All Sciences Proceedings

5th International Conference on Applied Engineering and Natural Sciences

July 10-12, 2023 : Konya, Turkey

All Sciences Proceedings
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The Recyclability of Composite Materials

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Abstract – In this study, the recyclability of composite materials created using various methods today, the problems that may be encountered during recycling, advantages and disadvantages were discussed. Information about the general properties of recycled composite materials was obtained and summarized.

Keywords – Composite, Recycling, Material.

I. INTRODUCTION

Composite materials are defined as materials that are formed by the combination of two or more components. Composite materials are divided into 3 main groups as metal, ceramic and polymer based, and these materials have superiors or weaknesses in their classes. The areas of use of composite materials are increasing day by day. Today, it is used in many fields such as maritime, rail systems, wind energy, space and aviation, defense industry, construction, automotive, food and agriculture.

Composite materials provide design engineers with superior quality and long life. Higher strength, lower weight and less maintenance are important when it comes to energy consumption and environmental impact (CO_2 emissions), especially in the transport sector.

In general, according to types of matrix element, composite materials can be classified as polymer-matrix composites (PMC), metal-matrix composites (MMC), and ceramic-matrix composites (CMC). According to the types of reinforcement, composites can be classified as particulate, fiber reinforced, layered and filled composites.

Composite materials are heterogeneously formed materials. Due to its heterogeneity, it's difficult to recycle composite materials. The use of composite materials is increasing day by day [1]. With this increase, the wastes of composite materials used or expired in production sectors are also increasing. In order to prevent these wastes, 3 main recycling methods have been developed in R & D studies [2]. These will be examined in the materials and methods section.

II. MATERIALS AND METHOD

It is considered that the three main recycling groups and the properties of recycled composite materials [3]. In composite recycling methods, amount of energy to be used is ranked from highest to lowest, as shown in table 1 below.

Table 1. Energy ranking of recycling methods [4]

No	Name
1	Chemical recycling (21–91 MJ/kg)
2	Thermal Recycling(5–10 MJ/kg);
3	Mechanical recycling (0.1–4.8 MJ/kg)

The path to be followed by a waste composite material is indicated in Figure 1:

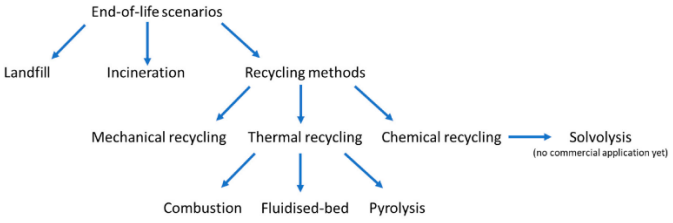

Fig. 1. Processes by which waste composite material can be applied [5]

1. Mechanical Recycling

In this recycling method, the composite material and the fiber inside of material are grinded into small pieces. The milled parts are sorted and separated. The mechanical recycling process can be carried out with parts grinding mill and high voltage pulse shredding machine. These are shown in Figures 2 and 3. There are areas where milled parts obtained after mechanical recycling are used. For example, after glass fiber recycling, it has been observed that the concrete flexural strength is strengthened when the filler of glass fiber is added to concrete [6].

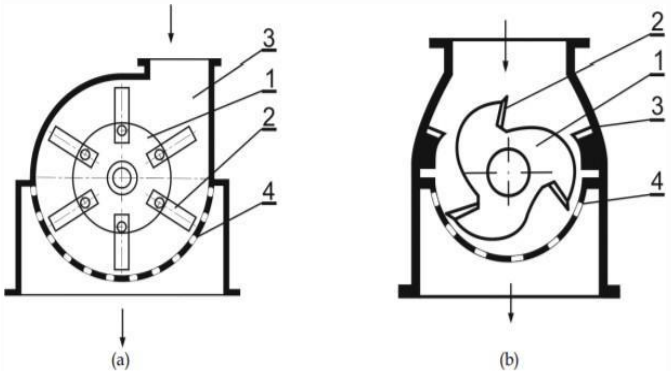

Fig. 2 Grinder mill [7]

