3D Printing of the Bike Frame Prototype

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Abstract. Design is the phase where abstract ideas tend to end up with form and function. There have been a lot of improvements in the last decade in design for 3D Printing. From an advanced manufacturing point of view, 3D Printing is a promising technology to come up with prototypes and products whose geometry is relatively complex, and in some cases when the parts are integrated from several pieces to one. This case can be recognized in the bike frame, which is our case study as an example. The problem that needs to be questioned is: Can we 3D Print the bike frame as a whole? The strengths and weaknesses of actual development will be presented in this article.

Keywords: 3D Printing, Bike Frame, Design, Complex, Integration.

1 Introduction

Recently, advanced production technologies have become very applicable. Based on the steps for product development, the prototype must be generated as soon as possible so that we have data from the physical model. Based on this, 3D Printing is a good opportunity to turn the digital CAD model into a physical model. Related to CAD model in advance we can do other analyses for optimization that make the whole process more flexible. In this research work, the possibility to produce the prototype through 3D Printing is presented. The analyses are important to have more clarifications about the procedure and preliminary calculations for optimization in cases where material is different from the original model.

The paper is organized in this way. In Section 2, the 3D Printing and process description are presented. In Section 3, data from the design of the bike frame was collected and finite element analysis (FEA) as well as optimization was calculated. In Section 4, the conclusions will derive the actual situation and limitations.

2 3D Printing

There are many terms used by the engineering communities around the world to describe this technology. Perhaps this is due to the versatility and continuous development of the technology. In the public domain, the most commonly used term is 3D Printing. Previously, the most commonly used term was Rapid Prototyping [1].

A recently formed technical committee within ASTM international agreed that new terminology should be adopted. While this is still under debate, recently adopted ASTM consensus standards now use the term Additive Manufacturing. Referred to in short as AM, the basic principle of this technology is that a model, initially generated using a 3D CAD system, can be fabricated directly without the need for process planning [2].

Additive processes, which generate parts in a layered manner, first appeared with stereolithographiy (SLA). Since then, several new ideas have been put forth, many patents have been approved, new processes have been invented, and a few have eventually been commercialized. The development of AM can be described in four primary areas. The AM wheel in Figure 1 depicts these four key aspects of AM. They are: input, method, material and applications [1].

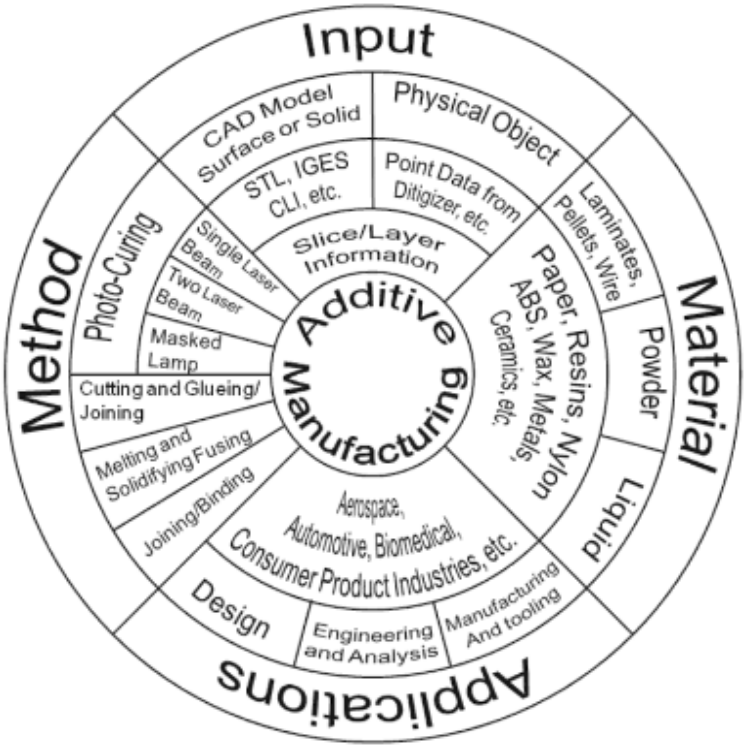


Fig. 1. The AM wheel with four major aspects [1].

All AM systems generally have a similar sort of process chain. Such a generalized process chain is shown in Figure 2. There are a total of five steps in the chain and these are: Step 1: 3D modeling, Step 2: data conversion and transmission, Step 3: checking and preparing, Step 4: building and Step 5: post processing [1].

