Joint Centers of Excellence for Advanced Materials

Development of Process Specification and Quality Assurance of Slit Tape for Automated Fiber Placement

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Development of Process Spec. and Quality Assurance of Slit Tape for AFP

Research Team

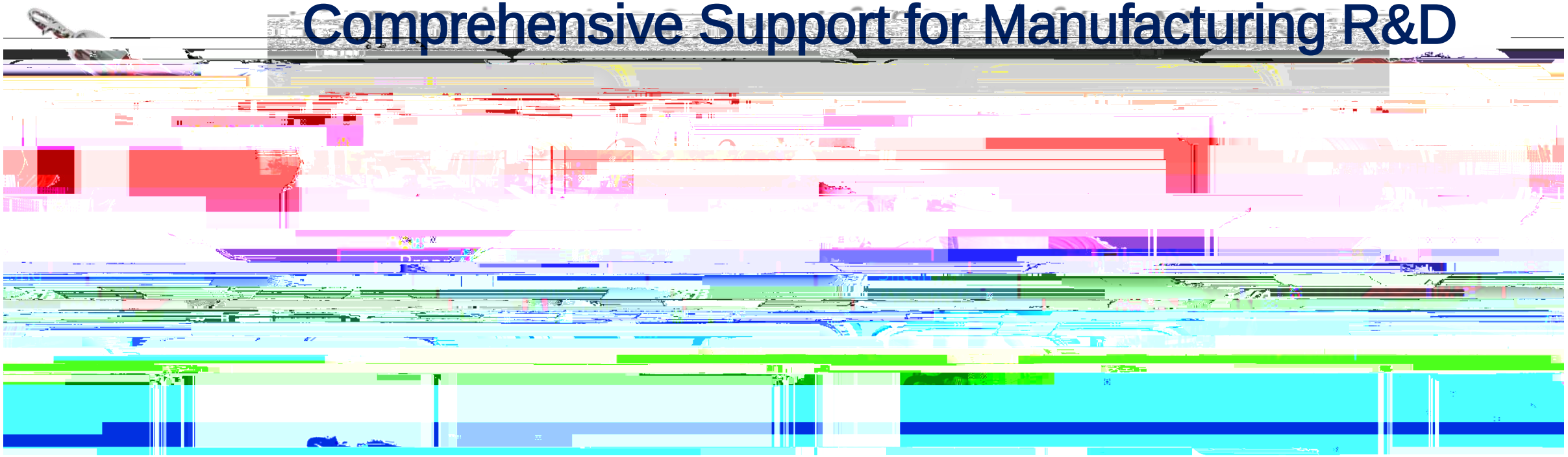
NIAR

FAA

Industry

NAR Advanced Technologies Lab for Aerospace Systems (ATLAS)

Comprehensive Support for Manufacturing R&D



Background

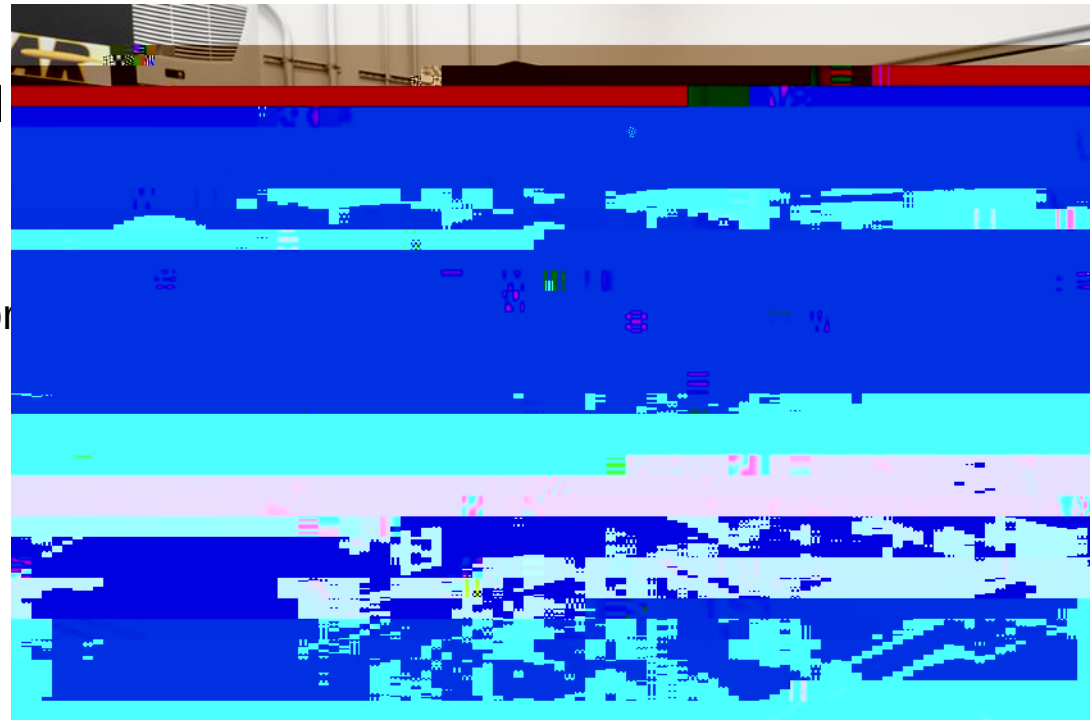
- Automated fiber placement (AFP) and automated tape laying (ATL) of fiber-reinforced composites provide great advantages in terms of production rate compared to traditional manual methods especially in high-volume environments.

