3D Printing in architecture

Impresión 3D en arquitectura

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HIGHLIGHTS

- Promote visual-spatial intelligence and cooperative learning.
- Develop teaching-learning activities to acquire new knowledge.
- Implement an educational method that promotes learning based on thinking.

TITULARES

- Fomentar la inteligencia visual-espacial y el aprendizaje cooperativo.
- Desarrollar actividades de enseñanza-aprendizaje para adquirir nuevos conocimientos.
- Implementar un método educativo que promueva el aprendizaje basado en pensar.

ABSTRACT

Currently, there have been significant advancements in technology in all areas of daily life. However, in education, the teaching methods and tools used have remained practically the same for generations. This suggests that although traditional methodology works perfectly, it must be adapted to existing technological advancements. One of the major recent discoveries is 3D printing, which offers the possibility of designing and printing any object, promoting visual-spatial intelligence and cooperative learning in the classroom. The emergence of additive manufacturing provides an opportunity to develop teaching-learning activities for acquiring new knowledge and developing creative and problem-solving abilities. For instance, students can learn to identify the views of an isometric drawing by creating a three-dimensional prototype. The objective of this work is to implement an educational method that promotes learning based on thinking and developing a project from an initial idea to the actual manufacture of an architectural model in an interdisciplinary way. This method will involve all the necessary processes for the model's construction, as occurs in the conception of a real architectural work. This procedure, based on learning by trial and error, is a cyclical methodology that allows the initial parameters to be modified based on the results obtained, both in the design process and in the construction phase. By using this method, students learn to learn with a practical methodology capable of identifying their own errors, correcting them, and giving the model maximum added value.

Keywords: *Teaching methods; 3D printing; Cooperative learning; Learning by error; Architectural model.*

RESUMEN

Actualmente, se han producido importantes avances tecnológicos en todos los ámbitos de la vida diaria. Sin embargo, en educación, los métodos y herramientas de enseñanza utilizados se han mantenido prácticamente iguales durante generaciones. Esto sugiere que, aunque la metodología tradicional funciona perfectamente, debe adaptarse a los avances tecnológicos existentes. Uno de los mejores descubrimientos recientes es la impresión 3D, que ofrece la posibilidad de diseñar e imprimir cualquier objeto, fomentando la inteligencia visual-espacial y el aprendizaje cooperativo en el aula. La aparición de la fabricación aditiva brinda la oportunidad de desarrollar actividades de enseñanza-aprendizaje para adquirir nuevos conocimientos y desarrollar la creatividad y la capacidad de resolución de problemas. Por ejemplo, los estudiantes pueden aprender a identificar las vistas de un dibujo isométrico creando un prototipo tridimensional. El objetivo de este trabajo es implementar un método educativo que promueva el aprendizaje basado en pensar y desarrollar un proyecto desde una idea inicial hasta la fabricación real de un modelo arquitectónico de manera interdisciplinaria. Este método involucrará todos los procesos necesarios para la construcción del modelo, tal como ocurre en la concepción de una obra arquitectónica real. Este procedimiento, basado en el aprendizaje por prueba y error, es una metodología cíclica que permite modificar los parámetros iniciales en función de los resultados obtenidos, tanto en el proceso de diseño como en la fase de construcción. Mediante este método, los estudiantes aprenden a aprender con una metodología práctica capaz de identificar sus propios errores, corregirlos y dotar al modelo del máximo valor añadido.

Palabras clave: *Métodos de enseñanza; Impresión 3d; Aprendizaje cooperativo; Aprendizaje por error; Modelo arquitectónico.*

1. INTRODUCTION

E Three-dimensional printing is a process that manufactures objects through the superimposition of material in successive transversal layers that generate a 3D model [1]. Previously, it is necessary to design the object and select the materials according to the production process [2]. 3D printing originated with inkjet printing in 1976 and evolved to print any object with any material in 1984 to become what we know today [3].

At present, 3D printing is being used to create various projects according to the demands of the market. Fundamentally in the field of healthcare, where precision in surgery is improved, personalized prostheses or surgical material are printed, among others [4].

In the industry sector, one of the greatest advances has been to send a rocket into space, whose engine has been manufactured using 3D technology, lowering production costs. Without going any further, NASA has already printed metal mesh fabrics to make astronaut suits, insulate spacecraft and capture objects on extraterrestrial surfaces.

Currently, 3D printing is consolidated, being the great protagonist in the manufacturing methods of large companies, such as restaurants that print healthy food that is easy to swallow or brands that manufacture high-performance footwear. Therefore, we can be sure that most of the industries are introducing new technologies to improve the original performance of their products [5].

Within the architectural framework several projects of relatively complex printed structures have been developed [6]. 3D printing in the building sector is considered to have several advantages over traditional construction, as it reduces labor, delivery time and waste generation.

In recently published research on 3D printing in the construction sector, modular parts manufactured using new technologies, primarily using recycled materials, were studied [7].

