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STUDY ON SINTERING CHARACTERISTICS OF ALUMINIUM OXIDE AND MAGNESIUM OXIDE

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Abstract : — Alumina is a ceramic substance with high melting temperatures and good mechanical qualities that is utilised in a variety of applications, including furnace components, electronics substrates, cutting tools, and abrasion and corrosion resistance. The main goal of this research is to figure out what sintering conditions are needed to get alumina powder to a near-theoretical density. This paper investigated the effect of sintering temperature on sintered density. By altering the sintering (soaking) time, the influence of sintering time on densification was also investigated, and it was discovered that densification increases as sintering time increases. Even after 14 hours of sintering, full densification was not achieved, despite the fact that density increased with soaking time. Alumina samples were sintered using 1 percent Magnesium Oxide (MgO) by weight to minimise the sintering time to a minimum. The amount of time needed to densify alumina powder with MgO addition to a near-theoretical value was calculated. The sintered samples' microstructures were developed, and the sintered product's hardness was assessed. MgO was found to be an excellent sintering aid for sintering alumina in this investigation.

***IndexTerms* - Sintering of Alumina, Characteristics of Alumina, Density of Alumina, Microstructure of Alumina, Soaking time of Alumina with Mgo.**

I. INTRODUCTION

Ceramic materials are a significant class of materials for two reasons: first, they represent a huge and fundamental industry, and second, their qualities are crucial in many applications. Aluminum oxide, also known as alumina, is an amphoteric aluminium oxide having the chemical formula Al2O3. Alumina is one of the most versatile refractory ceramic oxides, with uses in a variety of fields. Because of its high hardness, wear resistance, high modulus, inertness, refractoriness, and sufficient strength, Alumina, Al2O3, is the most extensively used oxide ceramic.[1] Alumina is an important engineering ceramic material because of its high-temperature stability, strength retention at high temperatures, and low-cost starting powder.

II. THE PROCESSES

A. Cold Isostatic Process (CIP)

Cold Isostatic Pressing (CIP) is a shape-forming method for metal and ceramic powder consolidation. Metals can obtain around 100% theoretical density, while ceramic powders that are more difficult to crush can achieve around 95% theoretical density after sintering. [5]CIP is done as per *ASTM standard D5373-02* ,To apply pressure to the powder, the CIP uses a liquid media such as water, oil, or glycol-mixed water. After filling a flexible rubber mould with ceramic powder and applying isostatic pressure, the powder takes the shape of the mould.[13] The mould also prevents fluids from reaching the powder.

B. Sintering

Sintering is a heat treatment procedure that involves heating a significant amount of loose aggregate material to a temperature high enough to induce the loose material to solidify into a compact solid piece. The temperature applied during the sintering process is lower than the material's melting temperature. The goal of sintering is to give the material strength and integrity.[3] During the first stage, particles start to stick together and form necks between them. The grain boundaries are set and grain growth begins after this stage is completed. Only a small percentage of the product shrinks. Grain growth continues during the middle stage. Along the grain edge, continuous pore channels arise.[2] The cross-section of these channels continuously reduces until, by the end of this stage, the channels are pinched at a relative density of roughly 95 percent[4]. At the end of the process, closed pores form at grain borders and grain corners. The holes may be removed from the grains, resulting in a nearly entirely dense material, or the pores may be left inside the grains, causing the boundaries to break away from them: the problem of pore grain boundary interaction becomes prominent. Pore growth will also occur.

III. Experimentation

A) Mixing of Alumina and Magnesia

A 25 g of alumina and 0.25 g of MgO (i.e., 1% of alumina powder) along with alumina balls were taken in a bowl. The bowl was fixed in a High energy planetary ball milling machine for proper mixing. The mill was run for 8 hours with the following conditions.The specifications of the process are:

- Plate speed=200rpm
- Bowl speed=460rpm
- Cycle time=20min
- On time=10min
- Off time=10min
- Density= 0.25wt%
- Total no. of cycles=48 cycles

B) Cipping Of Alumina Magnesia

After thoroughly mixing of alumina and magnesia powder the powder mixture was taken out and it was subjected to the CIPPING process. A 25 gram alumina +1%MgO (by weight) powder was taken in a rubber mould. The rubber mould was kept in a CIP -ing machine at a pressure of 2K bar. A dwell time of 2 minutes was given to complete the CIP-ing process. After CIP-ing it was observed that the alumina powder became a solid specimen due to the compacting process. [7]After completion of CIP-ing process the Alumina samples were dried in air and were cut into small discs of 10 mm thickness

C) Sintering of pure Alumina

The cut pieces of green alumina specimens were sintered with different soaking temperatures and dwell times. The heating rate for all sintering studies was kept at 18 °C/min, up to those soaking temperatures.[8] After the appropriate soaking period the specimens were furnace cooled.

