Cell Engineering – Work Overview
Intern Final Presentation

Maaz Azam: June 17th, 2019 – May 1st, 2020

Background

4th Year Electrical Engineering Major at McMaster University

Previous Work Experience:

- Hardware Development & Research Intern – Eaton
- Lab Assistant – McMaster Automotive Resource Center
- Avionics Engineer Intern – PAL Aerospace
- Production Operations Intern – WestRock

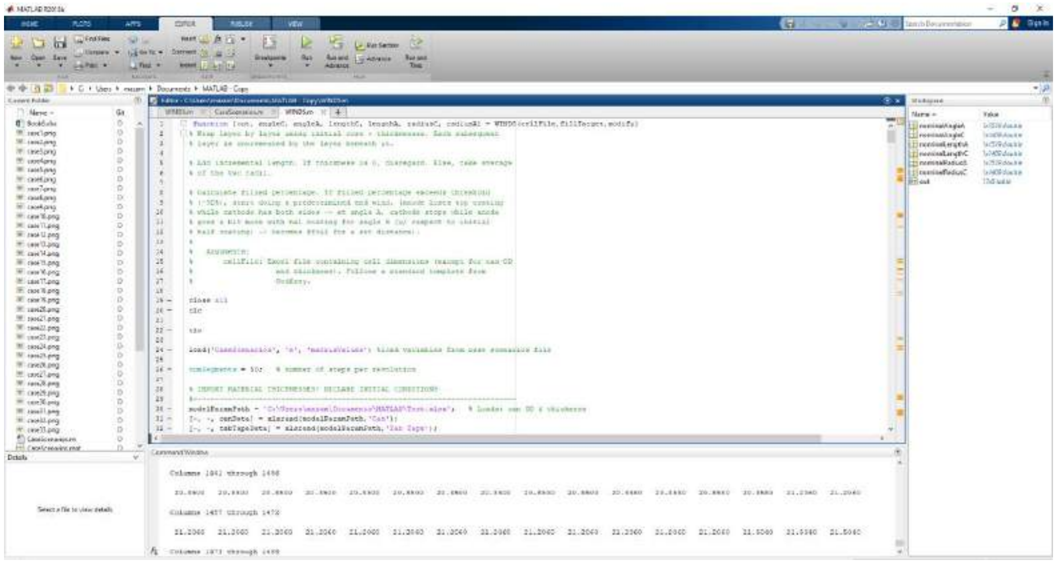
EcoCAR Mobility Challenge Team:

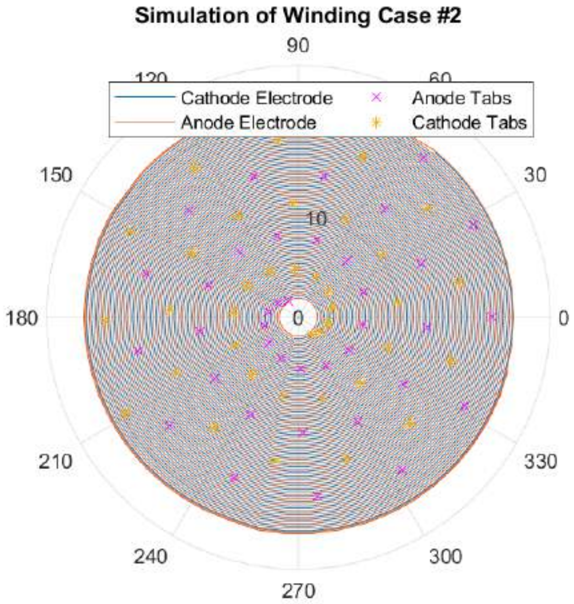
- Control Systems & Simulation Modelling Member

Project Overview

- MATLAB Winding Simulation
- 24L Winder Operation
- Pancake Edge Alignment Tool
- Kato Winder Operation and Commissioning
  - Diameter Analysis
  - Keyence Quality Inspections
- Swift KOEM Winder

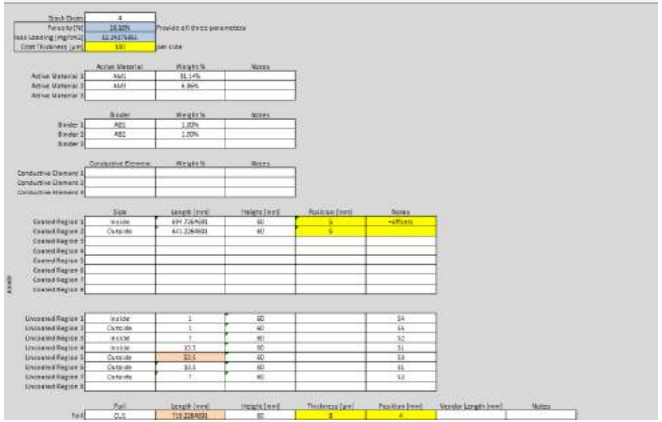
MATLAB Cell Winding Simulation

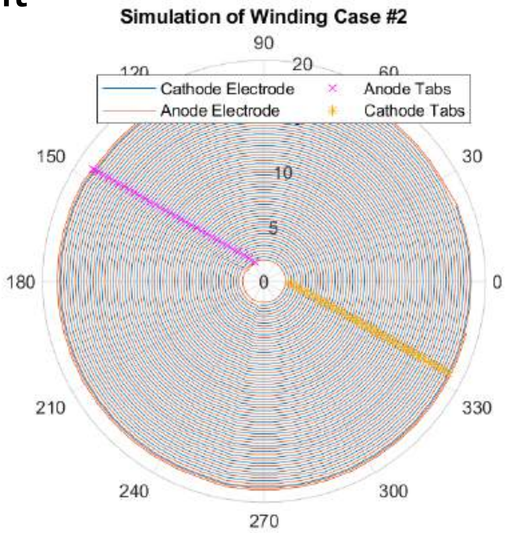




MATLAB Winding Simulation

- Takes into account various parameters (ex. length, thickness, coating pattern, etc.) and computes a polar plot of the jellyroll wounded
- Purpose of simulation is to visually show tab alignment in the cell, and how various factors affect this alignment





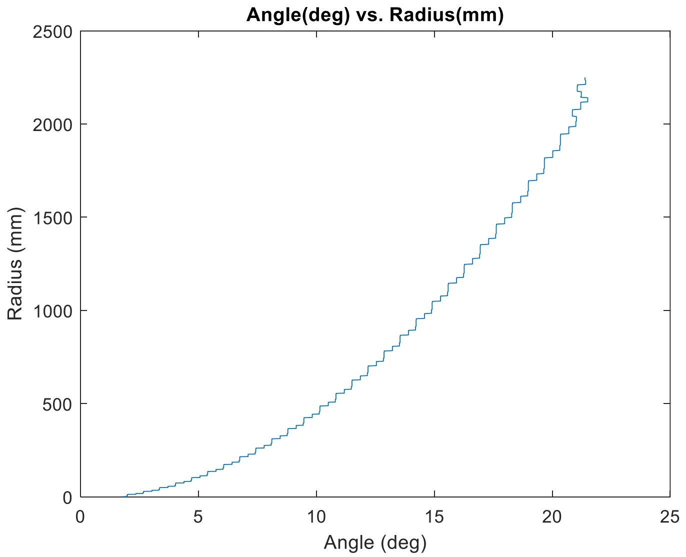
MATLAB Winding Simulation

- Outputs the length, radius, and total revolutions of winding
- Output graphs to show cause and effect of variations of certain parameters to the winding pattern

Command Window

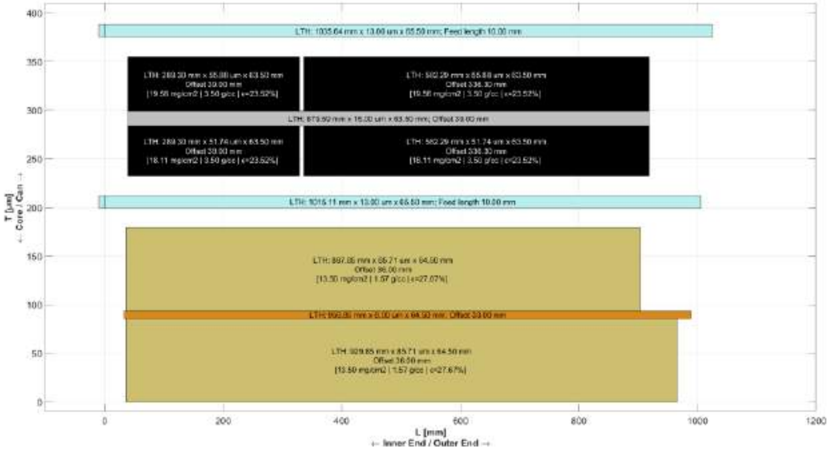
17×5 table

fieldNames	simLength	trackLength	error	pcError
'sepInner'	2140.4	711.43	1428.9	200.86
'electrodeInnerCoatBot'	2015.7	639.62	1376	215.13
'electrodeInnerTabBot'	0	0	0	NaN
'electrodeInnerTapeBot'	0	0	0	NaN
'electrodeInnerSubstrate'	2033	646.12	1386.9	214.64
'electrodeInnerCoatTop'	2038.3	639.62	1398.7	218.67
'electrodeInnerTabTop'	0	0	0	NaN
'electrodeInnerTapeTop'	0	0	0	NaN
'sepOuter'	2185.5	730.2	1455.3	199.3
'electrodeOuterCoatBot'	1996.3	641.23	1355.1	211.33
'electrodeOuterTabBot'	0	0	0	NaN
'electrodeOuterTapeBot'	0	0	0	NaN
'electrodeOuterSubstrate'	2207.1	719.23	1487.9	206.88
'electrodeOuterCoatTop'	2143	694.73	1448.3	208.47
'electrodeOuterTabTop'	0	0	0	NaN
'electrodeOuterTapeTop'	0	0	0	NaN
'AVGelectrodeInnerCoat'	2027	639.62	1387.4	216.9