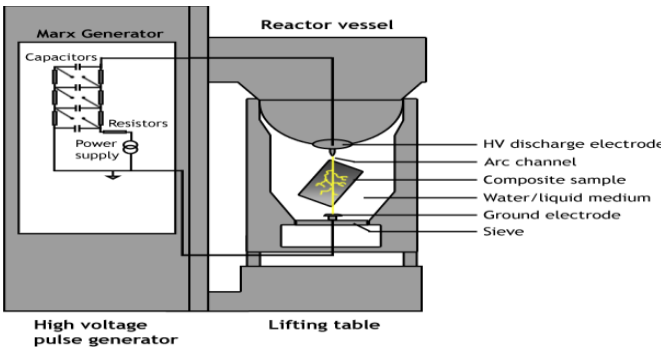

Fig. 3 High voltage pulse shredding machine [5]

2. Thermal Recycling

The purpose of thermal recycling is to separate the fibers from the matrix [4]. In the process of thermal recycling, heat is used to break down the composite. An operating temperature of 450–700 °C or higher is required, as insignificant volatile materials can burn out, leaving valuable fibres behind [4]. Usually the process temperature depends on the type of resin used in scrap plastic. It is noted that an unsuitable temperature can leave coal on the fiber surface or lead to a decrease in the diameter of the recovered fibers [4]. The thermal recycling process can be done in 4 different processes.

2.1. Incineration

Incineration is the process of completely burning a waste. In this process, the steam produced during combustion can be converted back into electrical energy. When processing composites, material content is very important in this process. This is because if the fiber in the composite is not completely broken down, it can lead to health problems [8]. The incineration process can be done in two types of ovens. These are illustrated below in Figure 4 to Figure 5.

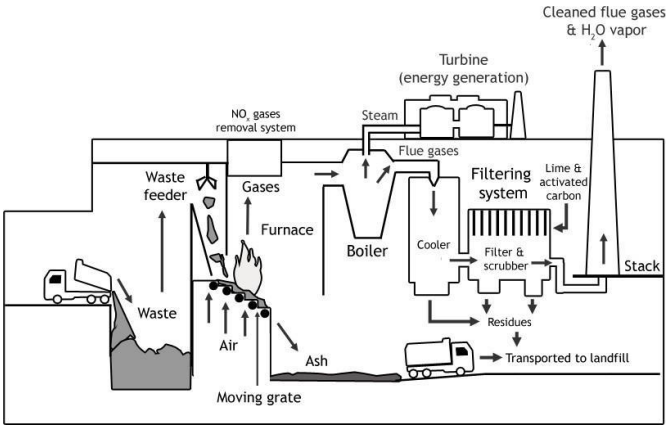

Fig. 4 Movable grill oven [5]

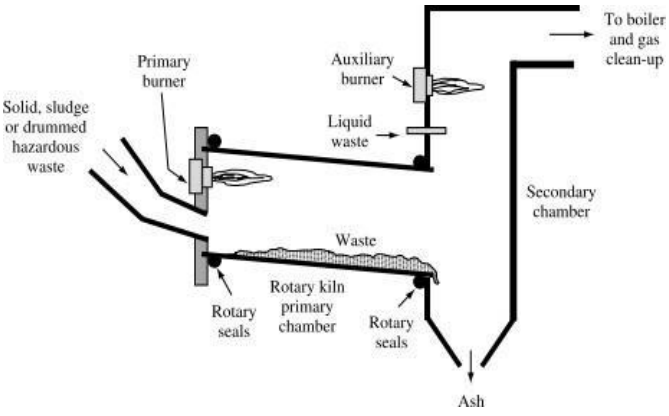

Fig. 5 Rotary oven [5]

2.2. Burn

This process is carried out by a more controlled burning process than the incineration process. In the combustion process carried out by the fluid bed burning process, the thermoset polymer is removed from the fibers by thermal oxidative process and the composite material is recovered by recycling the

fiber reinforcements [5]. Organic resins are used as energy sources and the heat of combustion is recovered by a waste heat recovery system [5]. This method has been deemed suitable for both glass and carbon fibers. However, carbon fiber composites have been used in research because they are more valuable for reuse. The fluid bed combustion process below is illustrated in Figure 6.