Below are the observations of sintering of pure Alumina

Sample Sl.No	Sintering Temperature °C	Duration (Hours)
1	1500	3
2	1600	3
3	1700	3
4	1700	5
5	1700	7
6	1700	14

Table 1: Observations of Sintering of pure Alumina

D) Sintering of Alumina with Magnesia

Three samples were cut and the green specimens of alumina + 1% MgO (by wt) were sintered at the same temperature of 1700°C (soaking temperature), but the dwell time was varied from 3-7 hrs. The heating rate up to the soaking temperature for all sintering studies was kept at 18 °C/min. After the appropriate soaking period the specimens were furnace cooled. Below are the observations of sintering of Alumina with Magnesia

Sample Sl.No	Sintering Temperature °C	Duration (Hours)
1	1700	3
2	1700	5
3	1700	7

Table 2: Observations of Sintering of pure Alumina with Magnesia

E) Measurement of Density of Samples

The Archimedes principle was used to assess the density of samples. According to Archimedes' principle, the upward buoyant force exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces and acts in an upward direction at the displaced fluid's centre of mass. The theoretical densities of the composites were calculated using the rule of mixture method (3.95 g/cm3 and 3.21 g/cm3 for Al2 O3 and SiC, respectively).[14]

Results and Discussions

F) Study of Temperature on Density

The sintering study on the effect of soaking temperature was studied on pure alumina specimens. The graph 1 below shows the results.[14] As show in the graph the sintered density increases as the soaking temperature increases. As the soaking temperature increased from 1500°C to 1700°C the sintered density increased from 62% to 74%.

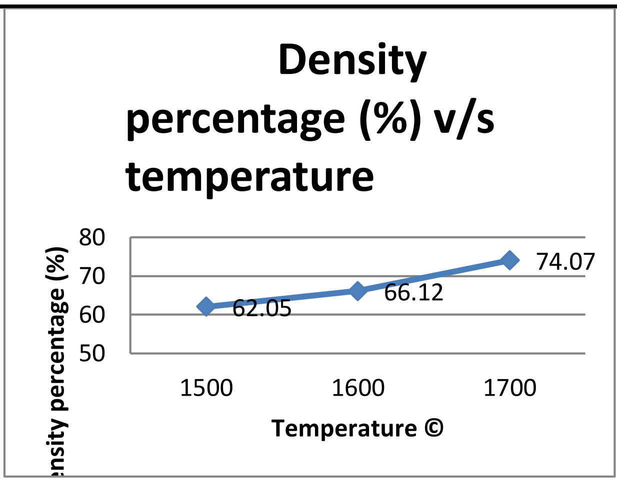

Fig 1: Effect of soaking temperature on density

G) Studies on Dwell time on Sintering

The sintering study on the effect of dwell time at various soaking temperatures was done on pure alumina specimens. As shown in the table 3, it is found that the sintered density increases as the dwell time increases. As the dwell increased from 3 to 14 hrs the sintered density increased from 74% to 83%.

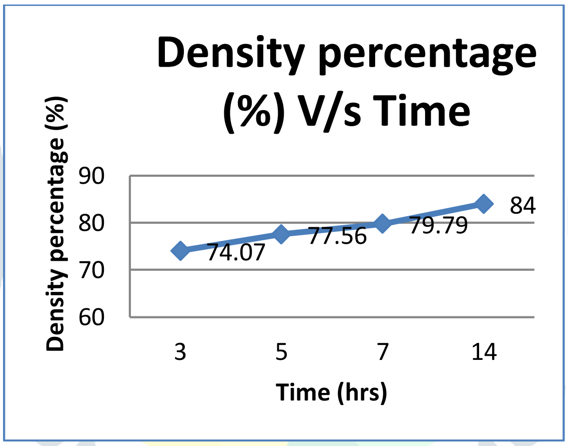

Fig 2 : Observations of Sintering of pure Alumina

H) Study on the effect of Sintering aid

The effect of sintering aid on the densification of alumina powder was studied. The sintering aid, 1% of Magnesia (MgO) by wt was added to the alumina powder and mixed in a high energy ball mill. All the samples were sintered at a soaking temperature of 1700°C. The dwell time was changed from 3-7 hrs.

