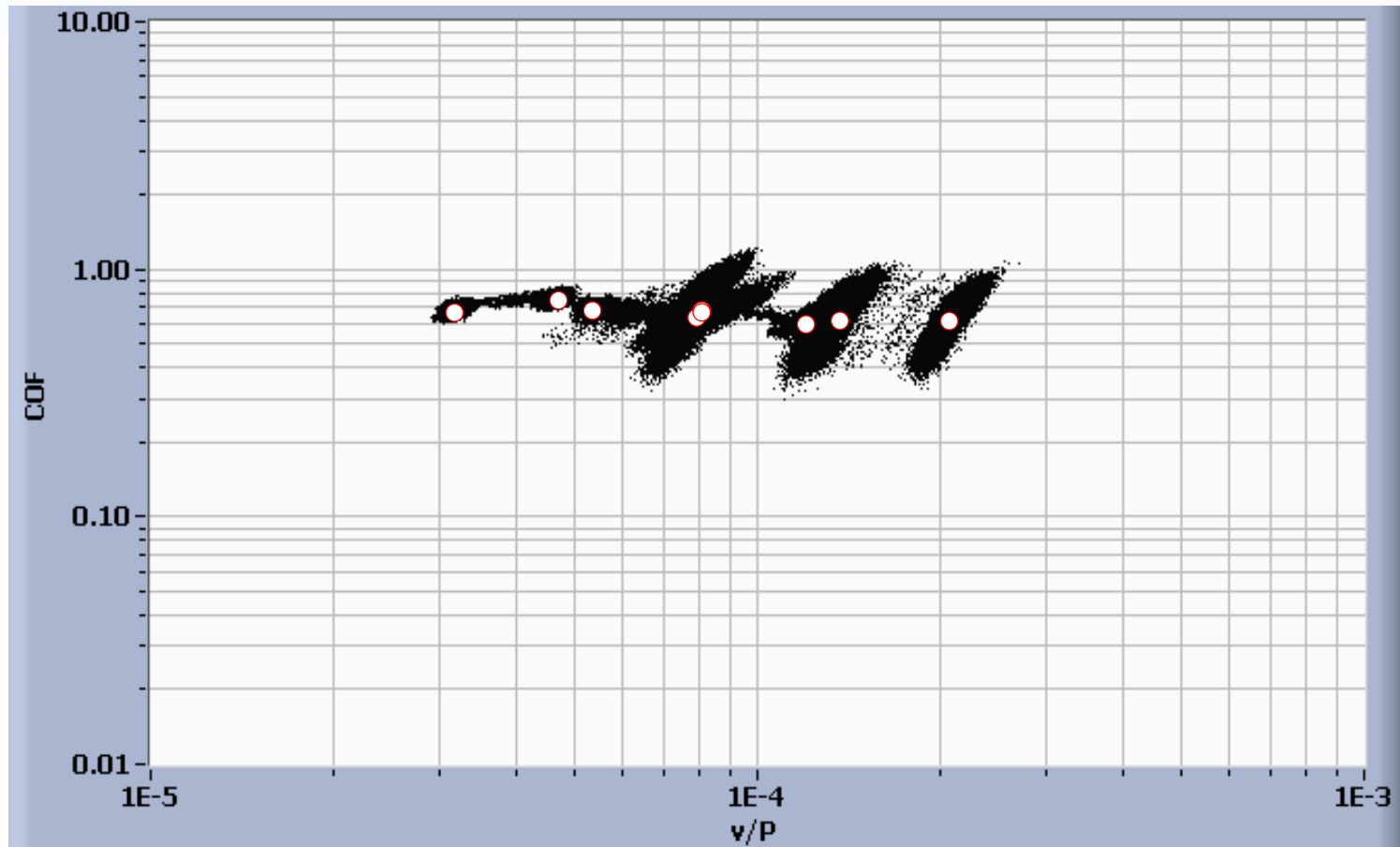
Stribeck+ Curves

Copper – IC1000 K-Groove – CMC 600Y-75



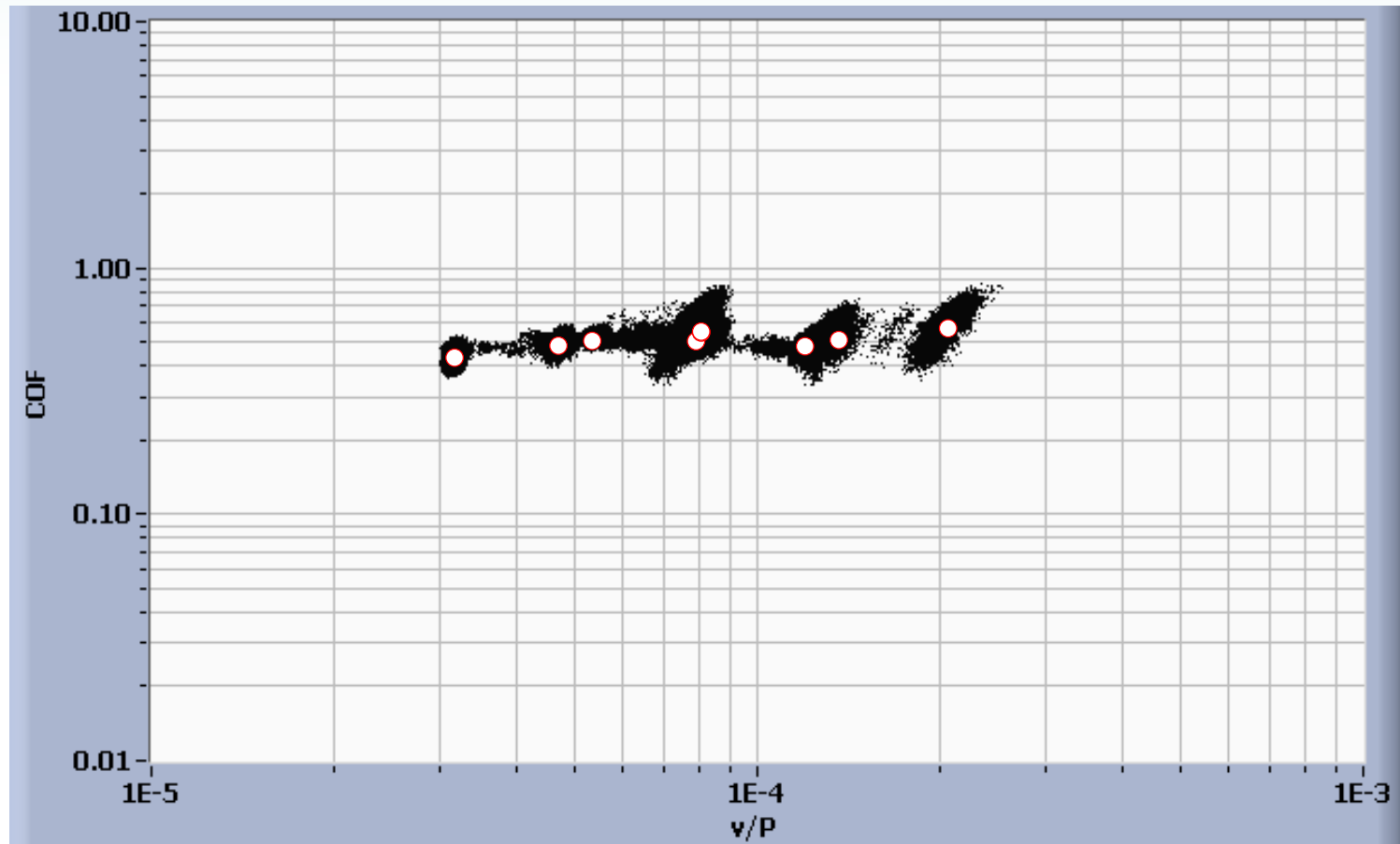
Stribeck+ Curves

Copper – IC1000 M-Groove – CMC 600Y-75



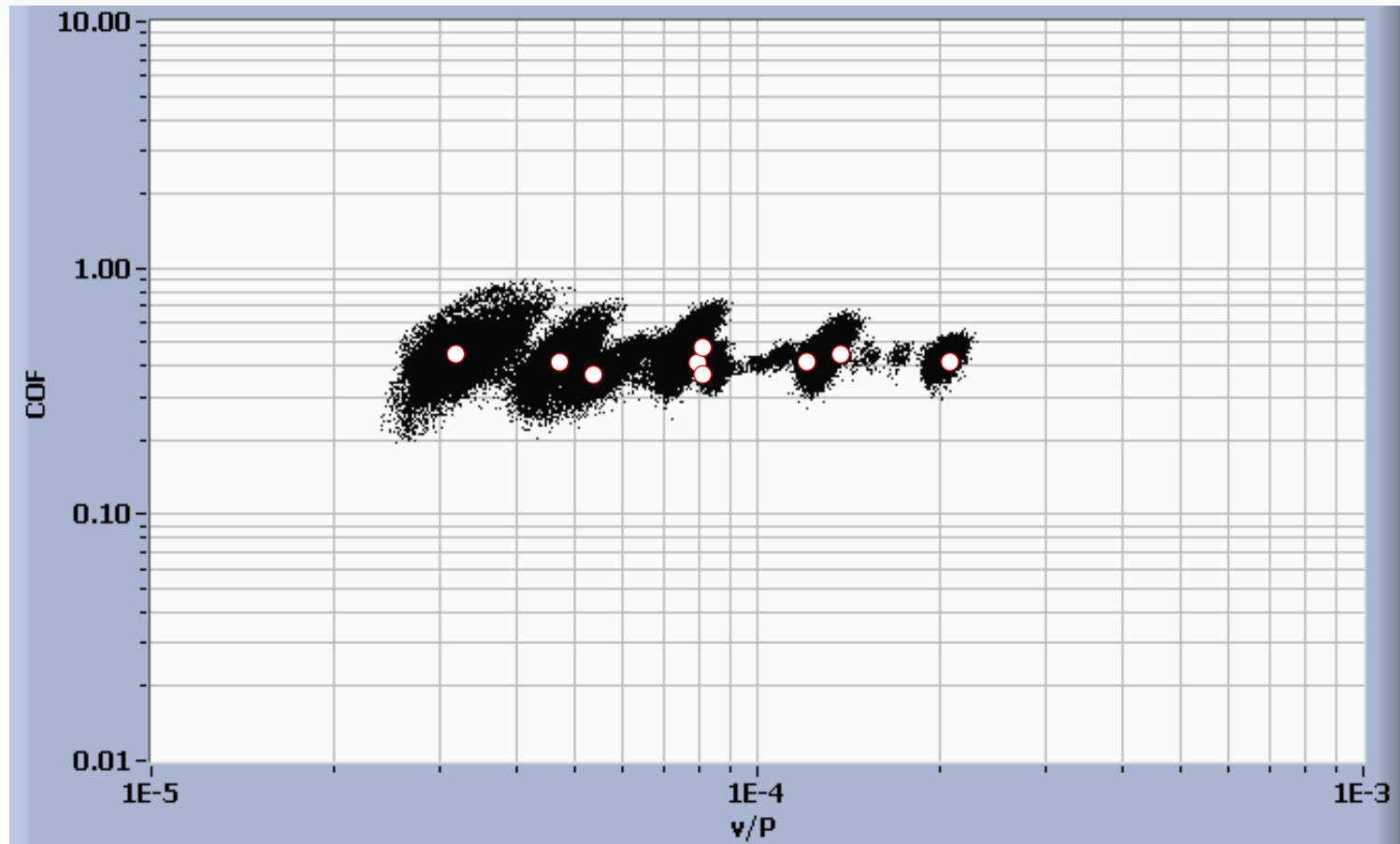
