

Fabrication and Investigation of Composite Made of Graphite, SiC, Mullite and Aluminum

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Abstract

Fabrication and investigation of composite made of graphite, SiC, mullite and aluminum as the additive are the aim of this project. Aluminum acts as an anti-oxidant. SiC is a non-metallic anti-oxidant that increases composite strength. Different compositions with influent percents of aluminum have been selected to determine product specifications by XRD, SEM and STA methods. Results show that the composition of 40wt% graphite-20% SiC- 20% mullite-20% aluminum is a more robust and occurs at elevated temperatures than other graphite combustion composites.

Keywords: SiC, Millite, Aluminum

1. Introduction

SiO₂/Al₂O₃/MgO/CaO/Cr₂O₃/ZrO₂ and combination between them are base oxides that used for producing refractory materials. Recently combination between the above oxides is used by carbon.

Furthermore of carbon and silicon carbide, the little amount of Behr carbide and nitride is used for special applications

[1]. The importance of these materials and basic combination is that these materials and combination of them melt at very high temperature. Referring to phases diagram help to understanding the softening multi phase material complicated relationship that made of refractory materials [1]. En masse the important parameters that investigated for evaluation refractory materials are as the below: [2]

1. Elasticity module
2. Thermal expansion
3. Variation of thermal shock
4. Refractory properties under load
5. Cold and hot mechanical strength
6. Thermal conductivity
7. Porosity
8. Erosion resistance
9. External materials permeability

Graphite refractory materials do not have replacement in industry. These materials are used as a furnace in non iron metallic industry [1]. Chamout-graphite materials are used as a stopper, nozzle and casting parts in industry. Nowadays, Al₂O₃-C and ZrO₂-C are used more in industry [1]. For baking graphite bodies, clay is added at first, but a lot of clay is needed in this method. Therefore by replacing silicon carbide with clay, erosion properties improve [1]. In the oxidation atmosphere, in temperature above 1100°C silicon will be converted to silicon carbide, therefore the

strong contact will occur [1]. The most important problems that exist in using the refractory materials with carbon base are leaning to oxidation when temperature rises. Recently for solving this problem, prefer to using aluminum and silicon carbide as the preventing oxidation materials [3].

2. Experiments

Particles size distribution analysis was performed by laser analysis particle device (Model: Fritsch-Analysette 22). At first, suspension with special liquid of 1g powder was prepared. In order to obtain a stable suspension, TPP is added to the suspension and for deflocculating agglomerates formation in this suspension, Ultra Sonic Waves were exerted to the grout for 1 min.

Finally, suspension passes through the transparent chamber and X-Ray (wavelength: 0.16 μm) will be struck to the suspension in this chamber. The degree of attraction and dispersion of the X-Ray depend on the size and amount of suspension particles. Attraction and dispersion of X-Ray will be measured by electronic devices, and test results will be printed out as a diagram by printer. For aluminum and graphite particles size determination, alcohol is used as wetter, because water can not wet the surfaces of the particles.

3. Phases Investigation

For recognizing forming phases in specimens after heating specimens in different temperatures, XRD analysis was done by X-Ray diffraction device (Model: D-500 Siemens Production). Cu-Kα Ray, accelerator voltage (30KV) and amperage (25mA) were used for doing this test.

4. Thermal Analysis

This device heats the specimens whilst investigates thermal treatment of specimens and shows weight variation and heat treatment variation of matter in comparison with reference matter. Heating rate was started from 0.5 Deg/Min and rised and all thermal analysis were investigated by simultaneous thermal analysis device (Production of Polymer Lab, Made in UK, Model: STA-1640).

5. Experimental Activities

Primary materials are as below:

- 1) Graphite
- 2) Silicon Carbide
- 3) Clay
- 4) Aluminum dust (With 99.9 Purity, MERCK No. 1056)
- 5) Feldspar

Graphite physical properties by STM test are as follow:

- 1) 2.1% desertter material
- 2) 0.6% Moisture
- 3) 92.01% Carbon
- 4) 0.29% Cinder
- 5) Particles size between 70 μm till 95 μm

Silicon carbide physical properties are as follow:

- 1) 99% Purity
- 2) Particles Size : under 12 μm

Physical properties of clay are as follow:

