Ceramic Materials Manufacturing

Dr.Alaa Aladdin

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Ceramic Powder Compaction

A. Pressure compaction:

These techniques involve application of external pressure to compact the loose powder particles; Pressure applied directions can be uni-directional, bi-directional or isostatic.

1-Single ended and double ended compaction uniaxial) (hot pressing

Die pressing is a very widely used process for forming ceramics.

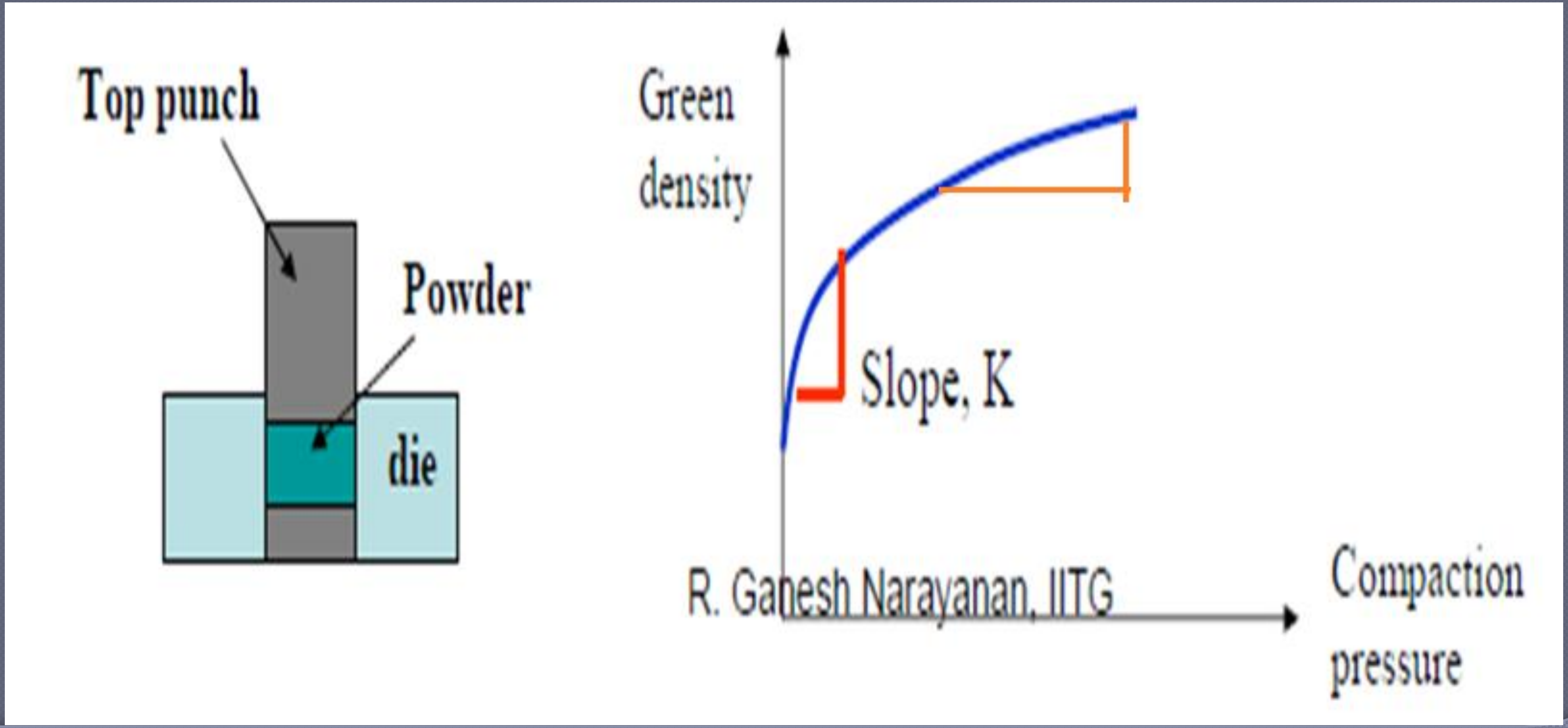
It is suitable for both fine and coarse grained ceramics.

Die compaction: In this process, loose powder is shaped in a die using a mechanical or hydraulic press giving rise to densification.

The mechanisms of densification depend on the material and structural characteristics of powder particles.

