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Considerations and Challenges with Additive Manufacturing of Nickel-base Superalloys for High Temperature Design in Gas Turbines

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Audience

Engineers in the power generation and/or aerospace industry interested in leveraging additive manufacturing (AM) technology to further improve the efficiency of gas turbines or similar systems through leveraging advanced designs and materials (nickel-base superalloys).

Training Description

Metal AM technology has made significant advancements over the last decade and has enabled the ability to fabricate more complex designs/features in even the most complex alloy systems (e.g. nickel-base superalloys). These materials are important alloys to the power generation and aerospace industry and these advancements have led to increase interest in leveraging AM into systems such as gas turbines. Although many of these alloys can be printed crack free and fully dense, there still exists many challenges and considerations before the technology can be fully realized. This training is designed to provide engineers with a general overview of the AM technologies utilized for fabricating nickel-base superalloys, such as laser powder bed fusion (LPBF), electron beam (EB) , and directed energy deposition (DED). The challenges associated with AM of these alloys will also be a core focus, such as optimization of alloy chemistry, orientation effects, microstructural differences due to build process, proper heat treatment, quality assurance, and optimization of printing parameters. Several examples will be discussed to show the potential benefits of AM in nickel-base superalloys when properly utilized, such as advanced designs in hot section gas turbine guide vanes.

Training Learning Objectives

The overall goal of this training is to provide sufficient background knowledge of AM in nickel-base superalloys to help enable engineers/students with the required knowledge to consider how AM can be leveraged in novel component designs for gas turbine engines or similar components exposed to extreme environments. After the training each participant should be able to:

1. Explain the fundamentals of typical AM methods that can be utilized to print complex nickel-base superalloys crack free and fully dense.
2. Understand the advantages and disadvantages of the various process methods.
3. Explain how composition of such alloys can be modified to improve the printability.

4. Understand the challenges associated with AM of nickel-base superalloys, such as orientation effects, heat treatment and the effect of processing method on microstructure.
5. Identify proper heat treatment temperatures steps needed to provide optimal mechanical properties in AM nickel-base superalloys.
6. Explain such as differences in microstructure and mechanical properties due to orientation effects.

Content and Outline

1. *Fundamentals of AM process methods for nickel-base superalloys*
    a. Laser powder bed fusion (LPBF)
    b. Electron beam powder bed fusion (EBPBF)
    c. Directed energy deposition (DED)
2. *Advantages and disadvantages of AM in nickel-base superalloys*
    a. Differences in process methods
    b. Enabling complex design/features in components
3. *Optimization of alloy chemistry*
    a. Process challenges with nickel-base superalloys
    b. Modifications of composition to improve printability
4. *Microstructural differences in AM alloys*
    a. Comparison to typical cast nickel-base superalloys
    b. Orientation effects due to processing and effect on mechanical performance
5. *Importance of heat treatment in AM nickel-base superalloys?*
    a. Why standard cast alloy heat treatments are not sufficient
    b. Importance of recrystallization and optimization of mechanical properties
    c. Challenges with heat treatment vendors
6. *Methods for quality assurance in additive manufacturing*
    a. Quality assurance test pieces for metallography and mechanical testing
    b. Various non-destructive testing techniques
    c. Potential opportunity for process compensated resonance testing (PCRT)
7. *Examples of how AM technology has been used in gas turbines*
    a. Printing of guide vanes in an F-class industrial gas turbine
    b. Current research to further improve efficiency of large industrial based guide vanes
    c. Pathways to decarbonization enabled by AM