Control of microstructure and mechanical properties of wire plus arc additive manufactured C-Mn steels

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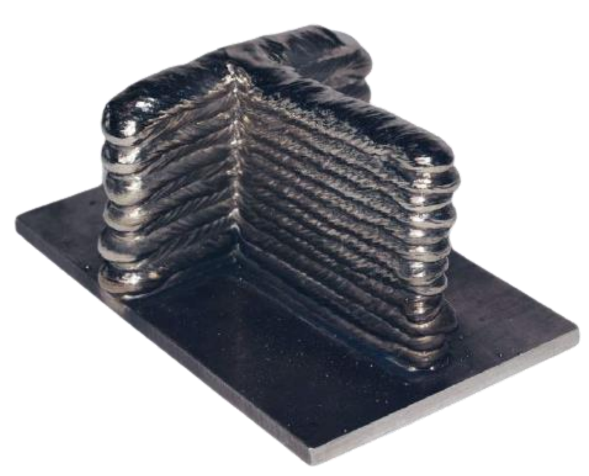
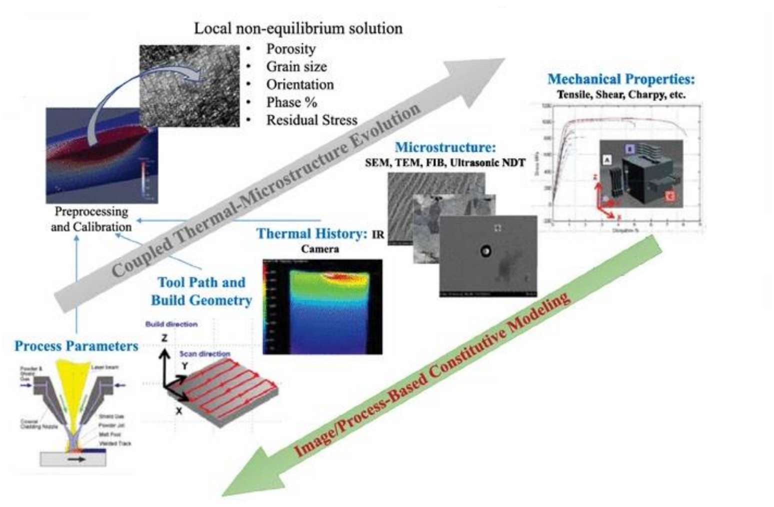
Overview

Image source: https://waammat.com/about/waam

- Wire plus Arc Additive Manufacturing (WAAM) is a direct energy deposition method to additively manufacture engineering components
- It utilizes an electric arc as a heat source with welding filler wires used as feedstock for the process of Additive Manufacturing (AM)
- WAAM demonstrates a high rate of deposition, minimal wastage of material, low cost and is an environmental friendly process