As a result of this research, "Printed Thermoplastic Modular Parts" (hereinafter, PTMP) were created as an element to take into account when producing any type of structure. To accredit these bricks, it is necessary to know their physical characteristics by carrying out laboratory tests and comparing them with the bricks that are currently used in construction [8].

This work demonstrates the complicated process of printing an object using new technologies, the problems that appear and how to solve them. Based on the results obtained, the printing parameters are modified to optimize the properties of the thermoplastic part [9]. The purpose of this study was to show the importance of the printing process on the part, the selected parameters and the materials used [10].

3D printing is a technique whose main characteristic is high geometric precision. In this way, the use of 3D printing can be implemented in the realization of architectural models [11], at an educational level, ensuring dimensional fidelity in changes of scale. In this way, an educational method capable of promoting learning based on thinking and developing a project from an initial idea to the actual manufacture of the architectural model is implemented, in an interdisciplinary way, going through all the processes necessary for its construction, as occurs in the conception of a real architectural work [12].

Additive manufacturing provides opportunities for teaching activities to gain new knowledge and develop creative skills, solving problems, including isometric viewing through 3D prototyping.

The process is based on learning from errors, since it is a cyclical method that allows the initial parameters to be modified according to the results obtained during the design process and the construction phase [13].

In this way, students learn to learn with a practical approach that is capable of recognizing their own mistakes, being able to correct them and providing the maximum added value to the model.

Fig. 1: Palladio Hauses. (3D printing laboratory - ETSEM)

Fig. 2: 3D printing workshop. (3D printing laboratory - ETSEM)

2. METHODOLOGY

In order to fulfill the previously described objectives, a study methodology is established in accordance with the existing material resources for this research. Next, the specific system developed in this work is explained, where the necessary steps for the construction of a printed piece are followed, whether it is a model or a prototype, and the variables that intervene in the final result of the pieces [14].

2.1 Desing phase

In this case, a printed modular part design, P.T.M.P., is proposed, which is taken as an example for the manufacture of a prototype that must faithfully keep the physical characteristics of the conceived idea. The established geometry defines the main shape of the prototype and the design of the joining systems, which make it possible to connect the pieces together. In the same way, the dimensions of the models are determined taking into account the measurements of traditional bricks in order to carry out an equitable comparative study [15].
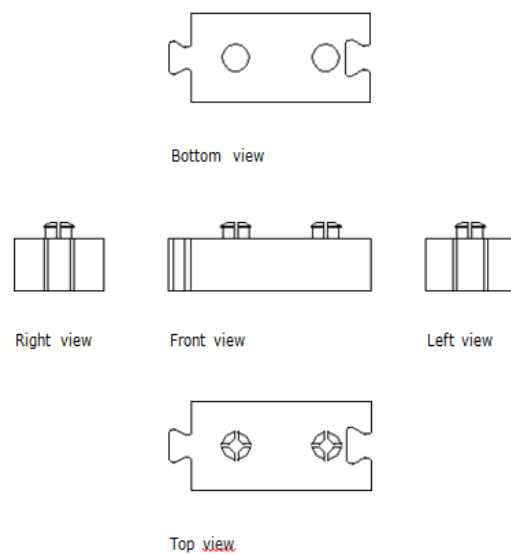

Fig. 3: Main views of the P.T.M.P. (Self made)

2.2 Choice of printing parameters

Lamination program parameters determine the final characteristics of the printed object. The most relevant are mentioned below and the function of each of them is explained [16].

2.2.1 Infill

The interior filling of a piece is the percentage of filling material with respect to the total volume. Depending on the use of the piece to be manufactured, one filling or another will be chosen.

The optimal filling of a piece is the one that, consuming the least possible material, allows it to meet the required specifications. A part with 90% infill is considered to be equivalent to a part manufactured by the injection molding method. Below is a list of the interior fillings to choose based on the final use [17].

- If the piece does not need to have any resistance to efforts, the percentage of internal filling is from 0% to 5%.
- For less resistant structures, such as models, the interior filling is 5% to 10%.
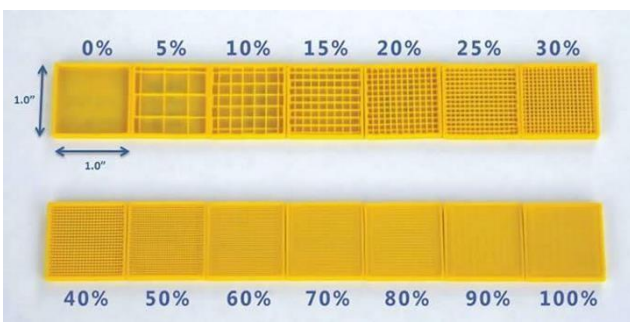- For general use, the filler to use is 15% to 25%.

Fig. 4: *Infill percentage. (3DWorks)*

- For moderate mechanical use, the percentage is 25% to 40%.