MATLAB Winding Simulation

- Great “introduction” into winding
  - What materials are involved in the process
  - Crucial parameters that affect winding machine
  - Interpreting cell design diagrams
  - Helped inform early decision of if cell should use aligned tab or not



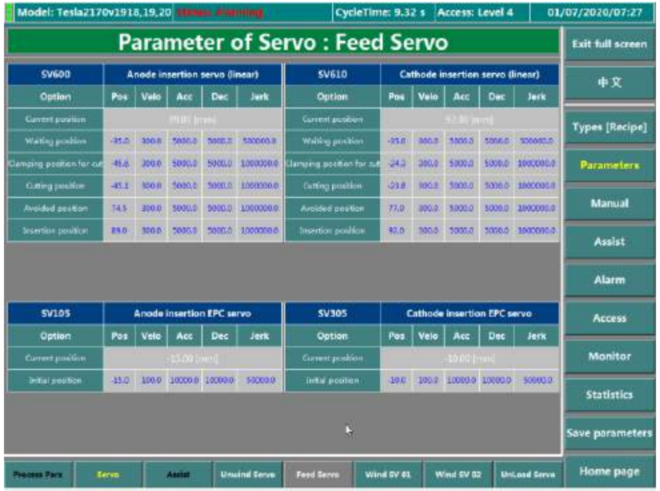
Anode Tab 1 (Can Side):
-Offset: 979.85 mm
-Length: 70.00 mm
-Width: 4.00 mm
-Thickness: 100.00 um
-Overhang: mm

Cathode Tab 1 (Core Side):
-Offset: 330.30 mm
-Length: 70.00 mm
-Width: 4.00 mm
-Thickness: 100.00 um
-Overhang: mm

24L Winder

24L Winder

- Learned operation and controls of 24L ‘baby’ winder
- HMI functionality and options
- Mechanics of how the winder works



SV100 – Anode Unwind Servo, responsible for unwinding the anode electrode from the anode shaft.

SV102 – Anode Unwind EPC Servo, moves the anode plate in or out to adjust for the unwind EPC.

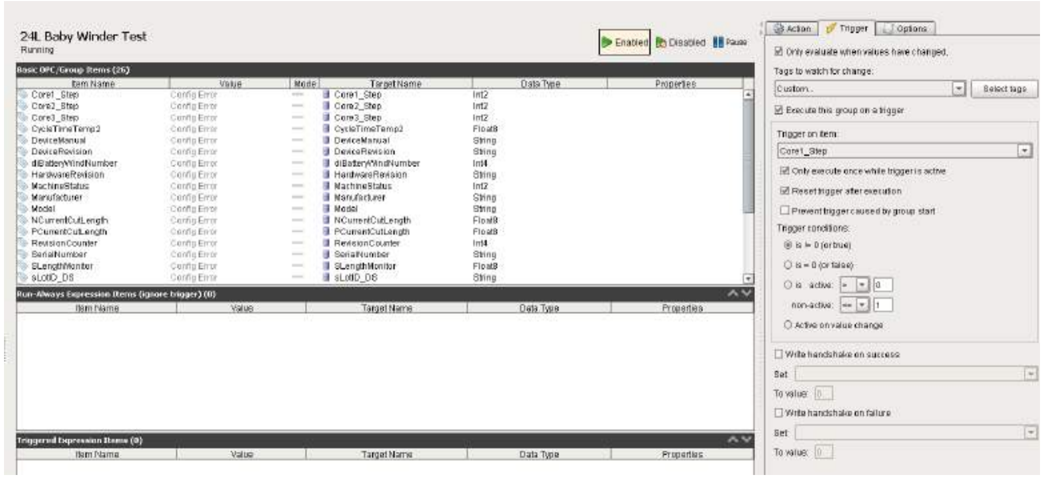
Winder Component Index

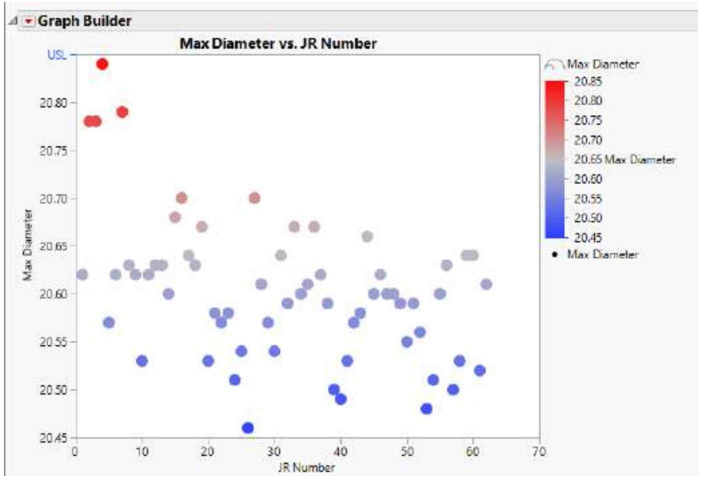
Servo	Description
SV100	Anode Unwind Servo
SV102	Anode Unwind EPC Servo
SV105	Anode Insertion EPC Servo
SV200	Upper Separator Unwind Servo
SV201	Upper Separator Unwind EPC Servo
SV300	Cathode Unwind Servo
SV302	Cathode Unwind EPC Servo
SV305	Cathode Insertion EPC Servo
SV400	Lower Separator Unwind Servo
SV401	Lower Separator Unwind EPC Servo
SV500	Turret Servo
SV501	Tape Core Servo
SV502	Unload Core Servo
SV503	Wind Core Servo
SV504	Wind Small Needle Servo
SV505	Unload Small Needle Servo
SV506	Unload Big Needle Servo
SV600	Anode Insertion Servo (Linear)
SV602	Anode Insertion Servo (Roll)
SV610	Cathode Insertion Servo (Linear)
SV612	Cathode Insertion Servo (Roll)
SV700	Rotate Unload Servo
SV701	Unload Transfer Servo
SV704	Battery Conveying Servo
SV706	Separator Cutter Station Servo

Actuator	Description
200Y08	Anode Unwind Air Shaft
205Y02	Clamp Anode Encoder Press Roller
205Y04	Clip Roller of Prevent Anode Flying
205Y05	Upper Seperator Unwind Air Shaft
205Y09	Clamp Seperator Press Roller
400Y08	Cathode Unwind Air Shaft
405Y02	Clamp Cathode Encoder Press Roller
405Y04	Clip Roller of Prevent Cathode Flying
405Y05	Lower Separator Unwind Air Shaft
405Y07	Press Separator Press of Prevent Flying [top or bottom?]
560Y01	Vacuuming at Anode Pallet
560Y02	Vacuuming at Endtape Pallet
600Y01	Clamp Anode Electrode
600Y02	Lock Anode Cutter [is this used?]
600Y04	Clamp Upper EPC Pinch Roller
600Y05	Clamp Lower EPC Pinch Roller
600Y06	Clamp Cathode Electrode
600Y07	Lock Cathode Cutter
600Y08	Blowing of Cathode Feeding
600Y09	Clamp Upper EPC Pinch Roller
600Y10	Clamp Lower EPC Pinch Roller
600Y11	Blowing Anode End in Turret Move
600Y12	Anode Force Cutter
600Y13	Blowing Anode End in Separator Cut
600Y14	Separator Cutter
600Y15	Separator Close Together [what is this?]
600Y16	Fixture Block at Winding Station
600Y17	Fixture Block at Unload Station
600Y18	Turret Lock
600Y19	Press Roller for End Wind at Tapecore
600Y20	Anode Knife Vacuum On
600Y21	Cathode Knife Vacuum On
600Y22	Small Core Lock at Unload Station
600Y23	Pallet for Anode in End Winding
600Y24	Cathode Force Cutoff
600Y25	Dodge Endtape Mechanism [get pic]
600Y26	Transport Endtape [get pic]
600Y27	Press Tape After Transport Endtape
600Y28	Press Tape in Paste Endtape
600Y29	Cutter of Endtape
600Y30	Clamp Endtape (Inside)
600Y31	Clamp Endtape (Outside)
600Y32	Pull Tape in Unwind Endtape
600Y33	Press Tape in Unwind Endtape
600Y34	Blowing of Endtape
600Y25	Pallet of Endtape
601Y04	Unload Claw1 Moving Out and Back
601Y05	Unload Claw1
601Y06	Unload Claw1
601Y07	Unload Claw2 Moving Out and Back
601Y08	Transfer Claw (Moving With SV701)
601Y09	Transfer Claw Moving Left and Right
601Y10	Transfer Claw Moving Up and Down
601Y11	Transfer Claw (To Conveyer Belt)
602Y02	NG remove (On Belt)

24L Winder

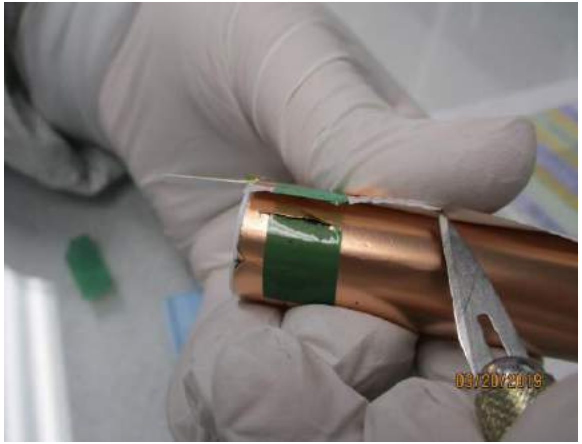
- Data collection process using Ignition
- Brief introduction into controls work
- Data analysis of various 2170 cell designs



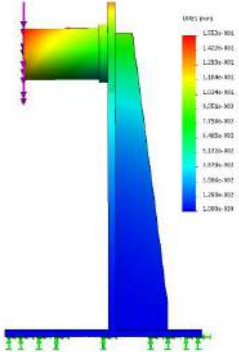


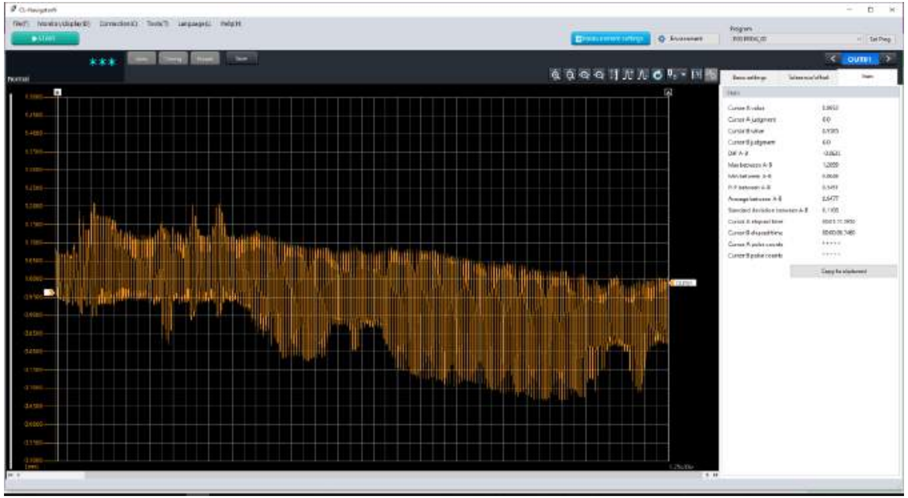
24L Winder

- Cell dissections, and how to evaluate winding parameters and quality
- Other processes involved in the development of a cell (ex. press, slitter, etc.)



