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# Design and Cost Drivers in 2-D Braiding

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## ABSTRACT

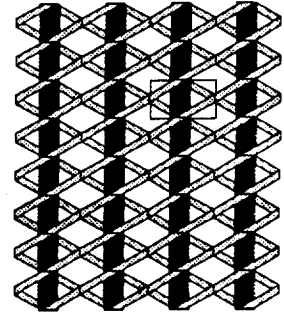
Fundamentally, the braiding process is a highly efficient, low cost method for combining single yarns into circumferential shapes, as evidenced by the number of applications for continuous sleeving. However, this braiding approach cannot fully demonstrate that it can drastically reduce the cost of complex shape structural preforms.

In this paper factors such as part geometry, machine design and configuration, materials used, and operating parameters are described as key cost drivers and what is needed to minimize their effect on elevating the cost of structural braided preforms.

# Introduction

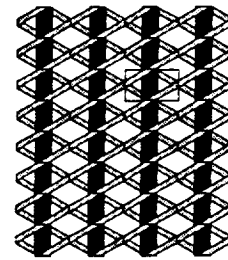
- **2-D Braiding is viewed as a highly efficient, low cost method for combining single yarns into circumferential shapes. i.e. continuous sleeving.**
- **This cost effectiveness prompted the use of braiding beyond continuous sleeving into complex shape structural preforms.**
- **However, the braiding approach cannot fully demonstrate that it can drastically reduce the cost of complex shape structural preforms.**
- **There are several factors why the cost effectiveness of 2-D braiding is not fully seen in structural preforms.**
- **Among these factors there are:**
  - **Low production quantities of preforms**
  - **Stiff, brittle fiber materials that are hard to braid**
  - **Stringent quality control requirements**
  - ***Fiber Architecture***
- **The first three factors are specific to each application and usually there is very little that can be done to minimize their effect on cost.**
- **Fiber architecture is a cost driver that is often overlooked.**

# What is fiber architecture?



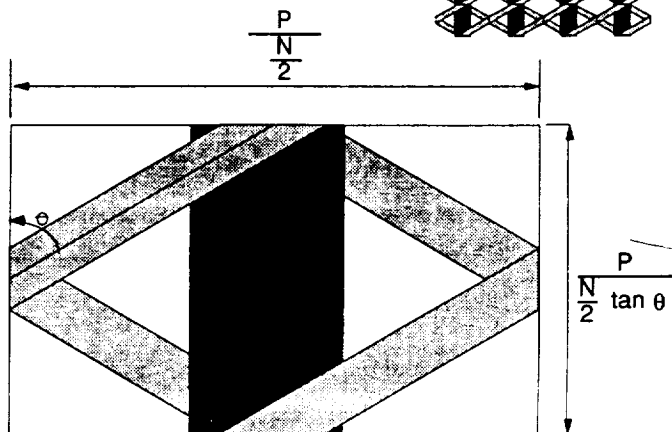
- **Fiber architecture is a graphical and numerical means by which a textile structure is described.**
- **This description must have sufficient elements to satisfy the needs of composite designers and textile engineers.**

## Braid Architecture



The braid architecture is defined by five elements:

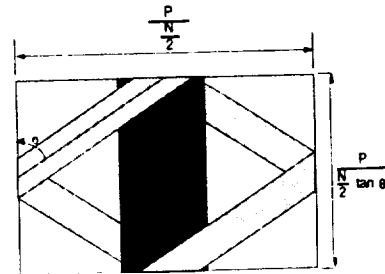
- 1) **Number of Carriers - N**
- 2) **Perimeter of the Part - P**
- 3) **Braid Angle -  $\theta$**
- 4) **Braid Yarn Yield**
- 5) **0° Yarn Yield**



**P = Perimeter of the part**

**N = Number of braider carriers**

# Braid Architecture



$P$  = Perimeter of the part  
 $N$  = Number of braider carriers

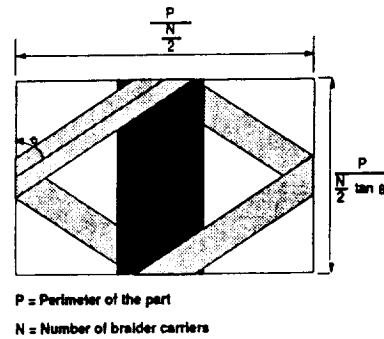
## Number of Carriers - $N$

- The number of carriers will influence the size of the braid unit cell.
- The more carriers used, the smaller the unit cell.
- A small unit cell translates into a more uniform fabric with greater coverage.

## Braid Angle

- The braid angle affects the size of the unit cell.
- The larger the braid angle the smaller the unit cell.
- A small unit cell means greater coverage and uniformity.

# Braid Architecture



## Perimeter of the Part

- 2-D braiding is unique in that braid unit cell is intimately linked to the perimeter of the part.
- A larger perimeter means a larger unit cell with less coverage.

## Axial Yarn Yield and Braid Yarn Yield

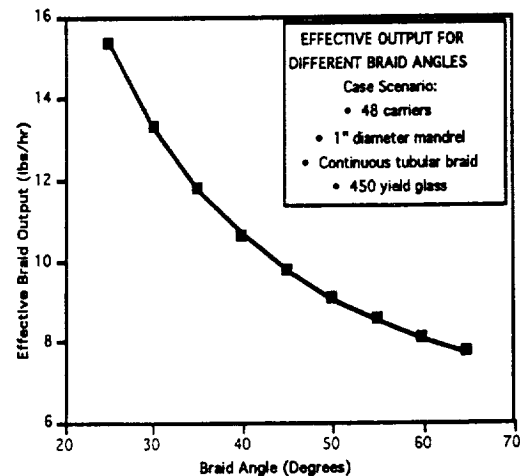
- The size of the yarns will not influence the size of the unit cell, but how well the unit cell is covered.
- Using fine yarns will leave a more open area than if using larger size tows.

