Abstract

Traditional additive manufacturing infills use uniform geometry through the printed part, but the stresses from applied loads rarely stress the part uniformly. This inefficient use of material can be fixed by applying an infill that adds additional material to the areas most affected by stress, while removing it from areas that have minimal stress. Ideally, this infill will maximize the part’s strength to weight ratio, which reduces print time and cost while increasing functionality.

Goals:
- Design an infill with a structural density gradient that can automatically be applied to any existing part.
- Test and simulate the infill to determine if it improves a part’s strength and weight properties.
- Find suitable applications for this infill.

Background

When torsion and bending are applied to a part, the stress is greatest in areas furthest from the centroid, which is where more material should be placed to improve part strength. Following this logic, if material is added to the center of the part, the stress increase will be minimal compared to the weight increase, which would make the part less efficient. These predictions were made using the torsion stress and bending stress equations below:

\[ \tau = \frac{M}{J} \]

\[ \sigma = \frac{M}{I} \]

When uniaxial compression is applied, the force is distributed evenly throughout the cross-section, since the stress is simply the force divided by the cross-sectional area. Consequently, adding additional material at the edges as opposed to adding the material to the center should provide no additional benefit; therefore, no change in the stress-to-weight ratio is expected when this infill technique is used on uniaxially compressed parts.

The affect that this infill has on transversely compressed parts can not be easily predicted with simple equations, but instead requires more complex testing and simulation.

The four tested and simulated infills are shown below:

Results

For torsion, only simulated results could be obtained. A torque of 20 Nm was applied normal to the cross-section, then the displacement and stress were calculated. By multiplying the stress and theoretical mass, a composite score for each part was calculated in order to determine a relative torsion resistance efficiency. Based on this, it can be expected that the modified double layer infill has the best strength-to-weight ratio.

For bending, only simulated results could be obtained. A torque of 50 Nm was applied tangent to the cross-section, then the displacement and stress were calculated. The same scoring system was used, which shows that the modified single layer infill offers the best strength-to-weight ratio for bending.

Conclusion

The density gradient infills offer structural and weight benefits when bending and torsion loads are applied, but has no benefit with uniaxial compression or transverse compression. Consequently, this infill can greatly benefit parts such as levers and shafts; however, the infill would be recommended against for parts that receive transverse compression loading, such as rollers. If applied correctly, this infill could provide an efficient way to improve the structural properties of a part. Further research needs to be conducted in order to analyze additional infill structure configurations. Additionally, more loading conditions need to be analyzed, such as shear and buckling load cases.

References


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