INJECTION MOLDING OF COMPOSITE USING COAL ASH

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1 Introduction

Currently large amounts of industrial coal ash waste are being discharged from coal electrical power plants. This waste is generally disposed at areas prescribed by public institutions. Therefore, an effective technique for using coal ash as an industrial material is expected to be developed. Mainly, its application extends to the civil and architecture fields [1] [2]. There have been very few papers, which describe an effective use for coal ash as a mechanical material [3]. Coal ash is classified into klinka ash and fly ash. Fly ash is a very small, fine particle that contains large amounts of Silica; therefore, it can be considered as a ceramics material [4]. In this research, fly ash was considered as a reinforcement for a composite material. Injection molding has an advantage in the making of complex 3D products, and in large quantity production. For these reasons, we investigated the application of injection molding for a composite material using fly ash. By varying the content of fly ash to plastic within the range from 10 to 40%, mechanical properties were investigated using the bending test. The mechanical properties of the injection molded products were then examined to understand the effects fly ash has upon the bending strength and flexural modulus.

2 Experimental Materials and Methods

The fly ash was obtained from coal ash using a particle collector machine in the electrical power factory. The chemical composition of fly ash is shown in Table 1. Fig.1 shows a microphotograph of fly ash particles taken by a scanning electron microscope (SEM). We can observe the globular shape of fly ash particles, because of surface tension by heat cooling process. The particle size of fly ash in its original state has an average diameter of 13 µm. By crushing the fly ash with a planetarium ball mill, the particle size was changed to 2.7 µm. Fig.2 shows the distribution of particle size for coarse (uncrushed) and fine (crushed) fly ash. Polyethylene (PE) and Polypropylene (PP) resins were used as the polymer matrixes. The composition ratio of fly ash in the composite was in the range of 0 to 40%. The experimental procedure is shown Fig.3. The fly ash and resin were placed into a twin screw type kneading machine, which was heated to a high temperature in order to melt the materials sufficiently. After mixing the materials for an appropriate time, the material was cooled; however, the screw motor was kept on, crushing the composite material into pellets. A Nissay Jushi injection molding machine was utilized: the cylinder temperature was 160 to 210°C; the injection pressure was 3.3 to 8.9 MPa; the injection speed was 62 to 93 mm/s; and the mold temperature was in a range of 40 to 80°C. An injection molded product can be seen in Fig.4; sections A and B were cut to create the test specimens. The shrinkage ratio was determined by comparing the average diameter taken from three points along the test specimen with the mold dimensions. As for the mechanical properties, the bending strength and flexural modulus were determined from a three point bending test. The flexural modulus was obtained from the following equation

$$E = \frac{L^3}{48I}\frac{P}{\delta} \tag{1}$$

where E is the flexural modulus, L is the span length, I is the geometric moment of inertia, P is the difference of load on elastic zone, and δ is the difference in displacement of span center on elastic zone.

3 Experimental Results and Discussion

First, we investigated the viscosity of PE to fabricate the composite material. Several types of PE, for example: HDPE, LDPE, and LLDPE were tested. Fig.5 shows the melt flow rate (MFR) measured for the different PE at 190°C. From this graph, LLDPE (Linear Low Density Polyethylene) was chosen as the resin for the composite material because of its low viscosity.

The change in density of the composite material composed of LLDPE and fly ash is shown in Fig.6. The graph reveals that the density increases as the content of fly ash increases, because the density value of fly ash is 2.62. Next, the comparison of the shrinkage ratio and amount of fly ash is shown in Fig.7. It can be seen that the shrinkage ratio decreases as the content of fly ash is increased. This happened because of the low heat conductivity of fly ash. This result shows that fly ash particles acted as a stone in preventing the shrinkage of the LLDPE polymer. The mechanical properties were determined from a three point bending test. The results of the bending strength are shown in Fig.8, and the results of the flexural modulus are shown in Fig.9. In these graphs, it can be seen that the bending strength and flexural modulus increase, corresponding to the addition of fly ash. This is considered to have occurred because fly ash is a ceramics material containing a high content of Silica, which caused the material to harden. Furthermore, the fly ash is thought have uniformly distributed inside the injection molding products acting as strengthening material; therefore, the bending strength and stiffness improved.

