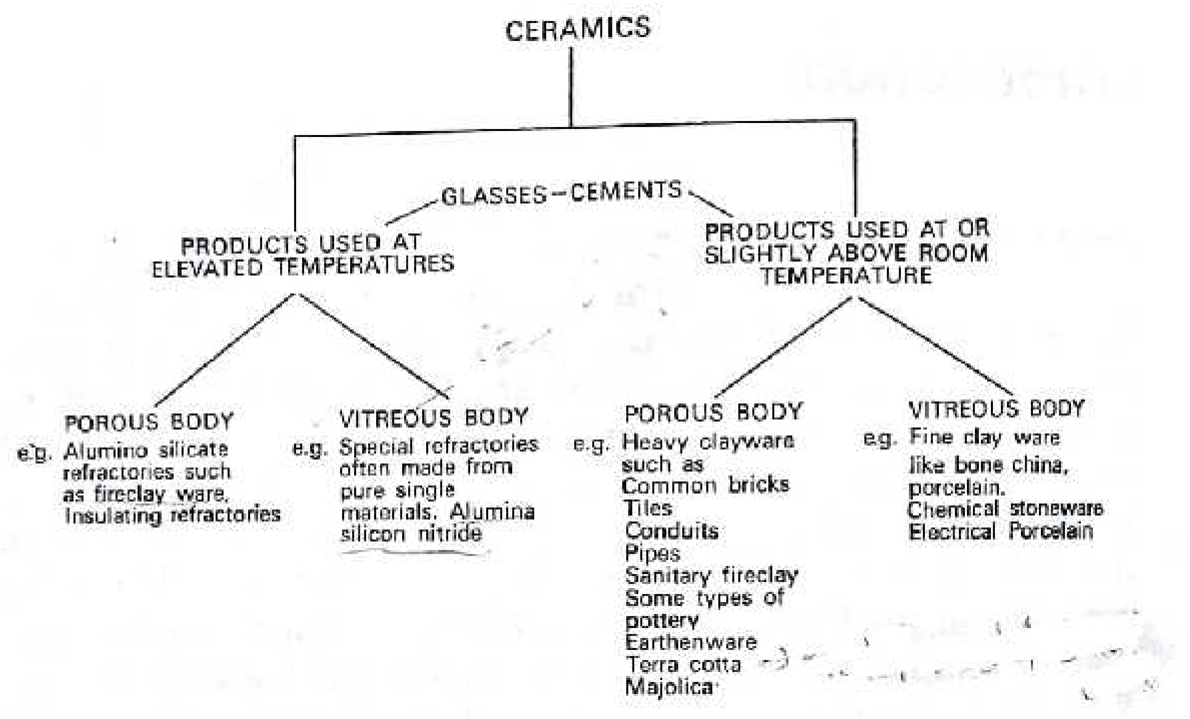
Ceramic Whitewares Technology-1
Unit 1

Syllabus covered: Introduction and classification: Division and brief history, scope and division of Pottery, Terracotta, Earthen ware, Stone ware, Porcelain ware.

1.1 Ceramics: Ceramics are the materials which are made from earthy deposits which are in organic and non metallic in nature. These are first shaped and then fired at high temperature to give them maturity and strength. OR

Ceramics may be defined as a product manufactured by heat treatment of a material (or mixture of materials) which is inorganic and non-metallic.

1.2 Classification of Ceramics Products:



Ceramic Body: It covers two things

i) Mixture of raw materials prepared for making any product

ii) Main part of the product (without glaze)

1.3 White ware:

It is defined as the product which is fired at high temperature and has fine texture. These can be glazed or unglazed. White ware products are generally white in color, have smooth finish and elegant appearance.

These wares are made from pure raw materials and fired at high temperature to give sufficient maturity and strength. Ceramic white wares products include

i) Heavy clay wares:-

Heavy clay wares are those ware which are made from raw materials easily found in nature and which need no or minimum processing before use.
For example:- Bricks, tiles, sewer pipes etc. These have coarse texture structure.

ii) Fine ceramics:-

As per Norton (1970)"Fine ceramics wares are those wares which have controlled and fine structure. The wares may be glazed or unglazed.

1.4 Brief History

Ceramics are the materials which are made from earthy deposits which are inorganic and non metallic in nature. These are fired at high temperature.

Earlier ceramic products were regarded as any article made wholly or partly from clay. These products were shaped and fired at high temperature to produce high strength. The word Ceramics was derived from Greek word keramos which means art of potter.

Several thousand years B.C. the samples of pottery were found in excavations in Egpyt, Asia minor, Crete and Greec. The word pottery is still used for some sections of the Ceramic Industries.

Samples of crude pottery was found on the Tigris of Selencia in near about 7000 B.C.

Glazed pottery has been found dating from 5000 B.C. These were mainly soft, low burnt and fragile.

In early centuries of A.D. high temperature firings were under taken by Chinies. These wares were more rugged and can be said to be of the stoneware type. This results in developments of earthenware to stoneware.
Near 15th century the stone ware was made in England by use of purer clays to make grayish-white body. It was mostly salt glazed.
Around this time vitrified mares made in China which was similar to stoneware. At this time variety of feldspathic glazes were also used. The composition was kept secret.

In the early 17th century Chines porcelain was attempted to made in Euorpe, especially in Germany. This was made by using Kaolin, flint and feldspar. This leads to setting up of many factories of whitewares in Europe.

In India pottery signs were found during excavations of Mohenjodaro and other places. Modern Whiteware plants were started by following footsteps of European manufacturers.

In India clay was used to make different wares. These are around 4000 years old. In our country these wares were generally red, black and brown in colour.These wares were not glazed. However galzed pottery started recently.
In the late 19th and early 20th century earthen wares and terracotta plants developed of its own in certain regions. It is believed that discovery of china clay in the Rajmahal hills in

Bihar leads to setting up of first factory of fine earthenware in Gwalior in 1858 and in 1860 in Calcutta.

1.5 Classification of white wares: White ware can be classified based on

1.5.1 Physical properties
1.5.2 Nature of firing & composition 1.5.3 According to use or application of the ware.

1.5.1 Classification based in the physical properties:- Ceramic white ware can be classified based on the physical properties such as porosity or water of absorption as follows:

Classification according to absorption

Class	% Absorption	Translucency
Earthenware	4-20%	None
Stone ware	1-5%	Negligible
China ware	0-2%	Usually good
Porcelain	0-0.5%	Moderate to Good
Technical Ceramics	0-0.05%	---

1.5.2 Classification based on nature of firing and composition

Sr. No.	Class	Nature of firing	Usually Composition
1	**Earthen ware**	High biscuit firing, Low glost firing	Single clay, Multiple clay, Triaxial body, Talc body
2	**Stone ware**	Mostly single fired	Same as above but fired at low
3	**China clay**	High biscuit firing, Low glost firing	Triaxial body, high bone ash, glassy flux
4	**Porcelain ware**	Low biscuit firing, High glost firing or Single fired	Usually Triaxial with special additions, steatite, zircon, alumina.
5	**Technical Ceramics**	Pre- sintered, pre calcined, high fired, fired and annealed, controlled and special firing	Triaxial composition, use of special and synthetic raw materials

1.5.3 Classification of ceramic wares based on use:

Sr. no.	Place of use/ Application	Types of ware	Typical composition
1	**Ceramic at Home**	Table ware including dinner ware and hotel war, Art ware, container ware, kitchen ware/flame resistant.	Triaxial, earthen ware, china ware, stone ware, porcelain ware, bone china.
2	**Ceramic in Constructions**	Sanitary ware, floor & wall tiles, low tension insulator.	Mostly Triaxial porcelain and earthen ware
3	**Ceramic in Electrical**	1) Low tension insulator 2) High tension insulators, high frequency & low loss insulators.	1) Mostly Triaxial single fired stoneware and porcelain. 2) Same with pure raw materials Steatite/ zircon and other special composition
4	**Ceramic in industrial use**	1) Abrasion resistance, Chemical Resistant & heat resistant	1) Hard porcelain, alumina, Zirconia composition 2) Mullite, cordierite compositions

1.6 Divisions of pottery

Whiteware is further classified as earthenware, stoneware, chinaware, porcelain, and technical ceramics.

1.6.1 Terracotta It is Italian word which means baked clay. This class include those materials which are made from simple clay and are fired at low temperature. These wares are generally red in colour and are made without glaze.
These wares have porosity more than 8%
Examples : Red bricks used for construction of buildings, roofing tiles, water pots etc.

1.6.2 Earthenware is defined as glazed or unglazed non vitreous (porous) clay-based ceramic ware. These wares are made from white clay or simple clay. These wares have porosity less than 8% and have less strength. The impact strength is from 0.2 – 0.22 Nm.
These are made at low temperature and cooled slowly. Sand and crushed pottery is added to prevent/ reduce shrinkage during drying and firing. These wares are glazed to make them impervious, to make them resistant to acids and other atmospheric agents.
Applications for earthenware includepartition blocks, cable conduits, artware, kitchenware, ovenware, tableware, and tile.
It is also known as semi-vitreous dinnerware which is porous, non-translucent and soft glaze.

1.6.3 Stoneware It includes those wares which are made from white clay and also have glazed on it. These are vitreous or semivitreous ceramic ware of fine texture, made primarily from non refractory fire clay or some combination of clays, fluxes, and silica that, when fired, has properties similar to stoneware made from fire clay.
These wares have water of absorption less than 3% and have low porosity. The impact strength is around 0.28 Nm. These wares are impervious and hence are resistant to acids and corrosive liquids.

Applications for stoneware include artware, chemicalware, cookware, drainpipe, kitchenware, tableware, tile, stoneware pipes for sanitary applications such as sewer pipes, drain pipes, guelly traps, wash basins.
They are the oldest ceramic wares which is used before porcelain. It is known as crude porcelain but its raw materials are of poor grade and not well fabricated.

1.6.4 Sanitary ware It was made from clay which is porous but nowadays vitreous composition is used. Prefired and sized vitreous grog is include with triaxial composition.

1.6.5 Chinaware is vitreous ceramic ware of zero or low absorption after firing that are used for Non-technical applications. Applications for chinaware include art ware, ovenware, sanitary ware, and tableware.
It is a vitrified translucent ware with a medium glaze which resists abrasion and used for non-technical application.
These wares have porosity less than 0.5%. These wares are white in colour, opaque and have impact strength between 0.22 to 0.5 Nm.

1.6.6 Porcelain is defined as glazed or unglazed vitreous ceramic ware used primarily for technical purposes. Applications for porcelain include art ware, ball mill balls, ball mill liners, chemical ware, insulators, and tableware.
These wares are made from pure china clay, quartz and feldspar. Porcelain have fine texture. Grains are closely packed. These wares have good strength, good translucency. These wares have very low porosity and hence are non porous.
It is vitrified translucent ware with a hard glaze which resists abrasion to a maximum degree and may include chemical, insulating and dental porcelain.

1.7 Scope of pottery

- Pottery skilled person can work in large factory or workshops.
- They can start holding exhibitions, displaying potteries in shops, can work with interior designer or architect.
- Can start own business i.e. entrepreneur.
- There is scope of teaching in school and colleges.
- In industries workshops can be conducted.
- The pottery manufacturers can supply crockery and earthenare to five star hotesl and restaurants.

Unit –II Raw Materials

Syllabus covered: Introduction to raw materials: Naturally occuring raw materials-Clay, Quartz, Napthelene cyanide, Talc, Sillimanite, Kyanite, Andalusite, Zircon, Bone-ash, Gypsum, Plaster of Paris, Synthetically prepared materials-Alumina, Zirconia, Beryllia.

2.1 Introduction to raw materials

Definition:- Raw materials are starting materials used for the preparation (or composition) of body and glaze of the ware. All materials are not raw materials. Examples all material are not found in their original condition as found in nature.

Raw material can be divided into four groups:-

2.1.1. Naturally occurring raw material.
2.1.2 Specially treated or synthetically prepared materials
2.1.3 Chemicals
2.1.4 Binders and lubricants

2.1.1 Naturally occurring raw material

These are those materials which may or may not be treated before use. Some treatment given to materials include beneficiation, purification, etc.

Untreated fire clay and plastic are used as such in sanitary ware and electrical insulators. Beneficiation is done to materials such as steatite or talc, pyrophillite, etc .These material are ground, sieved and sometimes foreign materials are removed for hand picking.

Fully beneficiation (or treated) material is china clay. The china clay is separated from other minerals by washing, decantation,elutriation, magnetic separation, etc

2.1.2 Specially treated or synthetically prepared materials

These materials are not found in their original condition as found in nature.

Examples of such materials are alumina, sodium free alumina and activated alumina. Alumina is prepared by Bayers process. In this process alumina is calcined to form α-alumina and is ground to fine powder.

