8. Using SMA the circuit can be connected and disconnected, depending on the variation in temperature. Hence SMA is used as a circuit edge connector.
9. They are used in controlling and preventing cracks.
10. They are used in relays and activators.
11. They are used for steering the small tubes inserted into the human body.
12. They are used to correct the irregularities in teeth.
13. Ni-Ti SMA is also used in artificial hip-joints, bone-plates, pins for healing bones-fractures and also in connecting broken bones.

Advantages

i. SMA is very compact in nature.
ii. It is safe and smart.
iii. They are flexible.
iv. They are Non-Corrosive.

Disadvantages

i. Cost is high.
ii. Efficiency is low.
iii. Transformation occurs over a range of temperatures.
iv. Structural arrangements may sometime get deformed.

Ceramic materials

"Ceramic materials" are defined as those containing phases that are compounds of metallic and nonmetallic elements.

Classification of Ceramics

1. Functional Classification

(i) Abrasives	: Alumina, carborundum
(ii) Pure oxide ceramics	: MgO, Al_2O_3, SiO_2
(iii) Fire-clay products	: Bricks, tiles, porcelain etc.
(iv) Inorganic glasses	: Window glass, lead glass etc.
(v) Cementing materials	: Portland cement, lime etc.
(vi) Rocks	: Granites, sandstone etc.
(vii) Minerals	: Quartz, calcite, etc.
(viii) Refractories	: Silica bricks, magnesite, etc.

2. Structural Classification

(i) Crstalline ceramics: Single-phase like MgO or multi-phase form the MgO and Al_2O_3binary system.
(ii) Non-crystalline ceramics: Natural and synthetic inorganic glasses.
(iii) "Glass-bonded" ceramics: Fire clay products-crystalline phases are held in glassy matrix.
(iv) Cements: Crystalline and non-Crystalline

Properties of ceramic materials

Mechanical properties

(i) The compressive strength is several items more than the tensile strength.
(ii) Non-ductile/brittle. Stress concentration has little or no effect on compressive strength
(iii) The ceramic materials possess high modulus of elasticity due to ionic and covalentbonds.
(iv) At high temperature, rigidity is high.

Electrical properties

(i) Ceramic exhibits low dielectric constant contributes to low power loss and low loss factor.
(ii) Porcelain has large positive temperature coefficient.
(iii) Rutile bodies have large negative coefficients,

- The specific values of dielectric strength vary from 100 V per mil for low -tension electrical porcelain to 500 V per mil for some special ceramics.
- Rutile bodies show higher breakdown strength at higher frequencies.

Thermal properties

Since the ceramic materials contain relatively few electrons, and ceramic phases are transparent to radiant type energy, their thermal properties differ from that of metals. The following are the most important thermal properties of ceramic materials.

1. Thermal capacity

- The specific heats of fine clay bricks are 0.25 and 0.297 at 1000˚C and 1400˚C respectively.
- Carbon bricks possess specific heats of about 0.812 at 200˚C and 0.412 at 1000˚C

2. Thermal conductivity

- The ceramic material possesses a very low thermal conductivity since they do not have enough free electrons.
- The impurity content, porosity and temperature decrease the thermal conductivity.
- In order to have maximum thermal conductivity, it is imperative to have maximum density which most of the ceramic materials do not possess.

3. Thermal shock

- "Thermal shock resistance" is the ability of a material to resist cracking or disintegration of the material under abrupt or sudden changes in temperature.
- Lithium compounds are used in many ceramic compounds to reduce thermal expansion and to provide excellent thermal shock resistance.
- Common ceramic materials graded in order of deceasing thermal shock resistance or given below:
  1. Silicon nitrite2. Fused silica3.Cordierite4.Zircon5.Silicon carbide6.Beryllia 7.Alumina8.Porcelain9. Steatite

Chemical properties

1. Several ceramic products are highly resistant to all chemicals except hydrofluoric acid and to some extent, hot caustic solutions. They are not affected by the organic solvents.

