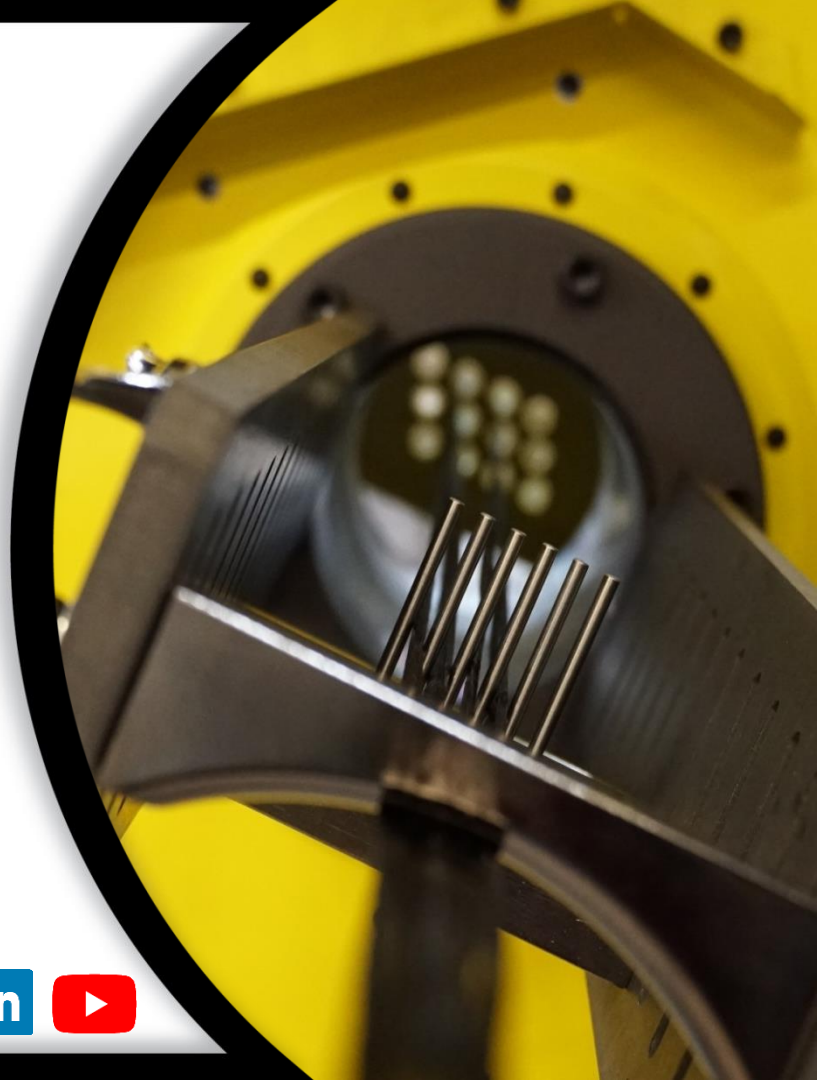
ENGINEERING TECHNOLOGY CORP.

Toray Group

National Composites Week

Filament Winding:

Efficient Material, Machinery & Process Decisions



CW CompositesWorld

Celebrating the innovation and creativity of composites in manufacturing

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Speakers

B Jay Larson
General Manager
Engineering Technology Corporation, Toray Group

- Over a decade in the composites industry focused on manufacturing of raw materials and process machinery
- Bachelor's degree from the University of Utah in Mechanical Engineering with an emphasis on composites

Mel Singh
Product Development Manager
Engineering Technology Corporation, Toray Group

- Over a decade in the machine manufacturing industry focused on control systems and application software
- Bachelor's degree from the University of Utah in Science with a specialization in software engineering

Agenda

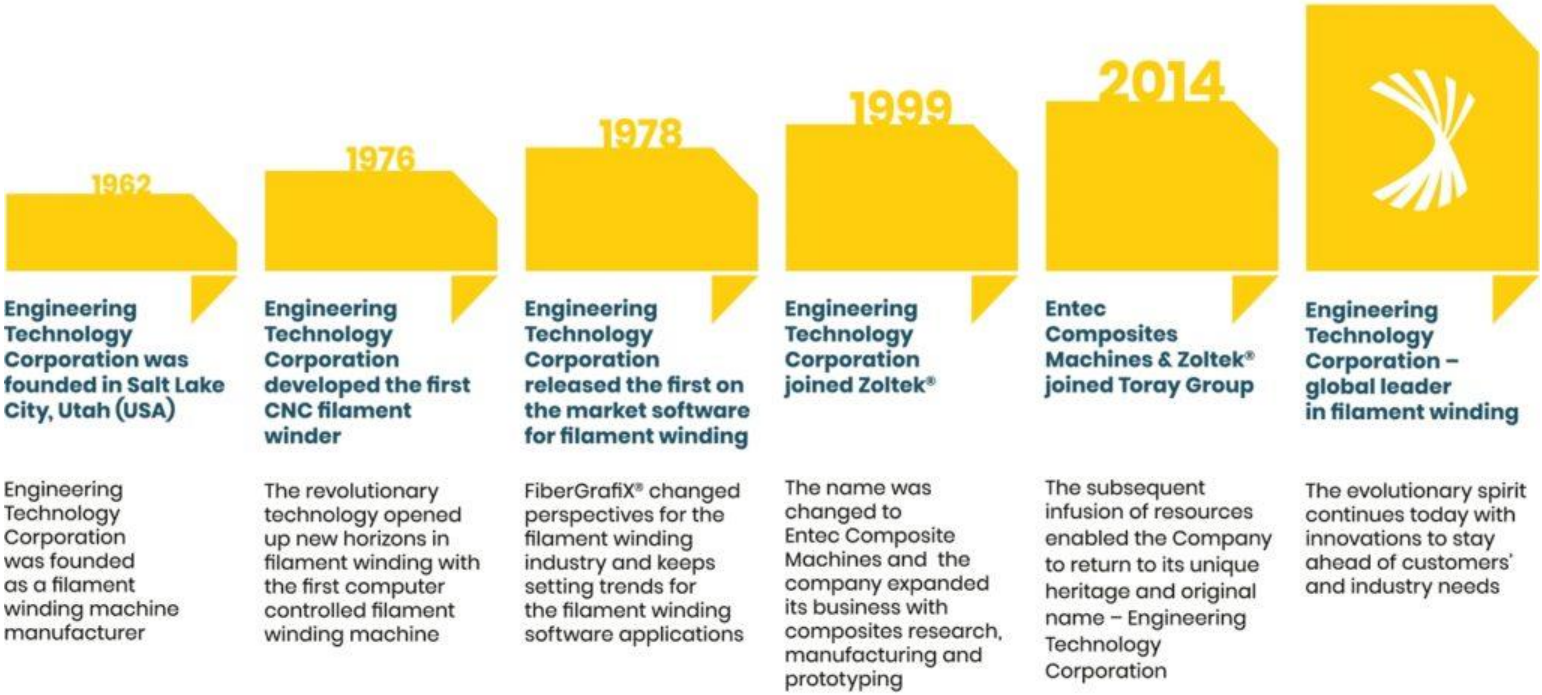
A high-level, yet informative, look into how decisions made during the filament winding process can trickle down to affect final throughput. Topics to be covered range from material selection to highly demanded industrial speed and robotic machine tending. The filament winding process as a whole will be discussed, we are willing to lend our experience to help companies capitalize on their products.

Primary Topics:

- Key Market Drivers and Industry Trends
- Part Definitions & Material Selections
- Design and Analysis
- Process and Machine Considerations
- What's Next in Filament Winding

Engineering Technology Corporation (ETC) History

GLOBAL EXPERT IN FILAMENT WINDING AND COMPOSITE SOLUTIONS



OVER 50 YEARS OF TRUSTED SERVICE

ETC has a Unique Vantage Point

→ As an OEM we have a unique vantage point. Filament winding has been around since the 1960's (so has ETC). We have worked with a large number of customers on a large number of projects. We have seen good examples of efficiency and we've seen bad.

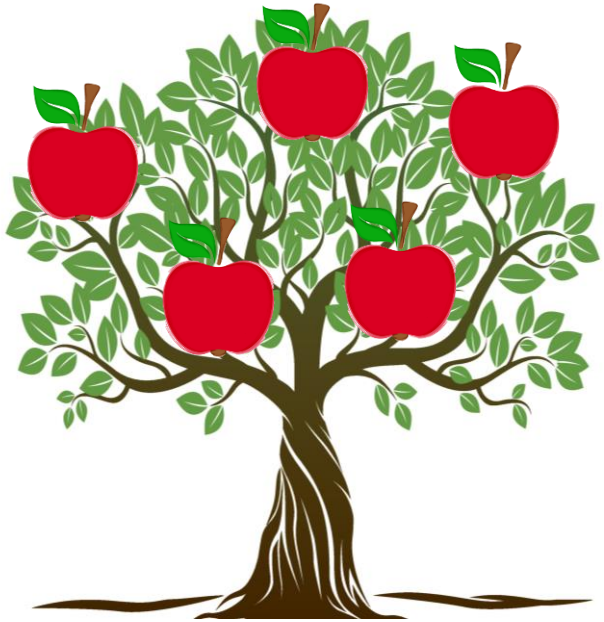
→ FW has had a long run and to some extent has been squeezed for all it's worth. I plan on sharing some tips that we've picked up along the way, but we do not have a silver bullet.

