POLITEKNIK
MALAYSIA
SULTAN MIZAN ZAINAL ABIDIN

eNotes

CERAMIC Processing

BY
TS. SITI AISHAH BINTI WAHID
NOR 'AMIRAH BINTI TALIB
TS. SULLYFAIZURA BINTI MOHD RAWI

SCAN ME

eNotes

CERAMIC Processing

eNotes : Ceramic Processing
First Edition 2022
eISBN 978-967-0047-07-2

Editor : Ts. Siti Aishah binti Wahid
Nor 'Amirah binti Talib
Ts. Sullyfaizura binti Mohd Rawi

Illustrator : Ts. Siti Aishah binti Wahid

Published by:
Department of Mechanical Engineering
Politeknik Sultan Mizan Zainal Abidin
KM 08, Jalan Paka,
23000 Dungun, Terengganu
Tel : 09-8400800 Fax : 09-8458781
Email : webmaster@psmza.edu.my

eNotes : Ceramic Processing
First Edition 2022
eISBN 978-967-0047-07-2

eNotes - Ceramic Processing is as general references and readings especially to lecturers and students of polytechnics and community colleges to apply best practices in method implementation online teaching and learning.

eNotes - Seramik Processing adalah sebagai rujukan dan bacaan umum terutama kepada pensyarah dan pelajar politeknik dan kolej komuniti Malaysia bagi mengaplikasikan amalan terbaik dalam perlaksanaan kaedah pengajaran dan pembelajaran atas talian.

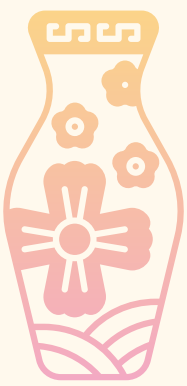
Editor : Ts. Siti Aishah binti Wahid
Nor 'Amirah binti Talib
Ts. Sullyfaizura binti Mohd Rawi

Illustrator : Siti Aishah binti Wahid

Published by:
Department of Mechanical Engineering
Politeknik Sultan Mizan Zainal Abidin
KM 08, Jalan Paka,
23000 Dungun, Terengganu
Tel : 09-8400800 Fax : 09-8458781
Email : webmaster@psmza.edu.my

ACKNOWLEDGEMENT

Praise our gratitude to the presence of God Almighty. By His grace and guidance, the authors were able to complete an eNotes entitled "Ceramic Processing". Not forgetting, authors thank to Mr. Roshaizul Nizam Bin Mohd Sani as an e-Learning coordinator who has assisted authors in producing this scholarly work. This eNotes provides guidance in the learning of Ceramic Processing for manufacturing and mechanical engineering. The authors realize there are shortcomings in this work. Therefore, suggestions and criticism are always expected for the improvement in future. Hopefully that this eNotes will be able to provide additional knowledge to students and anyone who wants to know the basics of the Ceramic Processing in Advance Manufacturing Process.



ABSTRACT

This eNotes - Ceramic Processing offers a comprehensive guide to the fundamentals of ceramic materials, including their properties, processing, and applications. It covers ceramics materials from structure, properties, classification, traditional and modern applications, technique processing ceramic and shaping process. Materials and design engineers can identify ceramic materials and able to design new ideas. Manufacture Engineers on the other hand, able to apply new techniques for developing brand-new applications. Several types of ceramic shaping processes such as tape casting process, slip casting process, hand modelling plastic forming, injection molding plastic forming, extruding, jiggering and semi-dry pressing that would all benefit from this eNotes - Ceramic Processing.
It is a short, relevant, and instructive reference guide to all. This is also as general references and especially to lecturers and students of polytechnics and community colleges to apply best practices in method implementation online teaching and learning.

CONTENT

1.0 INTRODUCTION TO CERAMIC MATERIALS

Ceramics fall within the category of inorganic, nonmetallic elements that are essential in our daily life. The professionals who design the manufacturing processes, create new types of ceramic products and find new uses for ceramic objects in daily life are known as ceramic and materials engineers.

Definition :

The word ceramic originates from the Greek word, keramos which means potter's clay.

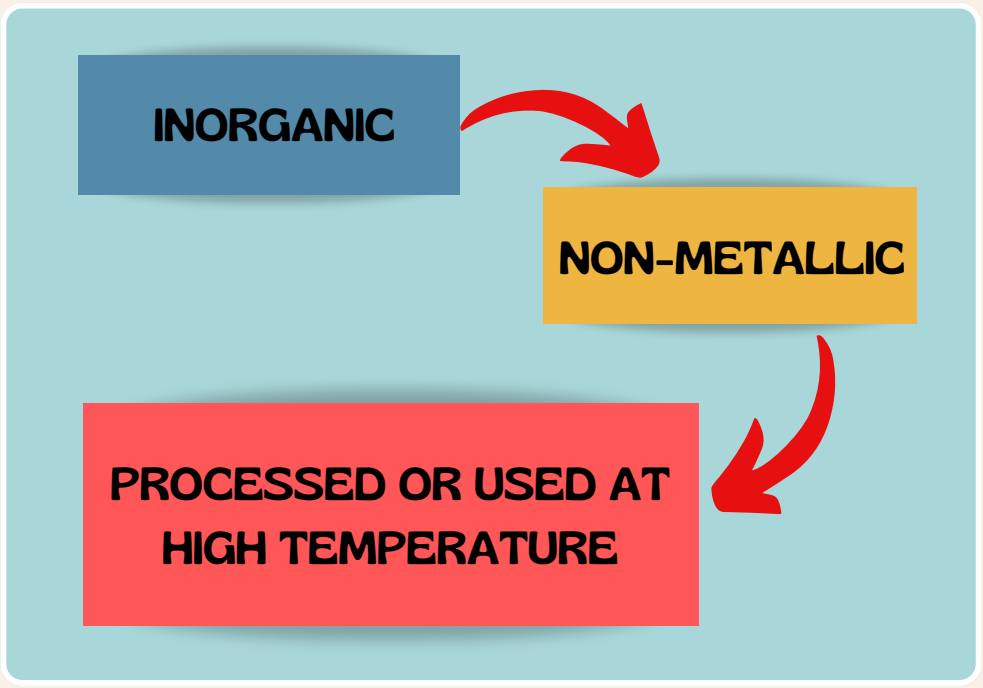


Figure 1.0 : Fundamental of Ceramic materials

Clay, earthy materials, powders, and water are often combined to create ceramics, which are subsequently molded into the appropriate shapes.

The pottery is baked in a furnace, a high temperature oven, once it has been formed.

Ceramics frequently have creative glazes on them that act as waterproof, paint-like finishes.

Ceramic is an inorganic compound. A metal and one or more nonmetals come together to form ceramic.

