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ANALYSIS OF CURRENT TECHNIQUES IN ADDITIVE MANUFACTURING

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ABSTRACT

Additive manufacturing techniques have inherent advantages in prototyping compared to traditional processes during new product development. They have become almost a subject of consultation and mandatory application in academic and business spaces related to the design and development of new products. The information starts from a computer-aided design file and is then converted into a stereolithography file. This document presents the different options currently available, analyzing their characteristics, benefits and possible disadvantages. Additionally, the development and application perspectives of this important process are presented.

KEYWORDS: Rapid Prototyping, Additive Manufacturing, Design, Technology

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Original Article

1. INTRODUCTION

The first techniques for rapid prototyping date from the late 1980s. Today these techniques are as varied as their applications and are used for the manufacture of parts in small batches and with low costs. This development has been driven by the fifth industrial revolution, and one of the advances that has had great impact is the trend towards prototyping through additive manufacturing. According to Espinosa [1], prototyping is a tool of innovation to test products and services before they are put on the market. It has been considered a great revolution in the industrial areas, showing for its followers, more advantages than disadvantages during its development, since, it has entered, not only in industrial activities, but in another diversity of areas. Education, industrial design, the aerospace industry, the automotive field, the diverse branches of engineering, architecture, construction, footwear, and even jewelry, have experienced great opportunities to make the creativity of the human mind a reality, offering better and higher competition in the market [2].

It is known that in the 1980s, rapid prototyping and manufacturing technology (RPM) originated, being an integration of many different disciplines, capable of forming parts with complicated structures and non-homogeneous materials. At that time, its main use was in the invention of products, techniques such as, manufacturing of laminated objects and molten deposition modeling allowed the generation of new models, and even redesign of the existing ones [3].

The rapid prototyping processes were developed in 1987, with the process of stereolithography (StereoLithography- SL), by means of this technique layers of photosensitive resin are solidified by means of laser, this being a rapid prototyping in the manufacture of models and prototypes from CAD models of 3D objects. The prototypes were made by solidifying layer by layer a translucent polymer, which changes its state when a laser light beam strikes it [4-5]. For this reason, authors such as García y Briceño [6-7] mention that the father of 3D technology was Charles W. Hull, who, in 1984, had managed to devise a stereolithography method. Later on, new RPM techniques emerged and today they are applied in fields such as fast tooling, direct use parts, nano, micro RPM and biofabrication. This development is a consequence of the progress of materials and technology as stated by Yongnian [8].

Today, when talking about 3D rapid prototyping, technologies such as, Fused Deposition Modeling (FDM) , Selective Laser Synthesis (SLS), Selective Deposition Lamination (SDL), laminated objects manufacturing (LOM), Injection Bonding (IV), Triple Injection (Polyjet), Digital Light Processing (DLP) and Electron Beam Melting (EBM) are included. These assisted design methodologies have led to the emergence of high-tech, easy-to-operate personal printers. The rapid manufacture of 3D prototypes, the reduction of stock of rare parts in auto parts stores, the production of parts that require customization such as prostheses, the sale of objects with low demand that does not compensate for making a previous batch of units, are advantages of this form of manufacturing. In particular, the most outstanding advantage is the adaptability of these printers to the common life of people [9]. This technological development, and its variability of methods, has made rapid prototyping a useful tool for reducing costs and decreasing manufacturing times, since it allows the creation of pieces without molds or dyes. It has also increased the percentage of reproducibility and repeatability of more complex pieces, and has created broader opportunities for competition in the market, which has allowed for a better product offering.

Also noteworthy is the variety of materials that can be used as polymers, metal or even ceramic. An example of this is the case of the dental sector, where some rapid prototyping techniques are used to manufacture metallic structures that are later covered with ceramics to make dental crowns and bridges [10]. This disruptive technology, has a wide untapped potential, for this reason, this work will show some of the techniques and their technological development as an innovation tool in the industry.

2. CURRENT RAPID PROTOTYPING TECHNOLOGIES

2.1. Stereolithography (SLA)

es a 3D rapid prototyping technique for the manufacture of parts through photosensitive resin that is cured by a laser beam. The 3D model file exported in STL format is tessellated and divided into thin 2D layers that are added in successive layers to form the final object. This technique was the precursor of 3D printing [11]. In this technique, the liquid material is introduced in a special resin tank, leaving a thin layer exposed. The light beam gradually solidifies the resin, creating the piece, which will have a resolution equal to the height of the layer [12].