Composites is a Search for Lighter & Stronger

→ Depending on your experience with composites you may be trying to reach fruit anywhere on this tree.

1. Composites are more expensive
2. More difficult to design
3. More difficult to process

→ Many of us are looking for that edge in composites that makes us more viable.
→ The complexity of composites processing is leaves room for efficiency savings all along the road to a finished product.



The Fruit Tree of Efficiency

Industry Drivers Calling for Efficiency

→ There are a lot of positive changes going on industry:

1. Fuel migration in Automotive spurring COPV technology for CHG and H2
2. Advancements in Aerospace pushing the search for new manufacturing techniques
3. Wider adoption of composites in general

→ New challenges as well:

1. Rising production and material costs.
2. COVID…

Composites Industry Overview

Challenges

01 **Regulations**

- Increasing compliance requirements due to the geopolitical situation
- Governments strict step towards economic and health measures due to COVID -19
- Sanctions, import/export regulations, embargo and tariff wars expansion (China, Russia, etc.)

02 **Markets**

- Markets are unpredictable due to COVID-19 factor and unstable oil prices
- Decrease in long-term investments and startups
- Development of new risk evaluation and mitigation strategies to address the current crisis and be better prepared in the future

03 **Companies**

- Supply and demand unpredictably changed*
- Develop new strategies to respond to the worldwide crisis
- Breakdown of entire locations and laid offs
- Shift to remote work
- Decrease number of people on a production
- Stuff qualification acceleration

04 **Supply Chain**

- COVID-19 drastically hit supply from China
- Overseas suppliers unpredictable
- Cost increase
- Delays in supply
  Lack of local suppliers
- Some supply routes don't work anymore
- Effects on customers, increased costs

05 **Operations**

- Social distancing pushes changes in operational practices
- Stuff absence risks due to COVID-19
- Implementation of automation and digital technologies through the entire business process

06 **Mobility**

- Travel bans and restrictions
- Commercial delivery industries remain slow
- Cancelation of industry shows
- Quarantines, effects on recreational activities
- Business interactions move to a virtual format

Drivers

Widespread automation and robotic technologies to minimize manual interventions*** & development of "intelligent flow"

Digitalization and technologies adoption across entire business and production process

Supply chains diversification across geographic reasons, develop local alternatives for resourcing and flexible logistic schemes

Flexible production to address fluctuated demand and "Boomerang effect" in demand**

Shift industrial supply from China to Asia, Mexico and local suppliers

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Customer Goals

→ What are the bosses looking for? Maximize profit! Gain a technological advantage.

→ Ongoing battle between managers and engineers. How do you increase profit, lower cost, and shorten timelines while maintaining safety, quality, and performance?

→ **In the end we want it all.**

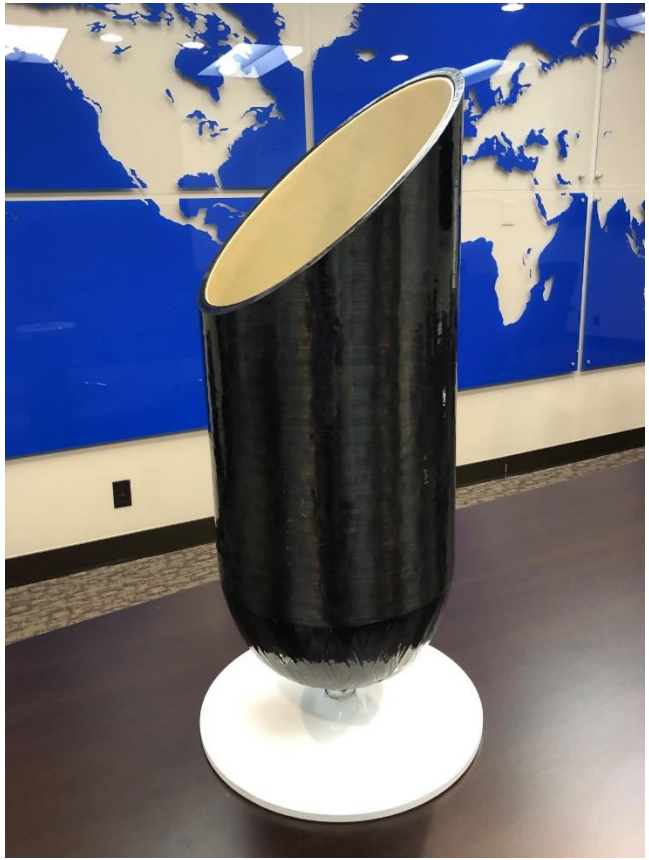
→ In the beginning we have an idea for a part.

Part Definition

→ We are assuming that the part is defined and a reasonable business model has been developed. We know roughly how much material will be in the part, how it will perform and how much it will cost.

→ For this presentation we are assuming axisymmetric parts.

→ We will reference a Type-4 pressure vessel moving forward (polymer liner with composite overwrap).



Part Definition Example

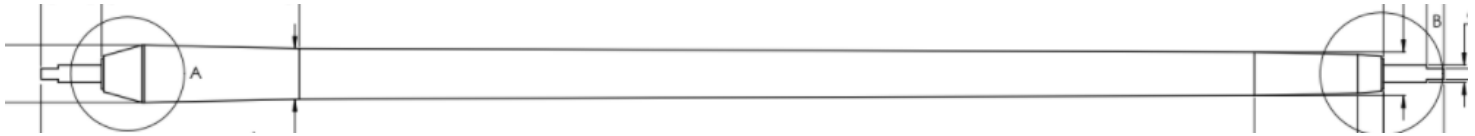
→ Customer was in early stages of development process and was purchasing a mandrel for a large tapered part.

→ Customer selected steel over aluminum mandrels to save a few pennies and had difficulties extracting, which ended up costing a lot of time and money.

→ Extending beyond this example, every part has tooling that needs to be carefully considered.

→ Low Hanging Fruit: Consult a Pro! Material Supplier? Consultants? Company already winding similar parts?

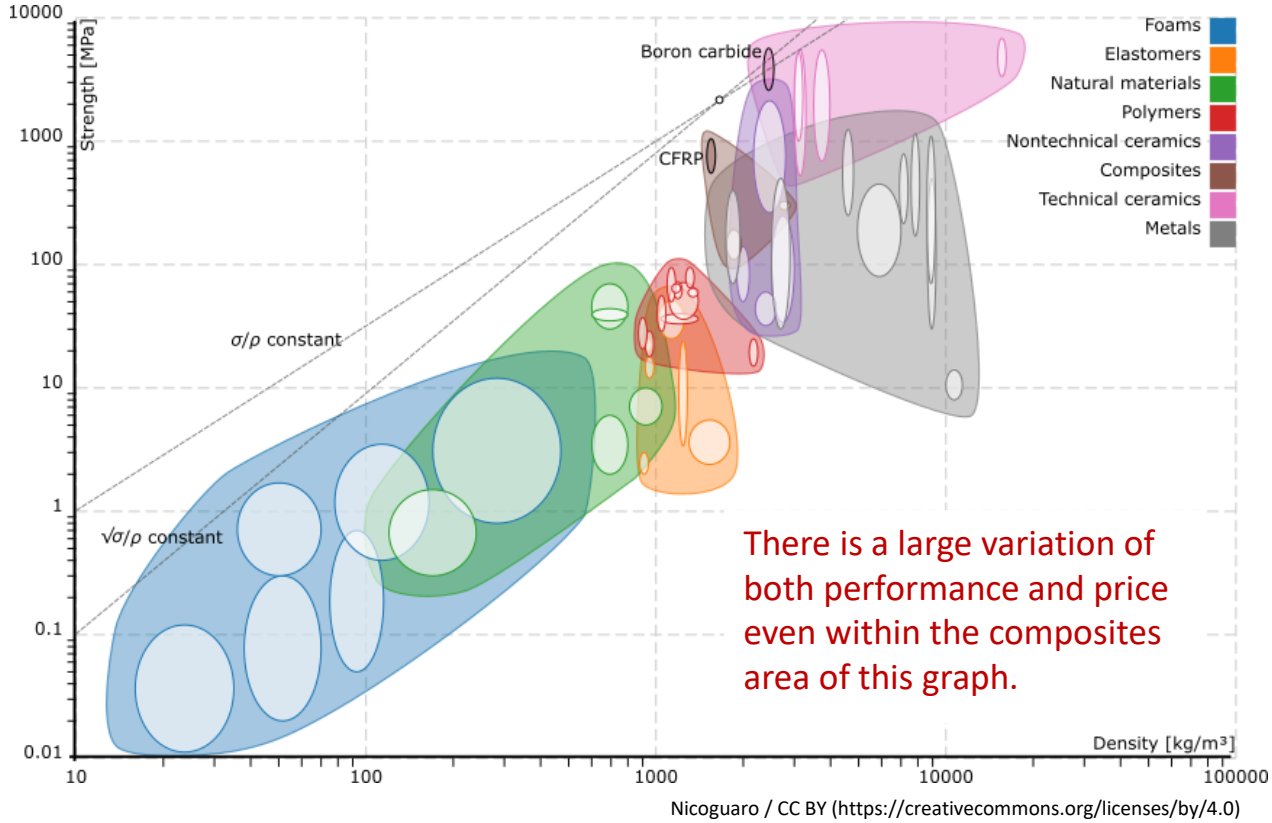
With type 4 tanks specifically, the liner design can have as critical a role as the composite itself in the performance of the final part.



