

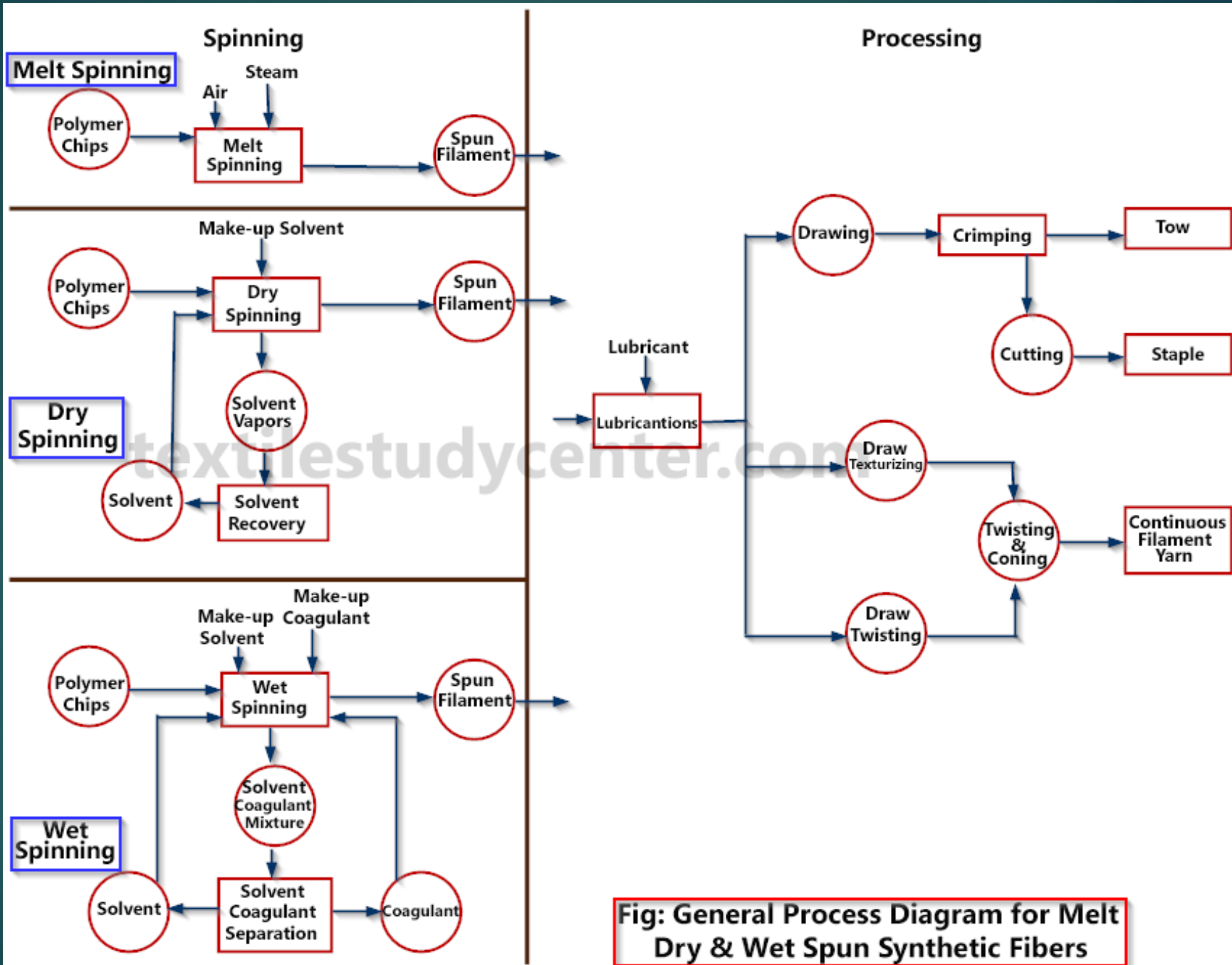
# SPINNING PROCESS

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# SPINNING PROCESS

- ▶ Spinning is a manufacturing process for creating polymer fibers. It is a specialized form of extrusion that uses a spinneret to form multiple continuous filaments.
- ▶ There are many types of spinning: wet, dry, dry jet-wet, melt, gel, and electrospinning.
- ▶ First, the polymer being spun must be converted into a fluid state. If the polymer is a thermoplastic then it can be simply melted, otherwise it is dissolved in a solvent or chemically treated to form soluble or thermoplastic derivatives. The molten polymer is then forced through the spinneret, then it cools to a rubbery state, and then a solidified state. If a polymer solution is used, then the solvent is removed after being forced through the spinneret.



**Fig: General Process Diagram for Melt Dry & Wet Spun Synthetic Fibers**

# MELT SPINNING

- ▶ In this process, a polymer is melted and heated to a suitable viscosity for fiber production.
- ▶ The melted polymer is pushed through a spinneret, which is a type of die consisting of several small holes.
- ▶ Each hole produces an individual fiber, and the number of holes on a spinneret defines the number of fibers in the yarn.
- ▶ The melted polymer fibers then pass through a cooling region and the fibers are combined to form a yarn and a spin finish is applied.
- ▶ The yarn is then drawn using several godets rolls with very good speed and temperature control to orient the molecules in the fibers and eliminate voids, making the yarn stronger.
- ▶ If the polymer is thermoplastic, then melt spinning should be used for higher productivity.
- ▶ Most of the manmade fibers, such as polyester, polypropylene, nylon and PGA, are produced using melt spinning.