2.1.3 Chemicals These are mainly used in glazes for their purity

The various chemicals used are

i) precipitated calcium carbonate (chalk), magnesium carbonate, zinc oxide (sometimes calcined) used in porcelain glazes and Bristol type glazes

ii) Lead compounds (red lead, litharge) used in raw or fritted glazes.

iii) Boron compounds (borax and boric acid) used in fritted glazes.

iv) The chemicals such as sodium carbonate and sodium silicate are widely used as deflocculants in casting slips. These are mostly used to control rheological behaviour of tri-axial compositions.

v) The acids (mostly hydrochloric acid) is sometimes used in casting slips of alumina, zircon and some other compositions.

vi) Chemicals are also used as colouring materials , mostly compounds of transition elements and of gold, silver,platinum and uranium.

2.1.4 Binders and lubricants

Binders are used mainly in dry and dust pressed bodies. Binder serves two functions

i) It produces plastic strength in non clay bodies during mixing to help in producing granulations

ii) Binders (in non clay bodies) help to produce required green strength in pressed pieces to prevent damage to produce during handling.

Examples: PVA(Poly vinyl alcohol), flour, starch, gums, lignin, sulphite lye, cellulose and soluble waxes.

Lubricants are the materials which are added in bodies granules to reduce die friction.

Examples: PEG (poly ethylene glycol), kerosene, oils and waxes.

2.1.1 Naturally occurring raw material

Different types of Naturally occurring raw materials are as follows

2.1.1.1 Clays : The most important constituent of white ware or ceramic-ware is generally clay. It is also known as china clay or kaolin. The word kaolin is derived from the Chines word kao-liang (high ridge). It contain kaolinite mineral.

China clay is weathered product of granite rocks or micaceous schist resulting from a process of hydrolysis , disilification and hydration of feldspar part of rock(other part is quartz) **.**

$$\mathbf{K.Al.Si_3O_8+H_2O \longrightarrow HAl\,Si_3O_8 + KOH \;\; (hydrolysis)}$$

$$\downarrow$$

$$\mathbf{HAlSiO_4+2SiO_2 \;\; (desilification)}$$

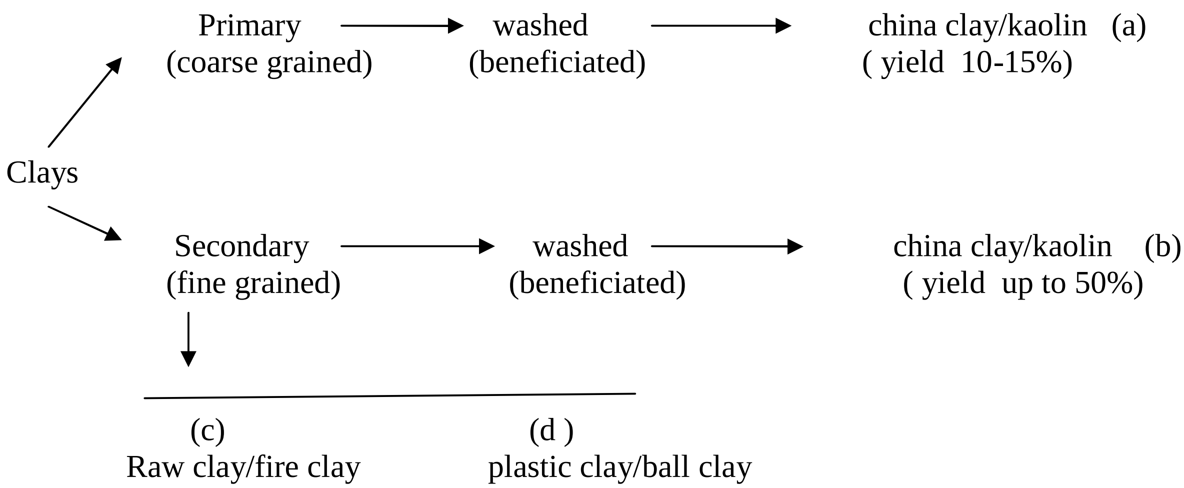
$$\mathbf{2HAlSiO_4+H_2O \longrightarrow Al_2\,(Si_2O_5)\,(OH)_4 \;\; (Hydration)}$$

(Kaolinite)

The weathered product containing china clay is naturally associated with the impurities. The minerals present in original rocks need to be separated. When a clay deposit is found in place of its parent rock, it is said to be primary clay.

A deposit transported distance away from its place from its place of decomposition is said to be secondary clay. During the process of transportation by flowing water, wind or other means, the clay

grains because finer, loose same of their parental minerals and their impurities but collect some new impurities on the way. The main impurities collected are organics like lignin and humus. The different from the clays used may therefore be indicated as follows:



Grade (a) clay is pure and main part of white ware bodies where colour plays an important role.

Grade (b) is used in white wares bodies along with (a) grade.

Grade (c) is used in ceramic bodies where impurities can be used and cost and properties of clay is important in bodies.

Grade (d) is essential ingredient of bodies which are formed by casting, jiggering, turning etc. such as sanitary wares and high tension insulators.

Clay deposits are widely distributes in India. The deposits that produce good (washed) china clay are Ramahal and Cossimbazar in Bihar , Kusumpur(Delhi) , Kundra (Kerala) , Mahsana (Gujarat), Neyveli (Tamilnadu) and Bakura (W.B.).

The plastic clays are found in Bikaner in Rajasthan, Panrutti and Neyveli (Tamilnadu), Trivandrum (Kerala) and Thane (Gujrat).

The main constituent of China clay is kaolin.

2.1.1.2 Quartz: Silica is found in the form of quartz or flint rock or quartzite sand. It also essential (major) ingredient of ceramic composition (triaxial body composition).

Quartz rock consists of massive or large hexagonal crystal and flint is cryptocrystalline silica with about 1% water in structure.

Some time the crystals of the quartz are free from impurities and are almost transparent.

In India quartz rock is very common and found in high purity. It is found in Bengal –Bihar border regions. It is found at many places.

Quartzite sand is used when it is obtained is required purity.

If we compare triaxial body with human body, silica forms the ‘ bone’ of the triaxial bodies whereas clay ‘flesh’ and feldspar ‘blood’. On firing the composition , feldspar first melt and starts taking some quartz in to solution and helps in its conversion. The melt gradually becomes more siliceous (more in silica).The clay on the other hand leads to formation of mullite.

The quartz under goes different crystallographic changes during heating with changes is volume (density). The following changes takes places.

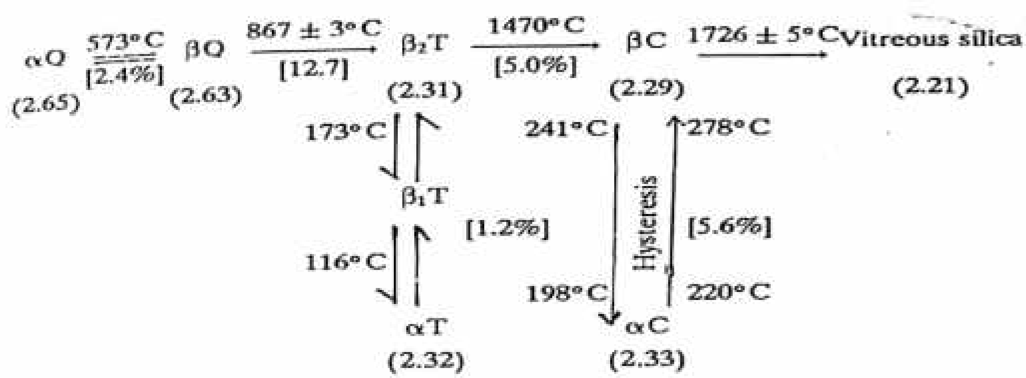


Figure 3.2. Transformation temperature, specific gravity and volume changes of different phases of silica

Q, T and C denote quartz, tridymite, and cristobalite respectively. Figures within parentheses indicate density and those inside square brackets give the percentage of volume changes during transformations.

Table 3.2. Temperature effect on different phases of silica minerals

Phase	Density	On heating	Stability range (°C)	Volume change to higher form	Type of change
α quartz	2.65	↓	room to 573°	2.4%	quick
β quartz	2.63	↓	573°–867°	12.7% to β_2T	sluggish
α tridymite	2.32	↓	room to 116°	—	quick
β_1 tridymite	2.32	↓	116° –173°	—	quick
β_2 tridymite	2.31	↓	173° –1470°	1.2% from α to β_2T	quick
α cristobalite	2.33	↓	room to 220°/278° on heating; 241°/198° on cooling	5.6%	slow
β cristobalite	2.29	↓	1470° –1723°	5.0% from β_2T β C	sluggish
Vitreous silica/ quartz glass	2.21		above 1670° from T above 1723° from C		slow

In theory, at normal pressure trigonal quartz (**α-quartz**) will transform into hexagonal **β-quartz** at 573°C, upon further heating the SiO_2 will transform into hexagonal **β-tridymite** at 870°C and later to cubic **β-cristobalite** at 1470°C. At 1705°C β-cristobalite finally melts:

	573°C		870°C		1470°C		1705°C	
α-Quartz	⟷	β-Quartz	⟷	β-Tridymite	⟷	β-Cristobalite	⟷	Silica Melt
trigonal		hexagonal		hexagonal		cubic		
2.65 g/cm^3		2.53 g/cm^3		2.25 g/cm^3		2.20 g/cm^3		

However, tridymite does usually not form from pure β-quartz, one needs to add trace amounts of certain compounds to achieve this (Heaney, 1994). So the β-quartz-tridymite transition is skipped and the sequence looks like this:

	573°C		1050°C		1705°C	
α-Quartz	⟷	β-Quartz	⟷	β-Cristobalite	⟷	Silica Melt
trigonal		hexagonal		cubic		
2.65 g/cm^3		2.53 g/cm^3		2.20 g/cm^3		

The changes in crystal structure lead to changes in the specific density: an increasing temperature corresponds to increasing vibrations of the atoms in the crystal lattice, and as these need more and more space, more open crystal structures are favored**.**

As long as the temperature changes very slowly, the whole process is fully reversible.

But things get far more complex when the temperature is increased or decreased more quickly. If one heats up a quartz crystal very quickly, it will still undergo a phase transition to β-quartz, but the β-quartz will then "skip" the transition to β-cristobalite and directly melt at a much lower temperature, at 1550°C**.**

	573°C		1550°C	
α-Quartz	→	β-Quartz	→	Silica Melt

It makes sense that β-quartz has a lower melting point: it is less stable than β-cristobalite at that temperature and its crystal lattice is more easily broken up. So it doesn't really make sense to say that *quartz* melts at 1705°C, because *low* quartz never melts, and because the melting temperature depends on how quickly you raise the temperature.
However, this process is not reversible. Instead, if a silica melt is cooled quickly, its liquid structure will be preserved and it will turn into amorphous **silica glass**, called lechatelierite when found in nature. There is no well defined melting point for silica glass which slowly turns into a very viscous liquid upon heating. It is often said (and I've written this before, too) that silica glass is an extremely viscous liquid, just like ordinary window glass, but both glasses are considered as regular solids.

	1000 - 1500°C	
Silica Glass	←	Silica Melt

Even more strange is what happens to silica glass that is heated up: one would expect it to be converted to β-quartz, β-tridymite or β-cristobalite, depending on the temperature. But in fact it will simply turn into β-cristobalite, just as silica melt would.

Silica Glass → (ca.1000°C) → β-Cristobalite → (1705°C) → Silica Melt

This conversion is of technical importance in the industrial production of silica glass, as great care has to be taken to avoid the formation of cristobalite crystals within the glass.

If the polymorphs β-tridymite and β-cristobalite are cooled quickly below the respective transition temperatures, their crystal structure is first preserved until they will transform into polymorphs with closely related structures, **α-tridymite** and **α-cristobalite**, at 114°C and 270°C, respectively:

α-Tridymite ↔ (114°C) ↔ β-Tridymite

α-Cristobalite ↔ (270°C) ↔ β-Cristobalite

The transition is fully reversible even at relatively quick temperature changes, just like the transition of α-quartz to β-quartz.

At low pressures there are actually **3 groups of silica polymorphs** each of which has 2 closely related members: one low-temperature member given an **α**-prefix, and one high-temperature member of the same name, but with a **β**-prefix. Some authors prefer a **low**-prefix and a **high**-prefix.