2.2. Digital Light Processing (DLP)

DLP technology uses resin with liquid photopolymers that harden layer by layer. The strong points of this technology are the high precision in the details and the excellent surface quality. Moreover, although it is not usual to work with large work containers, the manufacturing time of the parts is greatly optimized [13]. In this technology, different photosensitive resins can be observed, with varied technical characteristics and sometimes aimed at specific markets such as dental or jewelry.

2.3. Selective Laser Sintering (SLS), without supports

In the process of melting the material, a very powerful laser beam is used which melts the powder, creating a high resistance agglomerate. This laser beam, through a 3D file generated by a computer advances layer by layer on the bed of dust agglomerating them generating the object little by little. As a layer melts, the bed generates a new layer of powder for the laser beam to cover it [14].

A characteristic feature of this type of manufacturing is that it does not require supports on the parts, since the dust base (bed) itself serves as a support for the part. When the sintering process is finished, the piece is removed from the container, removing all the dust from the material around it, leaving the piece finished and with an almost perfect finish. One of the most popular methods of SLS is the polyamide (nylon) powder manufacturing technique. Among its advantages is its easy adaptation to the manufacture of short series and functional parts, its low costs in 3D printing and high strength of the parts.

2.4. Fused Material Deposition (FDM)

The raw material used is not in the form of powder, but in the form of plastic filament fed from a coil that is heated and melted inside the extrusion nozzle. The thin filament, which is 1.75mm to 3mm thick, is made of thermoplastic material that is wound onto a reel and melted in a part of the printer called the 'hotend' and extruded through a nozzle. This head that has movement in the three spatial axes, deposits on a base and gradually creates the piece. The minimum layer thickness in this type of printer is 0.1mm, although 0.2mm is usually used [15]. The pieces made with this technology have a medium surface finish since the manufacturing layers are not excessively thin and can be seen; however, since they are functional materials, finishes such as polishing, painting and silk-screen printing can be applied. Another characteristic is related to dimensional stability, since FDM materials are thermoplastic, so products made with this technology have fewer deformation problems than others.

2.5. Triple injection or Polyjet

This technique is the most advanced version of the Polyjet technology since three different materials can be printed in 3D, allowing many colors to be mixed. The printing heads are equipped with dozens of nozzles that project micro-drops of material on a manufacturing base. During each layer projection, an ultraviolet light is emitted and solidifies the material that will create the final product [16].

An outstanding feature of this technique is that the final piece does not require any post-processing stage (sanding, polishing, or firing). On the other hand, a limitation of this technique is related to the little functionality of the elaborated pieces, since its use is primarily aesthetic.

2.6. Multijet Fusion MJF

This technology is very similar to laser sintering, especially in terms of surface finish by working with polyamide (PA) plastic powder. The biggest visual difference lies in the available colors of grey or black [17].

The technique was developed by Hewlett Packard and although in many aspects it is similar to SLS sintering it has differences in color and porosity is somewhat less. Unlike parts made with FDM or SLA, the toughness of the material makes it a little difficult to give them a surface finish. Polyamides can be processed by this technique creating functional and resistant prototypes.

2.7. SLM Metal Sintering

This technology uses metal powders to manufacture functional parts in materials such as aluminum, steel or titanium, using a laser beam. The material is agglutinated by layers and with a surface finish similar to that of plastic sintering and with the possibility of complex geometries and fast. The porosity of the final product is low due to the very fine grain of the powder used [18].

This technology has characteristics that make it very competitive for the manufacture of metal parts with respect to processes such as machining or casting. As they are metal parts, it is possible to carry out functional tests and their mechanical characteristics make this technology an excellent alternative not only for the manufacture of prototypes but also for small batches of final parts. As these materials are metallic, they can be welded and finished according to customer requirements.

2.8. Manufacture of LOM laminated objects

With this technique it is easy to build large models. The materials used are also low cost, consistent and readily available.

In contrast to stereolithography (SLA), sheet-fed technology is not able to create such precise parts and, due to the difficulty in creating objects with complex geometries, it is not usually used to create functional prototypes [19-20].

2.9. Photopolimerization by ultraviolet light SGC.

According to its manufacturer, this technology offers greater precision and better mechanical properties due to the way of polymerization and the parts generated do not present shrinkage effect [21]. As for its disadvantages, it can be mentioned that the equipment is more expensive and heavier due to its large size. The complexity of its process requires qualified personnel to permanently supervise the process and is recommended for parts that maintain the same section. Due to the high acquisition costs and the complexity of its operation, this technology had little acceptance and is no longer commercialized. However, it is still an interesting example of the many different technologies other than stereolithography.

