Analysis and prospect of 3D printing technology research status

Jiacheng Ye *

The Gunston School, Centreville MD, 21617, America

* Corresponding Author Email: jye23@gunston.org

Abstract. The earliest idea of 3D printing can be traced back to the late nineteenth century, and now after nearly two hundred years of development, 3D printing has played an irreplaceable role in various fields. This article introduces several common printing methods, such as Fused Deposition Modeling, light curing, and powder molding, and demonstrates the application of 3D printing in some fields.

Keywords: 3D printing; fused deposition modeling; light curing; Stereo lithography appearance.

1. Introduction

3D printing is actually a common additive manufacturing name, which is different from traditional subtractive manufacturing. Instead of removing excess material by cutting, it builds the item layer by layer. Traditional subtractive manufacturing requires various processing methods when reprocessing complex shapes or parts, which is time-consuming and labor- intensive. First of all, different subtractive manufacturing production methods generate a lot of waste, in addition to this, much dust and fumes will be generated during the manufacturing process, which can be harmful to technicians. Secondly, subtractive manufacturing cannot achieve the freedom of 3D printing. A part may need to be operated multiple times, using different machines, disassembled into multiple small parts for manufacturing, and finally assembled. So if we use subtractive manufacturing to make some parts with very complex structures, it may generate a lot of waste and pollution.3D printing, which belongs to additive manufacturing, can realize complex shapes in a short time and simple materials. More importantly, it does not generate unnecessary waste and pollution. It uses as many materials as needed. In recent years, 3D printing has gradually entered people's lives and has developed rapidly in countries such as China, the United States, and Germany. At present, various technologies of 3D printing have been gradually improved, improving people's lives in many aspects and fields. Played major roles in medicine, archaeology, architecture, and aerospace, among others [1].

This article summarizes the origin of 3D printing, the principles of different types of 3D printing machinery, and the application of 3D printing in different fields. It analyzes the advantages and disadvantages of existing technologies and future development trends.

2. The origin of 3D printing

The original idea of 3D printing can be traced back to 1859 when a French sculptor named François Willème first devised a multi-angle imaging method to obtain three-dimensional images of objects [2]. He surrounded 24 cameras in a 360-degree circle to shoot simultaneously, then used a scale plotter connected to a cutting machine to draw the model's outline [3]. This is the originator of today's 3D scanning technology. Then in 1894, another Frenchman, Joseph Blanther, first proposed the idea of using the lamination method to make topographic maps. He invented the method of laminating wax plates into contour topographic maps. By imprinting topographical contours on a series of wax plates, then cutting the wax plates, and finally stacking them all, this is actually the basic principle of additive manufacturing [4]. Nearly a hundred years later, in 1980, American Carl Robert Deckard first proposed SLS (Selective laser sintering) and then applied for a patent. Later, in 1984, American Charles W. Hull invented SLA (Stereo Lithography Appearance), which works by using light to catalyze photosensitive resin and then molding. Four years later, another American, Scott Crump,

invented FDM (Fused Deposition Modeling). Its working principle is to use high temperatures to melt the material and then spray it out to re-solidify it.

