

# Advancement in Wind Turbine Blade Technology

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Organisers



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# సుస్వాగతము



# Overview of the topics

- Introduction
- Wind Turbine Rotor Blade
  - Concept
  - Configuration
- Advancement in Wind Turbine Rotor Blade Technology
  - Concept to Reality
  - Design
  - Materials
  - Manufacturing Methodology
- Challenges
- Future Development
- Business Opportunities



# INTRODUCTION



# Introduction

- Wind power is being used, for at least 5,500 years ago to propel sailboats and sailing ships.
- Today, Wind power is the fast growing source of clean, renewable energy. The key to harvesting this energy is the wind turbine and the advancements in technology that have been made. Wind turbines use the rotor blades to turn the kinetic energy of the wind into electrical energy that can be used to power the world.
- Rotor blades are the main part of wind turbine for Power Production. Improving the performance of the rotor is considered a very promising way to reduce the cost of energy from wind.
- Currently, most rotor blades in the market are built from glassfiber-reinforced-plastic (GRP). Other materials that have been tried include wood and carbon filament-reinforced-plastic (CFRP). Replacing the Hand Lay-up method, Vacuum Assisted Resin Infusion Moulding (VARIM) has now become the most widely used technique in blade manufacturing, irrespective of the resin system in use.
- The bigger multi megawatt wind turbines, are required blades, which are advanced aerodynamic and structural designs, new or optimized materials as well as cost-effective manufacturing technologies used.

# WIND TURBINE BLADE



# Wind Turbine Blade - Concept

Interface between the raw mechanical force of wind and the mechanism that translates this force into electricity

Converts Wind force into mechanical torque

Two main areas in Blade Configuration:  
Root area & Aerodynamic area

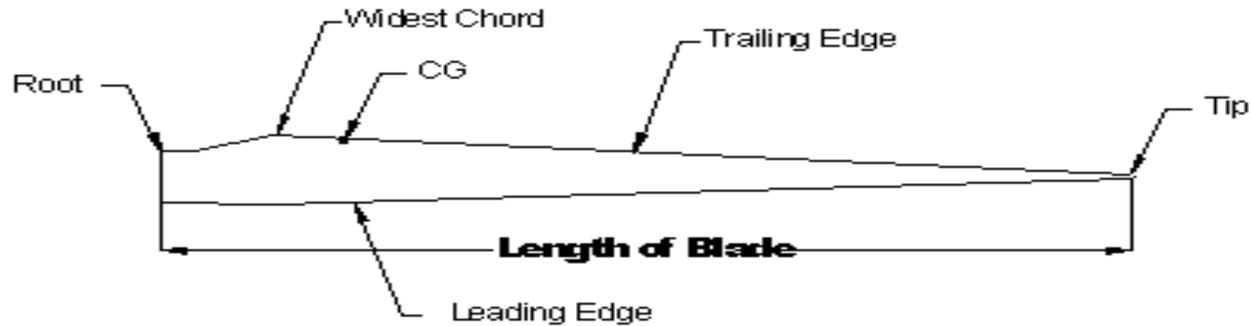
Aerodynamic area : Responsible for power production

Root area : Joins the aerodynamic portion to the Turbine

Airfoil sections are very critical for Power Production



# Configuration - Terminology

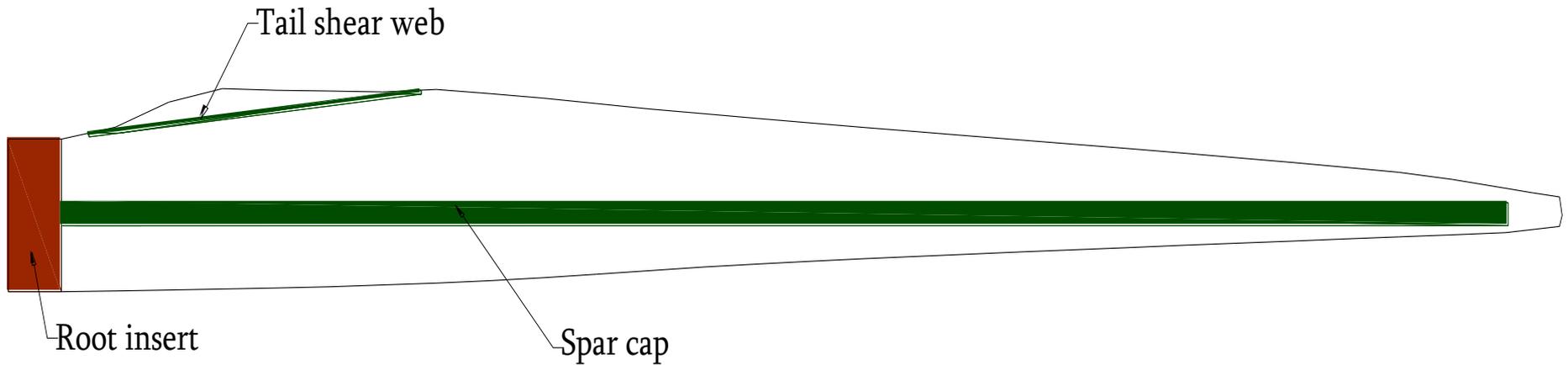


The Root End of the rotor blade is cylindrical in shape, fixed with Studs in a précised PCD to enable it to get connected to the Rotor Hub. The profile of the Tip is of very much importance because, it is main part for the turbine power production.