Stribeck+ Curves

Copper – IC1000 M-Groove – HCC HS-2H635



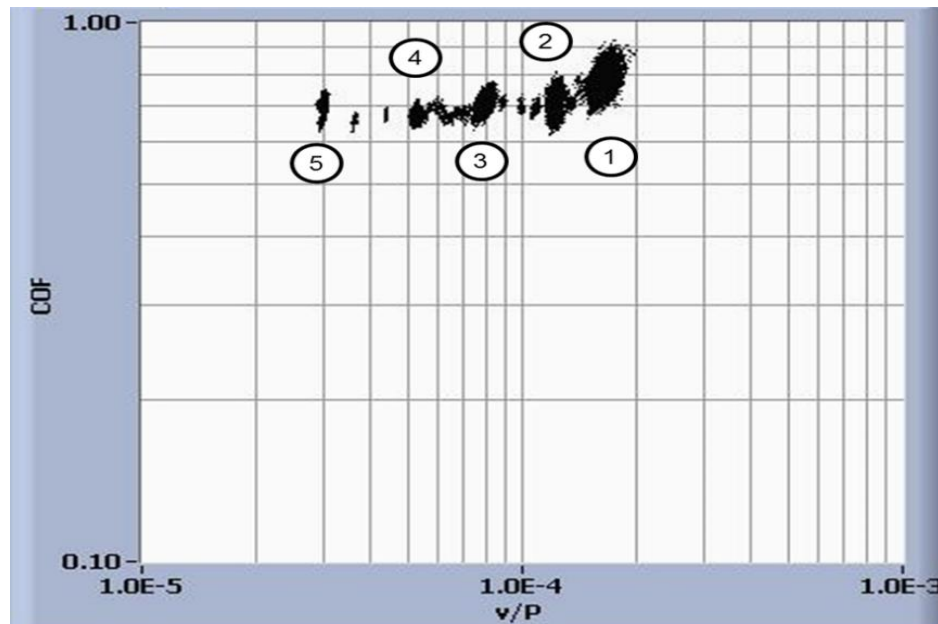
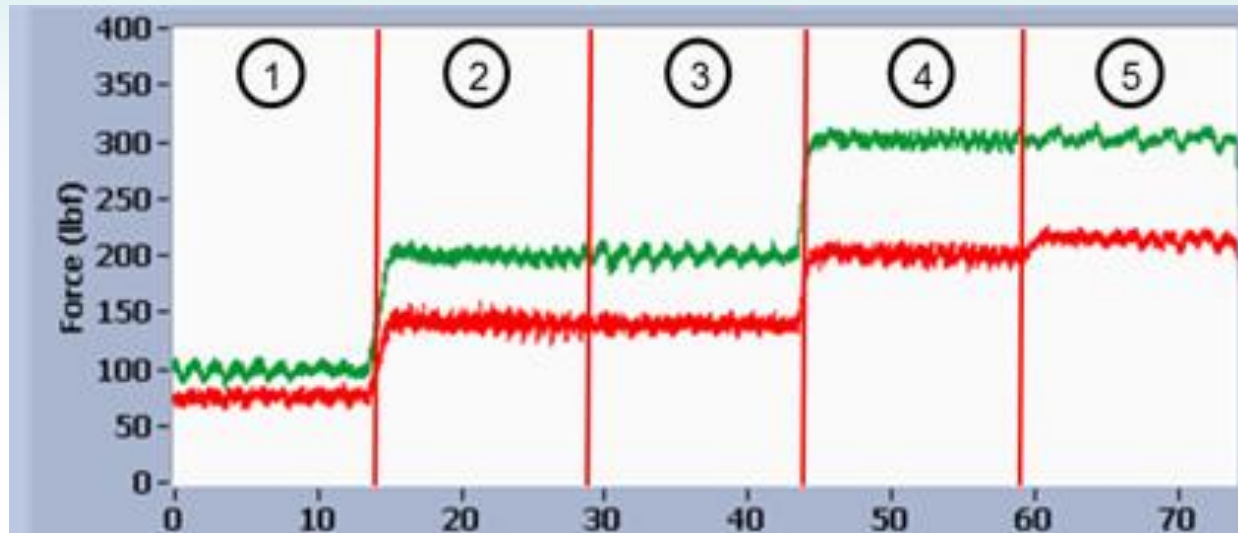
Stribeck+ Curves

Copper – IC1000 M-Groove – Fujimi PL-7103