# Effect of Braid Architecture on Cost

- Each component that defines the braid architecture has a direct effect on the time that it takes to braid the part.
- Depending on what parameter is changed
  - the braiding time varies or
  - the number of times the machine needs to be re-spooled changes.

## Effect of Braid Angle

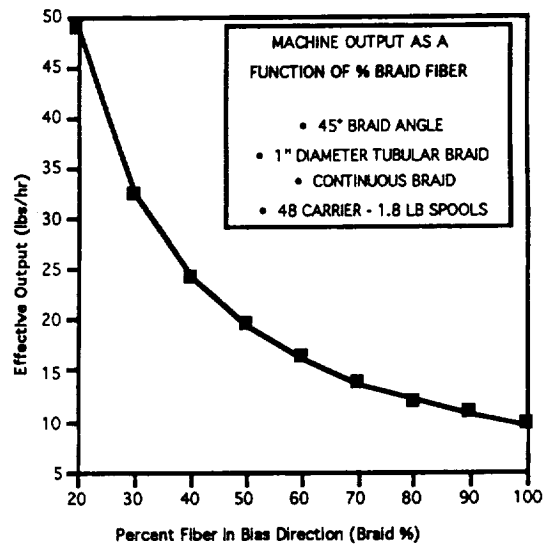
- The braid angle will determine the ratio of braider RPM and take-up speed.
- For a specific length of the part, a braiding machine takes longer to braid a large braid angle than a smaller one.
- The output in effective lbs/hr will be greater on a small braid angle.



*Note: Effective braid output takes into account the time that the machine is down for re-spooling.*

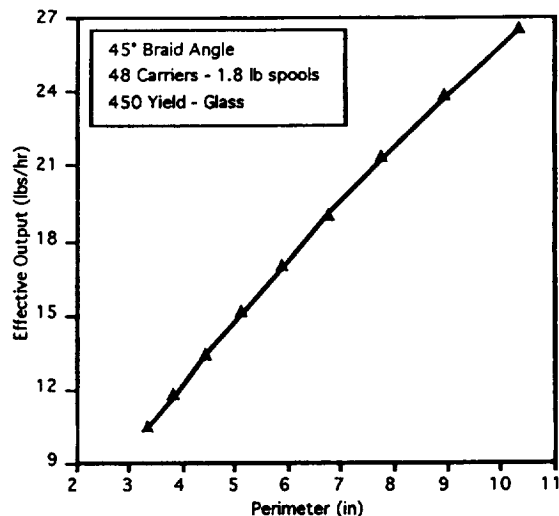
# Effect of Yarn Yield

- The 0° fiber is introduced into the braid from a stationary creel; therefore, very large spool packages (5 lbs) can be used in the 0° creel.
- The braider spools can only carry 0.25 - 1 lb of material.
- A higher percentage of fiber in the 0° axis will exhibit a higher output in lbs/hr, since the machine will yield more lbs of material before it needs to be stopped for re-spooling.



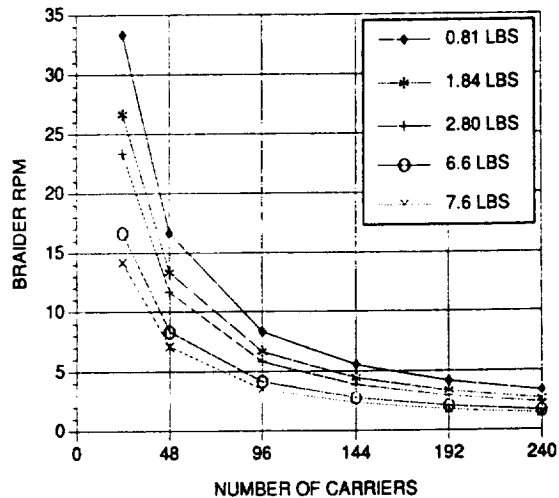
# Effect of Part Perimeter

- A smaller perimeter part will take longer to braid than a larger one.
- The braider has to make more revolutions to cover the same length.
- The coverage of the part has to be taken into account since a larger perimeter part will have less coverage.



# Effect of Number and Size of Carriers

- Intuitively, one would like to use a braider with the highest number of carriers capable of carrying the most material.
- This intuition is erroneous since the braider RPM is not taken into account.
- When the number of carriers increases so that the distance they have to travel to complete a revolution.
- The size of the carriers will also affect the RPM of the braider; larger carriers will slow down the machine.



## Summary

1. **Effect of Braid Angle** - A larger braid angle takes longer to braid than a smaller one.
  2. **Effect of Yarn Yield** - Having a higher percentage of 0° yarns will yield higher lbs/hr.
  3. **Effect of Part Perimeter** - A smaller perimeter takes longer to braid than a larger one.
  4. **Effect of Number and Size of Carriers** - Larger number of braiders and larger carriers will slow down the braiding machine.
- **ALWAYS** estimate the coverage of the part in order to establish how uniform a part you will have, or if the braid architecture is realistic (no jamming of tows).



# Conclusions

- **There are several factors that affect the cost of braided preforms.**
- **Most of the factors are inherent to their load bearing, structural applications.**
- **However, fiber architecture is a factor that we control during the design of the part.**
- **It is essential to understand each element of the braid architecture both from a performance and cost point of view in order to maximize the cost effectiveness of braiding.**