The Largest linear distance between the trailing and leading edge of the blade and which normally holds the CG point of the Rotor Blade is Widest Chord

The edge which leads the Rotor Blade revolution and is also the first point where the wind attacks the blade is called Leading Edge / Nose side of a Rotor Blade. The edge, which follows the Leading edge is called Trailing Edge / Tail side. Thickness of the blade in the Trailing edge area is of very thin and should be very precise.

# Configuration - Load Carrying Mediums



## Root Insert:

- The root insert is placed in the Root part of the rotor blade, which is a prefabricated FRP part.
- This takes care of the entire torsion load acting on the Root area during the blade rotation.

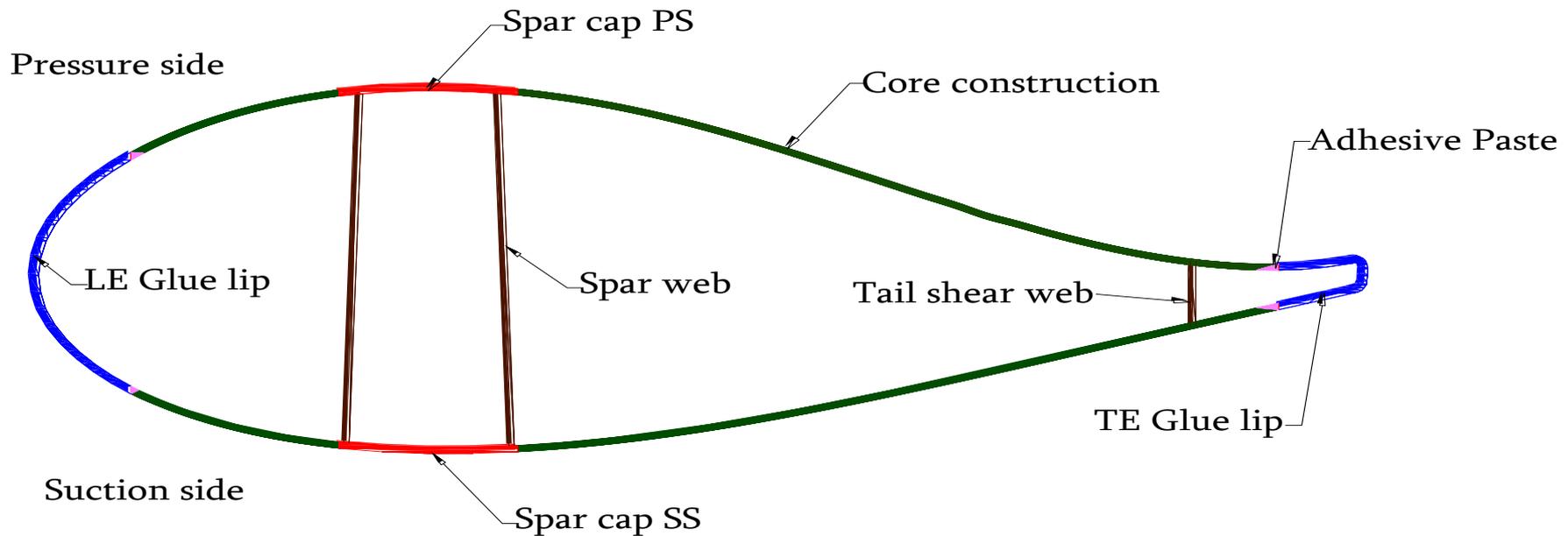
## Spar Cap:

- The Spar cap serves as the Spinal Cord of the rotor blade.
- It is placed along the central axis of the blade on both the shells and acts as back bone of the Blade.

# Configuration - Load Carrying Mediums

## Main Spar Web (MSW):

The Main Spar web acts as a Stiffener between the two half shells of the rotor blade, additionally, it joins the two halves of the blade. This can be seen along the center axis, for almost 85 % of the length of the rotor blade.