- 1) Consumable clay: W.B.B

6. Fabrication Process

- 1) Weighing in aluminum, graphite, clay, silicon carbide and feldspar
- 2) Stir by stirrer
- 3) Preparing wet mixture by alcohol
- 4) Drying with stirring
- 5) Pressing in 150 MPa
- 6) Baking in 140°C
- 7) Investigating by XRD, SEM and STA methods

7. Results

Strength was very low in the specimens without additives. Thus strength measuring is not possible but in the specimens that contain aluminum and feldspar, strength increases when Al/Clay and feldspar/clay ratios rise, but in the specimens that contain feldspar, strength is more than aluminum specimens, because feldspar decreases melting point. (see Figures 1).

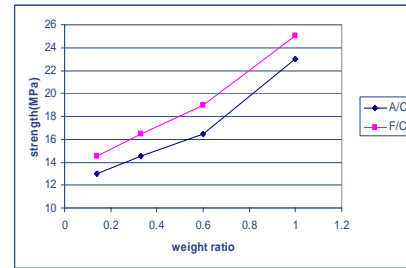


Fig. 1. increasing strength by aluminum and feldspar additives.

The densities of composites which contain aluminum are more than the composites with feldspar. Because aluminum becomes oxide therefore Al_2O_3 increases the weight and prevents from oxidation of graphite. (see Figure 2)

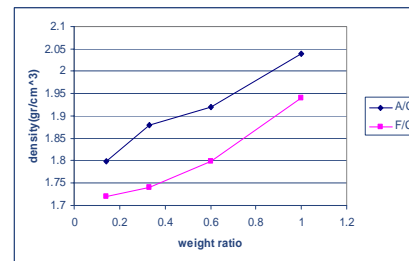


Fig. 2. increasing density by aluminum and feldspar.

Experiments show that strength decreases if feldspar is added by 1/1 ratio, because aluminum prevents of feldspar operation, Thus feldspar can't fill the porosity. (see Figure 3)

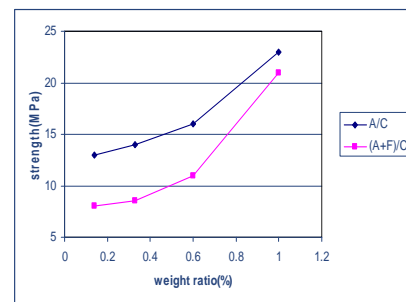


Fig. 3. comparison between strengths of aluminum specimen and aluminum + feldspar specimens.

8. Conclusion

Investigating on diagrams of thermal analysis:

One endothermic peak was considered in 1073°C in GS specimen because of melting of residual materials that remained after burning graphite (see Figure 4).

Investigating of graphite oxidation treatments with variation additives

No	Graphite %	SiC %	Clay %	Aluminum%	Composition	Temperature of Combustion (°C)
1	80	20	-	-	GS	809
2	80	10	10	-	GSC	814
3	80	-	20	-	GC	836
4	80	-	10	10	GCA	851
5	80	-	-	20	GA	857
6	60	20	10	10	GSCA10	849
7	40	20	20	20	GSCA20	851

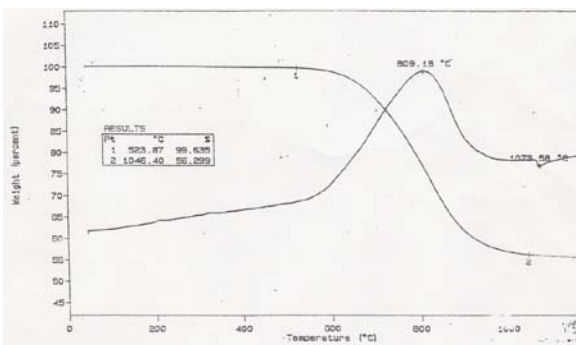


Fig. 4. thermal analysis diagram of GS specimen.

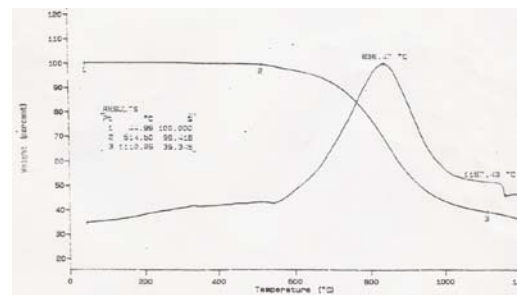


Fig. 5. thermal analysis diagram of GC specimen.

