CERAMIC IN ELECTRICAL AND ELECTRONICS

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Abstract

Porcelain body formulation which is completely vitrified composite of zero water absorption when fired, then covered with a glazeof expansion coefficient slightly lower than that of the body so that the greatest strength improvements, are obtained by applying the glaze. This gives complete imperviousness and resistance to freezing, very good mechanical strength in tension as well as compression.

1.0. Introduction

The demand for ceramics in the electrical industry has risen phenomenally both in quantity and quality during the century. As the applications have increase so has the need for different combinations of electrical properties.

Dielectric materials are defined as the broad expanse of non-metals considered from the standpoint of their interaction with electric, magnetic, or electromagnetic fields. Dielectric or breakdown strength of a material is its resistance to electrical breakdown and is the property which determines its ability to withstand high voltage. It is measured by applying an increasing voltage of known frequency across a test piece until puncture occurs. The thickness of the piece at the point of puncture is measured and the dielectric strength calculates in volts per mile or kilovolts per millimeter. Dielectric strength varies with the thickness of the piece, increasing as it decreases also with frequency and wave shape of the applied voltage, electrostatic field distribution and temperature of a specimen. Direct current gives 25 to 30% higher values than alternating current at 60 cycles bodies other than rutile bodies have decreasing dielectric strength at increasing frequencies.

Dielectric constant or permittivity, E_I is the ratio of the amount of energy stored in the dielectric to that stored ability or capacitance. The dielectric constant varies with temperature, ceramic dielectrics showing a range of high positive capacity temperature coefficient (porcelain) through low coefficient (rutile). The dielectric constant may be used to classify dielectric materials.

Loss Angle: A theoretically perfect insulator would throw current and voltage waves entirely out of phase, on which case the phase angle(s) would be 90^o. For actual insulators the phase angle is somewhat less than 90^o.

The loss angle (δ) is the different between 90^o and the phase angle, i.e power factor is a measure of the energy lost when an insulator transforms part of the electrical energy into heat. The power factor is given by the size of the loss angle.

Power Factor: Is a measure of the energy lost when an insulator transforms part of the electrical energy into heat. The power factor is given by the size of the loss angle. Loss factor is used in grading high frequency insulators. These properties vary considerably with frequency, and with temperature, values for more than one frequency usually being quoted.

1.1 Specific Resistance or Volume Resistivity- is the electrical resistance per unit volume of a dielectric expressed in ohms per cubic centre ceramic dielectrics are considered to be insulators if their specific resistance is greater than IMΩ ($10^6\Omega/cm^3$, but these drop considerably with increasing temperature. Surface resistivity is four times the resistance between electrodes which completely cover opposite faces of a centimeter cube of the insulator when all the current flows through the surface layer. This is very independent on the nature of the surface, particularly the amount of moisture absorbed there. Insulators to be used in humid condition are therefore dazed.Piezoelectric effect is the phenomenon exhibited by certain crystals of expansion along one axis and contraction along another when subjected to electric field. The converse effect, whereby mechanical strains produce opposite charge on different faces of the crystal, also obtains.Piezoelectric coupling coefficient is a measure of the strength of the piezoelectric effect. A coupling coefficient of 100% means that cell dielectric polarization would appear as an elastic stress, or inversely, that an applied external mechanical force would be converted into electric voltage.

Ferroelectric properties are characterized by a high dielectric hysteresis, polarization, saturation, piezo effect and a curic temperature. Curic point or curic temperature is the temperature is the temperature at which a ferroelectric material changes to a non-ferroelectric or at which a ferromagnetic one loss its ferromagnetic properties.

Ferromagnetic materials acquire magnetic properties when placed in a magnetic field. The main magnetic properties are defined by the relationship between induced flux caused by the application of a magnetizing force. When the magneting force is raised from zero, the increase in induced flux is non-linear, being at first slow, then faster and then slow again as saturation occurs. After this, cyclic variation of a magnetizing force is reduced to zero some flux is retained as the remnant induction and a negative magnetizing force, the coercive force is required to reduce the induction to zero.