Stribeck+ Curves

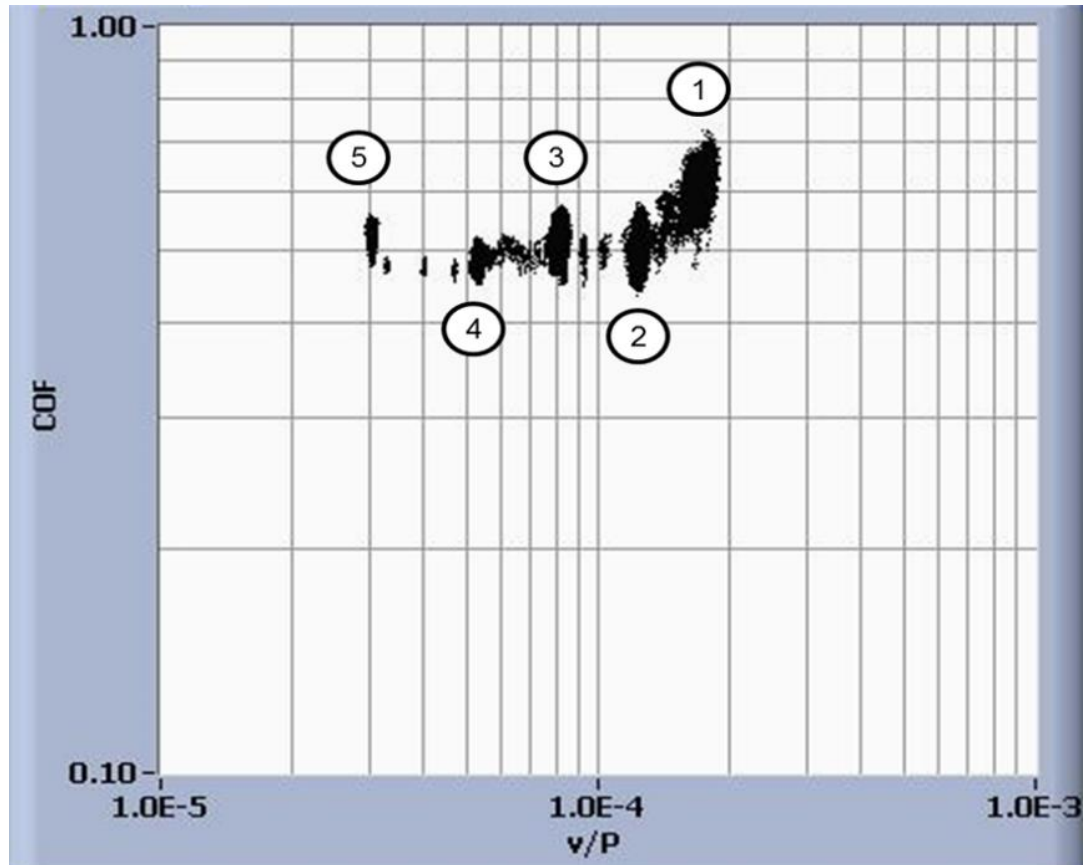
Copper – Embossed Politex – Fujimi PL7103 Slurry



Step	P (PSI)	v (m/s)	v/P (m/(Pa.s))
1	1	1.0	1.45E-4
2	2	1.5	1.09E-4
3	2	1.0	7.25E-5
4	3	1.0	4.83E-5
5	4	0.6	2.90E-5