## REQUIREMENTS OF MELT SPINNING :

- ▶ The polymer should not be volatile.
- ▶ The polymer should not decompose in the molten state and the melting point.
- ▶ Polymer should be 30 degree centigrade less than its decomposition temperature.

## FIBER CHARACTERIZATIONS :

- ▶ Different characterization methods were performed to study the resulting fiber properties, mechanical properties, rheological properties, molecular orientation, and crystalline behavior.

## FIBER WHICH PROCESSED BY MELT SPINNING :

- ▶ Polyester, Nylons, Olefins, Polypropylene, Saran, Sulfar etc.

# Process Flow Chart of Melt Spinning

Feeding (Polymer chips)

↓  
Melting

↓  
Metered extrusion

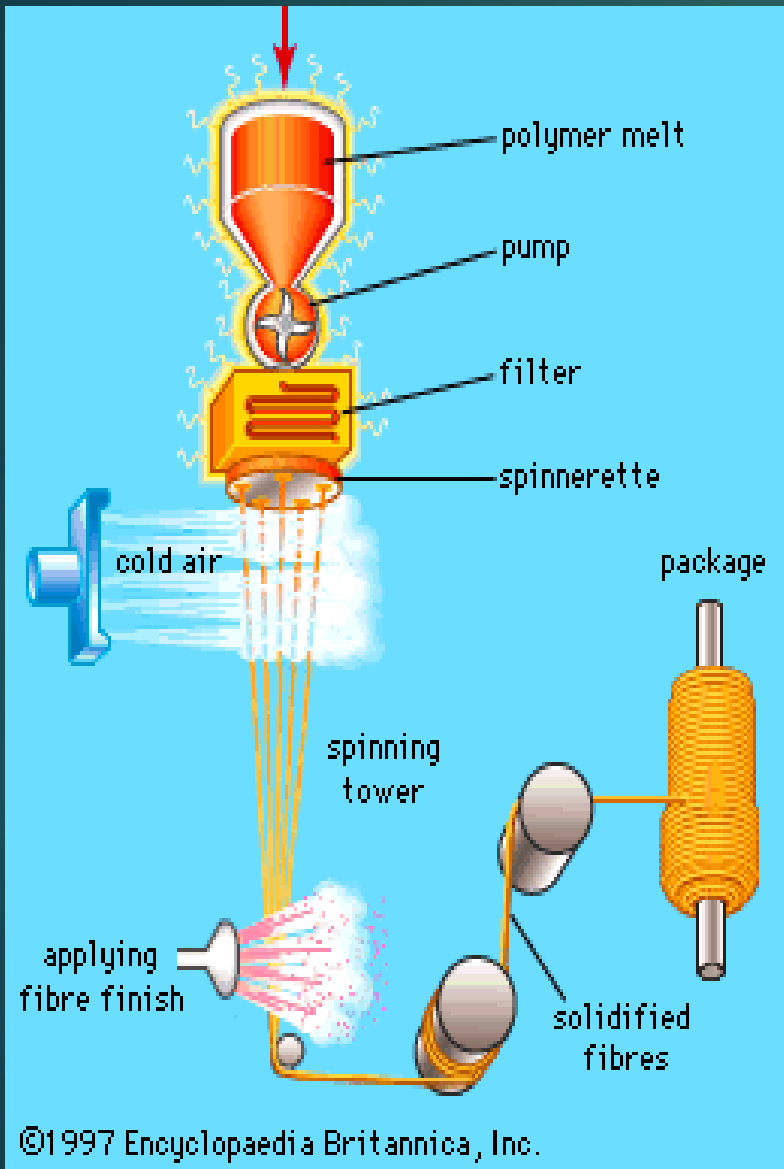
↓  
Cooling and solidification by cold air

↓  
Moisture conditioning

↓  
Lubrication

↓  
Yarn driving

↓  
Packaging



# ADVANTAGES OF MELT SPINNING :

- ▶ Can be used for both staple and continuous filament.
- ▶ Direct and simple process.
- ▶ No environment pollution.
- ▶ No solvent required.
- ▶ Non toxicity and no risk of explosion.
- ▶ High production speed ( 2500 – 3000 ft/min ).
- ▶ Low investment cost.

