Selecting an Enhancement Process for Large-Format Additive Manufacturing Using the Analytical Network Process (ANP)

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Additive manufacturing, also known as 3D printing, has revolutionized industry by enabling the creation of parts with complex geometries and significantly reducing waste compared to traditional methods [1] [2]. In particular, large-format additive manufacturing (LFAM) has established itself as a key tool in demanding sectors such as aerospace and wind energy [3]. However, this technology still faces significant challenges related to part quality, process efficiency, and economic and environmental sustainability.

This study addresses these issues by applying the Analytical Network Process (ANP), a multi-criteria tool for evaluating and prioritizing technology alternatives for improvement [4] [5]. This analysis evaluated four alternatives for improving large-format additive manufacturing. The first is the use of lasers integrated into the extruder to improve adhesion between layers and structural strength [6]. Another suggestion is the implementation of software that allows printing of non-flat layers, which increases strength in all directions and reduces manufacturing time [7]. The use of new materials such as ABS-CF20%, which offers better mechanical and thermal properties compared to conventional polymers, has also been studied [8]. Finally, the recycling of molds and materials was evaluated, a solution that not only contributes to sustainability, but also improves adhesion between layers and significantly reduces costs [9].

The methodology used combines geometric, cost, property and operational criteria. The geometric criteria assess the ability to produce complex parts with high precision and large size. Cost is evaluated from an economic and energy perspective, while property criteria consider the mechanical and thermal characteristics of the parts produced. Finally, the operational aspects include the implementation time and the investment required to implement the improvements. The evaluation process was carried out with the participation of experts from the Institute of Design and Manufacturing of the UPV, using comparison matrices and SuperDecisions software for analysis.

The results of the study highlight recycling as the most viable alternative, with a weight of 45% over the rest. This approach not only reduces operating costs, but also improves the mechanical properties of the parts and enhances the sustainability of the process. In addition, recycling allows molds to be reused in different materials, optimizing available resources. Although the other alternatives offer significant advantages, especially in terms of technological innovation, recycling offers an optimal balance between cost, sustainability and performance, making it the best option for the academic and research context.

The proposed approach is not only limited to technical implementation, but also opens the door to future lines of research. These include the study of the long-term effects of recycling on the physico-mechanical properties of materials and the possibility of combining this technique with other improvements, such as the use of non-planar layers or new materials. This would allow the development of hybrid processes that maximize the benefits of each alternative, further optimizing large-format additive manufacturing. The integration of these strategies could strengthen sustainable development and consolidate LFAM as a key technology in the industry of the future.

In conclusion, this study demonstrates that recycling is the most effective strategy to address the current challenges of large format additive manufacturing. Furthermore, it highlights the usefulness of ANP as a tool to support technological decision making, allowing the identification of solutions that promote efficiency and sustainability in a constantly evolving field.

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