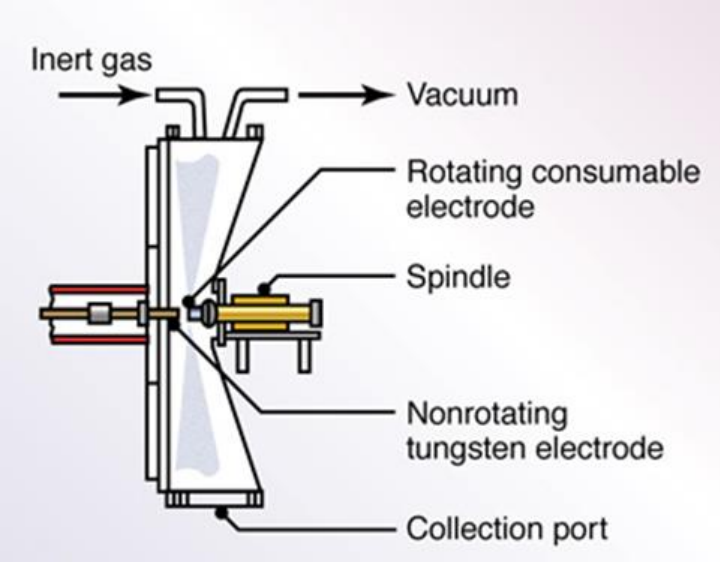
Benha University
Shoubra Faculty of Engineering
Mechanical Engineering Department

Lecture # 3

POWDER METALLURGY

متالورجيا المساحيق



Dr. Mohammed Gamil

Production of Metallic Powders

1. Atomization Method
2. Chemical reduction of particulate compounds
3. Electrolytic deposition
4. Pulverization or grinding of brittle materials
5. Thermal decomposition
6. Precipitation from solutions
7. Condensation of metal vapors

Types of Atomization

- On the basis of atomization media;

i) Gas atomization

ii) Water atomization

- On the basis of kind of energy being used;

i) Vacuum atomization

ii) Rotating disc atomization

iii) Centrifugal atomization(Rotating Electrode Process)

