The Effect of Various Sintering Temperature on Used Refractory towards Its Physical Properties

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Abstract. The used Magnesia refractory from the kiln of cement industry was successfully recycled to new refractory using Kaolin as an adhesive. In this work, the temperatures of sintering were varied from 1000°C to 1500°C. The result shows that the increment temperature effect in sintering process will enhance refractory physical properties such as bulk density, cold crushing strength or pressure strength and thermal conductivity. Mean while, the porosity was decreased as the increase of the sintering temperature.

1. Introduction

The increasing of global refractory demand enhances the cost of raw materials and freight and environmental pressures. Searching the cheaper mineral for refractory applications becomes a problem in the refractory industry. One of a cheaper refractory mineral is from recycling uses bricks.

However, the mineral form used brick has many contaminants hence need to process and add some mineral to improve the physical property such as bulk density, porosity, cold crushing strength or pressure strength and also thermal conductivity [1-4] (Efendy, 2008).

The refractory production use sintering process at a certain temperature. Sintering is one of the methods to produce material with controllable density from a metal component or ceramic powder by a thermal application. This technique also able to design microstructural control that is grain size, density post-sintering (sinter density), size and phase distribution included pores.

The binder material is needed to produce the high quality of refractory. Kaolin is one of clay that usually used as a binder material or adhesive in ceramic and refractory production due to the more stable and low cohesion at high temperature [2,3] (Schacht, 2004).

This work was used Kaolin as a binder in refractory production from used brick from the cement factory. This used brick was magnesite or magnesia refractory. This brick, in general, is made from natural dead-burn magnesite which containing 90% MgO or less, and for purified magnesite, it is containing 96% MgO or more [4,5] (Harbinson & Walker, 2005)

The temperature effect in sintering process towards refractory physical properties such as bulk density, porosity, cold crushing strength or pressure strength and thermal conductivity were studied also in this research.

2. Experiment Methods

The used magnesia bricks were from kiln unit in cement factory (Jui Shin Co. Ltd, West Java, Indonesia). The used refractory was crushed into powder. The powder than were screened to get desired size particles. New refractory were made from 300 gram material which consists 55.76% of used refractory powder with size particle 40 -80 mesh, 29.24% of used refractory powder with size particle 80-100 mesh, 15% of Kaolin size particle higher than 100 mesh. All material were mixed and then were pressed into solid (as known as green body) using a hydrolytic device with 10 ton of pressure and the dimension of refractory was 5×5×5 cm. After that, the density of green body was measured. Finally, the green body was sintered in a furnace at various temperature (1000 °C, 1100°C, 1200 °C , 1300 °C , 1400 °C and 1500 °C) for 6 hours.

The characterisation of the product was studied in this work were *apparent porosity, bulk density, cold crushing strength* (CCS), and thermal conductivity. The measure of apparent porosity and bulk density was conducted based on a standard test from ASTM C20-00. CCS test was conducted using Wykeham Farrance equipment. Meanwhile, the thermal conductivity of specimen is tested by using standard guarded hot plate method, ASTM C177-04.

3. Result and Discussion

In this work, the used refractory was recycled to produce new refractory using Kaolin as adhesive. The characteristic of product this experiment which were processed at various sintering temperature were listed in Table 1. Meanwhile, the correlations between CCS with sintering temperatures were shown in Figure 1. The figure shows that the CCS increase as the increment of sintering temperature. The increment of sintering temperature caused the enhancement number particles which were combined with the other particle making the single solid part, hence the value of CCS is increasing. In sintering process, the atoms in the materials diffuse across the boundaries of the particles, fusing the particles jointly and build a compact hard piece.

The effect of sintering temperature toward the percentage of porosity was shown in Fig. 2. The figure shows that the increasing of sintering temperature caused the decreasing of porosity percentage. This phenomenon due to the increasing of sintering temperature will increase the number of fusing of particles; hence the porosity between the particles will decrease.