- For high mechanical use, the filling percentage is from 40% to 80%.
- For parts with high impact resistance, the percentage to be used is 80% to 100%.

The interior fill percentage does not affect the final exterior appearance of the part.

2.2.2 Inner pattern

As with the infill percentage, the pattern or design for it influences the resistance of the object to print.
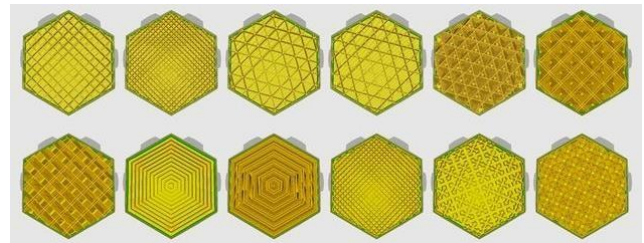

Fig. 5: *Inner filled pattern. (Thingiverse)*

The type of filling and its percentage must be intended for each type of printer and depending on the type of material to be used, in order to obtain the best possible result.

Depending on the lamination program, there are certain default patterns for printing. In this case, the most common ones are named and what they are used for.

- Rectangular (or rectilinear): This type of pattern is predefined in most laminating programs and provides resistance in all directions. It is the fastest model to print since they make perpendicular layers over each other.
- Triangular (or diagonal): It is used to achieve high resistance in the walls; this is due to the decomposition of the force applied at 45º. It requires more printing time.

- Wavy (or curvilinear): This type of filling is used for parts that require some flexibility, when they need to be twisted or compressed.
- Honeycomb (or hexagonal): It is a filler widely used for parts with good resistance in all directions and adds more robustness to parts made of fiber materials.

90% of the pieces are printed with rectangular or rectilinear fills, sufficient for their intended use, leaving the other 10% of pattern types for more specific pieces.

2.2.3 Enclosure wall thickness

It is defined by the number of turns that the extruder makes to form the wall and the caliber of the nozzle. When talking about the thickness of the walls, it does not only refer to the side walls of the same, but also the upper and lower faces of the pieces must be taken into account.

- Wall thickness: A minimum thickness of 1mm is recommended so that the object has some resistance. Usually, the wall is set to be at least two or three layers thick. This value corresponds to a multiple of the nozzle width.

Fig. 1: Wall thickness. (Flashforge 3D Printer)

- Upper and lower layers: The most frequent number of layers for the design of the pieces is from 5 to 7. Depending on the percentage of filling, this quantity is increased. The lower the fill percentage, the greater the number of closing layers and vice versa.
- Superposition of the upper and lower layers: It is used when you want the upper and lower layers to be printed together with the walls of the part, strengthening this union and giving the part greater stability.

The thickness of the side walls of the pieces must be adapted depending on the use to which the object is intended, for example, in the event that it is going to be screwed.

2.2.4 Layer height

The layer height determines the resolution or definition of the object to be printed. This parameter influences the final finish or the appearance of the part and is directly related to the printing time.

Fig. 7: Layer height. (MDP)

As can be seen in figure 7, the lower the layer height, the smoother the surface of the object and the more defined the details, if any.

Depending on the part to be printed, one layer height or another is used. The most commonly used are listed below.

- For very small parts, the recommended layer height is 0.05mm.
- For commonly used parts, a layer height of 0.1mm is used.
- On an object with a medium resolution, the layer height is 0.2mm.
- For basic and economic projects, the layer height is 0.3mm.
- From here on, for large or very large projects, a layer height of 0.4mm onwards is used.

These values are also defined by the diameter of the nozzle, the optimum is that the layer height is less than 80% of the diameter of the nozzle. If this value is exceeded, adhesion between the layers is lost.

2.2.5 Supports

These are structures that are printed attached to the piece to support those parts of it that, due to their morphology, would be in an unstable position if they were printed without them, either because they are cantilevers or because their original connection to the rest of the part is printed in a top layer [18].

Fig. 8: 3D printing supports. (Sabic)

In single extruder printers, the supports are printed with the same material that the part was made from, which are more difficult to remove afterwards. You can configure the distance "z" that is intended to be left between the object and the support itself, so that the removal of the product is easier.

On the other hand, if you have a printer with two extruders or a double extruder, you can use one material to manufacture the part and another material for the supports. In this case, a soluble material is used in a certain liquid in which, in turn, the material is not. In this way, if the printed product is immersed in the solvent, the supports are selectively removed. The most common support material is PVA, since it is soluble in water, which makes post-processing easier and cheaper by avoiding more expensive specific solvents and with greater risk in handling.

The use of supports increases manufacturing time, the use of material and, therefore, the final cost of printing. Depending on the laminate program, various types of support are available, such as rectilinear, rectilinear grid, honeycomb, triangles, zigzag, among others.

As for the location of the supports, they can be placed on all sides. If the supports rest on parts of the piece itself, or from the base, if it does so by leaning on the printer bed itself.