2. Oxidic ceramics are completely resistant to oxidation, even at very high

temperatures.

3. Zirconia, magnesia, alumina, graphite etc., are resistant to certain molten metal and are thus employed for making crucibles and furnace linings.

4. Where resistant to attack from acids, bases and salt solutions is required, ceramics like glass are employed.

Optical properties

1. Several types of glasses have been employed for the production of windows, subjected to high temperatures and opticals lenses.

2. Special glasses used for selective transmission or absorption of particular wavelength such as infrared and ultra violet.

Nuclear properties

As ceramics are refractory, chemically resistant and its different compositions offer a wide range of neutron capture and scattering characteristics. They are finding nuclear applications such as fuel elements, moderators, and controls and shielding.

Classification of Ceramic Products

A general classification of 'ceramic products' is difficult to make because of the great versatility of these materials, but the follwing list includes the major groups.
1. Whitewares2. Bricks and tiles3.Chemical stoneswares4. Cements and concretes
5. Abrasives6. Glass7.Insulators8. Porcelain enamel9. Refractories
10. Electrical porcelain11. Mineral ores12. Slags and fluxes

Advantages of Ceramic Materials

The ceramic materials have the following advantages

1. The ceramic are hard, strong and dense.
2. They have high resistance to the reaction of chemicals and to the weathering.
3. Possess a high compression strength compared with tension.
4. They have high fusion points.
5. They offer excellent dielectric properties.
6. They are good thermal insulators.
7. They are resistant to high temperature creep.
8. Cheaply available.

Applications of Ceramics

The applications of ceramics are listed below
1. Whitewares (older ceramics): are largely used as:
- Tiles
- Sanitary wares
- Low and high voltage insulators
- High frequency applications
- Chemical industry - as crusibles, jars and components of chemical reactors;
- Heat resistant applications as pyrometers, burners, burner tips, and radiant heater supports.

2. Newer ceramics: (e.g., borides, carbides, nitrides, single oxides, mixed oxides, silicates, metalloid and intermetallic compounds) which have the high hardness values

and heat and oxidation values are largely used in the following applications

- Refractories for industrial furnaces
- Electrical and electronic industries as industors, semiconductors, dielectrics, ferro-electric crystals, piezo-electric crystals, glass, porcelain alumina, quartz and mica etc.
- Nuclear applications - as fuel elements, fuel containers, moderators, control rods and structural parts. Ceramics such as UO_2, UC, UC_2 are employed for all these purposes.
- Ceramic metal cutting tools-made from glass free Al_2O_3
- Optical applications-ytralox is a ceramic material which is useful as window glass and can resists very high temperature

3. Advanced ceramics: (e.g., ZrO_2, B_4C, SiC, TiB_2etc)

   The advanced ceramics are used in the following areas.

   - Internal combustion engines and turbines, as armor plate
   - Electronic packaging
   - Cutting tools
   - Energy conversion, storage and generation

Structure of crystalline ceramics

Most ceramic phases, like metals, have crstalline structure. Ceramic crystals are formed by the pure ionic bond, a pure covalent bond or both the ionic and covalent bonds.

- Ionic bonds give ceramic materials of relatively high stability. They are also harder and more resistant to chemical reactions.
- Covalent bond usually gives high hardness, high melting point and low electrical conductivity at room temperature.
- The ceramic crystals structures are, however, invariably more complex as compared to those of metals, since atoms of different sizes and electronic configurations are assembled together

Common crystal structure found in crystalline ceramics particularly those of oxide type are:

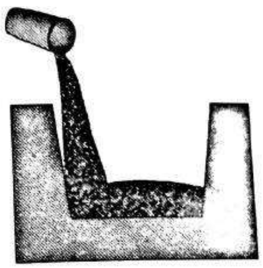
1. Rock salt structure 2. Cerium chloride structure 3.Zinc blend structure 4.Wurzite structure5. Spinal structure6. Fluorite structure7. Ilmenite structure

SLIP CASTING

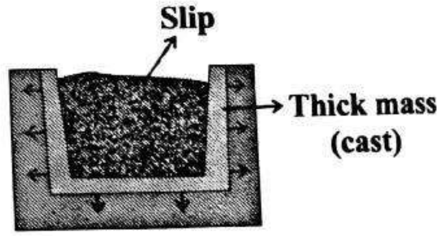
Forming a hallow ceramic part by introducing a pourable slurry into a mould is known as slip casting.

