Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 7, Issue 3; October-December, 2020, pp. 18-21

http://www.krishisanskriti.org/Publication.html

Effect of Change in Percentage Composition of an Insulator Body on Physical/chemical Properties and Commercial Viability

Nandish Khandhar

Class 12th, Oberoi International School
Mumbai, India

Abstract: The report explores how the percentage composition of a porcelain insulator body affects its physical and chemical properties such as Modulus of rupture, Bulk density and shrinkage. The focus will be on using experiments and changing the percentage of alumina, quartz and clay in the insulator body and carrying out tests on them. Formulae will be used to calculate the values of the properties and a graphical representation with the help of data points will be plotted. This will help in analyzing the nature of the product and its commercial viability.

Keywords: Porcelain insulator; Modulus of Rupture; Bulk density; Shrinkage

1. INTRODUCTION

The following experiments and data were collected during a visit to a ceramics factory called Ravikiran Ceramics Pvt.Ltd (RCPL) in the Kheda district of Gujarat. The data was collected in the R&D lab of the factory.

Ceramicsare nonmetallic, inorganic solid compounds thathave been shaped and then hardened by heating to high temperatures. The properties of a ceramic depend on two things; its materials, and the way they are joined together—in other words, on its crystalline structure. They consist of metallicand non-metallic elements held together in ionic and covalent bonds.Ceramics have high melting points, hardness, elasticity, chemical inertness andare good thermal and electric insulators. They are widely used in electrical applications such as power distribution and distribution.

The chemical composition of insulators consists of various compounds and clays, each of which have their own purpose and give the final product a certain useful property.

Quartz - Imparts strength to the material because it has a high melting point at $1670°C$. It affects the density of the final product as well as its Modulus of Rupture (MOR)

Alumina - Has the same properties and use as quartz. It melts at $2072°C$ and imparts hardness to the product, as well as stability while being fired.

Feldspar - This compound helps in the bonding of material during firing. Since its melting point is equal to the firing temperature, about 1200℃, it melts during firing and imparts strength. Feldspar is the reason that the final product loses all its porosity.

Ball Clay - It imparts high plasticity to the material, which means that it helps in increasing the structural stability of the material and binds it together. Without this, the material would collapse and would not be able to hold itself up.

China Clay - This compound has to property of high water absorption. Due to this, when water is added to the material in order to make it workable, it forms hard "cakes."

The company (RCPL) tests the final product based on its properties to check whether it is suitable for commercial use. These factors determine the nature and application of the product and will be explored in this report.

Modulus of Rupture (MOR) - MOR is the amount of stress or force the product can withstand before cracking. It is measured in SI units $kgcm^{-2}$. A higher MOR means a stronger and better product. The minimum MOR for a product to have commercial use is $1100\ kgcm^{-2}$

Dry and Fired Shrinkage - Both these shrinkages measure the percentage fall in the products length after drying and firing in the furnace. For RCPL, the standard for shrinkage has been set to $14-15\%$, depending on what length the customer demands. Anything above or below the specified value and the product will be rejected. It is measured in cm. The range for acceptable shrinkages:

Dry shrinkage - 4 to 8%, **Fired shrinkage** - 9 to 11%, **Totalshrinkage** - 13 to 16%

Bulk Density - Density is measured as the mass per unit volume of a substance. For insulators, higher density yields a better quality and high strength product. It is measured in gcm^{-3}. The minimum density of a product should be 2.3 gcm^{-3}.

Effects of changes in Alumina/Quartz proportions

The company has a set chemical composition they use for mass production and supply. But, sometimes customers require a special kind of insulator with different properties. Thus, in this investigation, the effect of altering the composition of alumina and quartz on the final product and its properties, such as **density** and **Modulus of Rupture** is tested. A series of experiments were performed at the RCPL laboratory and obtained readings for different compositions of alumina and quartz.

2. PROCEDURE

1) Weigh the Alumina, Quartz and Feldspar powder with a weighing balance and mix the appropriate composition in a bag.

2) Grind the Ball clay and China clay in the ball mill, along with water and pebbles for 6 hours so that it becomes a fine powder. Mix together the alumina, quartz and feldspar powder with the clay powder.

3) Drain the water of the slurry formed using a filter cloth so that it becomes a ceramic cake.

4) Insert the ceramic cakes into the pug mill and extrude a sample rod for testing.

5) Follow the drying and firing process in the furnace at 1300℃ and obtain a ceramic rod.

Fig. 1. Weighing materials while carrying out experiment

For this experiment, five different bodies were made with different compositions of Alumina and Quartz, while other materials such as Ball and Chine clay remained constant. The table below gives the compositions used in each of the bodies.