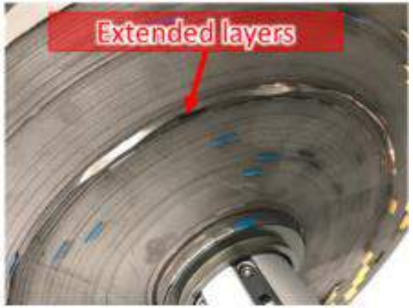
Pancake Edge Alignment Tool





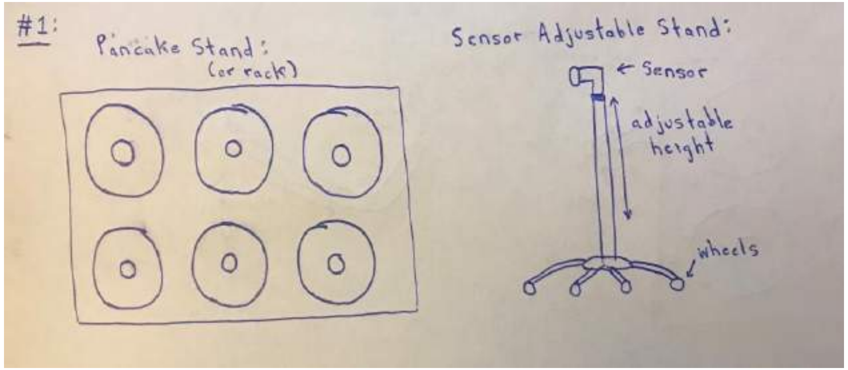
Pancake Edge Alignment Tool

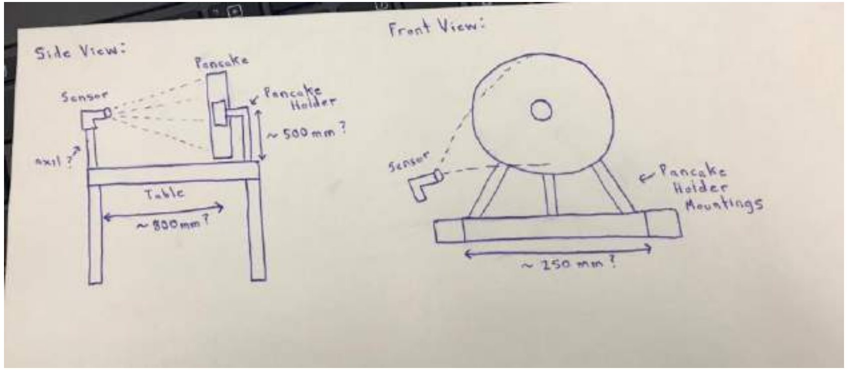
- Goal: to get edge alignment of pancake within 30 microns, to ensure there is no telescoping
- Winding EPC can not perfectly wind a telescoped pancake
- Can result in misaligned layers in cell -> fire



Pancake Edge Alignment Tool

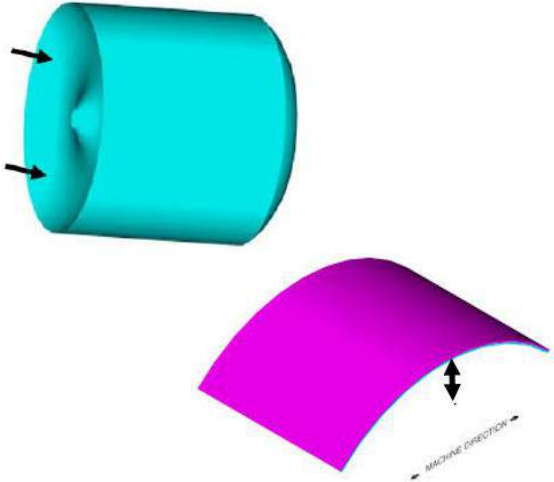
- **Step 1:** brainstorming and forming rough sketches of potential designs that can work
- Evaluating pros and cons, and potential challenges of each sketch
- Eventually combined ideas from multiple sketches to form final rough design

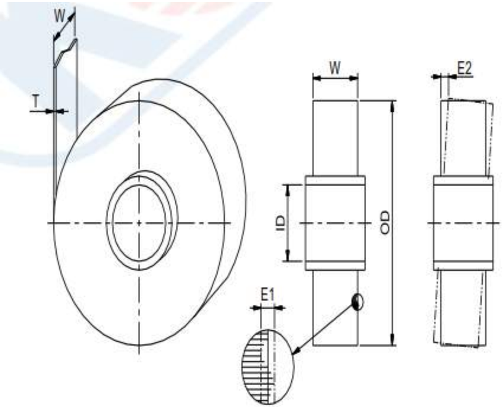




Pancake Edge Alignment Tool

- **Step 2:** defining requirements, acceptable tolerances, and types of measurements to capture
- Exploring functionality of device further, and determining critical parameters and variables in experiment

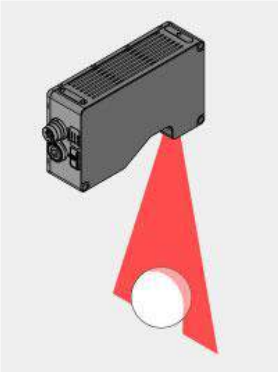


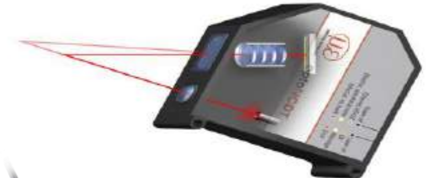


	Telescoping	Width Measurement	Warpage Measurement
Resolution	~ 30um	<5um (width measurement spec +/- 50um on slitter)	<5um
Diameter	700mm		
Width		<100mm	
Position on core	Anywhere on the flat surface		
Height			<10mm
Scan Axis Resolution	<50um		
Scan Axis Actuation	Manual		
Measurement Range	~ 5mm x 5mm (spot or field of view)	60 to 130mm	(100mm x 130mm, size of sheet)
Other Requirements:	-Resistant or minimal effect to texture, color, surface and temperature changes	-Resistant or minimal effect to texture, color, surface and temperature changes	-Resistant or minimal effect to texture, color, surface and temperature changes

Pancake Edge Alignment Tool

- **Step 3:** exploring types of sensors and vendor options
- Weighing pros and cons of different types of sensor (ex. Displacement sensor, profile sensor, laser sensor, etc.)
- Comparing sensor options to requirements and functionality of the device

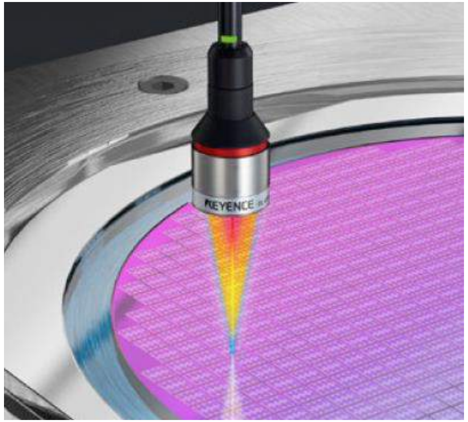




Type of Sensor:	3D Profile Sensors	Ultrasonic Displacement Sensors	Optical Displacement Sensors	Laser 3D Displacement Sensors
Advantages	- Very informative, other dimensions can be extracted - Accuracy - High response time	- Very long range - Unaffected by target material colors/texture - Greater field of view	- Small measurement range - Very high accuracy and response time	- Very high accuracy and response time - Decent measurement range
Disadvantages	- Not widely used for thickness, although possible - Limited field of view	- Slow response speed and not as high accuracy	- Depending on sensor type, may be affected by color or texture	- Limited field of view

Pancake Edge Alignment Tool

- **Step 4:** finalizing vendor, type of sensor to be used, and critical parameters to be met
- Keyence – high precision displacement sensor
- Further research and requesting demo from vendor