Material Selection

→ Material selection is highly driven by product specifications and desired properties.

→ This is a composites webinar, we know we'll be settling on composite materials but there are still many considerations that affect efficiency.



There is a large variation of both performance and price even within the composites area of this graph.

Fiber Selection Considerations

→ It's not enough to look at a spec sheet.

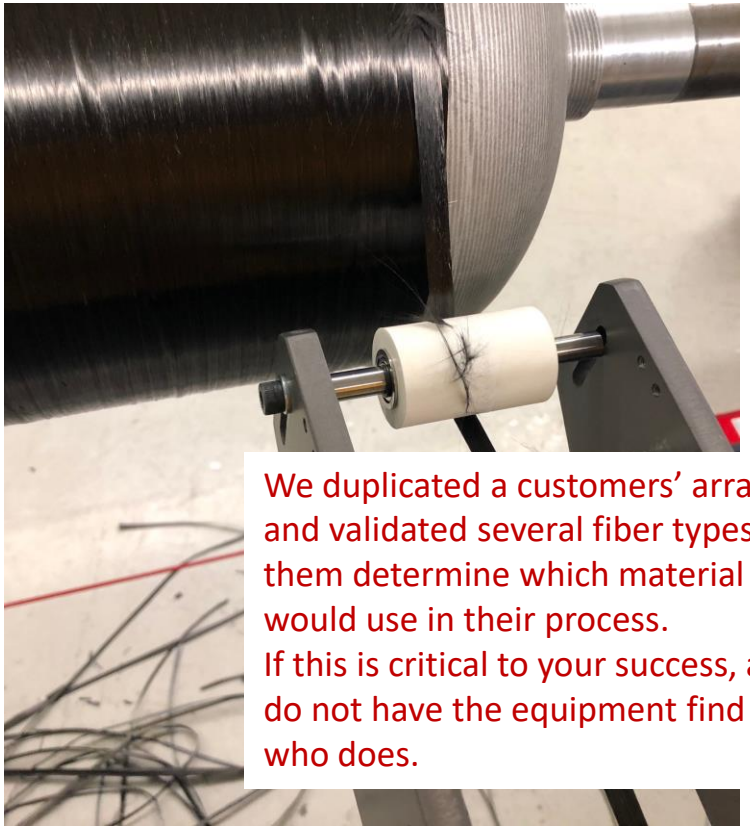
→ Get strength variation data by lot from the supplier. The lower the variation, the lower your design knock downs, the lower your part weight, the higher your efficiency.

→ Get samples and run them in a similar arrangement to your process.

→ If you can afford it make a prototype and close the design loop, do so.

FW typically utilized Fiber Glass and Carbon Fiber, however Basalt Fibers are becoming more popular.

Fiber Selection – Winding Trials



We duplicated a customers' arrangement and validated several fiber types to help them determine which material they would use in their process.
If this is critical to your success, and if you do not have the equipment find someone who does.

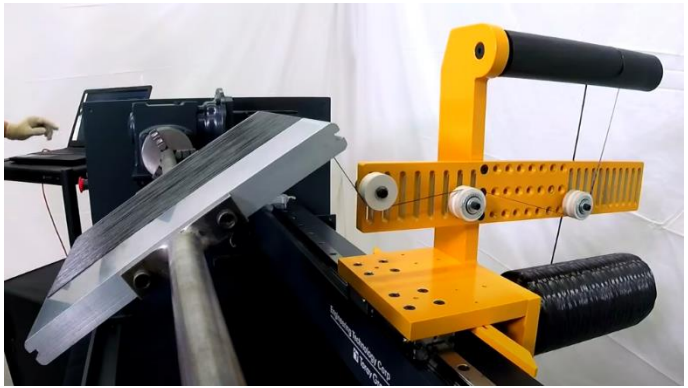
Resin Selection Considerations

→ Resin storage, preparation and mixing processes should all be carefully considered.

→ How well does it clean up, what solvents are required. Environmental Regulations? What PPE is required?

→ Cure time and method are probably the most impactful on your process.

→ Surface treatment, sizing, and resin compatibility are all big factors. **Get a sample and do mechanical testing of both laminate and neat samples**.



Lab Winder Link
https://www.youtube.com/watch?v=w3aDKmCReHg

Wet Winding vs Towpreg

→ During wet winding, fiber speed is limited by the time it takes for the resin to soak into the fiber and the ease of the resin to come back out during winding.

→ Towpreg is an uncured resin filled composite tow that eliminates the need for a resin bath.

→ The resin is pre-applied and has a much higher viscosity than wet winding which allows for higher speeds.

Wet Winding vs Towpreg

Wet Winding

Pros:

Low cost, widely available, resin content control, flexible

Cons:

Clean up, lower winding speeds, resin content control, onsite resin mixing and storage

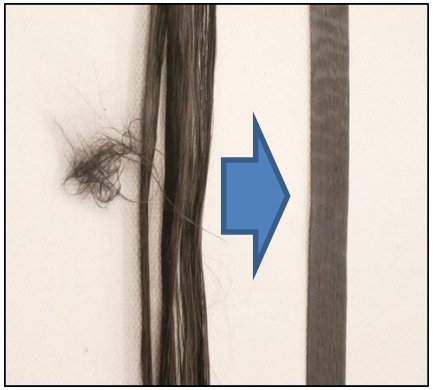
Towpreg

Pros:

Little clean up, high winding speeds, low variability, no onsite resin mixing or storage

Cons:

Higher cost, lower flexibility (cannot change width or resin type), more complicated fiber path



The claims made here are based upon personal experience; manufacturing, marketing, developing business models for, and winding with towpreg. Our suggestion to anyone is to work with suppliers and look at your process as a whole to see if towpreg works for your business.

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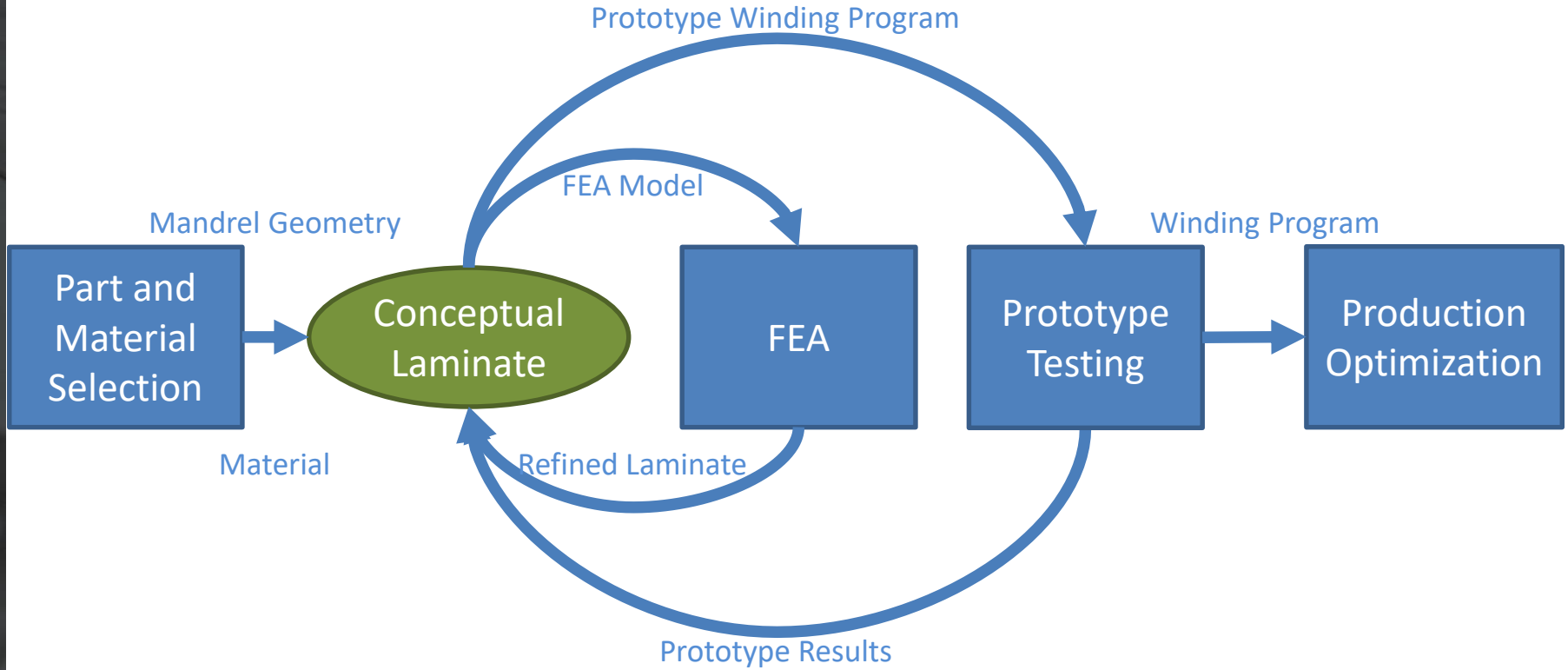
Part Design