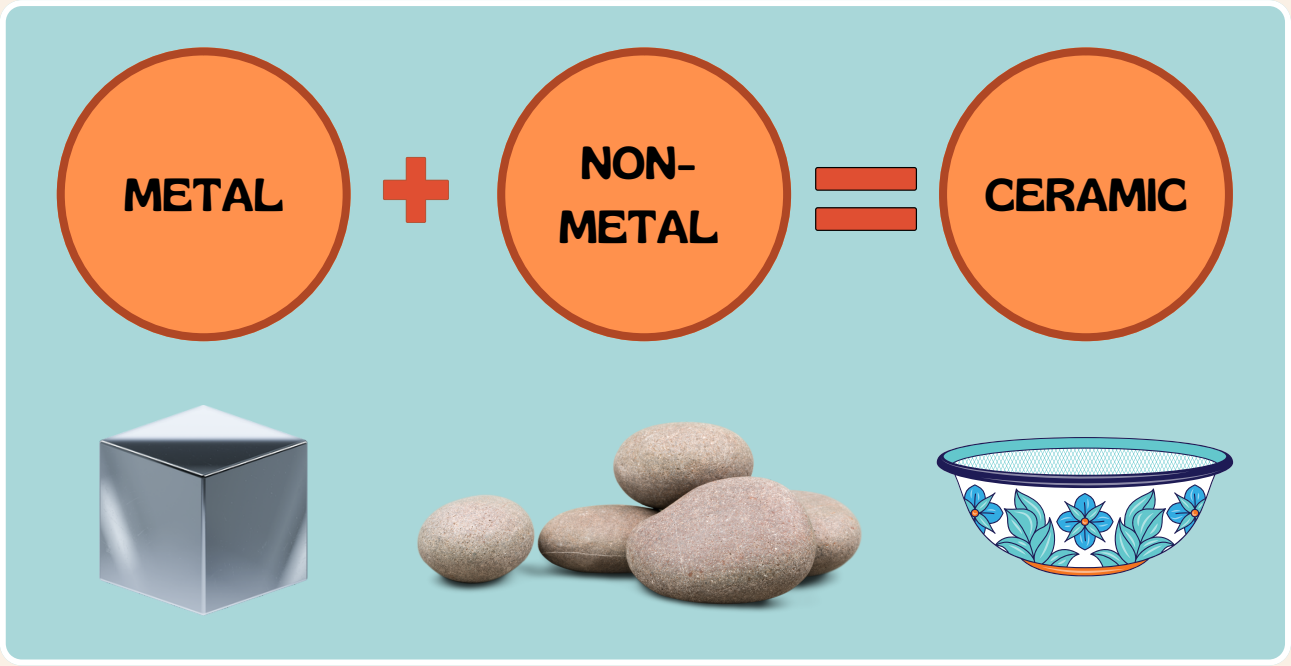


Figure 1.1 : Composition of Ceramic materials

TEST YOURSELF

1. Which category is ceramic fall in our life?

2. What is a ceramic simple definition?

3. What are the compositions of ceramic materials?

Lets check your answers SCAN ME

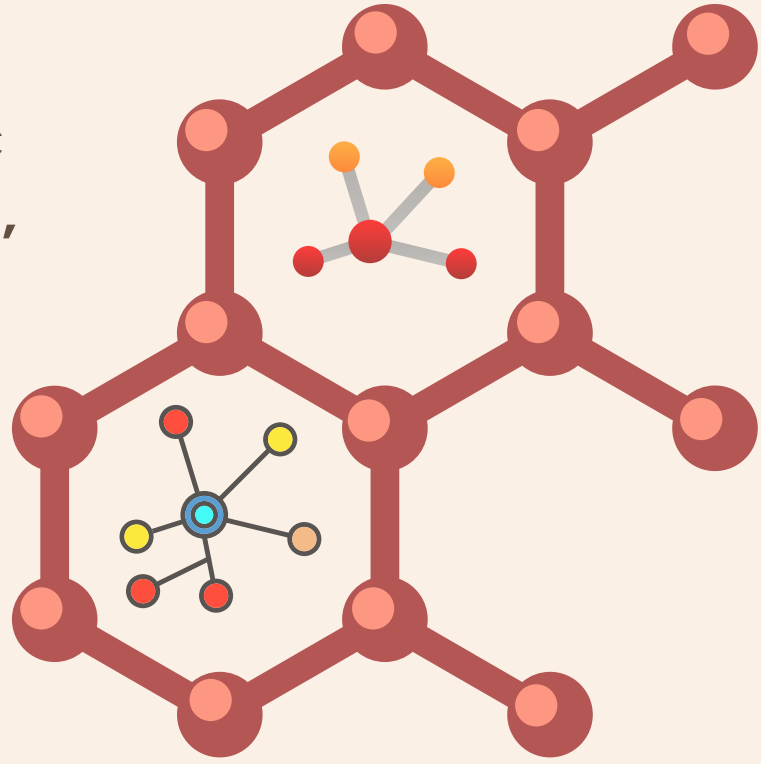
ONLINE QUIZ

SCAN ME

2.0 PROPERTIES AND CLASSIFICATION OF CERAMIC

The kinds of atoms exist, the natures of atom bonds present, and the way the atoms are stacked together have an impact the qualities of ceramics, just like they do for any material.

Ceramics include ionic and covalent bonding, respectively.



A metal and a nonmetal, or two extremely dissimilar elements in terms of electronegativity, form an ionic connection.

Electronegativity, which is dependent on the amount of electrons and the separation of the electrons in the nucleus' outer shells, is the capacity of the nucleus of an atom to attract and keep all of the electrons contained inside the atom itself.

Ionic Crystal Structure is the structure of ceramic materials, and the crystal structure depends on two properties:

1) Metal : +ve ion/cation
2) Non-metal : -ve/anion

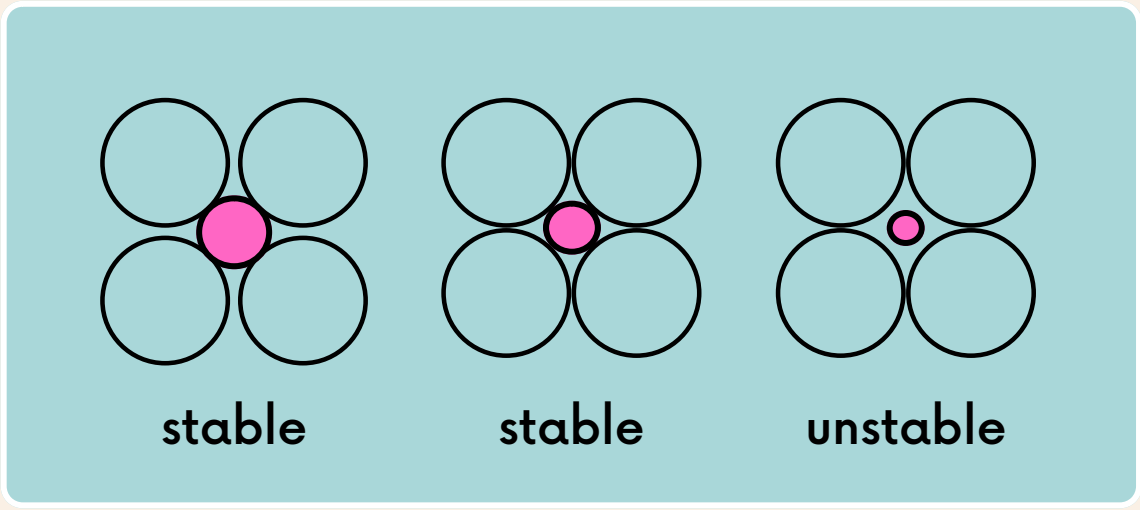
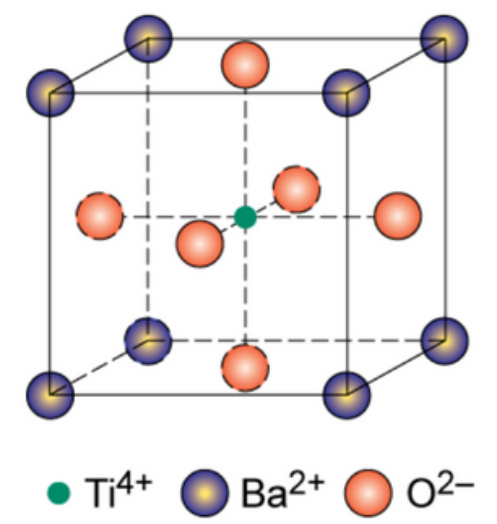
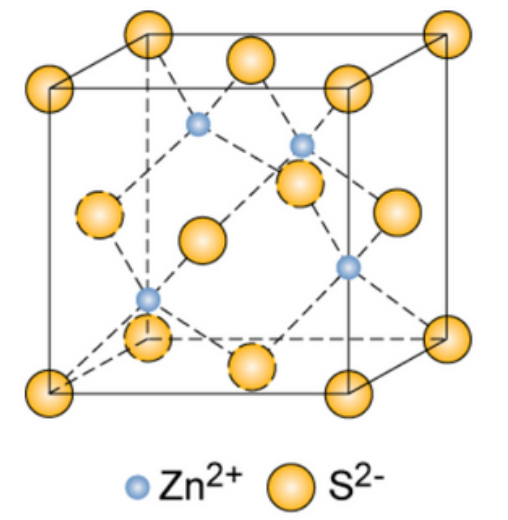


Figure 2.0 : Anion-cation coordination configurations.
Open circle represent anions; colored circles denote cations.

Example of ceramic crystal structure are shown in Figure 2.1(a) and Figure 2.1(b) below:



(a)Perosvkite (ABX3) structure



(b) Zinc Blende structure

Figure 2.1 : Example of Ceramic Crystal Structure (Figure Adapted from Callister Jr, 10th ed.)

Ceramic characteristics, microstructure grain sizes and shapes of have a significant impact on production and processing. This includes the parameters such as hardness, density, tensile strength, and optical properties which are directly correlated with the microstructure of the sintered item.

PROPERTIES OF CERAMIC

- Low density : porosity may affects the properties

- Low ductility : high elastic modulus and very brittle

- Low electrical & thermal conductivity/ thermal expansion

- Extreme hardness : High wear resistance

- Low toughness – fracture or defect to cause a catastrophic collapse

- High strength at high temperature

- Corrosion resistance

CLASSIFICATION OF CERAMIC

Composites

- particulate reinforced, oxide+non oxide
- high toughness
- low and high oxidation resistance (type related)
- high cost for complex manufacturing

Non-oxide

- carbides, borides, silicides, nitrides
- chemically inert
- low oxidation resistance
- electrical conductor
- high cost for difficult manufacturing

Oxide

- alumina, zirconia
- chemically inert
- oxidation resistance
- electrical insulator
- low cost for alumina
- high cost for zirconia

TEST YOURSELF

1. What is electronegativity in ceramic?

2. What are the properties of ceramic materials?

3. What are the classification of ceramic materials?

Lets check your answers SCAN ME

ONLINE QUIZ

SCAN ME

3.0 APPLICATIONS OF CERAMIC

Ceramic materials used in engineering applications are classified into two types:

a) Traditional/classic ceramics
b) Advanced ceramics.

Traditional ceramics are often comprised of three fundamental components: clay, silica (flint), and feldspar. For example bricks, tiles, and porcelain items.

Advanced ceramic materials, on the other hand, are composed of highly pure compositions of aluminium oxide (Al2O3), silicon carbide (SiC), and silicon nitride (Si3N4).

Traditional Ceramics

Traditional ceramics are ceramics built from raw clay or a blend of processed clay and powdered or granulated non-plastic materials. Traditional ceramics is a term that is usually used to denote ceramics that include more than 20% clay.

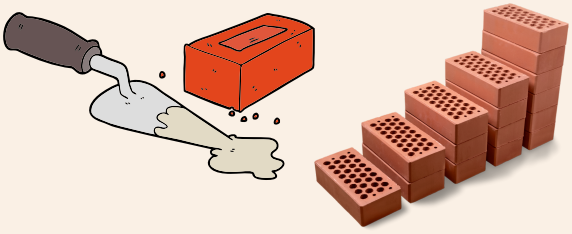
It founded on mineral oxides, silica and mineral silicates originate in nature. The goods and manufacturing procedures trace back thousands of years.

Examples of applications of traditional ceramics around us are pottery, tableware, bricks, tiles, refractories and natural abrasives.

Pottery and tableware

Tiles

Bricks and Refractory



Natural Abrasives

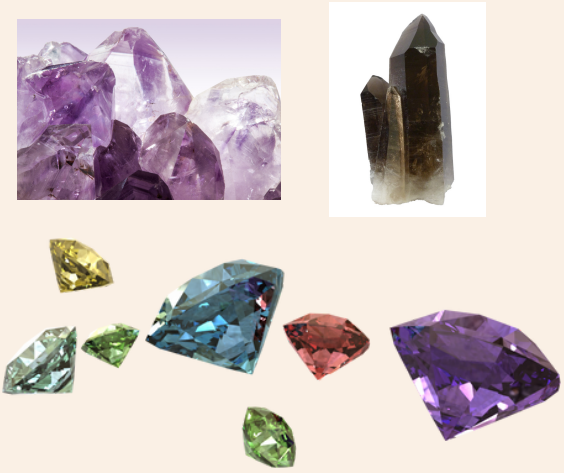


Figure 3.0 : Applications of Traditional Ceramics

Advanced Ceramics

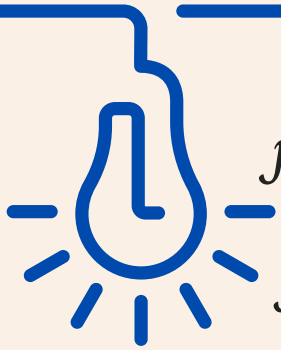
Advanced ceramics refers to ceramic goods that are created from vastly refined natural or synthetic conformations. It was developed synthetically over the last several decades.