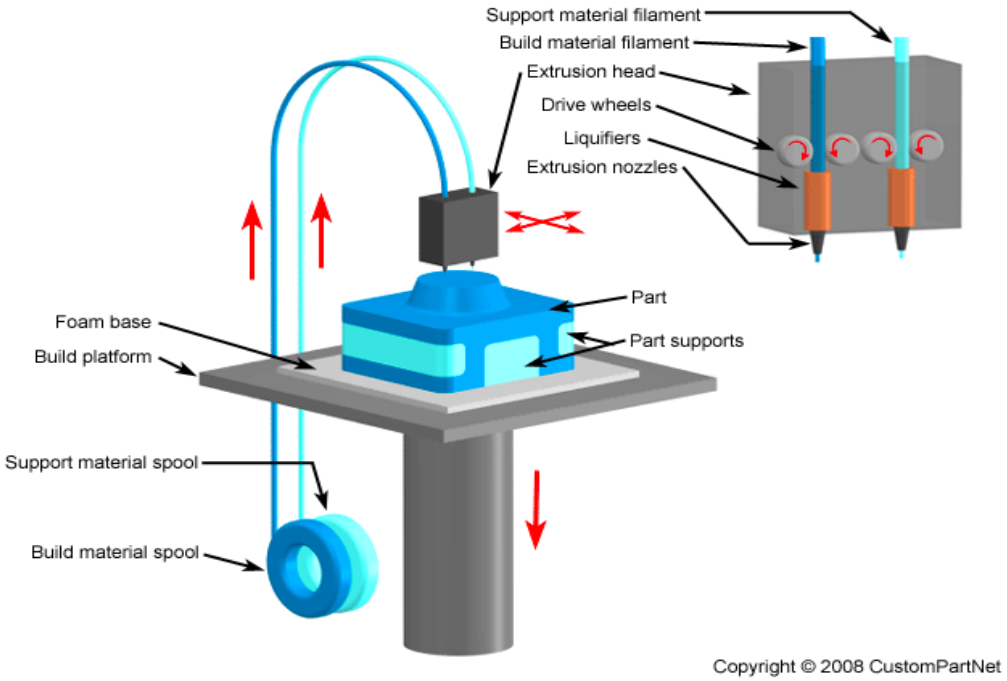


Figure 1. FDM structure.

3. The principle of 3d printing

3.1. Fused Deposition Modeling (FDM)

As the name implies, FDM is a manufacturing method of stacking melted materials layer by layer. The equipment heats and melts the filamentous raw materials and prints the materials on the platform through the nozzle [5]. After cooling, a layer of the cross-section is formed. Repeat this process until the entire entity is formed. This is one of the most commonly used printing methods for all of us. The molding method is point molding. The materials that can be used by FDM are PLA (Polylactic Acid), ABS (Acrylonitrile Butadiene Styrene), and PETG (Ploy). These materials need moisture-proof storage [6]. The advantage of this method is that the overall equipment and raw materials are relatively cheap, the operation is simple and the service life is long without causing additional pollution. But the shortcomings are also more obvious, such as slower printing speed, lower accuracy, and louder noise during work. The objects printed by FDM are stronger, and there are fine lines on the surface. After removing the support, it can be used after a little polishing.

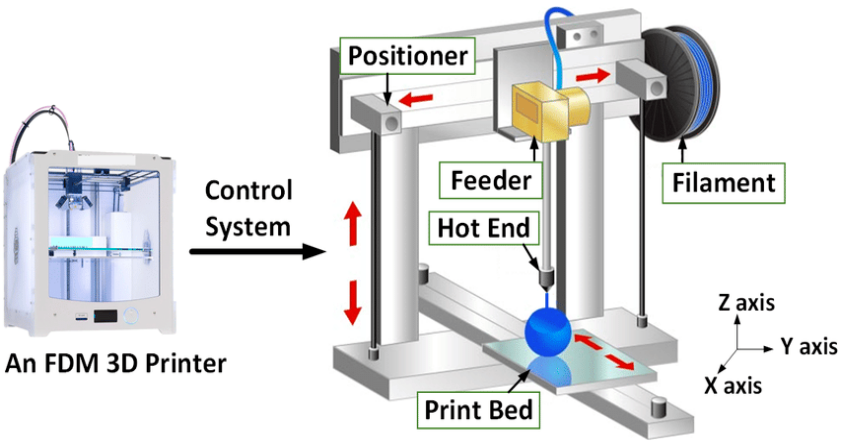


Figure 2. Schematic diagram of FDM principle.

3.2. Light curing

Light-curing consumables are photosensitive resins, which will produce a series of physical and chemical changes under the irradiation of specific wavelengths. According to the light source type and illumination method, it can be divided into SLA (Stereo Lithography Appearance), DLP (Digital Light Processing), and LCD (Liquid-crystal display)

3.2.1. Stereo Lithography Appearance (SLA).

The SLA tank is filled with liquid photosensitive resin raw materials. When printing, the printing platform is under the liquid surface, and then the laser beam is focused and reflected on the working platform through the lens and irradiated according to the originally set path. The irradiated resin will be cured [7]. After completing one layer, the platform will rise a little and then start the next layer of irradiation. The molding method is point molding. There are also many kinds of photosensitive resins as raw materials, such as rigidity, flexibility, and toughness, which need to be stored away from light. SLA also prints slower but with higher accuracy. The final product is smooth and detailed, but with that comes the price. SLA 3d printers and raw materials are expensive, the operation is more complicated, the material utilization rate is low, and the waste is serious. SLA needs to be further cured after printing, which will release pollution during operation and will cause harm to the human body if it is not handled properly.