Low Pressure Silica Polymorphs			
high- or β-polymorph	**β-Quartz**	**β-Tridymite**	**β-Cristobalite**
stable at	573°C - 870°C	870°C - 1470°C	> 1470°C
metastable at	-	117°C - 870°C	270°C - 1470°C
crystal system	hexagonal	hexagonal	cubic
Si-O-Si angle	153°	180°	151°
low- or α-polymorph	**α-Quartz**	**α-Tridymite**	**α-Cristobalite**
stable at	< 573°C	-	-
metastable at	-	< 117°C	< 270°C
crystal system	trigonal	triclinic	tetragonal
Si-O-Si angle	144°	140°	147°

During the transition from a α- to a β-variant the atoms in the crystal lattice only get slightly displaced relative to each other, but they don't change places inside the crystal lattice (the *topology* is preserved). Because these α-β-transitions are only based on alterations of the angles and the lengths of the chemical bonds, they take place **instantaneously**. Such a phase transition is generally called **displacive**, as it only requires relative displacements of the atoms without the need to break chemical bonds. Because the angular Si-O-Si bonds get straightened out, the high-temperature silica polymorphs all possess a **higher symmetry** than their low-temperature counterparts (hexagonal > trigonal > triclinic; cubic > tetragonal).

2.1.1.3 Feldspar:

It is one one of the most fluxing materials used in ceramic bodies and glazes. This is the most important constituent of triaxial ceramic compositions. These have same structure as that of silica, but some silicon is replaced by alumina and resultant negative charge is satisfied by potassium, sodium, calcium or barium. Feldspars are of following types

1. Soda feldspar (Albite)
2. Potash feldspar (Orthoclase)
3. Lithia feldspar (Anorthite)
4. Lime feldspar (Celsian)
5. Barium feldspar

Feldspars are found in pigmatite rocks usually granite rock. It is found as mixture of feldspars along with quartz and mica.
The potash feldspar is widely available in India. The good quality is found in Bengal-Jharkhand border region and Alwar Rajashan.

Potash feldspar is preferred in ceramic bodies because of its long firing range
Soda feldspar is used in glazes because it reduces the melting temperature and viscosity of melt.
The feldspar used should be evenly distributed throughout the body, so it must be finally ground before mixing.

2.1.1.4 Nepheline Syenite— $K_2O.3Na_2O.4Al_2O_3.8SiO_2$

It is mineral containing feldspar, mica, and Fe_2O_3. It is also imported flux material and is used in ceramic industries.

It is more strong flux then feldspar. It is more active than feldspar. When it is introduced in ceramic bodies it

i) lower maturing temperature greater then feldspar.

ii) It increases firing range and mechanical strength

iii) Reduces water absorption, moisture expansion, warpage, dunting and crazing.

So that the product having nephelene syenite have good translucency and brilliant color. In India, it found in limited places. The important regions are Girnar hill region in Gujarat, Kisengarh, in Rajasthan and Koraput in Orissa.

2.1.1.5 Talc:

Talc is naturally occurring hydrated magnesium silicate having chemical formula ($3MgO.4SiO_2.H_2O$).
It is used in small to moderate proportion in ceramic industries such as Art ware, tile, dinnerware, sanitaryware etc. It is used to improve physical properties such as maturing temperature and moisture expansion.

It is also used in high proportion in high frequency, di electric bodies because it affects electrical properties. It lower the dielectric loss and power factor. It also improves thermal shock resistance.

The massive rock having talc mineral is known as steatite. If a rock contains talc and other minerals it is known as soapstone. Soapstone is widely used in wall tiles bodies.
A part or most of talc is pre-calcined, if it is used in bodies where pressing is required.It is very soft and slippery minerals.

In India deposits of talc are found in Udaipur and Jaipur in Rajasthan. Soapstone is found in Singhbum, Ranchi, and hazaribagh district of Bihar, Anantpur and Chittoor in Andhra Pradesh and Jabalpur in M.P.

2.1.1.6 Sillimanite, Kyanite, Andalusite ($Al_2O_3.SiO_2$)

These minerals have same chemical composition but different crystallographic forms, physical and optical properties.
These minerals are mainly used in refractory. It is also used to make non porous ceramic ware like thermo couple sheet, electrical insulators parts and high density grinding media.
Sillimanite and Kyanite are easily available but Andalusite is rare. Kyanite deposits are found mainly in Bihar, Andhra Pradesh, Orissa, Rajasthan, Maharashtra, and Karnataka. Kyanite found in Bihar is of high purity.

Sillimanite are found in form of massive rocks in khasi and Jaintia Hills in Assam and Khasi and Jaintia hills in Assam and Khasi Hills in Meghalaya. Smaller amount of sillimanite are also found in M.P., Orissa, Tamil Nadu.

Table of Phyical Properties

Properties	**Sillimanite**	**Kyanite**	**Andalusite**
Formula	$Al_2O_3.SiO_2$	$Al_2O_3.SiO_2$	$Al_2O_3.SiO_2$
Crystal System	Rhombic	Triclinic	Rhombic
Color	Colorless	Pale blue	usually colorless
Specific gravity	3.23	**3.60**	**3.15**
Hardness	**6-7**	**4-5**	**7.5**
Vitrification Temperature	**1545^{O}C**	**1350^{O}C**	**1380^{O}C**
Volume change	slight expansion	**10%**	**NIL**

2.1.1.7 Zircon ($ZrO_2.SiO_2$):- The mineral zircon has formula $ZrSiO_4$. It is found as accessory mineral in granite and pegmatite rocks. These minerals in nature are found in acidic igneous rock and then concentrated by weathering agents when rocks are disintegrated. Zircon itself remain unaffected by weathering agent but being heavy it gets concentrated on beaches. The chief source of zircon is in Australia, India, and Florida.

It found as water colored white crystals or yellow, brown crystals or blue green crystals. Its specific gravity varies around 3.95 to 4.6.

In India zircon commonly found in beach sand in Kerla and it is also obtained as by product of sillimanite.
The zircon is found in Kerala beach sand (2.7-8.7%). It is also found in beaches sands of Tamil nadu with sillmanite having 5 to 6% of zircon.

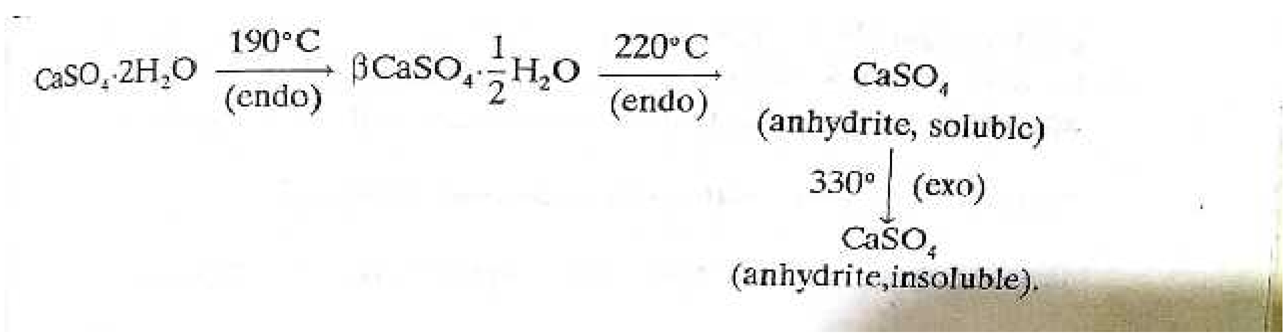
Uses:
It is used in chemical stoneware or porcelain due to high refractoriness and chemical resistance.
It is also used in grinding media due to high density.

It is also used in making steatite insulators and thermal shock resistance cordierite bodies.
Zircon sand is also used to prepare opacifiers.

2.1.1.8 Gypsum and P.O.P n Gypsum has formula of $CaSO_4.2H_2O$ and P.O.P. is made by calcination of gypsum and has formula $CaSO_4.1/2H_2O$.

P.O.P. is used for making moulds for making ceramic ware by jiggering and slip casting. So, it occupies the most important place in ceramic industries.

P.O.P. is prepared by heating naturally occurring gypsum ($CaSO_4.2H_2O$) at suitable temperature. So that theoretically ¾ of the chemically combined water is driven out and hemi hydrate $CaSO_4.¼H_2O$ is obtained. On heating gypsum, following different products are obtained.



Material	CaSO4	H2O	Molecular Weight
Gypsum	79.1%	20.9%	172.18
P.O.P.	93.0%	6.2%	154.16

Gypsum is found in Rajasthan, Jammu and Kashmir. In Rajasthan gypsum is mainly found in Bikaner. It is one of the purest forms of gypsum and have very small amount of impurities such as CaSO4 and clay. In Jammu and Kashmir, gypsum has impurities such as CaSO4 and MgSO4.

2.1.1.9 Bone Ash Bone ash is used as major constituents in certain ceramic bodies. These wares are known as bone china ware.

Production of bone ash:-

Bone ash is white material produced by calcinations of bones. Bone ash consists of 55.82% calcium oxide (CaO), 42.39% phosphorus pentaoxide and 1.79% water.

Bone ash is produced by calcining cattle bones. These are then finely ground to produce ash. To produce bone ash, bones of low iron content must be used. For this cattle bones are suitable. Horse and pig bones are not used as they have high amount of iron content. This gave yellowish wares.

The bone ash is produced as follows

1. First of all bones are cleaned and then treated with steam to remove fat and other bone glues.
2. The bones are then calcined in air at 1000˚C. After calcining bones are ground in wet pan mill. After this materials is passed through magnetic separator and allowed to age for 3-4 weeks. After aging liquid is decanted and remaining material is dried for 3-4 days to 12% moisture.

Approximate formula:- $4Ca_3(PO_4)_3CaCO_3$

Composition:-

Calcium phosphate:- 67-85% $[Ca_3(PO_4)_2]$

Calcium Carbonate 3-10% $(CaCO_3)$

Magnesium phosphate:- 2-3%

Caustic lime & calcium Fluoride:-less than 1%

Uses:- It is used to make bone china ware.

Flow chart of Bone Ash Production

Cleaning of bones

↓

Treatment with stream

↓

Calcination of bones (1000˚C)

↓

Grinding (in pan mill)

↓

Magnetic separator

↓

Aging (3-4 weeks)

↓

Decantation

↓

Drying (12% moisture)

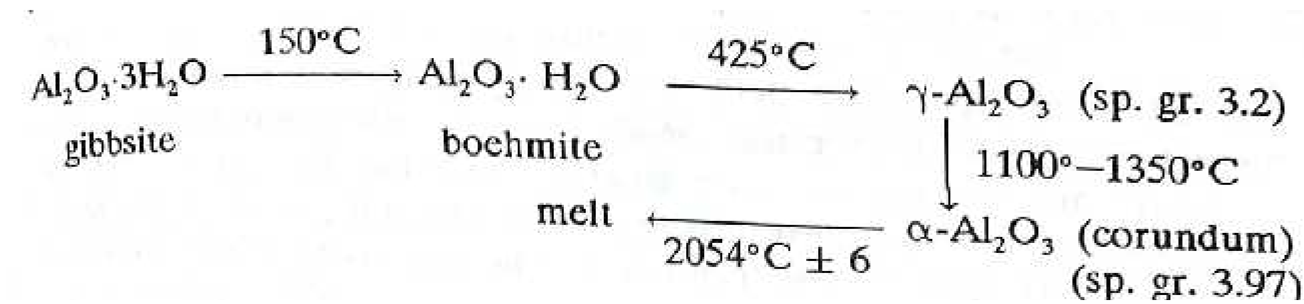
2.1.2 Specially treated or synthetic prepared raw material:-

Specially treated or synthetic prepared raw materials are those which are prepared by processing of naturally occurring material. Alumina, Zirconia and Beryilla material are synthetically prepared and are used in white ware industries.

2.1.2.1 Alumina (Al_2O_3) Alumina is an important raw material used in ceramic industries. This material is used to attain properties like high temperature resistance, high hardness, high density, high chemical resistance and good dielectric properties.

Preparation of Alumina The alumina which is used in ceramic industries is made by Bayer‘s process in alumina refractory. In these industries precipitated gibbsite (alumina mineral) is calcined at $1000\text{-}1100^0$C to convert it into alumina.

The alumina so found is α-alumina and ϒ-alumina. The alumina is made by the following reaction:



So, the material is to be calcined at high temperature, 1100-1130^{0}C to convert all alumina into α- alumina. The alumina product by Bayer‘s process contains soda (Na_2O) =0.5-0.7%. This soda create problem in electronic and electrical industries. The soda is removed by a washing method.

The alumina can also be prepared from bauxite. It is prepared by calcination or fusion of bauxite and then grinding the fused product

2.1.2.2 Zirconia (ZrO_2):- Zirconia is important raw material for certain ceramic ware and engineering components. This is particularly used in nuclear energy (nuclear reaction) and in space science, rockets space shuttles.
It is used mainly due to its high density (specific gravity 6.27), high refractoriness about (2665-2695), corrosion resistance, non wetting of some metals and low nuclear cross section.

It is natural mineral having zircvonia is beddelyte ,which is very rare. So, it is synthetically prepared from zircon (ZrO_2SiO_2).

Preparation: Zircon mineral from which zirconia is prepared is not stablised. So, this mineral oxide is first stabilised by heating with small addition of CaO, MgO, and titanium oxide or yttrium oxide.
Now-a-days partially stabilized zirconia is used.