It is possible to avoid placing supports and thus reduce the price of the resulting product, if the arrangement of the part on the base of the printer is varied, that is, the part is rotated with respect to its initial position. This influences the orientation of the surface layers in the final object.

2.2.6 Base

It serves to improve the adhesion of the pieces to the printing bed. As with the supports, it is important to determine the orientation of the object on the base of the printer. This should be conditioned by the surface of the piece that has the greatest support.
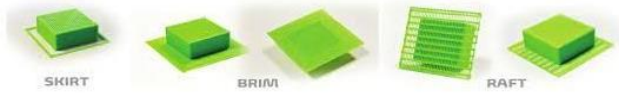
Fig. 9: Basis types. (ETP)

Like the rest of the parameters, these are configured in the laminating programs. Each of them is explained below [19].

- Skirt: It is about making a copy of the outline of the piece at a distance from it, prior to being printed. The purpose is to ensure the extruder purge before starting the print and check that the base is well leveled. You can set the width of this perimeter, the distance to the part and the height.
- Brim: In this case, the brim is in contact with the piece and is used when the pieces are small or have a very narrow base. A height of one or two coats is recommended to solve adhesion problems. A post-processing tool is required for brim removal, after printing is complete.
- Raft: This is the most suitable method for materials that are difficult to adhere to the base. In this case, a lattice layer is created between the printer bed and the part, favoring adherence by increasing the contact surface. This method is recommended when the printer has leveling difficulties, since the raft absorbs these differences, as long as they are small. In this case, removal is relatively easy and does not cause damage to the part once removed.

The placement of the bases also increases the manufacturing time, the use of material and, therefore, the final cost of the piece, but it is essential, in some cases, for the result to be as expected and to avoid, as you will see later, warping problems.

2.3 Manufacturing phase

This section shows the last step before printing the parts figure 10 interprets the information provided by the lamination program [20].

The manufacturing time for the parts is 20 hours and 3 minutes, but since the printer has two heads, two parts are manufactured in this time, which significantly reduces the unit price. Regarding the filament consumed, for each piece, it is known that 361.62 m will be needed, which is equivalent to a weight of 1087 g including the necessary material for the supports, in case it is necessary to anticipate the load of the spool. In addition, the program reports the cost of the material used for each piece, in this case it is €27.18.

And above all you can, at this point, decide the orientation of the piece in the printing area [21].
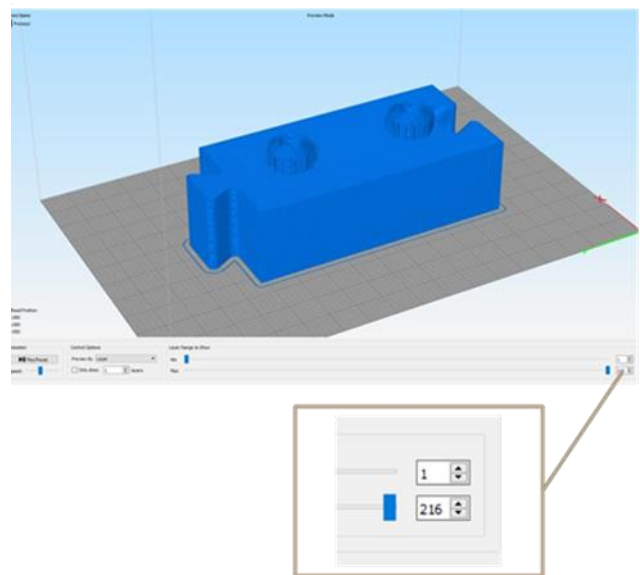

Fig. 10: Summary print information. (Dynapro)

In the lower area of the previous image, it can be seen that the piece is made up of 216 layers in total [22]. This is due to the dimension of the object and the height of the selected layer.

In figure 11, interface of the printer, a development bar is observed indicating the % of printing done and the remaining time, likewise, a graph is shown with information on all the temperatures involved in the process.

Fig. 11: Printer interface. (Dynapro)

Below are several images of the printing process of the P.T.M.P. parts where you can see the start of printing, the process and the end of it. In figure 12, the presence of skirt is observed, which is the first line that is deposited, outside the contour of the piece.

Fig. 12: Start of printing pieces. (Dynapro)

In the printing process, it is observed how the two heads work simultaneously to generate two pieces at the same time, without interfering with each other. The pieces can have the maximum size that occupies the area of each extruder.
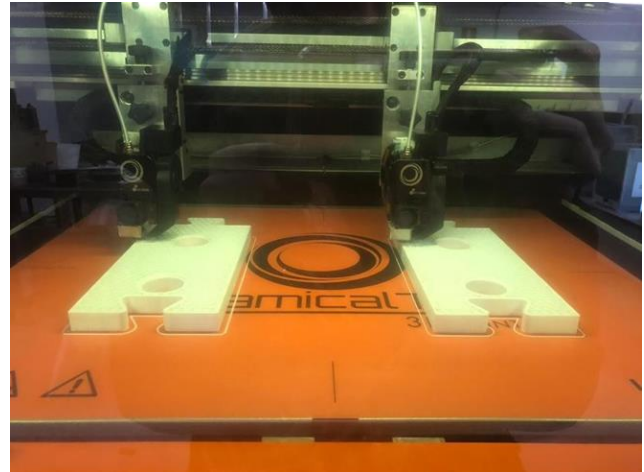

