Summary

In the realm of steel structures optimization, wire-arc additive manufacturing (WAAM) techniques have revolutionized traditional manufacturing processes by offering enhanced design flexibility, shorter lead times and intricate structural possibilities. However, despite the benefits, inherent manufacturing constraints must be considered to ensure optimal manufacturability and part quality. One critical constraint in metal additive manufacturing, particularly in steel structures, is the occurrence of local overheating during the fabrication process. Local overheating can lead to defects, diminished mechanical properties, and dimensional inaccuracies in the final parts. While efforts have been made to mitigate overheating by controlling overhangs, it remains a persistent challenge.

To address this issue, innovative methodologies have been developed, leveraging computational design tools such as topology optimization (TO) tailored specifically for steel structures. These methodologies aim to integrate constraints that minimize the risk of local overheating while optimizing structural layouts which are fabricated using WAAM. In this context, the following contributions have been made to enhance steel structures optimization in additive manufacturing:

1. **Geometry-Based Hotspot Detection Approach:** A novel approach is developed to detect potential hotspots by assessing the local conductivity based on the material distribution around each element of the structure. This information allows for the generation of a temperature field (hotspot map) to qualitatively estimate overheating risks in specific areas of the part.

2. **Integration into Topology Optimization (TO):** The geometry-based hotspot detection method is seamlessly integrated into TO algorithms as a constraint. This integration enables the optimization of structural layouts while suppressing features prone to local overheating, thereby enhancing the manufacturability and quality of steel parts produced through AM.

3. **Space-Time Topology Optimization (STTO):** The geometry-based hotspot detection method is further integrated into Space-Time Topology Optimization (STTO) techniques. STTO considers both structural layout optimization and fabrication sequence optimization simultaneously, thereby addressing challenges associated with curved layer deposition and minimizing the risk of local overheating throughout the manufacturing process.

Comparative studies demonstrate the computational advantages of the geometry-based constraint approach over existing methods for reducing local overheating. Additionally, the maximum temperature obtained from transient simulations aligns closely with results from established physics-based methods, validating the efficacy of the proposed strategy in mitigating overheating issues in WAAM-produced steel parts.

In summary, the integration of geometry-based hotspot detection techniques into topology optimization frameworks represents a significant advancement in the optimization of steel structures for WAAM, contributing to improved part quality, manufacturability, and design flexibility.