KEYENCE

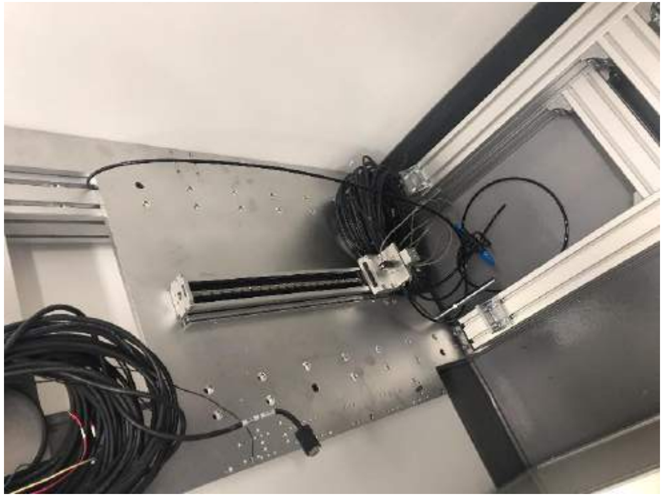
Focused spot type

Model*1	Head	CL-P007	CL-P015	CL-P030	CL-P070	CL-PT010
	Optical unit	CL-P007N	CL-P015N	CL-P030N	CL-P070N	CL-PT010N
Reference distance		7 mm 0.28"	15 mm 0.59"	30 mm 1.18"	70 mm 2.76"	10 mm 0.39"
Reference measurement range	Measurement range	±1.5 mm ±0.06"	±1.3 mm ±0.05"	±3.7 mm ±0.15"	±10 mm ±0.39"	±0.3 mm ±0.01"
	Linearity*2	±0.96 µm ±0.000038"	±0.49 µm ±0.000019"	±0.94 µm ±0.000037"	±2.2 µm ±0.000087"	±0.22 µm ±0.000009"
High precision measurement range	Measurement range	±0.5 mm ±0.02"	±0.5 mm ±0.02"	±1.0 mm ±0.04"	±3.0 mm ±0.12"	±0.15 mm ±0.01"
	Linearity*2	±0.58 µm ±0.000022"	±0.41 µm ±0.000016"	±0.72 µm ±0.000028"	±2.0 µm ±0.000079"	±0.2 µm ±0.000008"
Resolution*3		0.25 µm 0.000010"	0.25 µm 0.000010"	0.25 µm 0.000010"	0.25 µm 0.000010"	0.25 µm 0.000010"
Spot diameter		ø50 µm ø0.0020"	ø25 µm ø0.0010"	ø38 µm ø0.0015"	ø50 µm ø0.0020"	ø3.5 µm ø0.000138"
Laser class	Optical unit	Class 1				
Sampling cycle		100/200/500/1000 µs (Adjustable 4-stage)				
Environmental resistance	Enclosure rating – Head	IP67 (IEC60529)				IP64 (IEC60529)
	Ambient operating illuminance	Target surface illuminance 30,000 lux (Incandescent lamp)				
	Operating ambient temperature	0 to 50°C 32 to 122°F				
	Operating ambient humidity	20% RH to 85% RH (no condensation)				
	Vibration resistance – Head	10 to 57 Hz, double amplitude 1.5 mm 0.06"; 2 hours each for X, Y, and Z axes				10 to 57 Hz, double amplitude 0.45 mm 0.02" 2 hours each for X, Y, and Z axes
	Vibration resistance – Optical unit	10 to 57 Hz, double amplitude 0.3 mm 0.01"; 2 hours each for X, Y, and Z axes				
	Shock resistance	15G 6 ms				
Temperature characteristic	Head	0.006% of F.S. / °C				0.1% of F.S. / °C
	Optical unit	0.015% of F.S. / °C				0.015% of F.S. / °C
Material	Head	SUS	Front: SUS Rear: Aluminum			
	Optical unit	Polycarbonate				
Weight	Head	Approx. 140 g	Approx. 180 g	Approx. 200 g	Approx. 280 g	Approx. 1100 g
	Optical unit	Approx. 1800 g				

*1 Sensor head and optical unit are a matched pair. Not cross compatible. *2 Value measured in displacement mode with KEYENCE reference workpiece (mirrored surface).
*3 Value measured using 16,384 average cycles with KEYENCE reference workpiece (mirrored surface). (Value measured with 4096 average cycles on CL-PT010 only.)

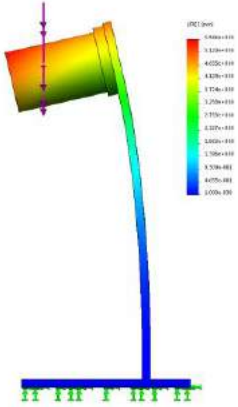
Pancake Edge Alignment Tool

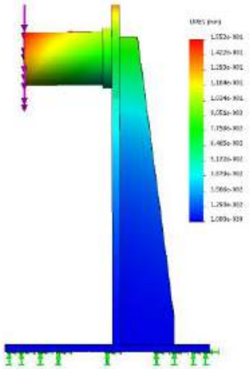
- **Step 5:** creating and testing prototype
- Evaluating performance of prototype device
- Transitioning from prototype to final design

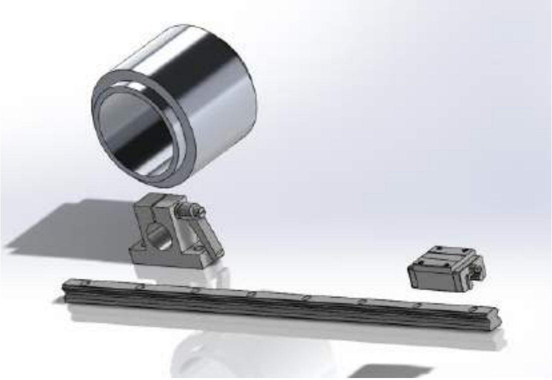


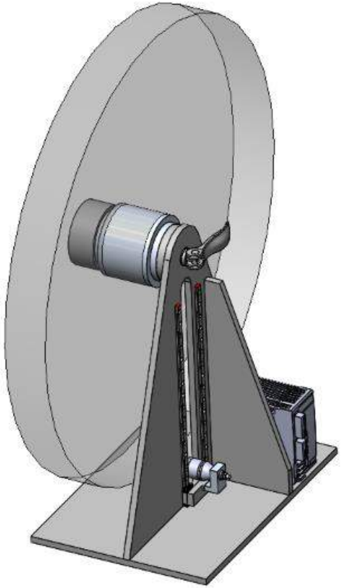
Pancake Edge Alignment Tool

- **Step 6:** creating ‘rough’ final design
- Integration of all components and creating assembly to evaluate all movement and functionality
- Simulation modelling and calculations



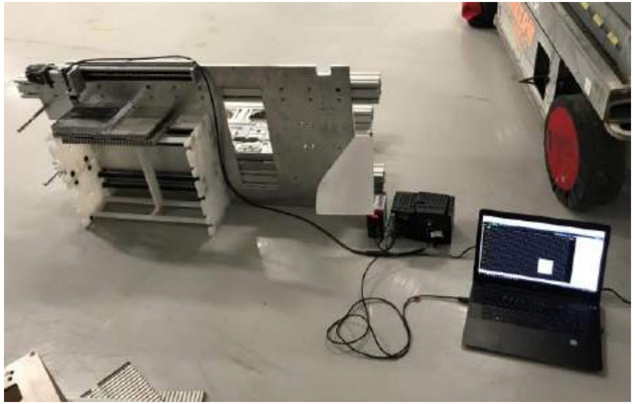


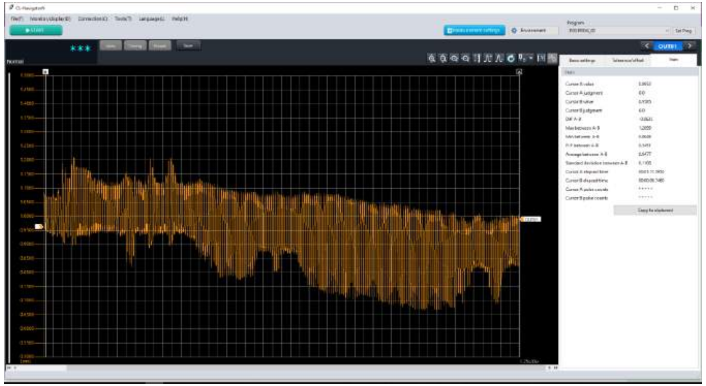


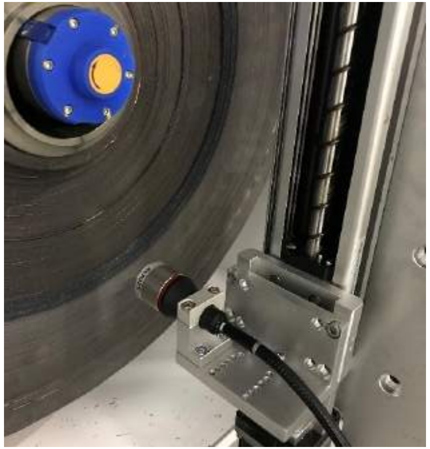


Pancake Edge Alignment Tool

- **Step 7:** hardware validation of purchased products
- CL sensor and encoder testing and validation based on given specifications of datasheet: prototype test set-up resulted in noise, although products found to meet specifications
- Creating trial conditions reflecting real-life conditions

