Analysis on the Application of Polyamide (PA) materials to Replace Existing Materials in Hair Dryer Housings

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Abstract. This paper demonstrates and explains various properties of Acrylonitrile butadiene styrene (ABS), the material used for the housings of hair dryers, and analyzes the advantages and disadvantages of Flame retardant Polyamide (PA) materials as an alternative replacement of existing materials from the same aspects under current situations where the development of flame retardants and applications is becoming more and more vital. ABS materials cost less during the manufacturing processes, have a longer usage life, and is more environmentally friendly. PA materials have better flame retardancy and temperature resistance. By making addition to PA materials, its properties can be further improved. From the review, it is indicated that it is likely to replace the existing design with the materials that has PA materials as the base, with the addition of glass fiber and graphene, which is proved to have a better performance in terms of heat resistance, flame retardancy, durability, and is UV resistant in the meantime.

Keywords: Polyamide, Acrylonitrile butadiene styrene, Hair Dryer Housings.

1. Introduction

According to a survey of stores in 2007, it is showed that most hair dryers had ceramic heating elements, for instance, ceramic heaters, because of their "instant heat" capability. The working principle of these elements are based on the property of ceramic elements [1]. This means that it takes less time for the dryers to heat up and for the hair to dry. Because of this function of hair dryers, it could be a possible hazard if the hair dryer is not equipped with over-heating protection such as circuit breaker or fuse, which break the circuit when they detect high temperatures [2]. A team has conducted the simple experiment to prove its potential danger. A towel was covering the hair dryer's inlet and outlet, then they turned on the power switch to make the hair dryer work. Only a few seconds later, the electric heating wire began to glow red, With the electric heating wire's temperature rising continuously, the hair dryer's material started to melt. After another 20 seconds, the air outlet position shot open flames [3]. Under daily use situations, when covered with non-ventilated materials, with the electric heating wire continues to heat up, in a short time the internal shell material can reach a temperature as high as 400 degrees, igniting the shell and surrounding combustible materials, starting a fire.

2. Materials Review

2.1. Introduction of the Structure of Hair Dryer Housings

The general structure of a hair dryer consists of an electric heating wire and a fan driven by a general motor. Most hair dryers use a bare, coiled Nichrome wire on a mica insulator as the electrical heating element [4]. With electricity on, the electric wire generates heat, and the fan blows air past the wire, which becomes hot during this process. One hairdryer also has a number of attachments, including a diffuser, an airflow concentrator, and a comb nozzle, where the airflow concentrator serves to make the end of the hairdryer narrower and thus helps to concentrate the heat in one place, allowing the user to dry stuff more quickly. Therefore, the temperature of air passing through the shell will be high. Hair dryers are used to help physiotherapy in laboratories, physiotherapy rooms and industrial production and aesthetics, but they are most used at home for drying and shaping hair.

The main materials used in hair dryer shell today is Acrylonitrile butadiene styrene (ABS). ABS has many favorable properties such as toughness, impact resistance among common polymers. Generally, ABS would have useful characteristics within a temperature range from −20 to 80°C [5]. However, ABS can decompose into its constituents and can be considered hazard to humans [6]. It also shows burning behavior at around 300 degrees Celsius.

Polyamide (PA) as a large portion of engineering plastics is widely used in machinery, electrical appliances, textile equipment, chemical equipment, aviation, and other fields. It has become an indispensable structural material in all walks of life. PA materials do not burn easily. Besides, modified PA materials usually demonstrate a significant improvement in many other aspects. Flame retardant materials are widely used nowadays and play a vital role in preventing or mitigating damage caused by fire and in ensuring public safety. PA, as a plastic with good flame retardancy, will be analyzed in this paper for its potential to replace existing materials in hair dryer shells.

2.2. Property Analysis

2.2.1. Flame retardancy

According to a paper in 2020, a test for PA switching applications on the electrical box cover was conducted. This gives a reference of the flame-retardant PA material's performance under high temperatures. This experiment used a scorching wire to simulate the source of ignition for material testing and screening. The material passed the 960 degrees Celsius wire test, this predicts that it can effectively prevent the electrical control box from having a burn-through when there is a circuit abnormality or an overload that causes heat. The comparative tracking index is 600V, and the flame-retardant level is 5VA at the thickness of 2mm [7]. Thus, indicating good protection of flame-retardant PA materials.

Better flame retardance can also be achieved by adding flame retardants to PA materials, however, common flame retardants tend to decompose at high temperatures, releasing acids that are corrosive to metals. So, for components such as screws, washers, hard Chrome plating treatment is required. Similarly, ABS material can perform better at flame retardance by adding retardants.

Mainstream flame-retardant materials are divided into two categories, organic and inorganic materials. Other than these, bio-based flame retardants possess a significant advantage over inorganic and chemicals, there are not many information or reports on this [8]. Organic materials take a larger share in the market, including magnesium hydroxide flame retardant materials, aluminum hydroxide flame retardant materials, halogen flame retardant materials, phosphorus flame retardant materials etc. Organic flame-retardant materials often produce toxic and harmful gases when burned. This can cause breathing difficulties.

On the contrary, inorganic flame-retardant materials such as silicon dioxide flame retardant materials have a good flame-retardant effect and can stop smoke emission at high temperatures. It also has the advantage of being non-toxic, non-corrosive, adequate raw materials and cheap.

