Alternative Evaluation of Synthetic Gypsum with Waste Polyethylene

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ABSTRACT Increasing environmental awareness, concerns and raw material cost has brought up the efficient usage of natural reserves. Synthetic gypsum is one of the mass product wastes from flue gas desulphurization (FGD) process to avoid industrial stack emission of SO_2. Coal power plants are especially the largest human-caused source of sulfur dioxide. The adsorption of SO_2 via caustic lime [$Ca(OH)_2$] produces a final product called synthetic gypsum. On the other hand, polyethylene is one of the most post-consumer plastics in the world and could be used instead of virgin polyethylene. In this study, recycled post-consumer plastics were used as binder and FGD waste was used as filler material for the aluminum composite panels. The plastic material was analyzed for non-challenge inspection via FTIR (Fourier Transform Infrared Spectroscopy -Thermo Scientific / Nicolet IS50) and DSC (Differantial Scanning Calorimetry-Mettler – Toledo / DSC 1 / 700). Recycled polymer and gypsum were mixed via Brabender / W50 EHT + Plastograph EC Plus and prepared by proper type mould with Haake mini injection molding. Fusion time, stability and total torque were recorded during the process. Shore hardness of composite was also measured using Mitutoyo 332 hardmatic hardness tester according to ASTM D2240. Finally, the morphological analysis via FEI / Quanta 450 FEG Scanning Electron Microscopy shows that FGD waste and plastic waste are useful as filler material especially for aluminum composite panel.

KEYWORDS: Composite; Plastic; Recycling; FGD; Filler

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INTRODUCTION

The main cause responsible for climate change due to greenhouse gas (GHG) emissions is energy production. Currently, approximately 82% of the world's commercial energy needs are met from fossil fuels (US Energy Information Administration, 2017a), and this is unlikely to decline in the near future. Since the production and use of energy is the main source of global emissions, it is the key to determining whether climate change targets have been achieved (Pacheco, 2017). Moreover, considering the relationship between energy need and population, the world population is growing by about 80 million people every year (United Nations, 2017). The population is another fact that continuously increases the demand for energy (King *et al.*, 2015). Under these conditions, the world net electricity consumption is expected to increase from 23.4 trillion kWh in 2015 to 34 trillion kWh in 2040 (US Energy Information Administration, 2017b). According to the International Energy Agency (IEA) report, only 22.3% of world electricity production in 2015 (International Energy Agency, 2017) is from renewable energy and is estimated to be around 29% by 2040 (International Energy Agency, 2016). This prediction means that fossil fuels will continue to be used for electricity generation over the next 20 years, and GHG emissions will increase steadily.

The gypsum obtained from citric acid, hydrofluoric acid, titanium dioxide and phosphoric acid manufacturing processes is called as citrogypsum (Kostić *et al.*, 2000), fluorogypsum (Garg & Pundir 2014), titanogypsum (Bensted, 1981) and phosphogypsum (Yoon *at al.*, 2015), respectively. The flue gas desulfurization (FGD) process is carried out to remove sulfur dioxide from gas pollutants of fossil fuel-fired power plants (Córdoba, 2015), and the by-product obtained in this process is called as FGD gypsum.

Reinforced materials are not limited to polymer-based composites. Materials such as clay, metal and gypsum can also be used as matrix. Ouattara *et al.* (2016) reported that the incorporation of sawdust in argillaceous matrix increases the compressive strength of the bricks up to 80% while decreasing the density around 50% (Ouattara *et al.*, 2016).

FGD is generally considered as waste and not sufficiently evaluated except for building materials. Besides, the usage of FGD as an additive in concrete is not efficiently enough. Since 1994, synthetic gypsum has been widely used for stucco and drywall (Dunster, 2007). According to Taha (1992), this type of product adheres to the Environmental Protection Agency (EPA) standards as a construction material.

In recent years, the use of natural stone, dye and stucco, coating materials and coating systems for exterior masonry has decreased the cost of the building. Light, durable and cheap materials are preferred as a facing material. Aluminium is one of the common desired materials due to its durable, aesthetics appearance and easy application. From economic aspect, composite aluminium plate is preferred as compared with the block aluminium. Aluminium composites are manufactured with filler material between aluminium sheets. The filler material can be Aluminium trihydroxide, Magnesium hydroxide, modified polypropylene, and silane based materials for different applications (Liauw *et al.*, 1998).