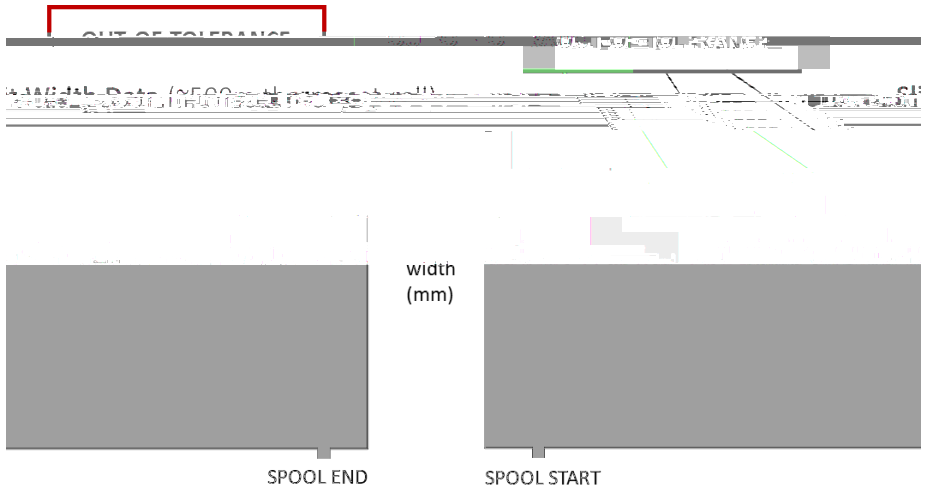
Program Goals

- Slitting process from wide roll of materials involves several steps such as unwinding of tape, separation of backing films, precision cutting, spooling, and rewinding.
  - During these steps, material travels through various blades, pulleys, and rollers that may introduce defects such as twisted or folded tows, fuzzballs, foreign object debris (FOD), and broken fibers.
  - Such defects can not only cause layup head malfunctions causing manufacturing delays, but also substandard parts that require repairs or scrap.

The primary goal of this research is to develop process specification and quality assurance methodologies for slitting materials for Automated Fiber Placement.

Secondary goals include an investigation into the state-of-the-art for slitting and in-process inspections and an investigation of the effects of defects or sub-standards slit tape quality on part performance.



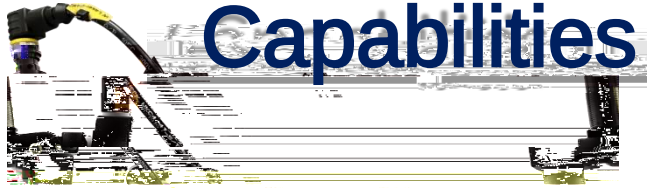


Technical Approach

- In order to produce aerospace quality AFP/ATL parts and maintain required manufacturing rates without unscheduled maintenance and repair of equipment, it is important to control all aspects of materials and processes including the quality of slit tape materials.
- Key enablers for ensuring the quality of slit tape are the in-process inspection system integrated to slitting machine along with a machine learning algorithm for detecting manufacturing defects as well as acquiring key measurements required for quality control.
- The investigation includes the following three tasks:
  - Investigation of state of the art (SOTA) equipments for slitting and in-process inspection

Quality Assurance of Automated Fiber Placement

Capabilities



IPLIS

(In-Process Laser Inspection System)

