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Applications and Prospects of 3D Printing in the Packaging Industry

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***Abstract*— In this paper four 3D printing technologies fused deposition modeling (FDM), selective laser sintering (SLS), stereo lithography appearance (SLA), and laminated object manufacturing (LOM) were examined for their characteristics its applications. Technology for 3D printing Since the 1980s, when the field of applications first began to take off, rapid advancement has been made. Materials for 3D printing have been introduced. In order to build items with a variety of shape, size, rigidity, and color, it entails layering materials such as plastics, composites, or biomaterials. Another innovation was the use of 3D printing in the engineering of packaging. It has been noted that the benefits of 3D printing technology in the packaging business are unmatched by other comparable packaging production technologies, and that 3D printing technology has a very broad range of competitive advantage through innovation in the future packaging industry. The development of 3D printing raw material technology determines the development of 3D printing technology Development boundary. It has high requirements on the purity, sphericity, particle size distribution, bulk density, oxygen content, fluidity and other properties of metal powder materials.*

I. INTRODUCTION

In contrast to the conventional subtractive manufacturing process, 3D printing uses layered manufacturing, which involves molding the part one layer at a time. a more conventional manufacturing process, and 3D printing It offers the benefits of cost savings and the ability to mold products with any complex shape. In theory, the warp is flexible. Mechanisms for 3D printing allow for sampling of designed models [1,5]. Technology for 3D printing Since the 1980s, there has been a lot of development, and the area of application has been growing. Containers, materials, and auxiliary materials used to protect products, make storage and transportation easier, and encourage sales while in circulation are collectively referred to as being packaged [2]. Technical measures are also used to accomplish the aforementioned goals. The use of 3D printing technology in the Chinese packaging industry has only recently begun, but there is still a lot of room for research because it can speed up packaging, cut down on material loss, and reduce the cost and time of molding.[3] The author summarizes the methods of 3D printing technology and the types of materials at home and abroad, so that readers can better understand the research status of 3D printing technology and materials at home and abroad and their application and prospect in packaging industry.

Printing technology

Currently commonly used 3D printing technology: 1 extrusion molding: melt deposition molding (FDM) technology; 2 granular materials forming: selective laser sintering (SLS) technology; 3 photopolymerization molding: light curing stereo molding (SLA) technology; 4 laminated type: layered solid manufacturing (LOM) technology. The main difference between these 3D printing technologies lies in the type, price, speed and color diversity of printing materials.

Fig 1: 3D Printing Technology

1.1 FDM technology

The fundamental principle FDM technology is to slightly heat the extrusion head above the material's melting point. Melt the polymer under the nozzle's guidance, layer by layer, and then use the computer to control the polymer's heat accumulation to complete the molding. The technology has the benefits of being easy to use and maintain, affordable overall, quick, low-pollution, and made of recyclable materials. O. S. Carneiro et al. used polypropylene as 3D printing raw material, used melt deposition molding technology to print materials, and discussed the factors affecting the molding properties of materials. M. Domingo espin et al. used FDM technology to build models with polycarbonate as raw materials, and designed and manufactured models for physical test performance in different directions. Ning f et al [4]. showed the construction of FDM thermoplastic carbon fiber reinforced plastics and tested the reinforcement of the mechanical properties of the model constructed by FDM method by adding carbon fibers with different lengths.