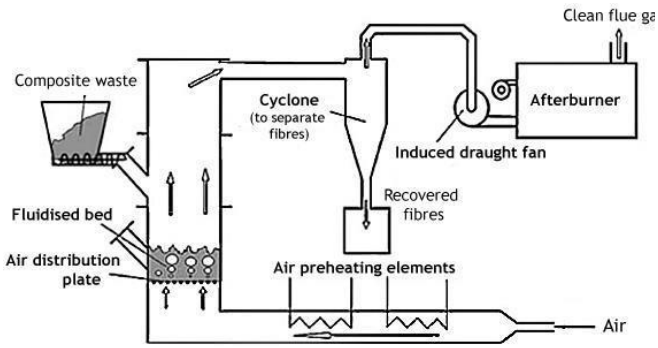

Fig. 6 Fluid bed combustion process [5]

2.3. Co-incineration in a cement kiln

In this process, the recycling of waste was used as a raw material or energy source. It can be used in industries such as cement, steel, glass and power generation. Composite waste is incinerated together with cement in a cement kiln, while the fibers and fillers in the material serve as a raw material for cement [5]. It is a method that can be used for carbon fibers and glass fibers, but since the cost of carbon fibers is high, it has been determined as a more suitable method for glass fibers. The processing furnace together with the cement is given in Figure 7.

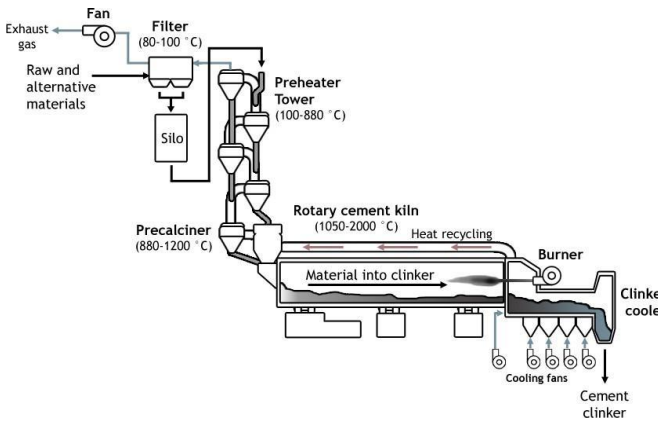

Fig. 7 Co-incineration in a cement kiln [5]

2.4. Prolysis

Prolysis process is the process in which organic substances undergo breakdown in a small amount of oxygenated environment at high temperature. The reason for the low amount of oxygen in prolysis is to minimize the formation of coal . The prolysis process ensures the recovery of fibers and fillers. The resin turns into a gas. This gas can be reused to provide heat to the system. The classical Pyrolysis process is shown in Figure 8.

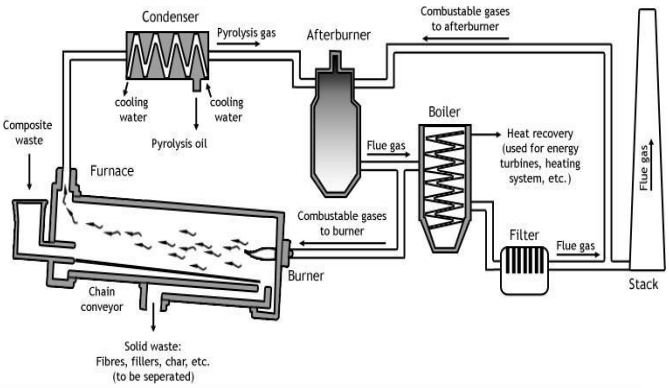

Fig. 8 Classic pyrolysis process [5]

3. Chemical Recycling

Chemical recycling is defined as the process by which polymers are chemically converted into monomers . The chemical recycling process, often referred to as solvolysis, is the chemical depolymerization of the matrix using heated solvent mixtures. In the depolymerization process, the fibers are insoluble and released together with the resins. This method can be used for both carbon and fiberglass. Glass fibers have low commercial value and undergo degradation due to their fragility when exposed to acidic conditions, so this recycling method is more suitable for carbon fibers. To apply chemical recycling to glass fibers, milder solvolysis conditions (such as low temperature, low pressure) are needed to improve. The Solvolysis process is given in Figure 9.

