Lightweight Additively Manufactured Bell Crank

Background:

The Air Force (AF) faces significant challenges sustaining the legacy fleet, which operates for extended periods of service. In fact, the average age for an aircraft in the AF inventory is 27 years. As an extreme example, the B52 Stratofortress was built in 1955. There are many challenges in sustaining these aircraft, including finding replacement parts for low-volume components and Out-Of-Production Spares (OOPS). Often, original manufacturers for these aircraft components have long been out of business and, while the most of the technical data may remain, there is often important information that has been lost.

One such component common across military and civilian platforms are bell cranks type parts. These bell cranks are responsible for a myriad of different functions, but typically are responsible for some sort of actuation and mechanical movement. Such a part would likely be produced in relatively low quantity, making the tooling required to manufacture the part hard to justify on a per part cost basis. When this consideration is combined with other design factors such as intricate part geometry, and desire for low weight, Additive Manufacturing (AM) seems a sensible route to production. In addition, AM allows new design freedoms not explored when the original part was produced. Topology optimization and organic design methodologies can be utilized to reduce weight while maintaining the required overall mechanical properties. For further information on Additive Manufacturing, please refer to the ASTM F2792-12a[1] document entitled "Standard Terminology for Additive Manufacturing Technologies."

Concept:

The purpose of this Senior Capstone Design project is to develop, build, and test a representative bell crank which meets baseline mechanical properties while minimizing weight, cost, and/or manufacturing time. Specifically, the Air Force sponsor will provide a paper drawing of an exemplar bell crank (shown in Figure 1). The revised bell crank design must have the same hole pattern and not exceed the original component's triangular bounding. Finite Element Analysis (FEA) will be required to determine the baseline part performance, as well as to assess new lighter weight or topology-optimized designs. It is desired that the bell crank be manufactured as a single component using an appropriate AM method. The final designed and manufactured bell crank must be failure or proof tested to ensure that it meet the baseline part performance.

Design considerations include, but are not limited to:

- Component level mechanical performance
- Weight
- Secondary post processing requirements
- Overall manufacturing cost and time

[1] ASTM F2792-12a is available for purchase at www.astm.org. It may also be available through your academic department or your university library.

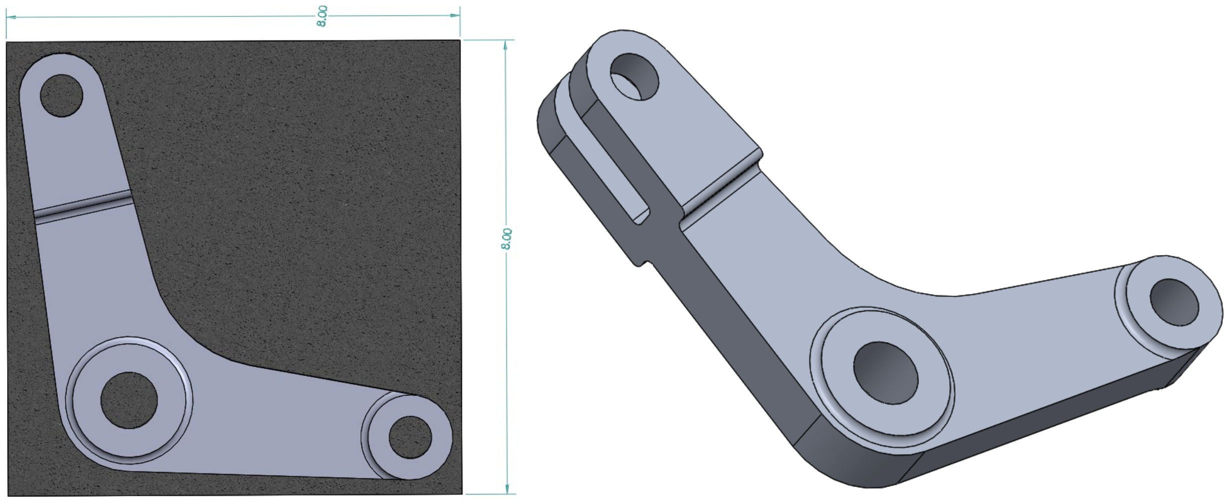

Figure 1. Image of the roughly 8''x8'' bell crank in top (left) and isometric (right) views.

While original material will be provided as part of the original drawing, anisotropic material properties must be obtained. It is therefore recommended that, prior to design and testing, tensile specimens are produced using relevant processing parameters to obtain the process and material specific anisotropic responses[2]. Creation of a several test bell cranks using the selected Additive Manufacturing technique is desired and, subject to approval, will be supported by the sponsor. Due to the lack of required tooling and low lead times typical of AM, multiple design iterations should be possible and are encouraged, but careful consideration of budgetary constraints of producing several full-scale parts must be undertaken.

Skills Needed for This Work:

1. Basic understanding of Additive Manufacturing.
2. Materials Science knowledge to analyze optimal materials selection, wear, and failure
3. Mechanical/Aerodynamic design skills
4. Finite Element Analysis proficiency
5. CAD proficiency

Sponsor:

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[2] While ASTM has standards for tensile testing in metals (ASTM E8) and polymer (ASTM D638), there is currently no standard for as printed additive specimens. Following an ASTM standards or similar is preferred, but other test methodology may be acceptable at the discretion of the sponsor.