# DISADVANTAGES OF MELT SPINNING :

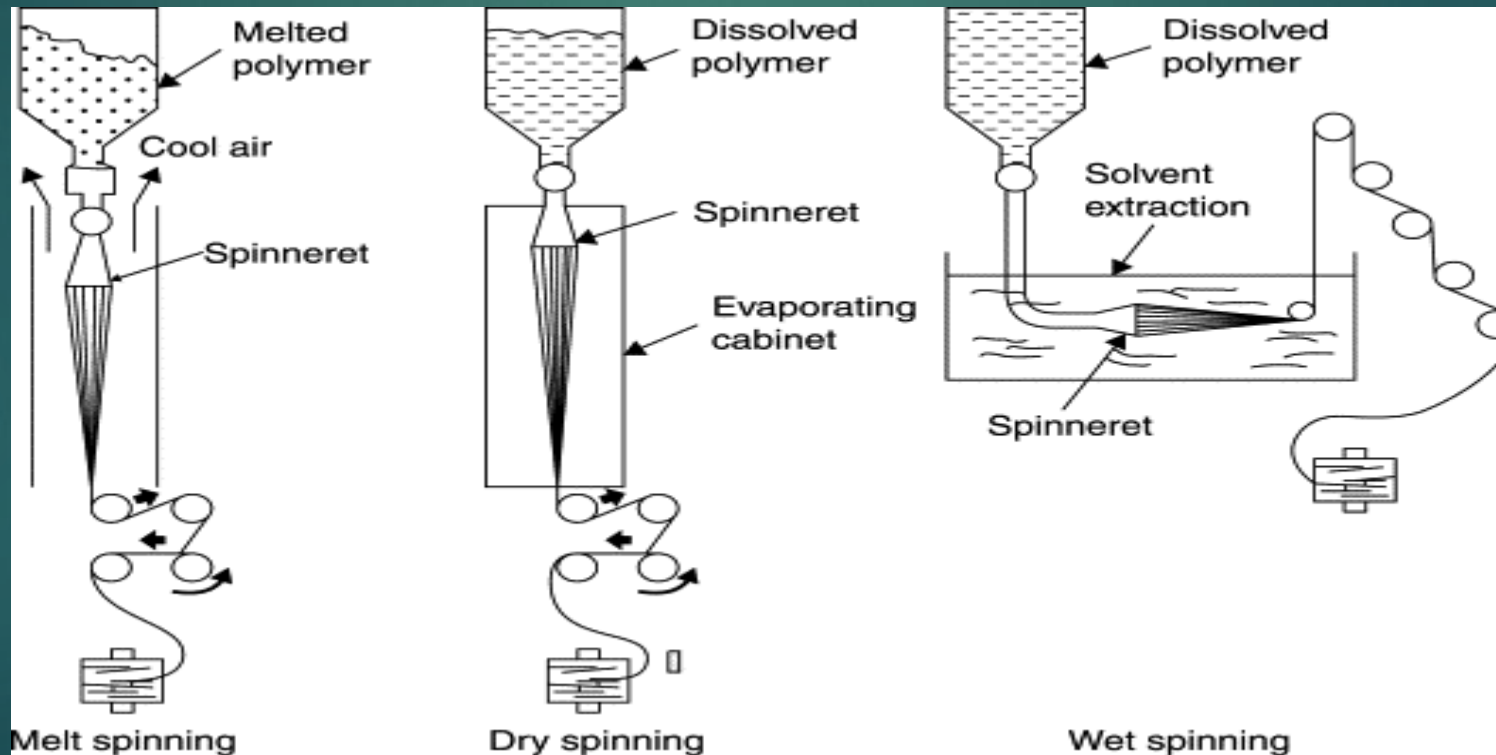
- ▶ Required more proper maintenance of the Moisture content.
- ▶ Heat of input is high.

<https://www.youtube.com/watch?v=cn6K1m7yH0I>



# SOLUTION SPINNING

- ▶ In solution spinning, a polymer is dissolved in a suitable solvent and is extruded inside a coagulation bath containing a non-solvent (immersion-jet wet spinning) or into a heated chamber of air (dry spinning).



# WET SPINNING

- ▶ These processes are used for thermoset polymers such as acrylic, liquid crystalline polymers (Kevlar and Nomex), and polyurethane. In wet spinning, the polymer is dissolved in a solvent at a target concentration to make a polymer solution with the desired viscosity. This polymer solution is then extruded under heat (if needed) and pressure into a liquid coagulation bath. Then fibers are combined as yarn and the yarn is drawn, with very good controls, to orient the molecules in the fibers so that it becomes stronger.

# Working Flow Chart of Wet Spinning Process

At first solid polymer and suitable solvent is dissolved in a solution vessel.



The solution is then heated in heat exchanger.



The solution is passed/extruded to spinneret which immersed in a coagulation bath/spin bath by pump.



The polymer is chemically regenerated and it is converted into the filament of solid form.