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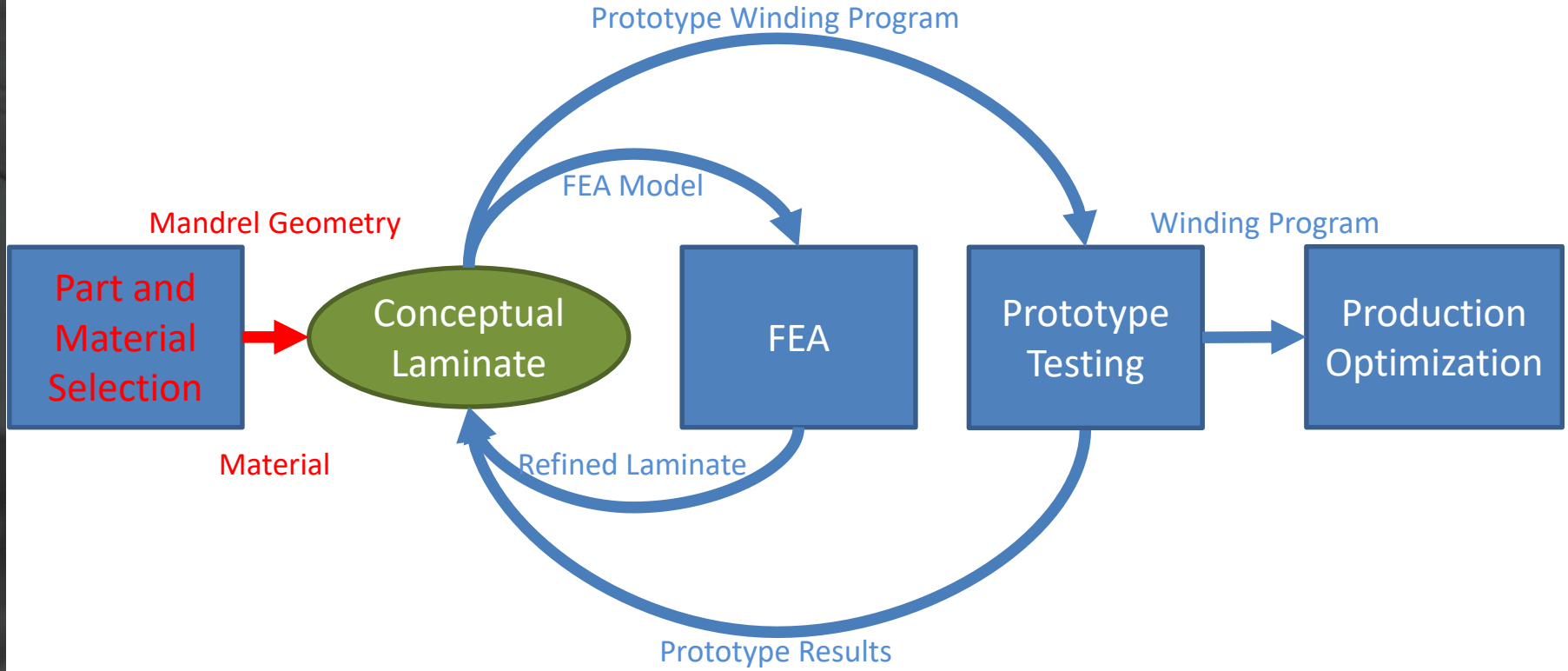