THERMOPLASTIC

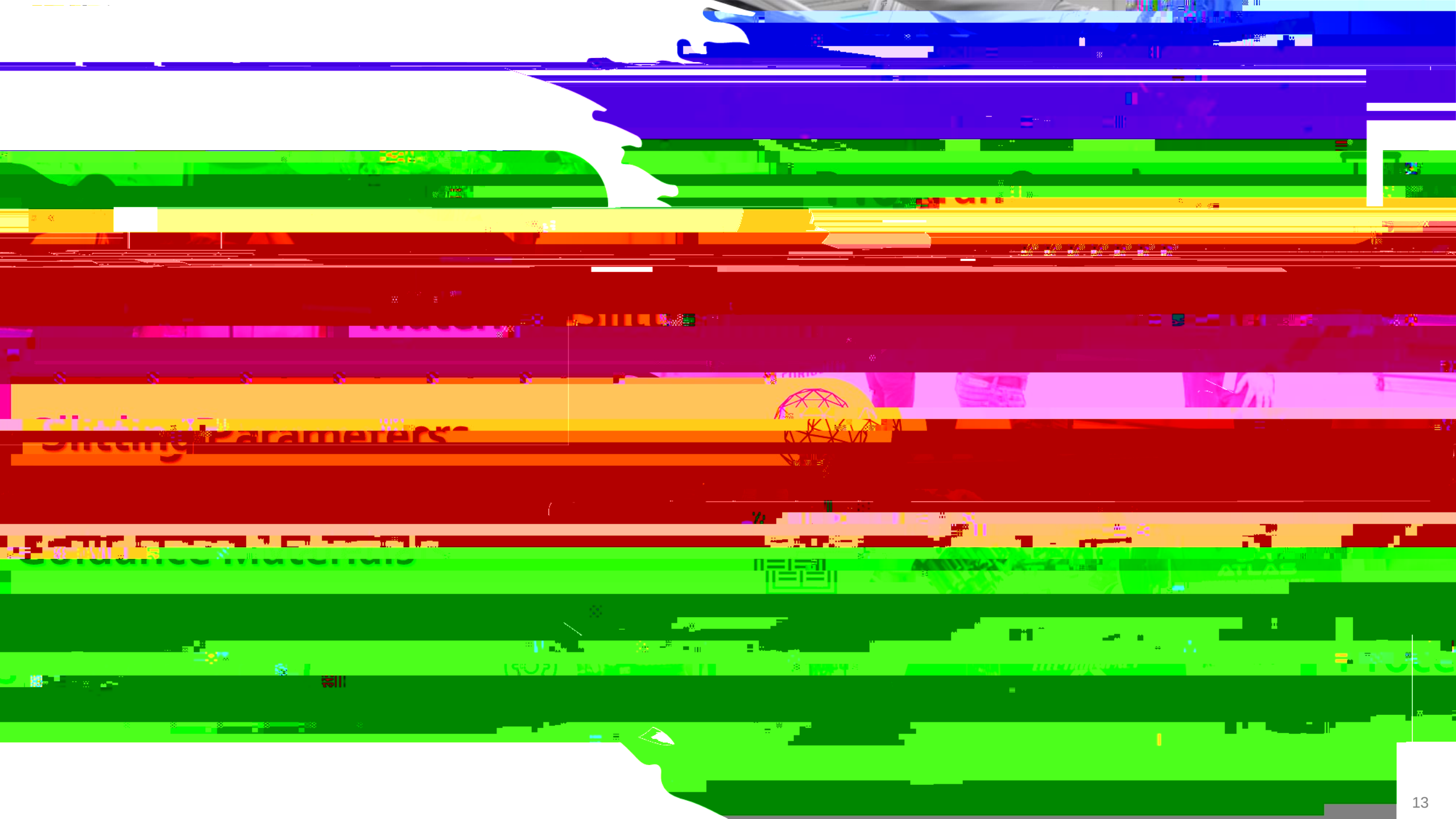
CMC

FIBER PATCH PLACEMENT

POLY/ BACKER

WEAVE

THERMOSET

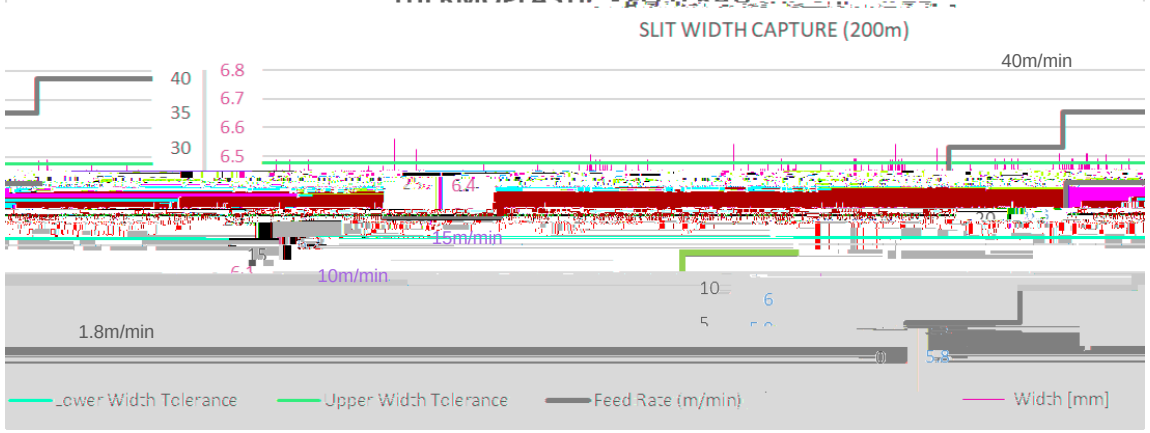



Scope
Work Instructions
Facilities
- Environmental requirements
- Emergency Response. Loss of power, shop air, Temp/humidity
- Machine maintena plan
- Cleaning practice
Manufacturing
- Requirements to
Post-Slit Operations
-Proper bagging/storage
- Standardized labeling
- Proper handling, transport and storage practices.

Slitting Parameters

Length of Roll

	0m-20m	21m-40m	41m-60m	61m-80m	81m-100m	101m-120m	121m-140m	141m-160m	161m-180m	181m-200m
Feed Rate	MIN	5m/min	10m/min	15m/min	20m/min	25m/min	30m/min	35m/min	40m/min	-

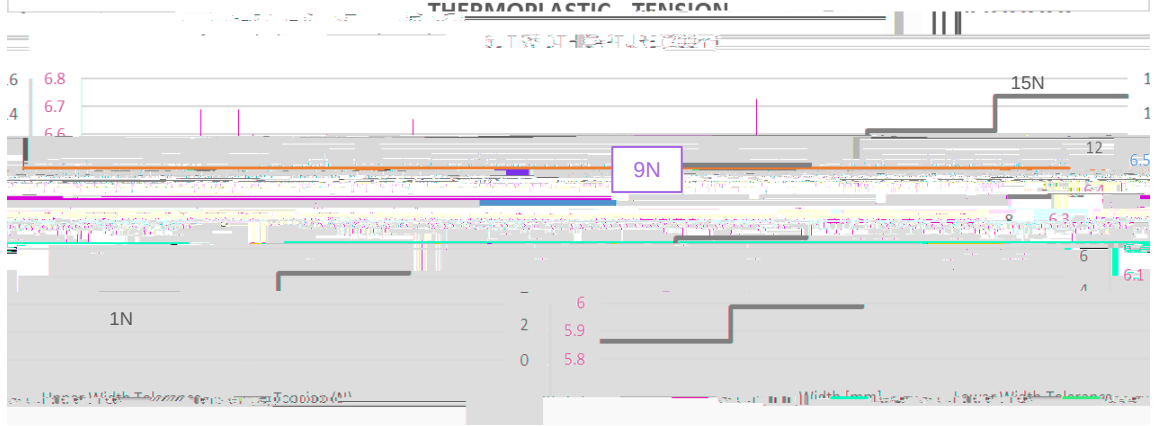


SLIT WIDTH (mm)