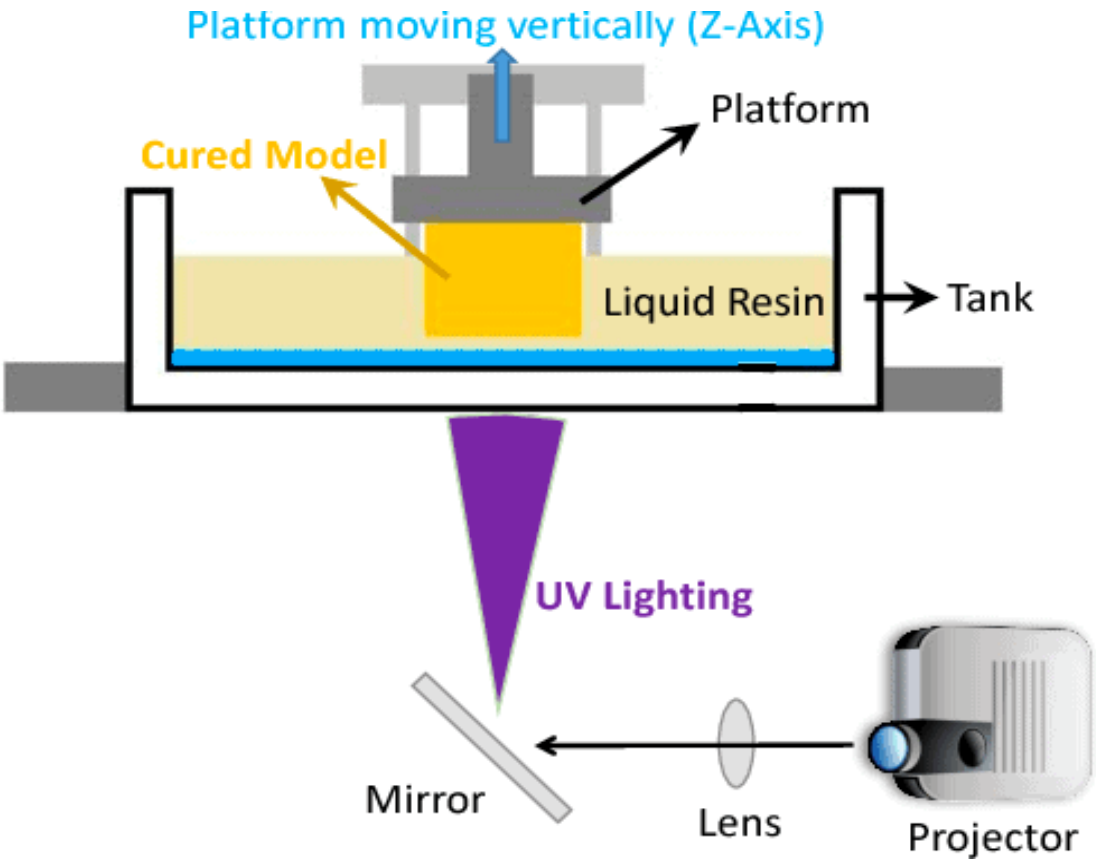


Figure 3. Schematic diagram of SLA principle.

3.2.2 Digital Light Processing (DLP).

The difference between DLP and SLA is that SLA reflects a beam of laser light onto the working platform, while DLP projects the shape of the first layer onto the platform, which belongs to surface molding. Since DLP prins a whole layer at a time, it will be much faster than SLA.

DLP works on the same principle as the projectors we use. Its mechanical price, raw materials, and characteristics are consistent with SLA. It is more expensive and will produce waste and pollution, but the product has high precision and rich details.