Generally, advanced ceramics are created on components other than variants of aluminium silicate, which constitute most conventional ceramic materials.

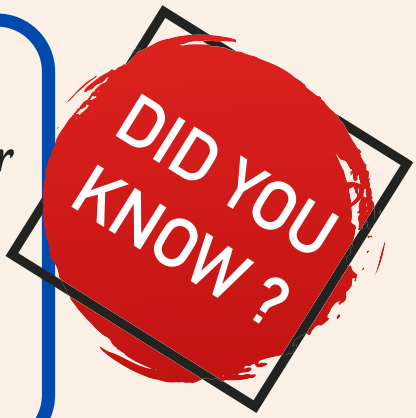
These ceramics been engineered to have specific features and categories into several types; mechanical, electrical, chemical, nuclear, magnetic, optical, thermal and biological applications.

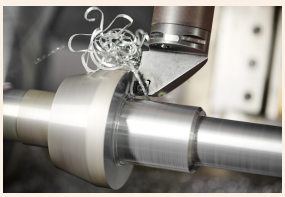
The “advanced” term also refers to advances in processing techniques that changes over structures and most properties of ceramic materials. Advanced ceramics are usually simpler chemically than traditional ceramics such as oxides and carbides.

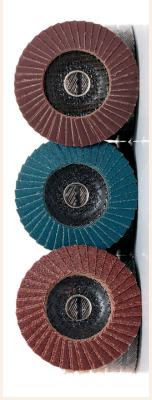
Common advanced ceramics around us are abrasives (used in grinding wheel grit), bio ceramic (artificial for bones and teeth), electrical insulators and electronic components, inserts for cutting tool and modern engineering components such as in aerospace industry.



Ceramics allow greater payloads on aircraft, faster speeds for military-grade jets, and increased mission time for space exploration

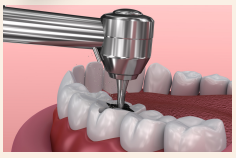


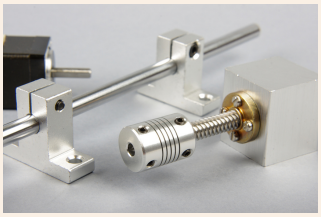




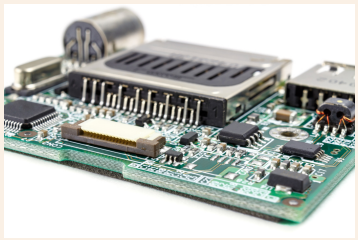

Abrasive & Cutting tools

Bio-ceramics


Electronic Components



Advanced Engineering Components



Figure 3.1 : Applications of Advanced Ceramics

TEST YOURSELF

1. What is traditional ceramic?
2. What is advanced ceramic?
3. Give two example of advanced ceramic applications.

Lets check your answers

SCAN ME

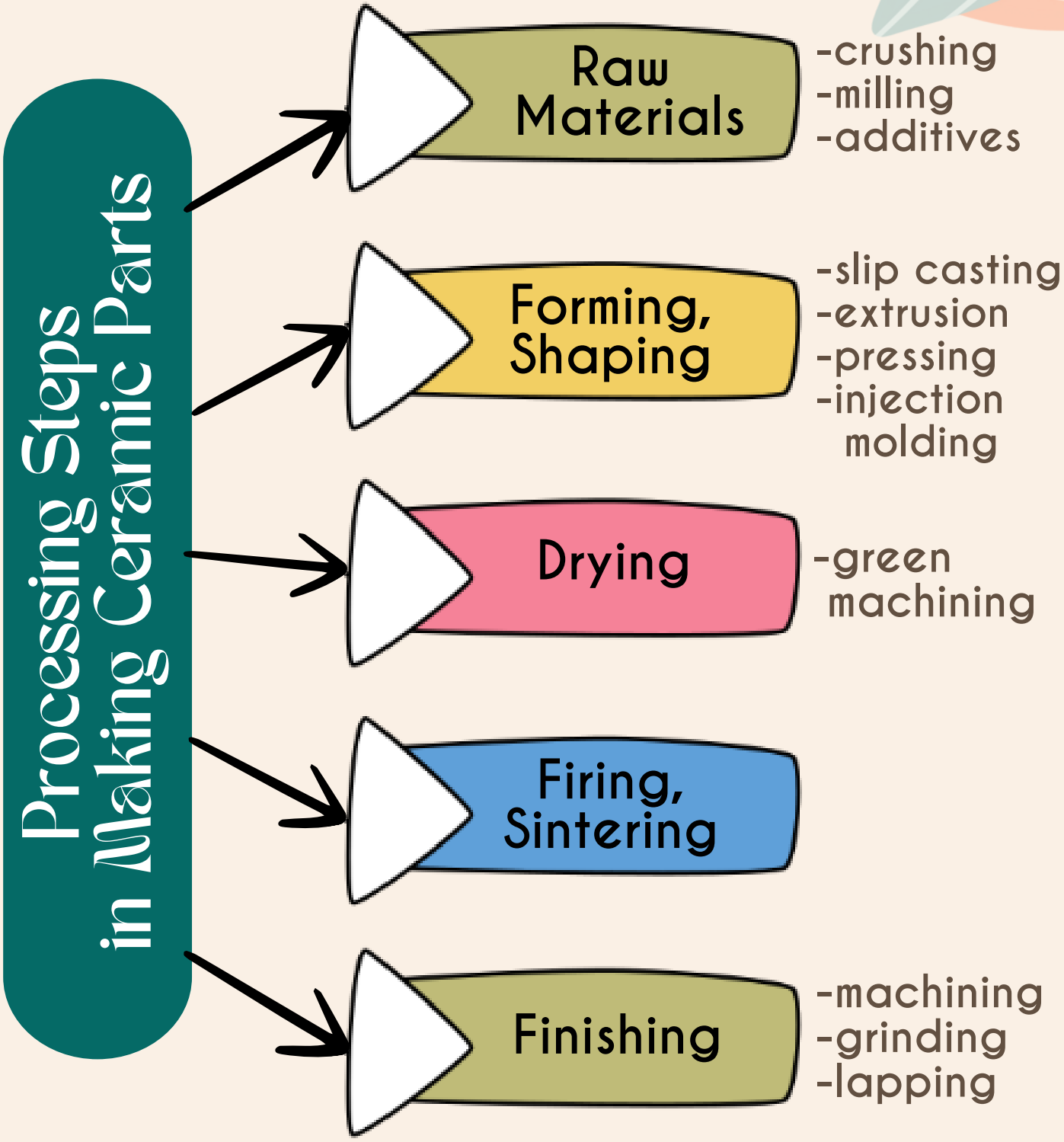
ONLINE QUIZ

4.0 TECHNIQUE PROCESSING CERAMIC

The aim of ceramic processing is to create commercial goods with a wide range of size, shape, intricacy, ceramic composition, and structure. The advancement of ceramics processing is a natural outcome of improved capacity to refine, produce, and describe ceramic materials. Ceramic products normally employ natural resources as a preliminary material.

Therefore, these raw materials require certain processing to manage particle size, size distribution and purity. These characteristics have a significant impact on the ending qualities of the ceramic.

There are some processing steps in making ceramic parts as shown :



Raw materials Preparation

Traditional ceramic shaping procedures demand the use of a plastic paste as the beginning ingredient. The goal of the preparation stage in ceramics processing and manufacturing is to reduce it to powder.

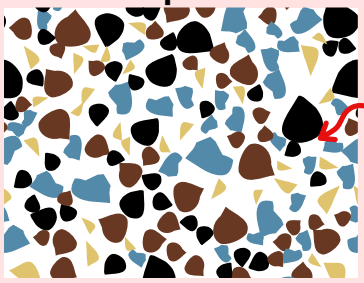
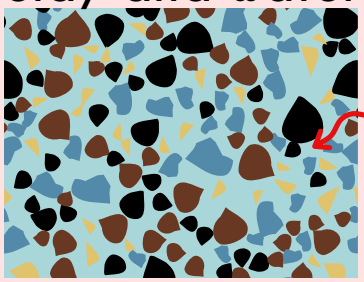
Processing Steps, Condition of Parts and Condition of Powders in Traditional Ceramic Processing are shown in Table 1.

DID YOU KNOW?

The raw ceramic material is normally found in nature as stony lumps.

Traditional Processing

Table 1: Processing Steps, Condition of Parts and Condition of Powders in Traditional Ceramic Processing

Processing Steps	Condition of parts	Condition of Powders
(1) Preparation of powders		Loose powder 
(2) Shaping of wet clay		clay and water 
(3) Drying		dried clay 
(4) Firing		fired clay 

Mechanical energy including impact, compression, and attrition are used in a variety of ways to reduce the particle size in ceramics processing. There are two types of comminution procedures: crushing and grinding.

Crushing is the process of reducing huge mining lumps to smaller pieces for further reduction. There are many types of crushing equipment such as jaw crusher, gyratory crusher, roll crusher and hammer mill.

Various types of crushing process with the equipment are depicted in figures below.

(a) Jaw Crusher : Crushing lumps against a solid surface by using a large jaw that toggles back and forward.