FEED RATE (m/min)

Length of Roll

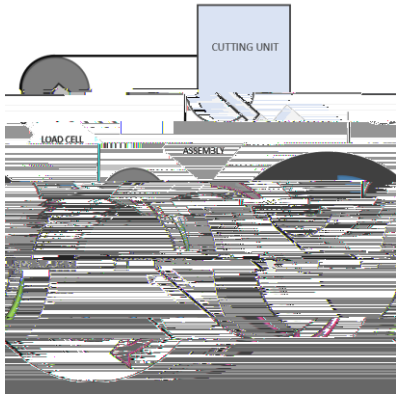
	0m-20m	21m-40m	41m-60m	61m-80m	81m-100m	101m-120m	121m-140m	141m-160m	161m-180m	181m-200m
Tension	1N	3N	5N	7N	9N	11N	13N	15N	17N	20N



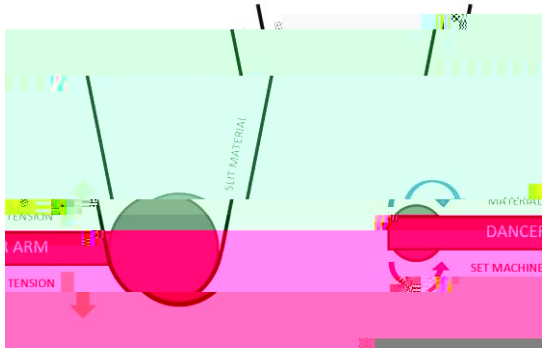
SLIT WIDTH (mm)

TENSION (N)

TENSION MONITORING

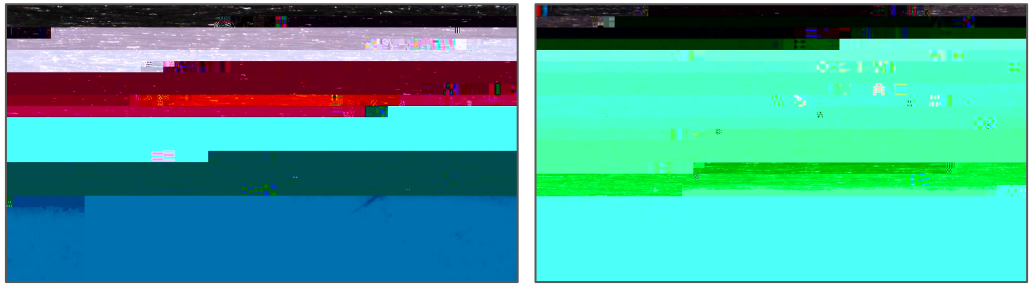


Before Blades

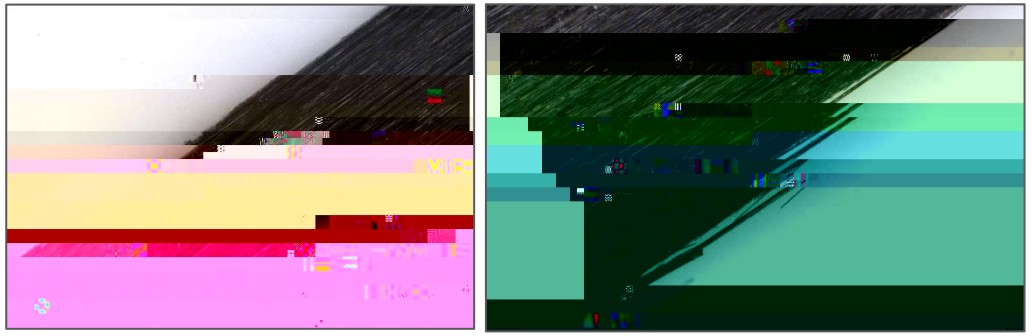


Before Finished Spool

Slitting Parameters



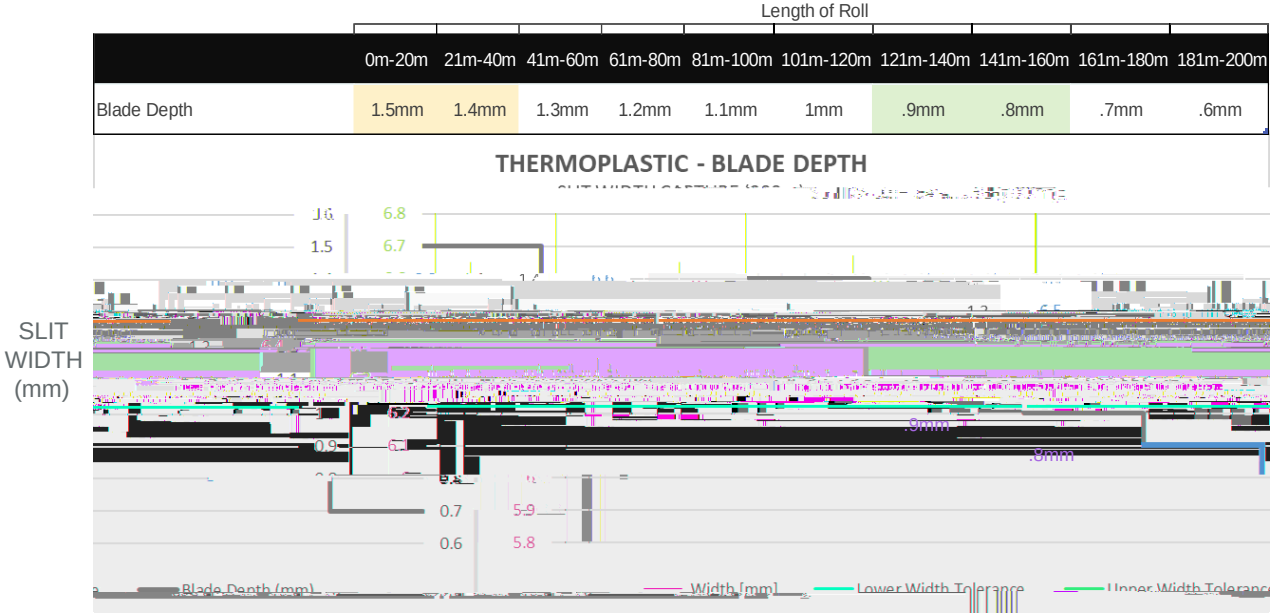
Thermoplastic Blade Depth Trials: 1.5mm (left) vs .7mm (right).