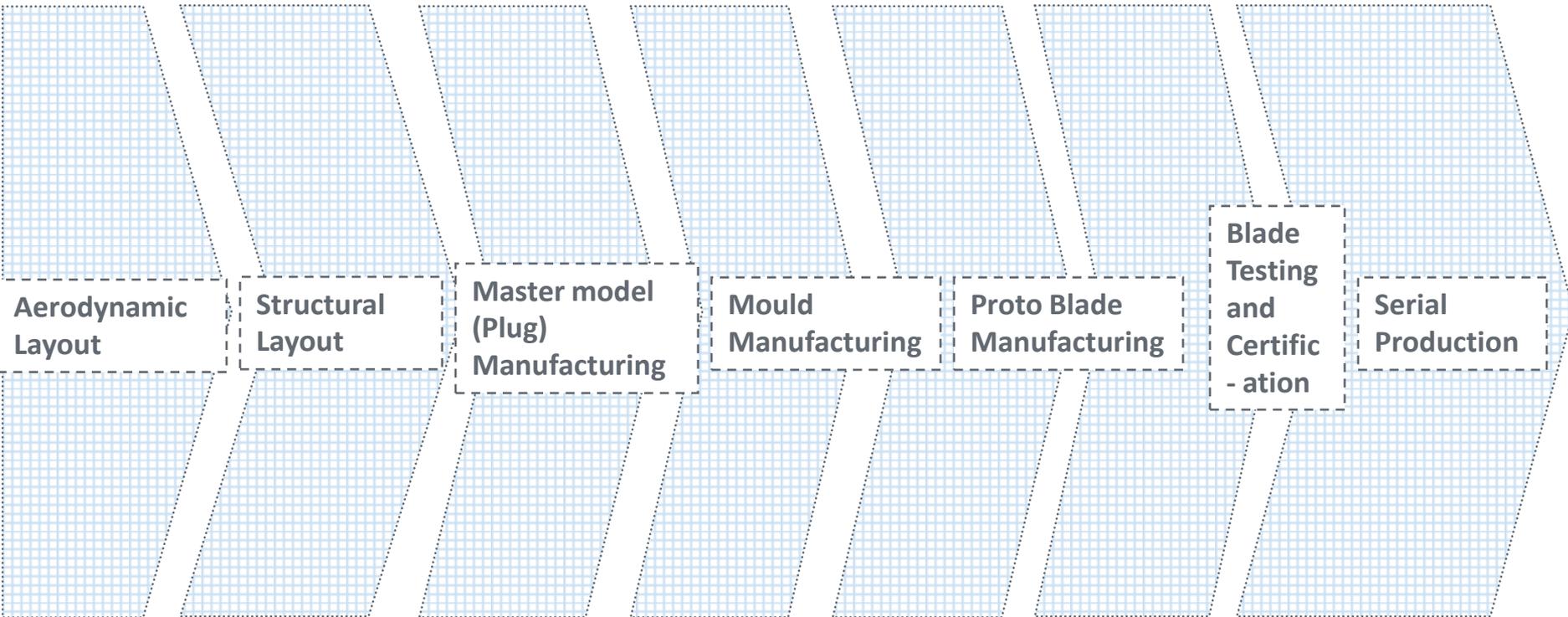
## Tail Spar Web (TSW):

The Tail Spar web serves the same purpose as the MSW the only difference being that it takes care of the buckling strength in the widest chord area of the rotor blade.

A photograph of a wind turbine in a field of rolling hills under a bright sun in a clear blue sky. The turbine is positioned on the right side of the frame, with its three blades extending outwards. The hills are covered in green grass and are slightly out of focus. The sun is in the upper left corner, creating a bright glow and a lens flare effect. The overall scene is bright and clear.

# ADVANCEMENTS IN WIND TURBINE BLADE TECHNOLOGY

# Concept to Reality





**DESIGN**  
DESIGN

# Advances in Blade Design

- It might seem obvious, but an understanding of the wind is fundamental to wind turbine design. The power available from the wind varies as the cube of the wind speed, so twice the wind speed means eight times the power.
- As well as, the wind speed varies very frequently. It also blows more strongly higher above the ground than closer to it, due to surface friction. All these effects lead to varying loads on the blades of a turbine as they rotate, and mean that the aerodynamic and structural design needs to cope with conditions that are rarely optimal.
- By extracting power, the turbine itself has an effect on the wind. The wind starts to slow down even before it reaches the blades, reducing the wind speed through the “disc” (the imaginary circle formed by the blade tips, also called the swept area) and hence reducing the available power. Some of the wind that was heading for the disc diverts and misses the blades entirely. This allows a theoretical maximum of 59% of the wind’s power to be captured (this is called Betz’s limit). In practice, only 40-50% is achieved by current designs.
- So, the blade design process starts with a “best guess” compromise between aerodynamic and structural efficiency. The choice of materials and manufacturing process will also have an influence the blade can be built. The chosen aerodynamic shape gives rise to loads which are fed into the structural design.

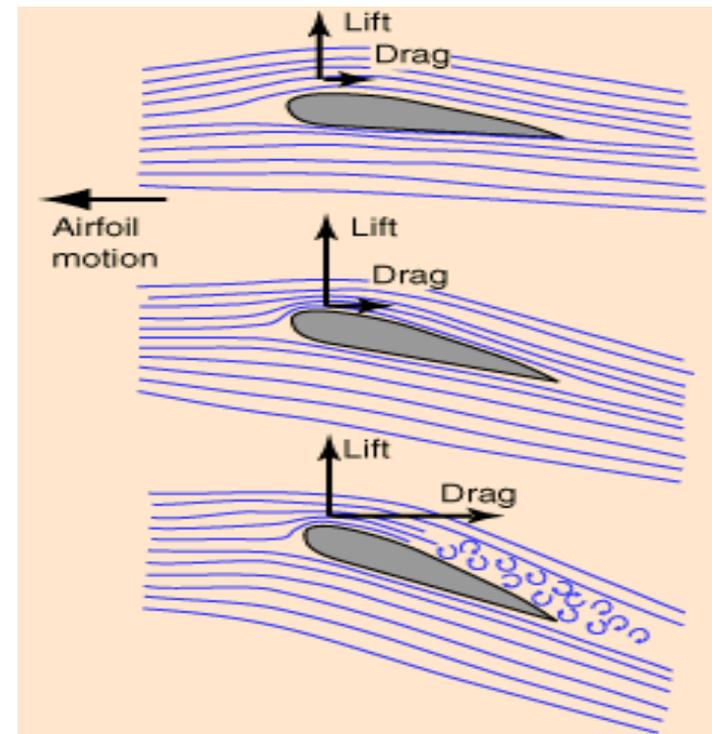
# Advances in Blade Design

## Drag Design:

- Drag design is where the wind pushes the blades out of the way. They are usually characterized by slower rotational speeds and high torque capabilities. Drag design is typically used for small scale home turbines.