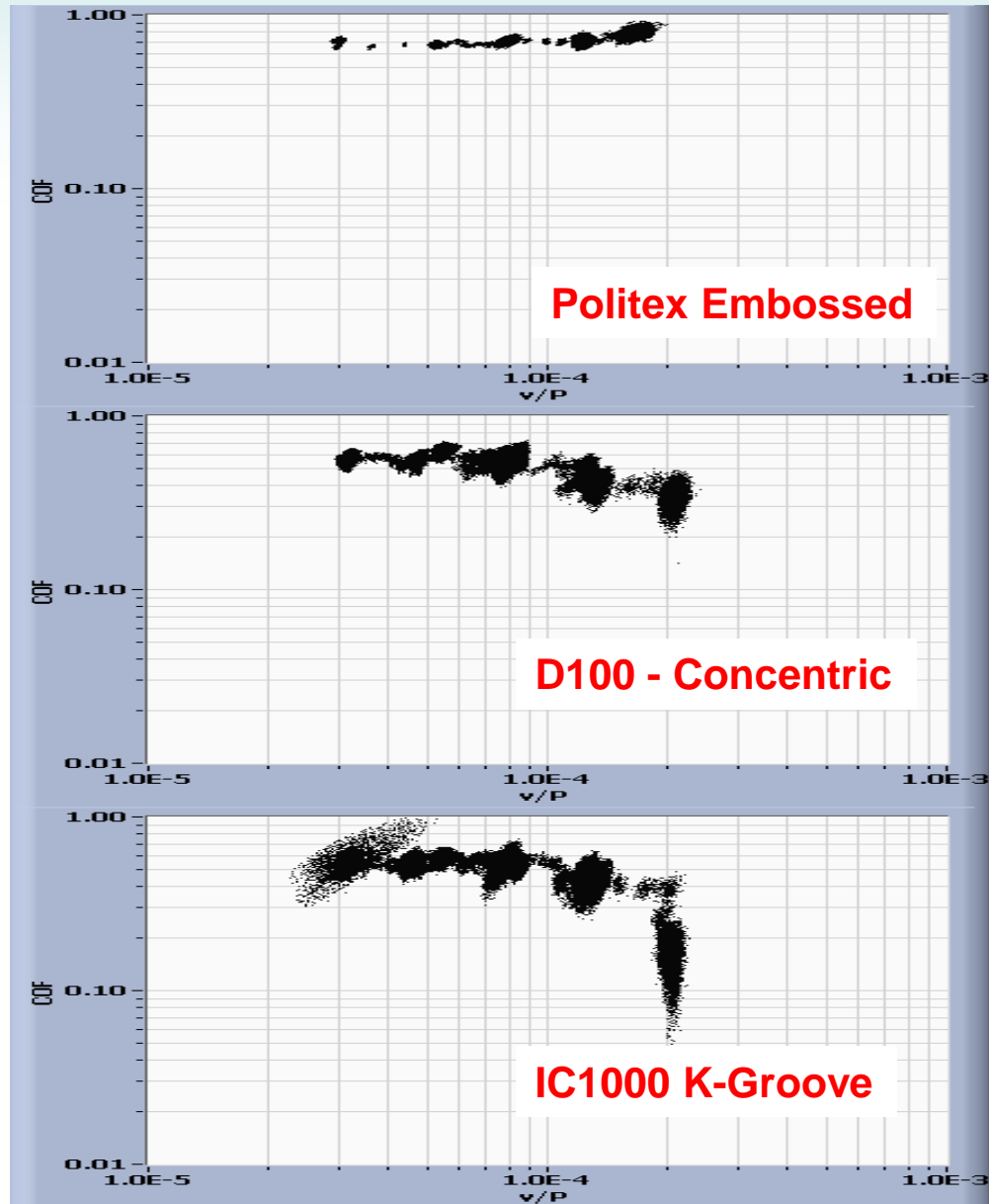
Stribeck+ Curves

Copper – Embossed Politex – C8902 Slurry



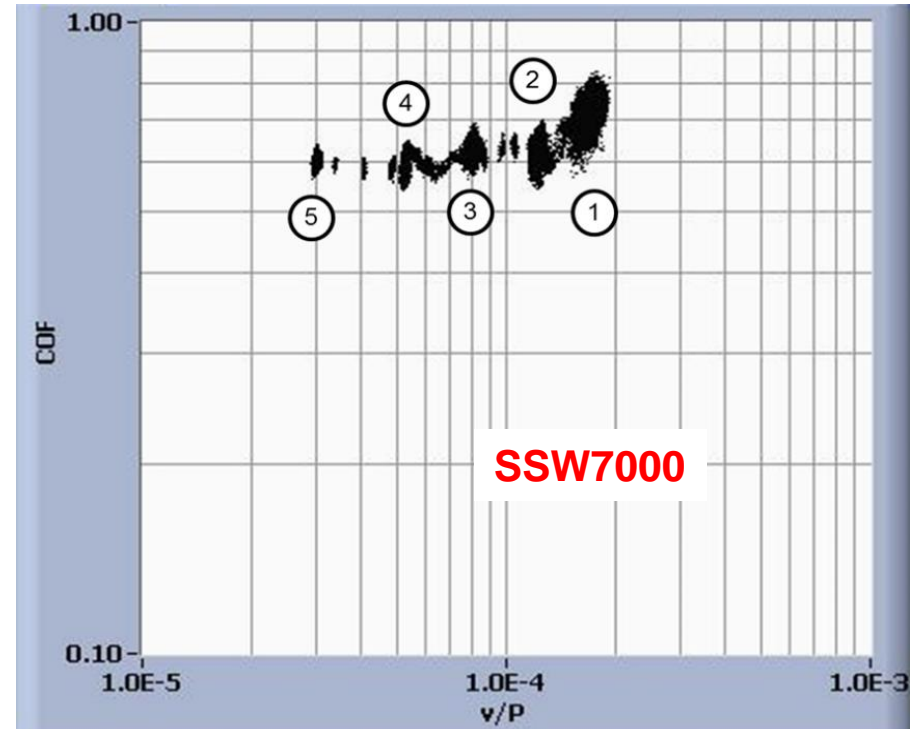
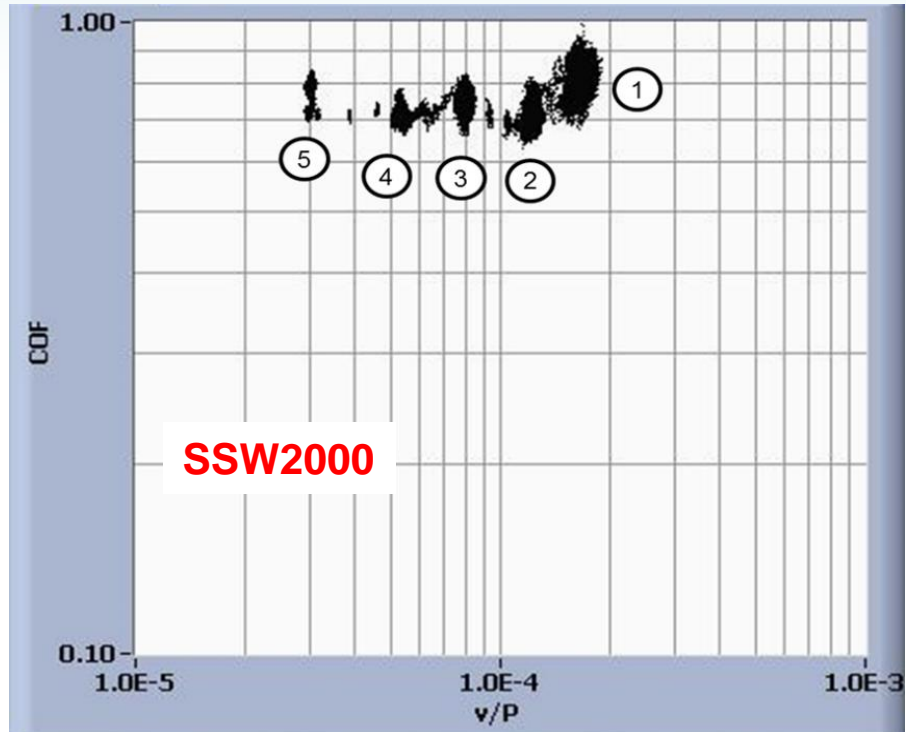
Stribeck+ Curves