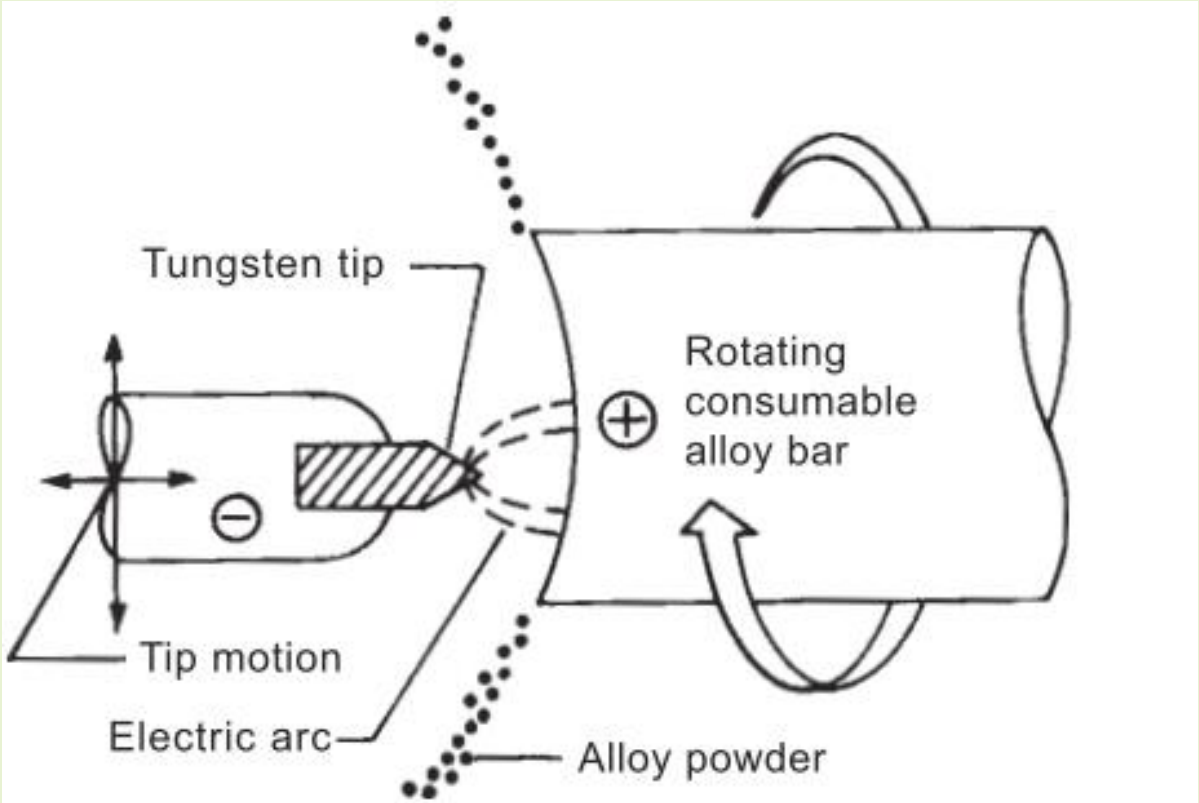
iv) Plasma atomization

v) Ultrasonic atomization

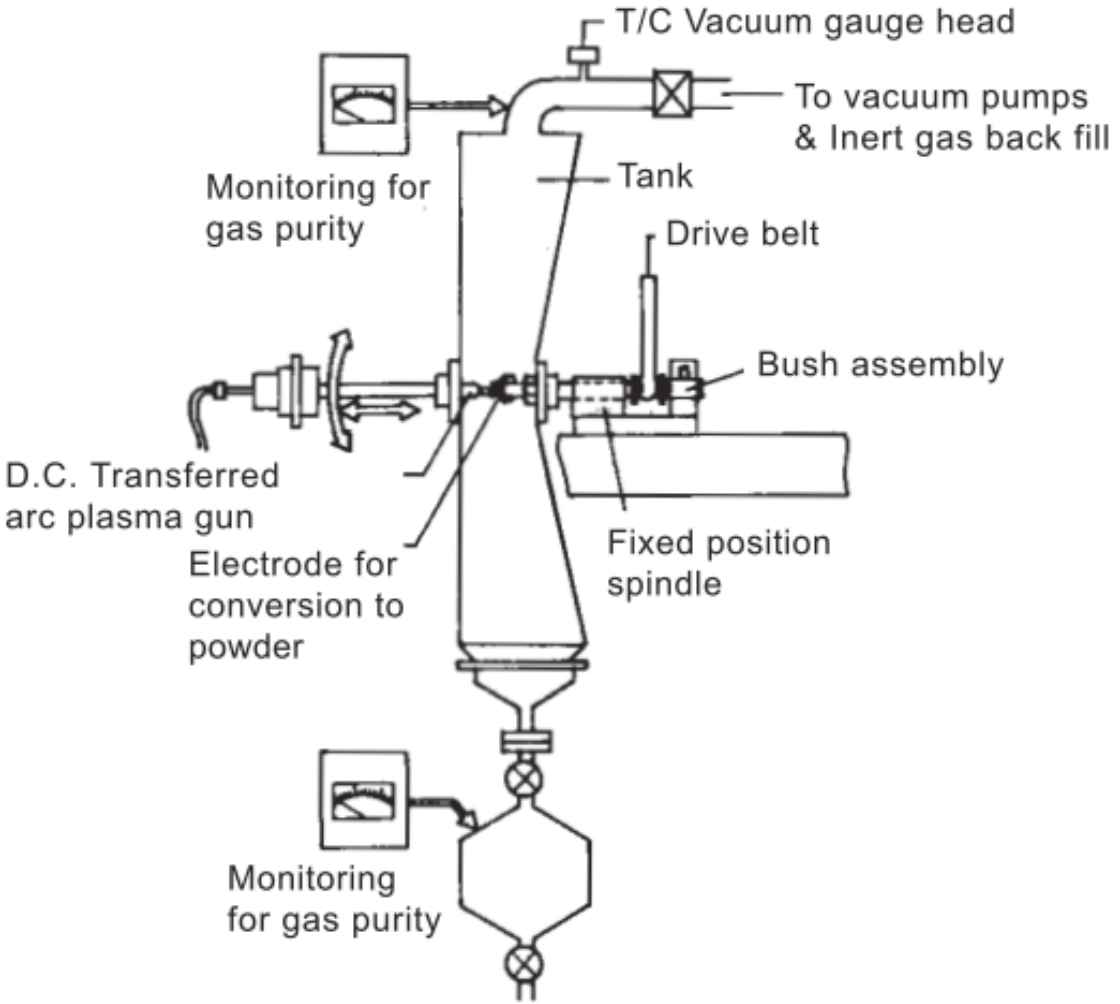
iii. Centrifugal atomization (Rotating Electrode Process)

- The end of a metal bar or rod is melted while it is rotated about its longitudinal axis.
- Molten metal produces droplets which by centrifugal force are ejected away from the center and solidify as spherical powder particles.
- It consists of a large diameter (more than 2 meter) tank mounted in vertical position.
- The consumable rotating electrode is fed through sealed assembly in horizontal position located in the central axis of the tank.
- This electrode is an anode of D.C. power supply.
- While non-melted permanent cathode may be a tungsten tipped device provided with adequate cooling

- Usually, melting is conducted under inert gas; the preferred medium is helium, which offers improved heat transfer properties and arc characteristics.
- This technique is used for short bar and long bar electrodes.



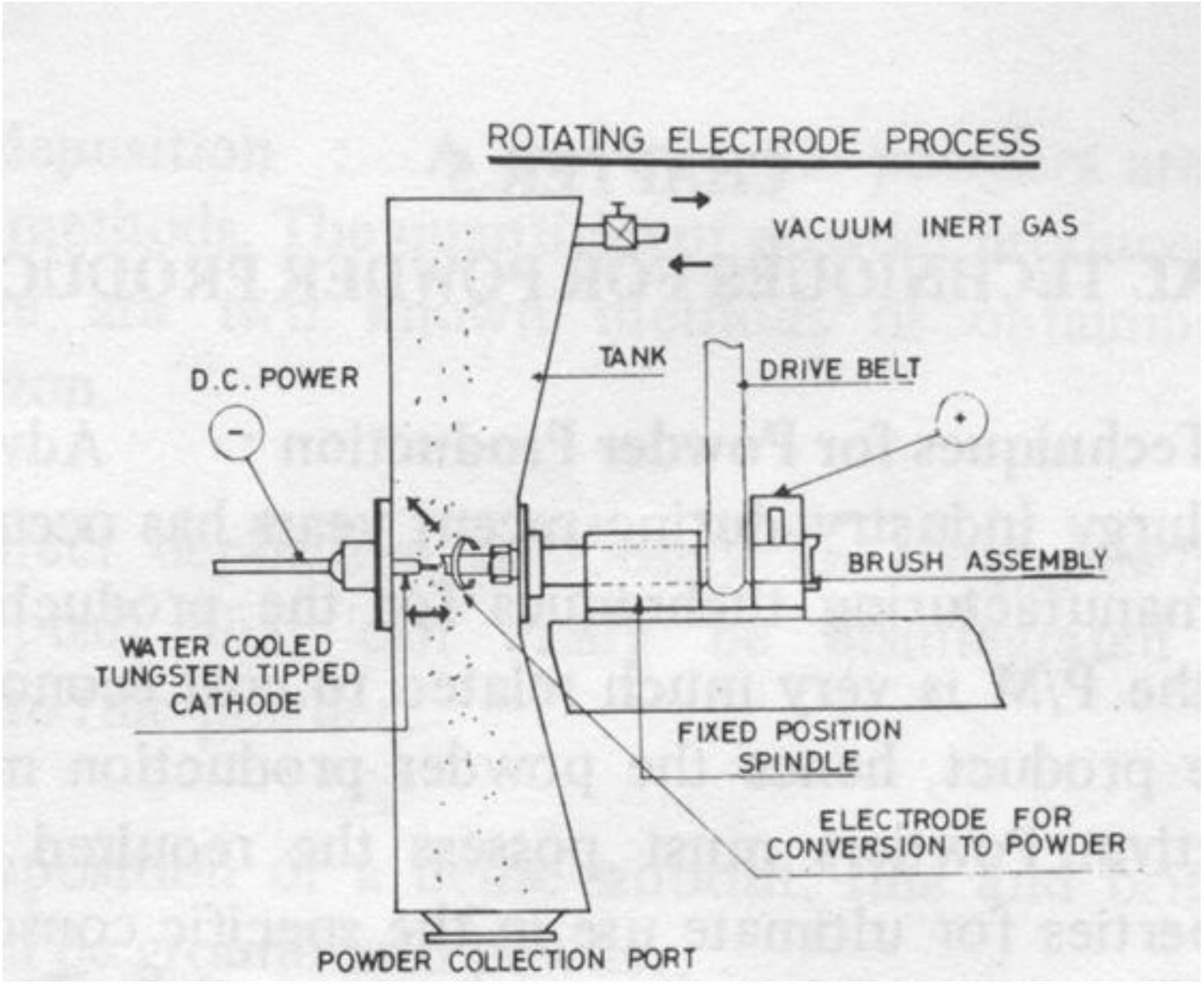
Centrifugal atomization (Rotating Electrode Process)