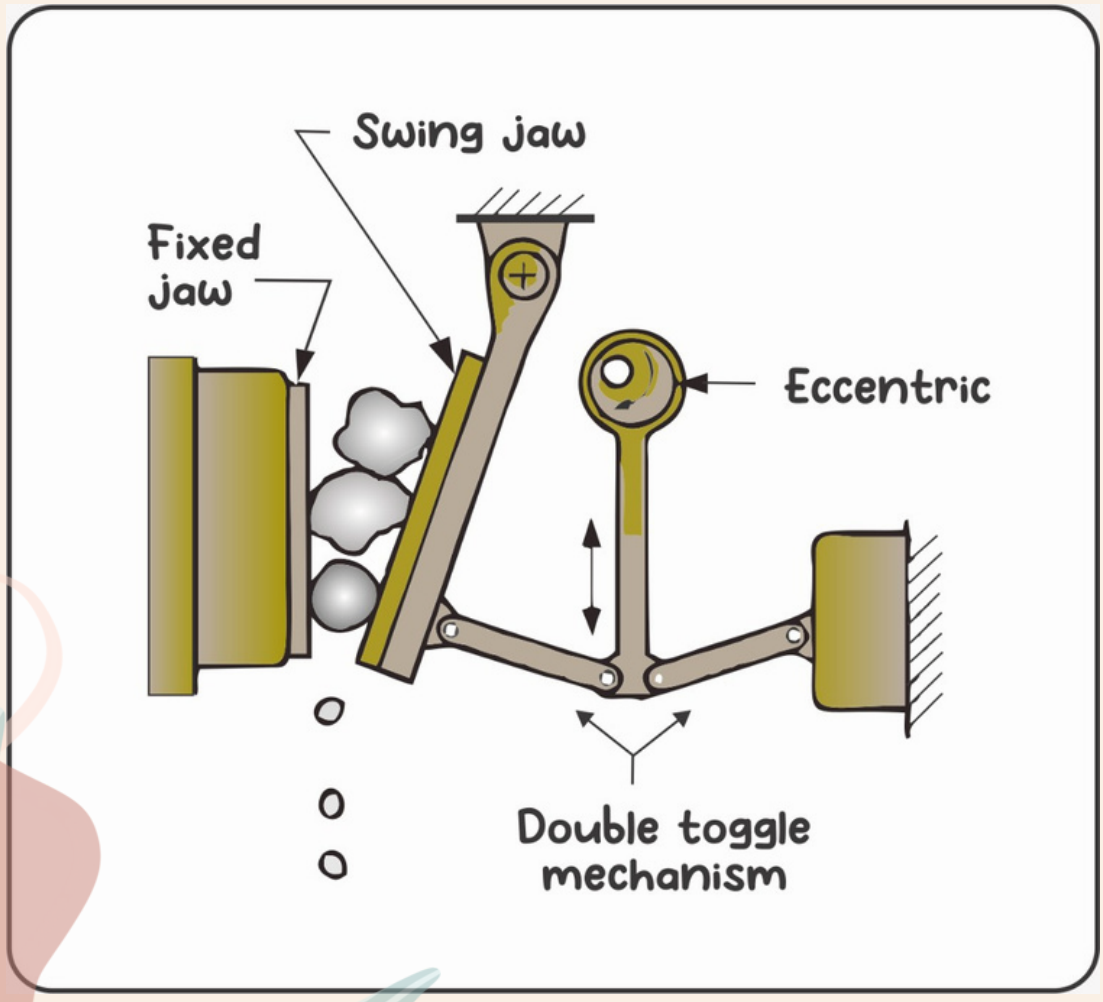
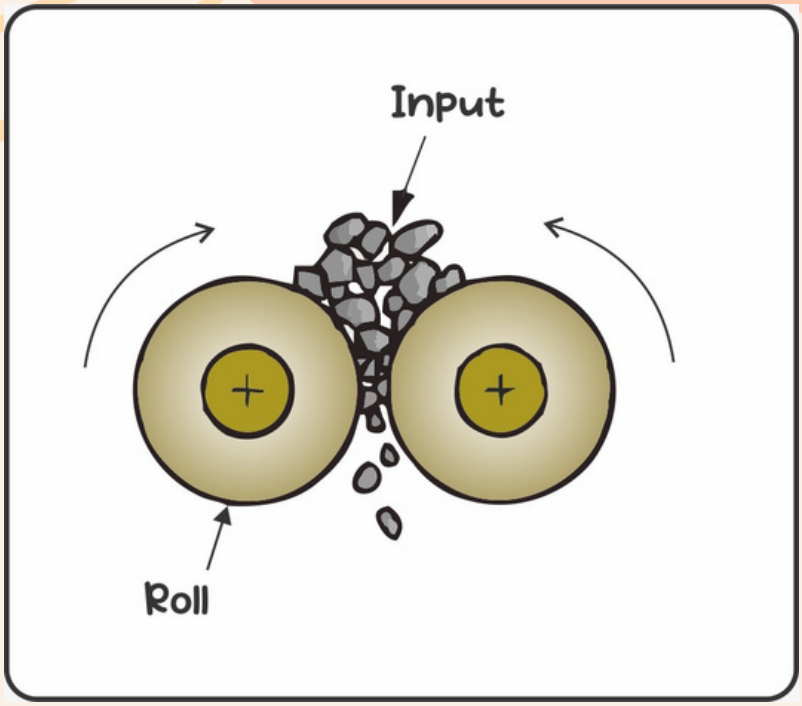


Figure 4.1 : Jaw Crusher



(b) Roll Crusher : Crush the ceramic lumps between spinning rolls.

Figure 4.2 : Roll Crusher

(c) Hammer Mill : Use rotating hammer to impress the material for break apart the lumps.

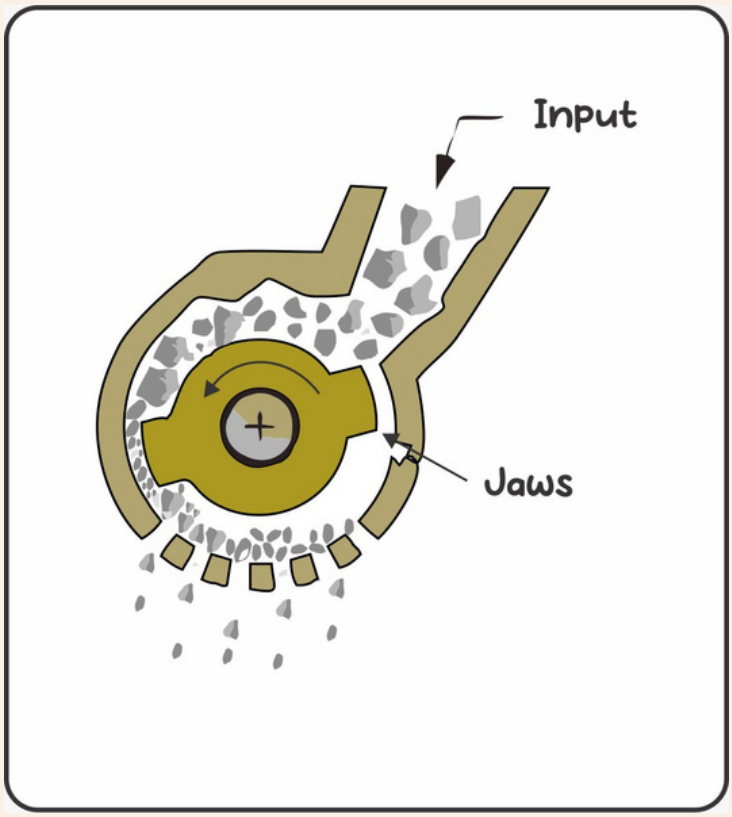


Figure 4.3 : Hammer Mill

(d) Gyratory Crusher : apply a rotating cone to compress lumps against a stiff surface.

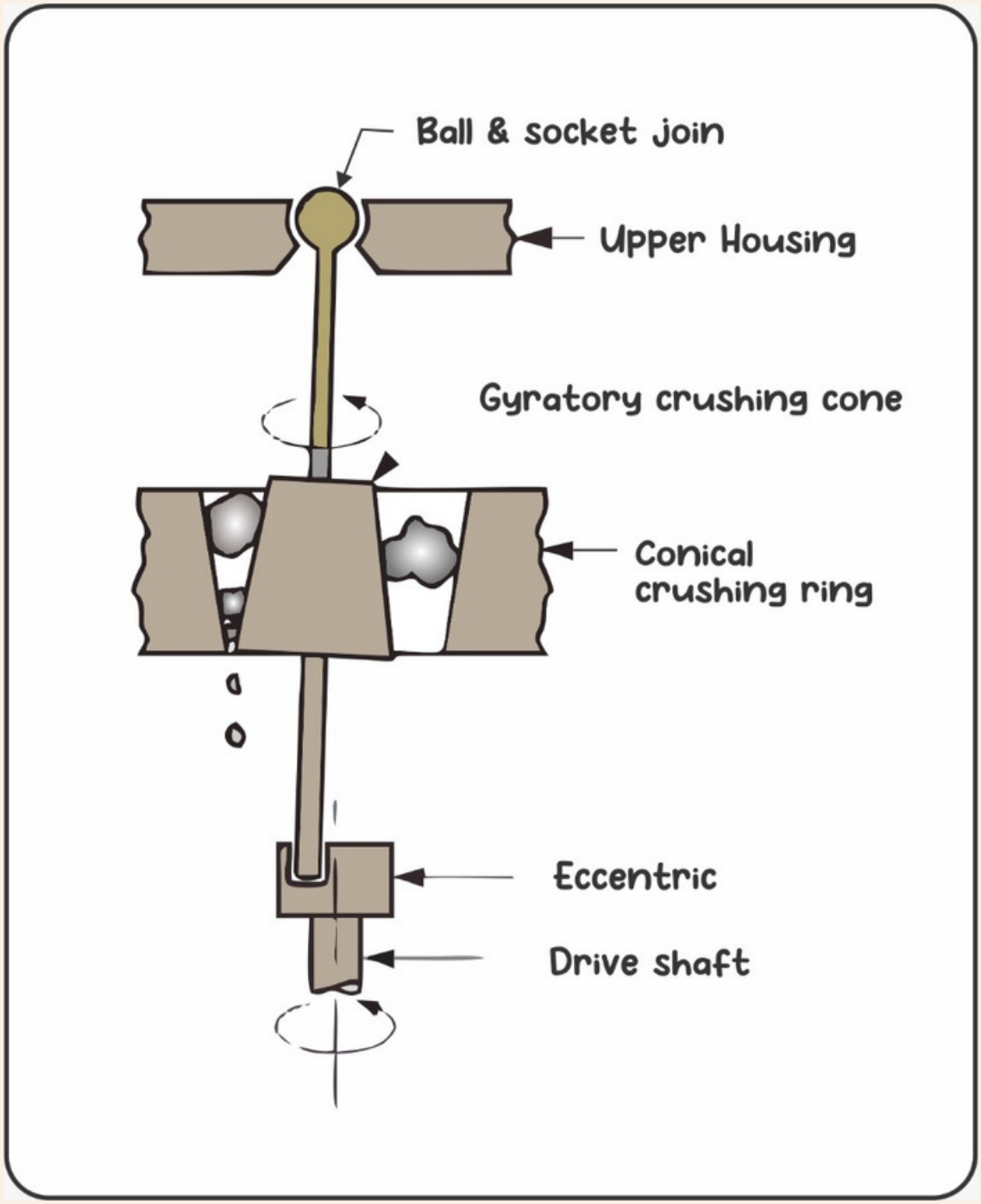


Figure 4.4 : Gyratory Crusher

Grinding is the process of turning tiny fragments of material obtained by crushing into fine powder. The free motion abrasion and impact of the crushed material of disconnected stiff utensil such as balls, small stones or rods are used to grind it. Examples of grinding include ball mill, roller mill and impact grinding as depicted in figures below.

