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Optimization-driven conceptual design tool for AM components

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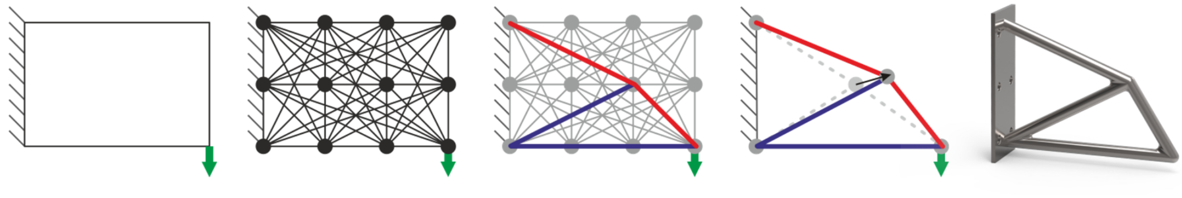
Additive manufacturing (AM) techniques are developing apace, and are now sufficiently mature to be used in the production of high value components. However to benefit from the unprecedented design freedoms offered, effective optimization techniques are required. Although topology optimization techniques have proved popular recent years, these are generally computationally expensive, particularly if a fine mesh is required in order to resolve fine detail when low volume fractions are involved (i.e. if the component occupies only a small proportion of the available design domain). Furthermore, topology optimization approaches normally require labour intensive post-processing in order to realise a practical component, often leading to long and labour intensive workflows.

In this contribution it is shown that layout optimization (LO) can be used in conjunction with geometry optimization (GO) to provide the basis for a powerful and effective conceptual design tool for AM component designers, building on previous work in this area [1, 2]. The approach is particularly useful when the degree of design freedom is high, where truss-like forms are typically found to be very structurally efficient. With LO the design domain is discretized using a grid of nodes which are interconnected with discrete line elements. Linear optimization is used to identify the subset of elements forming the minimum volume structure required to carry the applied loading. GO, which involves adjusting the positions of the nodes using non-linear optimization step, can subsequently be undertaken to simplify and improve on the solution. Simple rules can then be used to automatically transform a line element layout into a 3D continuum. The various stages involved in the process are shown in Figure 1. Smith et al. [2] demonstrated the efficacy of the basic approach, manufacturing various component designs in titanium Ti-6Al-4V using the electron beam melting process, and performing load tests to show that target load capacities could be attained.

As solutions can be obtained very rapidly using the approach described (often in a matter of seconds on a modern desktop PC) it can be incorporated in interactive CAD software tailored for use at the conceptual design stage. Also, because of the high-level nature of the solutions generated (which involve members and joints, rather than low-level meshes), these can readily be interactively modified by the user, and



(a) (b) (c) (d) (e)

Figure 1: Stages in the optimisation process: (a) design domain, loads & supports; (b) nodes distributed across the design domain & potential truss element connections; (c) resulting minimum volume truss; (d) positions of nodes modified using geometry optimisation to further improve the result; (e) truss elements replaced with solid elements (e.g. cylinders) and joints added to create a watertight volume

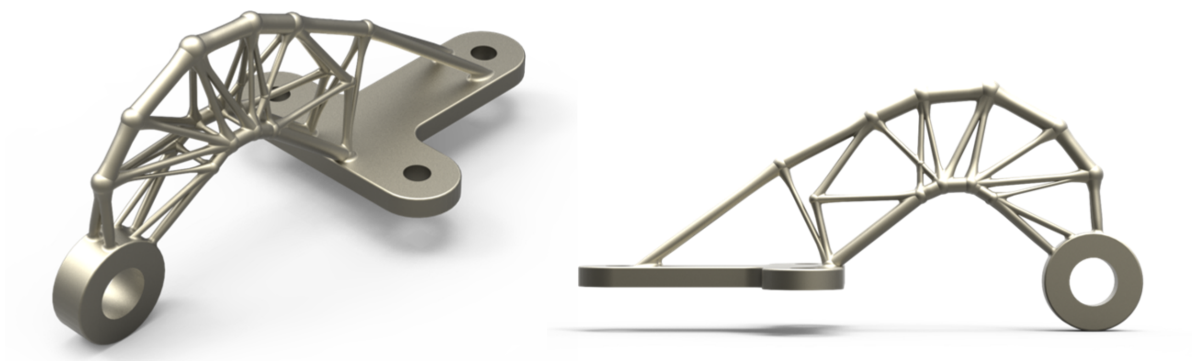


Figure 2: New design for Bloodhound SSC airbrake hinge

further optimized if required (i.e. as part of a 'human-in-the-loop' optimization process). This allows a range of issues not included in the original optimization formulation to be taken account of (e.g. aesthetic and/or practical considerations). Interactive software incorporating the approach described has recently been developed [3] and has been applied to a range of practical design problems. Figure 2 shows a new airbrake hinge design for the Bloodhound supersonic car generated using the software. This design is simpler than the design described by Smith et al. [2] yet is still approx. 70% lighter than the original, non-optimized component, clearly demonstrating the efficacy of the approach.

References

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