Types of centrifugal atomization (Rotating electrode process)

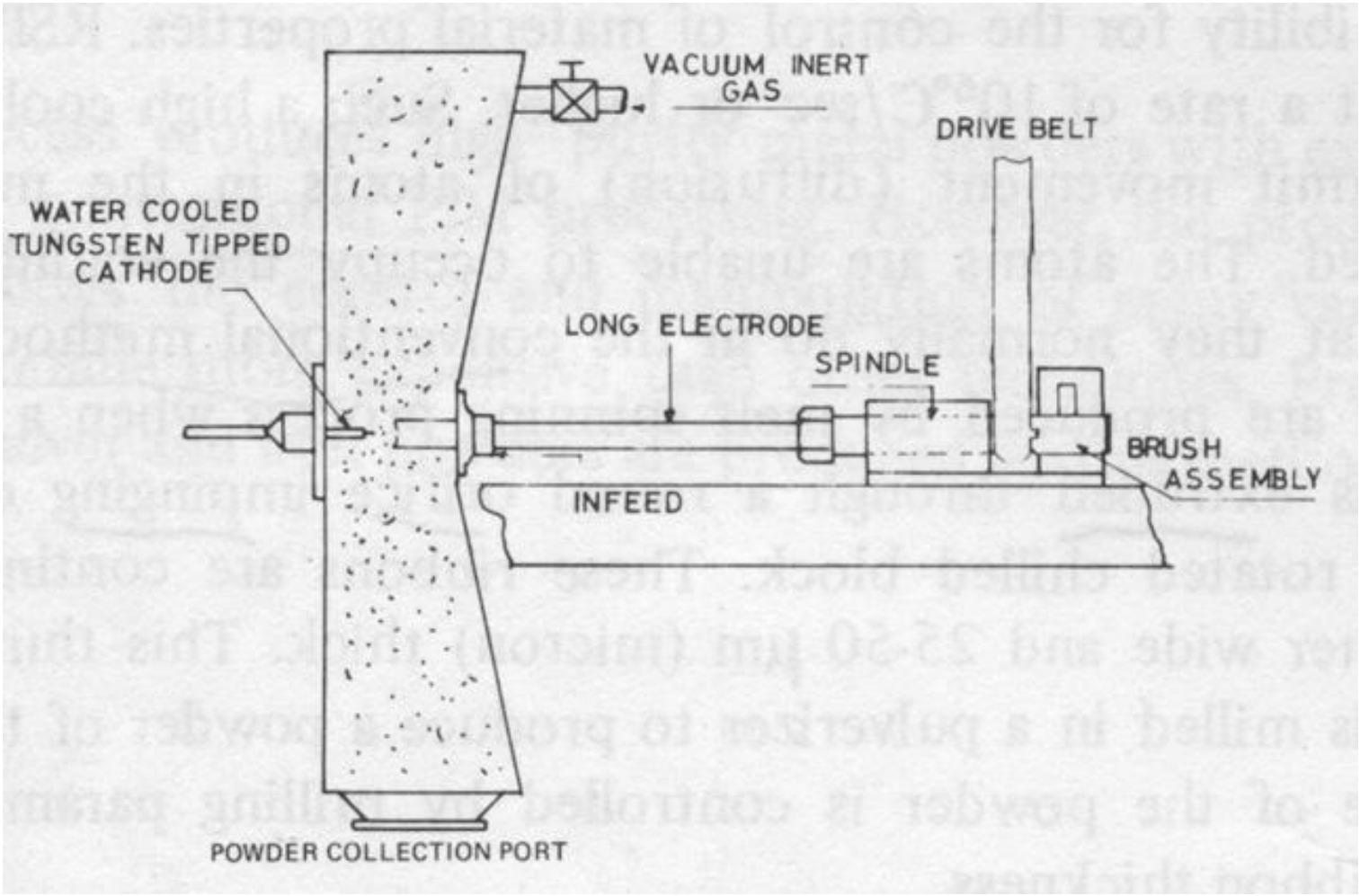
1. Short bar
2. Long bar

1. Short Bar Centrifugal Atomization



- In short bar apparatus a consumable electrode of 90 mm in diameter 200-250 mm in length is used.
- The anode is held in a collet of a precision spindle, the head of the spindle is projected into the tank through a fast rotating seal mechanism.
- Electrode stub عقب, removal and the introduction of new electrodes to the collet is done manually via a glove transfer port which is located in front of the machine adjacent to the cathode.
- Short bar methodology is appropriate for converting experimental quantities of materials specifically alloys that are inherently brittle, or materials that have low specific stiffness where an electrode of long aspect ratio is not practical.