In this study, recycled polyethylene and FGD are used as filler material for sandwich polymer-metal panels on the purpose of economically and environmentally concerns. Four different PE/FGD ratios are investigated as a parameter. Material characterization is carried out via FTIR (Fourier Transform Infrared Spectroscopy -Thermo Scientific / Nicolet IS50) and DSC (Differantial Scanning Calorimetry- Mettler – Toledo / DSC 1 / 700). Composites are investigated and characterized via shore hardness according to ASTM D2240, Brabender / W50 EHT + Plastograph EC Plus plastogram and FEI / Quanta 450 FEG scanning electron microscope.

METHODOLOGY

Sample Collection

Recycled polyethylene granules were provided by Guangzhou Lushan New Materials Co., Ltd. and used as a binder. Recycled Polyethylene (R-PE) has a melting temperature about 127 °C and 4,987 g/10 min MFR and standard deviation was 0,05. Flue Gas Desulphurization product was provided by İzdemir Enerji Elektrik Üretim A.Ş., Turkey

Preparation of filler

About 60 cm^3 desired amount of PE/FGD mixture were mixed well via counter rotated blender machine for 10 min at 190°C. PE/FGD ratio was selected at 0.2, 0.4, 0.6, and 0.8 respectively. Meanwhile total amount of power was recorded via torquemeter. After mixing the desired ratios, samples were cooled to room temperature and crushed with shredder on 0-1 mm sieve. For shore hardness measurement, crushed samples were flattened by injection molding at 210 °C for 30 sec.

RESULT AND DISCUSSION

Figure 1 shows the FTIR spectra of the recycled polyethylene. The characteristic PE absorbance bands are located around 2918 cm^{-1}, 2845 cm^{-1}, 1465 cm^{-1}, and 718cm^{-1}. Polyethylene is widely used in products such as tapes, litters and soft beverage bottles, food containers and etc.

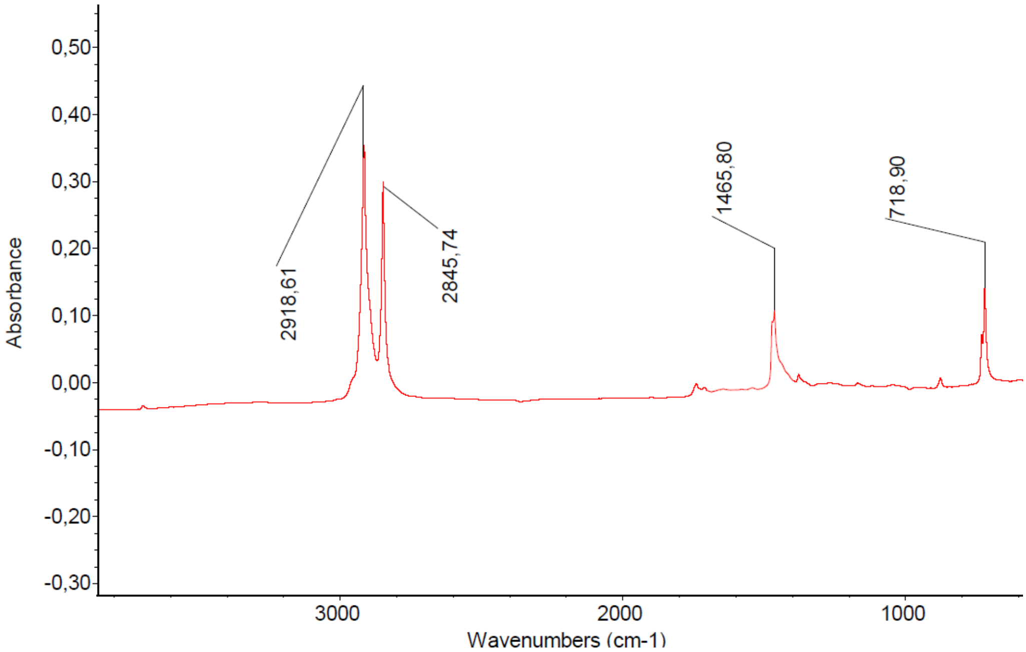

Figure 1. FTIR spectra of Recycled Polyethylene

Figure 2 shows that the DSC thermogram of plastic and supports that FTIR spectrum because endothermic peak and melting temperature. It is clear that melting heat is 92.99 j/g and density of polyethylene is 0.934 g/cm3.