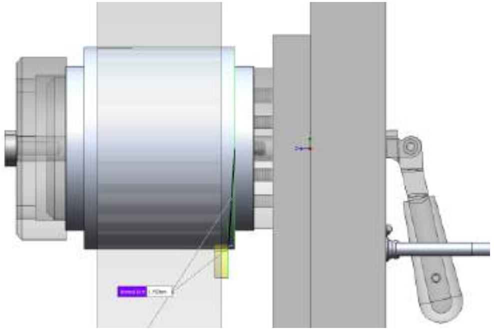


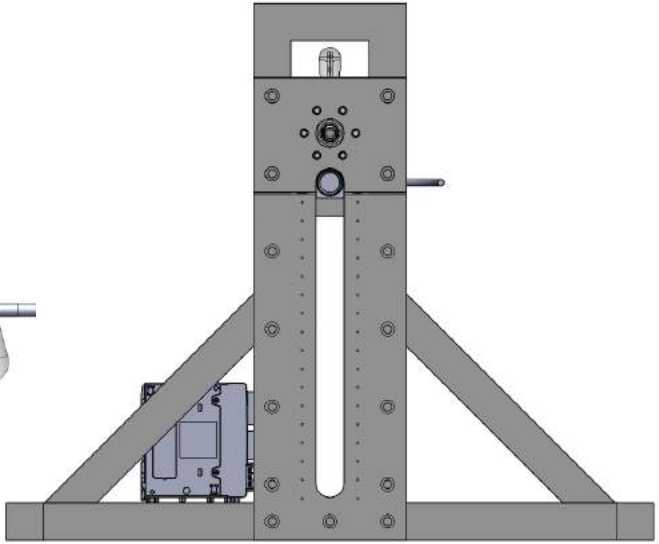


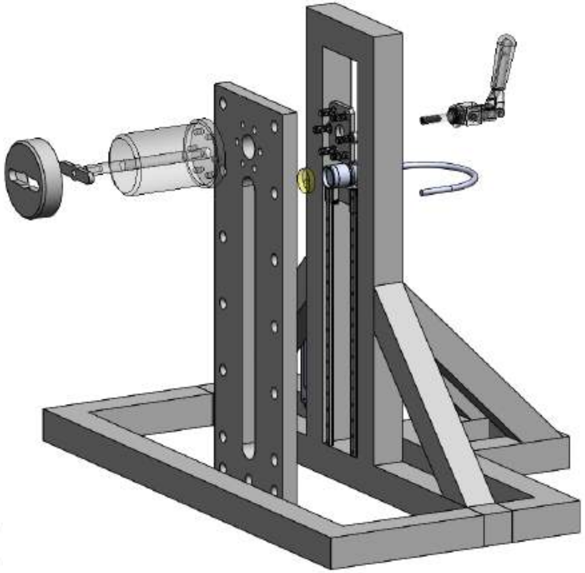


Pancake Edge Alignment Tool

- **Step 8:** finalizing and creating final design, and final validation testing to ensure device meets all requirements and is fully functionable
- In progress

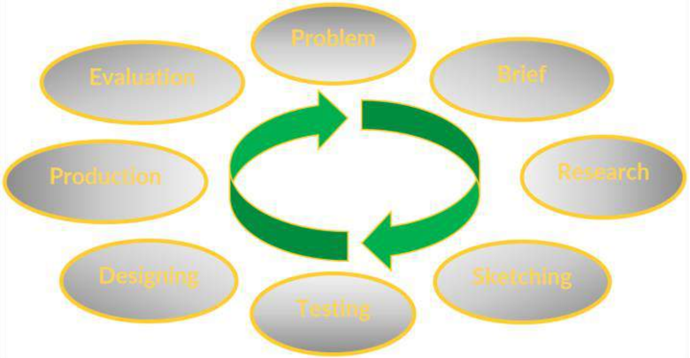


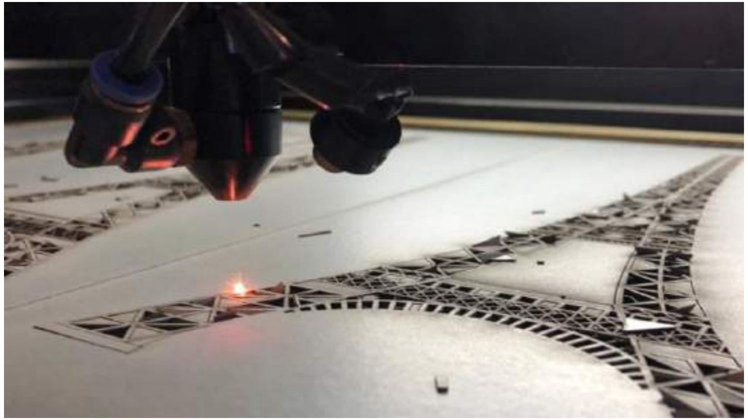




Pancake Edge Alignment Tool

- Skills/technologies used: Solidworks, 3D printer, laser cutter, rapid prototyping
- Managing and overview of the entire product design cycle
- Biggest takeaway: learning how to read a datasheet
  - Precision vs. accuracy vs. resolution





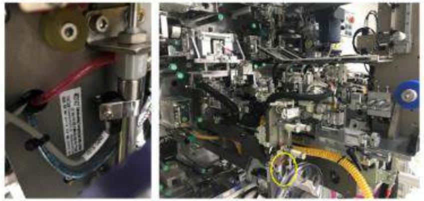
Kato Winder

- Deadliest, most complex machine on the floor – BY FAR

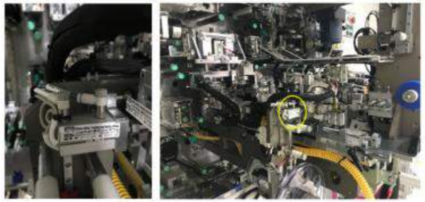
Kato Winder

- Assisted with moving-in process and early commissioning
- Learnt how the winder works, differences between 24L winder and Kato winder

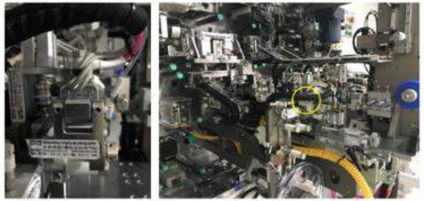
402YV27 – Cathode Welding 2 Wrapping Tape Buffer Cylinder



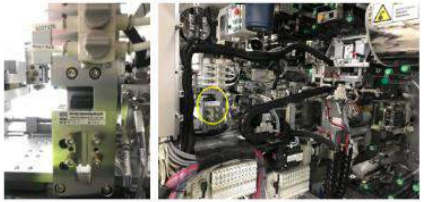
402YV28 – Cathode Welding 2 Wrapping Tape Feeding Cylinder



402YV29 – Cathode Welding 2 Wrapping Tape Pressing Cylinder

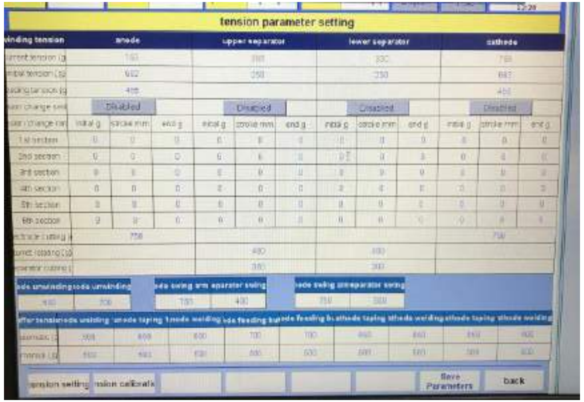


402YV32 – Cathode Welding 2 Wrapping Tape Cutting Up-Pressing Cylinder



Kato Winder

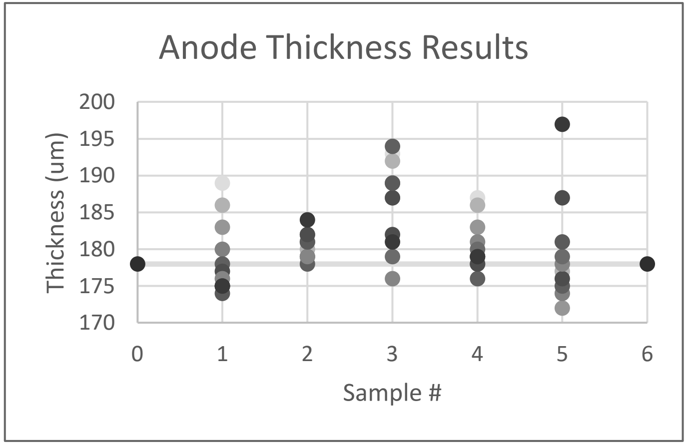
- Learning how to control the HMI, and establishing an SAT schedule with LEAD
- Overseeing LEAD progress on punch list items
- System and hardware validation of completed items
- First jellyroll!

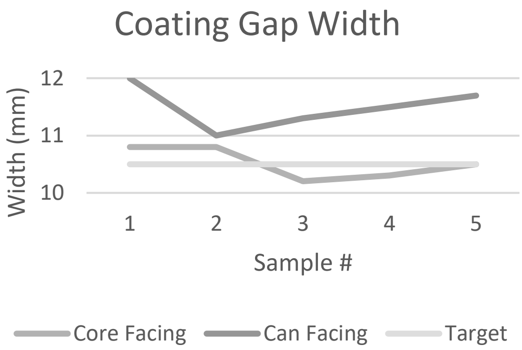


LEAD Update	Date Created	Tesla Contact	Owner	ETA	Last Che	Status
Need tesla to check	16-Jan	Kevin	Tesla			Open
need tesla to confirm if we can remove another air tubing from your lab.	31-Dec	Kevin	Tesla			Open
Tesla have purchased	26-Dec	Kevin	Tesla			Open
not clear for this question before, will check on site	15-Jan	Kevin	LEAD			Open
Need tesla to confirm the position	22-May	Kevin	LEAD			Open
		Kevin	LEAD			Open
We have put some label accordingly, need telsa to check		Kevin	LEAD			Open
Not clear the details		Kevin	LEAD			Open
LEAD confirm we have put easy page switching button, please check		Kevin	LEAD			Open
complete		Kevin	LEAD			Open
complete		Kevin	Tesla			Open
We got issue and will discuss internally		Ben	LEAD			Open
LEAD suppose there is data shared from Keyence		Ben	Tesla			Open
complete	10-Jan	Uma	LEAD			Open
complete	10-Jan	Kevin	LEAD			Open
complete	6-Jan	Kevin	LEAD			Open
Need tesla to check?		Ben	Tesla			Open
Need tesla to check?		Ben	LEAD			Open
have shipped to mental material, may due to production, didn't assemble on site		Kevin	LEAD			In Progress
now is fabricating;we will ship soon		Kevin	LEAD			Open
Need to check on site		Kevin	Tesla			Tesla Verify
will ship material and change on site		Kevin	Tesla		3-Jan	Open
complete		Ganesh	Tesla			Open

Kato Winder

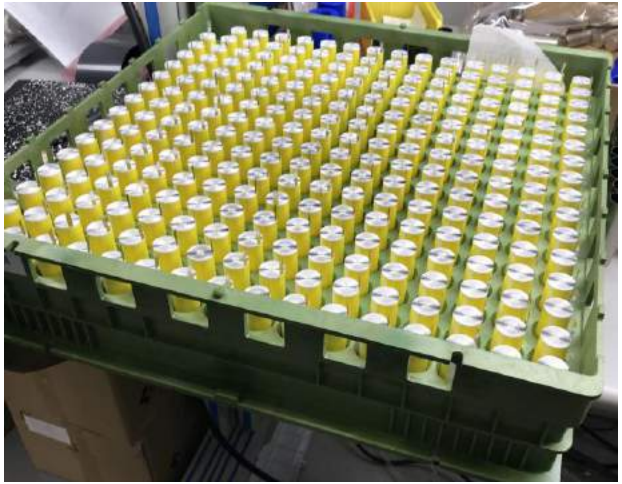
- Ramping up production of jellyrolls
- Stabilizing processes (ex. diameter, thickness, width, etc.)
- Further commissioning of the beast!

