Morphological Studies on Spark Plug Grade Alumina for the Improvement of the Electro-Mechanical Properties of the Material

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Abstract

Spark Plug is generally used in an internal combustion engine to produce a spark which ignites the air-fuel mixture in the combustion chamber. Basically, the key elements of spark plug are the shell, insulator, central electrode, and side electrode. The main part of the insulator is typically made by ceramic body that is produced with 92–95 % calcined alumina exhibiting desired properties like dielectric strength /constant which is governed by right quality alumina having desired morphology, particle size, specific surface area and impurity contents. The right combination of all these properties would lead to desired properties suitable for this specific application.

In the present study, all these properties were studied in detail to find out the suitability of alumina, with desired combination of properties. The development of required morphology was achieved through the combination of calcination process at a required temperature with the addition of a mineralizer having desired dielectric properties for these materials. Finally, a suitable alumina with roundish morphology and other required properties was found to be suitable to produce a high-performance product for this electro-ceramic application.

Keywords: Spark plug, electro-ceramic, calcined alumina, dielectric constant, roundish morphology

1. Introduction

Spark plug is an electrical device mainly used for internal combustion engines of automobiles. It ignites the compressed fuel mixture in the combustion chamber of the internal combustion engine. The role of the spark plug in IC engine is to deliver the electric charge from the ignition system to compressed fuel in the combustion chamber before the power stroke in the IC engine. Spark plug is shown in Fig.1, consists of various parts as central electrode, enclosed in ceramic insulator, and side electrode attached to the metallic shell. The insulators and central electrode can resist high combustion temperature. The reason is that heat must flow from insulator to metallic shell and after that it should go to the combustion chamber.

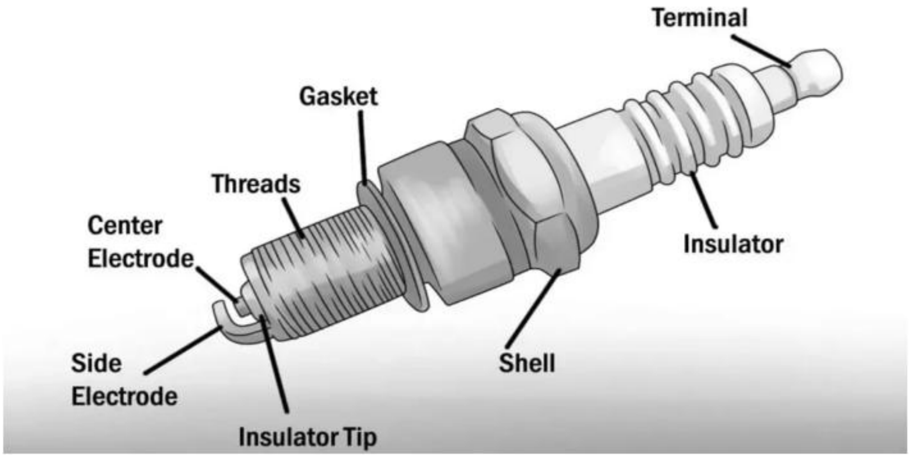

Figure 1. Image of spark plug [1].

The insulator is typically a ceramic material which is made from 92–95 % calcined alumina and the rest is flux made from clay, quartz, and feldspar to make sintered ceramic body to withstand elevated temperature and high voltage. It has good insulation capability even at a temperature of 1000 °C and can resist arcing & flashover. Dielectric strength or dielectric constant, volume resistivity, loss tangent etc. are the key properties of the ceramic material so that it can perform as an insulator in the spark plug. Calcined alumina is the major component of the ceramic insulator. Practically, these properties of the calcined alumina determine the quality of the ceramic insulator and its performance.

The properties of the alumina, like impurity content (soda, iron oxide etc.), microstructure or morphology (platy, flaky, roundish etc.), specific surface area, green density, fired density, porosity etc. are the major primary contributing factors of calcined alumina for exhibiting desired electrical – mechanical and dielectric properties of final ceramic body. Generally, hard calcined alumina with lower volatile material provides higher dielectric strength and higher volume resistivity and better insulating properties. Impurities, like sodium oxide create a low strength phase that leads to lower mechanical strength. It could also be noted that this mobile ion helps in dielectric breakdown that reduces the insulation capability of the material. Hence, it is a challenge to develop the required alumina having desired morphological structure and lower impurity with other required physio – chemical properties for designing the right kind of spark plug materials. Generally, roundish morphology with lower level of impurities, like Na_2O, Fe_2O_3 are suitable for spark plug application.

2. Conceptual Approach

Generally, calcined alumina is produced from the Bayer hydrate, through calcination at high temperature, along with other additive / mineralizer in the calcination process. Sometimes, hydrate is pre - calcined at lower temperature to increase surface area and then it is used as a feed for calcination. Mineralizer content, calcination temperature and feed material of calcination are the major variable parameters that can be controlled to get a desired alumina. The design of experiments was conceptualized using Taguchi orthogonal arrays model [2] to achieve the right kind of process condition for developing such type of alumina.

Table 4. Electro - mechanical properties of ceramic, made from alumina.

Properties	Ceramic body, made from alumina of trial 6	Ceramic body, made from alumina of trial 7	Ceramic body, made from alumina of trial 8
Morphology of alumina	**Roundish**	**Platy**	**Platy & partially roundish**
Mechanical properties			
Green density, (g/cm^3 & 90 Mpa)	2.36	2.36	2.35
Fired density, (g/cm^3 @ 1650 °C/4 h)	3.7	3.7	3.7
Porosity (%)	0.1	0.1	0.1
Co-efficient of friction	0.66	0.64	0.62
Wear resistance, ($mm^3/N\cdot m$)	6.50×10^{-05}	6.02×10^{-05}	5.50×10^{-05}
Electrical properties			
Dielectric strength, (kV/mm)	8.73	8.46	8.67
Volume resistivity, ($\Omega\cdot cm$)	8.67×10^{12}	5.00×10^{12}	8.36×10^{12}
Dielectric constant	5.94	5.88	5.59
Loss tangent	0.001392	0.003385	0.00229

5. Conclusion

- ✓ PCH feedstock is found to be a better choice, compared to ATH & SGA, for producing the right kind of alumina for spark plug application.

- ✓ The right combination of mineralizers and calcination temperature is required for producing the right quality of material. The present study shows that M_1 & M_2 mineralizers with 1 % & 2 % addition respectively exhibit roundish morphology, when calcined at 1650 °C.

- ✓ This type of crystal morphology helps to provide better dielectric and wear properties, compared to other morphological aluminas.

6. Reference

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