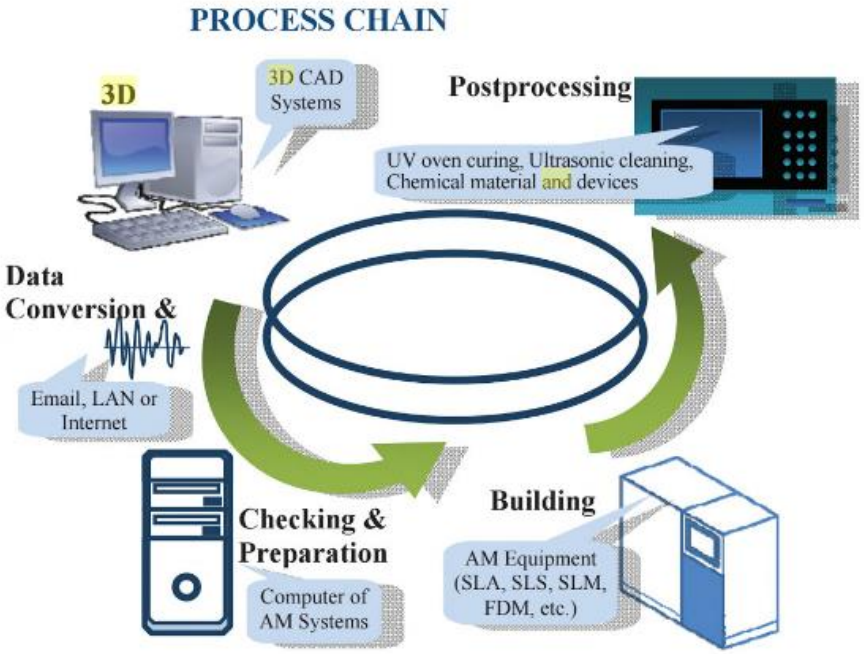
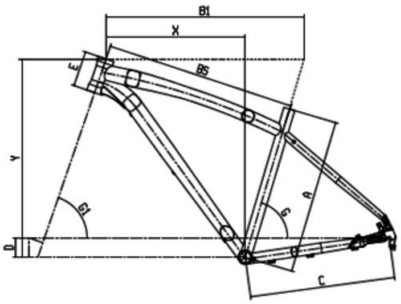


Fig. 2. Process chain of AM systems [1].

3 Bike Frame Analysis

The most popular frame design is known as the diamond or double- triangle [3]. The brands of the Bianchi group have met those of Cycleurope to constitute a unique network in the two-wheel market. Today Cycleurope can implement the most advanced operative synergies involving prestigious European companies, amongst which Bianchi represents the flagship brand. The strategic investments of the group aim at two outstanding targets: the development of a highly-advanced product and the establishment of Bianchi brand on international markets [4].

CAD involves the use of computers to create product design drawing and 3D models [9]. Today CAD systems are covering most of the activities in the design cycle, they are recording all product data, and they are used as a platform for collaboration between remotely placed design teams. CAD systems can shorten the design time of a product [5]. Therefore, the product can be introduced earlier in the market, providing many advantages to the company. CAD systems enable the application of concurrent engineering and can have significant influence on final product cost, functionality, and quality. The model in Figure 3 is Bianchi frame, so it's the first model from the table (M17”), according to all the parameters presented.



SIZE	A	B1	BS	C	D	E	G	G1	Y	X
M 17”	430	590	576	450	60	100	73.5°	71°	606	411
L 19”	480	610	587	450	60	110	73.5°	71°	615	428
XL 21”	530	630	606	450	60	120	73.5°	71°	625	445

Fig. 3. Bianchi frame M17” [6].

3D CAD is done with Autodesk Inventor, where two models are created: ABS plastics model and aluminum piping model.

FEA on bicycle frames has become a common activity for bicycle designers and engineers in the hope of improving the performance of frames. This is typically achieved by balancing priorities for key requirements, including minimizing the mass of the frame, maximizing lateral stiffness in the load transfer from the hands and feet to the drive, maximizing the strength capabilities of the frame to allow for a higher load capacity or better load distribution, and adjusting the vertical compliance of the frame to tune the softness of the ride [7]. The core of the FEA method is an idealization of the object or continuum by a finite number of discrete variables. The Finite-Element program assembles the stiffness matrices for simple elements to form the global stiffness matrix for the entire model [5]. This stiffness matrix is solved for the unknown displacements, given the known forces and boundary conditions. From the displacement at the nodes, the stresses in each element can then be calculated. A comparison of the two models has been made where one is realized according to the real parameters of the aluminum material while the other model is realized by ABS plastic as a possibility to produce in 3D Printer. From the analyzes carried out in the software it emerges that for a similar load in both models with F = 800 [N] we have different deviations based on the mechanical properties of the models as we show in Figure 4.