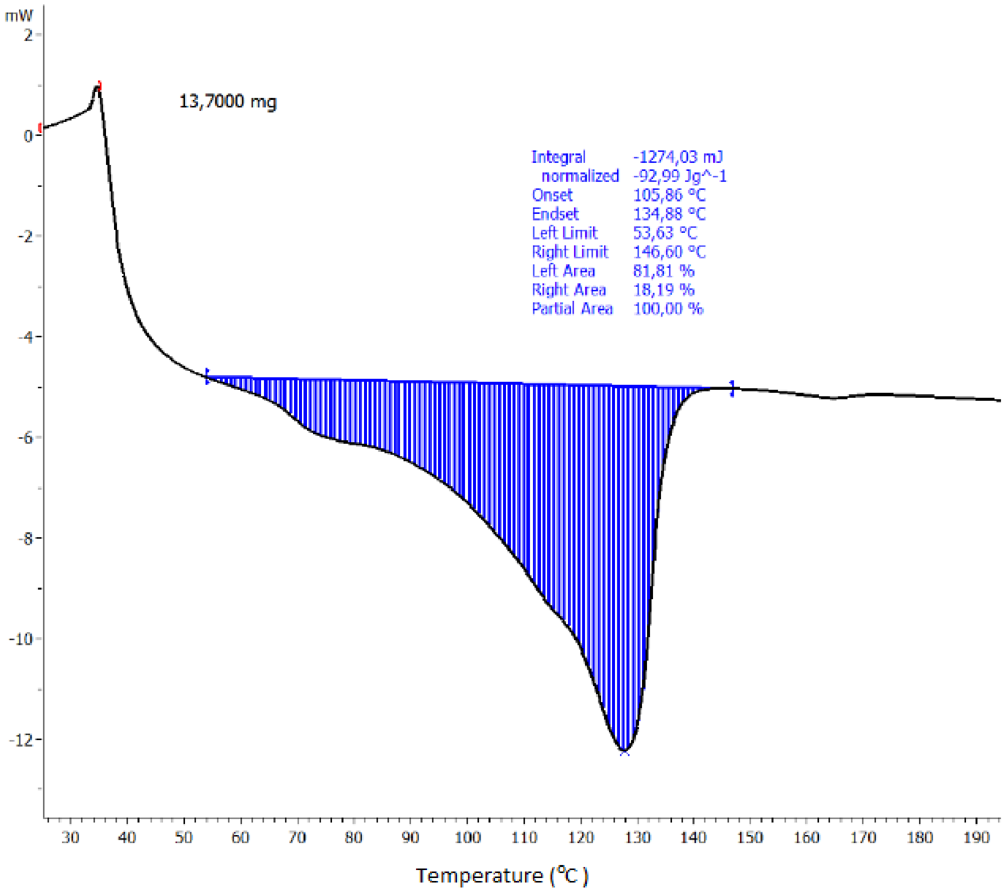

Figure 2. DSC analysis of recycled plastic.

Figure 3 shows that relationship between the torque vs. time curve ("Plastogram") from a mixer test and the estimated residence time of the product in a production extruder. This torque mirrors the resistance of the material opposes to the rotating blades during the mixing process. The torque moves the dynamometer out of its zero position. This path can be measured and visualized as a function of time. The resulting diagram (and rest of all) illustrates the relationship between torque (viscosity) and temperature over the measuring time and also shows that there has no oxidative reaction during the mixing.