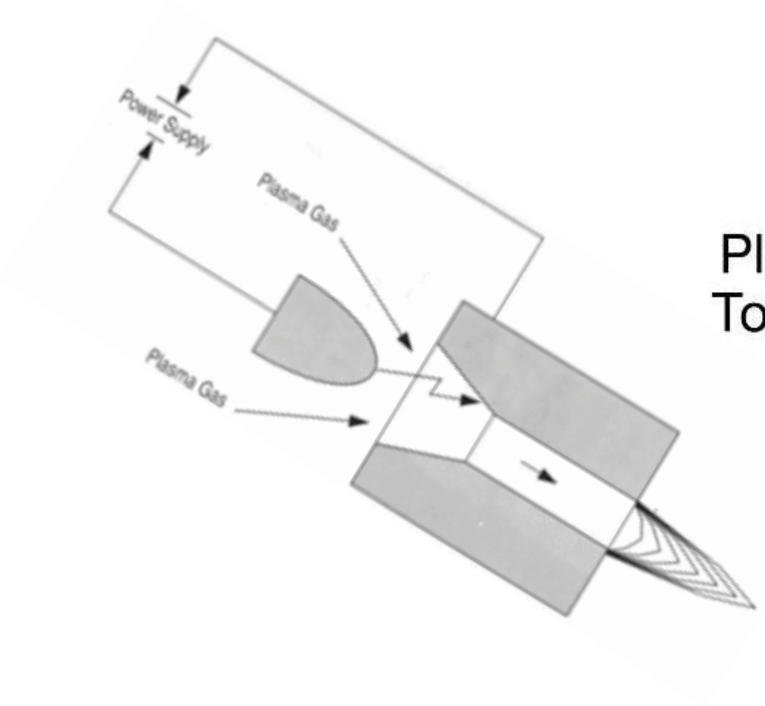
2. Long Bar Centrifugal Atomization

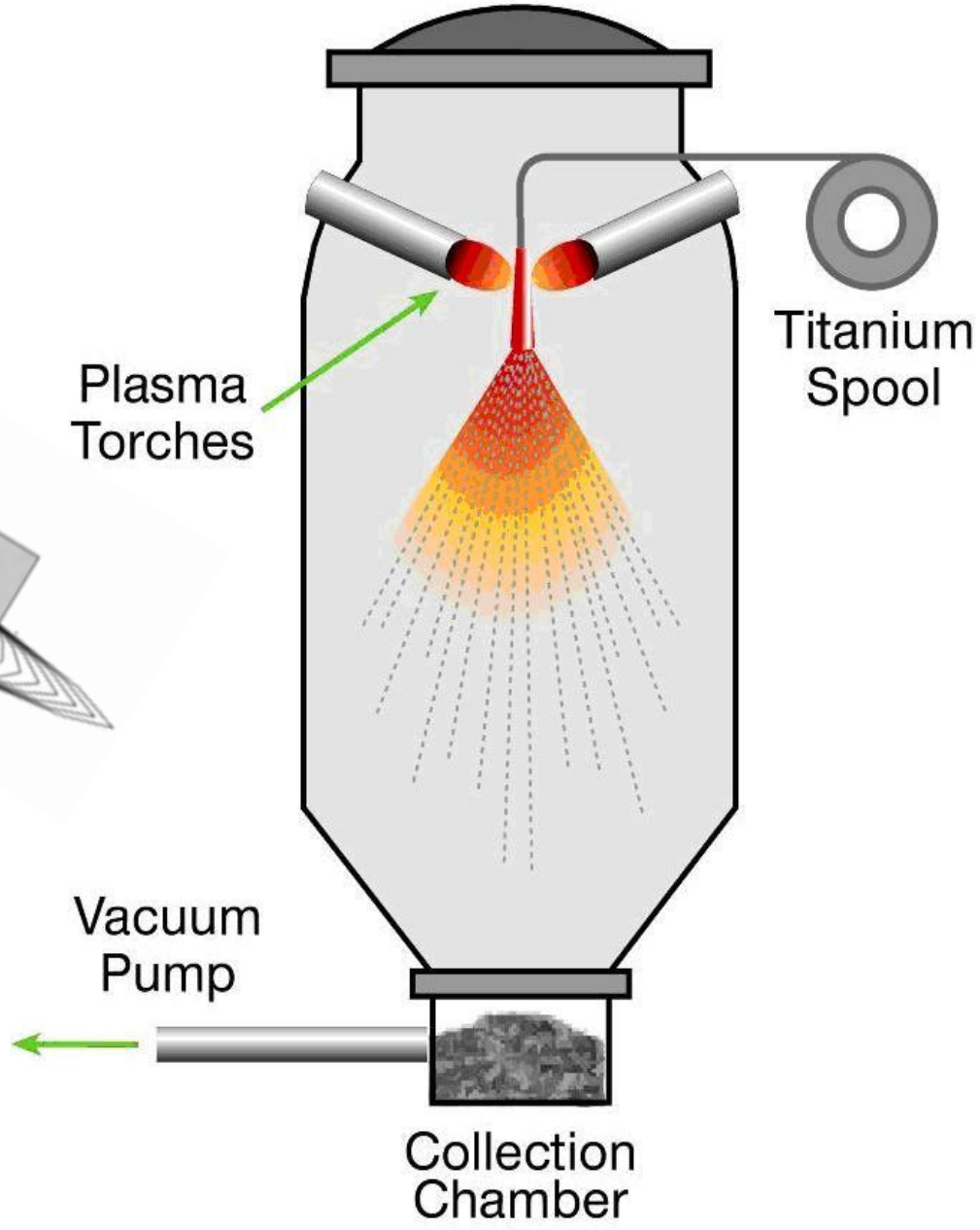


- Long bar apparatus is used to consume 60-65mm diameter and 1500- 1800 mm (length) electrodes.
- In this machine a precision spindle is mounted on a table that carries electrical drive mechanism outside the tank.
- The table moves towards the tank axially feeding the rotating electrode through special seal and bearing assembly.
- The rotation rate for long bar assembly is 15000 rpm. This rate is variable and is controlled by the machine operator who has to control the particle size and shape of the powder.

- The particle size is also dependent upon the surface tension of metal, electrode diameter and rotation rate.
- The shape of the particles is mostly spherical.
- Powders for photo-copying machines are being produced by this technique.
- Titanium and its alloys are being powdered by this method to suit it for near net shape compaction.
- Because this technique prevents contact of molten alloy or metal with any container material, hence the powder is produced with cleanliness.