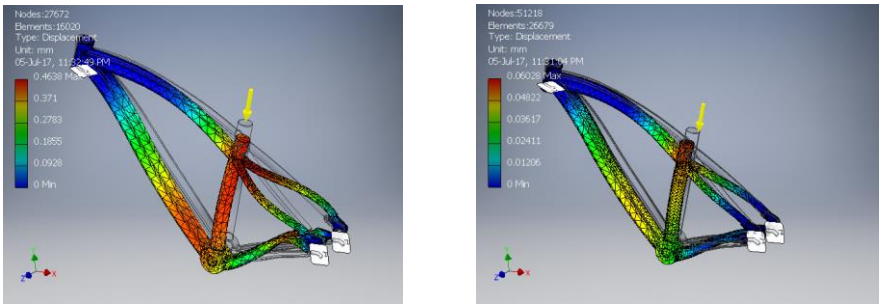


Fig. 4. FEA of bike frame: ABS plastic (left), aluminum (right).

There is the possibility of optimizing the approximation of values in the case of the ABS plastic model but the ability of the material is the one that requires great structural changes. The general work flow of optimization process can be shown in Figure 5.

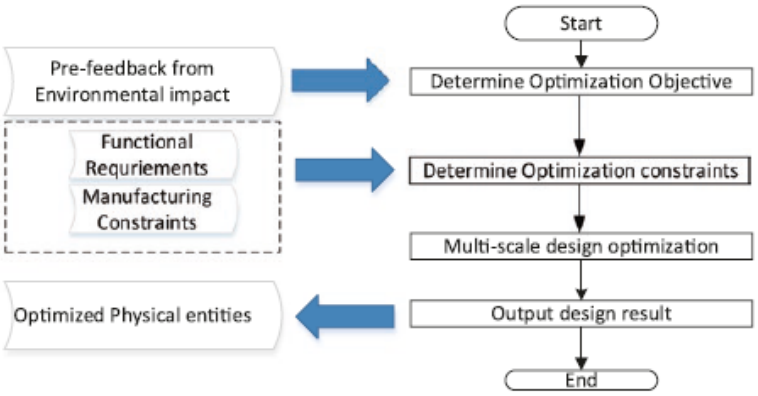


Fig. 5. General workflow of optimization process [10].

Finally, in Figure 6 we can see the CAD model of bike frame in virtual 3D Printer machine. As we know we can choose different 3D Printing patterns with wide range of scope [8], especially for complex designs like bike frame.

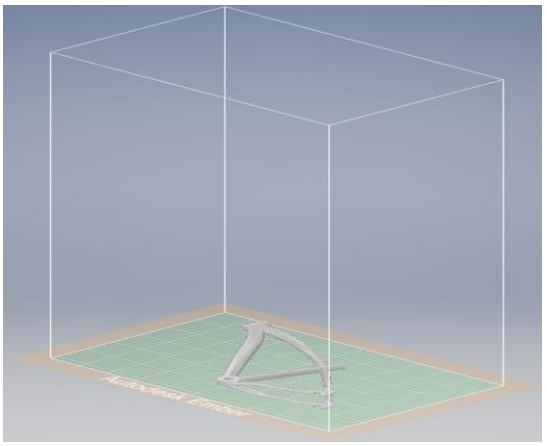


Fig. 6. Virtual 3D Printing of bike frame.

4 Conclusions

Prototypes are very important for the realization of concepts in design, manufacturing, and performing other analyses. Prototyping is an essential step of product development and manufacturing cycles required for assessing the form, fit, and functionality of a design before a significant investment is made. In the product design and development process, designers can have difficulties discussing many

design details on the computer screen, especially for complex shapes. At this moment, the physical model plays an important role from which we can find whether the final design is the same as the original design concept or not. Prototyping using 3D Printing methods is an advanced tool for new product development. Moreover, the comparison of the two models through the FEA of the bike frame shows the difference in stress analysis.

The model (bike frame) can be scaled to fit the corresponding capacity of the 3D Printing machine regarding different AM technologies. This presents the actual limitations of AM technologies when the part geometry is relatively big.

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