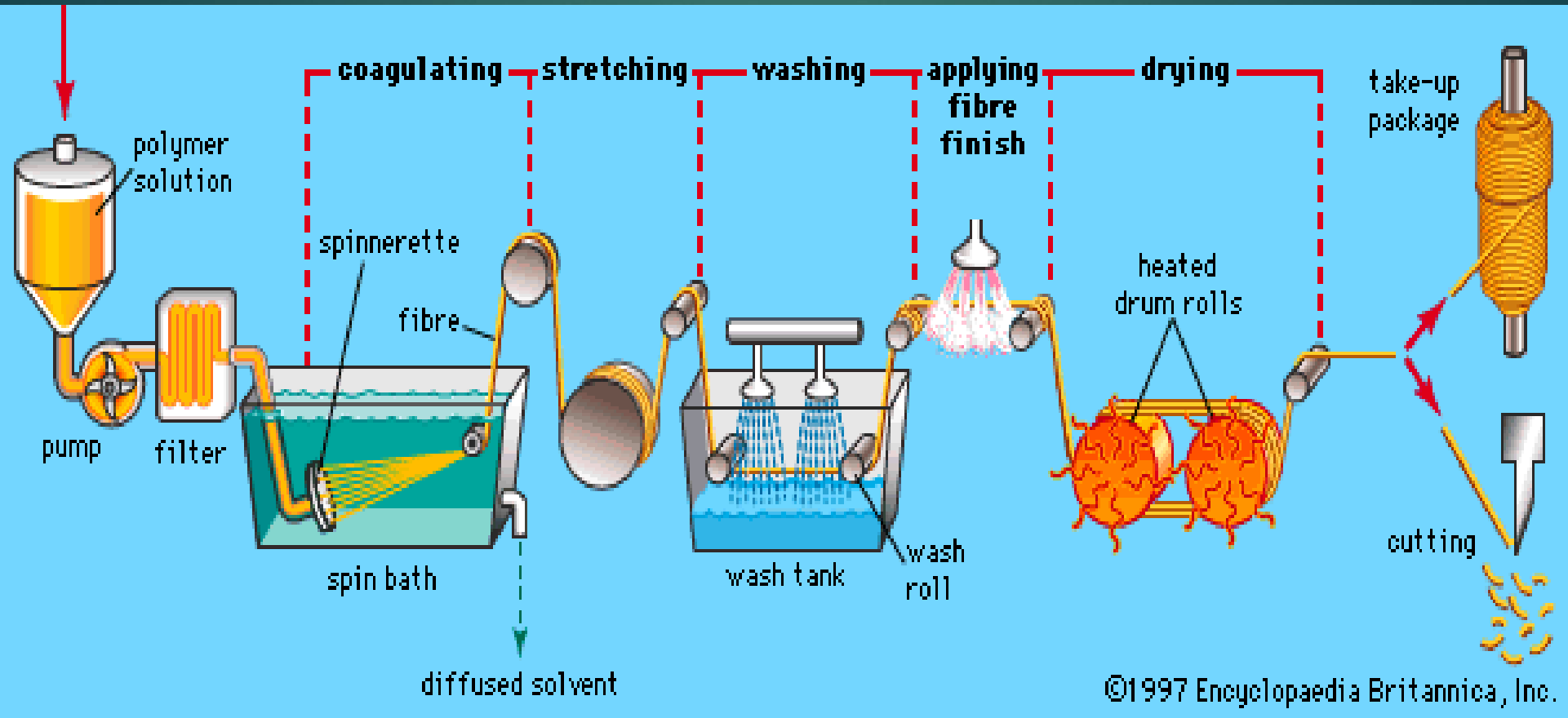
The filament is converged and wound on bobbin.



The wended filament is then drawn and finally it is washed & dried and is also wound on suitable package.



Delivery



## ADVANTAGES OF WET SPINNING :

- ▶ Large tows can be handled.
- ▶ Better than melt and dry spinning for temperature sensitive polymers.

## DISADVANTAGES OF WET SPINNING :

- ▶ Slow process ( 70 – 150 yd/min ).
- ▶ Washing to remove impurities.
- ▶ Solvent and chemical recovery is costly.
- ▶ Lower production rates than melt or dry spinning due to viscous drag.