Formation

Slip casting is the most conventional method of producing different pieces that can have complex shapes such as refractory, sanitary and technical ceramics, without the use of heat.



4.17 (a)
Fill mold with slip



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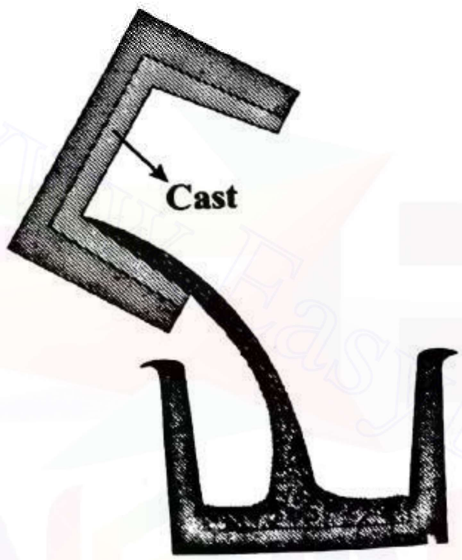

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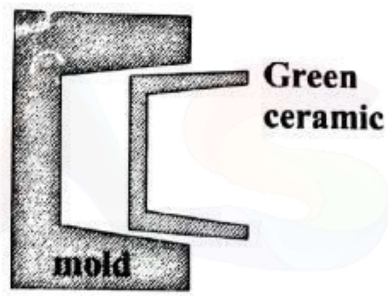


4.17 (d)

The following steps were involved in slip casting.

1. Slip casting technique normally uses aqueous slurry of ceramic powder. The slurry, known as slip, is poured into a mould [usually made of plaster of paris].
2. The fineness of the powder and the consequent high surface area ensure that electrostatic forces dominate gravity so that settling does not occur.
3. Now, sodium silicate is added to the slip to deflocculate the particles.
4. When the water from the slurry begins to move out by capillary action, a thick mass builds along the mould wall.
5. When sufficient product thickness is built, so called cast is formed and the rest of the slurry is poured out.
6. Now, the mould and cast are allowed to cry. After drying, casting is removed.
7. The green ceramic is then dried and fired or sintered at high temperature to obtain a dense ceramic material.

Uses of slip casting

1. Slip casting is a low cost way to produce complex shapes.
2. In traditional pottery industry, slip casting method is used for the production of teapots, jugs, statues and other ceramic sanitaryware.
3. Slip casting method is the standard method to make alumina crucibles which is used to make complex structural ceramic components such as gas turbine rotors.

Isostatic pressing

Isostatic pressing involves the application of hydrostatic pressure to a powder in a flexible container. The advantage of applying pressure in all directions is that there is more uniform compaction of the powder and more complex shapes can be produced

There are two types of isostatic pressing (i) Cold isostatic pressing (ii) hot isostatic pressing

(i) Cold isostatic pressing

A powder-shaping technique in which hydrostatic pressure is applied during compaction is known as cold isostatic pressing. This is used for achieving higher green ceramic density or compaction of more complex shapes.

There are two types (i) Wet-bag cold isostatic pressing (ii) Dry-bag cold isostatic pressing

(i) Wet-bag cold isostatic pressing

The following steps are involved in the processing.