Fig. 13: Parts printing process. (Dynapro)

And finally, the finished manufacturing process is shown. The pieces are prepared for post-treatment, which consists of the manual removal of the supports, which can be seen around the upper staples [23].
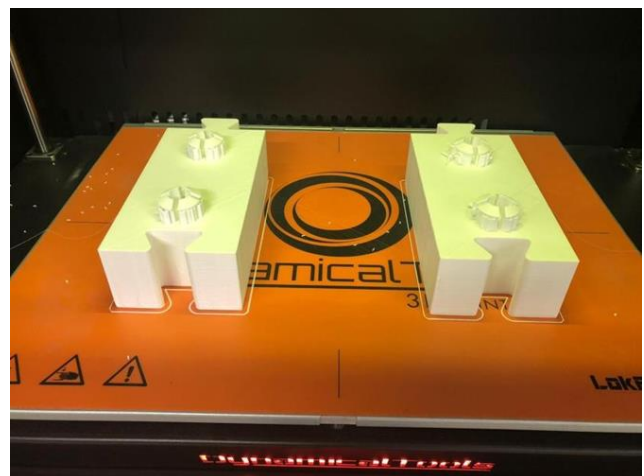

Fig. 14: End of print pieces. (Dynapro)

3. RESULTS ANALYSIS – PROBLEMS WITH 3D PRINTING AND APPROPRIATE SOLUTIONS

3D printing can present different problems that affect the quality of the final product. Several of these problems were experienced during the fieldwork of this investigation.
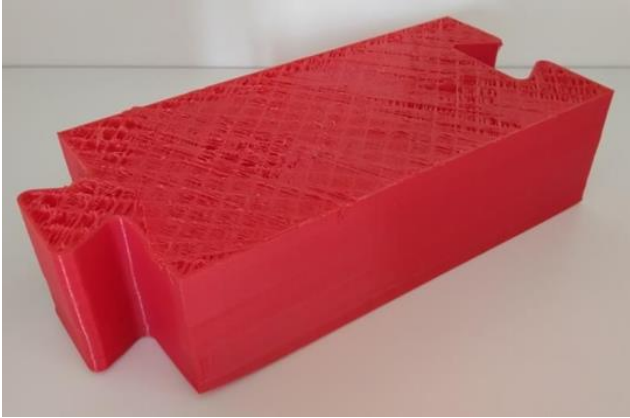
Fig. 15: Failed printing piece P.T.M.P. (Self made)

In this section, a P.T.M.P. part is shown. with a failed print, due to certain aspects that are explained below and how they should be solved.

3.1 Warping

Warping is a deformation that occurs in the piece as a buckling. This occurs because the corners of the part tend to lift due to thermal shrinkage. The center of the piece is where the heat is concentrated since the filament is deposited at a high temperature, depending on the material, and in the most remote parts the temperature is lower, so the material in the center pulls on the corners causing this effect [24].
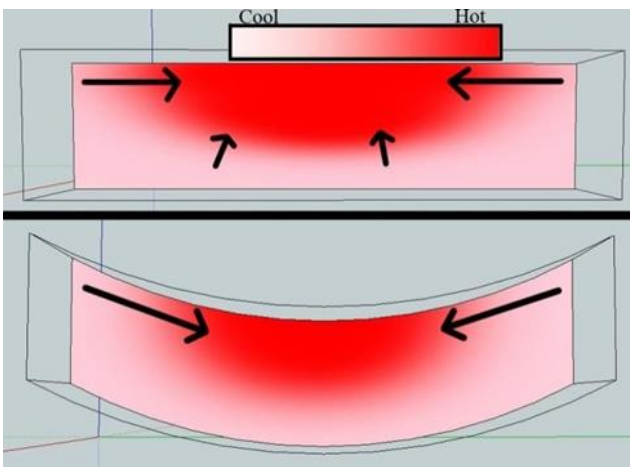

Fig. 16: Deformation of the piece. (Createc3D)

If this deformation occurs in the upper layers, it is called cracking and means that the adhesion between layers is less than the contraction force that is exerted from the inside of the piece, so that the layers separate.

Below is the impression of a P.T.M.P part in which you can see the deformation in the lower right corner, due to the warping effect [25].

Fig. 17: Warping, front view. (Self made)

There are materials more prone to warping than others. Here are some examples:

● PLA. It is the material that presents less warping in 3D printing because it has the lowest coefficient of thermal expansion of all and when it cools down it contracts less than ABS, for example. This material is the most used in parts where warping is guaranteed, such as large objects.
● ABS. It is the material that presents the most warping and cracking, this trend can be mitigated by placing the enclosure or closed chamber in the printer, so that the entire printing volume is kept at a constant temperature.
● PETG. It is a resistant material with a warping similar to PLA, but more resistant than ABS, which makes it a very suitable material for 3D printing.