The area of the hysteresis loop is a measure of the work done in traversing a complete cycle and is a measure of the hysteresis loss when an alternating field is used, the work done appearing as heat. Residual losses arise from the molecular structure of the magnetic materials and are strongly influenced by impurities and imperfections in the crystal structure. They cause the induced flux to be out of phase with the magnetizing field and are a further source of non-linear behavior.

1. Materials with dielectric constant below 12. Low frequency (a) low and high tension electrical porcelain (b) high temperature porcelains (c) sparking plus insulators high frequency. High frequency: (d) vitrified materials for high frequency (graded by loss factor) (e) refractory ceramic for electronic use.

Low-Tension, Low Frequency Porcelain Insulators

Characteristic: Almost vitreous to vitreous body consisting of mullite and quarto crystals imbedded in a glassy matrix the relative proportions of which are adjustable within limits to give different properties able to withstand normal domestic voltages, up to about 440v. Dielectric strength than dry-pressed ones. Both glazed and unglazed ware is made.Uses and Share: Unglazed for use in dry conditions fitting for open wiring or knob and tube wiring, kobs, tube, cleats, cable racks, bobbins reels, split insulators, bushes. Outlet boxes, switch boxes, connectors, plugs, sockets, ceiling roses. Lamp holders fuse holders. Appliance parts in numerous pieces of equipment, using electric resistances to generate heat, e.g electric irons, toasters, fires, sterilizers. Glazed, for weather exposed pieces. Farm fencing, telephone and power supplies to houses, part from neon signs, aerial insulators.

1.2 High Tension Frequency Porcelain Insulators

Characteristic: completely vitrified material of zero water absorption covered by a glaze of expansion coefficient slightly lower than that of the body so that the greatest strength improvements, are obtained by applying the glaze. This gives complete imperviousness and resistance to freezing, very good mechanical strength in tension as well as compression. Shapeability allows almost any shape to be made. Corona is reduced and interference with electronic equipment eliminated by using semi-conducting glazes or coatings on areas in contact with metallic surfaces.Fall of dielectric strength with rising temperature limits use to below 100^{o}C (212^{o}F). Suspension insulators to be used in strings for voltages over 66000v, pin-type insulator for voltages up to 50000 to 60000v. Tubes, bushings, lead-in insulators, guy-line insulators, housing for line cut-outs, fuse cut-outs, coil forms, transformer parts. Circuit breaker parts, mast basis, switch part.

1.3 General Production Methods for Electrical Porcelain.

Body Type: Porcelain, electrical

Raw Material: Clays, ball clays, potash feldspars, pegmatites, flint, quartz sand, quartz crystal, whiting, talc, pressing oil, vegetable oils, mineral oil, oleic acid, emulsified saponified oils, paraffin.

1.4 Preparation

(a) Wet methods

1. Casting slip; feldspar-jaw crusher or crushing rolls – wet cylinder mills, perhaps with quartz (particle size test before use).
   Flint, quartz etc – crushers if necessary – wet cylinder mills, perhaps with feldspar (particle size test before us)
   Ball clay – clusters – blunger – clay (kaolin) – bluner (deflocculants)
   Added – mixing ark – ground feldspar and quartz added – casting ship storage. Where raw materials obtained ready ground; batch + water +dafloccułant – pebble mill.
2. Plastic; feldspar and quartz – crushing – wet milling.
   Clays – blunging
   Scraps – blunged
   All to mixing ark – lawn – magnets – storage (slip may be heated t 40^{o}C or de-aired) – filler press – non de-airing pug – storage cellars – pugging (de-airing for extrusion or throwing de-airing optional for jolleying or hot pressing) and adjustment of water content. Where raw materials obtained ready ground batch
   Batch – blunger – filler press – de-airing pugmill (no maturing).