- Unidirectional and bidirectional compaction involves:

i) Charging the powder mix
ii) Applying load using a punch (uni-) or double punch (bi-) to compact powders,
iii) Removal of load by retracting the punch,
iv) Ejection of green compact.



The table gives compaction pressure ranges for metals and ceramics.

Metals	
Aluminium	70–275
Brass	400–700
Bronze	200–275
Iron	350–800
Iron-copper (2%) premix	600–720
Tungsten	70–140
Ceramics	
Alumina	100–140
Carbon	140–160
Hard metals	150–400
Magnetic ceramics (ferrites)	110–165

- Effect of powder characteristics For a good compaction:

1) Irregular shaped particles are preferred as they give better interlocking and hence high green strength,
2) Apparent density of powders decides the die fill during compaction. Hence powder size, shape & density affect the apparent density,
3) Flow rate affects the die fill time, and once again powder size, shape & density affect the flow rate.

- Powder behavior during compaction

1) flow of powder particles past one another interacting with each other and with die-punch, wall

2) deformation of particles.

In the case of homogeneous compaction, two stages are observed.

- Compaction involves:

First stage => rapid densification occurs when pressure is applied due to particle movement and rearrangement resulting in improved packing;

Second stage => increase in applied pressure leads to elastic and plastic deformation resulting in locking and cold welding of particles.

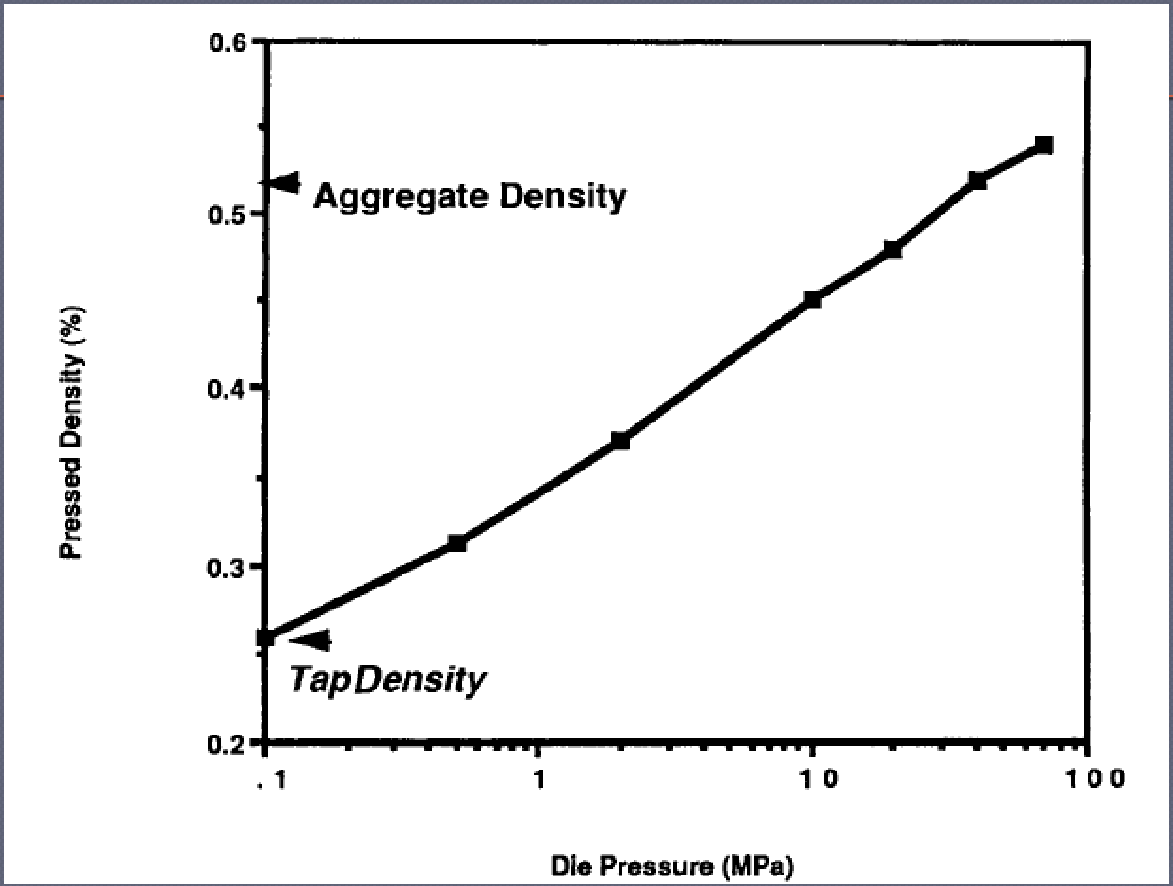
In the second stage, large increments in pressures are seen to effect a small increase in density.