With the choice of certain printing parameters, we try to avoid the appearance of this phenomenon, such as, for example, the printing speed, the extruder or bed temperature, the infill percentage, the layer height or the base placement, among others.
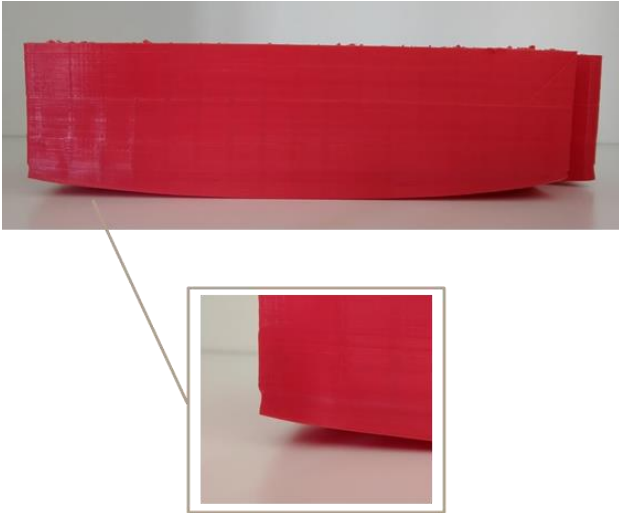

Fig. 18: Warping, side view. (Self made)

Another possible approach to try to avoid this problem is to increase the adhesion strength of the part to the base. One way to do it is with ABS juice, which is obtained by dissolving ABS, from the waste of 3D printing, in a suitable solvent, usually acetone. This product is applied on the printing base. In the case of PLA, the solvent used is ethyl acetate. Other means to increase adhesion that have been used in this work have been common lacquer, school glue based on polyvinyl alcohol, masking tape, supercoll, polyamide adhesive tape or kapton tape, medical adhesive for dressings and others. Later, reference is made to possible solutions to mitigate this effect.

Solution

Next, solutions are proposed to avoid the deformations produced by these internal temperature differences of the material.

- Place bases, such as brim or raft, explained above, to improve adherence or even circular supports in the corners, to reinforce them.
- Use printers with a heated bed, so that the temperature difference is less and the material cools down more slowly.
- Check that the printer bed is well leveled or calibrated before printing begins and, therefore, that the distance "z" between the bottom of the nozzle and the printing bed is the same at all points. It is important that the bed is free of residues between one impression and another.
- Use printers with an enclosure, to avoid drafts and ensure that the interior temperature is constant and homogeneous.
- Use adhesives, as we have commented previously, that contribute to the grip of the piece.

Fig. 19: ABS Juice. (Self made)

- ABS juice, or any other type of solvent-based paste, must be kept in glass containers, since if they are made of plastic they could be attacked by this solvent.
- Design the object with the lowest infill percentage possible, so that there is less material and therefore less internal shrinkage.
- Choose a material with a low coefficient of thermal expansion and, therefore, less deformable.

- Use a low printing speed, especially in the first layers, so that they cool down before placing the layer immediately above. This will prevent the appearance of warping, but will not prevent cracking from occurring, since the adhesion between layers is lost.
- And lastly, and as has been mentioned on other occasions, determine the position of the piece on the printing bed so that the contact surface with the base is the minimum possible.

Throughout this investigation, all the solutions proposed in this section have been used, due to the impossibility of manufacturing the parts.

Undoubtedly the most effective is to use printers with an enclosure, where a closed atmosphere is created during the printing process and considerably minimizes this effect.

3.2 Layer displacement: during printing, a layer is displaced in one of the "x" and "y" axes

This problem usually appears when the printer has been printing for a long time and tends to go out of calibration. The causes can be electronic or mechanical problems. This can also be caused by the head moving too fast when it is depositing the material [26].

Solution

Next, solutions are proposed to avoid the displacement of the layers in the "x" or "y" axis produced for the reasons described above [27].

- The excess or lack of tension in the belts causes irregularities in the transmission of movement.
- Adjust the motor control drivers and calibrate them properly.

- Check that the g-code file is not damaged, and these speed increases occur during the printing process.
- Reduce the printing speed so that the movements are not so fast and the material is not deposited where it should not be, as previously mentioned.

Fig. 20: Layer displacement. (Self made)

3.3 Does not finish printing correctly

As seen in figure 21, the part finished printing before the top layers were closed and the staples were printed. This can be due to several reasons such as the lack of filament in the beret; that the PTFE tube is damaged; that the filament has broken; that the motor has overheated or that there is insufficient pressure in the extruder [28].

Solution

This section lists possible solutions to interrupted printing.