Copper – Fujimi PL7103 Slurry



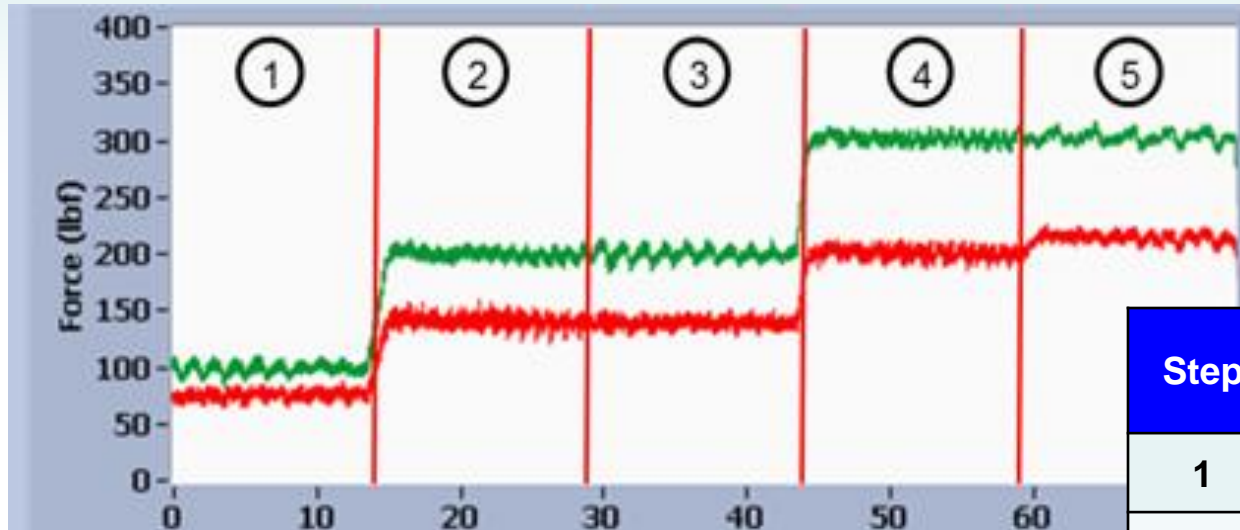
Stribeck+ Curves

Tungsten – Embossed Politex

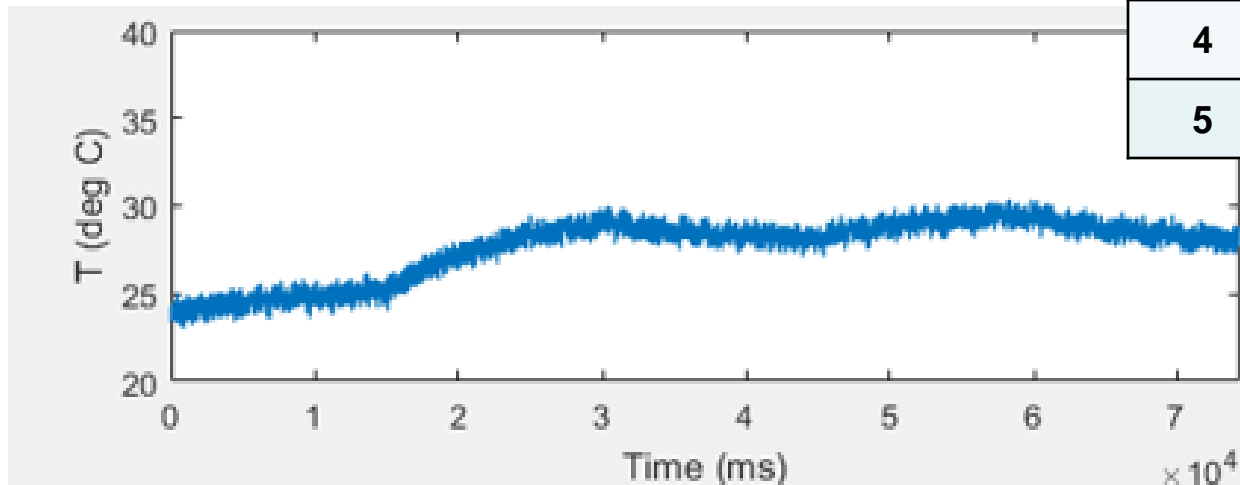


Stribeck+ Curves

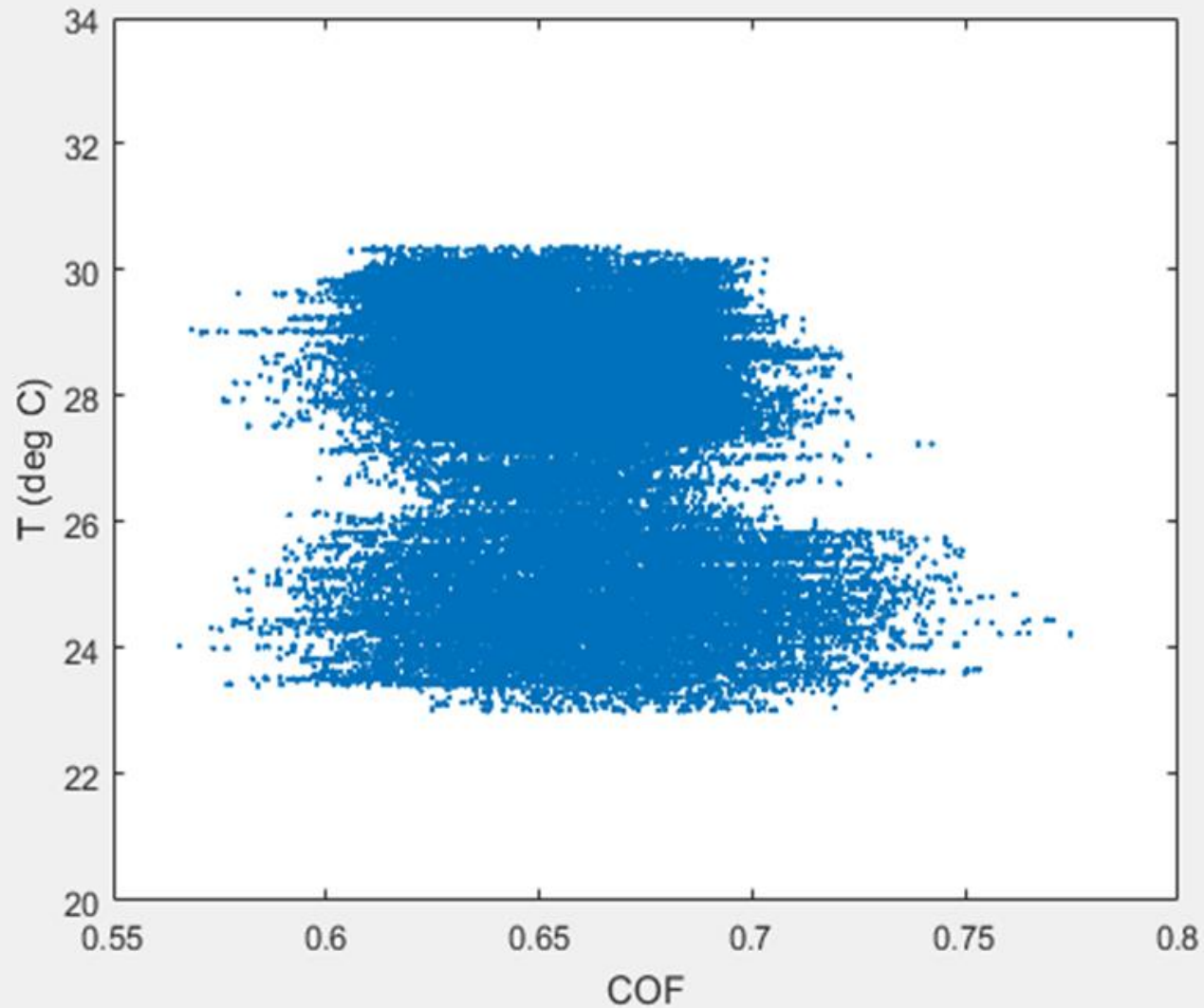
Copper – Embossed Politex – Fujimi PL7103 Slurry