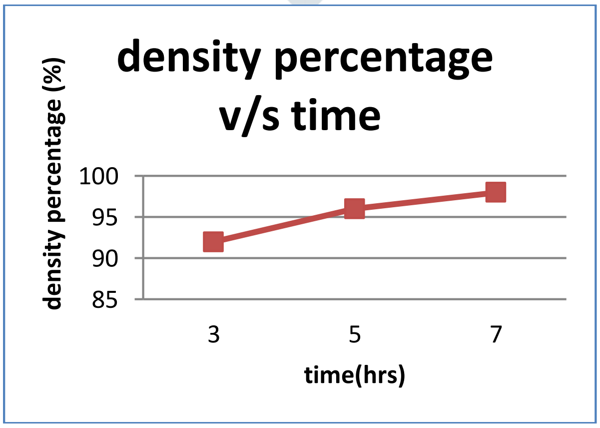

Fig 3: The effect of Sintering aid on density

I) Study of Micro structure

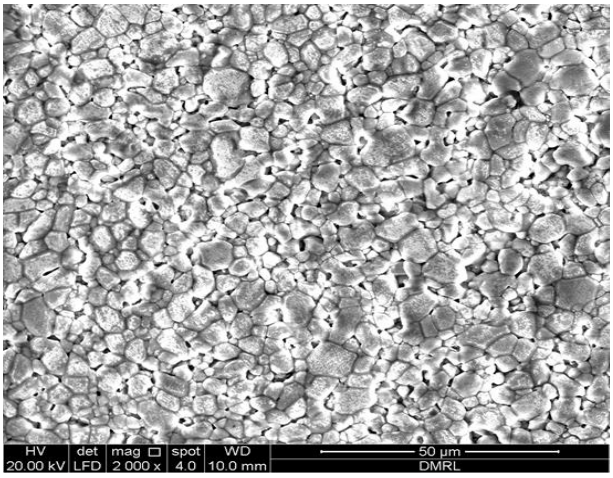

Figure 4: Etched microstructure of Al_2O_3+ MgO after 3 hours dwell

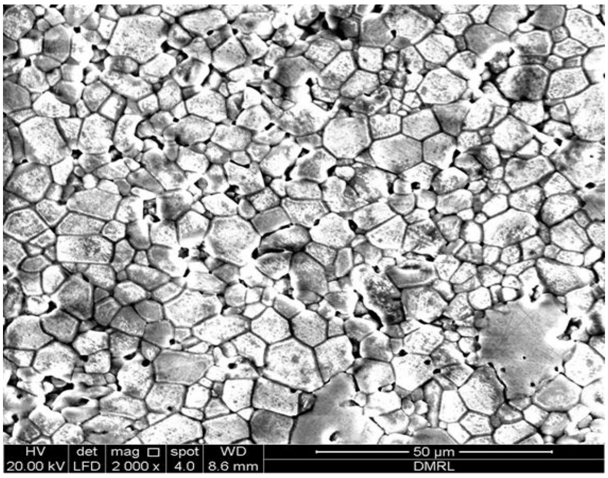

Figure5: Etched microstructure of Al_2O_3+ MgO after 5 hours dwell

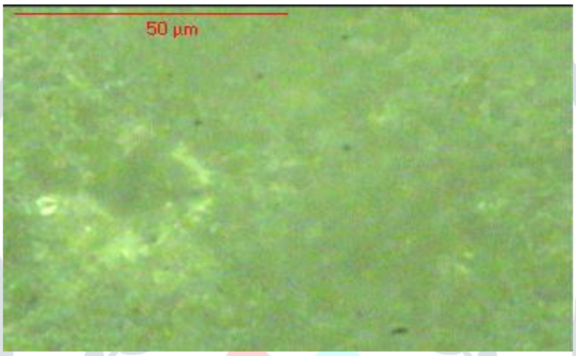

Figure 6: Etched microstructure of Al_2O_3+ MgO after 7 hours dwell

IV.CONCLUSION

In this experiment we have study was done on the Alumina to determine it'ssintering characteristics by varying sintering temperature and time. Also the effect of sintering aid MgO on the sintering characteristic of alumina was also studied. The ceramic powder was CIP -ed with 2K bar pressure for 2 min. The CIP –ed specimens were cut into pieces and sintering study at various time and temperature are carried out.

Finally, at 1700°C for 7 hours of dwell time the alumina specimen sintered to its near theoretical density of 98%. . It was found that the pure alumina could not be sintered to its fullest value without sintering aid even after sintering at 1700°C for 14 hours. Hence, it was found that the Magnesium oxide is a good additive to sintering alumina ceramic

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