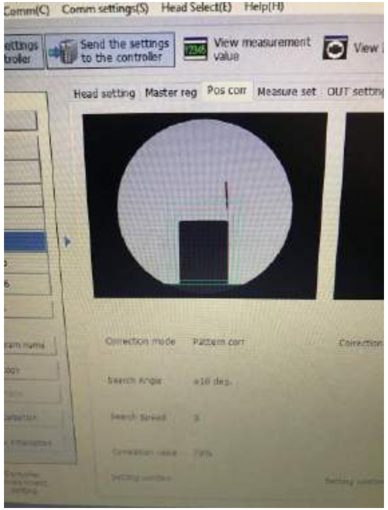




Kato Winder

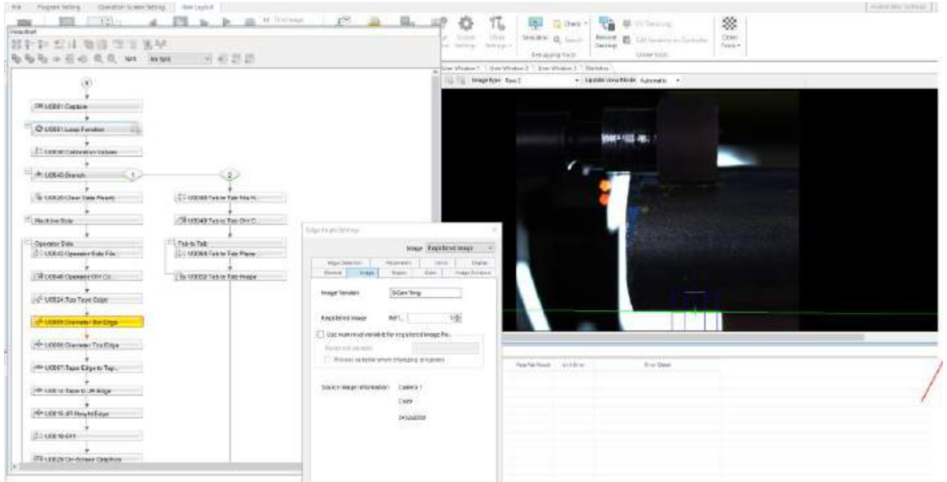
- Ramping up production even more!
- Running machine independently from LEAD
- Diameter analysis and DOE

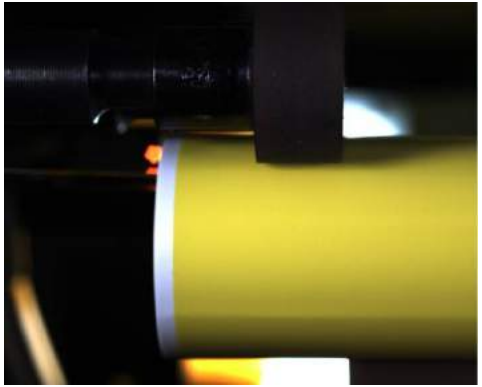


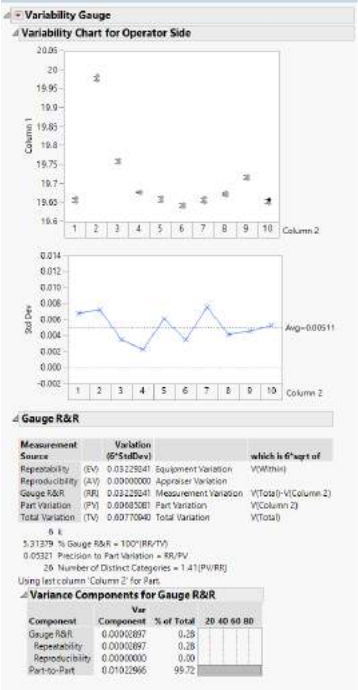


Diameter Analysis

- Used TM65 in addition to precise ‘golden’ sample as a reference for Keyence camera diameter check station
- Completed Gage R&R study to evaluate sources and causes of variation

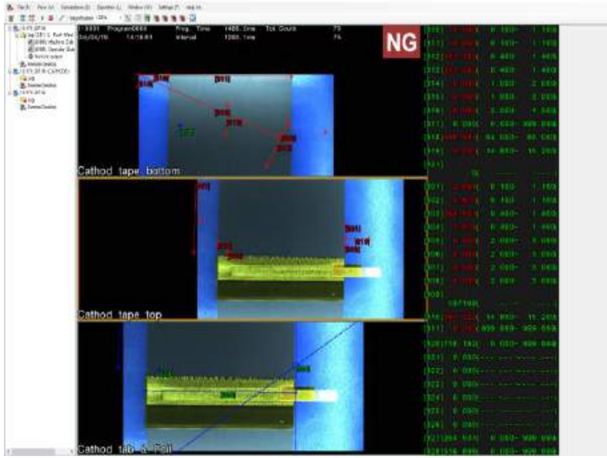


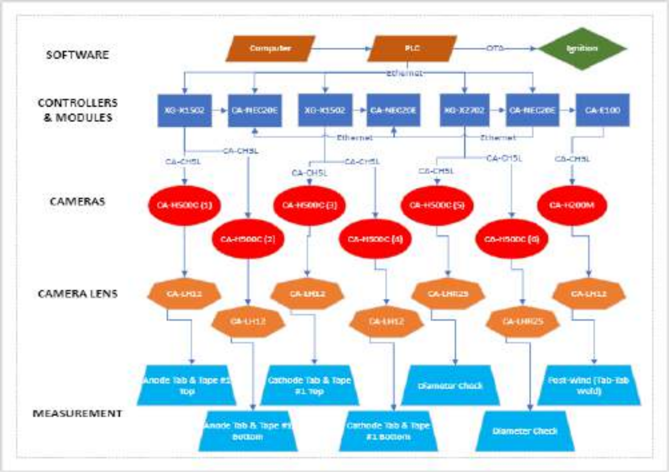


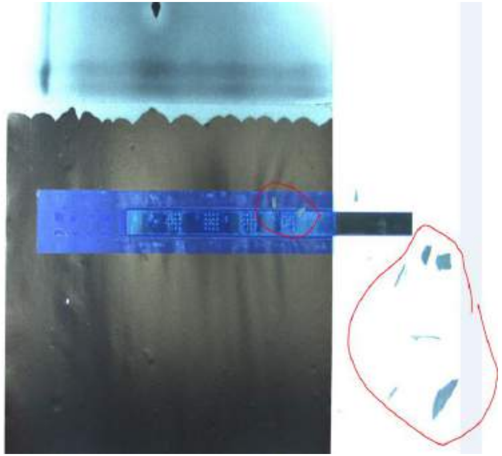


Keyence Inspection

- Responsible for bring-up of Keyence quality on winding, including controllers/cameras integration, tuning, inspection programs, and inspection validation, and creating SOP
- Total of 7 Keyence cameras on winder