Like alumina, zirconia is available in 99.7% pure in USA and Europe but not in India. Small quantities are available from atomic energy department.

2.1.2.3 Beryllia (BeO)

Beryllia is introduced in ceramic ware bodies as the mineral. Beryllium alumina silicates or as pure beryllium oxide. This has high melting point ranges from 2500-2560. Sintered beryllia is mainly used in nuclear reactors as moderators. It is used because of its high resistance to oxidation at high temp. It is also used in electronic circuits as heat sink and as cores for resistors. It is transparent to microwaves (windows).

It has high thermal conductivities, has high strength and chemical inertness but it is used very less in ceramic industries because of its health hazards and high cost.

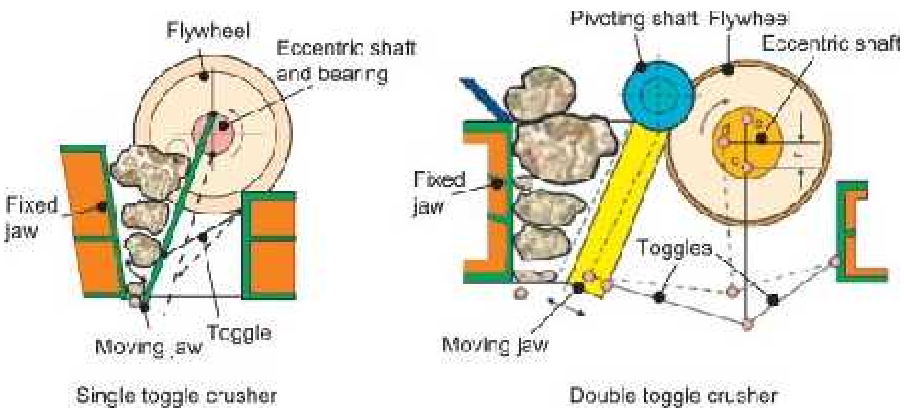
The commercial sources of beryllia is mineral beryl, a beryllium aluminium silicate composition having formula $3BeO.Al_2O_3.6SiO_2$. It is found in India in some places.

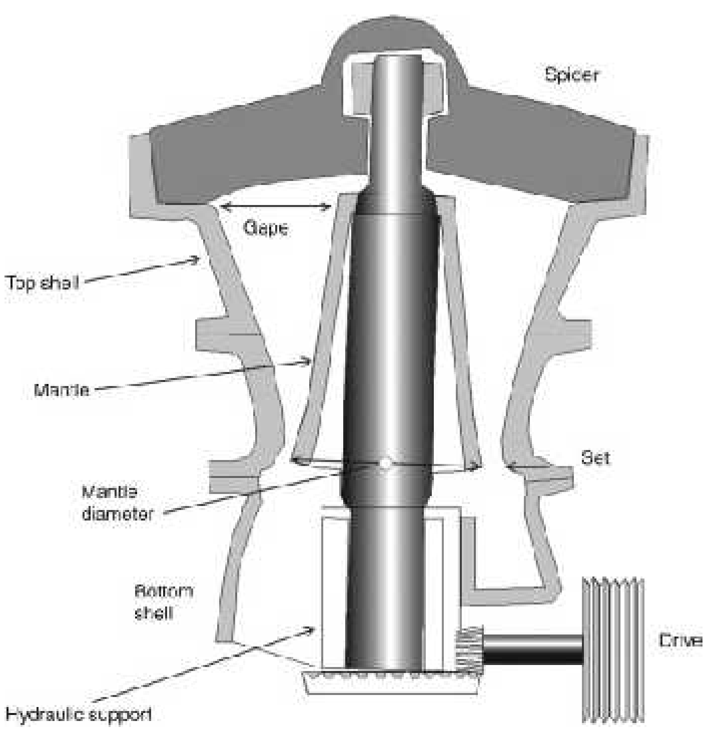
Unit-III

Processing

Syllabus Processes:- Crushing and grinding, mixing, agitating, magnetising, sieving, pumping, filtration, plugging and batting.

3.1 Crushing : Crushing is the operation in which ceramic raw material in the form of lumps are reduced to a desire size for secondary reduction. The primary crushing is carried out with the help of double and single toggle jaw crusher, gyratory crusher and hammer mill.





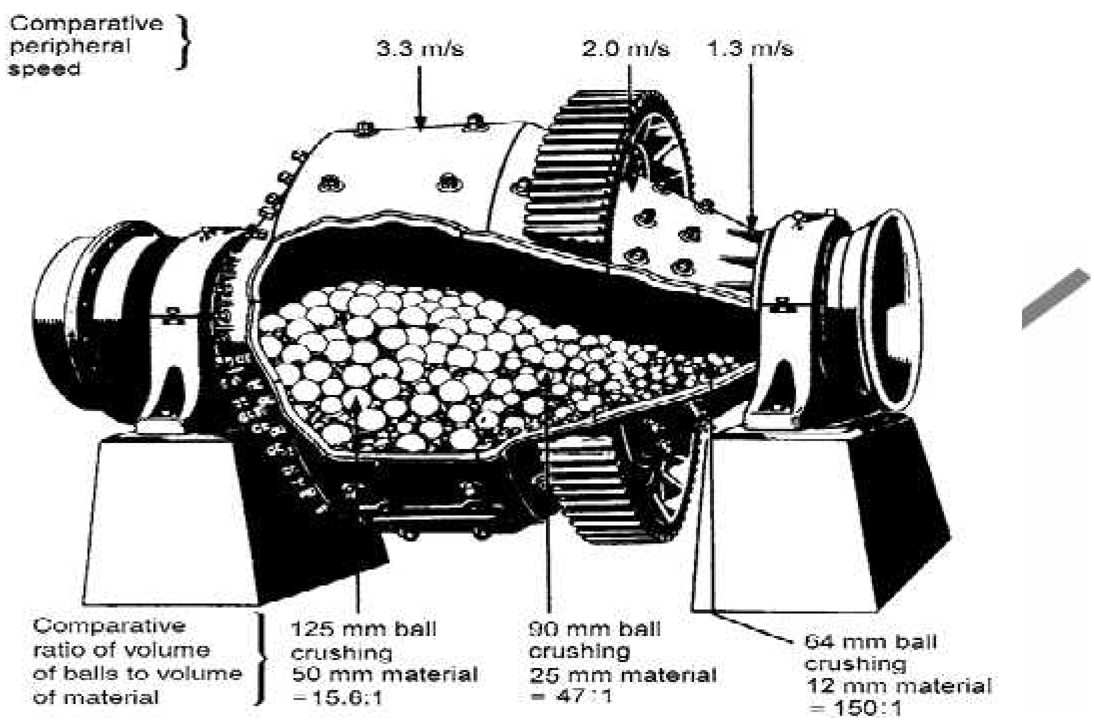
Gyratory Crusher

The raw materials received in lumps form from mining (like feldspar, quartz rocks or some hard clays, talc, shale, bauxite) needs to be crushed. Sometimes fused materials like fused alumina, fused magnesia, fused mullite, fused zirconia are needs to be crushed.

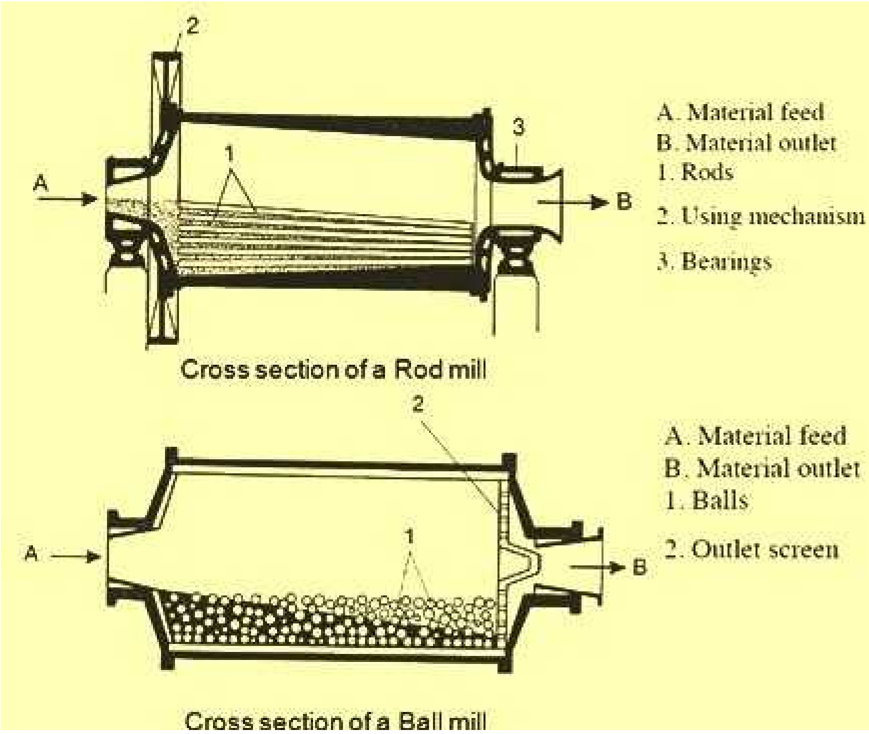
If clay lumps are sticky or wet toothed rolls are also used for crushing. The equipments like edge runner mill and pan mills are also used in ceramics industries for the purpose of crushing, grinding and mixing. They consist of a pan and two runners (rotating wheels). The edge runner pan have perforated bottoms and scrappers. Either pans remain stationary and rollers or runners move around fixed center while the pan turns under them.

3.2 Grinding : Grinding is the operation in which ceramic raw material obtained from primary and secondary crushers are reduced to fine powder.

Example: -Ball Mill, Pebble Mill, Rod Mill, Tube Mill, Conical Mill etc.



CONICAL MILL



ROD MILL VS BALL MILL

The most of the fine grinding is done with ball mills, rod mils or tube mill. The ball mill is most commonly used. Large mills of size 6-8 ft diameter and 8-10 ft in length can hold charge up to 3-4 tonnes. The charge can be ground to required size in about 24 hrs. The ball mills are lined with hard porcelain bricks and in special cases with high alumina bricks are used. The balls are used as grinding media of same composition.

For smaller charges of colours, glazes, enamels and in laboratory porcelain pots or jar mills are used.
The rotations per minutes of ball mill decreases with increase in diameter and size of balls. Normally for 5 ft diameter ball mill 20-25 rpm is kept. For wet grinding generally ratio of volume of balls to volume of charge to volume of water is kept as 55:25:20.

3.3 Batch (Body) Preparation:- This process involves proper mixing raw of various raw materials in right proportion and right degree of fineness. In this way mixture is prepared of required water content and consistency required for next stage of process- shaping or making.

3.4 Mixing :- Mixing can be divided into following major types

1) Gas –Gas mixing (LPG and air)
2) Gas –liquid mixing
3) Gas –solid mixing
4) Liquid –Liquid mixing
5) Liquid –Solid mixing
6) Solid –Solid mixing

But from subject view, the mixing can be divided into three types:-

1) Dry mixing
2) Plastic mixing *(18-22%water)*
3) Wet mixing *(25-50%water)*

I. Dry Mixing :

It is mostly used for the non –clay body. But now- a- days it is also used for clay containing bodies. This method is used for those materials which flow freely. Dry mixing is carried out with the help of Pebble Mill, Cylindrical Mill or Tube Mill. The moisture content in dry mixing can be from 0 to 4%.

The advantage of this process is that water can be added to the dry mixed body to obtain exact consistency required for making. The second advantage is that filter processing is not required in this process.

The disadvantage is that any soluble salt present in raw material remains in the body and these cannot be removed, as no filter pressing is carried out. These salts produce some difficulties in manufacture of ware or reduce plasticity.

Whereas the bodies which are prepared with the help of filter pressing, the soluble salts are removed during the process.
In case of non-clay bodies binders and lubricants are added to the dry mix. The material helps in shaping process and gives some strength to the ware before firing.

II. Plastic Mixing :-

This mixing is carried out for those materials mixtures which cannot flow easily in dry state and in wet state. These materials are sticky and form lumps.

The moisture content in this process is 18-22%. This mixing is particularly used in heavy clay ware, where plasticity is attained (developed) by addition of water. The addition of water to attain required plasticity (consistency) is known as *Tempering*. This mixing is carried out in Pug Mill to which vacuum apparatus is attached.

III. Wet or Slip Mixing:-

This method is mainly used for pottery and ceramic bodies. The moisture content in this mixing is 25-50%. In this mixing the raw material are mixed with required amount of water to from free flowing suspension.
In India, wet mixing is one of the most important processes of body preparation. In this process individual raw material are blunged and slip is obtained. The slip of different raw material is mixed in proper proportion to obtain required composition slip. This is done with large vessels fitted with stirrer.

The apparatus used in wet mixing is Blunger, Ball Mill, Rod Mill and Pebble Mill etc.