Table 1. Physical characteristic from experiment product of refractory using Kaolin adhesive

Sampel	Temperature Sintering (°C)	Crush Crushing Strength (Mpa)	Apparent Porosity (%)	Bulk Density gr/cm^3	Thermal Conductivity (W/m.K)
1	1000	1.44	20.6428	1.0358	11.6368
2	1100	2.06	20.4472	1.0420	11.6368
3	1200	5.76	19.5199	1.0503	11.8577
4	1300	9.56	17.8041	1.0706	12.0784
5	1400	13.36	16.0883	1.0909	12.2991
6	1500	15.5	14.9952	1.1234	12.3872

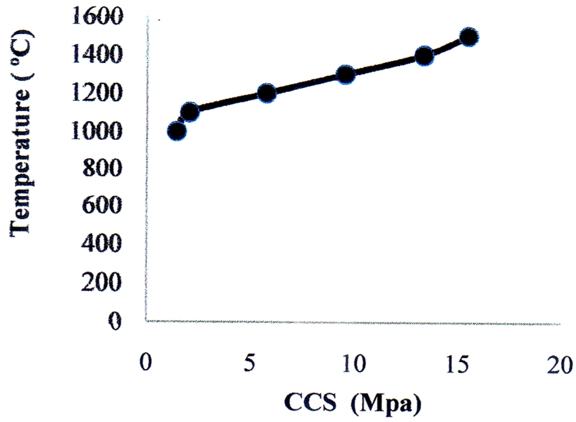


Figure 1. The effect of the sintering temperature towards Cold crushing strength (CCS)

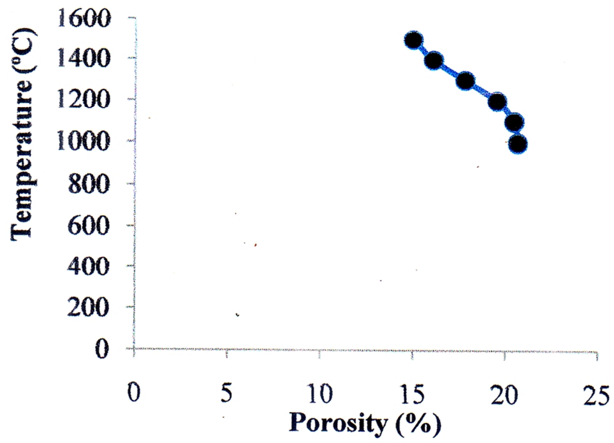


Figure 2. The effect of the sintering temperature towards porosity

Figure 3 shows the effect of the sintering temperature towards density. The figure shows that the increment of sintering temperature will enhance the density of refractory. The increasing of temperature will increase the number of fusing particles in refractory, it caused the decreasing the number of pores [5]. The density of refractory was increase as the decreasing the number of the pore in refractory.

The effect of the sintering temperature towards thermal conductivity is shown Figure 4. The figure shows that the enhancement of thermal conductivity as the increment of sintering temperature. This increasing of thermal conductivity is due to the decreasing of the number of pores when the sintering temperature is increased.