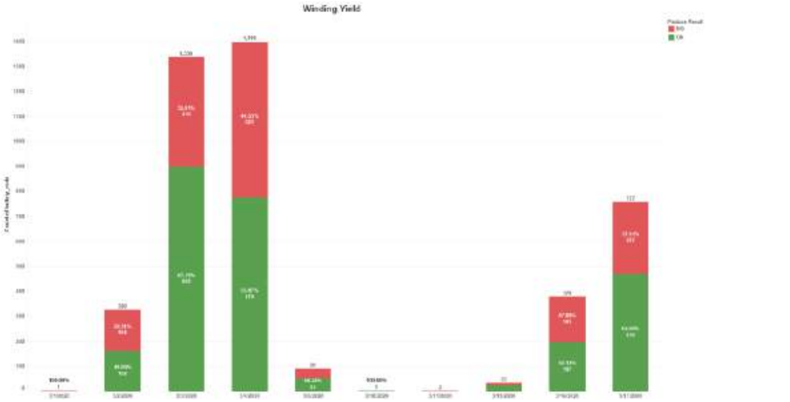


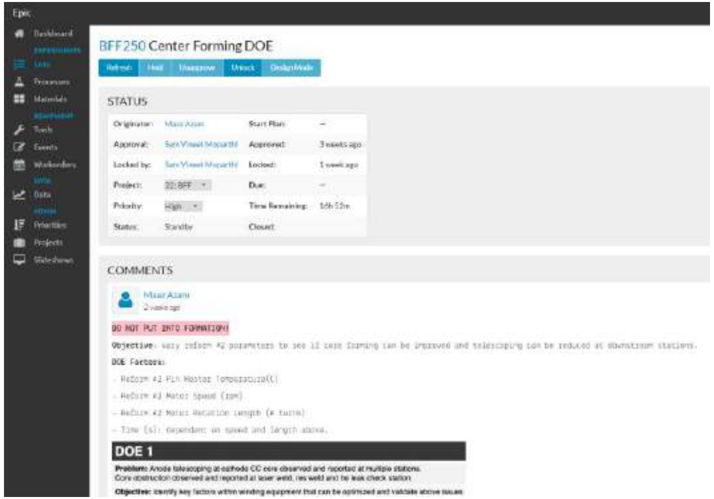


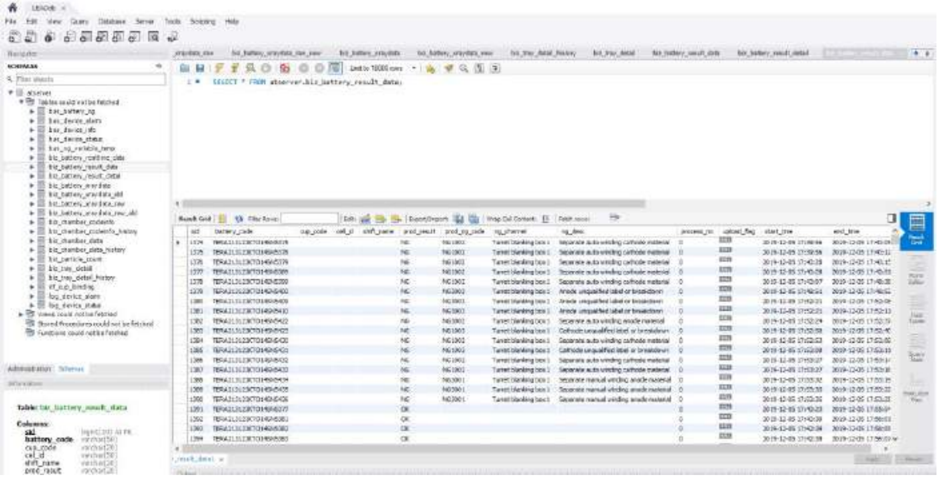


Kato Winder

- MES database and connectivity
- Tableau dashboard
- EPIC data logging

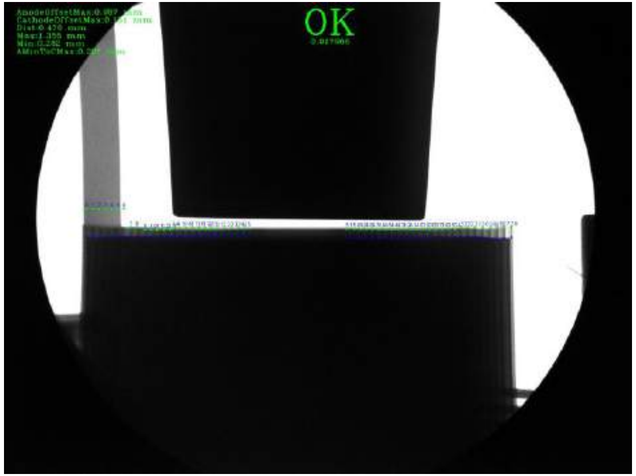


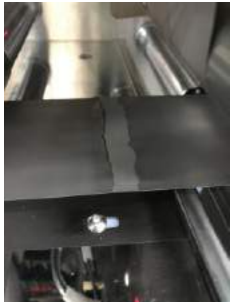


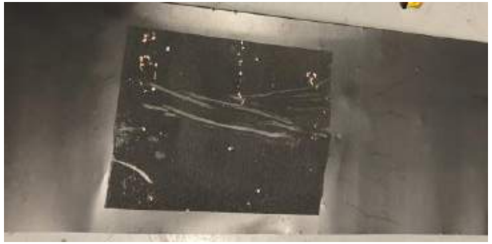


Kato Winder

- “Production hell” of the Kato winder
- Passing on the knowledge to technicians
- X-ray commissioning

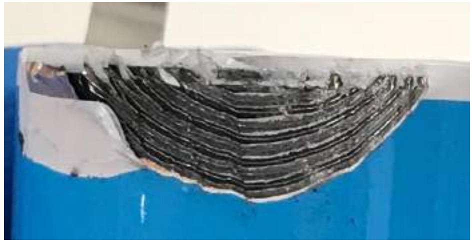


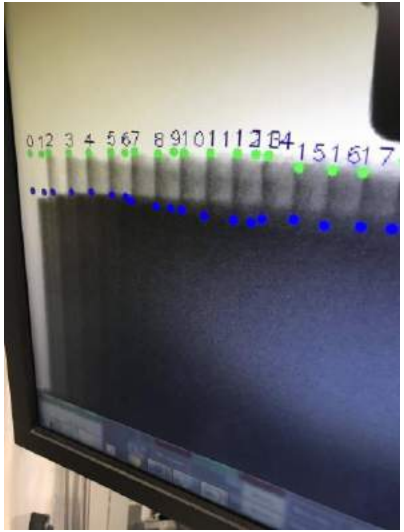




Kato Winder

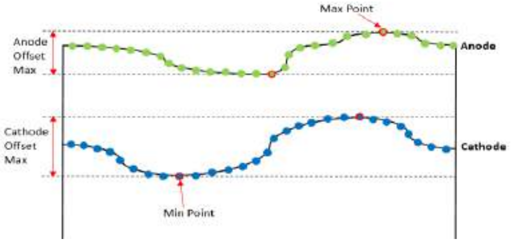
- More DOE’s (cracking, wettability, tension)
- Assisting LEAD with outstanding winder items

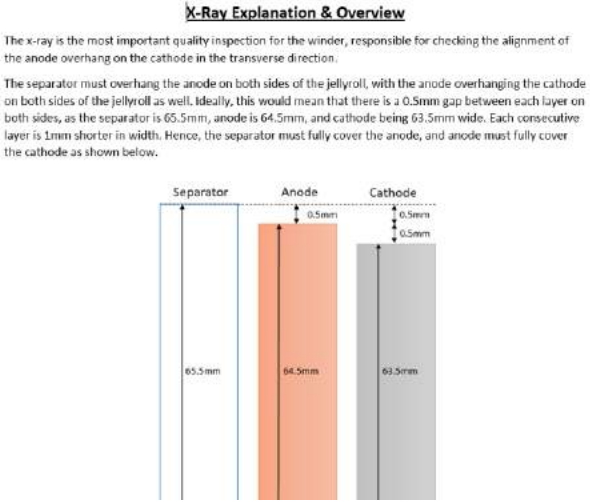






Kato Winder

- Cell quality and x-ray dissections and training
- Documentation of all processes
- Further advancing winder capabilities!

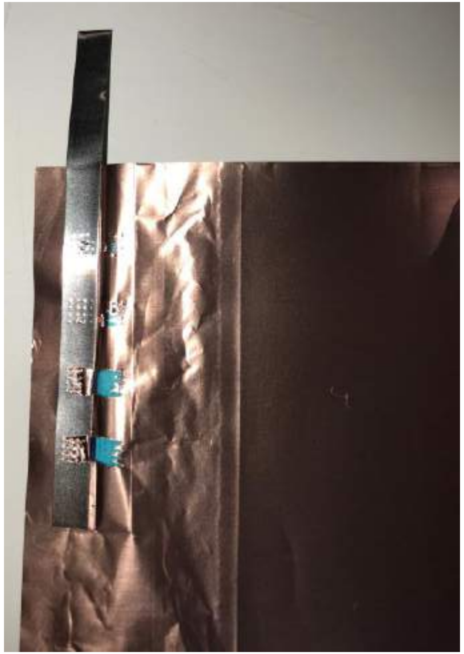


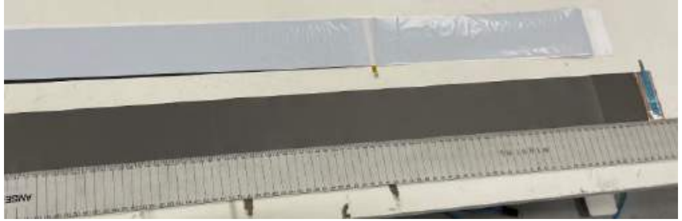


X-Ray Explanation & Overview

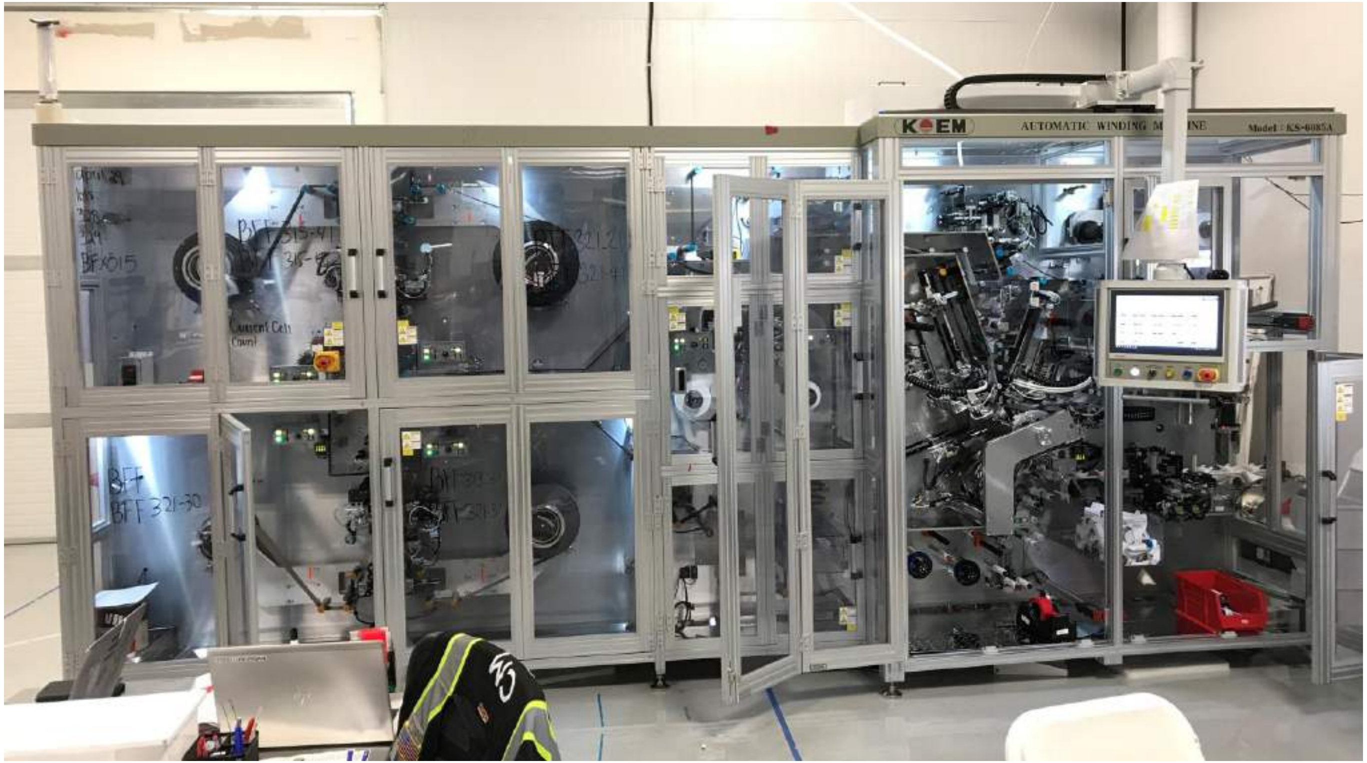
The x-ray is the most important quality inspection for the winder, responsible for checking the alignment of the anode overhang on the cathode in the transverse direction.