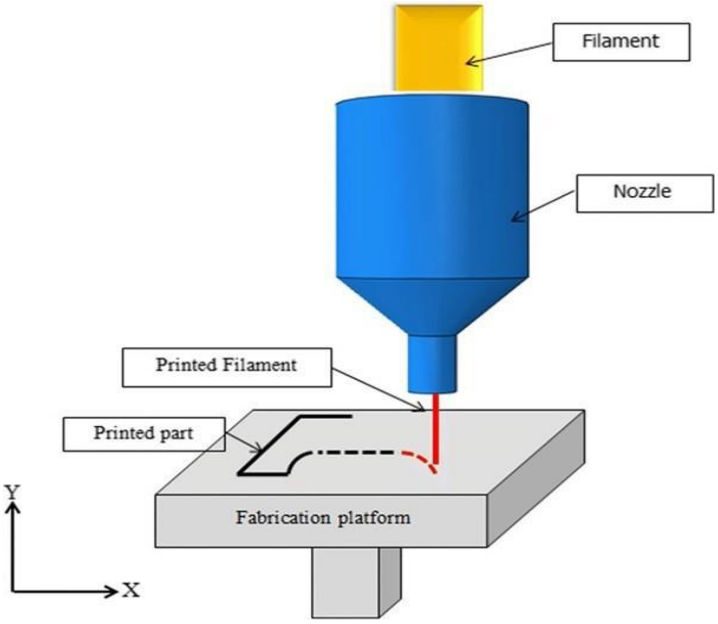

Fig.2: FDM Technology Process

1.2

1.3 SLS technology

SLS technology uses a high-power carbon laser that is controlled by software to sinter solid particle powder material that has already been laid out [3]. The sintered part is then solidified and formed during processing to form a layer of the part. Instead of using additional supporting materials, the non-sintered material is used as the supporting material and then superimposed to the entire model for molding [10]. After removing the unreacted powder, post-treatment is carried out to produce fine parts.

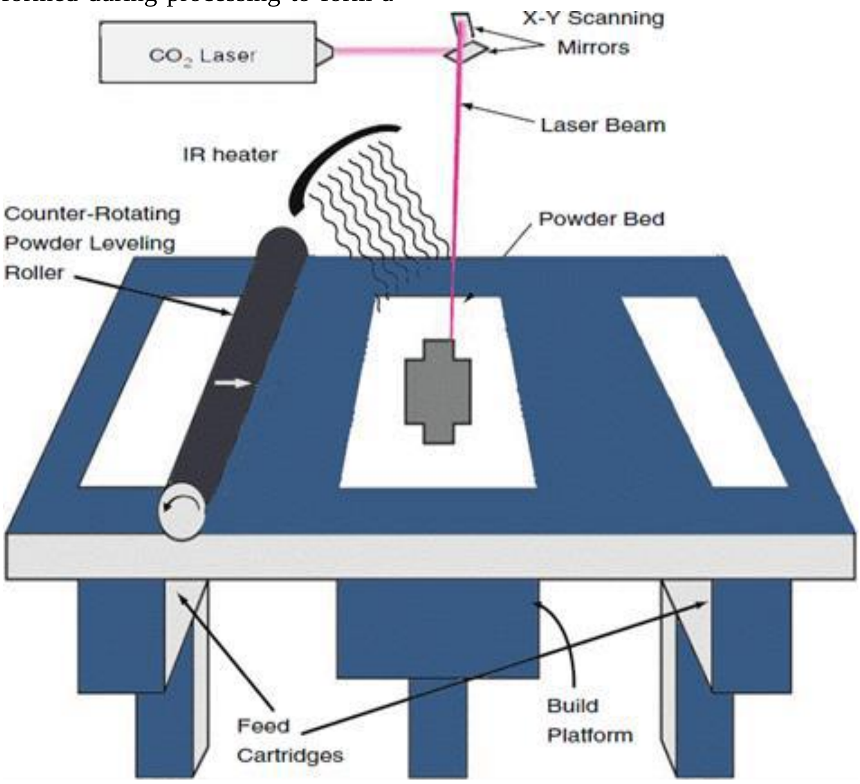

Fig: 3 SLS Technology process

This technology is characterized by good precision and high strength of finished products [5]. The main advantage lies in the production of finished metal products. SLS technology can produce high-strength nylon plastic parts directly used for equipment parts and strong and tough carbon fiber composite plastic resin parts instead of metal tools. Lu Zhongliang et al [6]. found that the densification of AISI316L products formed by SLS can be improved by using isotactic pressing technology and liquid-phase sintering of trace Si. Shi Yusheng et al. the polypropylene powder material prepared by cryogenic crushing method has excellent sintering performance and the SLS formed parts prepared by it have high mechanical properties and dimensional accuracy.