1. The powder is weighed into a sealed rubber mould
2. The rubber bag is sealed by using a metal mandrel over which mould seal plate is fixed.
3. Now the sealed bag is placed inside a high pressure chamber that is filled with a fluid and is hydrostatically pressed.
4. The pressure used can vary from about 20 MPa upto 1 GPa depending upon press and the application
5. Once the pressing is complete, the pressure is released slowly
6. After releasing the pressure, the mould is removed from the pressure chamber.
7. Finally the pressed component is removed from the mould.

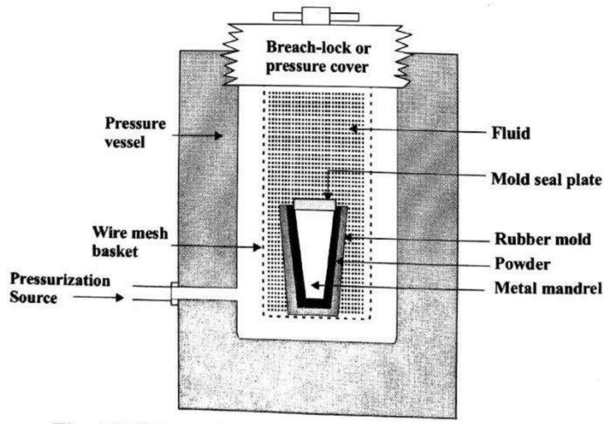


Fig. 4.18 Schematic of a wet-bag isostatic pressing system

Advantages

1. We can produce wide range of shapes and sizes.
2. Uniform density of the pressed product shall be obtained
3. Tooling costs is very low

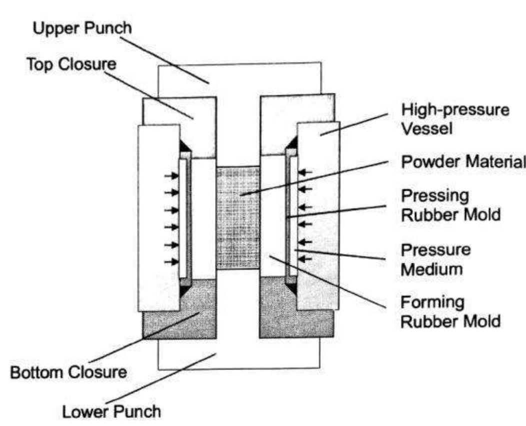
Disadvantages

1. Some time it forms poor shape and may not have dimensional control
2. Product often require green machining after pressing
3. It take long cycle time and give low product rates

(ii) Dry-bag cold isostatic pressing

The following steps are involved in the processing.

1. In dry bag process, the rubber mould is an integral part of the press, in which the powder material is taken.
2. The high pressure fluid is applied using pressure vessel.
3. The top closure, the bottom closure, the upper punch and the lower punch helps to hold the material tightly while pressing.
4. After pressing, the pressed part is removed without disturbing the mould.
5. Hence the dry bag press can be readily automated.
6. Production rates are as high as 1 part per second is being achieved industrially.



Uses

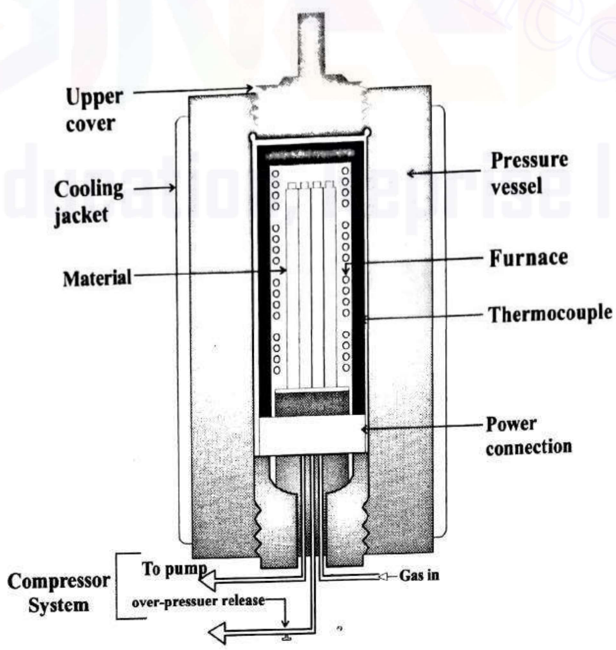
1. The dry-bag has been used for many years to press spark plug insulators.
2. The world's largest producers of spark plugs produced by this method are champion and AC spark plug