## Lift Design:

- Works as per the principles that enable planes to fly.
- A pressure differential is created between the upper and lower surfaces of the blade when air flows on it.
- The air sliding along the upper surface will move faster than the lower surface air. This causes the lower surface pressure to be greater than the upper surface.
- This creates the lift, which is perpendicular to the direction of the wind. The blades are attached to a central axis, the lift causes a rotational motion.
- Therefore, lift design blades are better for electricity generation than drag design blades.

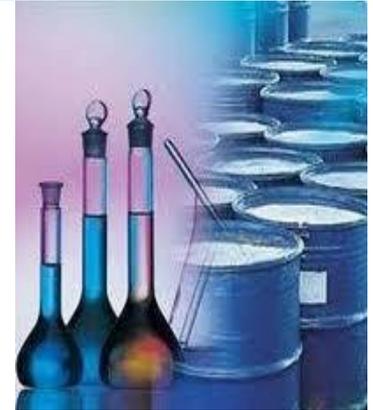


# RAW MATERIALS

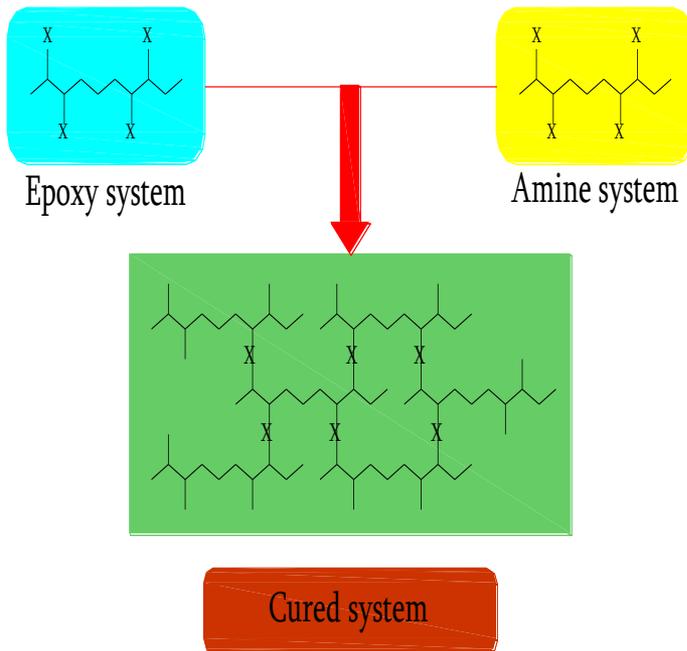


# Advances in Blade Materials – Resin / Matrix System

**Binder – Resin** provides a medium for binding and holding the reinforcements into a single object. It protects the reinforcement from environmental degradation. It serves to transfer load from one to the other medium. It provides finish, colour, durability and other functional properties required for the finished products.