Thermoplastic Blade Pressure Trials: 1mm (left) vs 4mm (right).

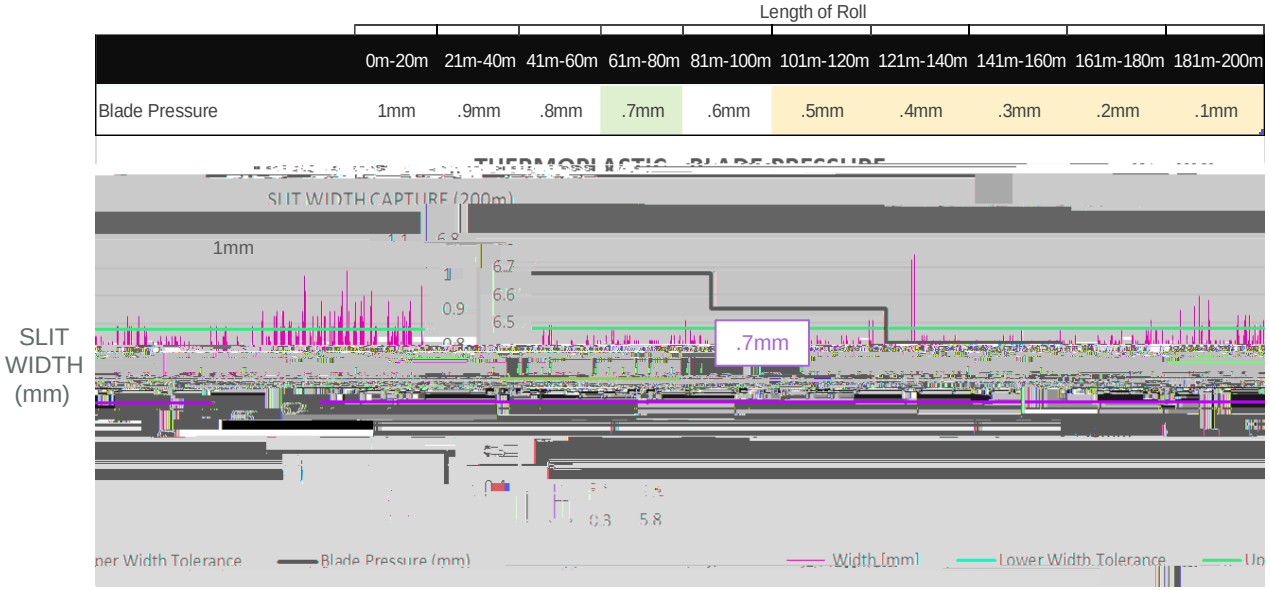
Length of Roll

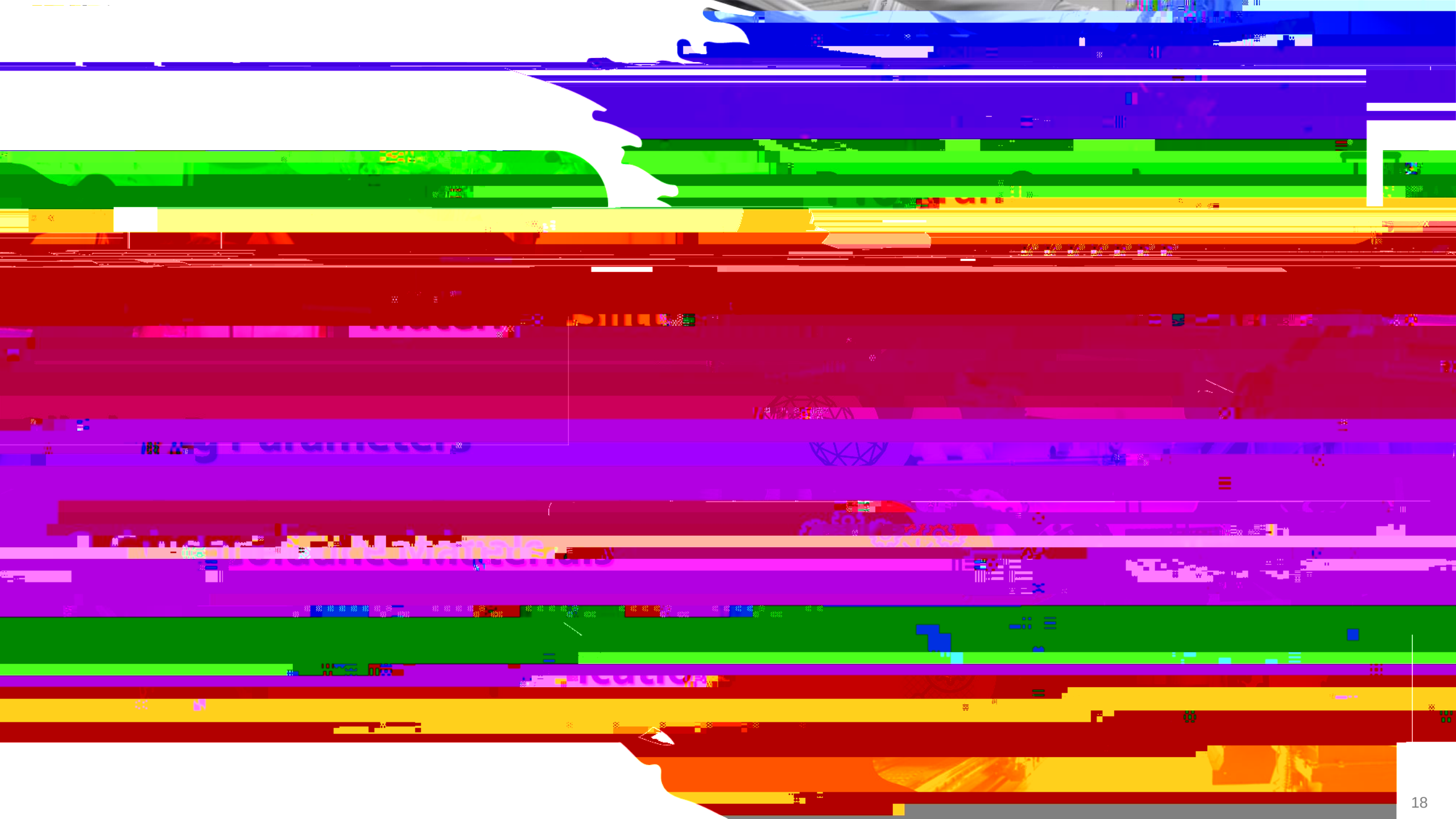
	0m-20m	21m-40m	41m-60m	61m-80m	81m-100m	101m-120m	121m-140m	141m-160m	161m-180m	181m-200m