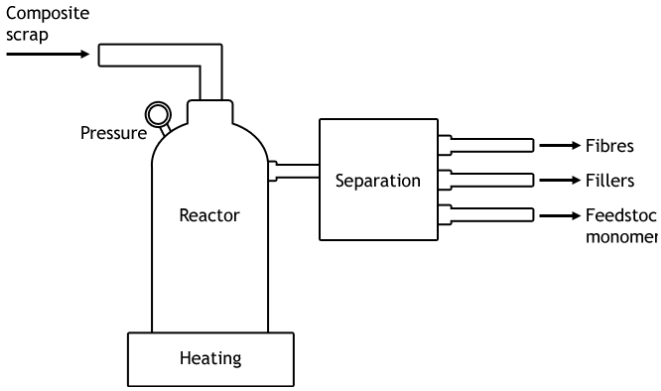

Fig. 9 Solvolysis process [5]

III. RESULTS

Mechanical recycling is recommended, mostly for glass fiber, due to the low recycling values of recycled products. Waste materials burned in the thermal recycling method cannot be recovered. Therefore, it is generally recommended to use fiberglass as it is cheaper, that is recycling of ash is used.

Chemical recycling it is mostly used for carbon fiber composites [5]. Any thermal or chemical treatment strips the fibers of the size, making this type of treatment unsuitable for glass fibers unless post-treated [5].

IV. CONCLUSIONS

In this study, the recycling of composite wastes was investigated. As a result, it has been determined that recycling of composite materials is difficult due to the heterogeneous nature of the composite material and limits these methods. However, despite these, the recycling of compose wastes has been improved from year to year and R & D studies have been continued. In the light of these studies, it has been concluded that the recycling methods of composite wastes will be used more in the future and that they are progressing on an optimistic path in terms of producing efficient methods.

REFERENCES

[1] Yang, Y., Boom, R., Irion, B., Van Heerden, D. J., Kuiper, P., & De Wit, H. (2012). Recycling of composite materials. Chemical Engineering and Processing: Process Intensification, 51, 53-68. velocity impact behavior of composite plates. Journal of Composite Materials, 50(25), 3551-3559..

[2] Pickering, S. J. (2004). Recycling technologies for thermoset composite materials, Adv. Polym. Compos. Struct. Appl. Constr. ACIC, 37(2004), 392-399.

[3] Oliveux, G., Dandy, LO and Leeke, GA (2015). Recycling of fiber-reinforced polymers is available Status: Review of technologies, reuse, and emerging features. Progress in materials science, 72, 61-99.

[4] Krauklis, A. E., Karl, C. W., Gagani, A. I., & Jørgensen, J. K. (2021). Composite material recycling technology—state-of-the-art and sustainable development for the 2020s. Journal of Composites Science, 5(1), 28.

[5] van Oudheusden, A. (2019). Recycling of composite materials.van Oudheusden, A. (2019). Recycling of composite materials.

[6] Pimenta, S. ve Pinho, ST (2011). Recycled carbon fiber reinforced polymers for structural applications: Technology review and market outlook. Waste management, 31 (2), 378-392.

[7] Macko, M. (2012). Size Reduction by Grinding as an Important Stage in Recycling. Post-Consumer Waste Recycling and Optimal Production, 273–294. https://doi.org/10.5772/33969

[8] Hedlund-Åström, A. (2005). Model for end of life treatment of polymer composite materials (Doctoral dissertation, KTH).