The green compact produced can be considered as a two-phase aggregate consisting of powder particles and porosity each having own shape and size.

- Compaction can be done at low and high temperatures:

Room temperature compaction employs pressures in the range of 100-700 MPa and produce density in the range of 60- 90% of the theoretical density.

At higher temperatures, pressures are kept low within the limits for preventing die damage.



aggregate density and tap density

- **In single die compaction:**

powders close to the punch and die walls experience much better force than in center.

This results in green density variation across the sample length. Longer sample mains more the density difference. This non-uniformity can result in non-uniformity in properties of sintered part.

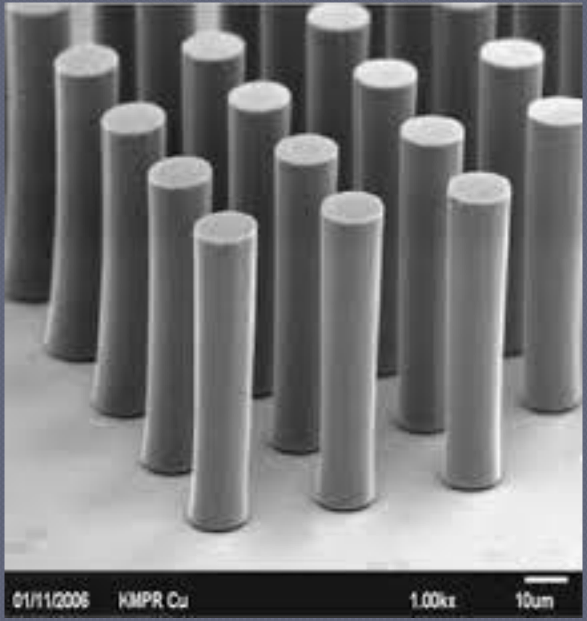
- This density variation and hence final property variation can be greatly reduced by having double ended die compaction.

In this case, (double ended die compaction) powder experiences more uniform pressure from both top and bottom, resulting in minimization of density variation.

But this variation will still be considerable if the components have high aspect ratio (length to diameter ratio).

This means that long rods and tubes cannot be produced by die compaction.