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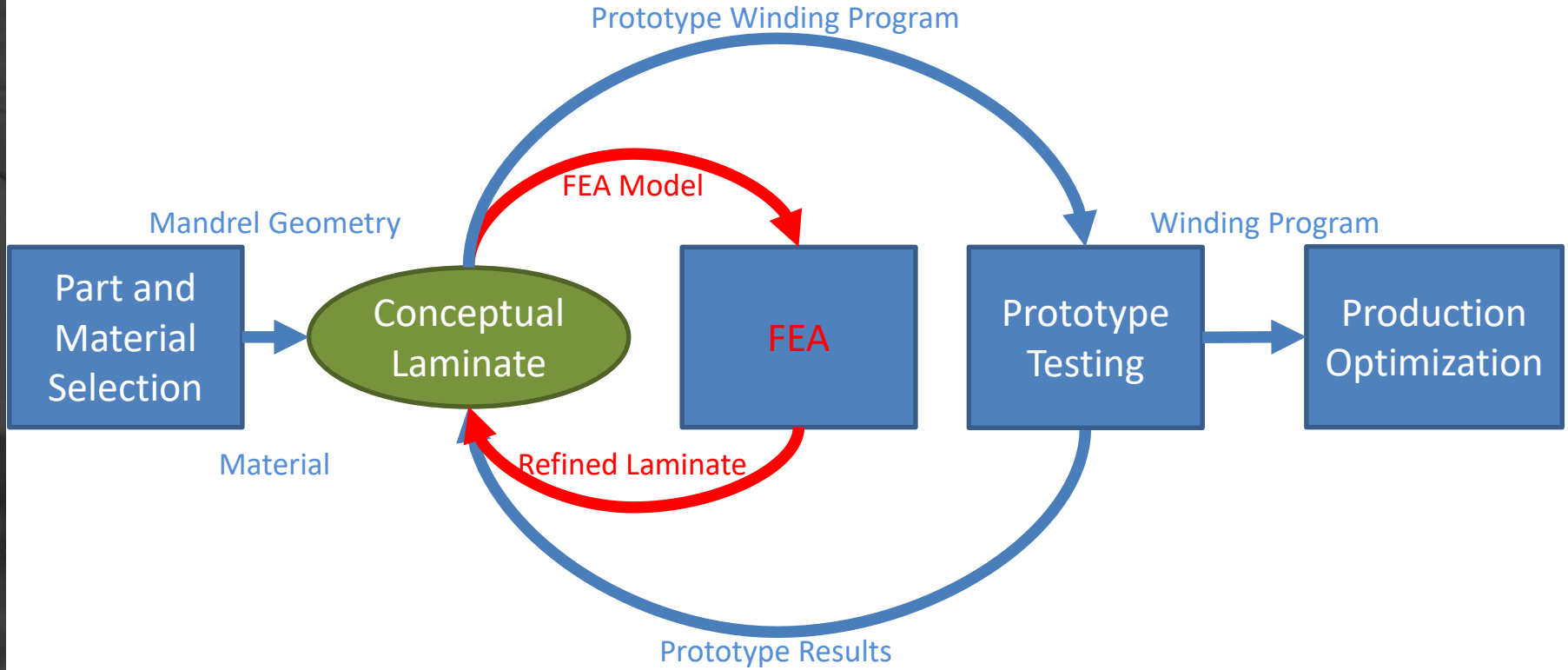
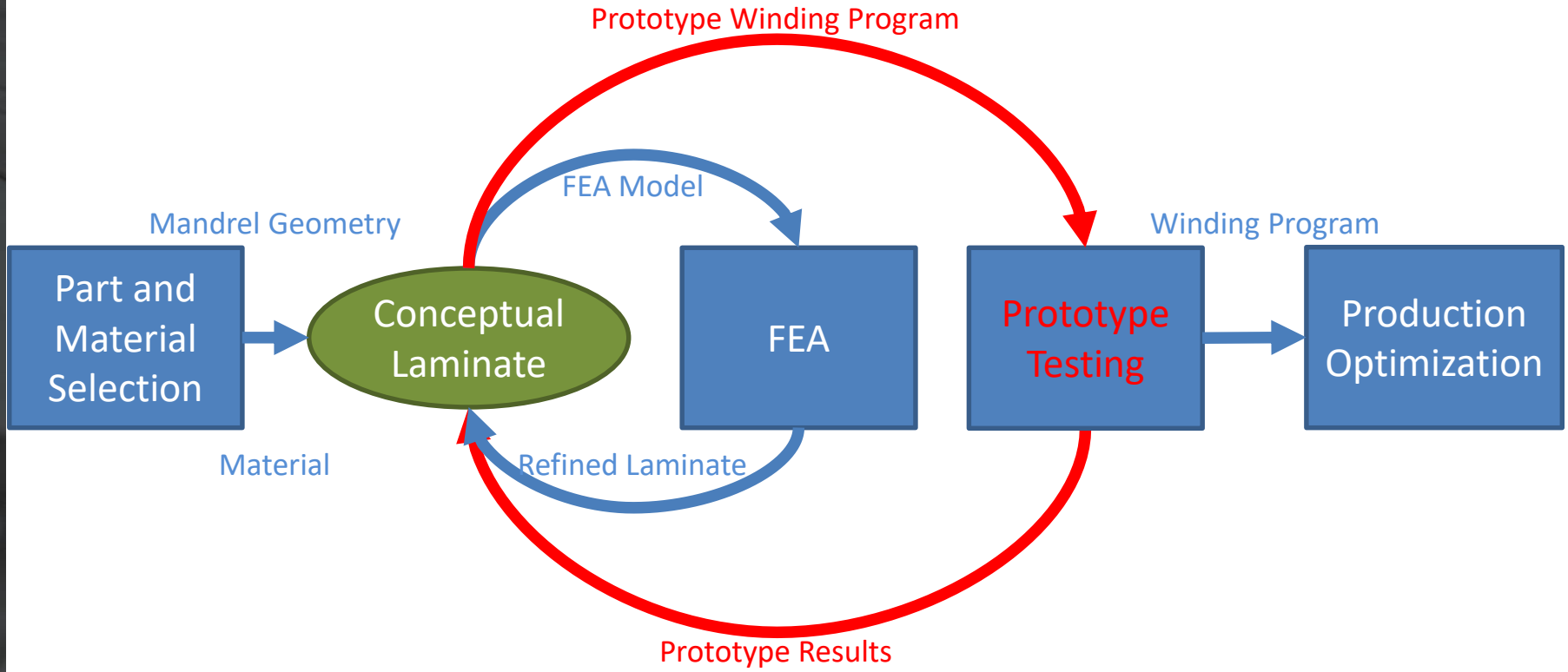
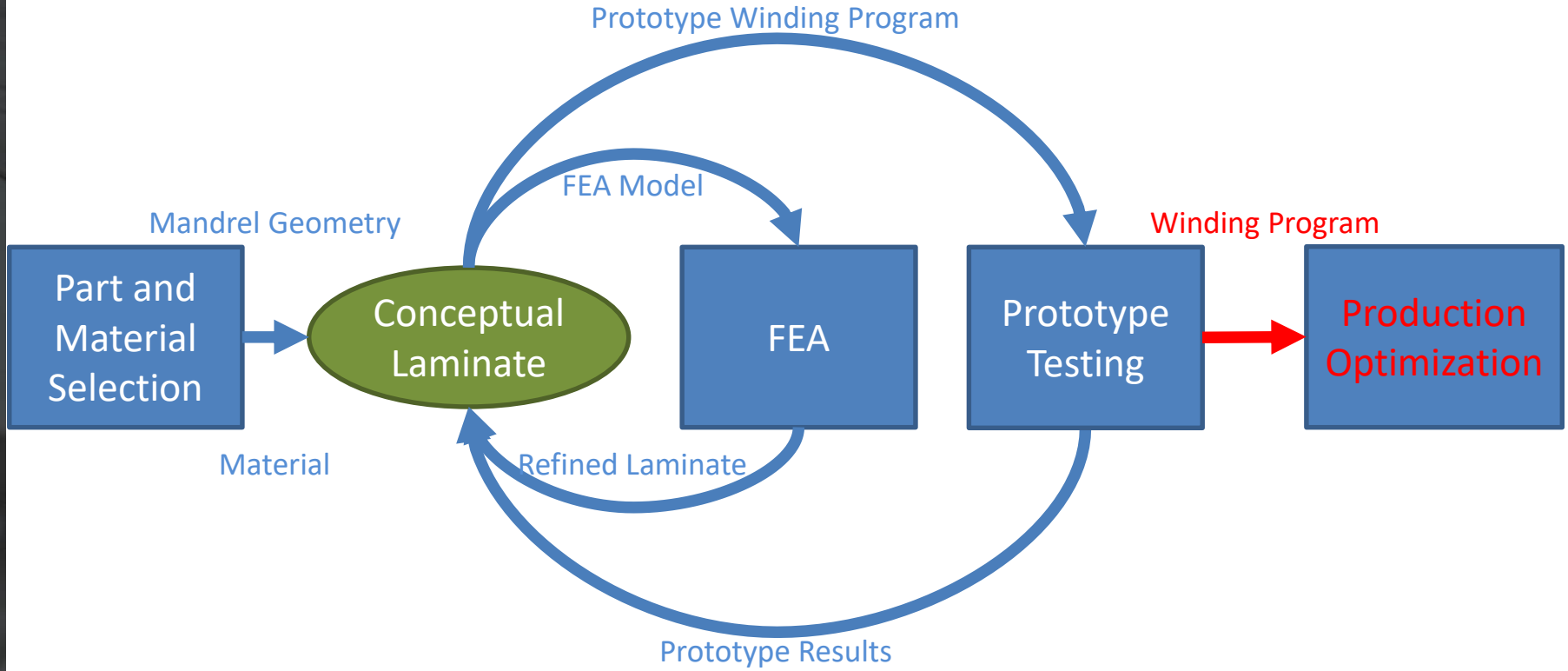


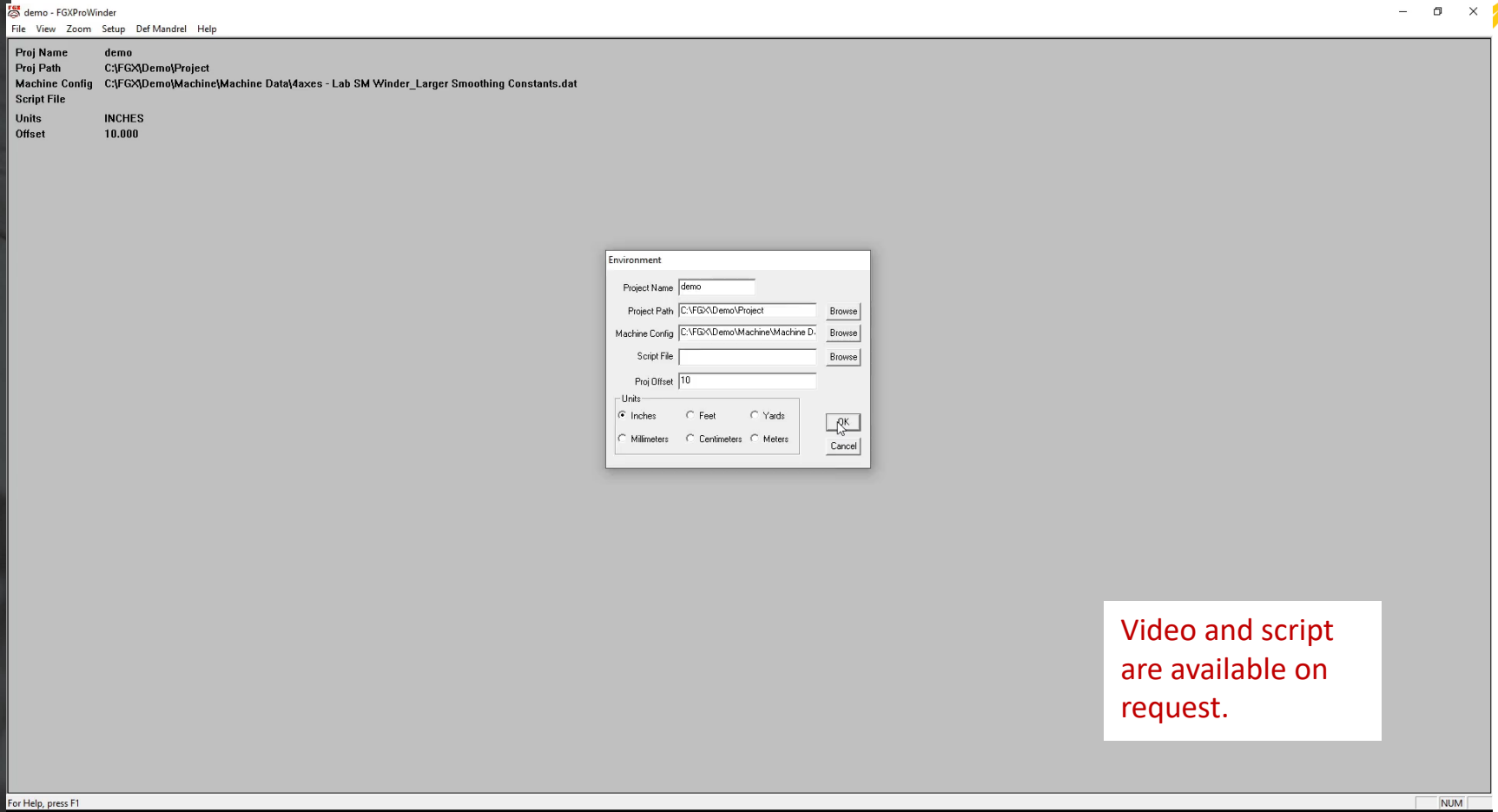
Part Design



Part Design



FiberGraFiX: Streamlining the Design Process



Video and script are available on request.