TABLE 1: Composition of Alumina and Quartz in experiment

Raw Material	Body 1	Body 2	Body 3	Body 4	Body 5
Alumina	22%	24%	26%	28%	30%
Quartz	8%	6%	4%	2%	0%
Total	30%	30%	30%	30%	30%

According to the research conducted by the company, 30% is the optimum percentage for Alumina and Quartz combined. The relative percentages is something that will be explored in the paper. The other components have been kept constant. **Feldspar:** 25%, **Than Clay:** 3%, **China Clay:** 24%, **Ball Clay:** 18%.

To calculate the Modulus of Rupture (MOR) for each of these bodies, a MOR machine was used which gave the value.

Fig. 2. MOR machine

The equation used to calculate the MOR is:

$$MOR = \frac{8FL}{\pi d^3}\ (unit: kgcm^{-2})$$

Where **F** is the mass in Kilograms, **L** is the length of the rod (10 cm) and **D** is the diameter of the rod that needs to be broken. Using this expression, the value was calculated for all 5 bodies.

TABLE 2: Results of experiment (MOR values)

Body	% Alumina	% Quartz	MOR $(kgcm^{-2})$
1	22	8	1596
2	24	6	1660
3	26	4	1760
4	28	2	1820
5	30	0	1963

Plotting these values on a graph (percentage composition vs MOR) will give a clear picture of the nature of the relationship between the two variables.

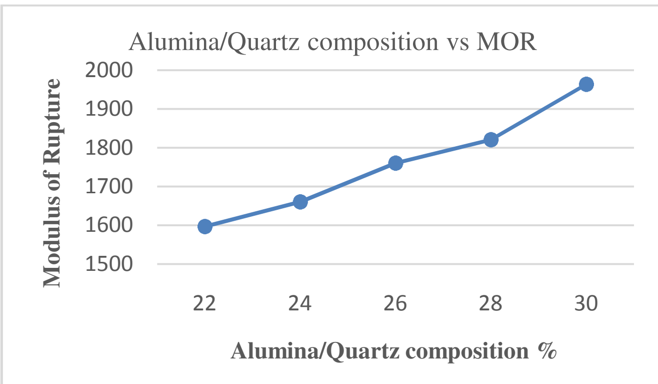

Fig. 3. Graph of Alumina/Quartz percentage vs MOR.

The above graph clearly portrays the positive correlation between increasing Alumina percentage composition in body against the final MOR. This means that the electrostatic forces of attraction from the ionic bonds in Alumina (Aluminum Oxide or Al_2O_3) are extremely strong and help in increasing the toughness of the final product.

The same data can be used to calculate the Bulk density of the insulator body, which is defined as mass per unit volume of the product. It can be measured through a simple weighing balance and measuring cylinder by weighing the sample and dividing that value by the volume obtained from immersing the sample in a water filler measuring cylinder. The table below gives the results.

TABLE 3: Results of experiment (Density values)

Body	% Alumina	% Quartz	Density (gcm^{-3})
1	22	8	2.60
2	24	6	2.62
3	26	4	2.65
4	28	2	2.68
5	30	0	2.76

The results are graphed below (percentage composition vs Density)

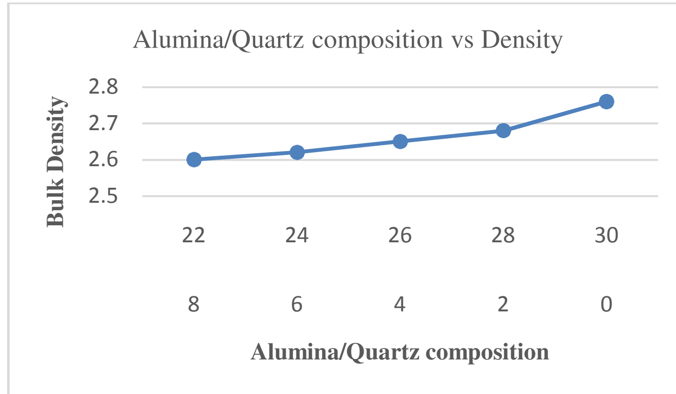

Fig. 4. Graph of Alumina/Quartz percentage vs Density

Again, the relationship is positive, which means that the insulator body is stronger with higher alumina percentage. This will help the body to withstand high voltage given across power lines.

3. EFFECTS OF CHANGES IN BALL/CHINA CLAY PROPORTIONS

After changing the alumina and quartz, experiments for changing the ball clay and china clay proportions were also carried out to test their effect on the shrinkage of the insulator body. The hypothesis is that if the proportion of ball clay compared to china clay increases, the material becomes stronger due to increased plasticity of the ball clay. The data table shows the proportions of ball clay and china clay along with the other materials in the body.