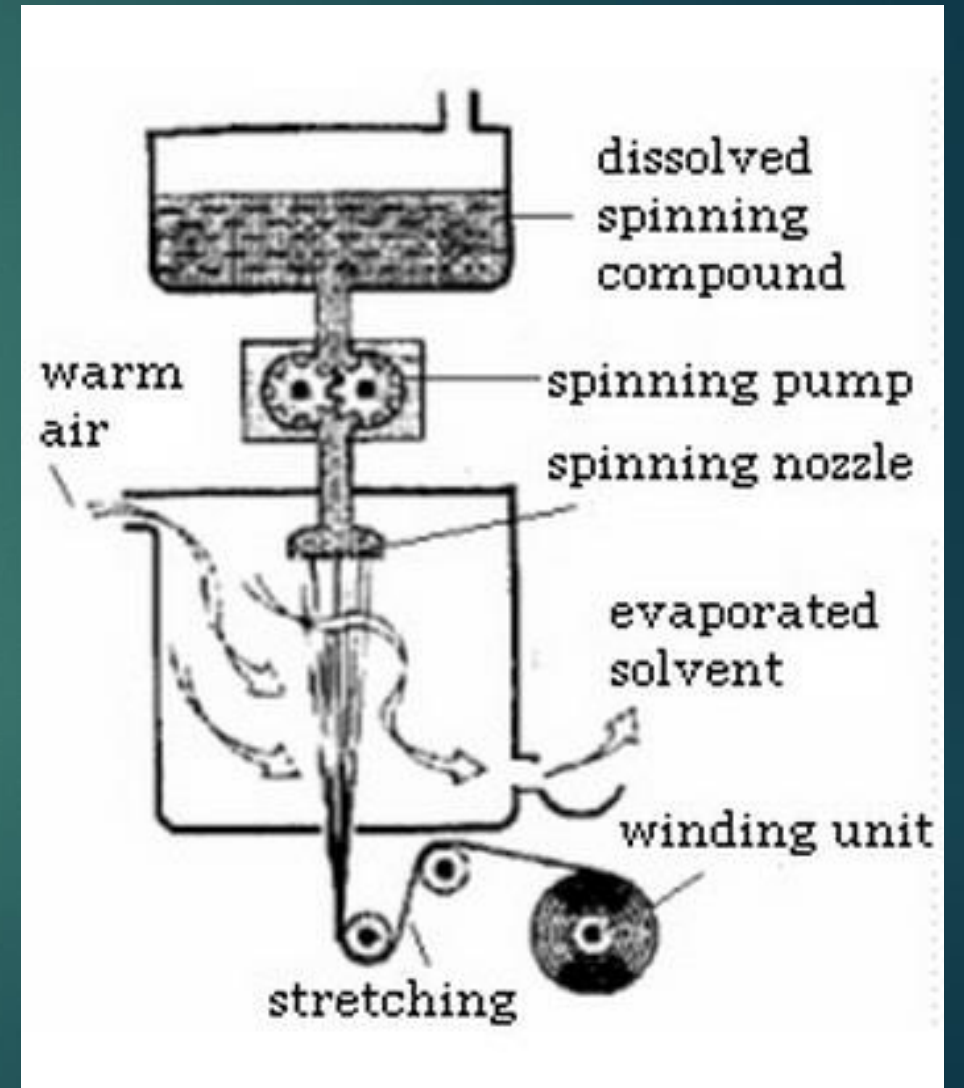
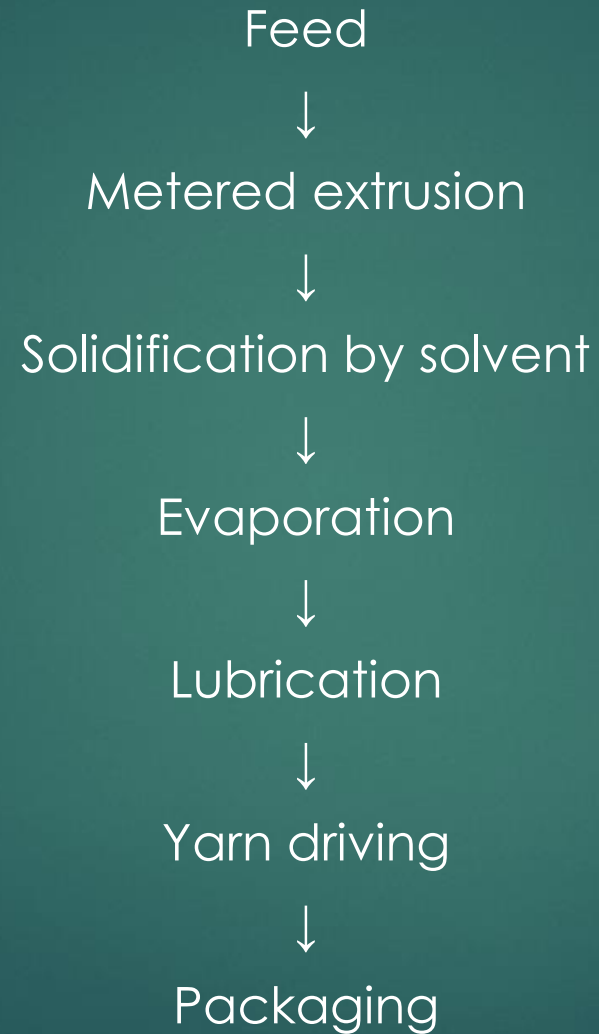
## TYPICAL WET SPUN FIBERS:

- ▶ Viscose ( Rayon )
- ▶ Cuprammonium rayon
- ▶ <https://www.youtube.com/watch?v=x0VFeMTSlb4>

# DRY SPINNING

- ▶ Dry spinning is used to form polymeric fibers from solution. The polymer is dissolved in a volatile solvent and the solution is pumped through a spinneret (die) with numerous holes (one to thousands). As the fibers exit the spinneret, air is used to evaporate the solvent so that the fibers solidify and can be collected on a take-up wheel. Stretching of the fibers provides for orientation of the polymer chains along the fiber axis.
- ▶ Cellulose acetate (acetone solvent) is an example of a polymer which is dry spun commercially in large volumes. Due to safety and environmental concerns associated with solvent handling this technique is used only for polymers which cannot be melt spun.

# Process Flow Chart of Dry Spinning



## ADVANTAGES OF DRY SPINNING :

- ▶ It is suitable for heat sensitive polymer.
- ▶ The post spinning operation is simple.
- ▶ High spinning speeds can be easily achieved.
- ▶ Moderate concentration of polymer is required.
- ▶ It is relatively flexible process and spinning conditions can be modified.
- ▶ Suitable for producing fine denier fibers.
- ▶ No need to wash the fiber.