- Printing has stopped because the filament has run out before finishing the part. This should always be checked before starting a new print, as the filament cannot be

changed midway through the process. Therefore, the supply of sufficient filament to print the object must be foreseen.

- Check if the PTFE tube of the hotend is damaged and, if so, it must be replaced.
- It may also be the case that the filament has broken because the pressure exerted on it is not correct or because the extrusion temperature is not adequate. In this case, the filament should be checked for any damage.
- In the case of motor overheating, it has stopped for safety reasons, finishing printing at this point. This happens when you have been printing for many hours or the drivers are not well adjusted.
- It may also be that the extruder pressure to squeeze the filament is not well adjusted. This will loosen over time, allowing plastic to come out.

Fig. 21: Stop extruding the plastic without finishing the print. (Self made)

3.4 Detachment of parts of the figure

As previously mentioned, if there are cantilevered areas, due to the design of the piece itself, that have an angle of inclination greater than 45º, they will tend to detach.
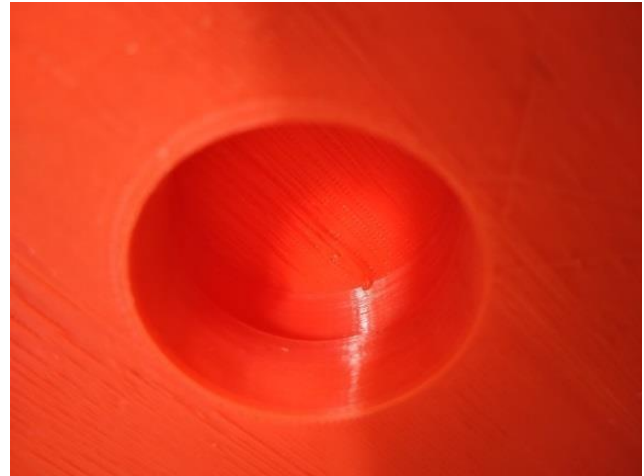
Fig. 22: Detachment of material. (Self made)

Solution

- A possible solution to this problem is the placement of supports, which give the parts a plane on which to stand.
- Another possible solution would be to change the orientation of the part on the build platform. However, in this case, it is not possible because the same problem would be generated in other parts of the part.

3.5 Layer separation

This problem is defined by the lack of adherence between them. It is caused by either the layer height being too high or the print speed being too slow.

Solution

Possible solutions to avoid this problem in 3D printed objects are referenced below.

- When the layer height is too high, greater than 80% of the nozzle diameter, the pressure exerted by the head on the lower layer is less, reducing the adhesion between them. Therefore, if this problem occurs, you must decrease the layer height in the

layering program and regenerate the g-code.

- If the printing temperature is very low, the filament cools faster and cohesion between layers is lost. The same is true if the print speed is too slow. In these cases, it will be enough to increase the temperature and the printing speed [29].
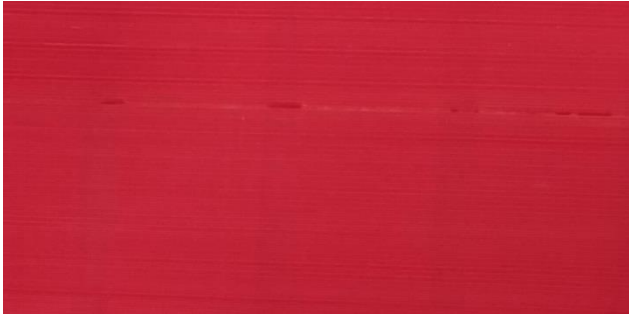
Fig. 23: *Separation between layers. (Self made)*

## 3.6 Stains from another filament

Sometimes, and always in the lower layer, remains of other printing materials are found, embedded in the piece itself. This may be due to the fact that when removing the filament that has been previously used, residues remain in the nozzle, or that possible residues produced by the previous print on the base of the printer have not been removed.

Solution

To fix this problem, it is important to follow these recommendations.

- When one print is finished and another is going to start, with a different material, it is important to remove the filament from the guide duct completely, this is normally done from the printer interface. It is also important to make sure that the previous filament has been completely removed, purging the extruder, letting the molten plastic flow until it comes out completely clean.

- In addition, it may be that, when removing a piece from the printing base and having placed special emphasis on its adherence, it may leave some residue on the base itself. Therefore, cleaning the print bed is very important so that this does not happen.

- Smudges on the print can also occur from overheating of the plastic. In this case it is necessary to decrease the printing temperature.
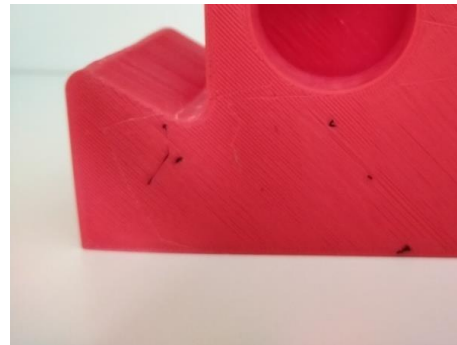
Fig. 24: *Stains from other material. (Self made)*

3.7 Threads

The appearance of threads, in general, is due to a retraction problem of the head during printing, which can be configured in the laminating program through the corresponding parameters.