(ii) Hot isostatic pressing (or) Gas pressure bonding

Hot isostatic pressing (or) gas pressure bonding is a method used to densify a material, where in heat and pressure are imposed simultaneously and the pressure is applied from all directions via a pressurized gas such as argon or helium.

Construction

1. A basic HIP unit consists of a water-cooled pressure vessel within which a furnace, thermally insulated from the pressure vessel is kept. The pressure vessel is usually made with low alloy steel.
2. Heating elements are arranged in multiple banks to obtain uniform temperature and each bank can be controlled independently. Temperature control is obtained using sensitive thermocouples while the gas pressure is controlled using a compressor system. The gas can be recycled for reuse.
3. It also consists of auxillary systems like vacuum pumps and materials pumps to release the excess pressure.
4. Power connection enables to switch ON and OFF the heater, whenever required.
5. Furnaces used are radiation or convection type heating furnaces with graphite, molybdenum and nichrome heating elements, and hence it is covered by the upper cover and is surrounded by the cooling jacket.



Working

1. The basic function of the HIP unit is to heat the material by applying uniform gas pressure on all the surfaces.
2. The material to be prepared is kept inside the furnace.
3. Normally, a metal container or glass is used as a flexible, a leak proof mould in hot isostatic pressing. The mould is degassed after filling with powder to remove volatile components then sealed, using upper cover.
4. The furnace heats the material to be pressed. At the same time, a pressurizing medium, usually a argon gas is used to apply a high pressure during the process for specific times.
5. The pressurizing gas is further compressed using a compressor so as to increase the pressure to the desired level
6. Thus, both temperature and pressure are raised to the required values.
7. The furnace is then allowed to cool, followed by depressurizing the chamber and removal of parts.
8. The process results in full density parts with isotropic properties, even in large and complex shaped parts. During HIP, the pores present not only get closed by flow of matter by diffusion and creep, but also bonded across the interface to form a continuous material.

Advantages

1. The process offers increase in design flexibility
2. The process is not shape or size dependent, which results in optimized usage.
3. HIP results in enhanced quality and improved mechanical properties.
4. Tooling is simple and scrap is minimized and machining is not required
5. HIP produces dense materials without growing the grains.

Disadvantages

1. The design of the equipment is very complex and critical as it has to withstand a combination of high pressure and high temperature
2. Cost is very high

Uses

1. HIP can be used for fabricating components of aluminum, magnesium, copper-base alloys, cemented tungsten carbides, magnetic materials.
2. HIP can also be used for bonding of dissimilar material, consolidation of plasma coatings, processing soft and hard magnetic materials.
3. HIP has also been applied to the formation of piezoelectric ceramics such as $BaTiO_3$, $SrTiO_3$, and lead zirconate titanate (PZT) for use in acoustic wave filters and oscillators.
4. HIP are mostly used in structural ceramics.

5.