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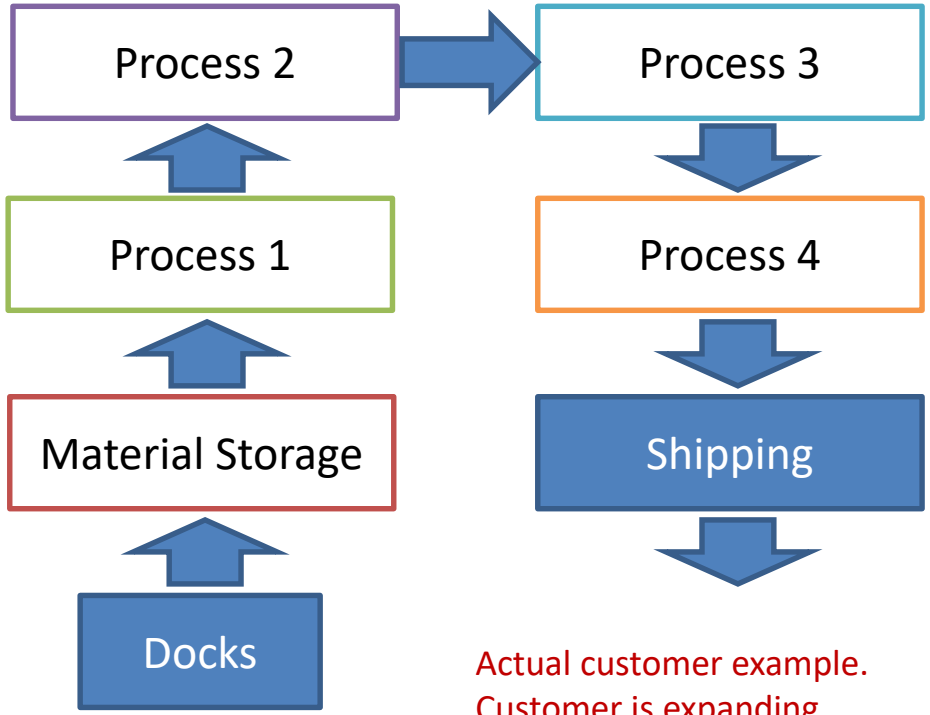
Process Layout

→ We've seen every layout under the sun: some are good, some are bad.

→ This can be low hanging fruit if you're starting from scratch.

→ It can also be high fruit if you're adapting a process to existing equipment.

→ Process should be one-way street.

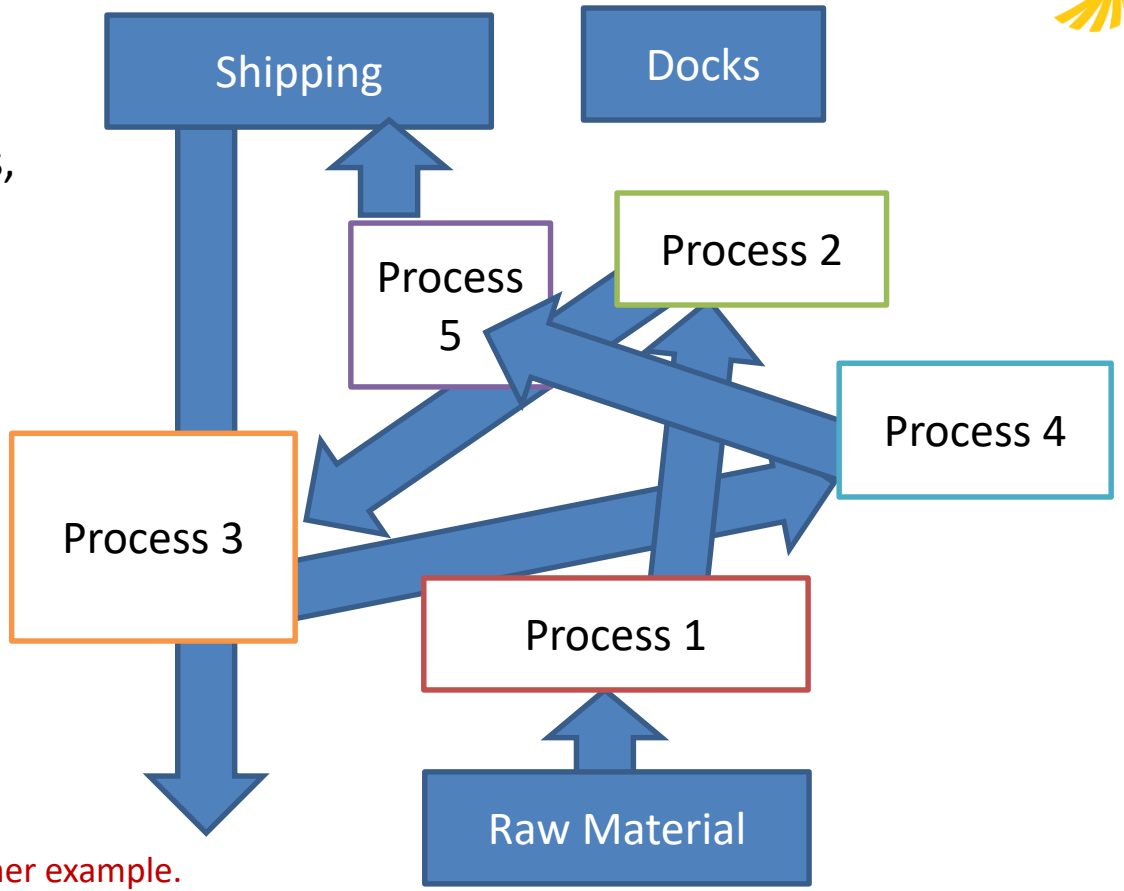


Actual customer example.
Customer is expanding.

Process Layout

→ Despite the seeming simplicity of layout benefits, this is often seen.

→ Only efficiency suggestion is where to put the traffic signal.



Actual customer example.
Customer is out of business.