Next, the MFRs of two types of PP: az8624, and u501e1 were compared (Fig.10). The u501e1 PP was found to have a lower viscosity; therefore, it was selected as the resin for the composite material. Injection molded products were then fabricated using coarse fly ash particles and fine fly ash particles. Fig.11 shows the comparison of the flexural modulus when using weight 20% coarse and fine fly ash particles in the composite. The flexural modulus containing the fine fly ash shows a higher value. Therefore, we fabricated the composite using fine fly ash. Fig.12 shows the comparison of shrinkage for the composite material. From this graph, the fly ash composite shows a lower value than the PP resin. As shown in Fig.13, the same phenomenon as PE regarding the results of the flexural modulus occurred for the composite material containing the PP.

4 Conclusions

In order to use fly ash as a high value mechanical material, composites were investigated by the application of injection molding. PE and PP were utilized with different combinations of fly ash in order to fabricate a composite material. The particle sizes of fly ash were changed by crushing them with a planetarium ball mill. The obtained results of the applied injection molding are revealed as follows:

(1) The shrinkage ratio of the composite that used LLDPE and fly ash decreased as the amount of fly ash content in the composite material was increased. The bending strength and flexural modulus showed an increase, as the amount of fly ash content in the composite material increased.

(2) The composite material that used fine fly ash particles and PP showed the same trend. The shrinkage ratio decreased and the flexural modulus increased, as the fly ash content in composite material was increased.

References

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Table 1 Chemical composition of fly ash

(mass %)

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O
62.4	23.5	3.3	1.43	0.75	0.51	0.35	0.61