## DISADVANTAGES OF DRY SPINNING :

- ▶ Investment cost is high.
- ▶ Slow process
- ▶ Difficult to achieve exact cross section of fibers.
- ▶ Additional post spinning process is required.
- ▶ Toxic and risk of explosion.
- ▶ Heat input is very high.
- ▶ Can not be used for staple fiber production.



# POLYMERS AND SOLVENTS IN DRY SPINNING

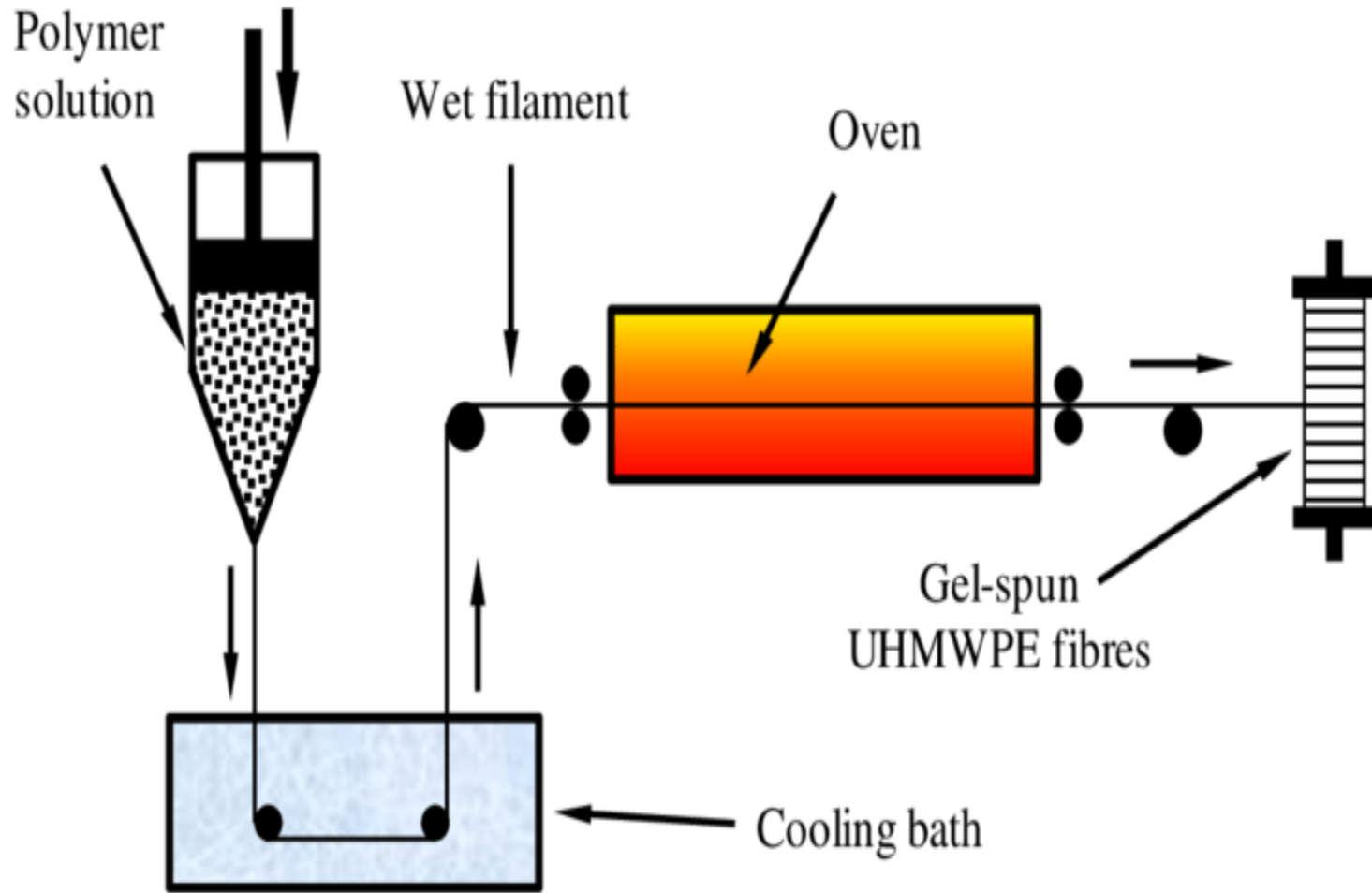
POLYMER	SOLVENT	BOILING POINT SOLVENT
Cellulose Acetate	Acetone	56 deg
Cellulose Triacetate	Methyl chloride	41 deg
PVC	Acetone	56 deg
PAN	DMF	153 deg
PU	DMF	153 deg

## PROPERTIES OF SOLVENT :

- ▶ Solvent should be volatile.
- ▶ It should be organic.
- ▶ It should have low boiling point.
- ▶ It should be comparatively cheap.
- ▶ It should be thermally stabilized.