Blade Depth	1.5mm	1.4mm	1.3mm	1.2mm	1.1mm	1mm	.9mm	.8mm	.7mm	.6mm



Length of Roll

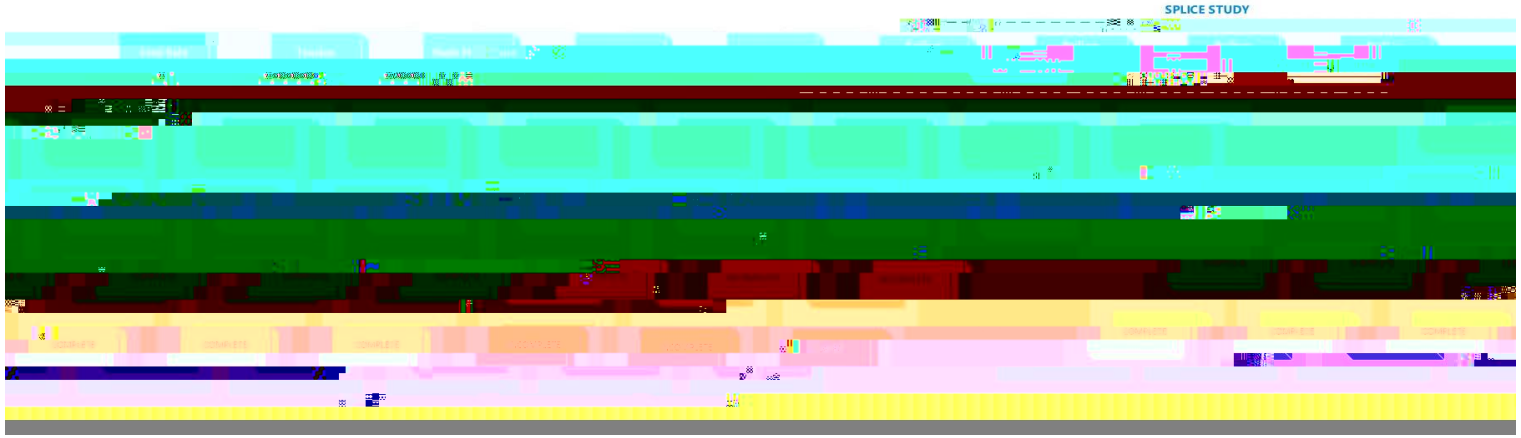
	0m-20m	21m-40m	41m-60m	61m-80m	81m-100m	101m-120m	121m-140m	141m-160m	161m-180m	181m-200m
Blade Pressure	1mm	.9mm	.8mm	.7mm	.6mm	.5mm	.4mm	.3mm	.2mm	.1mm