## Example - Epoxy, Vinyl ester, Polyester.

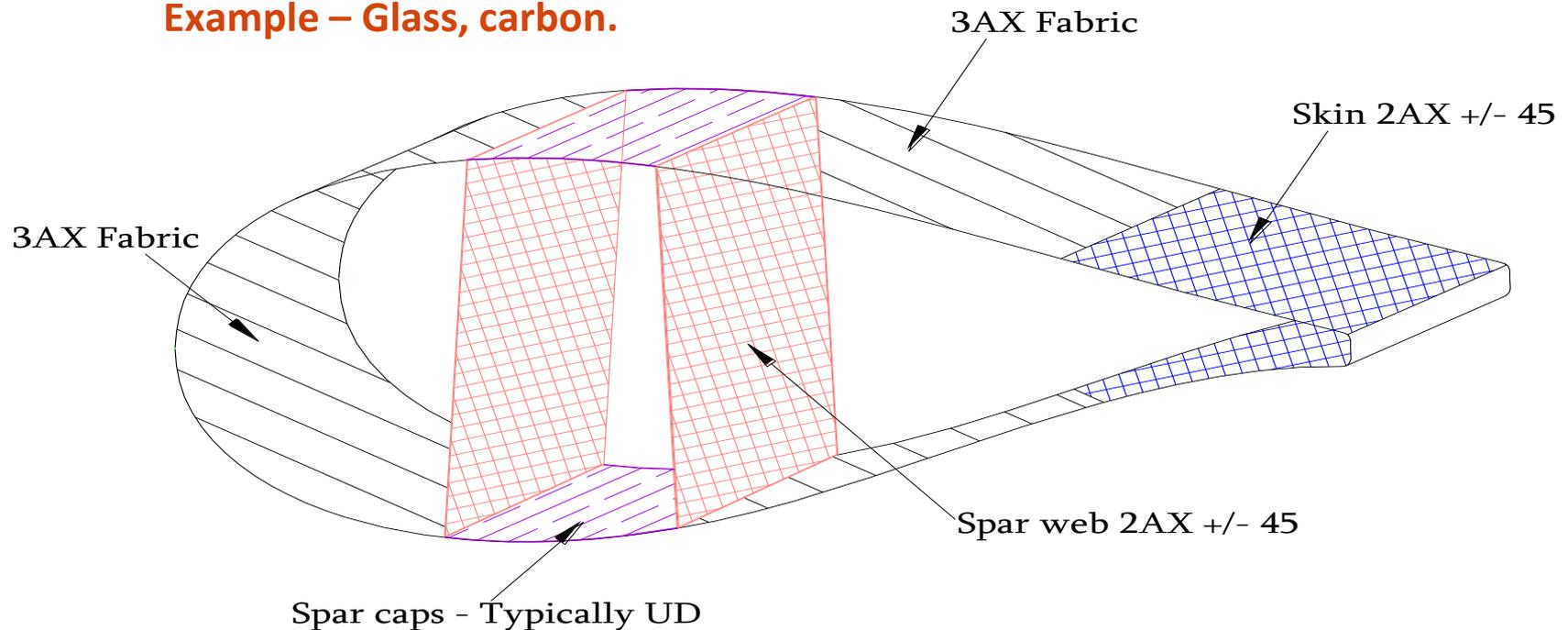


- Epoxy resins have a well-established record in a wide range of composite parts, structures and concrete repair. A major benefit of epoxy resins over unsaturated polyester resins is their lower shrinkage and better mechanical strength.
- Epoxies are used primarily for fabricating high performance composites with superior mechanical properties, resistance to corrosive liquids and environments, superior electrical properties, good performance at elevated temperatures, good adhesion to a substrate, or a combination of these benefits.
- Epoxy resins do not however, have particularly good UV resistance. The viscosity of epoxy is much higher than most polyester resin. It also requires a post-cure (elevated heat) to obtain ultimate mechanical properties making epoxies more difficult to use. However, epoxies emit little odor as compared to polyesters.

# Advances in Blade Materials – Reinforcement

**Reinforcement – Fiber** - Very high strength to weight ratio, perfect elastic behaviour with maximum elongation, high thermal conductivity, low thermal expansion and retention of strength at high temperature, excellent moisture resistance, Dimensional stability. Glass fibres do not shrink or stretch within the limits of their strength. Excellent resistance to solvents, most acids and alkalis.

**Example – Glass, carbon.**



The schematic representation of fibre position as a Skeleton in Blade Structure

# Advances in Blade Materials – Reinforcement (Glass)

**Glass : Low cost, high strength, modest stiffness**

Reinforcement fibre is named essentially based on the glass fibre orientation the glass mats.

## Uni-Directional

Uni-directional Glass Fabrics are the ones in which the orientation of the roving will be in one direction. It is used when there is a need of more strength in a single direction of the product.

## Biaxial

Bi-Directional mats are made by using two layers of UD mat fibres placed at  $0^\circ$  and  $90^\circ$  or  $+45^\circ$  and  $-45^\circ$ . These glass mats are used mainly in the areas where shear strength is highly important.

## Triaxial

Triaxial fabrics have glass fibres aligned in three directions. These are flexible without allowing the threads to separate when they are draped over a double curvature. They are mainly used in areas where there is a need for high flexibility. They are made by using polyester or glass yarn to knit straight and parallel fibres in the wrap and weft directions.

**Advancement : Enhanced sizing and coupling agents , trade of from E – glass to improved high strength S – glass fiber**

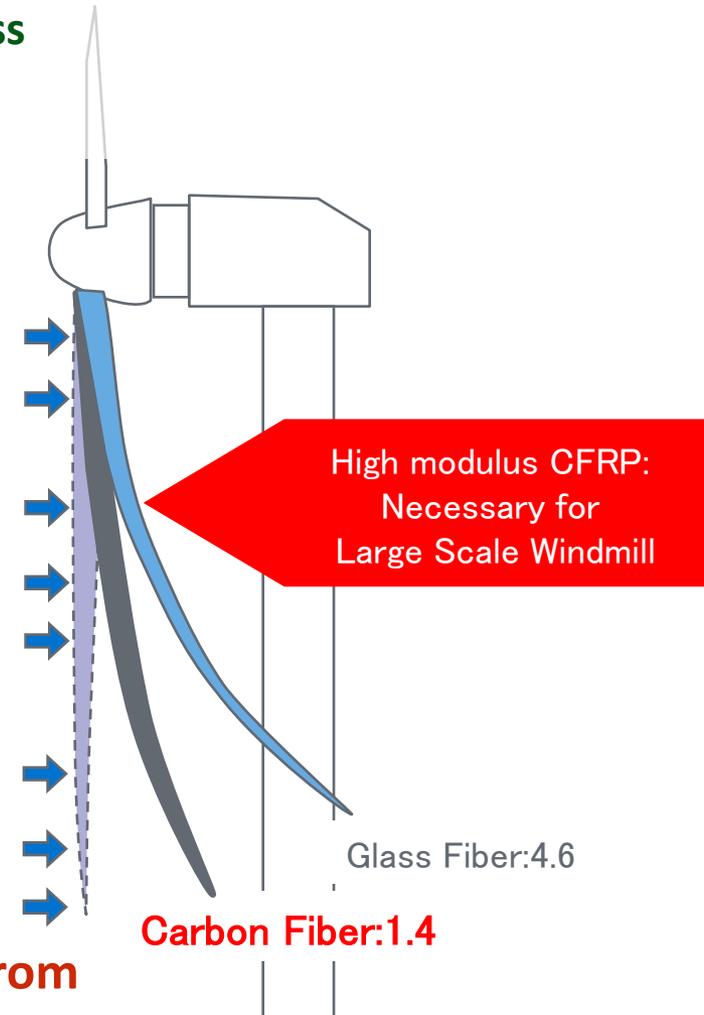
# Advances in Blade Materials – Reinforcement (Carbon)

Carbon : High Cost with high strength and Stiffness

Light Weight & Large Scale Blade with CFRP

- ① **Power Generation:**  
Proportional to Blade Length
- ② **High Modulus CFRP:**  
To prevent collision to Windmill Tower
- ③ **Light Weight Blade:**  
Total Cost Down

**Advancement : Spar cap, Root, Web parts are being just started converting from Glass to Carbon**



# Advances in Blade Materials – Structural Core - Foam

- The sandwich foam is rigid, closed cell foam with a tri-dimensional grid structure which gives high thermal stability and three dimensional structural integrity.
- The foam is providing structural strength and buckling strength to the blade.
- The foam has excellent mechanical properties even in its lower densities.