Step	P (PSI)	v (m/s)	v/P (m/Pa.s)
1	1	1.0	1.45E-4
2	2	1.5	1.09E-4
3	2	1.0	7.25E-5
4	3	1.0	4.83E-5
5	4	0.6	2.90E-5

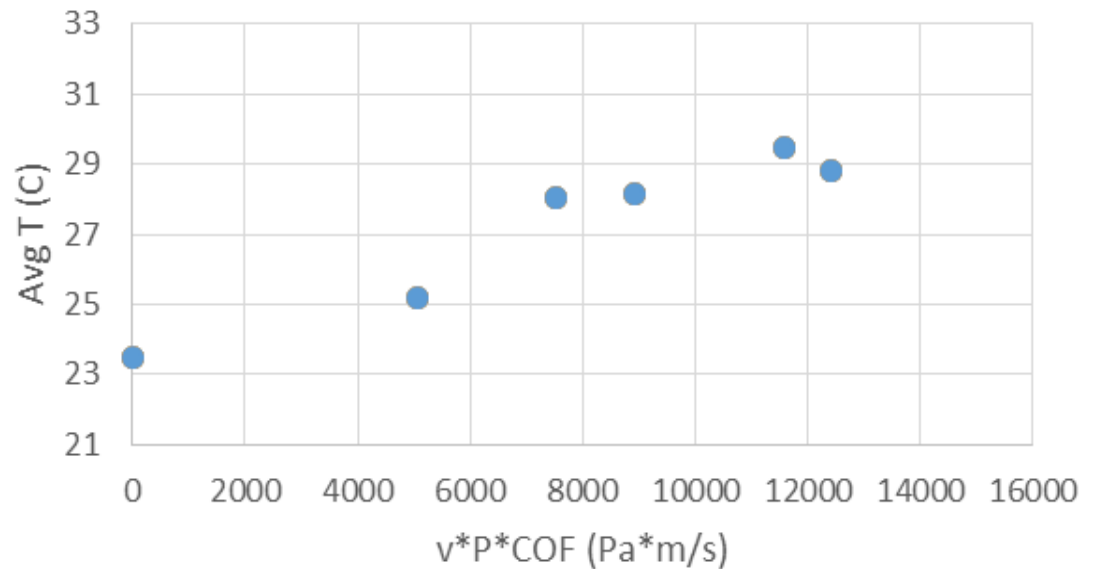
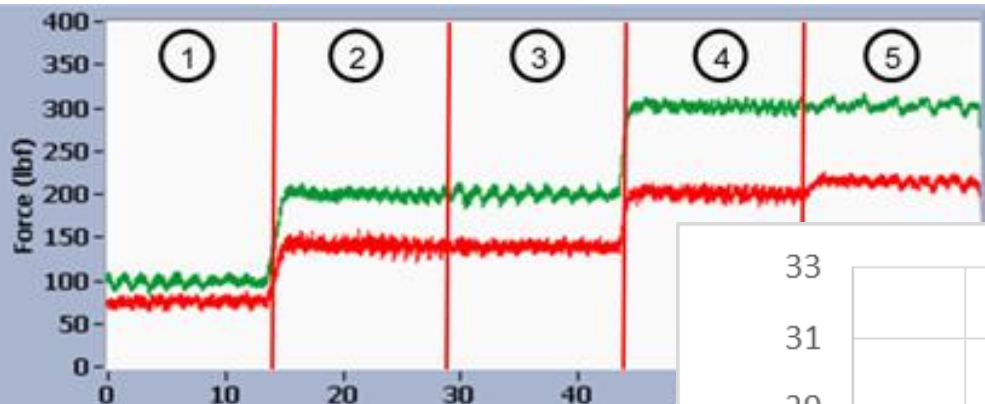
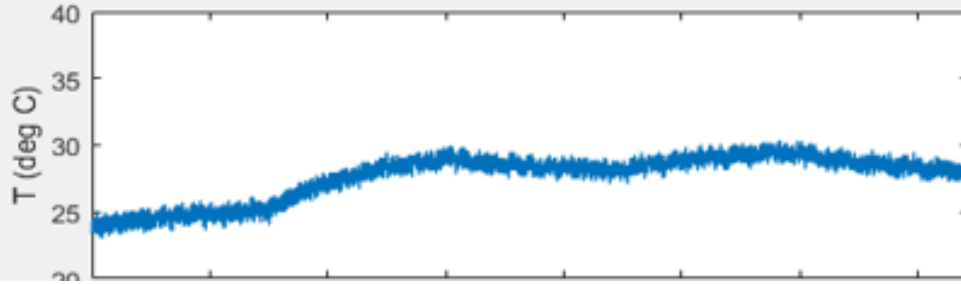