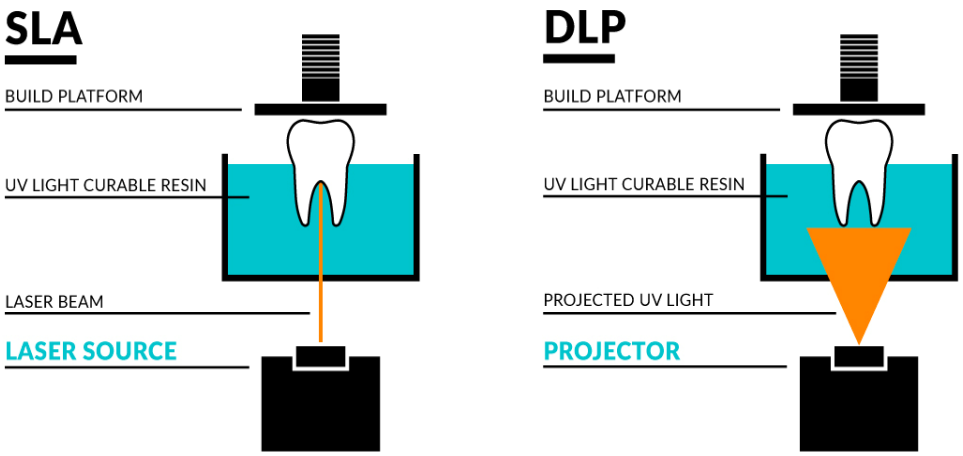


Figure 4. Differences between SLA and DLP.

3.2.3 Liquid-Crystal Display (LCD).

LCD is the method of using an LCD screen to print, which is the same surface molding as DLP. The advantage is that the printing speed is faster, and the printing accuracy is related to the screen resolution. The disadvantage is that the life of the LCD screen is short, and it usually needs to be replaced after thousands of hours of use. These three printing methods all need to be cured and cleaned after printing, and additional equipment needs to be purchased for processing, which is very inconvenient. This is one of the reasons why people use FDM more [8].

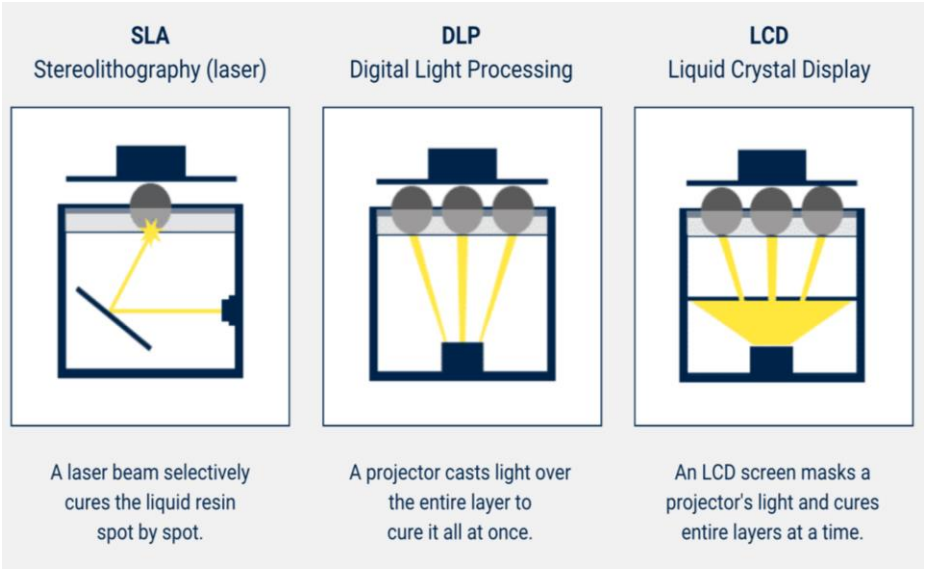


Figure 5. Differences between SLA, DLP, and LCD.

3.3. Powder molding

The representatives of powder molding are Selective laser sintering (SLS) and Selective laser melting (SLM). SLS works by laying down a layer of powder on a heated platform and then processing the powder with a laser beam. After one layer is completed, another layer of powder is applied and then processed until a complete body is formed. SLM and SLS work almost identically. The difference is that SLS requires the addition of additional binders such as low melting point metals or resins, whereas SLM is processed directly by melting and cooling the powder [9]. The advantage of powder molding technology is that it has high printing accuracy and can print materials such as metals and ceramics. The disadvantage is that the machinery is expensive, the surface of the product is rough, it will produce odors when working and it is prone to warping when printing large parts. Since this method is processed by melting and cooling, it takes a long time and preheating and cooling are required before and after processing [10].