(a) Ball Milling : Tumbles solid spheres mixed with the stock to be crunched inside a spinning container.

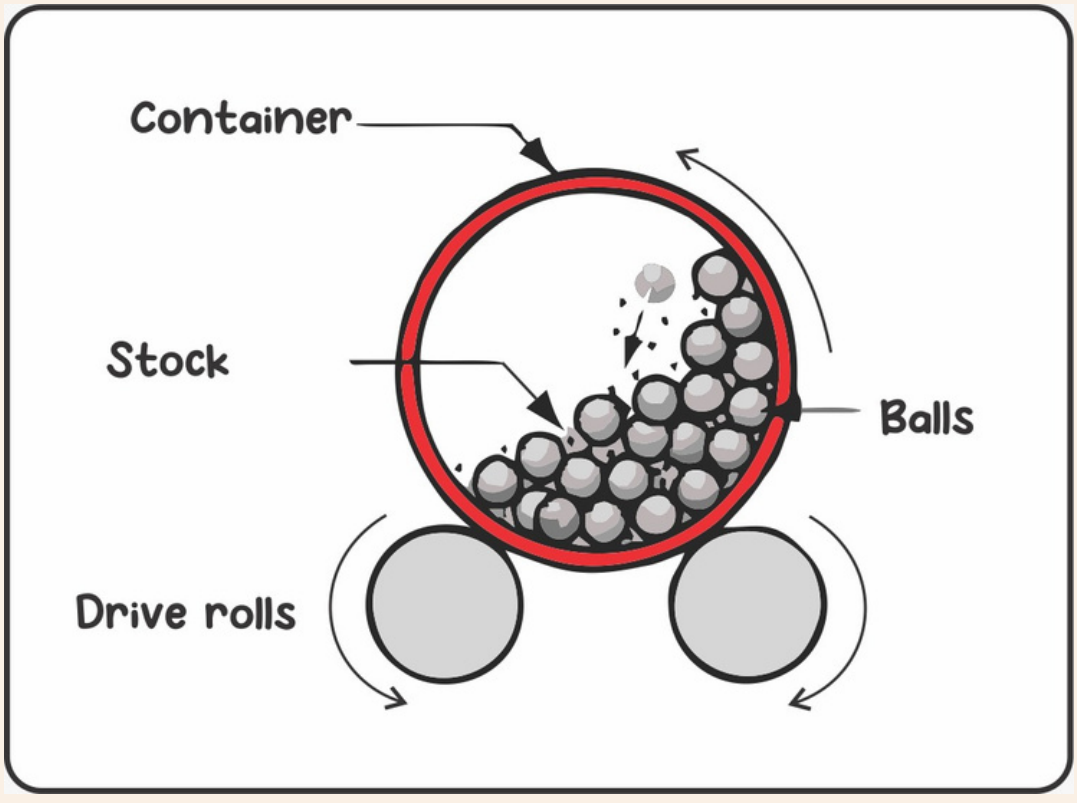


Figure 4.5 : Ball Milling

The rotation allows the balls and stock to pass up the container wall before being dragged down gravitily for an impact and attrition grinding action. These activities are frequently performed by adding water to the mixture, resulting in a slurry of ceramic.

(b) Rollers : Rolling over the table surface compress stock against a plane grinding table in a roller mill.

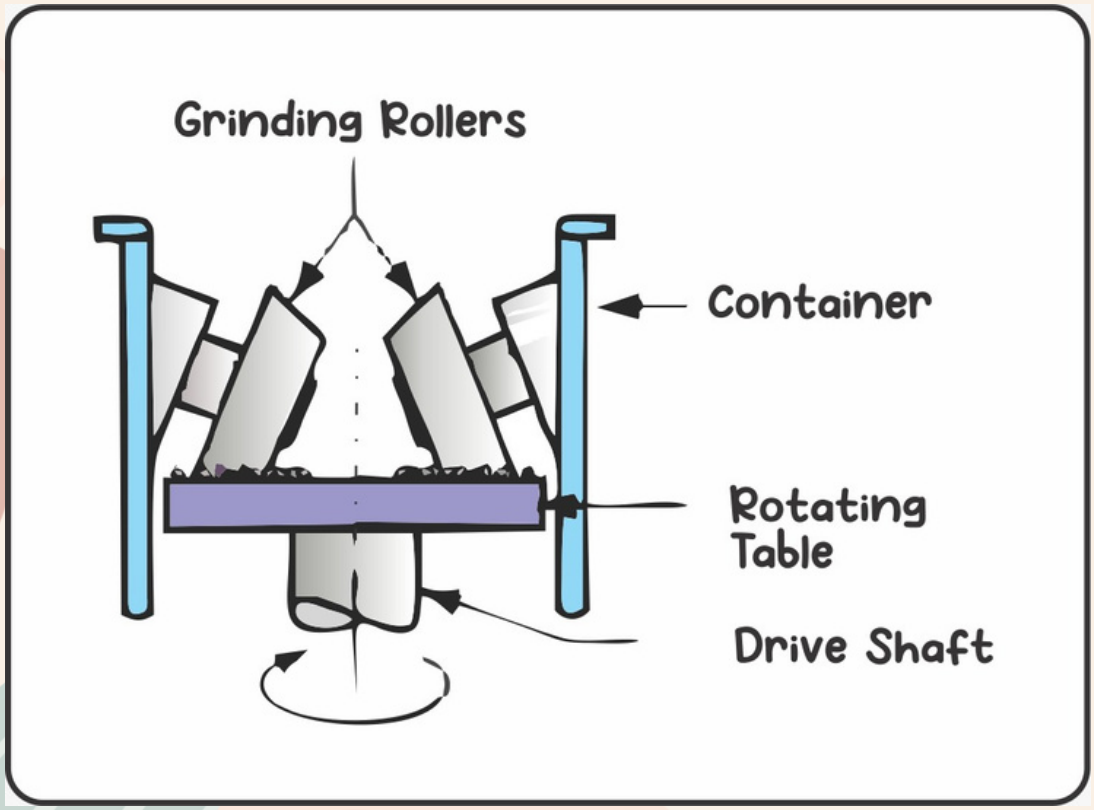


Figure 4.6 : Rollers

Mechanical springs or hydraulic-pneumatic systems control the pressure of the grinding rollers against the table.

(c) Stock Particles : Flung against a rigid flat surface in impact grinding. This happen either in a high-velocity air stream or a speedy slurry.

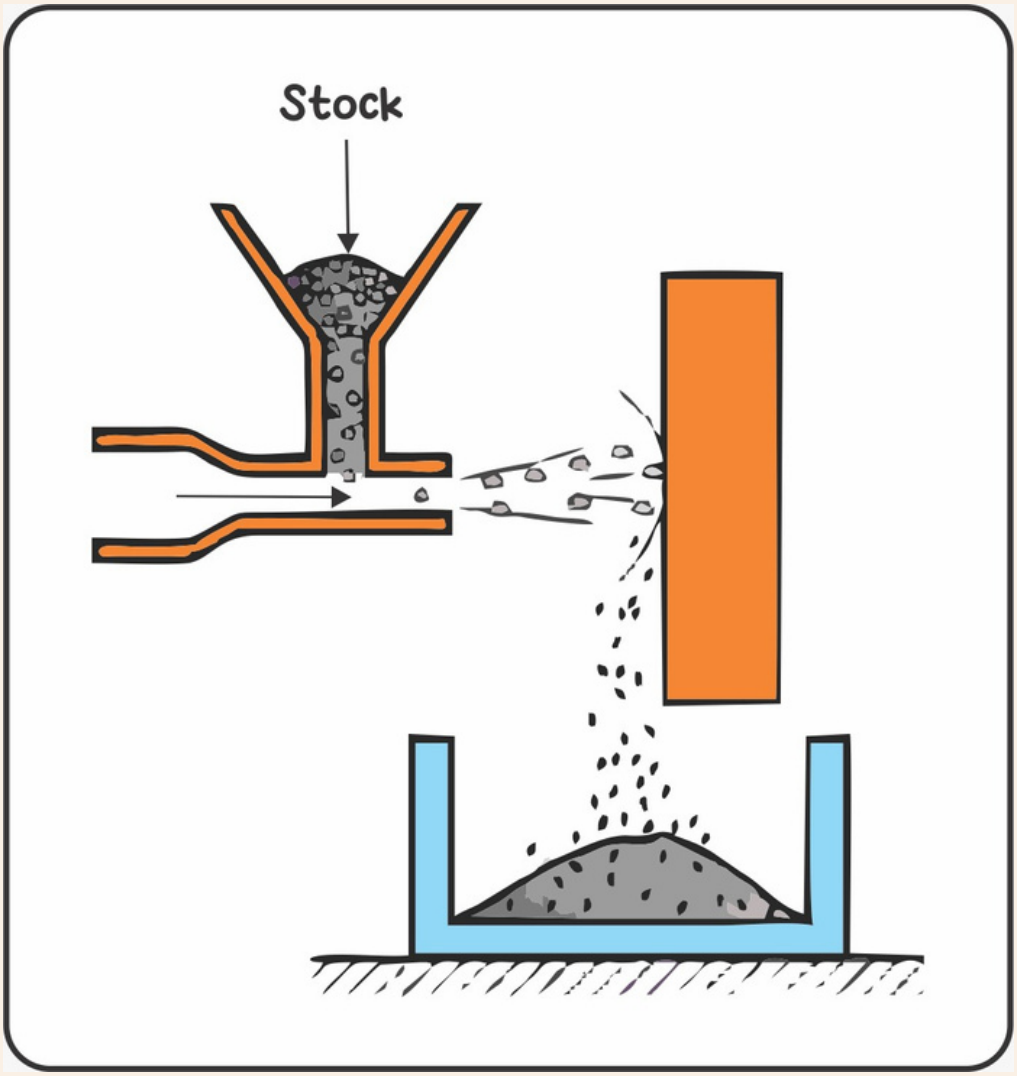
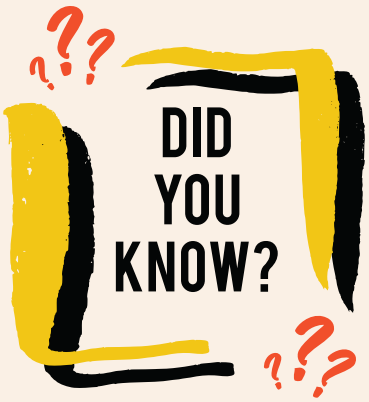