2.10. Ballistic Particle Manufacturing (BPM)

The BPM technology was developed by BPM Technology, the system uses a jet of molten material or droplet based manufacturing (DBM) technology. The material jet is separated into small drops which hit the substrate and immediately cool down to form the part [22].

The materials used in this technology can be zinc, tin, lead, copper and some alloys and thermoplastics whose melting point is low (<420 °C). Among the advantages offered by this technology we can mention the low production and maintenance costs, the good mechanical properties, which do not require post-processing, low process toxicity, low energy consumption, low system and material costs, and that some systems can handle double material such as thermoplastics or wax [23]. On the other hand, the range of materials handled is one of the limitations.

3. RESULTS AND DISCUSSIONS

The constant growth of 3D techniques has already been mentioned, which has made this technology an invaluable tool for production workflows. Many industries are adopting this type of technology, seeking not only to improve the technical quality of their final products, but also to increase their aesthetic quality, especially in the design of the products they offer to the market by optimizing their production processes, manufacturing them more quickly.

However, it is important to mention that this change of idea at a global level, and the adoption of these technologies, has not been in an equitable manner, since powerful companies that are in industrial sectors such as aerospace, medicine and the automotive sector, find it less complicated to embrace these methodologies. Meanwhile, in less developed industrial sectors, the implementation of this technology is a little more complex, not only because of the high cost of equipment and raw materials, but also because of the technical level of their human capital, which means that these companies risk losing their positions at the head of the world's 3D printing industry, rapidly losing ground in today's globalized market [25-26].

Proof of this is the automotive sector, a sector that in recent years has been at the forefront of technological advances. The company Massivit 3D Printing Technologies Ltda. a provider of large format 3D printing solutions [27], presented a full-size 3D printed prototype car, named as shown in the A Portrait of db

Figure 1: A Portrait of db , massivit3d font.

It is worth mentioning that one of the main difficulties at present is the choice of materials to build prostheses, due to the cost and delay of the process. In as well as the technology 3D will achieve, in a short time, the modification of these tendencies, because prosthesis will be obtained of fast, economic, precise way and of high quality, due to that they have very resistant and lasting materials. Joda et al [28] conclude that, digitization with AI/ML and RA/VR represent the most promising tools for innovative research today, where research in the digital age will also be increasingly evaluated in terms of "impact" as a deliverable.

Another sector that has been making inroads into 3D technology for some time is the aeronautics sector. In this 2020 a 3D printed device was manufactured that filters the air in the vehicle. This is an air sterilization device that uses a wide spectrum of UVC light and a photochemical process to eliminate volatile organic compounds [29]. See Figure.

Figure 2: 3D printed air filtering device, 3dprintingdesign font.

Rua [30-31] mentions that, it is not a question of refuting old educational programs with new technologies, but of designing and applying innovative pedagogical models that guide students towards the skills they will need to adapt in an already digital world.

The incursion of 3D printing is so promising that today, this technology is helping the health medicine, although it has always been present in this area, today it is more immersed in these issues, so that, due to the COVID 19 virus that we are currently facing worldwide, 3D printing has shot up, with the manufacture of masks, isopes and swabs used to perform PCR tests, managing to react quickly and flexibly to such an emergency.

Finally, rapid prototyping offers great technological potential for the various industrial, medical and educational areas that exist on the planet, making it not only a technological but also a didactic tool for the understanding, development and evolution of many industrial, educational and medical models. Therefore, in the short term, whether they want to or not, industries, educational institutions and the medical sector will have to modify the way they apply their knowledge, evolving towards a more effective, didactic but above all economic model that helps humanity.

4. CONCLUSIONS

Due to the advance and evolution of the development of software, hardware and the appearance of new materials, the 3D printing has evolved in the last decade in a drastic way, with application in several fields of the industry, generating that in a future it is a basic tool of the development and an option for the production, taking to the education to form new professional profiles to the use of these technologies.

3D printing has been in constant growth, which has made this technology an invaluable tool for production workflows. Many industries are adopting this type of technology, seeking not only to improve the technical quality of their final products, but also to increase their aesthetic quality, especially in the design of the products they offer to the market.

Rapid prototyping offers a technological potential that has made inroads in various branches of industry, becoming an essential tool for technical and human development in different companies, educational institutions and medical centers of the planet, developing as an effective, efficient and economic process that will lead the world markets, offering comprehensive benefits for humanity.

The advance in the different rapid prototyping technologies means a new step towards the improvement of the design and development processes of new products towards more effective business practices and with greater satisfaction of the customer's expectations. Its implementation allows, to a greater or lesser degree, to combine the care in details and personalization typical of handcrafted work with batch production.

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