iv. Plasma Atomization

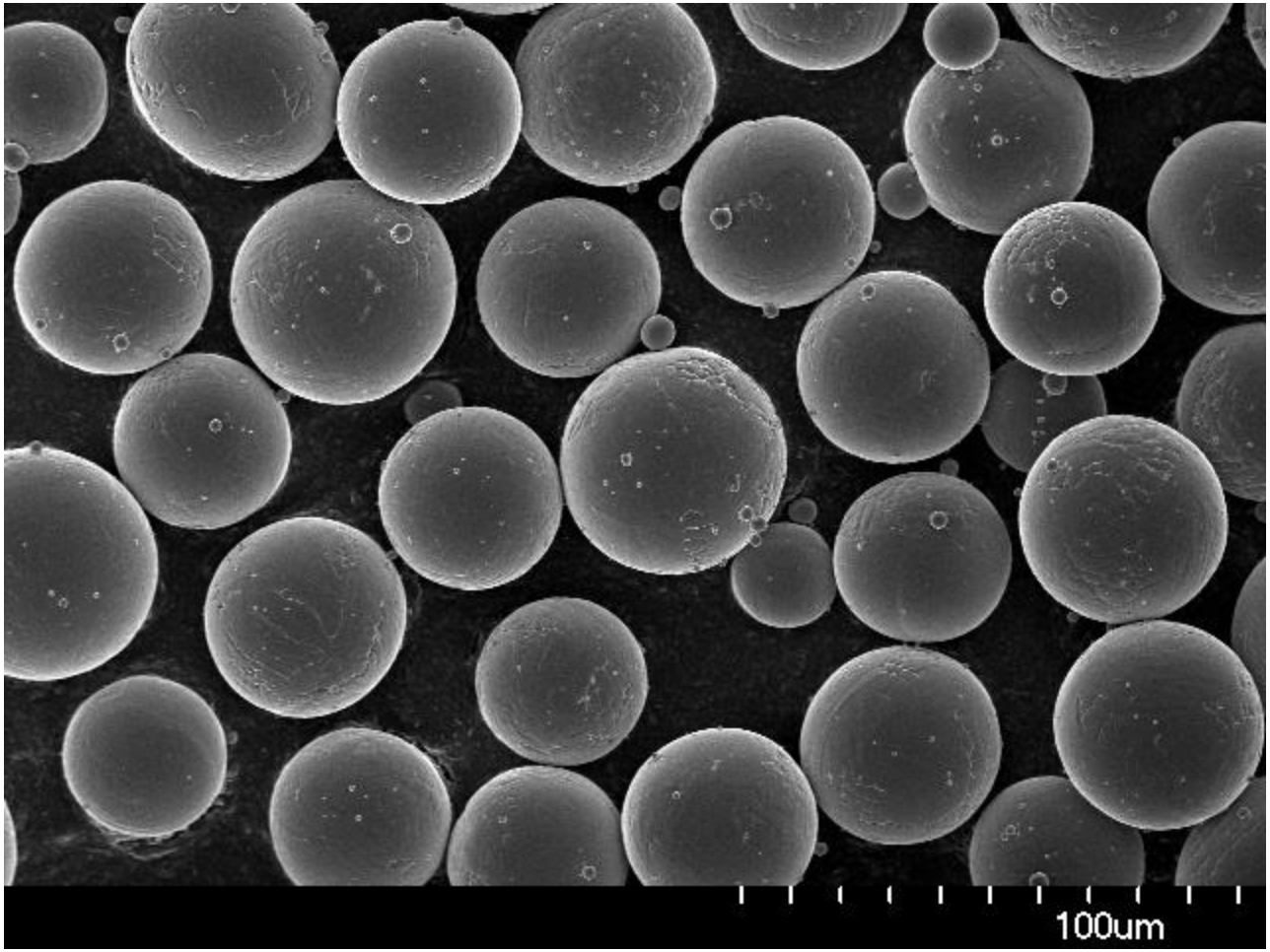




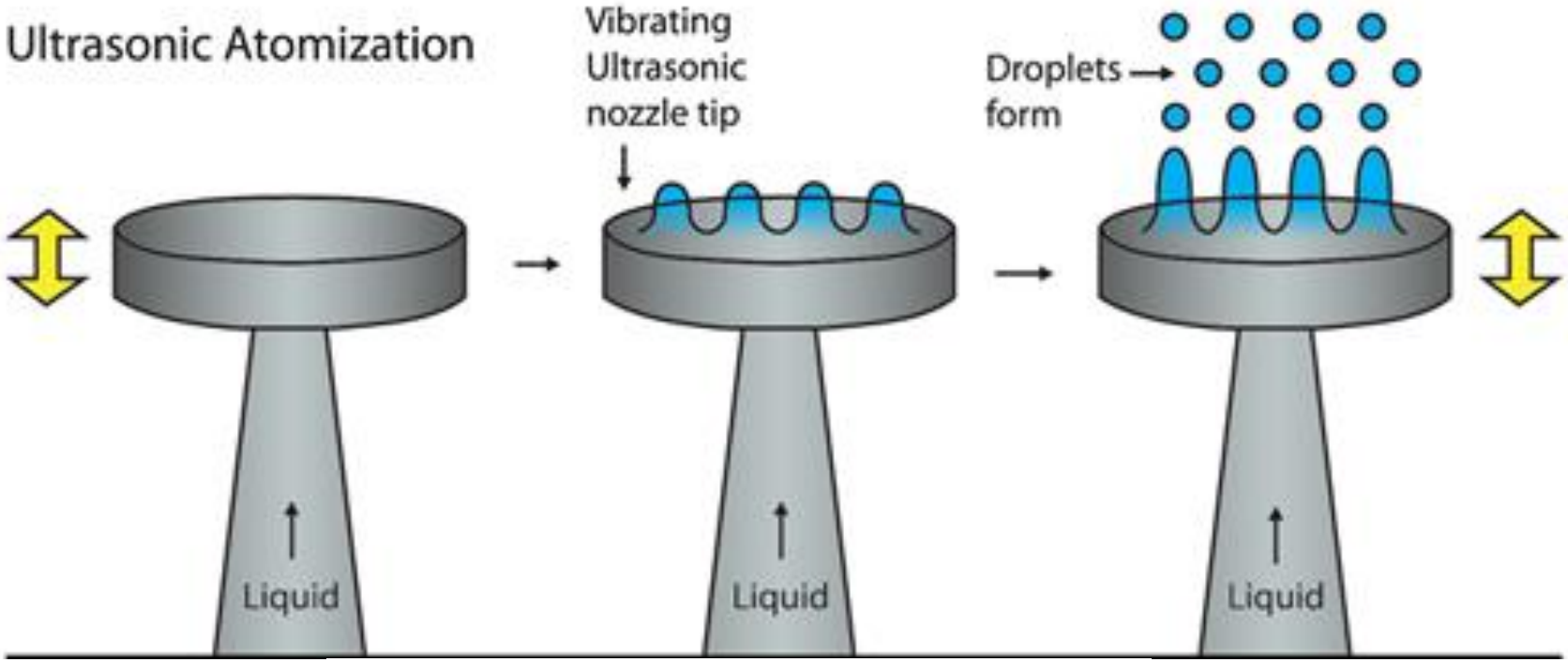
iv. Plasma Atomization

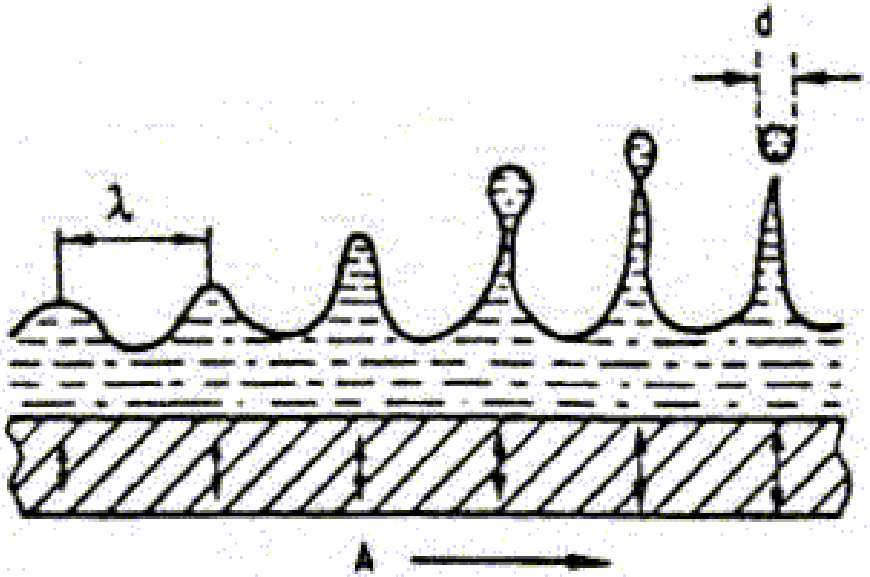
- Plasma Atomization produces premium quality spherical powders of reactive and high melting point materials such as titanium, nickel, zirconium, molybdenum, niobium, tantalum, tungsten and their alloys.
- Plasma Atomization offers the highest purity possible with the highly spherical particles
- Wire, rod or bar is fed into a plasma torch where melting and rapid acceleration of particles occurs.
- As a result of this rotation a fine powder is sprayed out of the torch.
- If the powder is provided a long flight path, a spherical shaped powder results.

