Design for Metal Additive Manufacturing of a Bicycle Truss

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Introduction

3D printing (additive manufacturing) is a new manufacturing method that gain attention in the recent decade [1,2]. There are few technologies and methods where most differences are by applying the concept to different materials. Metal printing is done with few technologies (DMLS, SLM, EBM) [3,4]. Thus far there are many applications to 3D printing in plastic or metal, where most focus was on applying the process to rapid prototyping, personalized hardware and curved surfaces.

The project overviews a project which aimed to focus on DFM (Design For Manufacturing) suggested optimization for metallic 3D printing [5,6], so the final construction would be simple, efficient, and will require no professional hardware for post processing of the printed parts or for their assembly. The concepts are demonstrated on known and common bicycle truss structure, which already got lots of reference 3D printed design solutions. One visionary horizon, utilizing the direction proposed by the project, is establishment of databases for designs, where the end user, would be able to pick a design, bicycle frame as example, to insert his desired personal parameters, such as body height, type of bicycle, logo. Then, to print them, in what may be his future local 3D print store, so the end results can be directly used for the final assembly, without a need for professional knowledge or tooling.

Design Aspects

Various designs of truss structures where the 3D printed joints are described in [7,8]. All of those designs did not emphasize the post processing stage required to remove support structures from the printed parts. Moreover, the manual labor and professional tools required for treatment of the printed joints post manufacturing was highly evident in the artistic design of bicycle 3D printed joints by Ralf Holleis [9].

Several design iterations of the bottom bracket joint are illustrated in Figure 1. The joints design approach converged to splitting the joint into two mirror parts, and deciding upon one out of two key options - holding the truss rod by the joint body from the inside, or caging it by the joint body from the outside. The selection of inside versus outside joint holding also dictates the print direction, from the symmetry place outward or vice versa respectively.

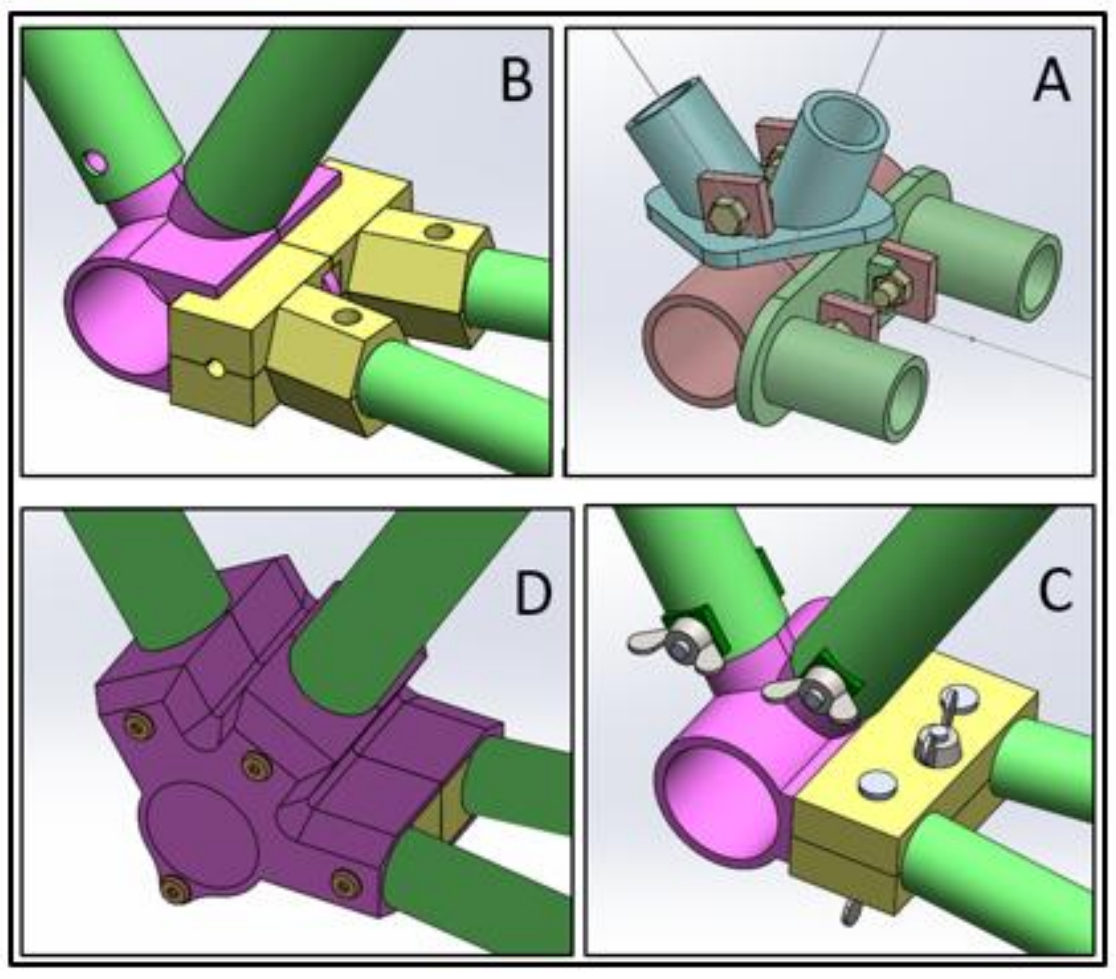

Figure 1: Evolution of bicycle bottom bracket joint design (A to D)

Figure 2 illustrates the complete CAD model whose joints were prototyped by 3D plastic printing, to verify that the parts fit into the assembly and for inspecting the compatibility with peripheral bicycle elements (wheel, chain, pedals, fork). The joints A,B,D,E are outside caging joints type, while joint C is inside holding joint type. It is interesting to note that one of the insights from the prototyping process is that the rear wheel joints (E in Figure 2) were poorly designed for the constraints imposed by the rear wheel and its central axis bolt, and that the design solution was to change the joint design to the inside holding joint type. This modification enabled a better flexibility in setting the width of the wheel joint extension.