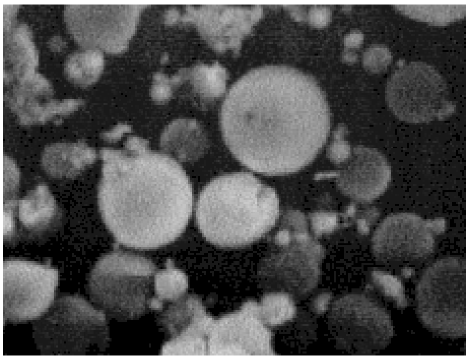

Fig.1 Microphotograph of fly ash particles

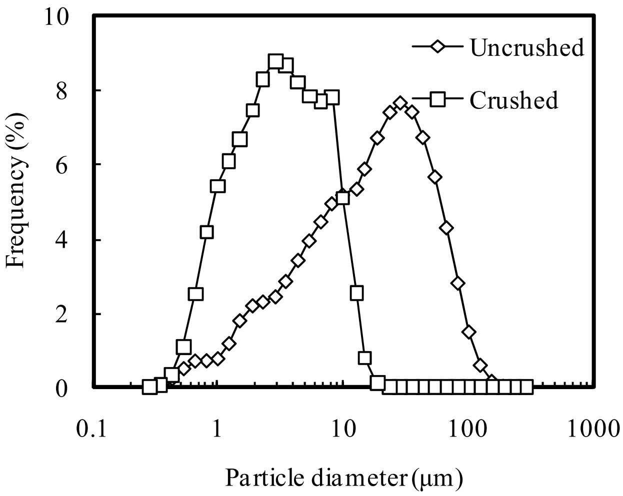

Fig.2 Distribution of particle sizes of fly ash

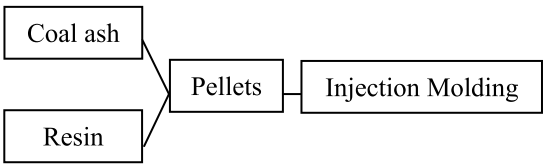

Fig.3 Experimental procedure

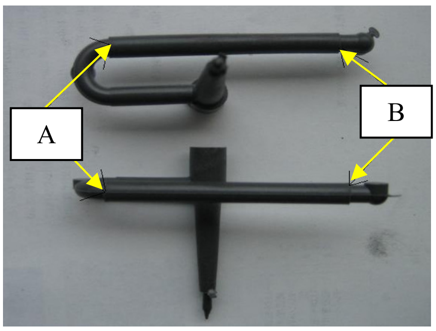

Fig.4 Injection molded product

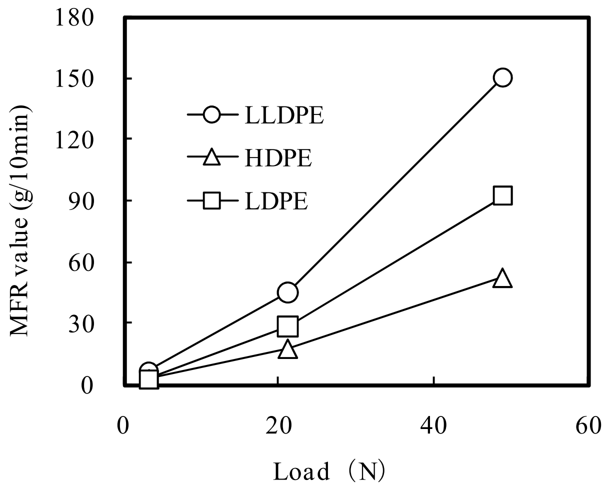

Fig.5 Comparison of MFRs for PE

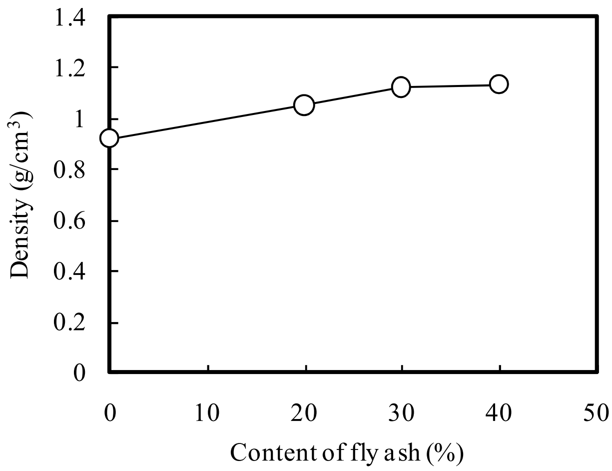

Fig.6 Relationship between content of fly ash and density

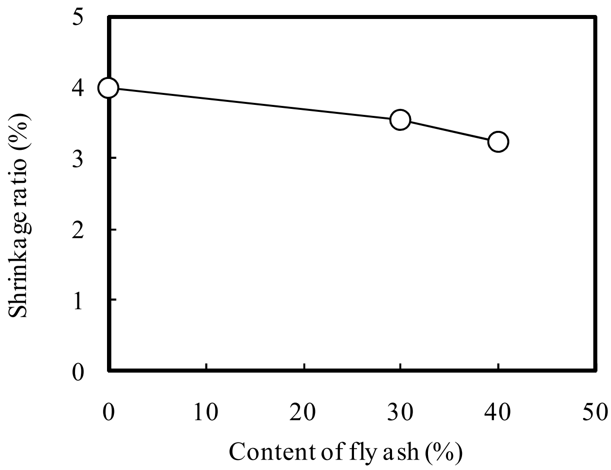

Fig.7 Comparison of shrinkage ratio of composite materials

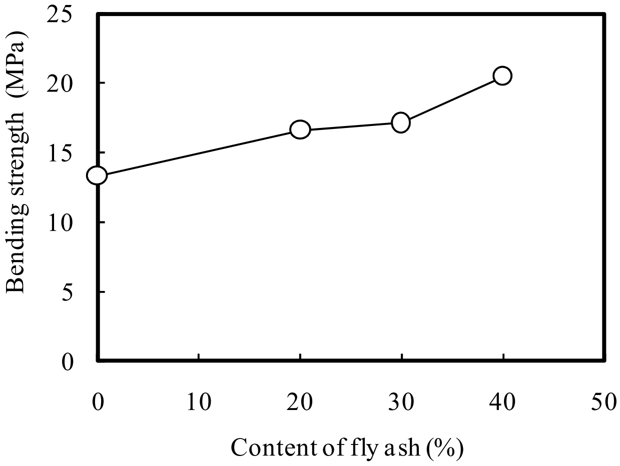