3.5 Blunging: This is the most important equipment for wet preparation. It consists of large vertical cylinder made up of cement concrete or lined with brick, with a vertical shaft. The shaft has number of wooden or stainless steel paddles or blades. They are rotated at very high speed of 100 rpm. This is done to carry out through mixing of body and dispersions of clay particles.

When non plastic materials and clays are separately treated, they are fed into blunger and blunged for shorter times. For initial clay blunging 4 to 6 hrs are required whereas for mixing 2 to 3 hours are required.

3.6 Agitation:- Agitation is carried out with the help of agitators. These are temporary storage tanks in which slip is kept agitated or stirred to prevent setting. Agitator is similar in shape as that of blunger. These are located under the slip house floor. In agitators peddles are attached to vertical shaft.

A common type of agitator blade contains 12-20 pickets, equally spaced on both side of shaft. The shaft is slowly rotated. The slow agitation of slip helps to remove entrapped air in the raw materials. The slip is then fed in to filter press. The slip having required water content for slip casting, that slip from agitator is directly pumped to slip house.

3.7 Demagnetization :- The slip from blunger is passed through sieves/ screens and then through magnetic separator. This process is used to remove iron particles from the body. The body can be in slip form or in powder form. The iron particles are present in mixed raw material or are present during process of crushing and grinding, blunging etc. These iron particles are required to be removal as it impart (give) color to the body especially in Whiteware plants.

In this process, the slip from the blunger after screening is passed on to a magnetic separator. If the material is in powder form, then it is passed through roller magnetic separators. It is an essential equipment of white ware plants. The magnetic separators are of two types:-

3.7.1 Flat Table Types (Slightly inclined):- It consists of a number of strong electromagnetic in the form of open mesh grids. This allows easy flow of large volume of slurry or slip. Sometimes rows of grids magnet are arranged in the form of two or three steps and slip flows down each steps. This type of magnetic separator gives a very large area of magnetized surface and more efficient and through removal of magnetic particles takes place. Now-a-days magnetic separators having high intensity permanent magnets are used.

3.7.2 **Funnel Shaped:** This is another type of magnetic separator. In this separator, slip is poured in the funnel. The slip passes through the grid of powerful permanent magnets which is set into the neck of funnel. This is easy to use for smaller charge and can be cleaned easily.

For dry powders, the V-types, chute type or roll type separators are generally used. After passing through magnetic separator slip goes in to agitators for temporary storage.
Magnetizations are of two types:- Permanent and Electromagnetic.

3.8 **Sieving or Screening :-** Sieves and screens perform different functions in the ceramic industries. These are used for

- testing of sample for particles size,
- grading of raw material and
- for removing over size particles.

The sieve or screen consists of mesh which is mounted on aluminum frames in oval, circular or rectangular shapes. These sieves are mounted at charging and discharging ends.

The product of crushing and grinding is sieved for removal of oversize materials. For this 80,100 and 150 mesh size sieves are used. *(The mesh is made up of brass which is fitted in aluminum frames by giving correct tension).*

The sieve frames can be rectangular or circular and sloped so that oversize particles will move off. The sieves are vibrated and this is done to prevent clogging. The screen or sieves are set in two to four tiers and are slopped so that material can flow easily. The oversize particles remain on sieve. The vibrating mechanism (sometimes tapping mechanism) is provided to the bottom of the sieve to speed up the process of serving.

In case of plastic material (clays are blunged) and non- plastic material (milling of Quartz and Feldspar) are separately treated, then each material is separately screened before mixing.

3.9 **Pumping :-** During the preparation of body, slip has to be plumped several times. The pumps are used to lift the slurry are known as slip lifting pumps. These pumps are used in slip house where slip is transported to spray driers and filter press. These pumps have not only to counter act, the head of slip, or liquid to be transported in addition of this, these pumps has to fill filter press at very high pressure.
This pressure has to be applied uniformly thorough out the operation.
There are various types of pumps used to pump the slurry e.g, Dead Weight Pumps and Other Ramp Pumps, Diaphragm Pump, Gland And glandless Centrifugal Pumps, Hydraulic Pumps, Plunger Pumps etc.
Dead Weight Pumps are very widely used for filter press and slip casting. In these pumps tap can be fitted on the delivery pipes which when turned off automatically stops the pumps. For filter press, constant pressure blunger pumps are used. These pumps are so designed that they will start pumping when required pressure drops and stop pumping when required pressure is achieved.

3.10 **Pugging Mill (Pug Mill):**

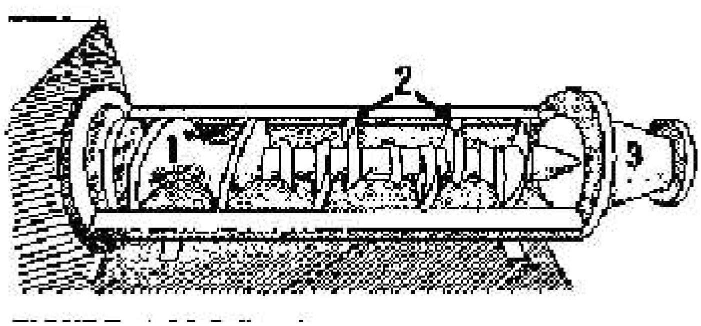
Pugging mill (pug mill) is used for mixing of water with clay. The machine used for pugging is known as pug mill. Pugging is due to improve uniformity of plastic clay body and hence giving greatest workability because of proper coating of clay particles with water.

Construction: The pug mill consists of knife set on a screw on one or two rotating shaft. This machine as a continuous one. The one end of which is fitted with a suitable feeding hopper and other end (discharging end) has are auger and mouth piece for extrusions of solid columns of pugged material.

The knives and auger screw can be set on one shaft.

The pugging machines are of two types

i) Pug mill



ii) De airing pug mill

The main disadvantage of normal pugging machine is that it tends to incorporate air bubbles in clay which have bad effect on plasticity of clay. To remove the air bubbles of other type of pug mill are used which is known as de-airing pug mill.

3.11 **Filtering/ Filtration:-**

The clay slurries and slip are made by mixing water with different raw material. This is done

i) To mix homogeneous different raw materials

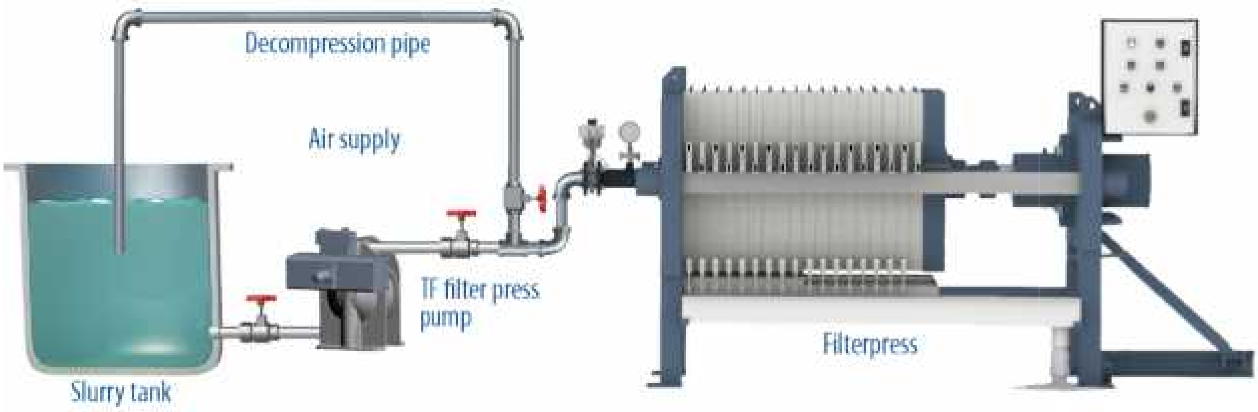
ii) To remove soluble salts present in raw material and

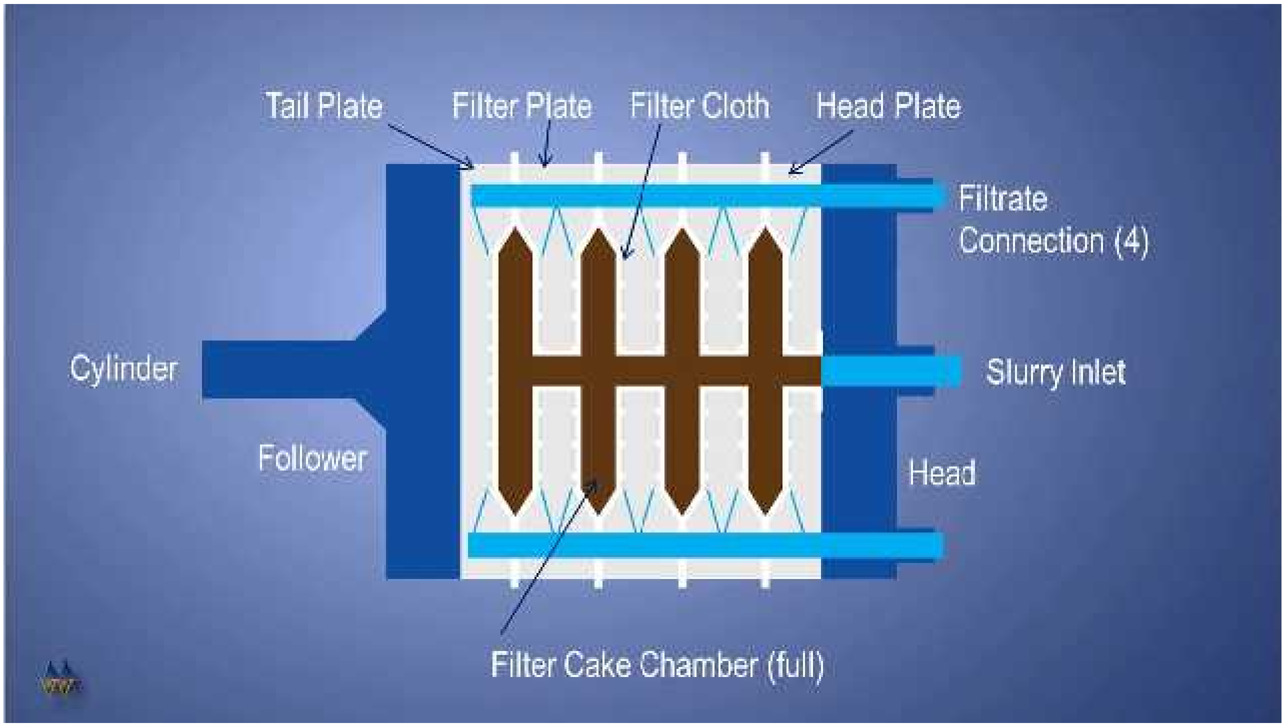
iii) To make slip casting for slip process.

The mixing of water and raw materials is done in blunger. After Blunging (wet mixing) the water has to be removed to make plastic mass or dry powder.

a) Filtering : The removal of water from slip is carried out with the help of process known as *filtering*. The various machines used for filtering are Filter Press, Vacuum Filter, Centrifugal Dewatering Heated Drum and Spray Dryer.

Filter press:-





Principle : Filter press work on the principle of removing water from slip or slurry with the help of cloth filter. The filtration takes place under pressure.

Construction : A filter press consists of series of wooden or metal plates to provide a series of chamber or compartment. These chambers can be circular or rectangular. These chambers are covered with filters clothes. Each chamber has its own inlet which is connected to common pipe. This pipe supplies slip or slurry to each chamber with the help of diaphragm pump.

Mostly the compartments are formed by moulded polypropylene plates. These Plates are 6 to 50 mm thick and frames are 6-10 mm thick. Plates and frames set vertically in a metal rock. This metal rock is covered with clothes. These plates are squeezed tightly together by a screw or a hydraulic ram.

This screen or hydraulic ram enters at one end of the assembly of plates and of frames. It passes through channel running length wise through one corner of the assembly.

Working :- The slip or slurry enters at one end of the assembly of plates and frames.It passes through pipe length wise and from this pipe the slip enters in each compartment. The slurry is admitted from a pump or pressurized tank under pressure of 3-10 atmospheric pressure. Under this pressure, filtration take place as water comes out through these filters. The squeezing is carried out for removal of water until liquid stops flowing through the filters. This is indicated by sudden rise in pressure. This happens when frames are full of solid and no more slurry can enter. At this stage, the filter press is said to be jammed. After this pump is switched off and filter cakes in solid forms are removed from the compartment. These cakes are then dried in air.