New inexpensive, smokeless during combustion, non-toxic and no harmful gas generation, good flame-retardant properties of flame retardants to become the focus of research is the future development trend [9]. Currently PA materials show a better performance on the flame-retardant property, it is possible that ABS can be improved in this aspect with newly developed flame retardants.

2.2.2. Temperature resistance

The mechanical properties of ABS materials are strongly influenced by temperature [10]. Generally, ABS materials would have useful characteristics within a temperature range from -20 to 80 degrees Celsius. ABS has an HDT of around 90 degrees Celsius. By changing the proportions of its components, ABS can be prepared in different grades, and its HDT can be increased to 110 degrees Celsius. This is one of the three ways of improving HDT, which are fiber reinforcement, blending or increasing crystallinity [11]. PA materials have an HDT of around 110 degrees Celsius. The operating temperature of PA materials can be improved if 30 percent of glass fiber is added.

Heat deflection temperature (HDT) is a parameter expressing the relationship between heat and deformation of the object being measured. It is the temperature of the specimen of plastics and other polymers in a liquid heat transfer media, under a certain load and a certain isothermal heating condition, when pressed by a pressure needle of 1 mm^2 for 1mm deep. Though this is not a direct indicator showing the useful temperature of the materials, by comparing the values of both materials, it can be concluded that PA materials do better than ABS materials under high temperatures.

2.2.3. Material cost

Generally, PA materials have a higher price than ABS materials. Nevertheless, for ABS at higher grades, the prices can be higher than the average. For same HDT, ABS is more expensive.

2.2.4. Processing conditions

ABS is one among many different types of thermoplastics with injection-molded components being easy to manufacture for single-use, normally for biomedical applications.

Both ABS and PA have great water absorption and should be dried before processing to ensure the dimensional stability of the products [12].

Nevertheless, there are specific procedures that need to be done under certain cases. If flame retardants are added in PA materials, then in the processing process, it needs to be controlled that the barrel temperature cannot be too high, and the injection speed cannot be too fast, in order to avoid the decomposition of the high temperature of the material and mechanical properties decline caused by product discoloration. If glass fibers are added in PA materials, the performance of PA is significantly improved, at the same time, its fluidity becomes worse. So, the injection pressure and injection speed should be increased accordingly on the basis of keeping the process the same as before the enhancement of the material. The mold temperature should be increased properly as well. In addition, when graphene or glass fiber are added, they generate wear on the components of the injection molding machine because of its self-lubricity.

2.2.5. Service Life

According to the crystallization index, ABS materials have smaller numbers than PA materials. This suggests that PA materials used in hair dryer shells are more durable. On the other aspect, ABS is UV-protective, while PA material itself is not UV-protective, it appears to be vulnerable ultraviolet ray, under prolong or intensive UV exposure, discolorations and photodegrades can even occur, requiring the addition of UV-resistant agents, for example graphene. As a result, ABS is more suitable as household appliance materials that may be exposed to UV light during use, in other words, the advantage of ABS materials used in hair dryer shells is that there is a higher aesthetic appeal.

2.2.6. Environment impact

It is expected that the materials used are environmentally friendly, recyclable, biodegradable or renewable. However, one commonality of plastics is that they are difficult to degrade. ABS material, among all, is a kind of environmentally friendly, green materials, because they can be recycled for secondary use. Through environmentally friendly recycling it will not cause damage to the environment. The previously mentioned flame-retardant PA material, as thermoplastic material, is recyclable and meets green design principle. But there is more to do than realizing whether the materials are recyclable. People need to take actions.

Fortunately, after the outbreak of pandemic in 2019, which is more known as covid-19 now, the inefficiency of plastic system has been noticed [13]. With an accurate understanding of the current situation, there is a corresponding increase in awareness and involvement of society in environmental protection. It is a trend that the recycling of plastics will be taken more seriously.

2.2.7. Current applications

Because of ABS's ability to be injection molded and its light weight, it is useful in manufacturing products such as pipe systems, musical instruments, automotive trim components, enclosures for electrical and electronic assemblies, pen housings, and toys like LEGO. Of which household goods

comprise the majority of applications of ABS. ABS is now the most commonly used plastic in the world, accounts for approximately 41% of the demand worldwide.

Due to PA materials' high durability and high strength, they are commonly used in kitchen utensils, carpets, automotive industry, and sportswear. The transportation manufacturing industry is the prime consumer, counting or more than one third of PA consumptions [14].

3. Conclusion

This paper lists and reviews the current situation of the hair dryer housing's materials, as well as key indicators of PA and ABS materials and several application conditions that need to be met in the real case of hair dryer shells. The current main materials are ABS materials. ABS materials are more environmentally friendly, low cost and have good UV resistance, thus implying ABS based hair dryer shells have a longer serving life, cost less when manufactured, and cause less harm to the environment. However, PA materials have more reliable values at flame retardancy and temperature resistance, which represents that PA based hair dryer shells perform better at high temperatures. The two materials have similar shrinkage factors, making it convenient to replace ABS materials with PA materials. As people become more safety conscious, from the current situation, the continued research on flame retardant materials is a future development trend, and new effective flame retardants will be invented that are more suitable to be combined in the hair dryer structure to reduce the risk of fire and ensure human safety. This paper should provide some certain reference value for future decision on the replacement of materials used on hair dryer shells.

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