1.4 SLA technology

of all of the other the rapid prototyping technologies, SLA technology has the longest history, the most extensive research, and the greatest adoption. In order to finish the graphics of the single-layer material and stack it layer by layer to the entire sample, the UV laser is focused on the surface of the liquid photosensitive resin layer to cause it to solidify quickly from point to surface [7]. Immerse the formed component in the prepared chemical solution, wash off any extra resin, and then finish the product's additional curing under ultraviolet light in the oven.

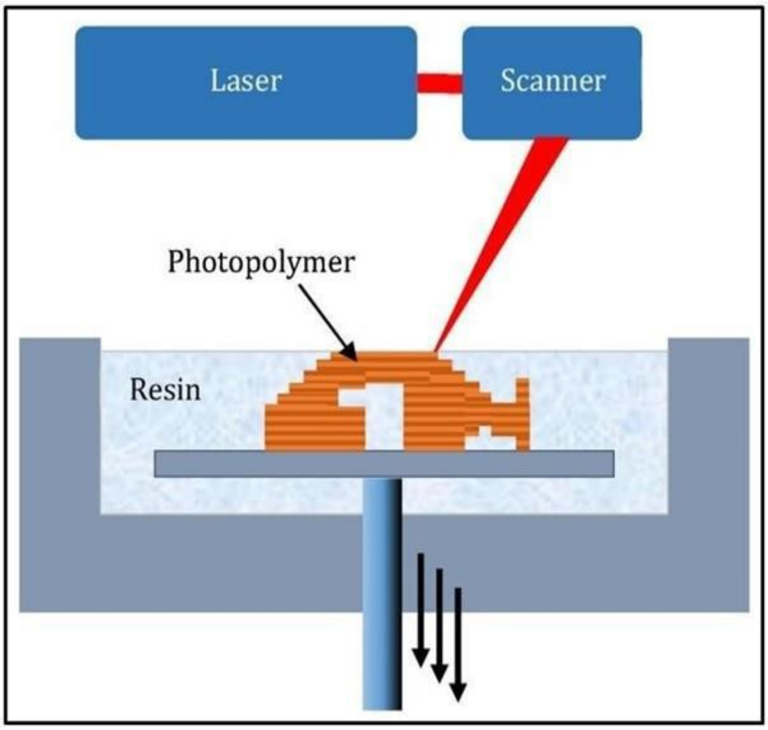

Fig 4: SLA Technology

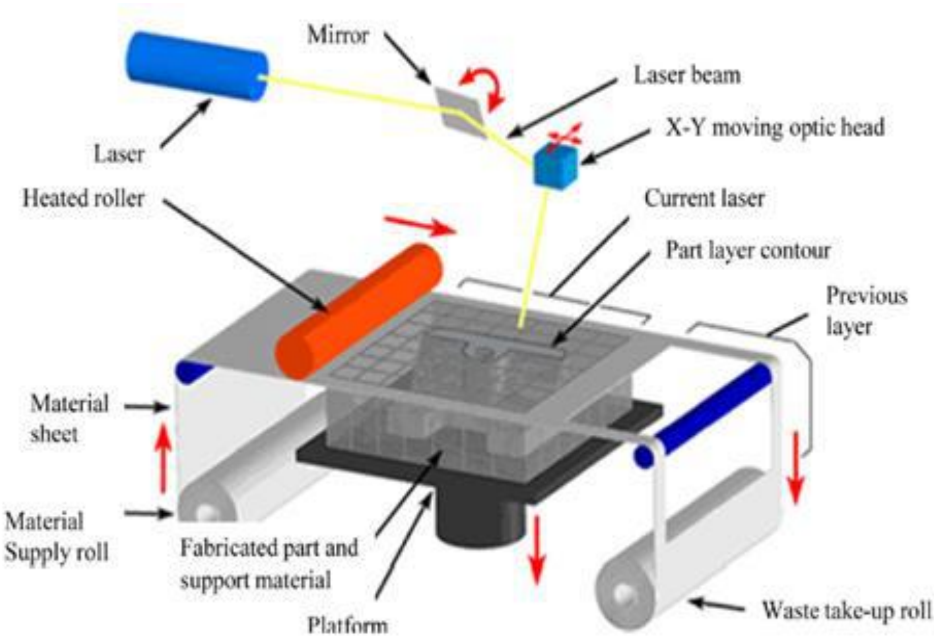

Fig:5 A typical type of LOM process

The benefits of SLA technology include a nearly 100% raw material utilization rate, high dimensional accuracy, excellent surface quality, quick forming speeds, and a high level of automation. It can create models with extremely intricate structures. Despite the fact that it requires post-processing, it is currently the technology with the highest machining accuracy. According to Xi Jun et al [8]. stereo molding technology that uses light curing to project a series of mask images onto a resin surface has a quick molding time and is inexpensive. SLA has a wide range of potential applications because it can use various types of raw materials.

1.5 LOM technology

LOM technology takes solid sheet as raw material and precuts laser cutting hot pressing roller for the thin material heated first and coated with hot melt adhesive on the back in advance, after cutting the internal and external contour of a layer of material, stack a layer of new paper sent by the feeding mechanism, and the cut layers are bonded together by the bonding device. Repeat this to prepare the sample. The combination between each layer of metal plates is usually realized by welding and bolt connection. LOM technology has the advantages of reliable operation, good model support, low cost and high efficiency. Zhong, H et al [9]. found that LOM is suitable for the manufacturing of silicon carbide products, especially the small batch manufacturing of ceramic parts with complex shapes.

II. PRINTING MATERIALS