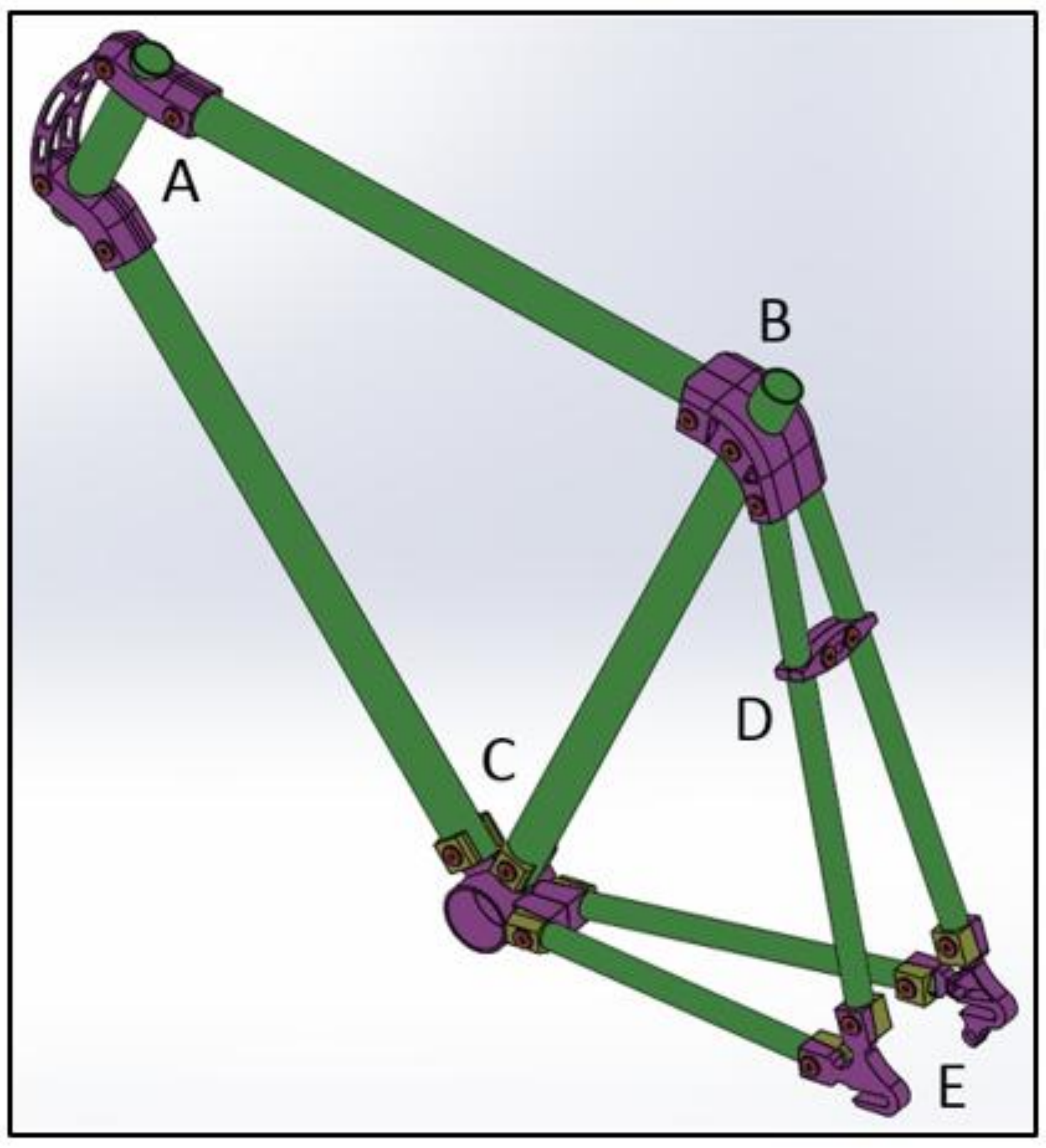

Figure 2: Bicycle frame that was prototyped with plastic joints

Figure 3 shows the assembly of the prototyped parts whose joints are printed in plastic. No post processing or professional tools were needed for the cleaning or assembly of the parts. The assembly was as simple as one which a child can hook up correctly and without any special need for additional hardware.

Figure 3: Bicycle frame prototyped assembly

Figure 4 shows the complete bicycle assembly with peripheral parts. Note this assembly was made with Plastic joints printed parts to validate the design.

Figure 4: Complete bicycle assembly

Conclusions

The project illustrates a design approach of a bicycle truss that is optimized for additive manufacturing. It alleviates some of this manufacturing technology disadvantages for the sake of broader usage and applications. A design process is demonstrated, where external supports are entirely removed by construction and where the final assembly is made as simple as one which an unprofessional adult (or even a child) can handle by its own. The belief is that wide spread usage and availability of design databases as such will advocate broader usage of additive manufacturing in the future.

References

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