The separator must overhang the anode on both sides of the jellyroll, with the anode overhanging the cathode on both sides of the jellyroll as well. Ideally, this would mean that there is a 0.5mm gap between each layer on both sides, as the separator is 65.5mm, anode is 64.5mm, and cathode being 63.5mm wide. Each consecutive layer is 1mm shorter in width. Hence, the separator must fully cover the anode, and anode must fully cover the cathode as shown below.



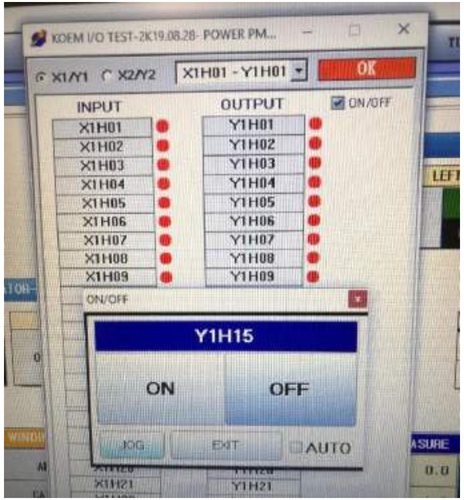


Swift KOEM Winder



Swift KOEM Winder

- Assisting with KOEM winder production, operation, and jellyroll quality
- Created documentation to further understand controls and capabilities of winder



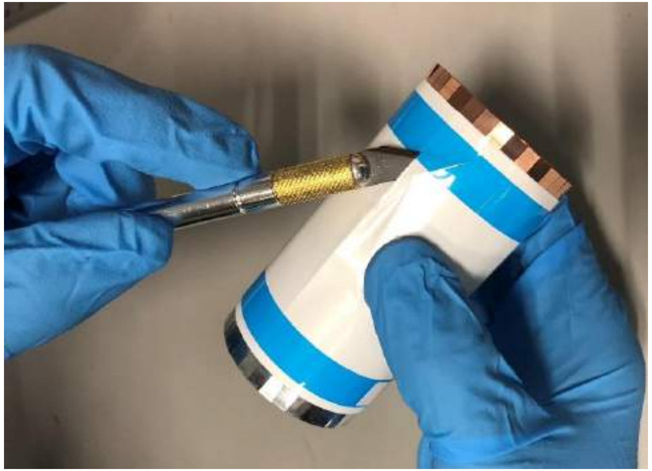
KOEM Winder Start-Up Process

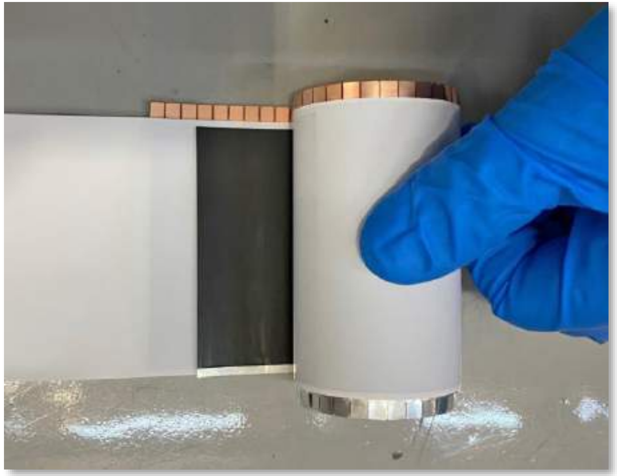
1. Turn on the main breaker for the KOEM winder if off.

2. At the back of the machine, the center cabinet contains a central power switch to power on all the components and HMI for the winder. Turn this switch on.

Swift KOEM Winder

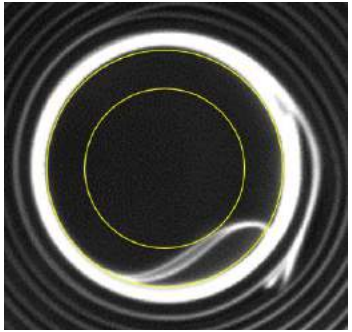
- Jellyroll dissections and quality inspections
- Creation of SOP for quality at winding





Swift KOEM Winder

- DOE's (center forming and tension)
- Process capability analysis
- Core obstruction analysis



Larger Center Form Pin Trial #1

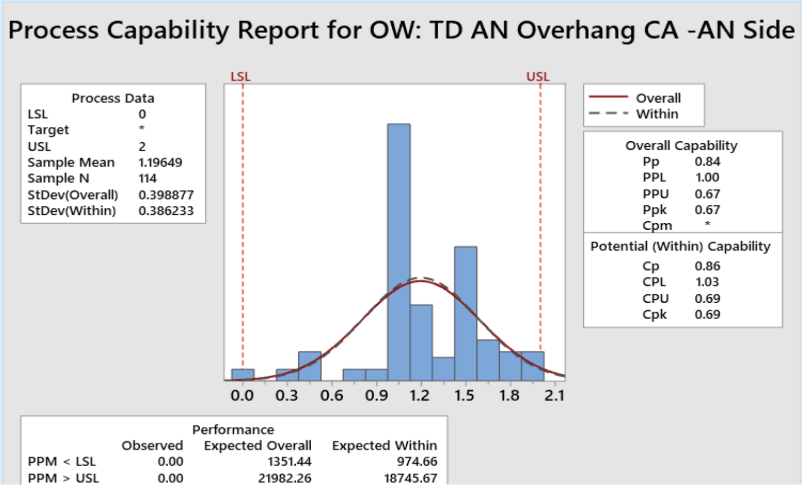
Plan Date	4/23 10:30	Planned By	K. Mori
Run Date		Run By	

Step	Result	Action
1	Done	Confirm current center form #2 configuration in table below

Parameter	Current (Expected)	Current (Confirmed)	Trial Setting	Notes
Diameter (mm)	4.4		See below	
Coating	Sanded		DLC	
Orientation of bevel	Straight up		Straight up	
Resting pressure of overforce air regulator (MPa)	0.1		Fill in what you use here	Adjust as needed so it triggers appropriately. Record new value here.
Motor speed (rpm)	60		75	
Motor length (turns)	2		2	
Temperature (C)	80		100	
Bevel fully emerges past end of the cell when pin inserted	Yes		Yes	To make sure the whole length of the core sees the full diameter of the pin.

Step	Result	Action
5	Done	Replace center form #2 pin with 4.5mm size (verify size by reading the markings on end of shaft)
6	Done	Check orientation: bevel straight up
7	Done	Run 10 cells and fill in the table below

Pin Diameter	Cell #	Overforce Alarm (Y/N)	Visible telescoping (Y/N)	Photo of core open area	X-Ray for Telescoping Check
4.5	1	N	N	Done	Done
4.5	2	N	N	Done	Done
4.5	3	N	N	Done	Done
4.5	4	N	N	Done	Done
4.5	5	N	N	Done	Done
4.5	6	N	N	Done	Done
4.5	7	N	N	Done	Done
4.5	8	N	N	Done	Done

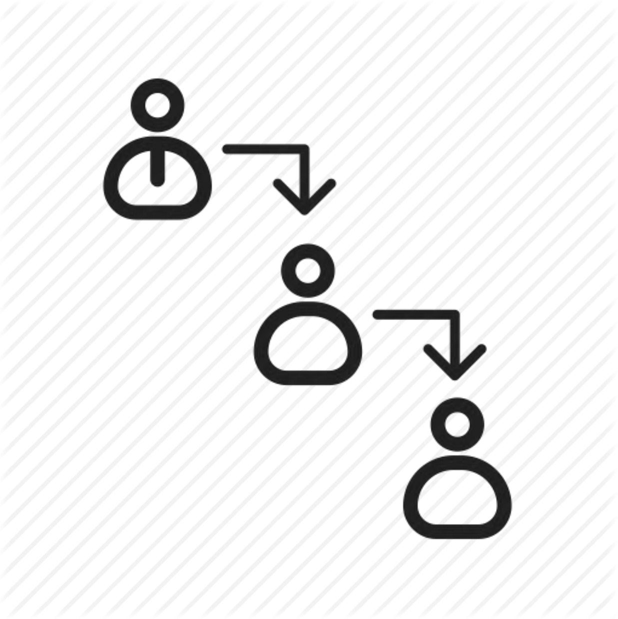


Work Overview

- Can be found on the following link: Maaz's Work
- Documentation with links to all the work I've done
- Further questions? Contact me!
  - 647-880-2395 or azamm3@mcmaster.ca

Challenges I Faced

- Language barrier and time difference with vendors (LEAD)
- “Chain of command” with LEAD
- Occasionally, very slow response time



What I LOVED!

- Cross functionality between other processes and teams
- Diversity of cell engineering lab
- Revolutionary work
- Learning curve
- Much more!

Most Importantly... THE TEAM!

In Addition…

- First time in California!
- Countless memorable experiences

Thank You TESLA!