- Plasma Atomization can produce powders of particle size distribution (PSD) ranging from 0 to 250 μm



v. Ultrasonic Atomization





- When a liquid film is placed on a smooth surface that is set into vibrating motion such that the direction of vibration is perpendicular to the surface, the liquid absorbs some of the vibrational energy, which is transformed into standing waves. These waves, known as capillary waves, form a rectangular grid pattern in the liquid on the surface with regularly alternating crests and troughs extending in both directions.
- When the amplitude of the underlying vibration is increased, the amplitude of the waves increases correspondingly; that is, the crest become taller and troughs deeper. A critical amplitude is ultimately reached at which the height of the capillary waves exceeds that required to maintain their stability. The result is that the waves collapse and tiny drops of liquid are ejected from the tops of the degenerating waves normal to the atomizing surface.

v. Ultrasonic Atomization

- Low Velocity Pressureless Spray
- Liquid is atomized into a fine mist spray using high frequency sound vibrations.
- Soft and low-velocity fine mist spray, typically on the order of 3-5 inches per second.
- Piezoelectric transducers convert electrical input into mechanical energy in the form of vibrations, which create capillary waves in the liquid when introduced into the nozzle.
- In coating applications, the unpressurized, low-velocity spray significantly reduces the amount of overspray since the drops tend to settle on the substrate, rather than bouncing off it.

Mechanical methods for powder production

- Cheapest of the powder production methods; These methods involve using mechanical forces such as compressive forces, shear or impact to facilitate particle size reduction of bulk materials; Eg: Milling
- Milling: During milling, impact, attrition, shear and compression forces are acted upon particles.
- During impact, striking of one powder particle against another occurs.
- Attrition refers to the production of wear debris due to the rubbing action between two particles.
- Shear refers to cutting of particles resulting in fracture. The particles are broken into fine particles by squeezing action in compression force.

Milling Objective

- Main objective of milling:

1. Particle size reduction (main purpose)
2. Particle size growth
3. Shape change
4. Agglomeration (joining of particles together)
5. Solid state alloying
6. Mechanical or solid state mixing
7. Modification of material properties.

Milling Mechanism

- Mechanism of milling: Changes in the morphology of powder particles during milling results in the following events.

1. Microforging
2. Fracture
3. Agglomeration
4. Deagglomeration

- Microforging => Individual particles or group of particles are impacted repeatedly so that they flatten with very less change in mass
- Fracture => Individual particles deform and cracks initiate and propagate resulting in fracture
- Agglomeration => Mechanical interlocking due to atomic bonding or vande Waals forces

- Deagglomeration => Breaking of agglomerates

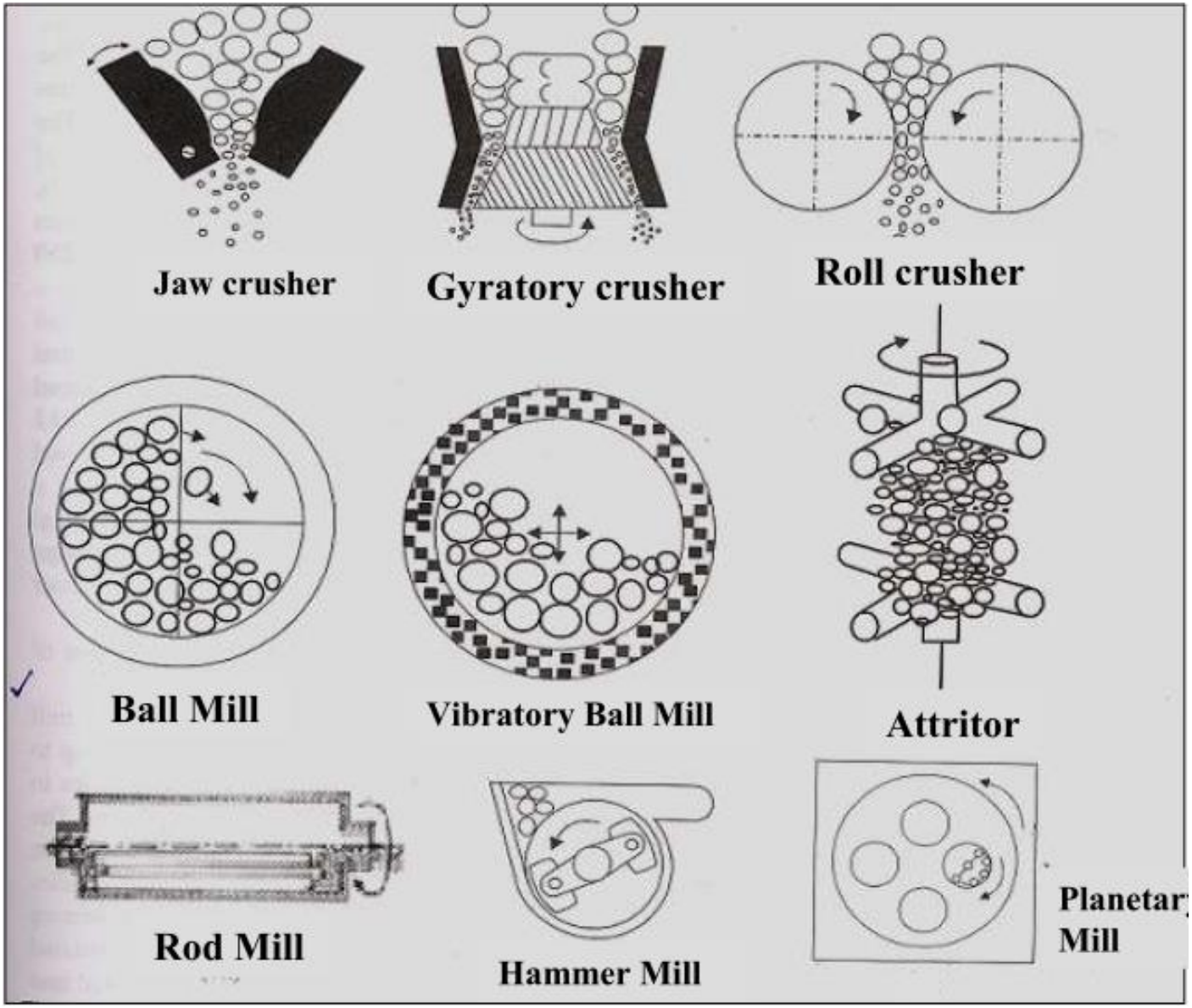
The different powder characteristics influenced by milling are shape, size, texture, particle size distribution, crystalline size, chemical composition, hardness, density, flowability, compressibility, sinterability.