Fig.8 Relationship between content of fly ash and bending strength

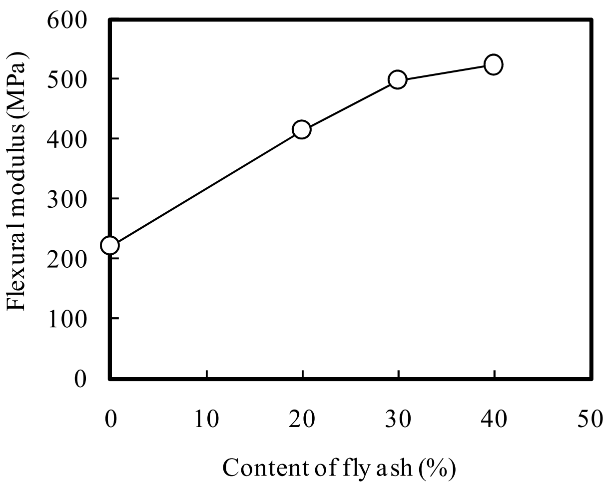

Fig.9 Relationship between content of fly ash and flexural modulus

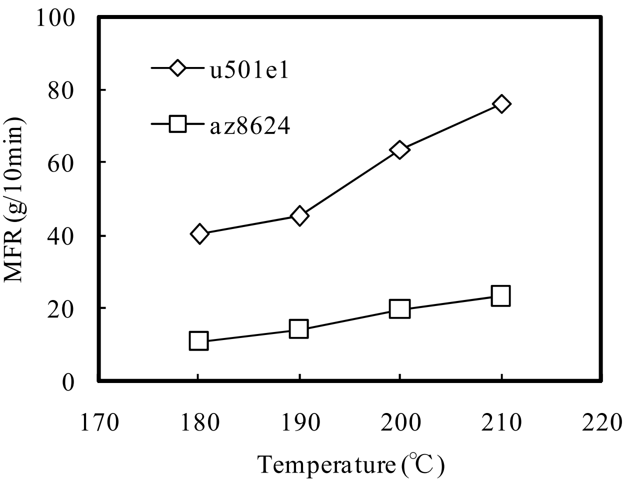

Fig.10 Comparison of MFRs for PP

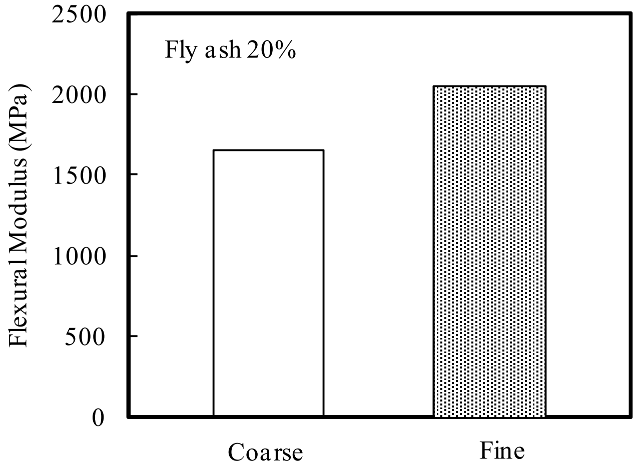

Fig.11 Comparison of the flexural modulus of composite changing the particle size of fly ash

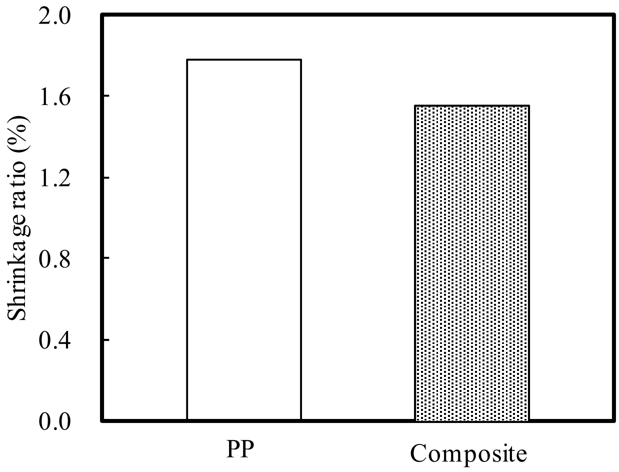

Fig.12 Comparison of shrinkage ratio for PP and composite

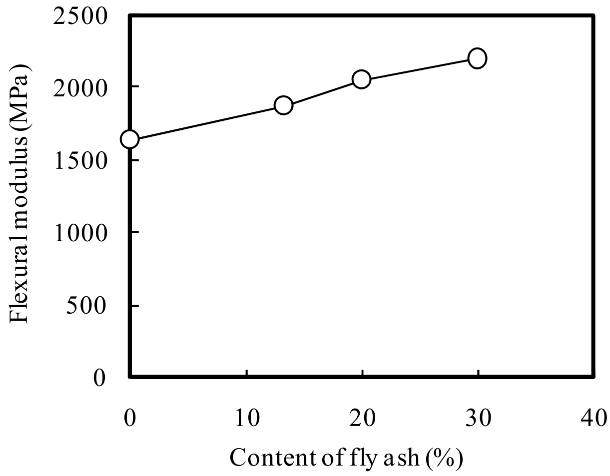

Fig.13 Relationship between content of fly ash and flexural modulus using PP