Machine Selection – Wide Range of Parts

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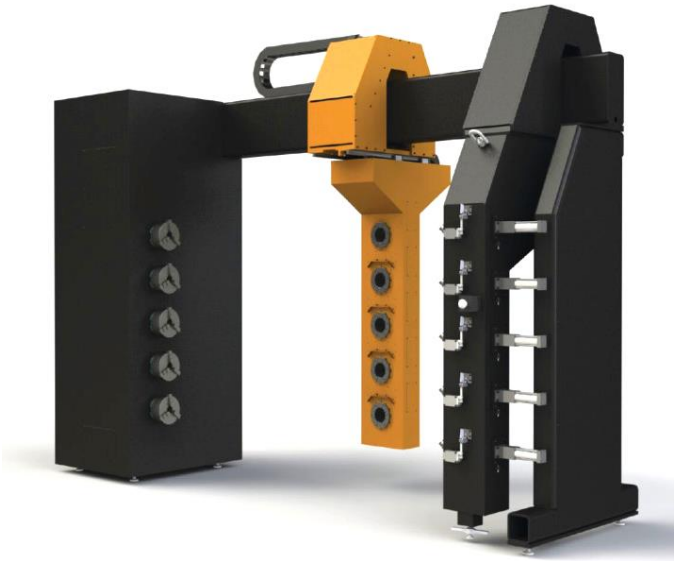
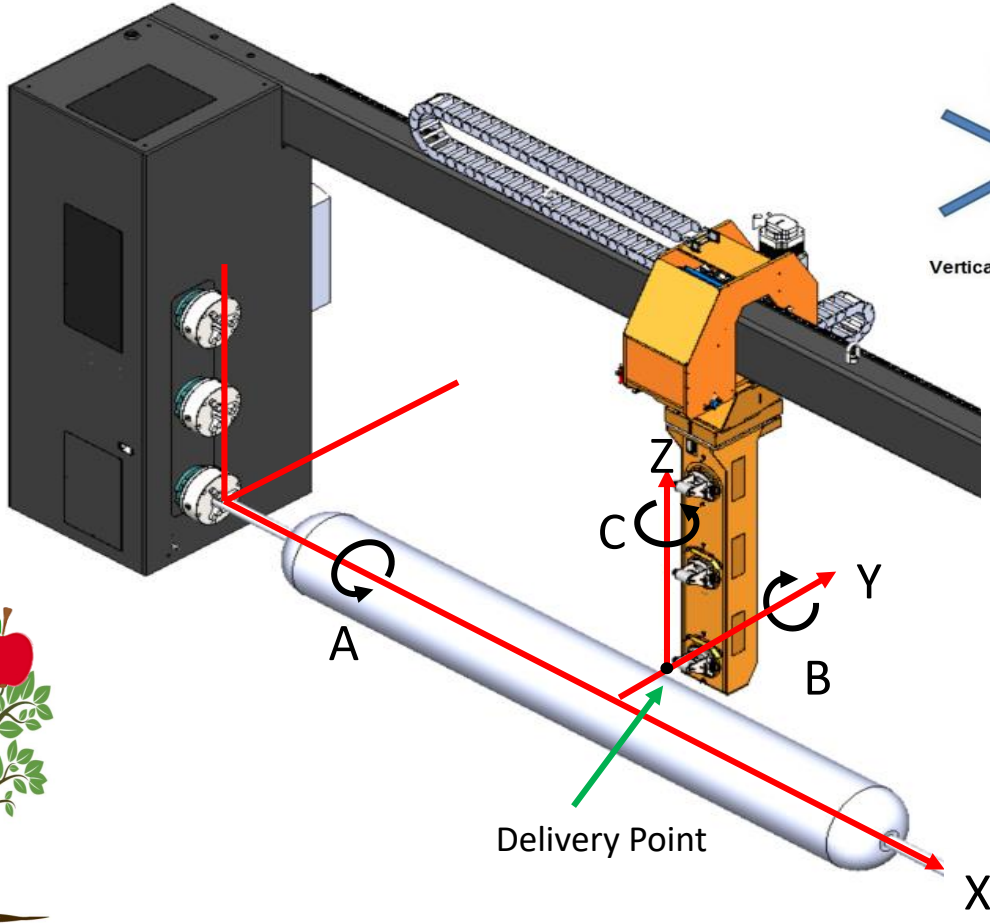
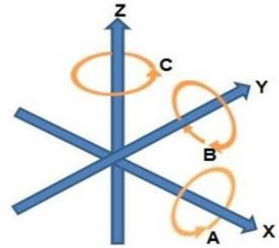
Machine Selection – Wide Range of Machines

Machine Selection – Wide Range of Machines



Machine Selection – Selection of Axes





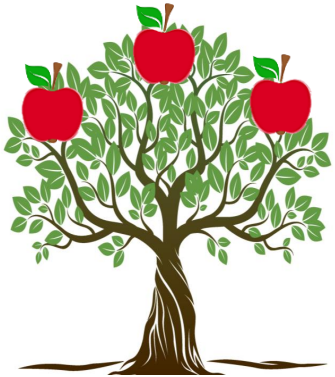
Vertical Machining Center (VMC)

C axis

=

YAW

=



A and X are most common, used for simple tubes.
B and Y come into play for parts with changing cross sections.
C comes into play with technical domes and the need for very flat bands.
Z is rare.

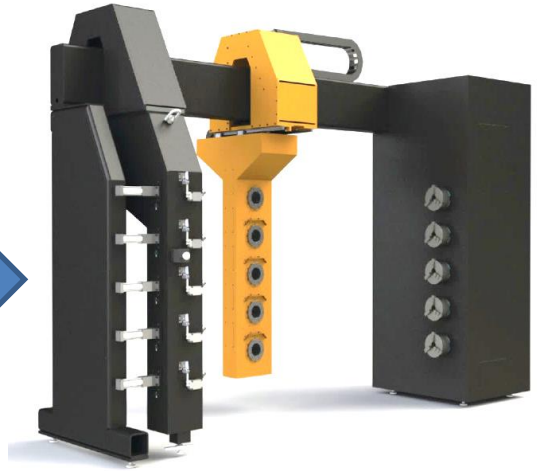
Machine Selection – Basic Process Improvements

→ Utilize servos with closed loop feedback

→ Minimize contact points

→ Drums provide better resin regulation over dip

→ Eliminate and run towpreg



→ Add spindles

→ Upsize motors

→ Increase tow count

→ Smooth patterns

Machine Selection – Throughput vs Flexibility

→ The majority of our customers are interested in making one type of part and making it well.

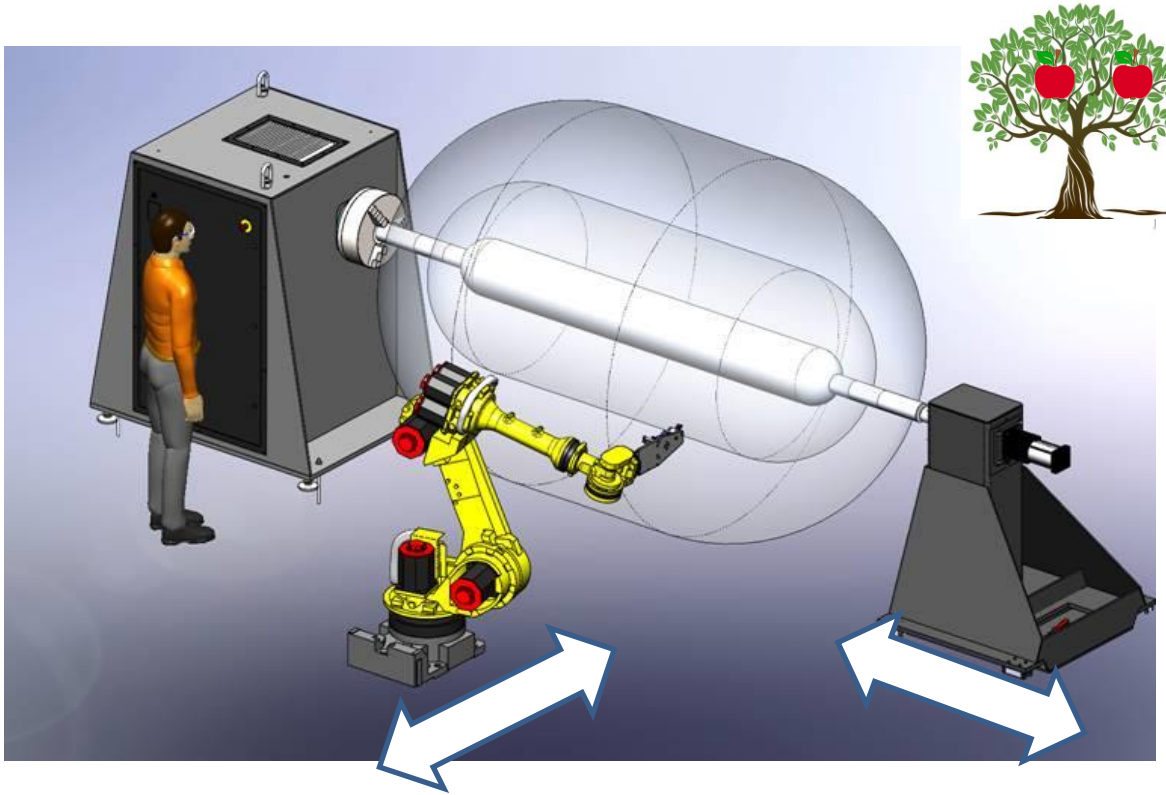
→ This lends to multi spindle machines running parts simultaneously.

→ A traditional Filament Winding machine lends itself to this type of high-volume production.

Machine Selection – Throughput vs Flexibility

→ Some Filament Winding companies are interested in prototyping and job-shop work. Traditional Winders are not very flexible in these types of applications.

→ Robotic winders have the ability to run several types of materials on many mandrel sizes.