Milling Equipment

The equipment are generally classified as crushers & mills

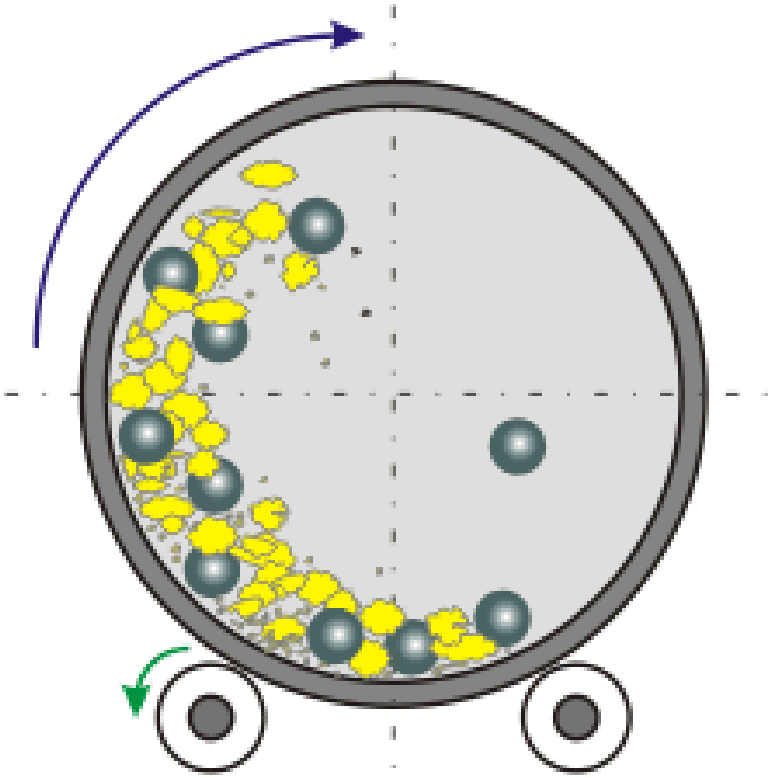
- Crushing => for making ceramic materials such as oxides of metals;
- Milling (grinding) => for reactive metals such as titanium, zirconium, niobium, tantalum

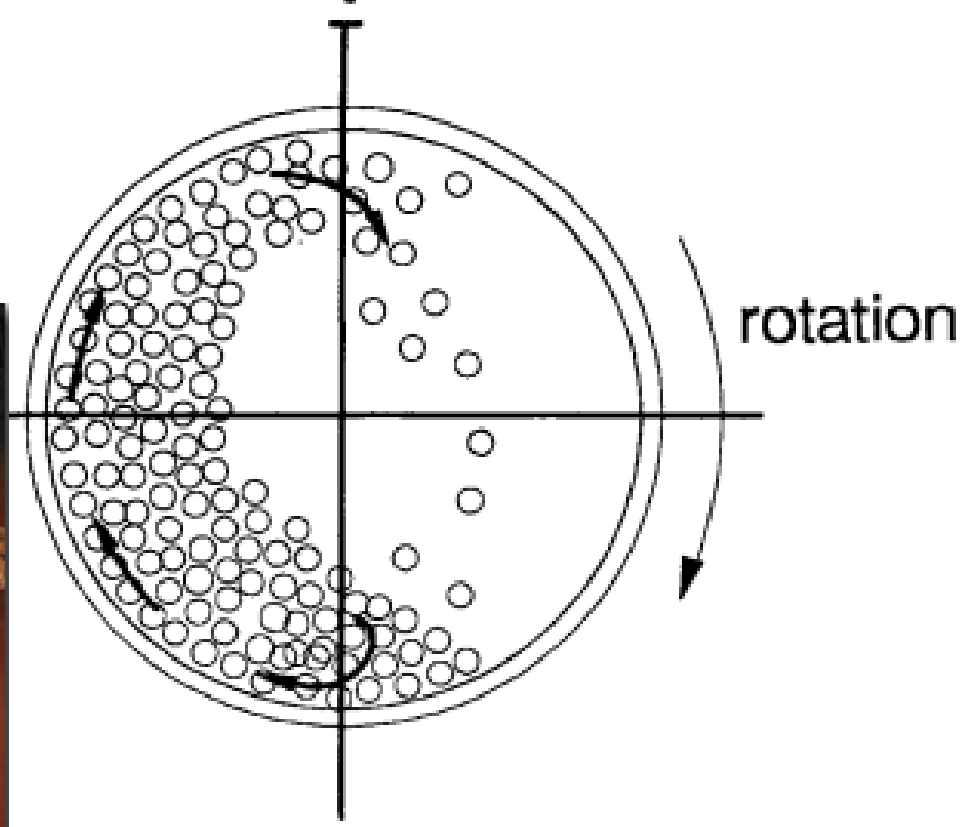
- Different types of grinding equipment/methods are shown in the figure