For this case, isostatic pressing can be used.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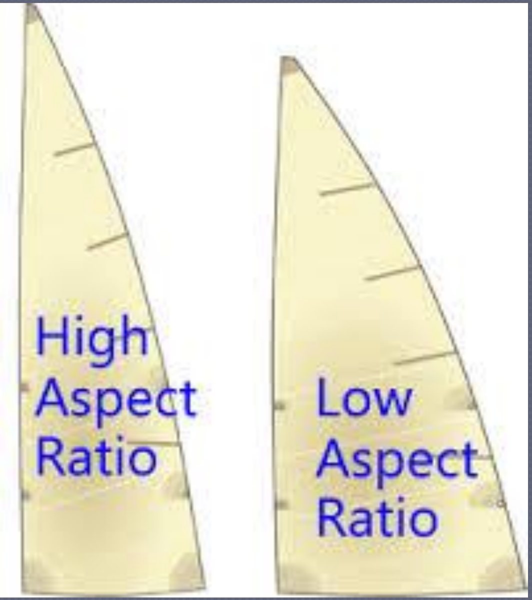
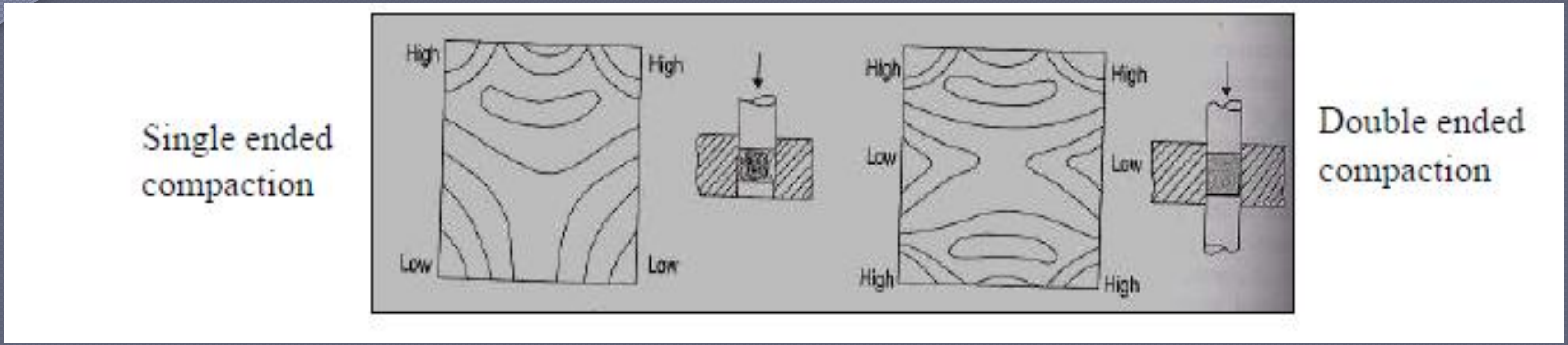
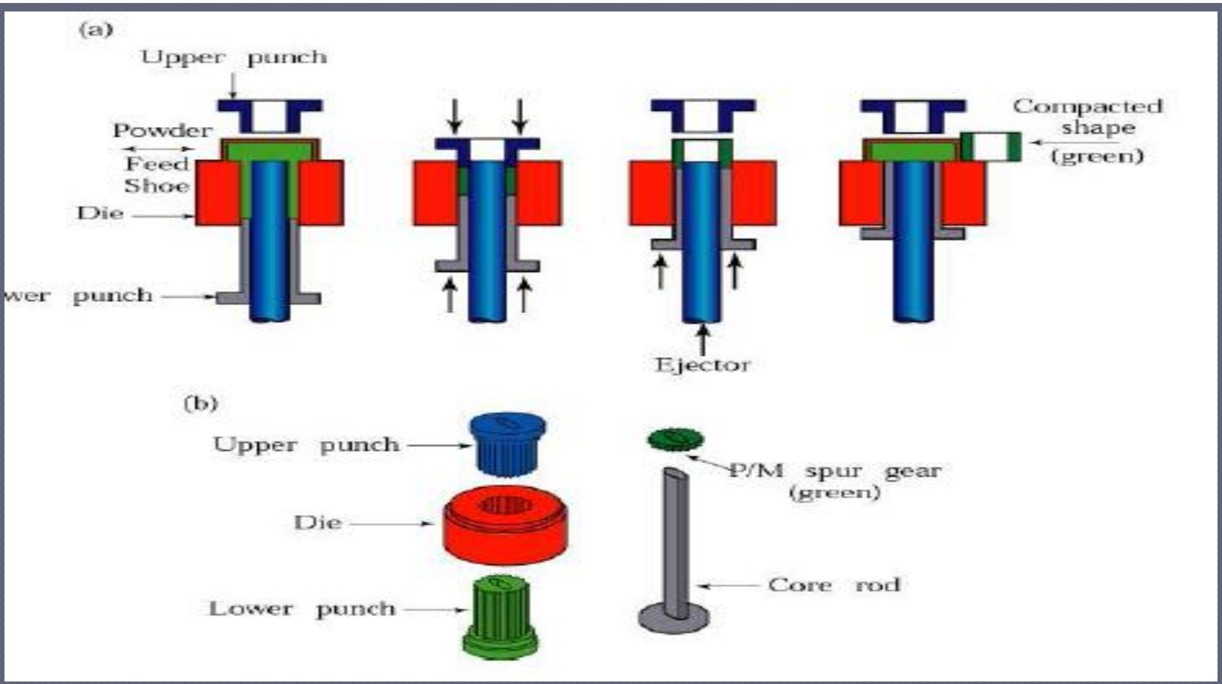
KMPR Cu
1.00kx
10um


High Aspect Ratio
Low Aspect Ratio





same number of stages and are described in this figure.

Die compaction lubricants

- It is known that presence of frictional forces limits the degree of densification.

- Usage of lubricants either mixed or applied to contact surfaces can be done to minimize friction.