4. The application of 3d printing in various fields

4.1. Medical

With the rapid development of 3D printing technology, various fields have begun to introduce and apply 3D printing. 3D printing technology has been widely used in the field of biomedicine. In orthopedic surgery, hospitals can print implants and prostheses. Traditional implants and prostheses are made in batches by factories, and their sizes are only a few fixed, but each patient's bones and limbs are all different sizes and may have specific structures, so traditional implants, and prostheses are often mismatched or not ideally matched to the patient. 3D printing technology can quickly and accurately print personalized implants and prostheses that match patients, thereby reducing hidden dangers and providing patients with better rehabilitation effects. At present, 3D printing heads, vertebral bodies, maxillofacial parts, joints, and prostheses have been used in clinical practice.

Another application of 3D printing in the medical field is called bioprinting. 3D bioprinting is a technology that prints living tissue from living cells and other biological agents on the basis of 3D printing. Using this technology, liver tissue, kidney tissue, transplantable kidney, auricle, muscle tissue, skin tissue, bone tissue, blood vessels, tracheal splint, heart tissue, and cartilage tissue can be printed. Bioprinting is suitable for drug testing, organ transplantation, etc. important meaning. Taking 3D-printed blood vessels as an example, this technology can customize personalized blood vessels for patients to replace necrotic blood vessels and solve the current problems of insufficient blood vessel sources and poor tissue compatibility. In addition, there are researchers trying to print organs, because organs have been in a state of short supply, and there will be immune rejection after transplantation, requiring lifelong medication.3D printed organs promise to solve this problem. Researchers have used 3D printing technology to develop a completely air-driven silicone rubber artificial heart that can beat about 3,000 times and generate blood flow and pressure signals. It can be seen that 3D printing has opened up a new path for the medical field.

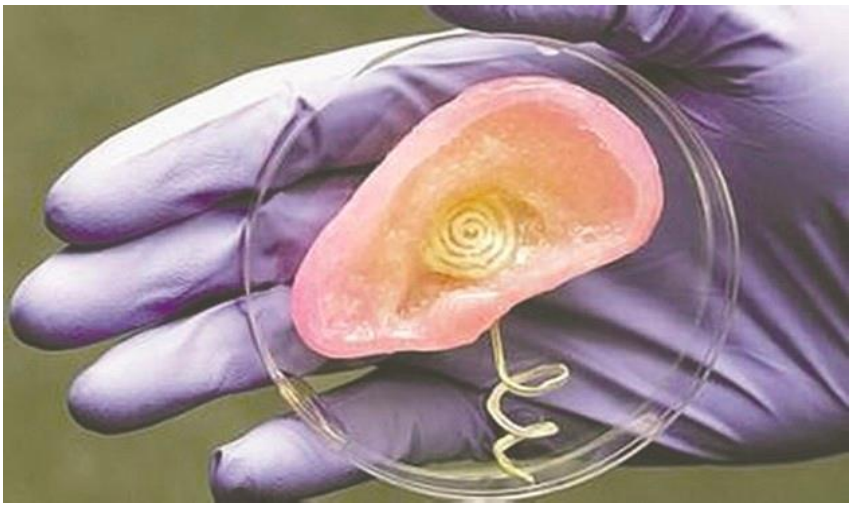


Figure 6. 3D printed organs.

Doctors will also print medical models and surgical guides as needed before surgery. Three-dimensional modeling is performed based on the patient's CT or MRI data before surgery, and then the model is printed by a 3D printer to obtain a medical model. The main function of 3D-printed medical models is to allow doctors to visually see the three-dimensional structure of the surgical site before surgery, which is helpful for doctors to plan surgical plans. Especially for complex surgery, it helps to reduce the risk of surgery and improve the success rate of surgery. Surgical guides are an important tool for doctors to assist in surgery, and 3D printing technology is especially suitable for manufacturing special-shaped or personalized guides. During the operation, the doctor only needs to attach the guide plate to the joint surface and then perform the positioning osteotomy. The accuracy is higher than that of the traditional method, the human factor is avoided, the operation is simple, and the controllability is high.