Figure 4.7 : Stock Particles Process

The collision shatters the fragments into smaller bits. The plastic paste used for shaping is made up of ceramic granules and water.

Because clay has excellent forming properties, it is frequently the predominant element in the paste.



clay may be generally described as 40% aluminum oxide, 46% silicon oxide, and 14% water.

TEST YOURSELF

1. What are the processing steps in making ceramic parts?
2. Give two types of comminution procedures in powder preparation.
3. How ball milling works?

Lets check your answers

SCAN ME

ONLINE QUIZ

SCAN ME

5.0 CERAMIC SHAPING PROCESSES

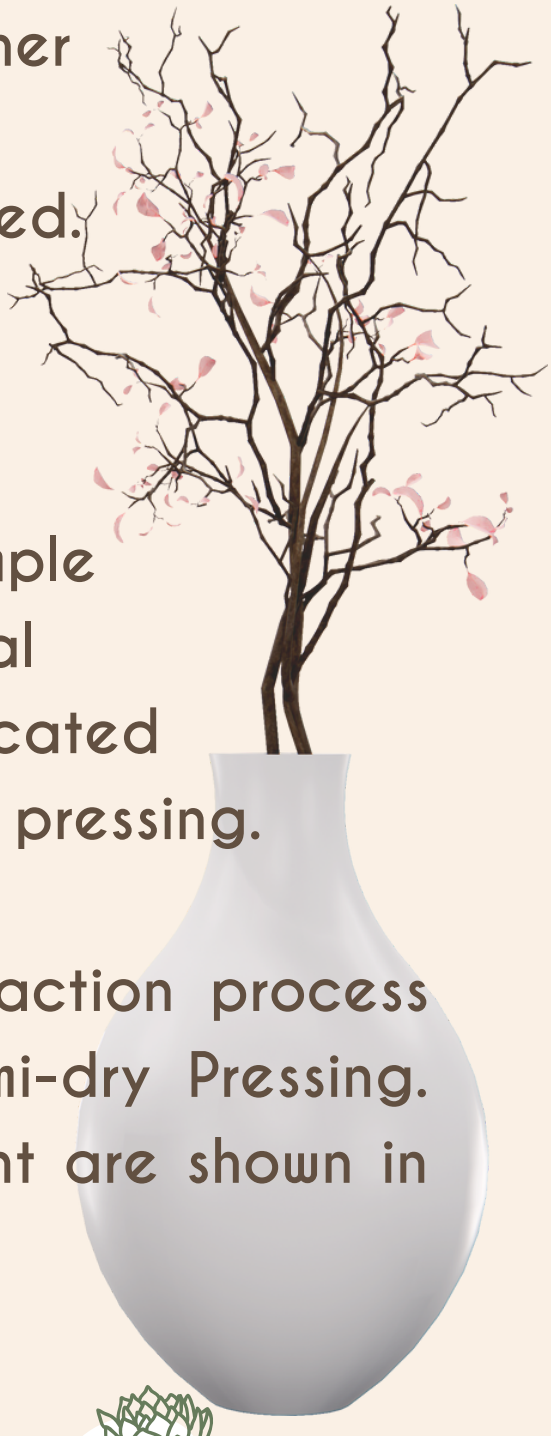
Ceramic products usually require to be shaped into desired and useful forms once the component powders have been produced to the correct particle size and purity.

There are three categories of shaping methods used for ceramic production, which are not necessarily independent. The categories are dependent on the consistency of water mixture.

a) Powder compaction (10% to 15% water)
   - slurry
b) Casting (25% to 40% water)
   - plastic clay
c) Plastic forming (15% to 25% water)
   - moist clay

a) Powder compaction (10% to 15% water) - slurry

Powder compaction is nothing more than the pressing of powder. The powder can be pressed dry or with an amount of a suitable binder added. Either uniaxially Pressure or iso-statically can be applied.



The pressing process chosen is determined by the final product's form. Simple forms are formed by uniaxial pressure and more sophisticated shapes formed by isostatic pressing.

Example of powder compaction process in ceramic shaping is Semi-dry Pressing. The process and equipment are shown in Figure 5.0.

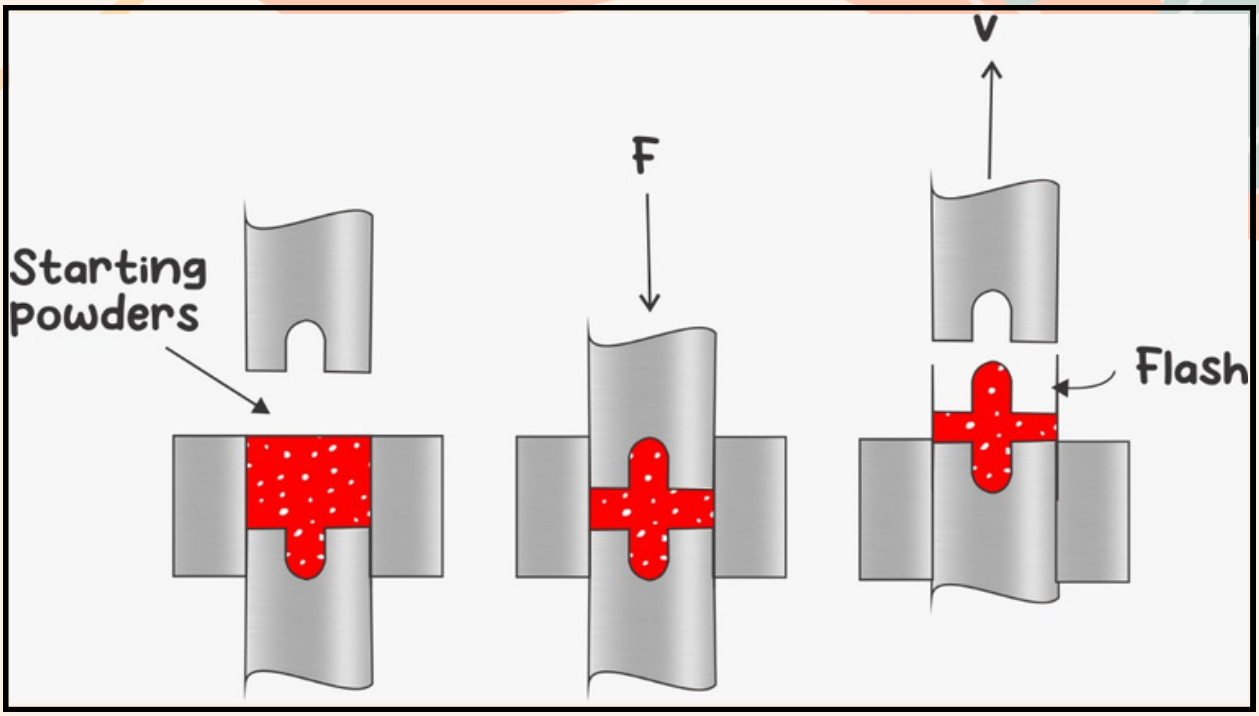


Figure 5.0 : Semi-dry Pressing

In semi-dry pressing, amount of starting moist powder is deposited into die cavity. Then followed by closing and pressing the die.

The final product can be collected by opening the die section and ejected. Trimming of the flash is the final or finishing process of ceramic shaping in semi-dry pressing.

b) Casting (25% to 40% water) – plastic clay

Casting of ceramics is done at room temperature and usually involves suspending ceramic particles in a liquid to produce a slurry. Slip casting is one of the well-known process. It is shown in Figure 5.1 below.