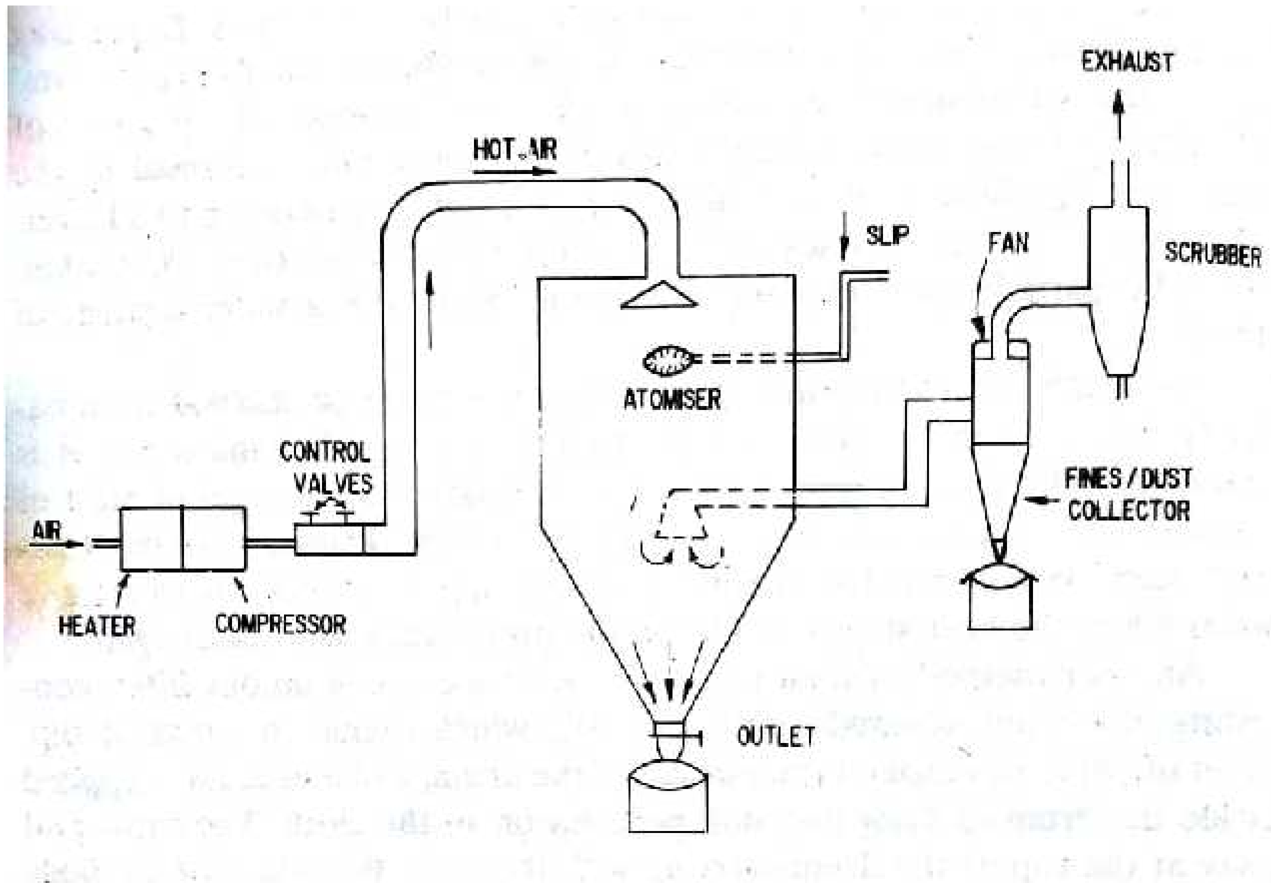
b) Dewatering by Spray drier: When shaping is carried out by pressing a powder (tile pressing), the powder should be free flowing and must have required moisture content (7-8%). Earlier powders were prepared by drying plastic body from filter press and crushing to produce suitable powder.

Now a days powder granules are prepared directly from slip by spraying (atomization in fine drops). These fine drops are subjected to hot air which evaporates off the excess water and leaves the powder with desired moisture content. The equipment used for this purpose is known as spray drier.

The spray drier consists of drying chamber, cylindrical at the top and conical at bottom. At the bottom of cone outlet is provided for dried granules. It consists of atomizing nozzle or rotating disc at the top of cylindrical chamber which breaks the slip and spreads it around in the form of small droplets. The hot gases under some pressure usually enter at top. The droplets gets dried in contact with hot gases so that when they reach at bottom becomes small spheres (mostly hollow). With moisture content 4-6%.

The granules so obtained are free flowing and can be used directly for pressing. The granules should have enough strength so that they can flow into corners of die without breaking.

The product from spray drier is stored directly in storage bins or hoppers or directly into top of presses. The aging of granules for 24 hrs is required for even distribution of moisture and good quality of pressing.



OUTLINE OF SPRAY DRIER

3.12 **Batting :** Plates and other flatware pieces are made by jiggering operation. In this process, mixed plastic body is placed in the form of flat, circular bat on the mould. The process of making the bat is known as *Batting.*

A bat is formed on a plaster base, covered with filter cloth. The plastic body is smashed on the mould. This is the old manual method of making bat. This can also be made by machines.

The batting (automatic) is carried out with the help of miller automatic jiggering machine. In this machine batting and jiggering is done simultaneously. This machine can be also be used only to make bat.

Larger pieces of hollow ware are made by jollying operation. In this operation clay is first spread slightly on mould to make thicker piece. The extra clay is then removed by hand and bat is transferred into jollying mould and cloth is removed.

Unit 4

(Fabrication and shaping methods)

Syllabus: Fabrication or Shaping Methods: Detailed study of slip casting, pressure fabrication, hot pressing, plastic forming, dry pressing, isostatic pressing, jiggering & jollying, extrusion, injection moulding, throwing, finishing operation; sponging, smoothing, fitting, jointing or stickup. Theoretical concept about slip casting, zeta potential, double layer formation, role of electrolytes, deflocculants

4.1 Making method: The major method of making can be divided into four classes according to the moisture content of the body at the time of making.

Table: Making methods: Typical moisture contents and fields of applications

Making Method	**Approximate moisture content**	**Physical state of body**	**Typical fields of use**
Slip casting	25- 50%	Fluid suspension	Generally used for large or awkwardly shaped pieces or small orders (quantity)
Plastic Making	18-22 %	Plastic mass	Relatively simple shapes, pottery, bricks, pipes
Semi dry pressing	4-9 %	Damp powder	Automatic processes , bricks, tiles etc
Dry pressing	0-4%	Dry powder	Non plastic materials, usually addition of binder if required

4.2 Slip casting:- In slip casting, slip prepared by adding water in the required body composition and then water is removed. It is slow method of production and it is generally used when size and shape of the article can't be made by using other rapid (fast) method of making. The slip casting process making consists of two steps:

(a) Preparation of required body composition in the form of slip with minimum water content and with good flowing properties. This is achieved by adding chemical (deflocculant) to the slip.

(b) Pouring the slip into POP moulds. Here double action takes place, first flocculation of slip and then removal of water.

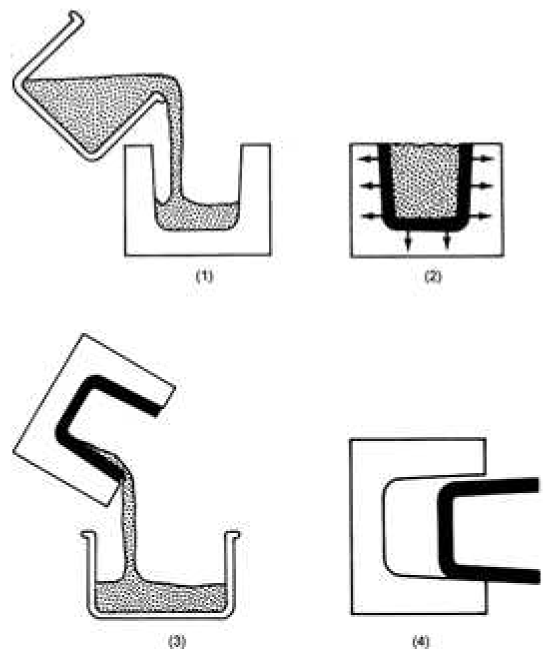


Fig :   Slip Casting Process

The fluid slip is poured into P.O.P. mould of the required shape. Water from the slip is absorbed in to the pores of the mould and as this process continuous (proceed) a layer of the solid material is build up on the inside wall of the mould and takes the shape of mould. Casting is allowed to continue until layer of the cast material is of required thickness. After this, mould is inverted and excess slip is removed.

The mould is kept inverted for few minutes to drain the slip. After this, mould is kept upright again and any excess slip which has casted on the face of mould is removed (scrapped off) with knife. The cast is then allowed to partially dry in the mould. As the cast dries it shrinks and gets apart from the mould. It is then removed from mould and is fully dried. It is then passed for biscuit firing.

Since the water is removed from the slip during casting process. Level of slip in the in the mould falls and for this reason, a ring is generally attached at the top of the mould to keep the level of the slip above the height of the article being made. The ring may be made of rubber or plaster. If made of plaster, casting will takes places on the side of ring. This excess cast is removed by scrapping with the knife when it is partially dry and damp sponge is applied around the cut to give smooth finish.

The process described is to make hollow casting and is used to make hollow wares such as vases, basins etc. Solid casting is made by allowing casting to continue until whole of the interior material has cast up.

For complex shapes plaster mould is made in several part so that cast can be removed easily. Each part is provided with ‘natch’ to keep them in correct position.

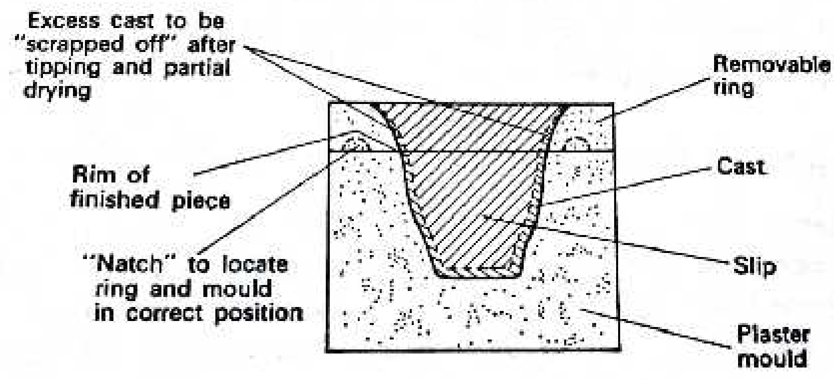


FIG. 2. Plaster mould containing slip and cast.

4.3 Plastic making/ forming: Plastic making processes are used to shape the ceramic ware where plasticity is developed in the body by adding water. Such bodies have high clay content. In bodies where clay content is low or there is no clay, in such cases plasticizing material (bentonite or organic plasticizers) are added.

Plasticity is defined as the property of a material to be deformed or shaped without cracking or breaking under the influence of an applied force and retains its shaped when deforming force is removed.The material used for plastic making methods must be plastic in nature. In ceramic bodies clay is responsible for plasticity. So, materials having high clay contents are used in plastic making methods.

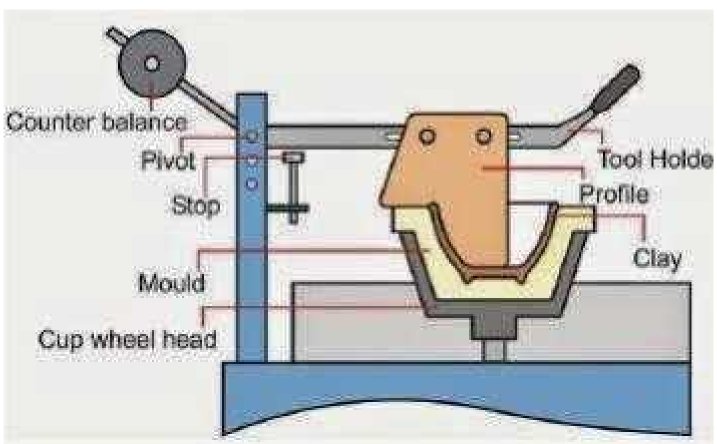
The development of plastic qualities of the bodies depends upon amount of the water in the body. In general if clay content is higher in the body higher water will be required to produce workable consistency. However a body should be able to develop required workable consistency with minimum water content, because at lower moisture content the shrinkage will be less and there is less danger of cracking during drying.

The material used in plastic forming methods is obtained from filter press in the form of filter cakes. These filter cakes are processed in de-airing pug mill to remove air and for homogenization of clay mass. From pug mill the material is extruded in the form of solid compact column. These columns are cut into suitable size is the form of bats.
Different plastic making methods used are as follows.

4.3.1 Jiggering and jollying: In jollying outside surface of the hollow ware article is formed in the plaster of paris mould and inside made by metal profile brought down manually or automatically onto the revolving mould. The body gets squeezed between the mould and tool, while the mould is revolving. In this way both surfaces are formed.