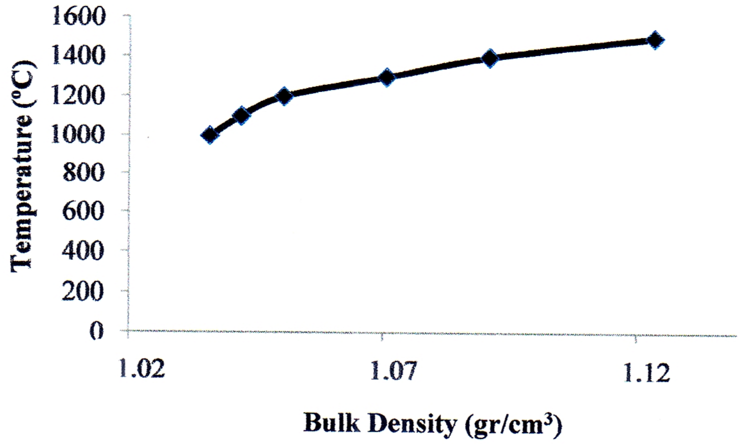


Figure 3. The effect of the sintering temperature towards density

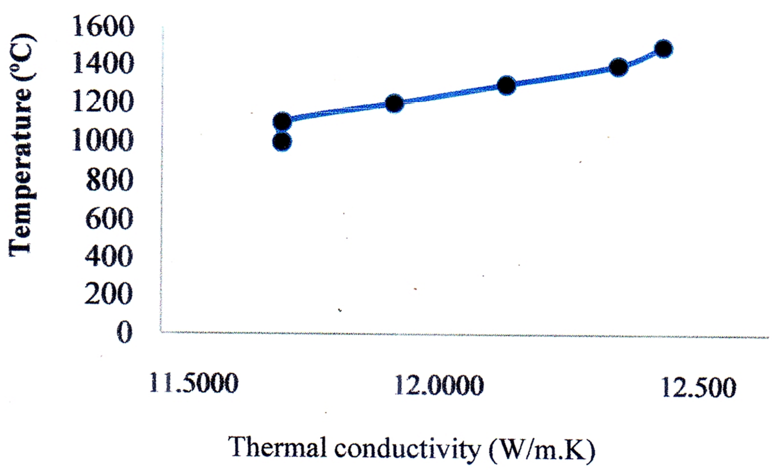
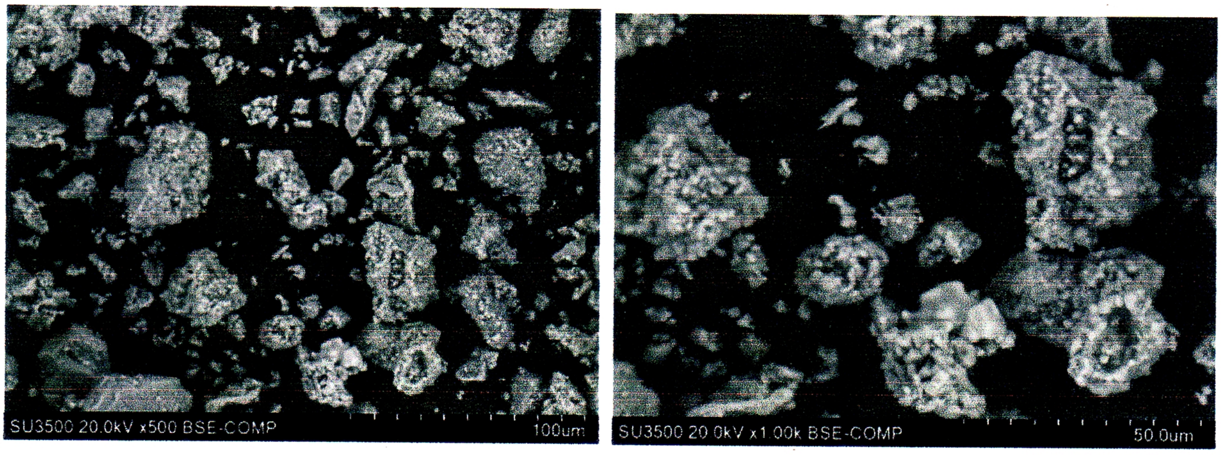


Figure 4. The effect of the sintering temperature towards thermal conductivity

Table 2. The characteristics of refractory

Sample	**Crush Crushing Strength (Mpa)**	**Apparent Porosity (%)**	**Bulk Density gr/cm^3**	**Thermal Conductivity (W/m.K)**
Used refractory from Kiln	48.1920	6.7385	2.8072	11.2401
Recycled refractory (refractory from used refractory)	15.5000	14.9952	1.1234	12.3872
New magnesia refractory (standard)	34.47-55.16	15.5-19	2.84-2.9	10.56

The physical characteristics of used refractory, recycled refractory (refractory from used refractory) and new magnesia refractory [3]. The value of CCS show that Recycled refractory (refractory from used refractory) is smaller than the standard new magnesia refractory, meanwhile, the value of thermal conductivity was higher than the value of the standard new magnesia refractory. These different values were due to the process of recycled refractory using 34.47-55.16 Mpa and 1500°C, meanwhile, the production of standard Magnesia refractory used 192 Mpa and 1800°C.



(a) (b)

Figure 5. (a) SEM result from sample for size of 50 μm (b) SEM result from sample for size of 100 μm

SEM images from the sample which was sintered at a temperature of 1500 °C were showed in Figure 8a and 8b. The figures show that the growth of particle grains and the fusing of particles which show the evidence of sintering process.

5. CONCLUSIONS

The used magnesia refractory from the kiln of cement industry was successfully recycled to new refractory. Kaolin was used as adhesive in this magnesia refractory. The product of this work shows that the refractory has different physical properties than the standard of Magnesia refractory due to the different pressure of green body development and the temperature of the sintering process. This differentiates of operation condition is caused by the limitation of the processing unit in a laboratory.

Acknowledgment

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References

[1] Efendy, H 2008 *Studi Antioksidasi pada Refraktori MgO-C Monolitik denagn Bahan Pengikat Tar-Resin.* Bandung: Institut Teknologi Bandung.

[2] Schacht, CA 2004 *Refractories Handbook.* New York: Marcel Dekker, Inc.

[3] Carniglia, S C, & Barna, G L 1992 *Handbook of Industrial Refractories Technology.* Westwood, New Jersey: Noyes Publication.

[4] Rahaman, M N 2007 *Sintering of Ceramics.* Boca Raton: Taylor & Francis Group, LLC.

[5] Harbinson & Walker 2005 *Handbook of Refractory Practice.* Moon Township: Harbinson-Walker Refractories Company.