**Example - PVC, PS, SAN, PALSA Wood.**

**Advancement : New generation material with low cost and high strength materials are just introduced in the market.**

# MANUFACTURING METHODOLOGY

MANUFACTURING METHODOLOGY



# Advances in Blade Manufacturing – Mould Making



## COMPOSITE MOULD

Glass Epoxy Shell mould suitable for Vacuum Infusion Process, with fine finish and zero leakage level

Steel structure to retain the profile

## COMPOSITE TOOLING

Master Plugs by 5 axial milling machine for Zero level tolerance



# Advances in Blade Manufacturing – Mould Making

## ELECTRO-MECHANICAL TOOLING

- Mould Heating System – Electrical wire system, Hot air system through Honey comb core structure
- Mould Closing Device – Hydraulically operated hinge system, turning devices



# Advances in Blade Manufacturing – Blade Making

## Hand Lay up Method - HLU

- ✦ Labor intensive method in which reinforcing fabric is positioned manually in the open mold
- ✦ Resin is applied to the glass plies
- ✦ Entrapped air is removed manually with rollers.

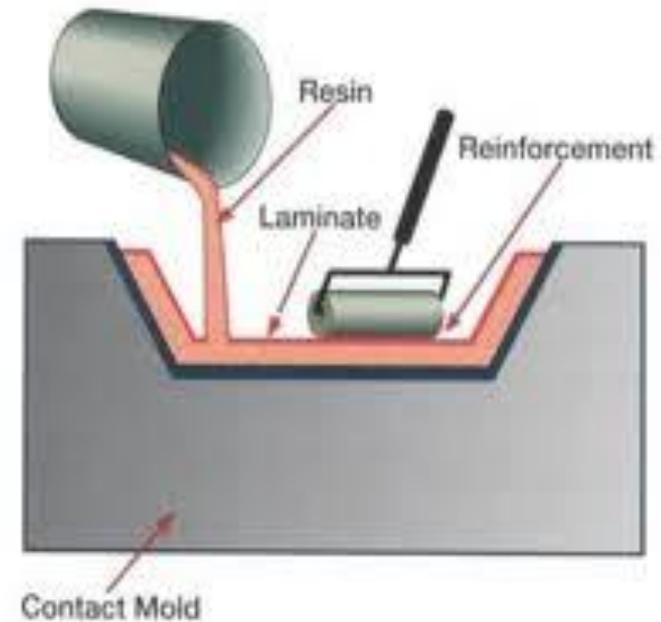
## PREPREG

- ✦ Difficult handling in large structures
- ✦ Higher production costs
- ✦ Raw Material Storage

## VARIM

- ✦ Excellent resin consolidation
- ✦ Excellent fiber impregnation with more fiber content
- ✦ Environmental free