# GEL SPINNING

- ▶ Gel spinning is a special process used to obtain high strength or other special fiber properties. The polymer is not in a true liquid state during extrusion. Not completely separated, as they would be in a true solution, the polymer chains are bound together at various points in liquid crystal form.
- ▶ This produces strong inter-chain forces in the resulting filaments that can significantly increase the tensile strength of the fibers. In addition, the liquid crystals are aligned along the fiber axis by the shear forces during extrusion. The filaments emerge with an unusually high degree of orientation relative to each other, further enhancing strength. The process can also be described as dry-wet spinning, since the filaments first pass through air and then are cooled further in a liquid bath. Some high-strength polyethylene and aramid fibers are produced by gel spinning.



# ADVANTAGES OF GEL SPINNING :

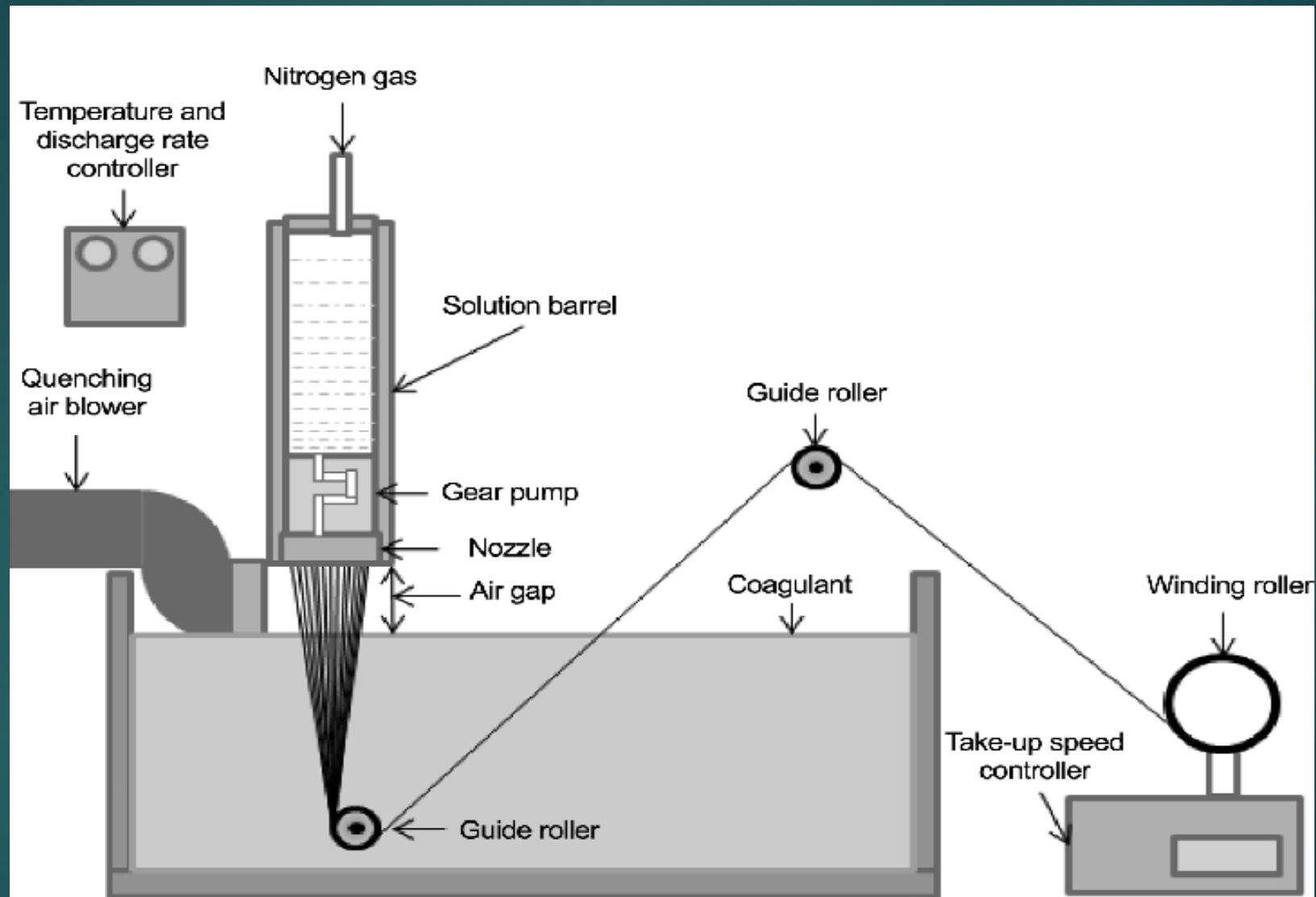
- ▶ Medium speed ( up to 1500 m/min).
- ▶ Suitable for liquid crystalline polymers.

# DISADVANTAGES OF GEL SPINNING :

- ▶ Environmental pollution hazards.
- ▶ Purification of the filament is needed.
- ▶ Cumbersome technology.