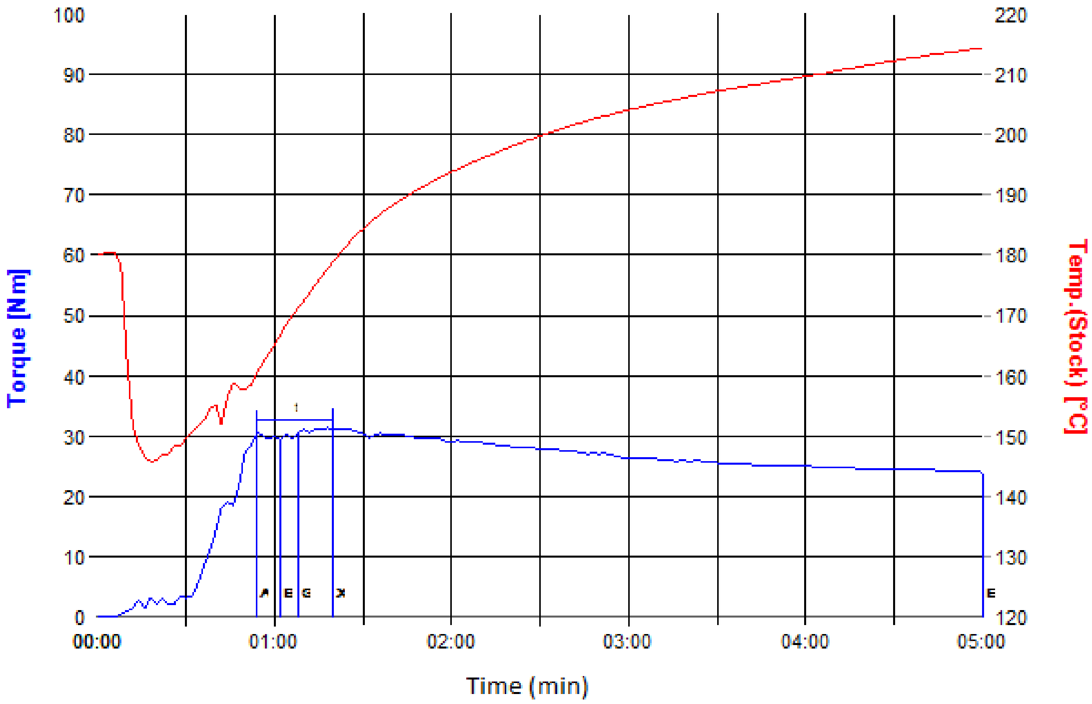

Figure 3. Plastogram of sample

Table 1 shows the Shore D hardness of the composites. A total of 10 measurements were performed for each sample, and average values and standard deviations were calculated. Hardness results show that increasing PE ratio is expected in the composite structure softening.

Table 1. Shore D hardness of composites

PE Ratio	Measured data										Mean	Standard Deviation
0.20	61.1	60.7	60.8	59.8	59.3	62.2	62.3	61.6	58.9	60.4	**60.7**	**1.15**
0.40	56.3	57.6	59.8	55.3	56.3	56.6	57.1	55.5	56.4	56.1	**56.7**	**1.28**
0.60	47.1	48.5	46.4	47.4	49.6	48.6	49.3	49.5	48.6	49.3	**48.4**	**1.11**
0.80	47.8	48.2	48	48.9	49.2	50.1	49.1	48.4	48.8	46.8	**48.5**	**0.91**

Figure 4 shows the morphological analysis and relation between matrix and gypsum. It is clear that PE and FGD are well mixed and surrounded by polymer. Interface of the PE and FGD is smooth and there is no cap between them.

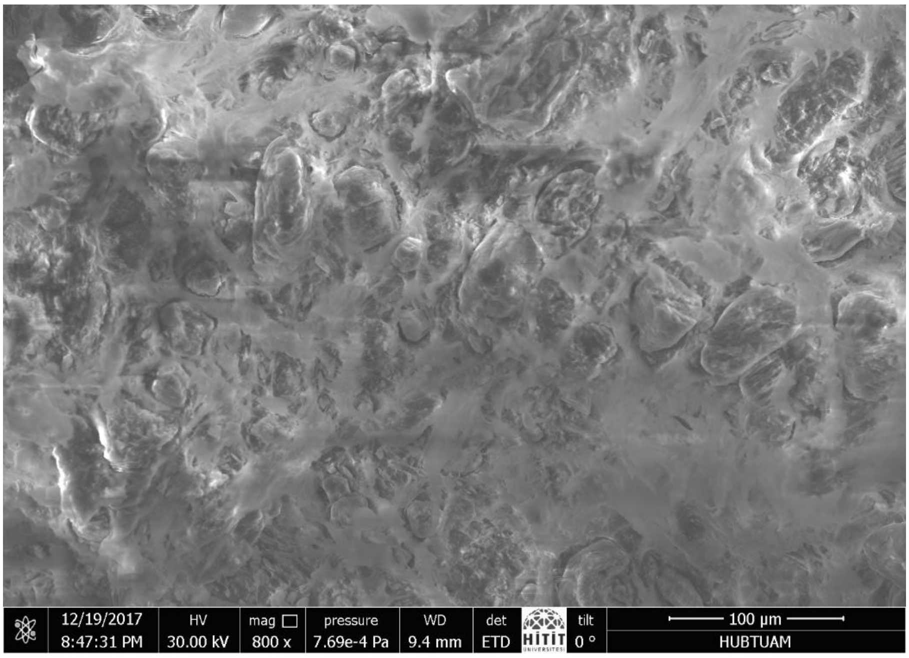

Figure 4: Composite material SEM image

CONCLUSION

This type of composites production commonly come across to some manufacturing problems such as gap between the filler and binder, blockage of the nozzle or hardness of the filler so on. By means of overall results, especially plastograms in this study, show that FGD based composite fillers are applicable for aluminium or metal composite panel. The plastograms demonstrated the compatibility of FGD and PE which reveals that they can be used together in the manufacturing. Hardness of fillers is also another simulated experiment for the manufacturing line to spread up on the sheets. In addition, the morphological analysis of final product reveals that no gap is observed between the interfaces of matrix material. It is refer to well mixed and perfect interface interaction. FGD waste and recycled plastic mixed well and produced composite filler material successfully. By these means, FGD and PE wastes can be alternatively evaluated, economically and ecologically.

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