3. Press dust; wet grinding, blunging mixing and filter pressing as in (II) – cakes to dry – edge runner or

harmmer mill – mixer, oil (1-4%) and water (II – 18%) added – sieve or special granulators to make dust more solid.

(b) Dry Method

1. Press dust: Feldspar and quartz – dry grinding in tube mill and air floating, clay – air floated. All to trough or pan mixer, water II – 18% and oil 1 – 4% added – sieves or special granulators to make dust more solid.

1.5 Shaping

1. Casting
2. Jollying – conditioning in humid chambers for large pieces – air drying – trimming – stricking up
3. Hot pressed in two stages in plaster mould with heated revolving tool.
4. Extrusion (upto 30in, 76cm, diameter) – air dried to leather –hard condition – turning
5. Throwing (up to 3ft, 90cm, high) – air dried to leather-hard condition – turning – stricking up if necessary
6. Extrusion of low moisture content (15%) by hydraulic press. Product leather – hard has no drying warpage.
7. Dust pressing in hand or semi-automatic hydraulic machines with possible vacuum control in dies to reduce porosity – holes drilled and tapped (if not evacuated only suitable for low-tension use)
8. Hydrostatic pressing;
   Drying; humidity dryers, chamber or tunnel
   Fettling and sponging;
   Glazing: The need for the right fitting glaze that is under compression. Single fine brown, white or semi-conducting glazes applied to all but some small pieces. Sand grit (porcelain grit) applied with and of glaze adhesive to parts of glazes where joints have later to be made, spraying or dipping.
   Making of glaze joints for very large pieces.

1.6 Firing: Low-tension insulators 1150°C (2182°F) upwards, normal 11300-1350°C (2372-2462°F) cone 10-12, high-tension insulators up to 1400°C (2552°F)
Intermittent kiln, coal fired, very large pieces must always be fired in intermittent kiln
Tunnel kilns gas fired: Unlike table porcelain the atmosphere may kept oxidizing throughout.
Finishing: grinding of surfaces that must be planar. Assembly, cementing together and curing in steam, sobtening and brazing, glass bonding. Inspection and routine testing of every insulator.
Testing: Electrical, pressure, load and tension, torsion and blending. Thermal shock and water absorption
Output: Examples weekly: 60-100 tons large insulators with 250 men
Hourly: Throwing of 4½ insulator blanks, one man with one woman, 300.
Turning of leather – hard blanks, two women, 60.

1.7 High-Tension, Low Frequency mullite Porcelains

Characteristic: Better resistance to temperature and thermal shock than normal porcelain.
Uses: sparking plugs. Fuse cores, electric water boiler, insulators, carbon and wire resistor cores.
Body Type: Mullite porcelain
Raw Material: Dumortierite, Kyanite, Andalusite, alumina, ball clay and kaoline
Preparation: Andalusite and dumortierite are very tough; crushing – finger crushing – continuous high speed dry grinding cylinder – wet grinding cylinder
Ball and kaoline clay – wet cylinder grinding
Mixing: magnetizing sieves 140 and 325 – mesh – filter, pressing. For dry pressing – drying of press cake – pulverizing – moistening – sieving and grading.
For plastic making: thorough purging of press cake – de-airing pugmill
Shaping: Dry pressing followed by fettling and polishing, or followed by turning with carborundum or corundum tools. Extrusion, cutting off, followed by turning when leather hard.
Drying: Humidity Dryers
Grazing; All over, by spraying. Within defined units, by rolling over glaze bearing cushion.
Firing: Cone 16-17, 1460-1480°C (2660 – 2696°F) in saggers, oil fired tunnel kilns

1.8 Stone Ware Electrical Insulators

Characteristics: special stoneware bodies resemble electrical porcelain in many respects but always have the advantage of better workability and therefore ability to make larger single pieces up to 26ft high
Uses: Large one piece insulator high tension conduits.