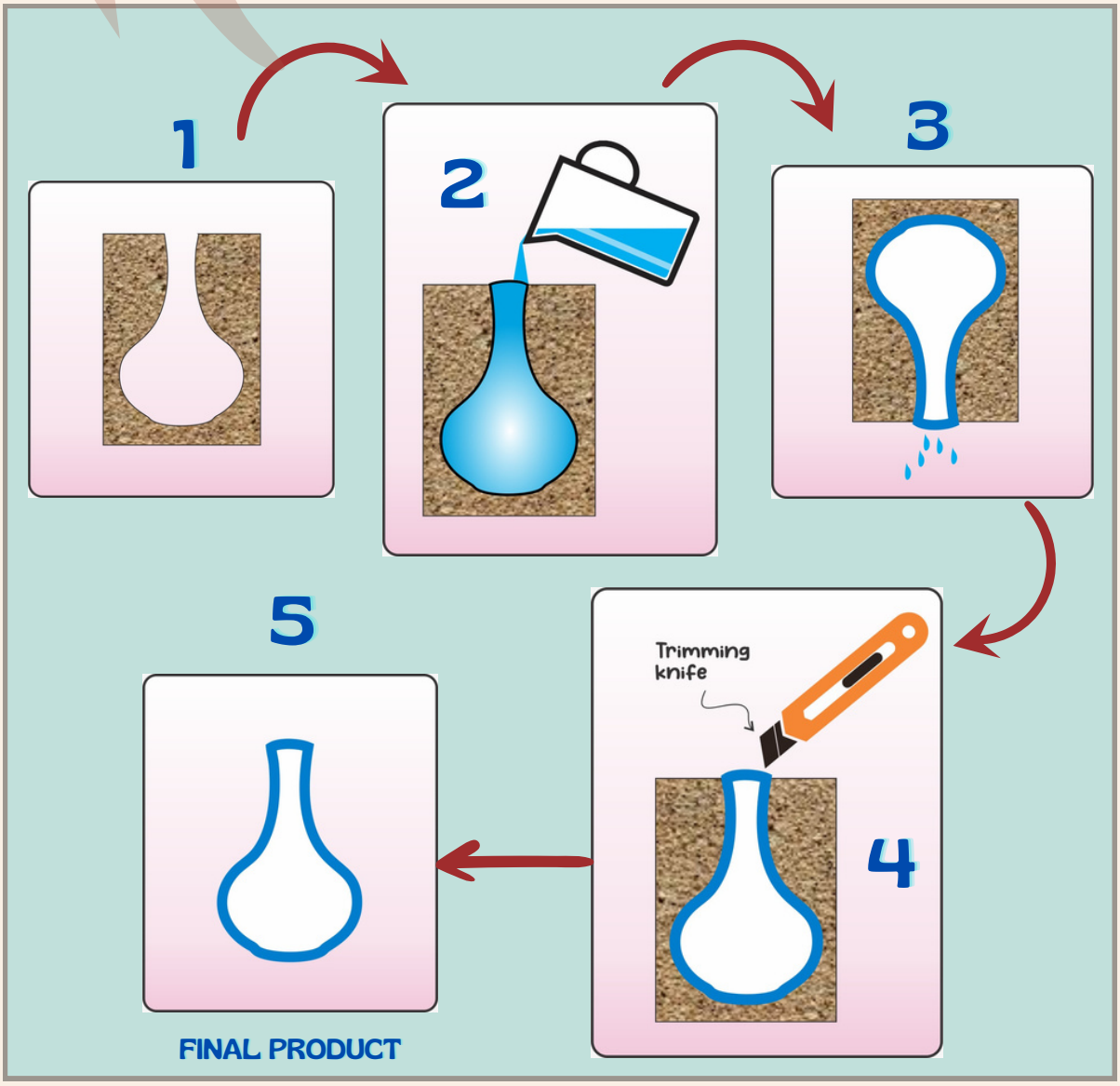


Figure 5.1 : Slip Casting

In this slip casting process, the slurry is transferred into a porous mould, which extracts the fluid while leaving a particle dense in the mould.

After the pouring process, the part is then dried and fired in an oven. The strong and hard part can be trimmed using a knife as finishing process.

Tape casting is another important ceramic casting technology that is used to manufacture sheets or thicky films. This is a powder metallurgy method in which a thin layer of ceramic slurry is cast onto a flat surface, dried, and sintered. Figure 5.2 depicts the steps, process and equipment of tape casting.

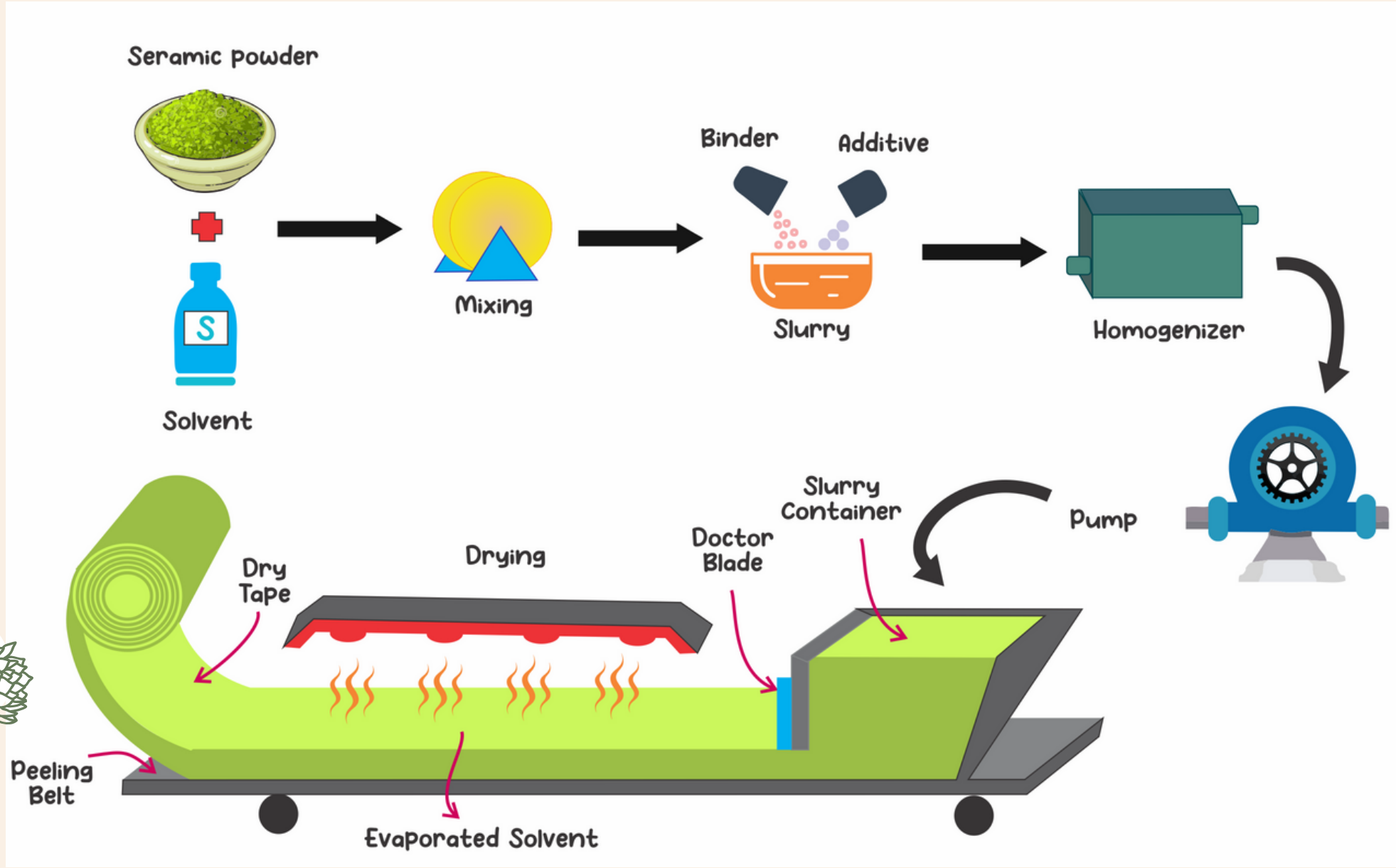


Figure 5.2 : Tape casting process

c) Plastic Forming (15% to 25% water) – moist clay

Plastic forming is the process of combining ceramic powder to a significant volume proportion of a fluid to create a mass that can be deformed (plastic) with a pressure. The liquid in traditional clay-based pottery is mostly water.

In ceramic structures that are not clay base, an organic might be employed instead adding water.

There are few types of plastic forming operations that been practiced in ceramic industries. This includes hand modelling, powder injection molding, extruding and jiggering.

Hand modelling is a ceramics method that allows you to construct shapes using clay and your hands rather than a throwing wheel. Hand modelling was the only means for ceramicists to make useful and aesthetic ceramic shapes before the invention of the wheel. Hand modelling consist of three main techniques and forming methods named pinching, coiling, and slab building

Figure 5.3: Hand Modelling Process

Meanwhile, for powder injection molding, it use a machine that complete with injection unit and clamping unit. Powder, binder and additives are being mixed and put into the feedstock. The final products are based on the mould shape. This process is used for making small complex shapes.

