Overhang free design for Additive Manufacturing using Genetic Algorithm based Topology Optimization

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1. INTRODUCTION & OBJECTIVE

Additive Manufacturing (AM) has now become a matured technology to print parts of very high complexity to be directly used in applications. Topology Optimization (TO) is an ideal candidate to benefit from this free form manufacturing capabilities of AM as optimum designs generated by TO generally are very complex. However AM processes have limitations especially metal based AM process (SLM/SLS) while printing parts which have overhangs. There exists maximum length of overhang and angle with respect to build direction beyond which parts can't be printed without defects. Several methods have been applied previously to overcome this limitation such as use of sacrificial supports which can be removed during post processing [4] or providing minimum support to overhangs that becomes part of design [6]. Both these methods have drawbacks as they consume time, energy, are costly and labor oriented.

In this paper, a general frame work is proposed to design components using genetic algorithm (GA) based Topology Optimization in which overhangs are restricted within their critical value in such a way that it can be conveniently printed by AM process. The design is discretized in to finite elements where each element is assigned design variable 0 or 1. '0' represents absence of material and '1' represents presence of material. Customized GA is applied for TO using novel crossover and repair operators. The operators are designed in such a way to mimic AM process of adding material layer by layer. The Additive Manufacturing constraint is implemented such a way that material will be deposited to an element if there is sufficient material in layer below it.

The objective function is the compliance of the structure subjected to volume constraint. The optimization problem can formally posed as.

$$
\begin{aligned}
\text{min}:\ & c(\boldsymbol{x}) = \boldsymbol{q}^T \boldsymbol{K} \boldsymbol{q} \\
\text{st:}\ & \boldsymbol{K}\boldsymbol{q} = \boldsymbol{F} \\
& \frac{\mathrm{V}}{\mathrm{V_0}} = vol.\ frac \\
& 0 \le \boldsymbol{x_{min}} \le \boldsymbol{x} \le 1
\end{aligned}
$$

Where c(x) is compliance/strain energy objective function, **x** is design variable vector, **K** is global stiffness matrix, **q** is nodal displacement vector of entire structure, **F** is force applied, v is volume of structures, V_0 is initial volume of structure, vol. frac is limit on volume of structure.

2. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

The domain is discretized in 320 elements a vertical load acting downward as shown in figure 1. The GA parameters are initialized and maximum number of iteration is set to 100. The optimum value of objective function is 7.8 which is slightly more than without overhang as search space is now restricted due to overhang consideration. The deterioration of objective function value is compensated by gain in manufacturability of the design .The optimized design is shown in figure2. Convergence history plotted in figure3. It can be observed that the overhang is reduced to a greater extent hence part can be printed directly without additional support structures needed. This customized GA can be implemented with other objective functions and constraints. It can also be utilized to solve multi objectives Topology Optimization problems.

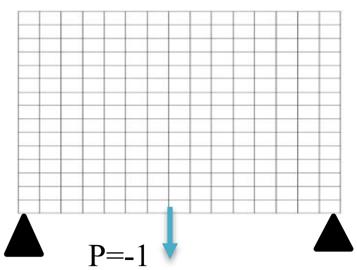

Figure1: Discretized Domain

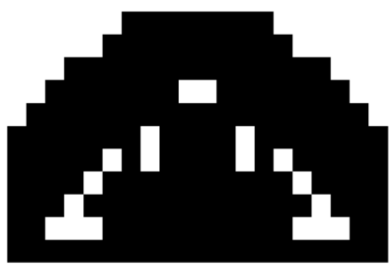

Figure2: Optimized Design

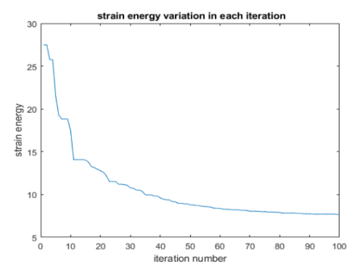

Figure3: Convergence Plot

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