Ferroelectric ceramics

- **Ferroelectric ceramics** exhibit *electric polarization even in the absence of electric field*
- **Fabrication** – Powders made by *traditional methods* – *Forming process* (like slip casting) is done – Followed by *densification* by hot isostatic pressing – Later, ceramics are *sliced, lapped and finally polished*
- **Micro-structure** – *Grain size in the range of 2-6 μm* – Uniform grain size is highly

desirable

- **Electrical / Electro-mechanical property** – *High dielectric constant* – Exhibit *hysteresis behavior* – PZT and PLZT possess *highest electromechanical coupling coefficient*
- **Thermal / Optical properties** – Better choices for thermal imaging applications because of their *high pyroelectric coefficients* – PLZT have *high optical translucency and transparency*
- **Electro-optic properties** – *Quadratic, Kerr and birefringence effects* are observed

Applications of ferroelectric ceramics

- Ferroelectric ceramics are used as **capacitors** because of their *high dielectric constant* – *$BaTiO_3$*
- Ferroelectric ceramics can *convert electrical signal into mechanical signal* (such as sound) and vice versa and hence used as **transducers**
- Ferroelectric ceramics are used as *medical ultrasonic composites*
- Ferroelectric ceramics can be used in **photostrictors** and **integrated circuit** (IC) applications
- Ferroelectric ceramics can be used in *medical diagnostics through transducers*

Ferromagnetic ceramics

- Ferromagnetic ceramics, also known as ferrites, are compounds of various oxides
- General formula $MO.Fe_2O_3$ where M stands for a bivalent metal ion such as Zn, Ni and others
- Ferrites are ceramic materials with a crystalline structure of *spinel type*
- *Mineral magnetite* ($FeO.Fe_2O_3$) is the only naturally occurring mineral of this type
- Properties – *High volume resistivity* and *high permeability* – Specific gravity is between 4 and 5, which is less than iron (8) – Can be made both into *soft and hard permanent magnetic* materials – Exhibit a *square hysteresis loop* of magnetization – Extremely low switching time between magnetic saturation and demagnetization
- Applications – *Cores of radio and television loop antennas*, high reception quality and selectivity in antennas – *Memory cores in electron computers* – Military airborne applications due to 35% lower density than metallic magnets

High aluminium ceramics

- These ceramics are composed with ***more than 92wt% of alumina***, along with additives such as silica, iron oxides and alkaline oxides
- High alumina ceramics are *readily coupled with metals and other ceramics* by metallising and brazing techniques
- Offers a combination of *good mechanical and electrical properties* leading to wide range of applications
- **Properties** – *Excellent wear characteristics*, white in colour with *high hardness*, *good chemical resistance*, *good electrical insulation*, *high mechanical strength*, *high compressive strength*, *high dielectric strength*, half the density of metals and hence half the weight of metals
- **Applications** – *Electric arc furnaces*, manufacturing gem stones and laser components,

manufacturing *insulators and capacitors*, bio-ceramic parts for *orthopedic and dental surgery*, *thermocouple protection tubes* and refractory parts

UNIT -5 HAZARDS

INTRODUCTION

A hazard can be defined as "the degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude"

It is expressed on a scale from 0 (no damage) to 1 (total loss). When the risk becomes tangible and impeding, there is a distinct threat of disaster. Hence, the sequence of states permitting to disaster is as follows:

HAZARD ⟶ RISK ⟶ THREAT ⟶ DISASTER ⟶ AFTERMATH

Globally, it appears that the toll of death and damage in natural disasters is increasing. Recently the disaster is reduced to large extent by improvements in prediction, warning, mitigation and international aid.

FUNDAMENTAL CONCEPTS RELATED TO EARTHQUAKE

1. Earthquake

   Earthquake is term used to describe both sudden slip on a fault and the resulting ground shaking and radiated seismic energy caused due to the following reasons viz., (i) the slip (ii) by volcanic and magmatic activity and (iii) other sudden stress that changes in the earth.

2. Earthquake source

   Earthquake source is the released forces that generate acoustic or seismic waves. During an earthquake when the ground is shaking, it also experiences acceleration. The peak acceleration is the largest increase in velocity recorded by a particular station during an earthquake.

3. Hypocenter

   The hypocenter is the point within the earth where an earthquake rupture starts.

4. Epicenter

   The epicenter is the point on the earth's surface vertically above the hypocenter and the point in the cruct where a seismic rupture begins.

5. Ground motion