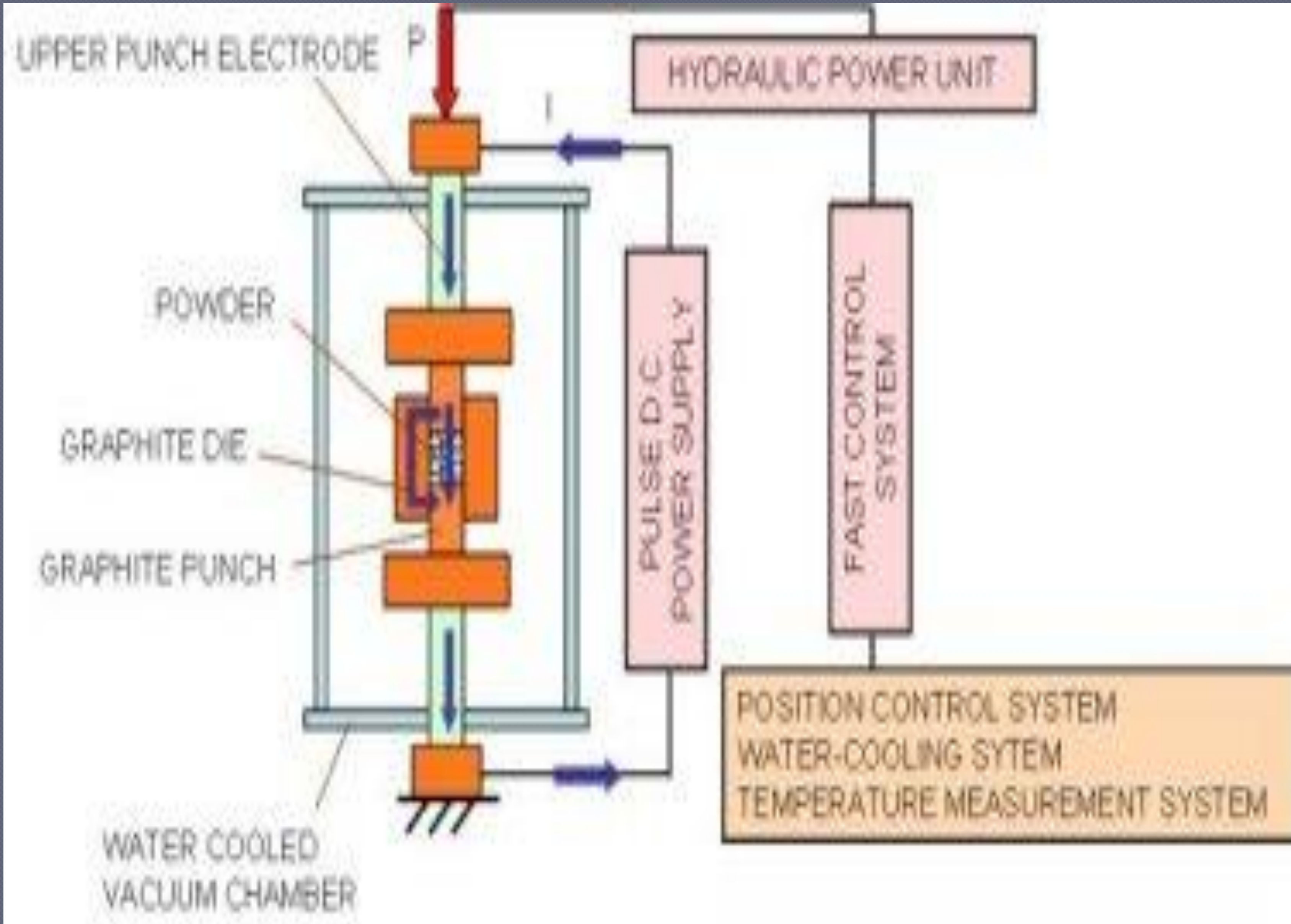
- Lubricants => organic compounds :waxes or metallic compounds :salts and they generally have low boiling point; Amount of lubricant added can be 0.5 to 2 % by weight of charge.

- Mixed lubrication => Reduce the inter particle friction and aid better packing. But they may affect the densification property depending on their volume and density. The mixed lubricants should be removed before sintering to avoid distortion of compact.
- Even 1 wt% of lubricant can occupy large volume of app. 5% and maximum attainable density will be 95% (assuming zero porosity) only.