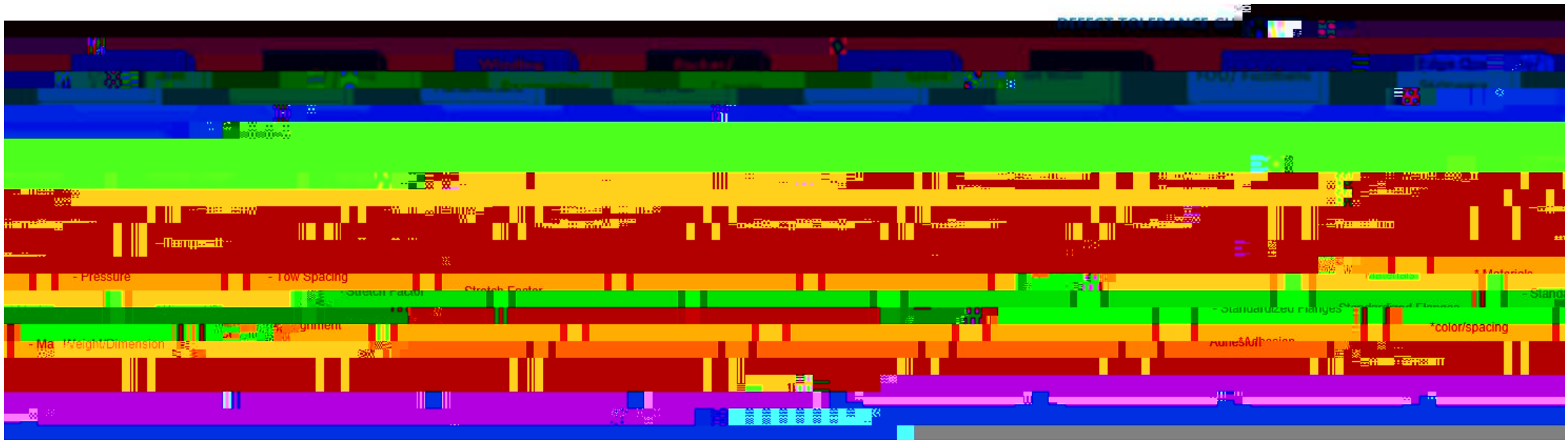
Slitting Parameter Study

- Feed rate
- Tension
- Blade Pressure
- Blade angle
- Splice Overlap
- Splice Temperature
- Splice Pressure
- Splice Hold Time