In case of jiggering, the inside surface of the flat ware is made by P.O.P. mould and outside surface is made by metal profile on the revolving jigger head. A flat bat in the form of flat disc is made and placed on revolving P.O.P. mould. The bat is made by spreading mix body on a flat surface. This bat is then placed on revolving plaster mould. Then metal file tool is brought down to the body from the above. In this way, the body gets squeezed between metal profile tool and P.O.P. mould. The outside of the shape is this formed by metal profile while inside formed of P.O.P. mould.

There appears to be same confusion about the word jigger and jolly. In case of jiggering convex mould is used to give inside shape and metal profile to gives the outside shape where as in case of jollying outside of an article is made with the help of concave P.O.P. mould and inside of it article (cup) is made by metal profile.



4.3.2 Extrusion:

Extrusion process is used for shaping of the piece with regular cross section. In the extrusion process the stiffer plastic mass (15-20% water) is forced through a nozzle ending in a die to produce a column of uniform cross section. This process is used to produce symmetrical shape like tube and insulator to produce spark plug. This can also be used to produce tile.

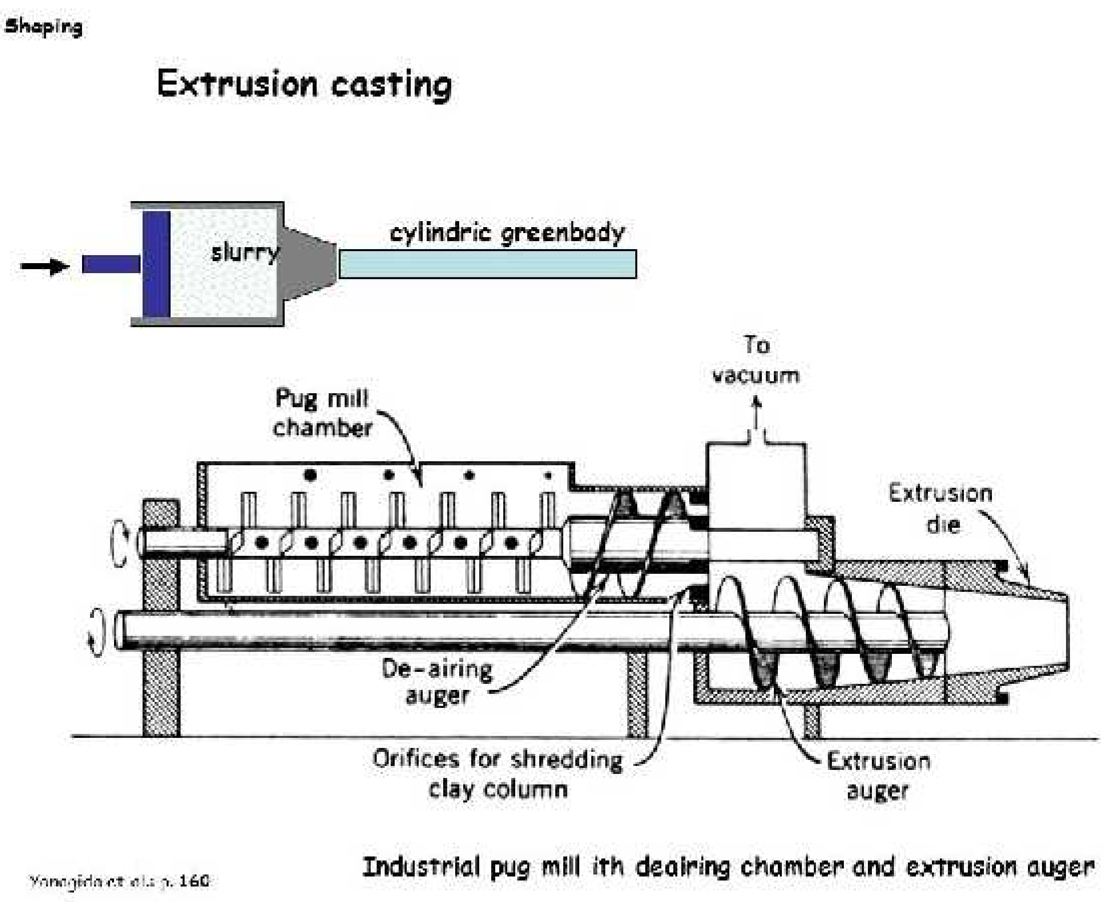
Two types of extrusion machine are used:

A. Auger (vacuum) machine which can be run continuously or intermittently.
B. Piston (vacuum) for intermittent use.

A) **Auger machine:** This machine consists of knifes or blade set on a screw on one or two rotating shaft. This machine is continuously one. The machine is fitted with suitable feeding hopper to feed the plastic clay body at one end and other end (discharging end) it is fitted with mould piece for extrusion of solid column of pugged material. This machine consists of two cylinder separated by vacuum chamber. In one cylinder, a shaft is fitted with blades or knives. To this cylinder a hopper is attached. In other cylinder shaft having auger blades is fitted. The one end (discharge) of the cylinder is fitted with mouth piece (die) of the required shape. The two cylinders are separated by vacuum chamber. A vacuum pump is attached to the vacuum chamber to remove the air from the material.

Working:

The plastic clay body is fed through feeding hopper in first cylinder. In this cylinder moving knife or blades of shafts separates the clay particles and hence better coating of the water takes place. This material is pushed to next cylinder through vacuum chamber. In second cylinder, the auger blades the material through mouth piece. In this way extruded column is obtained, which is cut into required size**.**



Industrial pug mill ith deairing chamber and extrusion auger

B. Piston type machine: The piston type extrusion machine is used for making small diameter tube. It is also used in hydraulic extrusion of large diameter pipes like sewer pipes, horizontal machine for rapid production or smaller diameter pipes. Vertical machines are used for socket, spigot pipes**.**

4.3.3 Throwing: It is the oldest method of shaping plastic body by hand on potter‘s wheel. This method is rarely used in industries. This is used for making some pottery wares and for high voltage insulators of special shapes and size. In this method, throwing of plastic clay is done on rotating disc mounted on a shaft. The wheel has heavy disc mould on vertical shaft and which is turned by motor. The plastic mass contains 32-35% by volume water and it can be shaped by little pressure.

In this method, lumps of well prepared clay is thrown on the center of the wheel. It is then centered by hand pressure. It’s shape is then changed several times by being drawn up and down by hand pressure. The desired shape is then made gradually by hollowing out the piece and drawing out the sides.

4.4 Pressing Operation: This is the rapid and chief method of producing large number of simple shapes. The body granules are fed into metal die and pressure is applied. The formed article is then ejected from the die by ejector and the process is repeated.

The four types of presses are used. The type of press used depends upon the body, speed of production, shape of ware and other factors.

Types of presses:

i) ScrewPress (Hand operated press or automatic):

These presses are used for small and medium size industries. In this case pressure is applied only from top side.

ii) Toggle press: These presses are hand operated or automatically controlled. The pressure is applied from top and bottom side. This press is used for small and medium scale industries.

iii) Pneumatic/ Hydraulic press: These are semi-automatic or fully automatic press. The pressure is applied from top and bottom. These can be used for large wares also.

iv) Tabletting Press: These are used for making small pieces.

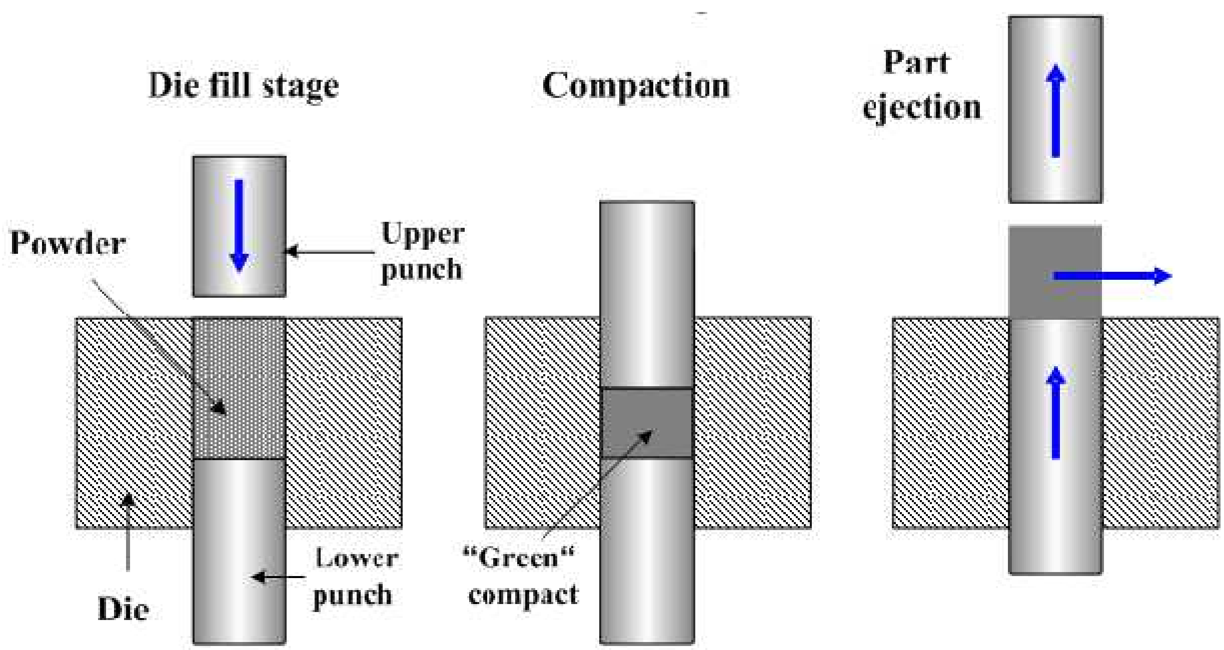
v) Rotary press: These presses are used for high production. In these presses die moves in circular paths. Number of dies are arranged on circular path.

Mainly two types of presses are used for pressing. These are mechanical press and hydraulic press/Pneumatic press. Mechanical presses are used for lower pressure, small size component and greater rate of production. Hydraulic presses are used for larger pieces requiring more pressure.

The press can be of single punch type or multiple punch type. The rate of production of rotary table press is higher as it consists of large no: of dies.

Pressing Process:

The principle of punch and die arrangement for pressing is shown in figure.



The dies are designed in such a way that when they are filled with the powder they have exactly the right quantity of material to make the finished piece. The die is fitted in die box. The dies are made of cast iron, steel, satellite or tungsten carbide. The press consists of two punches i.e., top punch and bottom punch.

In first step, top punch is kept above the top surface of die and bottom punch is moved correct height in die to make room to receive the predetermined (required) amount of material.

Then powdered granules are filled in die.

The upper punch moves down in the die cavities filled with powder granules and lower punch moves up. The powder is compressed between two punch surfaces and pressure is released.

After pressing the compact is ejected out of die.

The die cavities should be very smooth and it is also provided with slight taper so that compact can be ejected without friction.

The punch pressure is exerted (applied) from the upper as well as from bottom side, so that pressure throughout the compact body is uniform as possible. The travel of punch depends upon compressive ratio required for compact.

4.4.1 Dust pressing: The powder granules are mixed with 5-10% moisture. The pressing is carried out in steel dies under high pressure. This method is used for pressing low tension insulators and tiles. During dust pressing granular powder is prepared by first making cakes of raw material and then drying the filter cakes to correct moisture content. Then granules are made with the help of the disintegrator. This method is used as granules can easily flow in die and have sufficient strength until it gets pressed

In small scale low tension insulators industries, the granules are prepared by drying the cakes and grinding them. The pressing is carried out in toggle press.

In case of tiles, granules are prepared by spray drier method.

4.4.2 Dry pressing: The pressing is said to be dry when moisture content in powder in 0-4%. Mostly it is kept in range of 1-2%. In this case, there are no plastic properties in granules. As a result , binders and lubricants are also added. This require high pressure for pressing.

Advanteges over dust pressing: The dry pressing has advantage

- There is less drying shrinkage, so greater accuracy of product is obtained and closer tolerance in product dimensions can be obtained.
- The pressed wares have less flash or fins**.**
- Generally better electrical properties are obtained.

4.4.3 Isostatic pressing:

Very high pressures are required for dry and dust pressing. By these methods, the pressed density is not uniform. Also the high pressure leads to other faults. In dry pressing, pressure drops from pressed surface to the farthest face from the pressed surface. The greater is the distance, greater is the pressure drop. This leads to greater difference is density throughout the pressed piece**.**

This problem is maximum in single acting pressing. This problem can be improved by pressing from two directions i.e. from top and bottom. In this case there will be low density layer in the center of the pressed piece where as in outside the density is high. This problem leads to defects if the thickness of the piece is more.To remove or minimize the problem of density variation, the pressure can be applied evenly to whole exterior of the articles. This is known as Isostatic pressing.

Process of isostatic pressing: The isostatic pressing method consist of filling, the granular material in a flexible envelope usually rubber. This envelope is first filled with powder and then immersed in oil or any suitable liquid contained in pressure vessel. Then pressure is applied to the bag with the help of liquid.