1.9 High Temperature Insulators

Characteristic: Bodies of incomplete vitrification and the minimum of glassy phase that could soften. The porosity, together with low coefficient of thermal expansion, assists in giving good thermal shock resistances. To retain good resistivity at high temperatures and to prevent attack of the resistor wire no alkalies may be present, fluxes may consist of alkaline earths.

Uses:
1. Insulating supports for electrical heating elements
2. Vacuum spacers, high-temperature insulation
3. High-frequency insulation, vacuum tube spacers

Body Type: porous, cordierite, alumina, aluminium silicate refractories (mullite), massive fired talc, pyrophllite, pure magnesia, beryllia, zironia and thoria.

2.0 Impervious Recrystallised Retractory Alumina

Characteristic: Highly refractory, can be used up to 1950°C (3542°F), very high degree of chemical inertness, impervious.
Uses: Tubes for wire-wound furnaces e.g moly baenum and tungsten. Pyrometer sheaths especially for the rare metal thermocouples

Body Type: Alumina
Order of Increasing the Value for Ceramic Dielectrics
Feldspathic Porcelain – 400°C (75°F)
Feldspathic stealite - 450°C (842F)
Cordierite bodies - 700°C (1292°F)
Zircon bodies - 700°C (1292°F)
Alumina bodies - 750°C (1382°F)
Quartz glass - 900°C (1652°F)
Spec steatite - 1025°C (8776°F)
Magnesia bodies - 1150°C (210δF)

2.1 Sparking Plug Insulators

Requirements (in order of importance as cited; (1) Good hot dielectric properties.

2. High dielectric strength: The insulator is relatively thin-walled and completely surrounded by metal. To be a reliable insulator it must be in perfect and homogeneous condition. Conductivity may not increase greatly with temperature.
3. Resistance to thermal shock.
4. Good thermal conductivity
   There is a sharp rise and fall of temperature hundreds of times per minute in an engine and also temperatures up to 1100°C (2012°F) may be generated in hot spots.
5. Good mechanical strength and resistance to mechanical shock. The insulator is clamped into position in the sparking plug by a gland nut exerting consideration force. The insulator also has to withstand constant vibration.
6. Resistance to tetra-ethyl-lead corrosion. This additive to petrol forms a load oxide deposit on the mose of the insulator and will eat into a silicate body to form lead silicate. The glazes the surface, is itself a conductor and forms a gummy surface that collects carbon and dirt and lead to short circuiting.
7. Low dielectric constant
8. Resistance to abrasion
9. Resistance to attack by carbon
10. Low modulus of elasticity.

Uses: Insulators for sparking pugs for all types of internal combustion engine.

Body Type: Sinter alumina, usually with small additions to reduce sintering temperature, e.g 3% SIO_2 or control crystallization e.g Cr_2O_3. Also high alumina porcelain, high mullite porcelain, zircon porcelain, steatite

Raw Material: pure alumina fuse, alumina, controlled crystal size alumina, silica, chrome oxide, manganese oxide, organic binders, clay, rircon, fluxes, etc, e.g magnesia lime

Preparation: Wet or dry ver, fine grinding – mixing, spray drying to form free-flowing pellers for hydrostatic pressing

Shaping: Extrusion followed by turning, Dry pressing followed by turning, hydraulic pressing, injection moulding with thermoplastic and slowly, thermo-setting resin mixed with body hydrostatic pressing followed by grinding

Firing: 1600 – 1800°C (2912 – 3272°F) gas muffle tunnel kilns, or open flame gas tunnel kilns with sagging
Glazing: Spraying
Glost Firing: 1450°C (2642F)

Conclusion

The area of the hysteresis loop is a measure of the work done in traversing a complete cycle and is a measure of the hysteresis loss when an alternating field is used, the work done appearing as heat. Residual losses arise from the molecular structure of the magnetic materials and are strongly influenced by impurities and imperfections in the crystal structure. They cause the induced flux to be out of phase with the magnetizing field and are a further source of non-linear behavior.

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