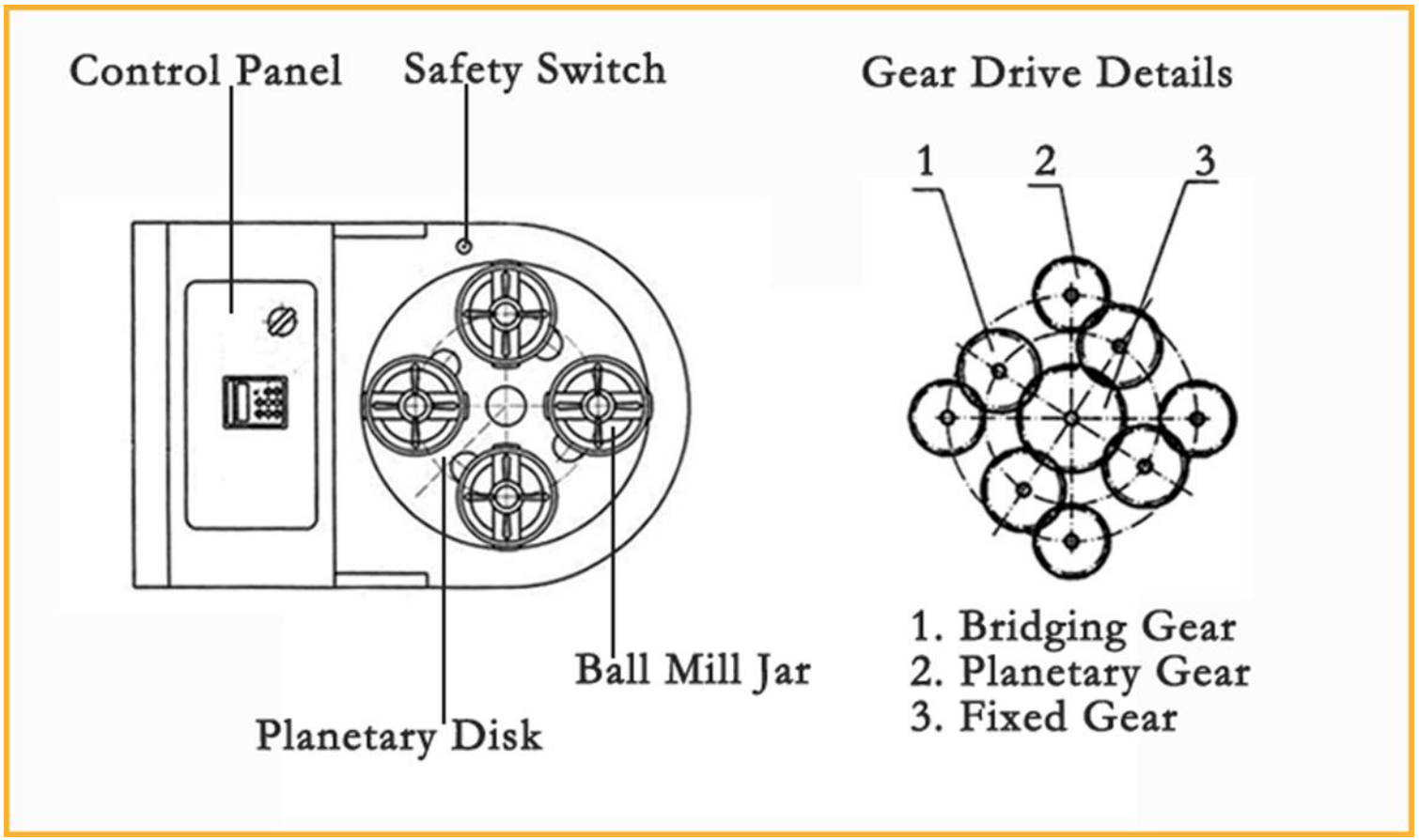
Ball Milling

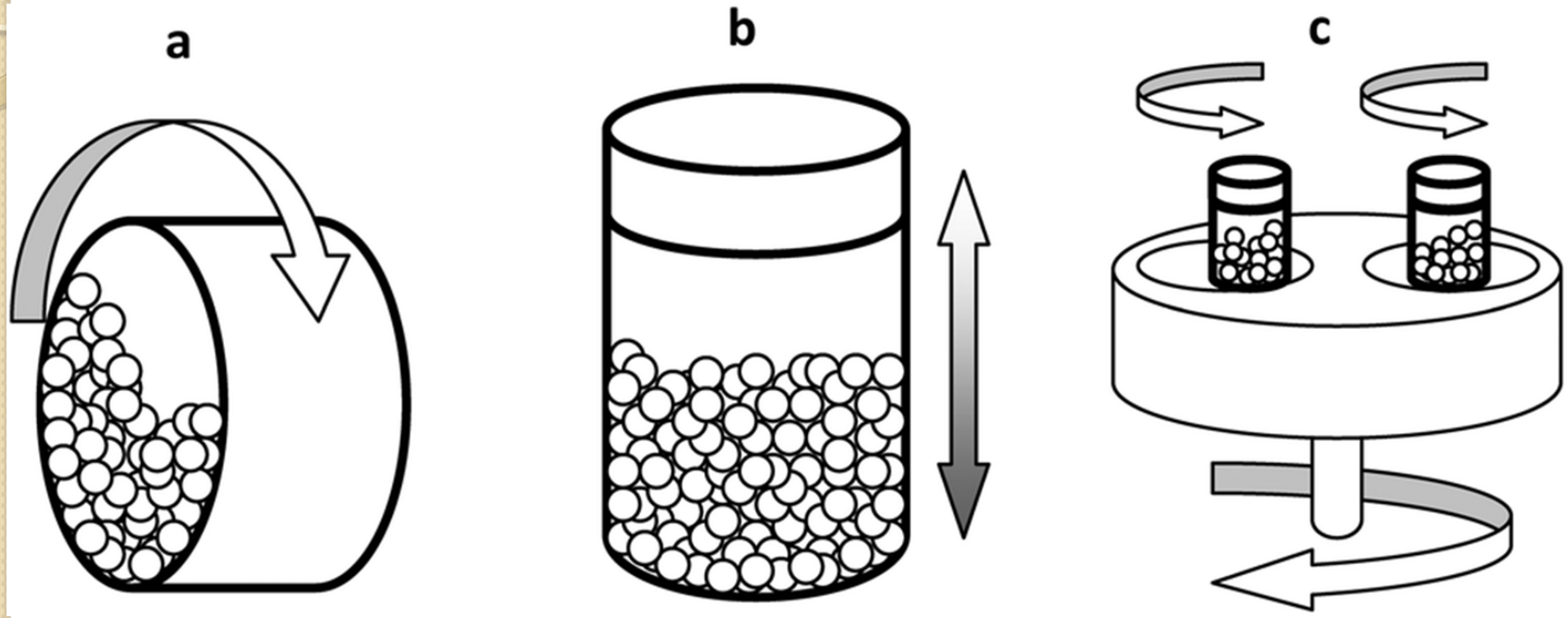
- This contains cylindrical vessel rotating horizontally along the axis. Length of the cylinder is more or less equal to diameter. The vessel is charged with the grinding media. The grinding media may be made of hardened steel, or tungsten carbide, ceramics like agate, porcelain, alumina, zirconia. During rolling of vessel, the grinding media & powder particles roll from some height. This process grinds the powder materials by impact/collision.
- Milling can be dry milling or wet milling. In dry milling, about 25 vol% of powder is added along with about 1 wt% of a lubricant such as stearic or oleic acid. For wet milling, 30-40 vol% of powder with 1 wt% of dispersing agent such as water, alcohol or hexane is employed.
- Optimum diameter of the mill for grinding powders is about 250 mm




rotation


Retsch
PM 200


Control Panel
Safety Switch
Ball Mill Jar
Planetary Disk
Gear Drive Details
1
2
3
1. Bridging Gear
2. Planetary Gear
3. Fixed Gear


a
b
c

Thank you