Solution

To solve the problems of the appearance of threads in the final result of the piece, the following recommended solutions are proposed [30].

- The filament retraction parameter determines how much plastic is retracted at head strokes. If this value is increased, the appearance of debris in the form of threads will be less.

- The retraction speed also influences the appearance of this problem, it is advisable

to handle this parameter with caution, and since increasing it too much can cause air bubbles inside the nozzle, so balance must be sought.

- An extrusion temperature is too high, causes the filament to melt inside the nozzle and become too liquid, resulting in it coming out of the extruder itself [31].
- When very long movements of the head occur, and for the same reason as before, the filament reaches a higher temperature inside the nozzle, causing it to come out due to the texture of the material.
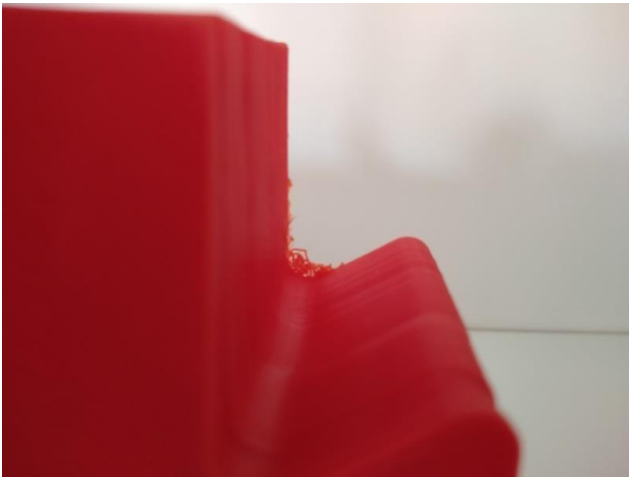
Fig. 25: Appearance of threads. (Self made)

3.8 Inner fill marks on the lateral surface

In this case, it can be seen that the interior fill lines are intuited on the surface of the envelope. This is caused by an insufficient thickness of said wall.

Solution

- When the wall thickness parameter is configured in the lamination program, this value must be increased by at least two layers or 1 mm, as previously mentioned [32].

Fig. 26: The inner filling is perceived on the surface. (Self made)

4. CONCLUSIONS

Once the research work has been carried out, there is sufficient information on the main characteristics of the printed parts and how they can be improved from the manufacturing process. Based on the above, it is concluded that, in the development of this study, the initial objectives have been achieved.

The use of new technologies for the creation of modular pieces makes it possible to reproduce external and internal designs, unfeasible using the extrusion manufacturing method.

Both the choice of printing parameters, as well as the problems derived from it, are determined by the trial and error method depending on the type of printer and the type of material chosen.

The better the part is printed, the less time and costs are invested in the post-processing phase. Likewise, different treatments can be applied to the same piece, as long as they keep

the correct order. Tool polishing post-processing is time consuming.

Regarding the manufacture of the parts, numerous problems have been detected when printing the prototypes with a medium quality, avoiding or minimizing them with the solutions proposed in the development of this research. Likewise, several pieces have been printed using different parameters in each case, choosing the most favorable depending on the needs of the product.

With additive manufacturing, parts with very complex geometries can be designed, but the characteristic initial finish of this technique are the marks caused by the arrangement of the printing layers. These marks depend on the height of the printing layer, with a value of 0.15 mm the resolution of a medium size part is improved.

The position of the piece on the base of the printer determines the elimination of the supports with the consequent saving of printing time and cost, but, for this, it must be taken into account that if the final position of the object presents the line of layers parallel to the load subjected, the resistance is greatly reduced.

If it is necessary to increase the resistance to compression or bending of the object, it is enough to increase the filling density in the manufacturing process, thereby increasing the final cost of the part.

Depending on the results obtained, it is possible to go back, cyclically, to the beginning of the investigation and modify the initial design and manufacturing premises, intuiting the final result.

For any part printed using 3D technology, it is better to have a positive inaccuracy than a negative one, that is, that the part has excess material, since it can be corrected with post-processing. Otherwise, adding material to a part, with negative inaccuracy, is more complicated.

Therefore, 3D printing can be implemented in the field of education through the manufacture of architectural models, designing a methodological proposal through learning based on the construction process from the beginning of the project. With the completion of this study, it can be concluded that the manufacturing process of the parts is complex, that there are many obstacles that we are going to encounter and that the best way to learn any process is to make mistakes and start over, learning to solve each of the problems that arise, as occurs in the actual execution of an architectural project.

In short, this research has qualitatively demonstrated one of the many advantages of 3D printing, both in the manufacture of prototypes for construction and in the implementation of an educational model by making architectural models.

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