4.2. Architecture

3D printing also plays an important role in the field of architecture. Starting from the design drawing, the traditional design should not be too complicated due to the difficulty of construction. If the 3D printing model is used to assist the design, any complex spatial surface can be produced. Compared with the traditional design, it saves a lot of manpower, Material, and time costs, and this model is fast, environmentally friendly, low-cost, and beautifully modeled. At the same time, compared with the exaggeration caused by the deliberate creation of aesthetic effects in the 3D renderings, the 3D printing models are much more realistic and intuitive. At the same time, when communicating with Party A, the display of a model is more intuitive than several design drawings, and the designer does not need to consider the difficulty of construction and can design the building he wants with confidence and 3D printing. Put into practice. No matter how complex the structural design is, as long as the drawings can be designed, 3D printing technology can be used to form it at one time, which solves the problems that traditional construction methods cannot break through. And building a typical residential construction site generates around 4 tons of waste. Because the concrete used in traditional floor construction is spread evenly, about half of the concrete is wasted whether or not structural support is required in a particular area. This is especially harmful to the environment. In contrast, 3D printers can change the thickness of structures very precisely, using concrete only where it's really needed. But this technology is not without its shortcomings. Compared with ordinary 3D printing technology, the 3D printing technology of concrete is more difficult. First, make sure that the concrete can flow smoothly during the printing process so that it can enter and exit the printer smoothly without clogging. Second, the concrete extruded from the printer must be able to harden quickly and become strong enough to withstand subsequent layers. On the basis of meeting the above requirements, it is also necessary to achieve sufficient adhesion between these layers. In addition, 3D concrete printing also needs to overcome a series of challenges in the open air environment (work), because environmental dust, humidity, moisture, temperature, etc. are all variables that affect the performance of concrete, so these influencing factors must be precisely controlled.

4.3. Aerospace

From the time 3D printing technology has developed to the point where it has been possible to manufacture finished parts, the first industry to benefit from this process is undoubtedly the aerospace sector. The benefits of reducing the weight of parts by manufacturing complex structures are obvious, such as shortening the research and development cycle of new aerospace equipment and improving the utilization of materials, saving expensive strategic materials, and reducing manufacturing costs. Aerospace technology is a symbol of national defense strength and a manifestation of national politics. The competition among countries in the world is extremely fierce. Therefore, all countries want to try to develop newer weapons and equipment at a faster rate to make themselves invincible in the field of national defense. The metal 3D printing technology greatly shortens the manufacturing process of high-performance metal parts, especially high-performance large structural parts. There is no need to develop the molds used in the part manufacturing process, which will greatly shorten the product development and manufacturing cycle. Before the advent of 3D printing, it would take at least a decade to develop a new fighter jet. For example, if you need a new part, if the traditional manufacturing method is used, this part may require a large tonnage press to forge, which is not only time-consuming and labor-intensive but also wastes raw materials, but 3D printing is different, due to its high flexibility, high performance, and flexible manufacturing characteristics, and the free rapid prototyping of complex parts, metal 3D printing will be widely used in the aerospace field, providing strong technical support for the manufacture of defense equipment.

5. Conclusion and prospect

In recent years, 3D printing technology has developed rapidly around the world and is widely used in various industries. It subverts the traditional production model, which undoubtedly promotes the

improvement of modern production technology. 3D printing can automatically convert the three-dimensional design in the computer into an actual model, or even directly into parts that do not need to be processed, thereby effectively shortening the product development and manufacturing cycle and efficiently using new materials. But this seemingly convenient technology is not without its shortcomings. In terms of technology: the common Fused Deposition Modeling has poor accuracy and slow speed; light curing consumables have a very high cost, low strength, and low material strength and durability; In terms of environmental protection and energy consumption, 3D printers commonly used in the market need to work continuously for 28 hours to print an irregular three-dimensional plastic model of about 30 cm in size. Scanning layer by layer results in a lot of unnecessary energy consumption and the consumed materials cannot be recycled, which wastes a lot of materials. In order to solve these shortcomings, I think we can continue to develop new materials and new printing methods.

There are many high-quality alloy materials, composite materials, and nanomaterials on the market now, and it will undoubtedly be a huge improvement if these materials can also be shaped by 3D printing. This paper introduces the principle of 3D printing, reduces several common printing methods, and the application of 3D printing in three fields. Recommendations were also made. At present, 3D printing technology seems to face many difficulties in its promotion and development, but it is an emerging technology, and it will definitely get better and better with the progress of society and the development of science and technology in the future.

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