The materials used in 3D printing typically come in the forms of powder, filament, flake, and liquid Shape, among others. The main market in China today is still comprised of imported raw materials, and the price is high [10]. Alternatively, the development of 3D printing raw material technology establishes the development boundary for 3D printing technology.

2.1 Polymer composites

Wendel B, et al [11]. invented a 3D printing aromatic polyester material and its preparation method. The method adopts aromatic polyester, thermoplastic elastomer, etc. for blending modification to improve the impact resistance of the material. Shi Yusheng et al [12]. prepared polymer composites for SLS 3D printing, and prepared composites by adding micro / nano fillers or post-treatment infiltration to improve some properties of SLS formed parts. Guo Yanling et al. proposed the preparation method of stone plastic composite powder for laser sintering 3D manufacturing technology, using powdered nylon 12 and limestone as raw materials to solve the existing problems of materials for laser sintering. Arevo laboratory in Silicon Valley, USA, 3D printed high-strength carbon fiber reinforced composites that can strictly set their comprehensive properties, and optimized specific electrical, mechanical and thermal properties by accurately controlling the orientation of carbon fibers during printing.

2.2 Photosensitive resin

The liquid photosensitive resin composed of polymer monomer and prepolymer added with UV initiator can react and complete curing immediately under UV light to make high-temperature resistant, high-strength and waterproof materials. Du Yulei, et al [13]. synthesized a series of prepolymers acrylic acid as main raw materials, and used the synthesized products as photosensitive prepolymers to make 3D printing light curing resin with low volume shrinkage. Du Yulei, et al. invented a photosensitive resin modified by 3D printed polystyrene microspheres with fast molding speed, high mechanical strength and good dimensional stability. Min Qinqin, et al [2]. reported a preparation method of 3dpsl-1 photosensitive resin applied to 3D printing stereo lithography rapid prototyping. The results show that the resin has moderate viscosity, good photosensitivity, small volume shrinkage of cured product, and good mechanical and thermal properties.