A Common Mistake re: COF vs. Temperature



Temperature Curves

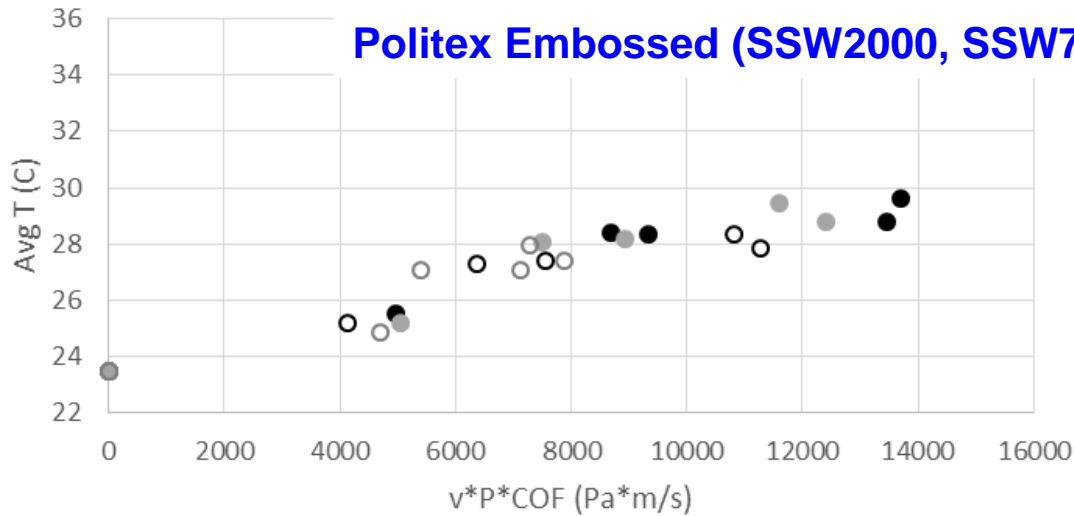
Copper – Embossed Politex – Fujimi PL7103 Slurry



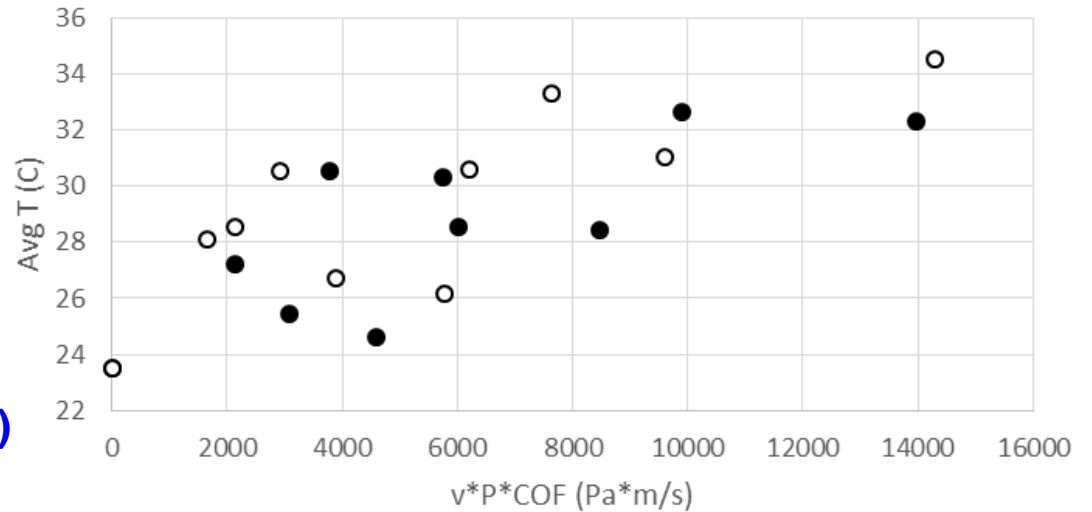
Average temperature is calculated from data during the last 1-second of each step.

Temperature Curves

Politex Embossed (SSW2000, SSW7000, C8902 and PL7103)