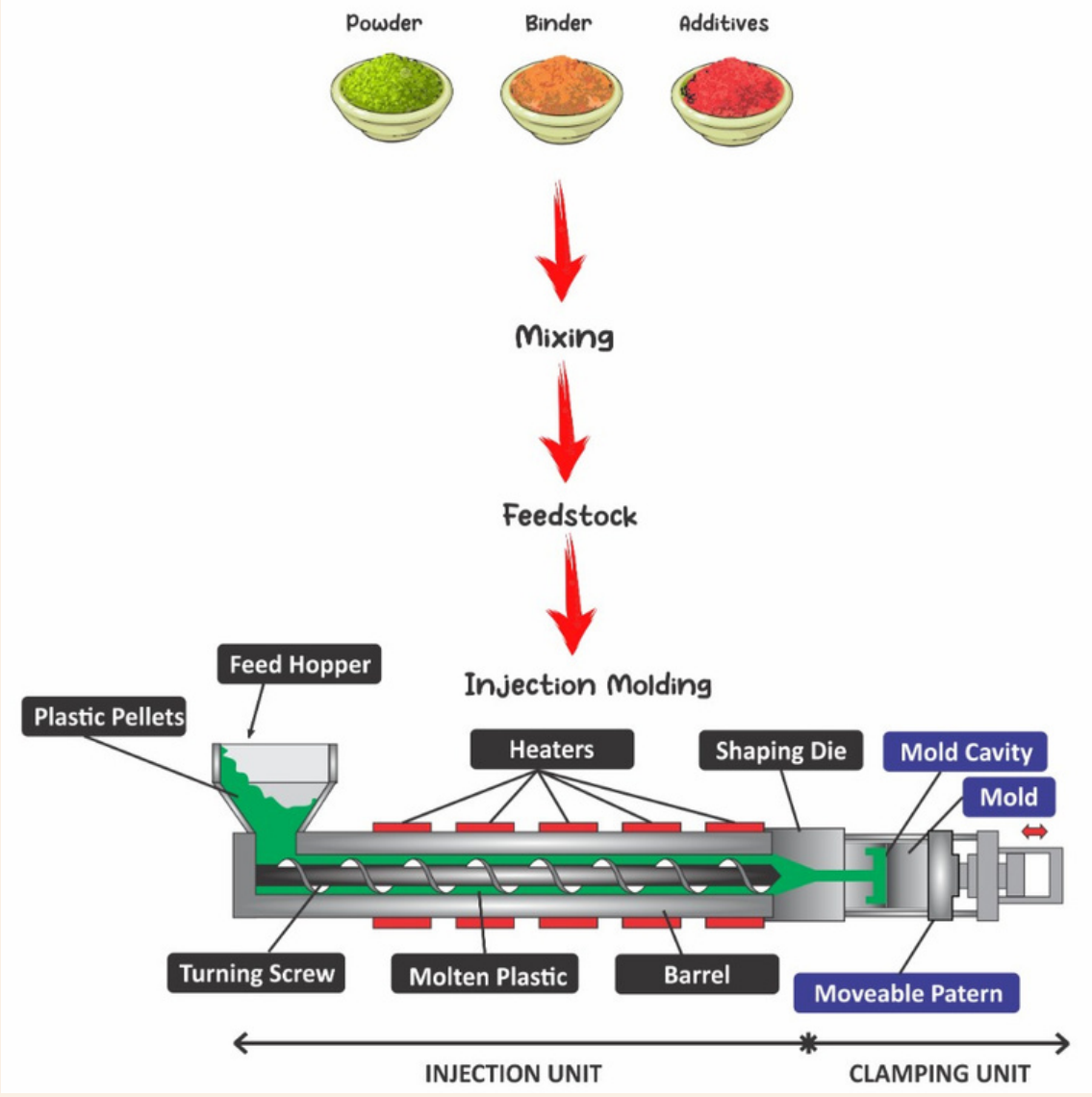


Figure 5.4: Powder Injection Molding Process

A ceramic extruder is a mechanical device and a basic mechanism that uses pressure to move clay through a column. A die form is attached to the bottom of the column. The clay is forced through the die's form with the force of a lever to extrude a specified shape of clay.

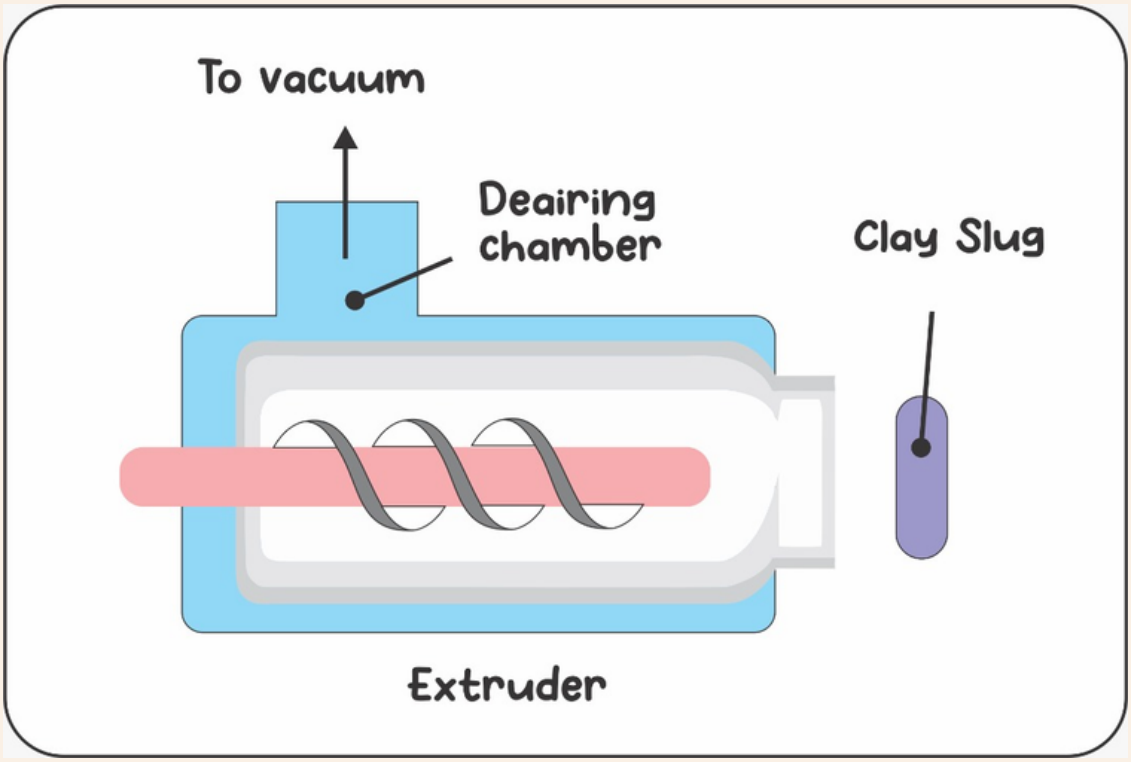


Figure 5.5: Extruding Process

Jiggering is a technique commonly employed in the production of tiny, basic, axially symmetrical whiteware ceramics such as cookware, fine china, and electrical porcelain.

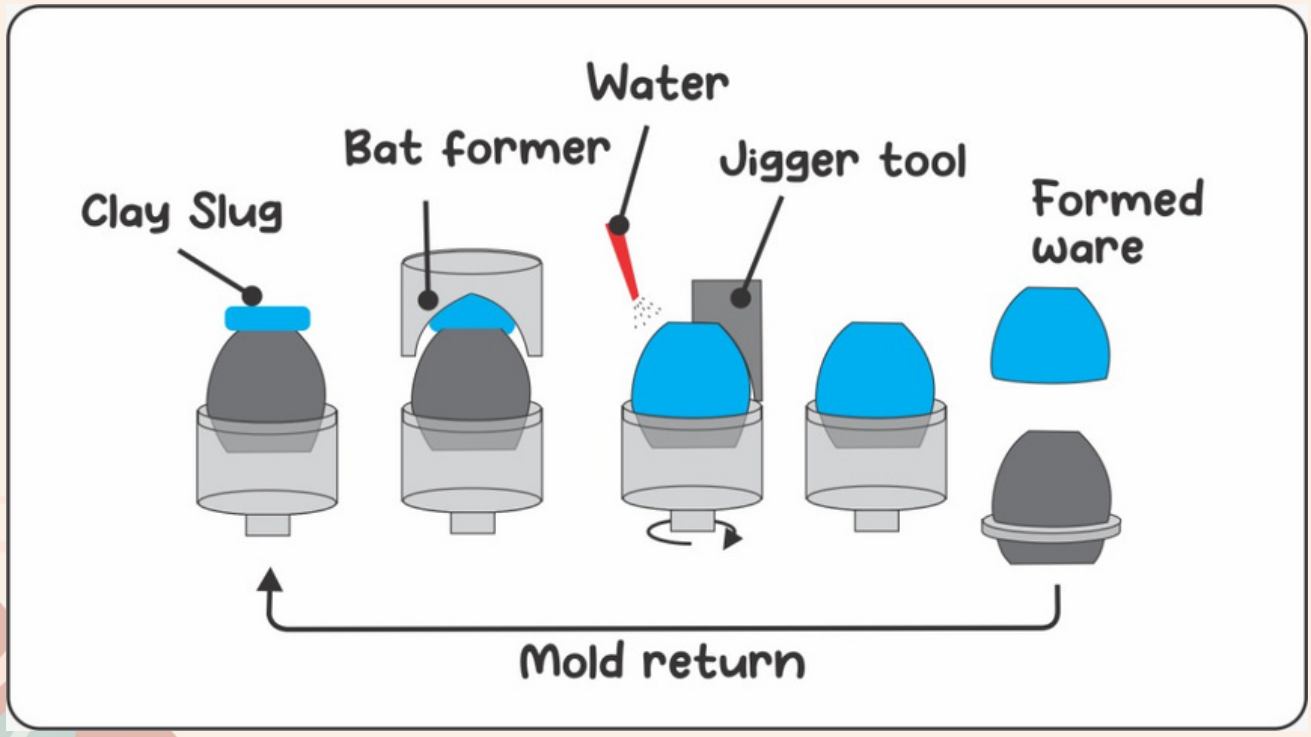


Figure 5.6: Jiggering Process

TEST YOURSELF

1. What are three categories of shaping methods for ceramic processing?
2. What is the name of processing that used to manufacture sheets or thicky films?
3. What is the process use to produce tiny, basic, axially symmetrical whiteware ceramics?

Lets check your answers

SCAN ME

ONLINE QUIZ

SCAN ME

REFERENCES

Callister Jr, W. D., & Rethwisch, D. G. (2020). Callister's materials science and engineering. John Wiley & Sons.

Carter, C. B., & Norton, M. G. (2013). Shaping and Forming. In Ceramic Materials (pp. 423-437). Springer, New York, NY.

Groover, M. P. (2013). Fundamentals of Modern Manufacturing: Materials, Processes and Systems. Hoboken, NJ: John Wiley & Sons.

Kalpakjian, S., Schmid, S. R., & Sekar, K. S. (2016). Manufacturing: Engineering and Technology. Melbourne, Victoria, Australia: Pearson Australia.

Published by:
Department of Mechanical Engineering
Politeknik Sultan Mizan Zainal Abidin
KM 08, Jalan Paka,
23000 Dungun, Terengganu
Tel : 09-8400800 Fax : 09-8458781
Email : webmaster@psmza.edu.my

SCAN ME

e ISBN 978-967-0047-07-2

9 7 8 9 6 7 0 0 4 7 0 7 2