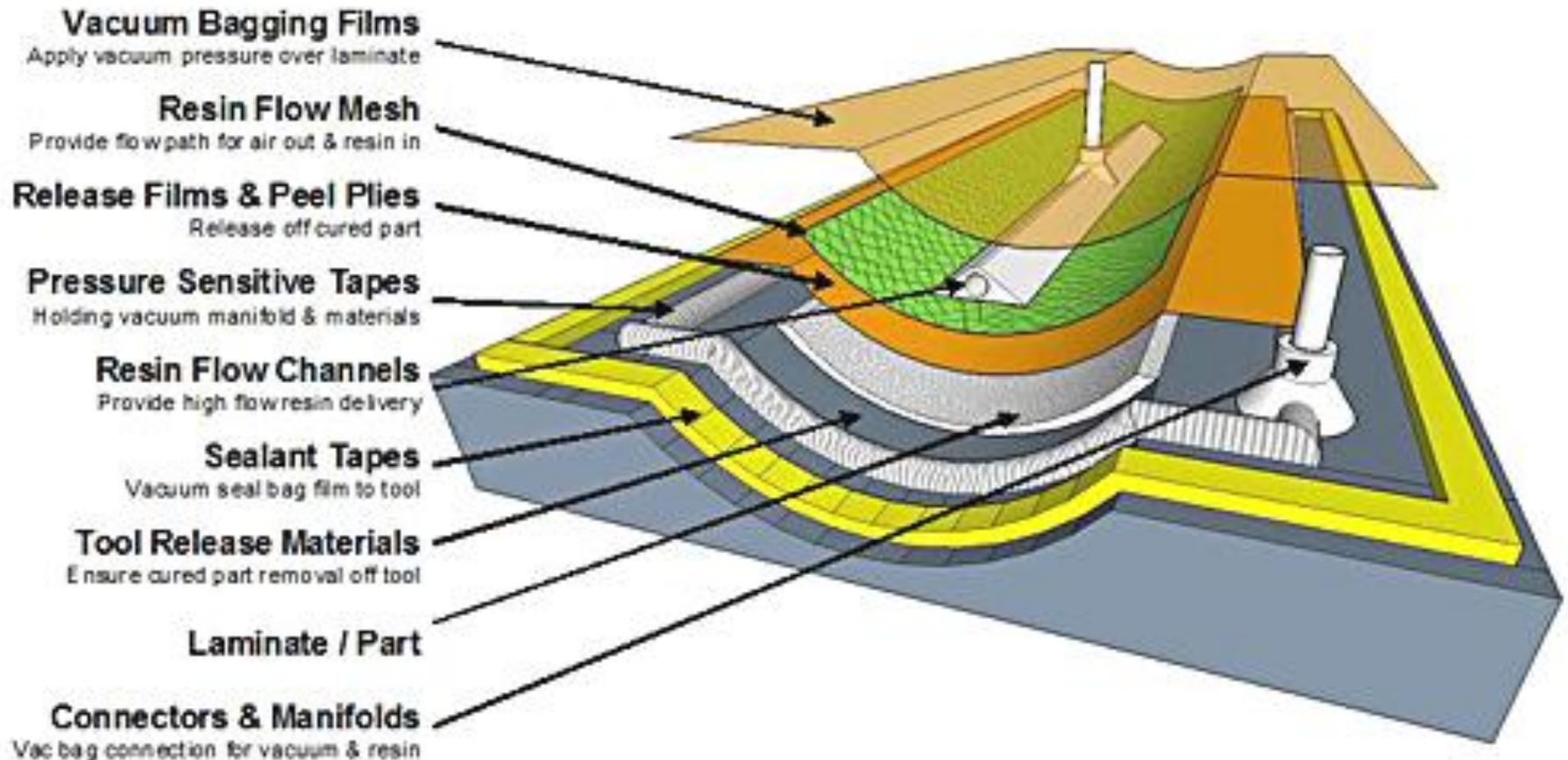
Hand Lay-Up



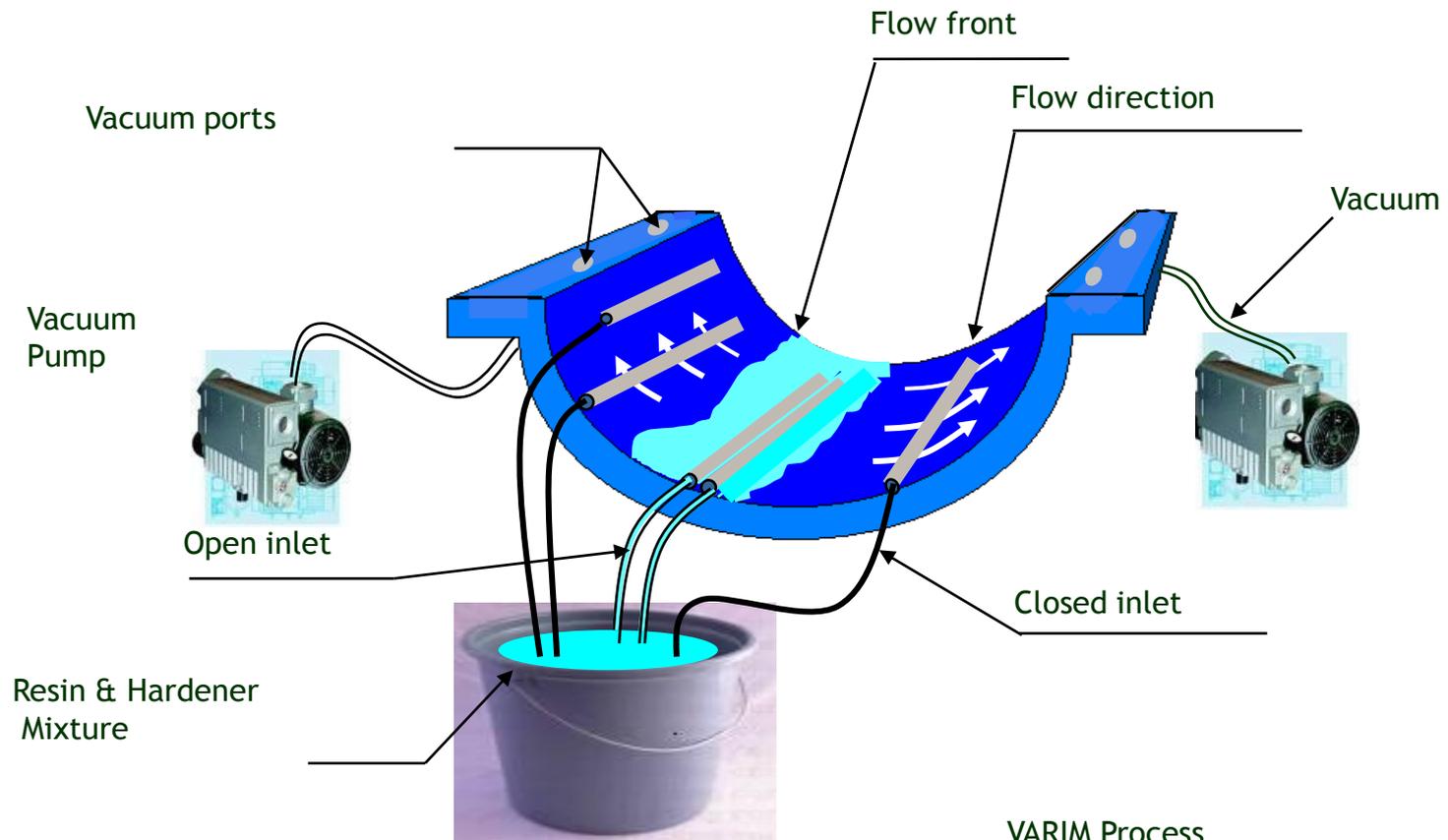
# Advances in Blade Manufacturing – Blade Making - VARIM Process