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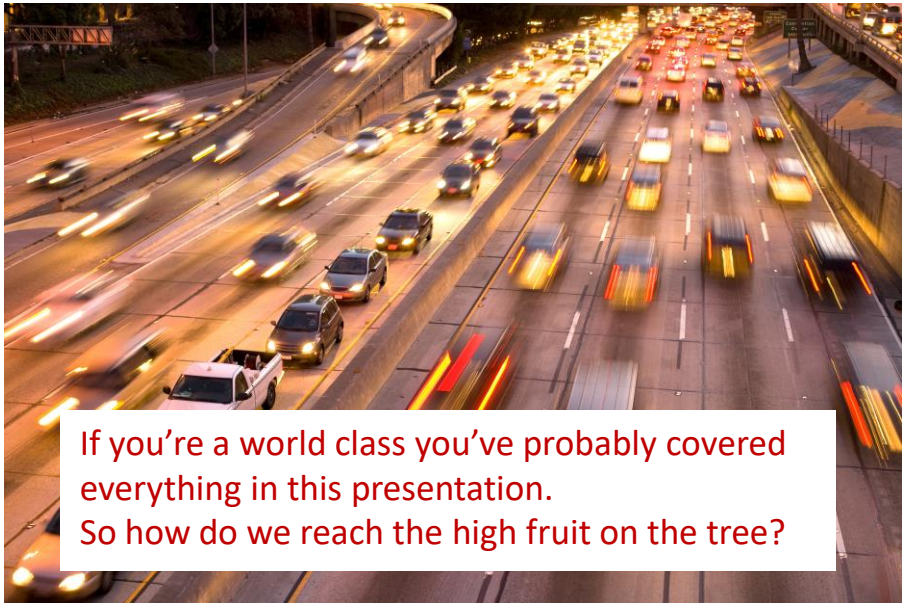
What's Next with Filament Winding

→ The automotive industry and the global shift toward CNG and FC vehicles has spurred many advancements in composites.

→ The four main topics of conversation seem to be as follows:

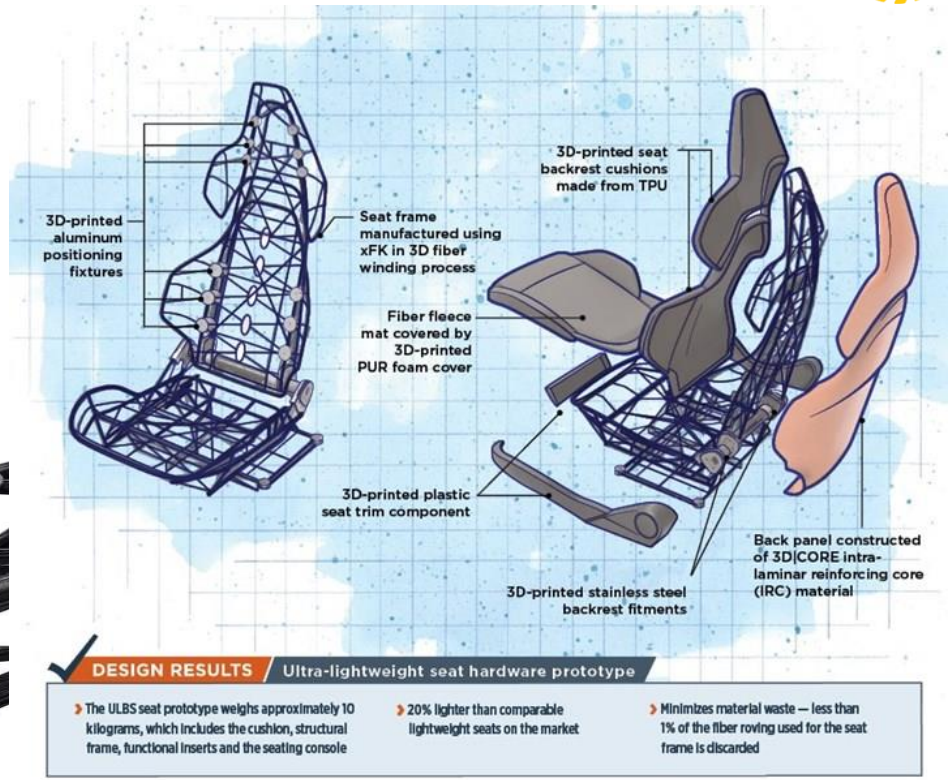
1. Structural Components
2. Work Cell Automation
3. High Speed Winding
4. What is beyond filament winding?



Winding Structural Components

→ Robotic winding also allows for non-axisymmetric part creation.

→ This opens many new doors for composites within the automotive industry and aerospace industries.



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CompositesWorld (2019, February 12).
Retrieved from https://www.compositesworld.com/articles/3d-filament-winding-enables-vehicle-seating-concept

Work Cell Automation

→ Material Conveyance

→ Material Inspection

→ Mandrel Prep

→ Mandrel Loading

→ Auto-tie-on-cut-off

→ Part Unloading

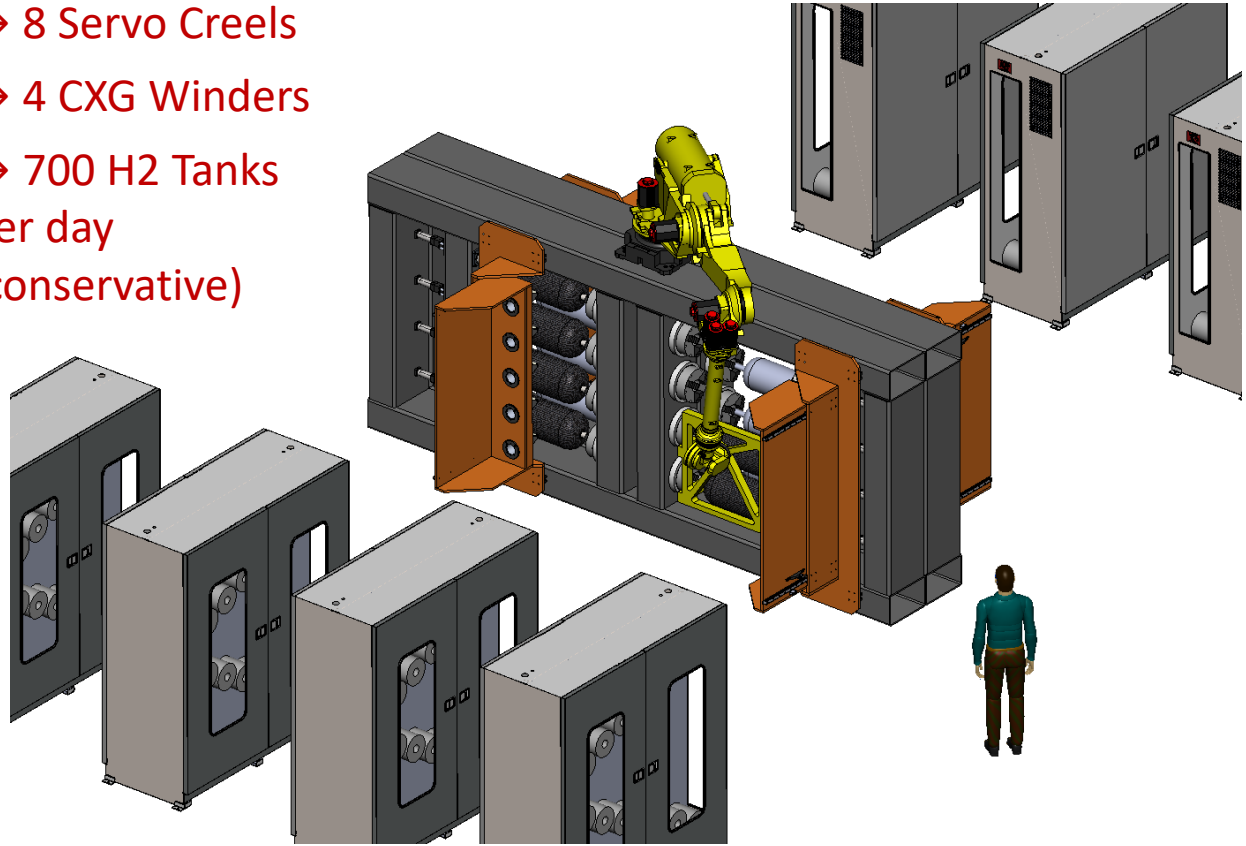
→ Part Curing

→ Part Inspection

→ 8 Servo Creels

→ 4 CXG Winders

→ 700 H2 Tanks per day (conservative)



Fastest Filament Winding Machine

In 2019 several of our customers were asking for efficiency in the form of a fast machine. All seemed to want 5 meters per second.

Fast Filament Winding

→ What is the fastest filament winding machine? 5m/s???

→ Yes, 5m/s on hoops. All machines slow down to around 2m/s on the helical winds.

→ Limitations like: motor performance, material packaging, tensioner capability, and safety are limiting factors.

→ Should we be looking at a linear fiber payout speed as a measure of efficiency?

→ **No** we should be looking at Parts/time/dollar. (and every consideration above this slide)

CXG

What's Beyond Filament Winding?

→ What's next? Collaboration. It will be the growth of our composites community that is going to increase composite adoption, and drive process and equipment improvements.

→ An auto manufacturer and a material supplier have proven this with a 10% reduction in COPV weight.

→ ETC is excited to lend our expertise and resources to the conversation.

ENGINEERING TECHNOLOGY CORP.

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Thank You!

Any Questions?

B Jay Larson

Mel Singh

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