2.3 Green and environmentally friendly materials

a) Materials containing vegetable fibers

Liu Kewu proposed a preparation method of plant fiber composites, which takes filamentous plants such as bamboo, coconut or sugarcane as raw materials. The finished products prepared by using the composites have the characteristics of high bending strength, light weight, not easy to thermal deformation and small thermal shrinkage. Liu Kewu et al [14]. proposed the preparation method of rice husk hot melt adhesive composite powder for SLS. Taking rice husk powder as the main raw material, there is no need to modify rice husk powder in the preparation process, which simplifies the process and reduces the production cost while ensuring various properties of the composite. Cheng Lingyu, et al [10]. prepared PVC / distiller's grains wood plastic composites by hot pressing technology, and effectively improved the mechanical properties of wood plastic composites by adding calcium zinc composite heat stabilizer and maleic anhydride. Cheng Lingyu, et al. prepared a 3D printed wood plastic composite with natural plant fibers, which has the appearance of wood products and the processing characteristics of wood plastic materials.

b) Polylactic acid materials

Lactic acid serves as the primary raw material in the polymerization of polylactic acid (PLA), which is an eco-friendly polymer. Texture feature extraction, good clarity, good biocompatibility, good high thermal stability, good solvent resistance, and a variety of processing options are all benefits of PLA. The stability of PLA is higher, it does not easily warp, and it has a low shrinkage ratio. Several different renewable sources, primarily corn and cassava, are used to produce raw materials. By using the melt blending method, Serra T, et al [15]. prepared general injection grade PLA materials. It was discovered that a synergistic toughening agent had a better toughening effect on PLA than a single toughening agent. Tang Yiwen et al [16]. found that inorganic toughening agent can improve the toughness and rigidity of PLA at the same time. Tang Yiwen et al. proposed a preparation method of 3D printing modified PLA material. The modified PLA was prepared by low-temperature crushing and mixing method, which greatly improved its thermal deformation temperature, toughness and impact strength.

2.4 Metal materials

Metal is typically a very expensive raw material for 3D printing technology. Purity, sphericity, particle size distribution, bulk density, oxygen content, fluidity, and other properties of metal powder materials must meet strict requirements for 3D printing. Due to its affordable price and resistance to chemical corrosion, stain-less steel is widely used. It is a type of expensive metal powder material that is frequently used in 3D printing with metal. Its design is strong and suitable for printing large-sized items.

Cheng Lingyu et al [10]. studied the microstructure and mechanical properties of laser selective melting formed stainless steel and nano hydroxyapatite (NHA) composites. It was found that when the content of NHA was 5%, the density and tensile strength of the materials were similar to those of pure stainless steel. Cheng Lingyu et al. densified the aerosol 316L austenitic stainless-steel powder by hot isostatic pressing. Its density is close to the theoretical full density, with high tensile strength, yield strength, hardness and excellent elongation.

2.5 Ceramic materials

A specific binder powder is combined with ceramic powder to create the ceramic powder used in 3D printing. The performance of ceramic powder is transformed by adhesive bonding, making it comparable to the performance when only metal powder is used. Ceramic products can be 3D printed using aluminum silicate ceramic powder. The products are non-toxic, recyclable, and have good airtightness and high temperature resistance.

In order to create AlN ceramics with a relative density greater than 98% using spark plasma sintering technology in an N2 atmosphere [17]. used AlN powder as the raw material, tin powder as the regulator, and rare earth metal sintering additives. It has reduced electrical properties and a dense sintering. Zirconia ceramic parts were produced using laser selective sintering/cold isostatic pressing composite forming technology by Shi Yusheng et al. They proposed a near net forming process method for zirconia parts, which has a great deal of potential for producing ceramic parts with complex shapes and high performance, despite the fact that the density and hardness of the final sintered parts still needs to be improved.

III. APPLICATION OF 3D PRINTING IN THE PACKAGING INDUSTRY

3.1 Application in packaging container molding

The advancement of human society and the development of packaging containers are closely related. It has now evolved into a product that combines function and aesthetics and is a significant component of commodities [18]. There are many different types of packaging containers, and because different materials are used, their properties also vary. Molds must frequently be made before parts can be molded in the traditional packaging container process, which is laborious, time-consuming, and difficult to modify. Through 3D software, 3D printing technology simulates physical reality and allows for easy modification. At the same time, it increases technology's accuracy while reducing costs and using less raw materials.