- Die wall lubrication => Graphite & MoS_2 can be applied physically on the die, punch surfaces; They can be easily removed, but takes longer production times.

Die materials

Soft powders like Aluminum, copper, lead => abrasion resistant steel such as air hardened steels, die steels are used for making die .Relatively hard powders => dies made of tool steel is used. More hard & abrasive powders like steel => tungsten carbide dies are used. But carbide dies are costly & high hardness (difficult to machine) .Coated dies with hard & wear resistant coating material like titanium nitride or titanium carbide can be used.


UPPER PUNCH ELECTRODE
P
I
HYDRAULIC POWER UNIT
POWDER
GRAPHITE DIE
GRAPHITE PUNCH
PULSE D.C. POWER SUPPLY
FAST CONTROL SYSTEM
POSITION CONTROL SYSTEM
WATER-COOLING SYTEM
TEMPERATURE MEASUREMENT SYSTEM
WATER COOLED VACUUM CHAMBER

Isostatic pressing

cold isostatic pressing (CIP) ,hot isostatic pressing (HIP)

Cold isostatic compaction (CIP)

- CIP is a compaction process in which isostatic fluid pressure is applied to a powder mass at room temperature to compact it into desired shape.

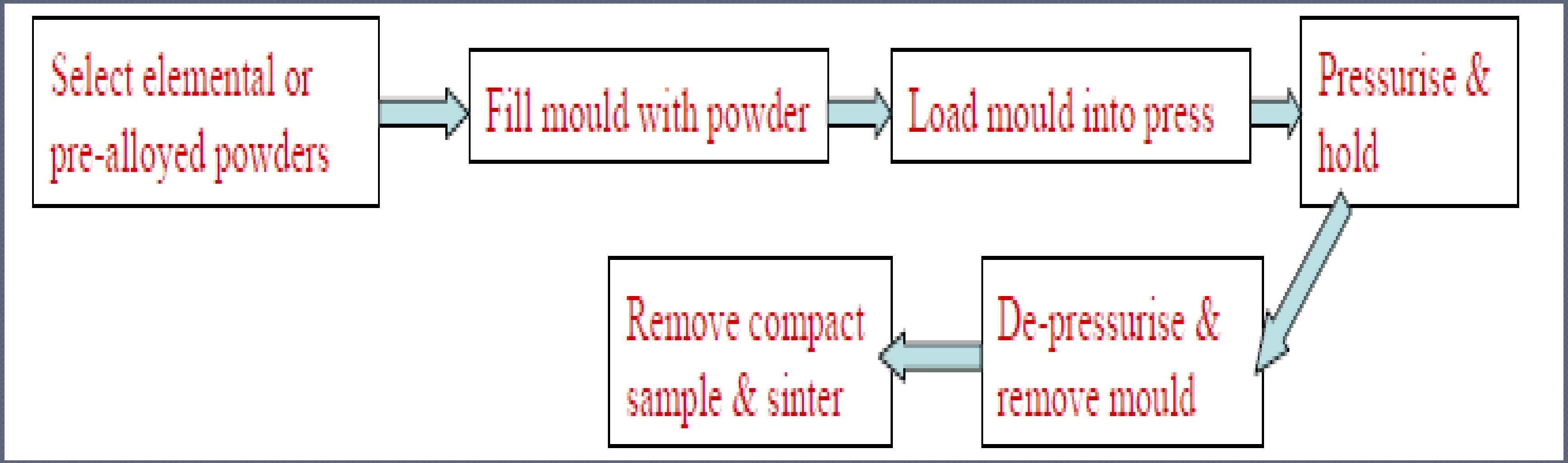
The powder parts can be compacted up to 80-90 % of their theoretical densities.

Water or oil can be used as pressuring medium.

- Process details: High density near-net shape green parts, long thin walled cylinders, parts with undercuts can be readily fabricated.

In this process, pressure is applied together and equally in all directions using a fluid to an elastomeric fluid with powder at room temperature.

Sintered CIP component can reach up to 97 % of theoretical density. Steps in this process is shown in flowchart.