Comparing between graphite-silicon carbide-clay composite, graphite-silicon carbide-aluminum composite and graphite-silicon carbide-clay-feldspar composite show that graphite-silicon carbide-clay composite has lower density and strength against two others and graphite-silicon carbide-clay-feldspar composite has low refractory properties under load. Thus, this kind of composite is not preferred to use in high temperature fire proof works; so graphite-silicon carbide-clay composite with aluminum as the additives is the best composition in these situations.

As the silicon carbide is non metallic anti oxidant, graphite combustion temperature occurs in 809 °c when silicon carbide with fine grains is added.

Graphite combustion temperature transfers to 836 °c by replacing silicon carbide with clay (see Figure 5); this transfer is done because of:

- a) Clay has fine grains
- b) Surrounding graphite aglets by clay

When temperature rises, graphite becomes pasty and prevents against the oxidation.

Phases investigation results show that when temperature rises, the amount of alumina forming increases. Phases results show that mullite phase will be deleted by adding 15% of anti oxidant. This deleted phase is cause of loss clay weight. Graphite combustion temperature transfers to 857 °c by replacing aluminum with clay. One sharp endothermic peak in 1005°C is considered because of high oxidation of aluminum (see Figure 6)

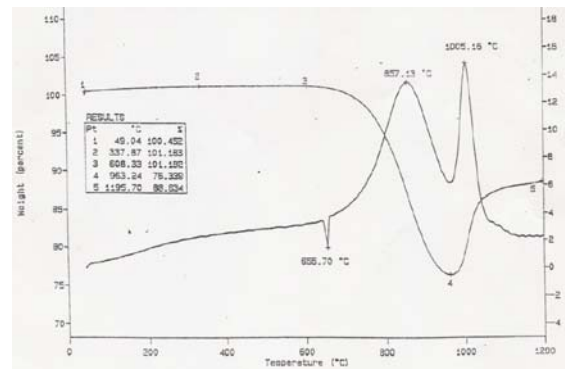


Fig. 6. thermal analysis diagram of GA specimen.

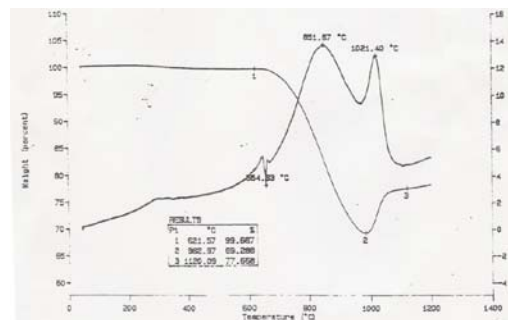


Fig. 7. thermal analysis diagram of GSCA20.

The best specimen is GSCA20 that graphite burning occurs at 851°C and at 654°C and 1021°C, melting and oxidation of aluminum occurs. The oxidation of graphite starts from 621°C. (see Figure 7)

Figure 8 shows that with increasing temperature, porosity will be increased, and at the constant temperature, by increasing of aluminum percentage as an anti oxidation, porosity will be decreased.

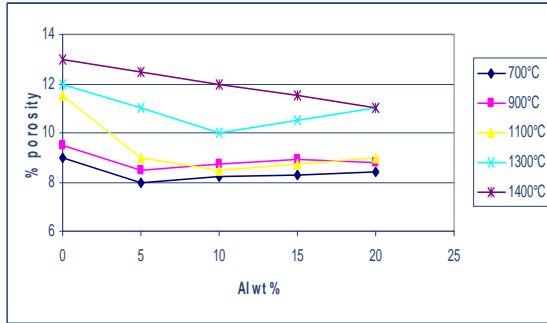


Fig. 8. porosity of different combinations in different temperatures.

9. References

1. Gerald Roteszka, translated by Dr. B. Mirhadi, "Refractory materials" publication of science and industry of Iran university, 1378.
2. Bokaeian manouchehr, "Refractory materials in rotating furnaces" Publication of industrial material of ABYEK cement.
3. A.Yamaguehi, "behavior of silicon carbide and aluminum added to carbon-containing refractories" taikabutsu overseas, vol.35, 617-622, 1983.