The liquid transmits the pressure uniformly all over the surface of the bag and the powder within it is uniformly compressed. This method is help full for producing complex shapes and for used with non- plastic material. By this method, the material can be pressed to high pressure and uniform densities.

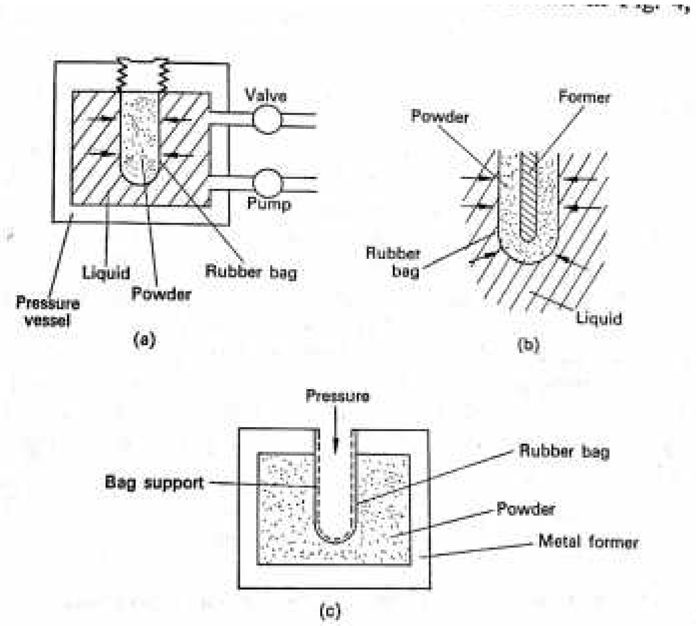


FIG. 4. Isostatic pressing.

Isostatic pressing arrangement is shown in figure ‘A’. The variation in pressing arrangement can be made to make different shapes.

In fig. B, a metal former is shown in bag containing powder. On the application of pressure the powder is pressed between metal former and bag, producing close ended tube.

In figure C the powder is contained between the outside of the bag and a metal former and the pressure is applied from inside the bag. The bag then expands and presses the powder against the former. The external shape is determined by shape of former. The quality of pressed piece depends upon

- The increase of pressure.
- Dwell time (time of holding maximum pressure)
- Rate of pressure release.

4.4.4 Hot pressing: In this method of forming heat and pressure are applied simultaneously to the powered material. The forming and firing of article is carried out at same time.

Advantages: High density can be achieved at lower temperature then required for firing under atmosphere pressure.

Disadvatages: In this method only simple shapes can be pressed.

To obtain maximum strength and thermal shock resistance, the pores must be eliminated during firing without grain growth (i.e. growth of large grains at the expense of smaller ones). This can be better achieved in hot pressing, than normal firing. So this method is used where high qualities are required in the product. By this method only small and high cost items are made. By these method boron carbides, nitrides or other single material bodies are made.

Arrangement of Hot Pressing:

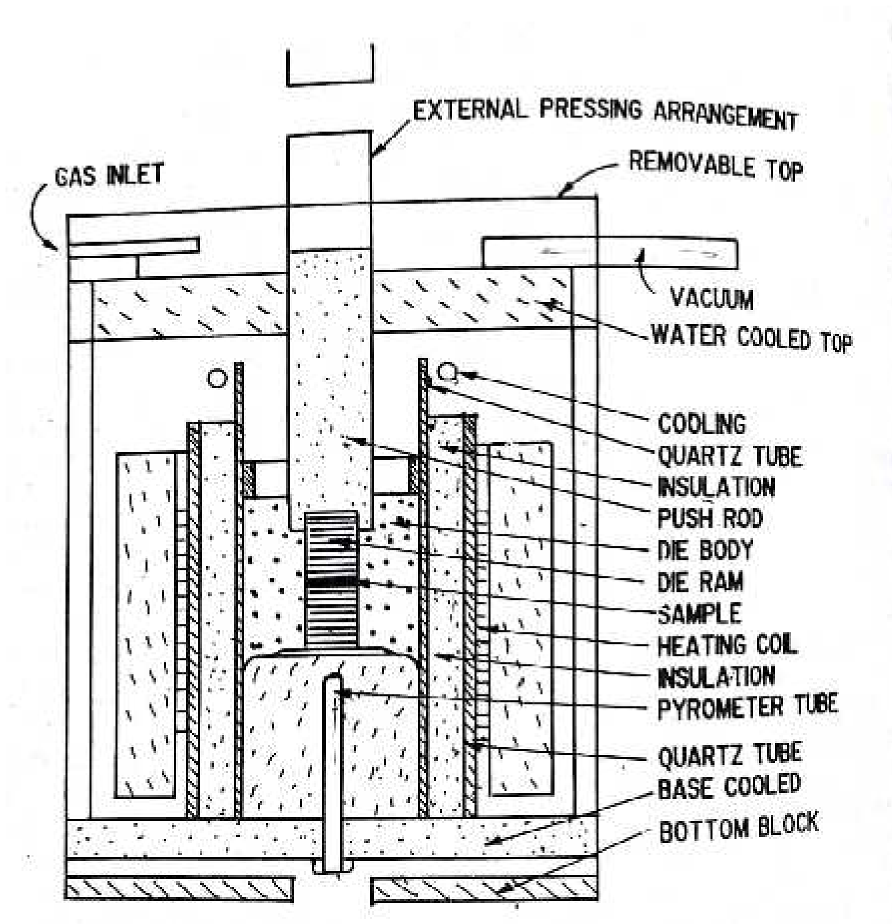


Figure 6.8. Arrangement for hot pressing

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The arrangement in which hot pressing consists of a cylindrical furnace heated by induction or resistance coils. This arrangement is provided with evacuating system (feed mix). The innermost quartz tube encloses the pressing arrangement. The pressing arrangement consists of fixed die-support block, die body and die ram. The die push rod comes in from the top during pressing. All these parts are made up of graphite. Some have ceramic dies.

During pressing of alumina the best results are obtained when alumina grain size is 0.5 to 3 micron grains using graphite press materials. The pressure used during hot pressing varied from 4000 - 10000 psi and temperature varies from 1100^{o}C - 1400^{o}C.

4.5 Injection moulding: This process is used for making plastic articles including low tension house hold insulator parts. This method is used to produce ceramic parts quickly. In this method, the ceramic batch powder is mixed with certain amount of plastic powder, so as to give inject able suspension at melting point of plastic powder. This plastic powder burn away during firing and hence gives high shrinkage. So, its quality should be carefully selected.

This method is used to produce complete shaped components or articles. Ceramics injection moulding (CIM) uses ceramic powders such as alumina, Zirconia, titanate, ferrite powders etc.

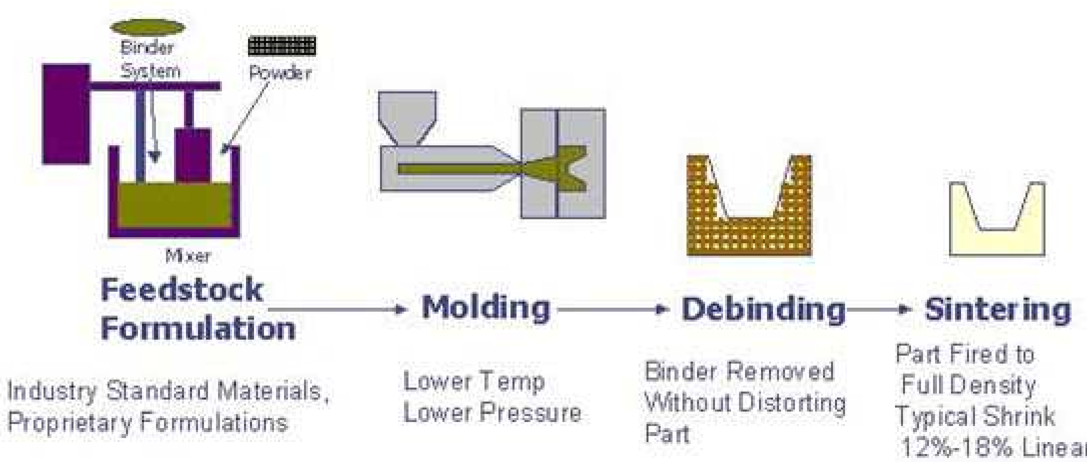
Ceramics injection moulding mainly consists of four steps:

i) Feedstock preparation (raw material preparation)

ii) Injection moulding

iii) Debinding process (Binder removal)

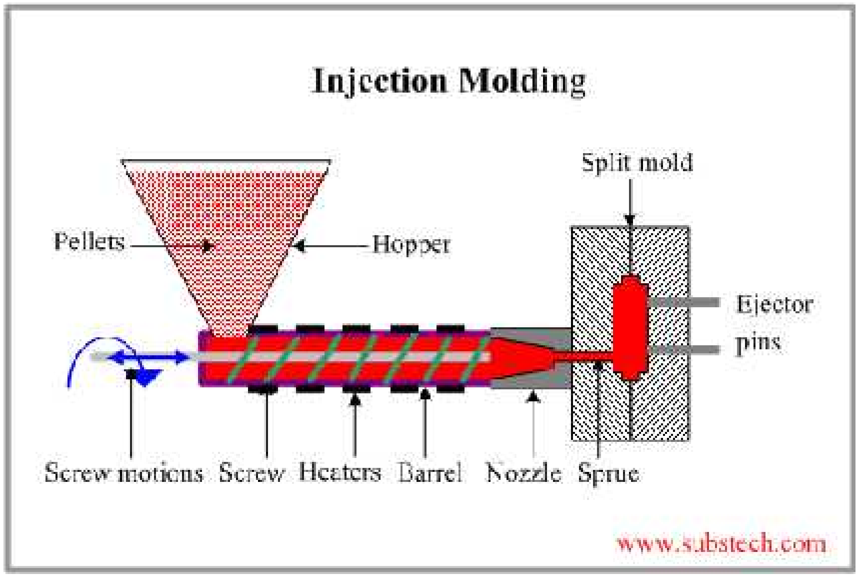
iv) Sintering or firing



i) Feedstock preparation (raw material preparation):

First of all required raw materials are selected having required particle size, specific surface area, particle size distribution, particle shape and purity. These properties affect viscosity of slip suspension. The material is mixed with thermoplastic binder.

ii) Injection moulding: In this process material is fed in to heated barrel, it is mixed and forced in to mould. In mould it gets cooled and gets hardened. Hence it takes the shape of mould cavity.



iii) Debinding process (Binder removal) Binder (plastic powder) is removed in two steps

a) First of all shaped article is dipped in suitable solution. Here soluble part of binder gets dissolved in solution.

b) In second step, it is heated to suitable temperature to remove remaining part of binder.

iv) Sintering or firing: In this step, the article free from binder is fired at suitable temperature and in suitable atmosphere to get desired properties.

4.6 Finishing operation: Finishing operation is the part as forming process. Finishing operation included removing flashes or fins or seams of the formed piece and joining pieces or handles. The finishing operation is done when the material is in leather hard condition.

A. **Finishing operation is case of cast ware**:-

a. Trimming: Trimming is the process or removing or cutting excess material or spares materials from surface of cast piece. Trimming is done is the mould itself, generally it is done after casting has takes place. Trimming is done after removing ring of plaster mould. Trimming is done with the help of sharp thin knife held parallel to the surface. At this cast should not be too soft.

b. Scrapping and sponging: When pieces are casted in multiple piece mould then there are always some seems or raised edges. These are removed by scrapping or sponging. Sponging is carried out until becomes invisible on green ware. Sometimes on the surface of cast ware a groove appears on the surface due to worn out moulds. This is filled by plastic body. Similarly sometimes material built up occurs on the surface of the body which are removed by sand paper or brush or by sponge.

B. Finishing operation is jiggered ware and dust pressed ware:

a. Fetting: In case of jiggered ware after drying, sharp edges appear on the surface of the ware created by profile. This is removed by hand or by fettling operation.

In case of pressed wares, a flash (extra material) appears on the joints of die halves. This flash is also removed by fettling operation. So, fettling is the operation by which the extra material is removed with the help of brushes.

C. Sticking up or joining: Joining or sticking up is the operation of joining handles to cups or jugs.

Several types of ware are made is two or more pieces and latter jointed together when the material is partially dry, as in case of cast wares. It is observed that two pieces will stick (join) together in plastic state. The joining tendency decrease as the pieces dries and when the material (piece) is completely dry sticking will not takes place. In this case, the piece has to be dipped in water for sticking up.

Sticking is done with water only, in case of heavy ware having more moisture. For example: - joining of china clay handles. If the cup is dry and it has thin wall then in this case slip is used to join the handle. The slip used for joining should have same composition as that of body. Sometimes the adhesive properties of slip is increased by adding 0.1-0.4% of $MgSO_4$ aqueous solution into the deflocculated slip. After joining the piece, the excess slip must be removed.