# DRY JET WET SPINNING

- ▶ In this method the polymer is dissolved in an appropriate solvent to make the fibre solution. This solution is then extruded under heat and pressure into an air gap before it enters a coagulation bath. The produced fibre is then washed and dried before it is heat treated and drawn.
- ▶ This is an alternative method to wet spinning and is required as spinning directly into the bath, for some fibres, creates microvoids that negatively affect the fibre properties, this is due to the solvent being drawn out of the liquid too quickly. An inert atmosphere may be required to prevent oxidation in some polymers, if so fibres are extruded into a nitrogen atmosphere.
- ▶ This method is often required for high performance fibres with a liquid crystal structure. Due to their structural properties their melt temperature is either the same as, or dangerously close to their decomposition temperature, therefore they must be dissolved in an appropriate solvent and extruded in this manner.



## ADVANTAGES OF DRY JET WET SPINNING :

- ▶ High speed of spinning than wet spinning.
- ▶ High concentration of dope.
- ▶ High degree of jet stretch ratio.
- ▶ A greater percentage of solids can be tolerated in spinning solution.
- ▶ The solvent is removed to greater extent by evaporation into air.
- ▶ Control of coagulation kinetics by monitoring coagulation bath parameters.

## DISADVANTAGES OF DRY JET WET SPINNING :

- ▶ Due to large amount of heat, it can effect adversely the properties of the produced filaments. It may give a colour effect.
- ▶ Turbulence in air flow can disturb the regular filament.

# ELECTROSPINNING

- ▶ Electrospinning is a fiber production method which uses electric force to draw charged threads of polymer solutions or polymer melts up to fiber diameters in the order of some hundred nanometers.
- ▶ Electrospinning shares characteristics of both electrospaying and conventional solution dry spinning of fibers.
- ▶ The process does not require the use of coagulation chemistry or high temperatures to produce solid threads from solution.
- ▶ This makes the process particularly suited to the production of fibers using large and complex molecules.
- ▶ Electrospinning from molten precursors is also practiced; this method ensures that no solvent can be carried over into the final product.

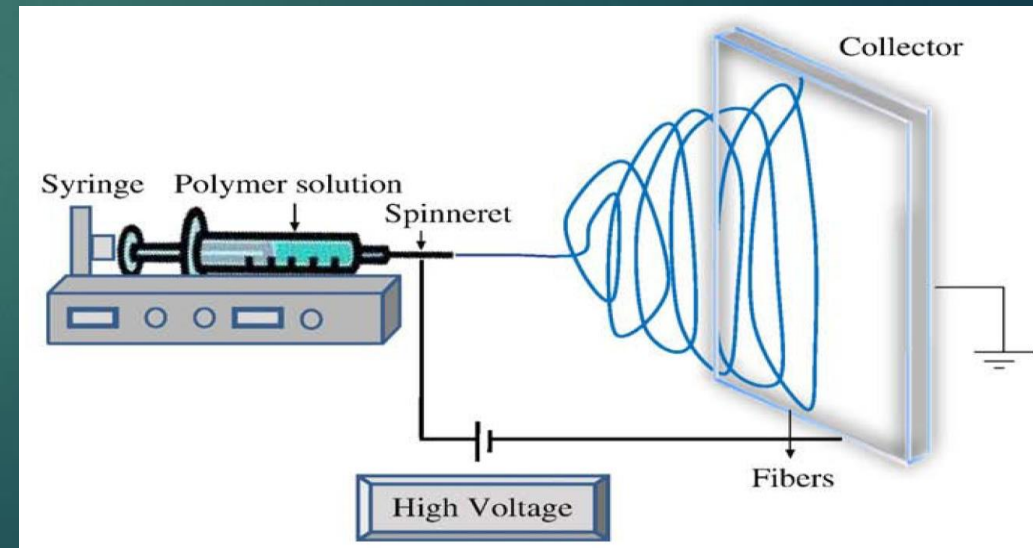


# STEPS OF PROCESSING

- ▶ When a sufficiently high voltage is applied to a liquid droplet, the body of the liquid becomes charged, and electrostatic repulsion counteracts the surface tension and the droplet is stretched; at a critical point a stream of liquid erupts from the surface. This point of eruption is known as the Taylor cone.
- ▶ If the molecular cohesion of the liquid is sufficiently high, stream breakup does not occur ( if it does, droplets are electrosprayed ) and a charged liquid jet is formed.
- ▶ As the jet dries in flight, the mode of current flow changes from ohmic to convective as the charge migrates to the surface of the fiber.
- ▶ The jet is then elongated by a whipping process caused by electrostatic repulsion initiated at small bends in the fiber, until it is finally deposited on the grounded collector.
- ▶ The elongation and thinning of the fiber resulting from this bending instability leads to the formation of uniform fibers with nanometer-scale diameters.
- ▶ <https://www.youtube.com/watch?v=SGXR14a3nRI>

# PARAMETERS OF ELECTROSPINNING

- ▶ Molecular weight, molecular-weight distribution and architecture (branched, linear etc.) of the polymer
- ▶ Solution properties (viscosity, conductivity and surface tension)
- ▶ Electric potential, flow rate and concentration
- ▶ Distance between the capillary and collection screen
- ▶ Ambient parameters (temperature, humidity and air velocity in the chamber)
- ▶ Motion and size of target screen (collector)
- ▶ Needle gauge



# APPLICATIONS OF ELECTROSPINNING