- o The Vacuum Assisted Resin Infusion Moulding (VARIM) is a technique that uses vacuum pressure to drive resin into a laminate. The low density liquid can be sucked easily in a vacuumised atmosphere. The liquid can follow the determined path during suction.
- o The defined fabrics along with core are laid up as per Structural Lay out on the mould. The glass fabrics are then covered with peel ply. The whole dry material is then vacuum bagged.
- o The vacuum is applied before resin is introduced. Once a complete vacuum is achieved, resin is literally sucked into the laminate via carefully placed tubing. Resin is allowed to flow into the laminate.
- o The resin distribution over the whole laminate is aided by resin flowing easily through the non-structural fabric, and wetting the fabric out from above.

# Advances in Blade Manufacturing – Blade Making - VARIM Process



# Advances in Blade Manufacturing – Blade Making - VARIM Process



VARIM Process  
Vacuum bag is not shown!

# Advances in Blade Manufacturing – Blade Making - VARIM Process

## Advantages of VARIM

- Good consolidation between resin and fabrics, reduces resin usage due to pre-compacted fabric, increases the strength of the blades
- 60 – 70 % of glass achieved in laminate and low void content ensures consistent quality in each and every product
- Lower tooling cost compared with other latest technology
- Reduces exposure to harmful emissions increases the safety the operators
- Faster ply lay-up, rapid infusion with low resin content
- Different types of glass fabrics are used with different orientation to get the maximum load carrying capacity at respective areas in blade. The fabrics are having different area density.



# CHALLENGES



# Challenges

## Manpower Resource

Availability of Required Manpower  
Up gradation of their Skill Level



## Automation Support

Availability of custom made software for Lay up nesting etc..  
Energy Efficient Heating System, Precise Closing device etc...

## Waste Management Service

Development of a User friendly Waste Management system  
Governments support in terms of Policies in handling the Waste

# FUTURE DEVELOPMENT

FUTURE DEVELOPMENT



# Future Wind Turbine and Blade Design

## Segmented Rotor Blade :

- There is a developmental activities to make segmented rotor-blade design that enables production and easy transportation in individual sections.
- Outside the bolted circular root joint, the blade structure is similar to conventional blades. Shear web reinforcements connect the primary spar caps, which are covered by a moulded aerodynamic skin.

## Offshore Floating Wind Turbine :

- A floating wind turbine is an offshore wind turbine mounted on a floating structure that allows the turbine to generate electricity in water depths where bottom-mounted towers are not feasible.
- Floating wind parks are wind farms that site several floating wind turbines closely together to take advantage of common infrastructure such as power transmission facilities.

# BUSINESS OPPORTUNITIES

ROZIME?? OBBOKIOMLIE?

# Business Opportunities

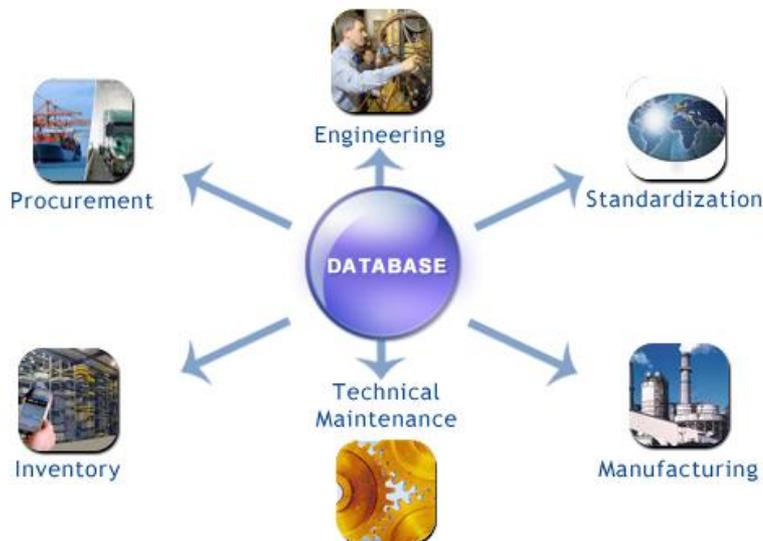
There is a huge demand for

- Quality focused shop floor
- Consistent quality supply
- Skilled man power
- Best Equipments.



There is a potential for employment

- Very limited qualified professionals are available.
- Wind Energy jobs sector will have organic growth in the coming years and huge number of job opportunities are expected. App 0.2 million job profiles may be required for the wind industry, in the coming years.





நன்றி

*köszönöm !תודה dēkuji*

*mahalo* 고맙습니다

*thank you*

*merci* 谢谢 *danke*

Ευχαριστώ شڪرا

どうもありがとう *gracias*