TABLE 4: Composition of China and Ball Clay in experiment

Raw Material	Body 1	Body 2	Body 3	Body 4	Body 5
Ball Clay	0%	15%	20%	25%	38%
China Clay	38%	23%	18%	13%	0%

The company conducted research and came to the conclusion that 38% is the optimum percentage for Ball and China clay combined. The relative percentages are something that will be explored in the paper. The other components have been kept constant. **Feldspar:** 25%, **Than Clay:** 3%, **Alumina:** 34%.

PROCEDURE

1) Extrude the ceramic rod of 10cm in diameter from the pug mill. Immediately mark 2 points 100mm apart and keep the rod for drying at room temperature overnight.

2) Keep the rods in the oven at 180℃ for slow drying and then measure the distance between the two points to obtain dry shrinkage.
3) Send the rods for firing at 1300℃ for 72 hours and then keep for cooling
4) Measure the distance and use formula to calculate total shrinkage.

The equation to calculate total shrinkage is calculated as a percentage of fired length:

$$Total\ Skrinkage = \frac{L_{wet} - L_{fired}}{L_{fired}} \times 100$$

As a sample calculation, the total shrinkage for the body that has 20% ball clay and 18% china clay is:

$$Total\ Skrinkage = \frac{100 - 86.92}{86.92} \times 100 = 15.04\%$$

The table below shows the results for the experiment:

TABLE 5: Results of experiment (Total Shrinkage values)

Body	% Ball Clay	% China Clay	Shrinkage
1	0	38	14.19%
2	15	23	15.14%
3	20	18	15.45%
4	25	13	16.25%
5	38	0	17.08%

Plotting these values on a graph (percentage composition of clay vs Total Shrinkage) will give an indication as to the relationship between the two variables.

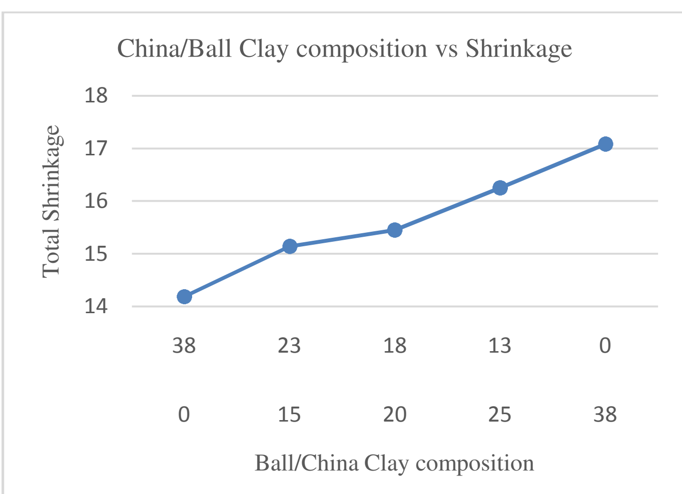

Fig. 5. Graph of Ball/China clay percentage vs Shrinkage

The relationship is also a clearly positive, since increase in Ball Clay composition causes increase in total shrinkage.

4. EVALUATION OF RESULTS

The results show that the changes in composition have anincreasing relation, since increase in Ball clay causes increase in shrinkage. Increase in Alumina also increases the MOR and Bulk density. This is because the strong electrostatic forces of attraction in the ionic bonds of Alumina increase the strength of the material. This leads to greater energy needed to break bonds, thus higher MOR and Bulk density. As for the commercial viability, the company has many international clients that require different specifications. An MOR below 1400 is prone to crack under high voltages. This makes it commercially unviable and unsafe. Any density below 2.55 grams is also commercially unviable for companies, since the material will melt at high temperatures. The heating effect of current will break the insulators if the density is not high enough

5. CONCLUSION

Ceramics is a growing industry with applications in all fields. Solar panels are now being made of ceramic material and nanotechnology is being explored in the context of ceramics. I look forward to continuing my research on ceramics at university.

REFERENCES

[1] "Climate and Earth's Energy Budget." *NASA*, NASA, 14 Jan.2009,earthobservatory.nasa.gov/features/EnergyBalance/page 5.php.

[2] Rose, Brian. "ATM 623: Climate Modelling." *ATM 623: Climate Modelling*, University at Albany, 2015, http://www.atmos.albany.edu/facstaff/brose/classes/ATM623_Spring2015/Notes/index.html.

[3] Sanchez-Lugo. "Global Climate Report - May 2018." *National Climatic Data Center*, NOAA National Centers for Environmental Information, June 2018, http://www.ncdc.noaa.gov/sotc/global/201805.

[4] Ritchie, Hannah, and Max Roser. "CO_2 and Greenhouse Gas Emissions." *Our World in Data*, Our World in Data, 11 May 2017, ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

[5] "Program on Climate Change." *Absorption of IR Energy*, UniversityofWashington, http://uwpcc.ocean.washington.edu/file/Absorption_of_IR_energy_.