Select elemental or pre-alloyed powders
Fill mould with powder
Load mould into press
Pressurise & hold
De-pressurise & remove mould
Remove compact sample & sinter

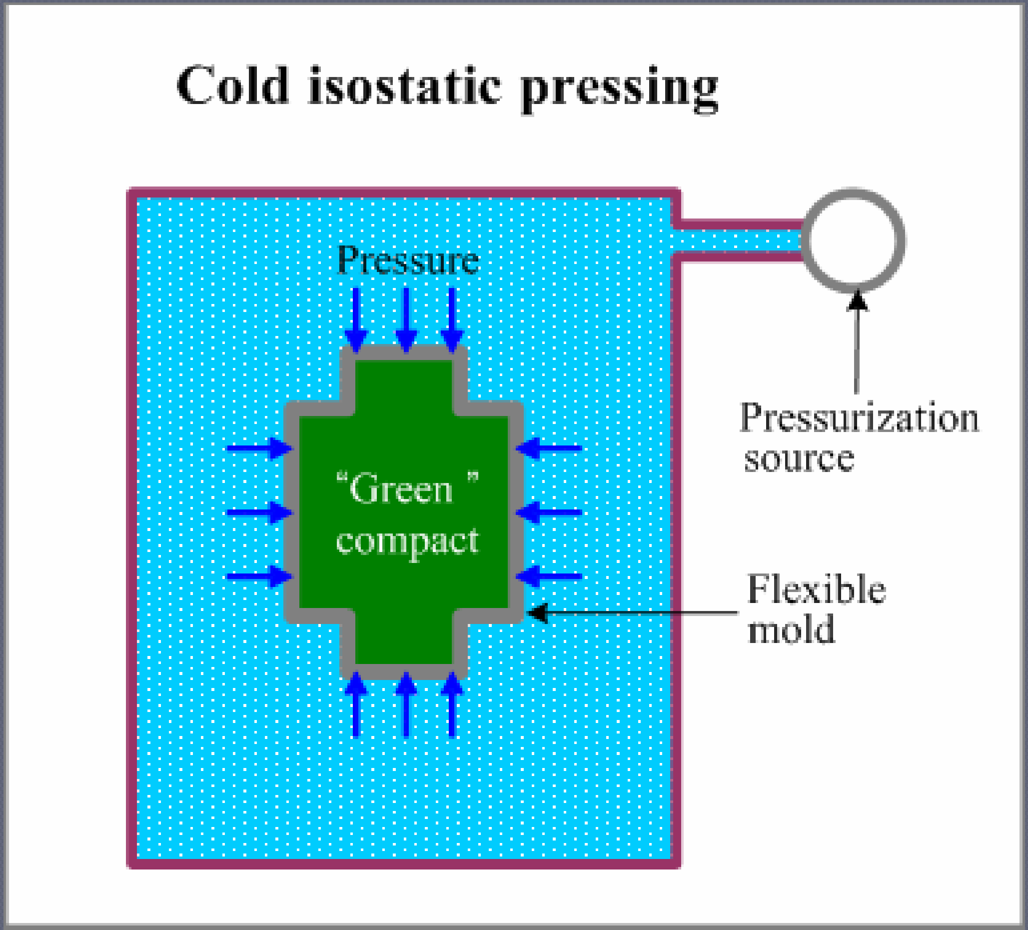
Good mould filling is required in CIP because the initial powder distribution and density affect the perform shape.

Powder size, shape, density and mechanical properties affect the flow-ability of powder into the mould and the packing density.

Optimum pressing is obtained by using a free-flowing powder along with controlled vibration or mould tapping.

Materials used for flexible moulds are natural, synthetic rubber like neoprene, urethane, silicones.


Cemented carbide products
Parts Produced from isostatically pressed graphite
Long refractory nozzles and stoppers
Metal filters produced to net shape
High voltage ceramic insulators
Molybdenum billets weighing approx. 1000kg


Cold isostatic pressing
Pressure
"Green"
compact
Pressurization
source
Flexible
mold

During pressing, high density is achieved at a low pressure, while the green strength of the compact rises linearly with pressure.

The pressure applied can range from 100- 400 MPa.

Initially the applied stress (exactly shear stress) serves to improve the density of the compact by particle sliding and rotation. In the next stage, deformation of powder particles occur and particle characteristics like shape play vital role in deciding this stage.

- Irregular particles which interlock with one another and also deform during both the stages, tend to densify much easily than spherical powders.

In the case of spherical powders, in spite of their higher initial packing densities, particles do not mechanically interlock with one another and hence do not easily deform.