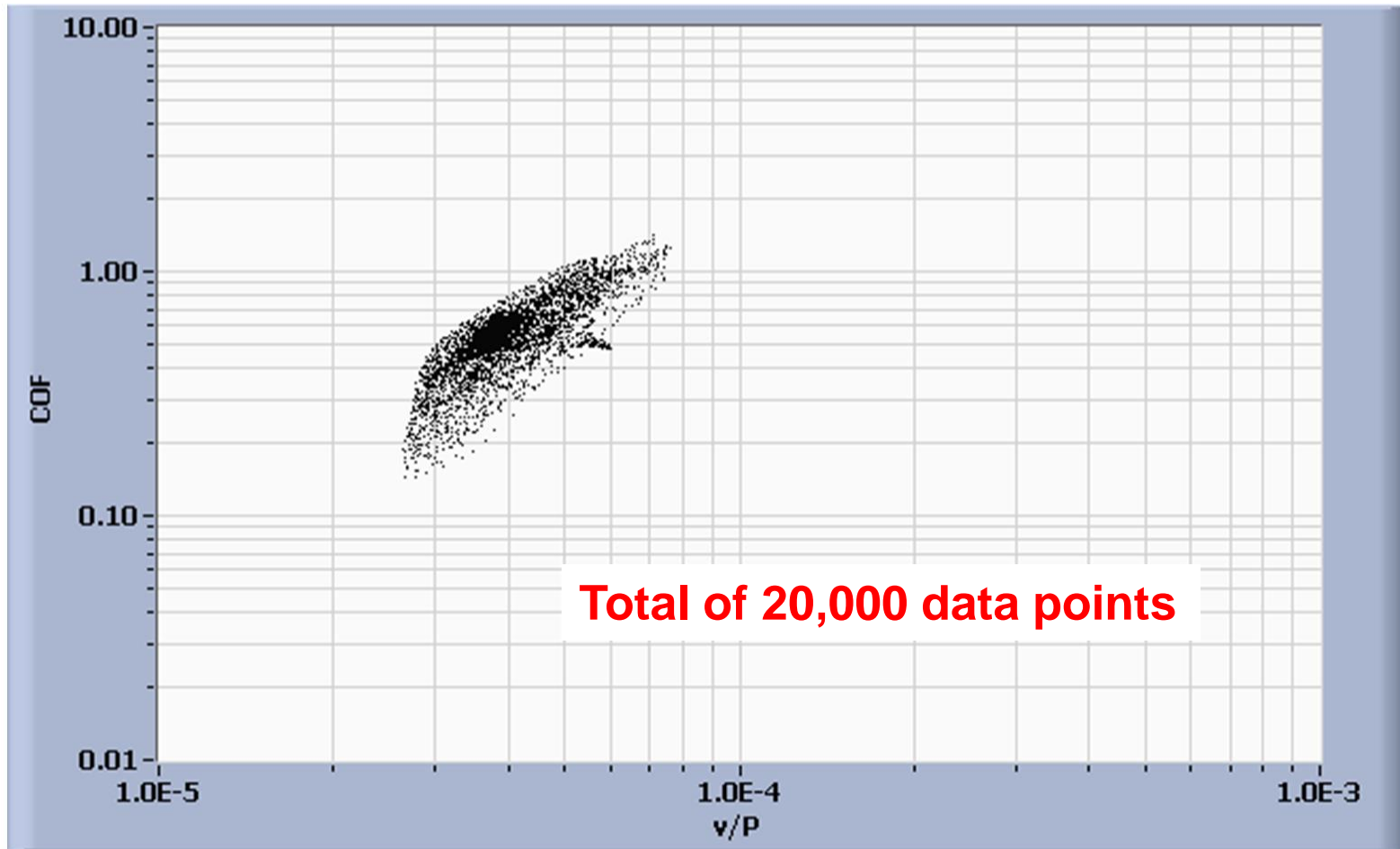


PL7103 (D100 and IC1000)



Evidence of Gross Vibrations

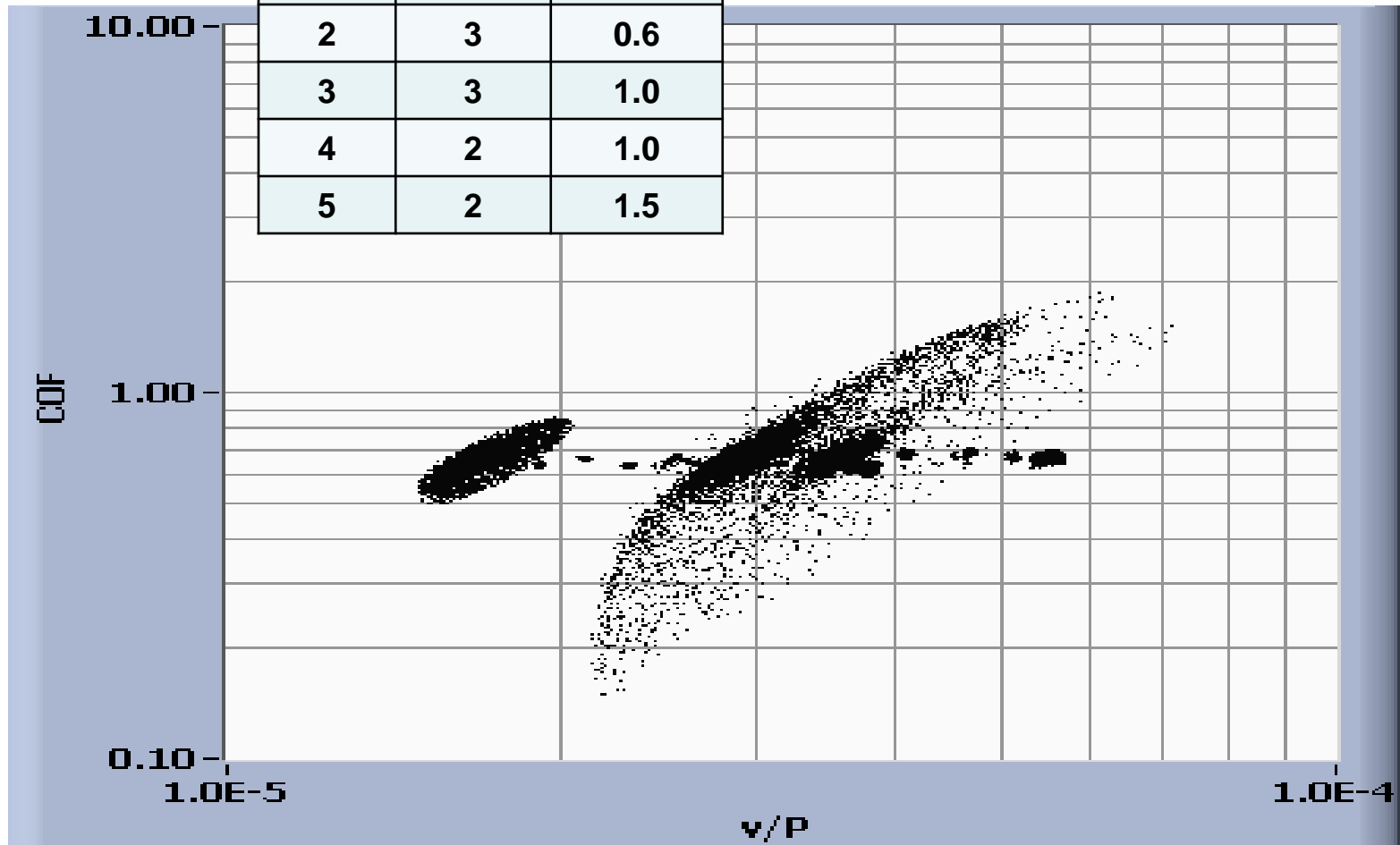
Oxide – IC1000 M-Groove Pad – 4 PSI – 1.8 m/s – Ceria Slurry



Stribeck+ Curves

ILD – IC1000 K-Groove – HVM Ceria Slurry

Step	P (PSI)	v (m/s)
1	4	1.5
2	3	0.6
3	3	1.0
4	2	1.0
5	2	1.5



Summary

- Traditional Stribeck curves based on **average COF** are not the full explanation.
- COF fluctuations (stick-slip) can be dramatic and sometimes more important than average values (**RSD data is critical**).
- Sommerfeld number lumps V and P together – Key information is lost (**need for Lim-Ashby plots**).
- New method for obtaining **Stribeck curves** by polishing only **1 wafer** is presented.
- **Stribeck+** curve is obtained using polishers capable of simultaneously measuring **shear force** and **down force** (and **pad temperature**) and rendering a value for COF while simultaneously enabling a multitude of changes in **P** and **V** in **real-time**.
- For Cu and W CMP, slurry type, pad type and grooving pattern are critical in dictating the tribological mechanism.
- **Stribeck+** method sheds new light on **CeO2 slurry** processes – They show gross vibrations!
- Plots of average **pad surface temperature** vs. **COF×P×V** show a **linear and somewhat universal** relationship for all cases.