Direct molding and indirect molding are both possible with 3D printing molding technology. After treatment, the 3D-printed sample can serve as the master mold, and the polyimide compound can be added to the vacuum pouring machine to replicate a specific batch of parts and containers. Due to this, the technology of 3D printing has numerous potential applications in the process of molding packaging containers. Straw can be used to create 3D printing materials thanks to a new technology created by Zhao Chenfei and colleagues. Products printed with this material have a woodsy feel to them. The printing of packaging boxes and other items using this material increases packaging efficiency, lowers costs, and creates new development opportunities for the packaging sector's future growth. Zhao Chenfei proposed a technique to produce exquisitely printed cartons by printing raw materials like plant fibers using 3D printing technology [19]. The utility model addresses the issues of the existing packaging carton's extended production cycle, significant material waste, and environmental pollution.

3.2 Application in the manufacture of packaging materials

Nowadays, there are many kinds of packaging materials, including paper, plastic, metal, ceramic, biodegradable and so on. We mainly discuss the following.

a) Polymer composites

A method for preparing polypropylene and polyethylene composite consumables for 3D printing was recommended by Xie Jinneng et al. The items printed using the consumables don't absorb moisture or water. The products are also simple to color and have a good surface gloss. With basic hemihydrate calcium sulfate and polyvinyl alcohol, Liu Kew created a composite powder material suitable for industrial 3D printing.A method for preparing soft, elastic 3D printing rubber consumables was suggested by Xie Jinneng et al. The three-dimensional model that was printed has excellent dimensional stability, viscosity, and very little shrinkage [20]. A 3D printing-based preparation method for new acrylonitrile butadiene styrene plastic (ABS) was created by Xie Jinneng et al and colleagues. After polymerization, the preparation technique uses a continuous bulk method to produce ABS resin.

b) Green and environmentally friendly materials.

A 3D printing material preparation technique based on edible wax was proposed by Wang Hong [21]. After the mixture has been heated, stirred, reacted, thoroughly dispersed, and cooled, it is crushed and ready to be utilized for wire extrusion. Wax wire that has been extruded can be used right away in 3D printing. A method for preparing the materials for wood 3D printing was suggested by Xie Jinneng et al [20]. The consumables are used to create molded parts that have been well-optimized physical and chemical qualities throughout and a texture that is similar to that of real wood. By using a two-step process, Huang Xuhui et al [22]. created a modified PLA material for 3D printers that addresses the offset and poor effect issues brought on by the direct addition of a tiny molecular crosslinking agent.

c) Metallic materials

The Extrude Hone firm in the United States uses an ultraviolet light-curing process to cure metal pieces using metal and resin adhesive powder materials. Its benefit is that a variety of metal powder materials are available for application [23]. The Pro Metal Company of the United States sinters the created sample and produces metal components directly using the technique of spraying adhesive into metal alloy powder and bonding layer by layer.

IV. CONCLUSION

The use of 3D printing technology significantly accelerates and streamlines packaging. certain procedure Enhance the packaging industry's structure to a certain level and encourage multi polarization in the sector. Additionally, it reduces the need for raw materials, makes recycling easier, and supports environmental preservation and sustainable development. This lessens the workload of the environmental protection division and increases the efficiency with which resources and energy are used.

The preparation of packaging materials, the molding of packaging containers, and the entire packaging business all benefit greatly from 3D printing technology. As 3D printing technology advances and becomes more sophisticated, it is paired with cutting-edge packaging materials and containers to create products that are more energy-efficient and environmentally beneficial. Other comparable packaging manufacturing processes cannot compare to the benefits of adopting 3D printing technology. In the future packaging sector, 3D printing technology has a very broad range of potential applications.

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