Research Limitations



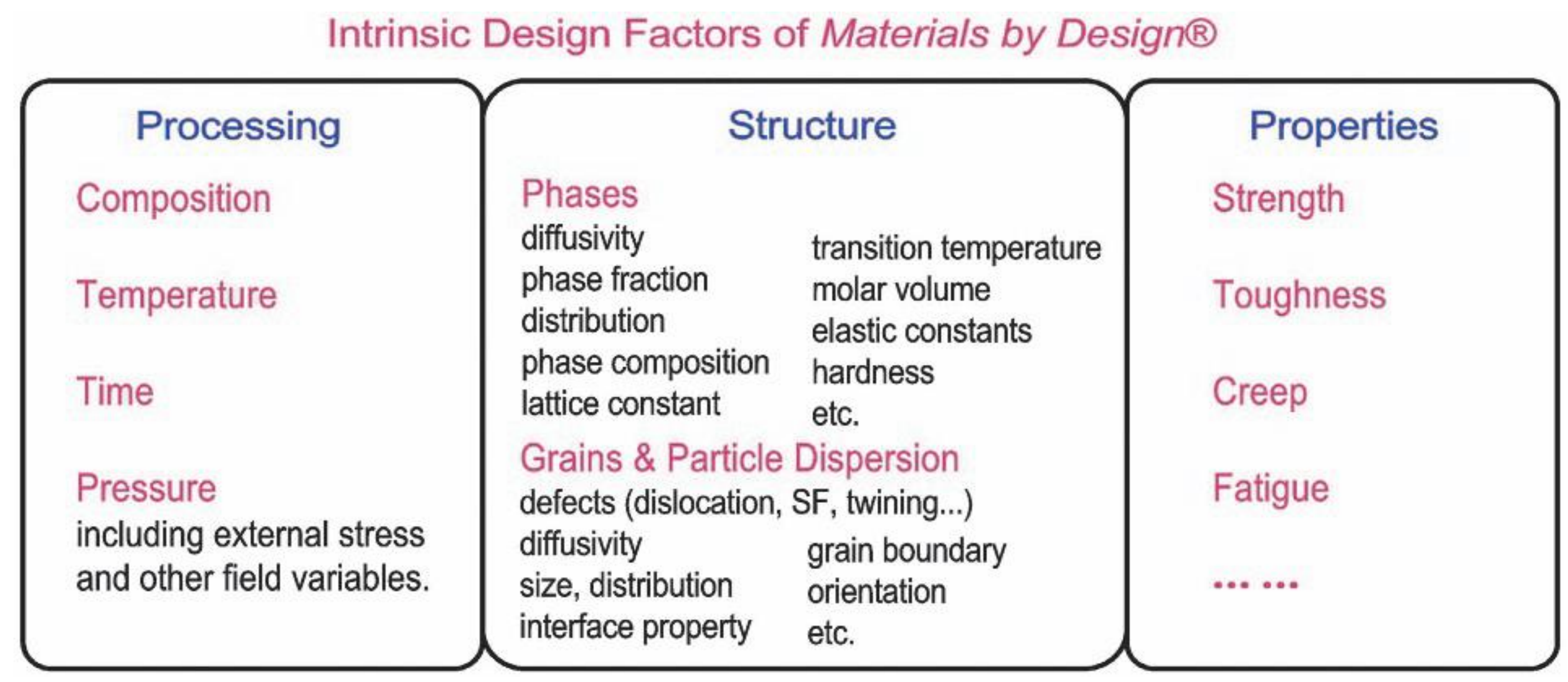


- Although WAAM research has been carried out on other materials, little research has been carried out on steels due to the complex phase transformations
- WAAM products have a rough finish, structure integrity & lower mechanical properties
- C-Mn engineering steels manufactured by WAAM exhibit good toughness but poor strength
- A Structure-Property relationship with sound microstructural basis translating to mechanical property is required

Research Objective

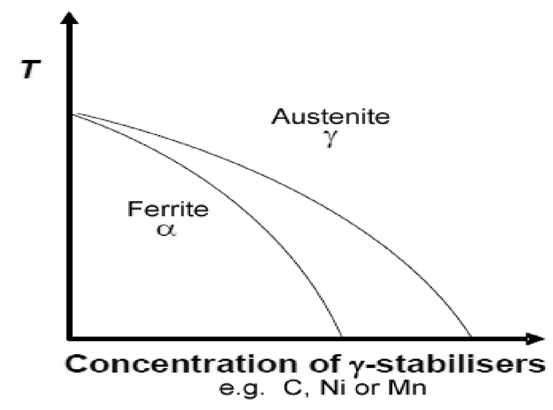
- The objective of this research is to attain homogeneous microstructure throughout the material and minimize anisotropy in the material's properties
- To identify the affecting process parameters and element's influence on the final microstructure
- The qualitative effect of elements are to be identified from literature, while thermodynamic simulations can determine the composition for stable phases
- Mat calc or PyCalphad can be used to estimate the stable phases and the cooling curves for a given material composition can be estimated with JMatPro

Factors influenceing Microstructure



- Fundamental parameters which influence the materials property / structure are: temperature, time and its composition.
- In AM processes these are interdependent parameters
- The effect of these parameters in Carbon-Manganese steels are discussed;
- **Stable Austenite (γ) region:**

  The temperature range for stable austenite phase



- **Cooling rate:** Cooling rate through upper critical region ($t_{8/5}$)
- **Alloying elements:**

Carbon:
- γ stabilizer
- Leads to carbide precipitation and inversely affects temper resistance
- Influences microstructure such as idiomorphic ferrites, bainite, martensite

Manganese:
- γ stabilizer
- Solid soln strengthening
- Mn concentration has different effects on AF

Titanium:
- Ferrite stabilizer in large quantities
- Benefits Acicular Ferrite (α_a), due to low lattice mismatch with ferrite lattice

Vanadium:
- Leads to precipitation during reheating of weld bead
- Precipitates increase strength but decreases toughness
- The top bead lacks V precipitates

Chromium:
- Cr reduces the allotriomorphic ferrite content
- Hence in lower quantities, AF is promoted
- While on higher conc. Bainite phase is favoured

Nickel:
- γ stabilizer
- Affects carbon activity, leading to formation of ferrite with second phases

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