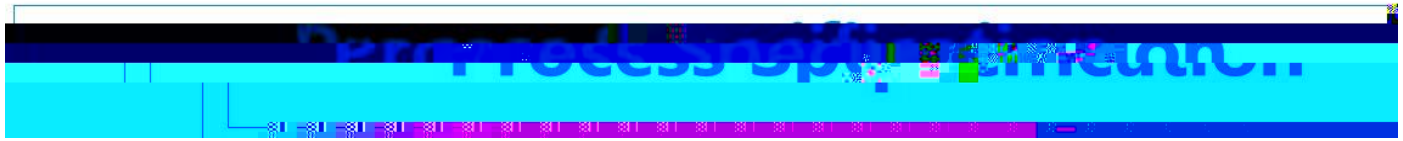


Splice Overlap

Guideline Document




Effects of Defects
Efficiency
Performance
Mechanical
Performance




Facilities
Calibration

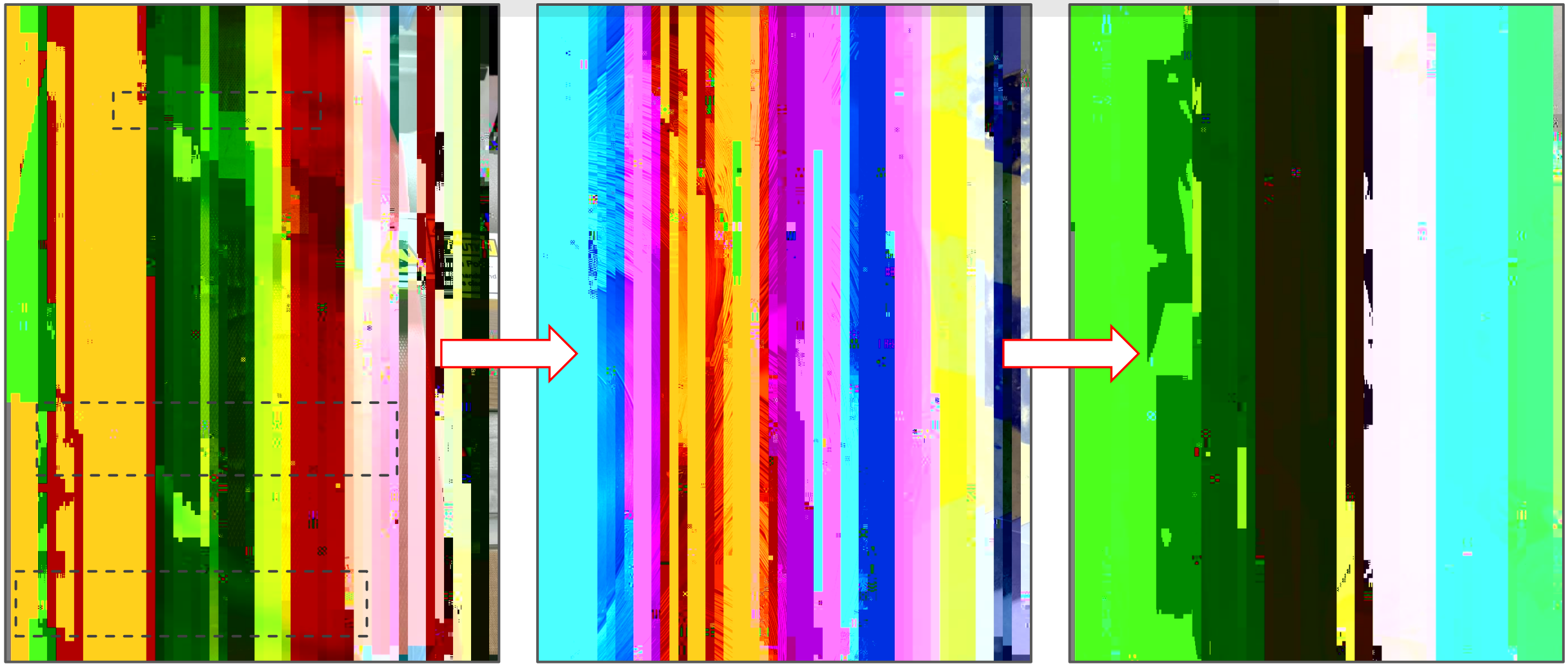
Traceability

‡ Developing traceability methods to account for and track every portion of an incoming roll front to back and left to right. If a material manufacturer has concerns for dry or heavy resin areas on their roll, fuzzballs, splits, etc..

‡ We can relay where those defects occurred on the width and length.

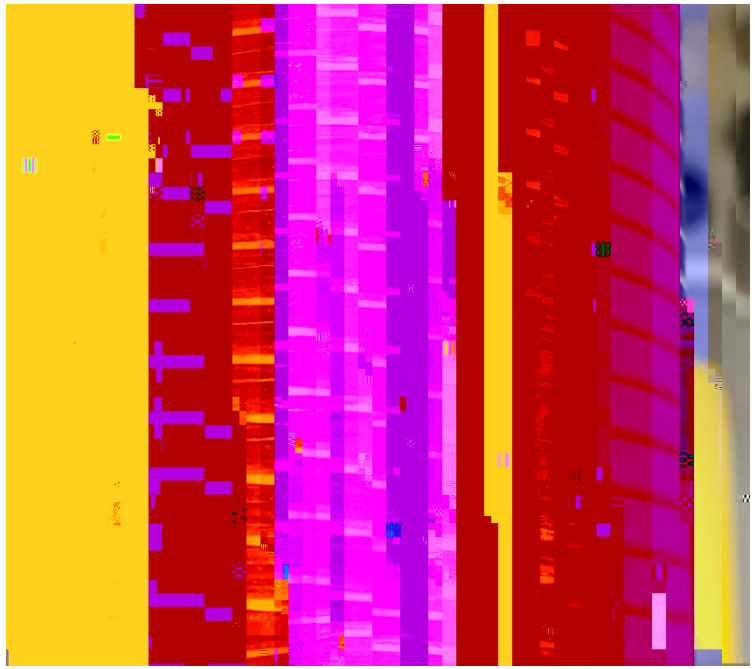
‡

Effects of Waviness in the Carrier on CMC



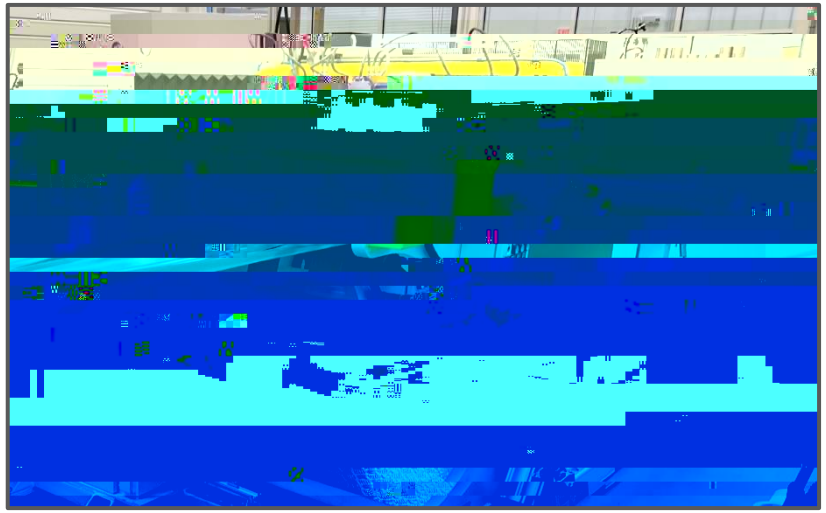
Waves caused by the carrier on the parent roll resulted in broken fibers later on during rewinding.

POLY CARRIER PARAMETERS STUDY
TENSION OVER TIME



BMI Trials

Removing poly precut results in fiber pull



Removing poly postcut prevents error

64,908ft of .5in slit tow

Processed through ElectroImpact

Summary

- In order to meet the quality requirements associated with AFP/ATL process, it is imperative that the slitting process produce slit tape to meet required specifications, which includes dimensional tolerances and requirements for defects in slit tape.
- Several key in-process inspections and machine learning algorithms for detecting defects during slitting and develop slitting specifications for thermoset, thermoplastic, and CMC will be evaluated for slitting and automated fiber placement.
- Calibration and verification procedures for in-process inspection systems will be developed for quality assurance and traceability.
- Guidance materials will be developed for determining acceptance limits
  - Effects of slit tape quality
  - Effects of slit tape quality on AFP operational efficiency

Looking Forward / Future Work

- Benefit to Aviation
  - Industry standard process specification and quality assurance methodologies for slitting materials for automated fiber placement.
  - An investigation into the state-of-the-art for slitting and in-process inspections
  - Investigation of the effects of slit tape quality on part performance
  - Identification of critical slitting parameters impacting the slit tape quality
- Next Steps:
  - Complete slitting parameter evaluation
  - Develop manufacturing and test plan for effects of slit tape defects on AFP part quality
  - Develop guidance materials and slitting specification