Fabrication of Extreme Environment Materials for Large Parts Using Additive Manufacturing Methods

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AM Process Development for High Temperature Superalloy IN939
Design of Large-Area Selective Laser Melting (LASLM)
Develop In-situ Microstructure and Mechanical Property Enhancement Process for SLM

The Challenge/Opportunity

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- AM process using high temperature superalloys for engine components is needed
- Few AM options exist for large metallic components
- Improved quality, microstructure, and mechanical properties of AM parts is needed

Project Objective and Benefits

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- Develop AM process for IN939
- Design cost-efficient large area selective laser melting system (LASLM)
- Develop In-situ microstructure and mechanical property control for AM process

AM Process Optimization of High Temperature Materials (IN939)

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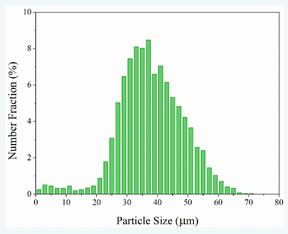

IN939 powder and size distribution

A commercial 3DSystems ProX300 machine was used to develop machine parameters to yield dense parts with the IN939 powder.

Microstructure and Hardness of AM IN939 samples

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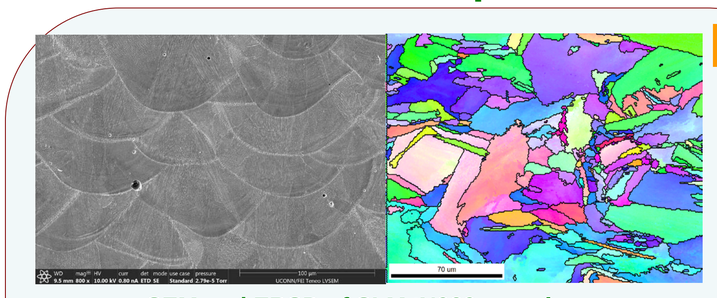

SEM and EBSD of SLM IN939 sample

Sample	Average HV	STD
1	360	15
2	365	8
3	364	8
4	361	15
5	367	8

Summary of average Vickers hardness

Generic nozzle guide vane ring with internal cooling, 180 mm diameter.

AM Demonstration of IN939 engine component

In-situ Microstructure and Mechanical Property Optimization

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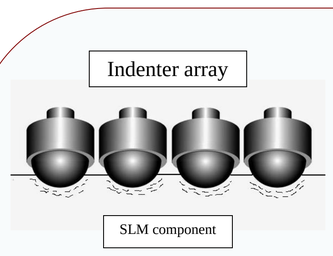
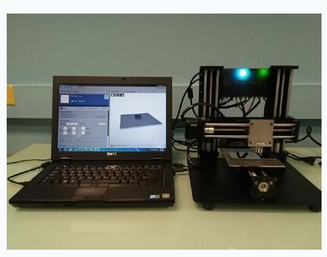
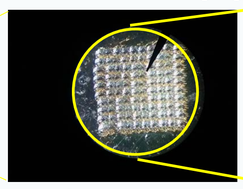
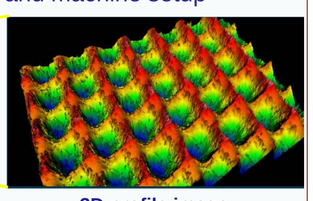




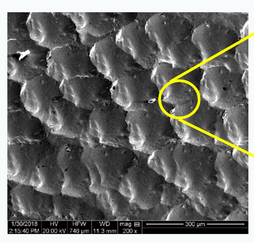
Schematic of Selective Area Forging and machine setup

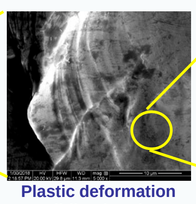


SAF Pattern

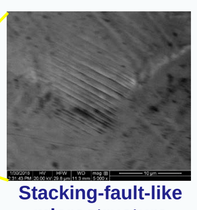


3D profile image





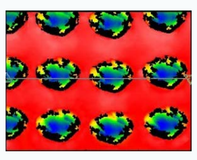
Plastic deformation sliding bands



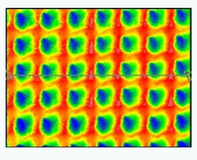
Stacking-fault-like microstructure

Severe plastic deformation and defects were introduced by Selective Area Forging (SAF)

0.5 mm



2 mm



	Overall PV (Peak to Valley)	
	Average (μm)	St Dev
Sharp Tip (0.5 mm)	18.3304	2.351383
Sphere Tip (2 mm)	7.5	1.12867

0.5 mm diameter tip with current loading conditions generates plastic deformation depth more than 10 μm, comparable to current LSM layer thickness.

Develop Large Area Laser Beam X-Y Scanner

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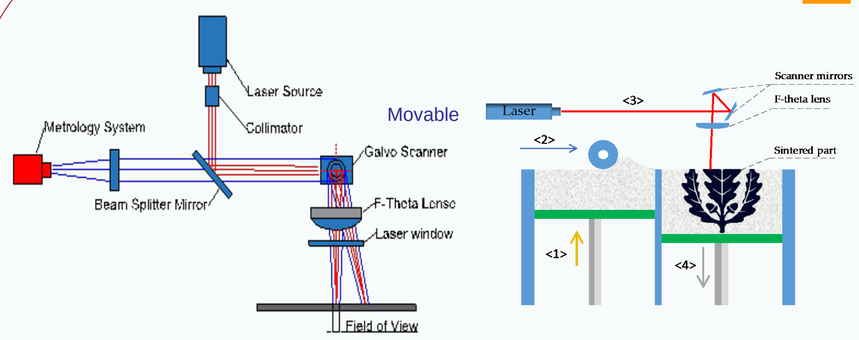
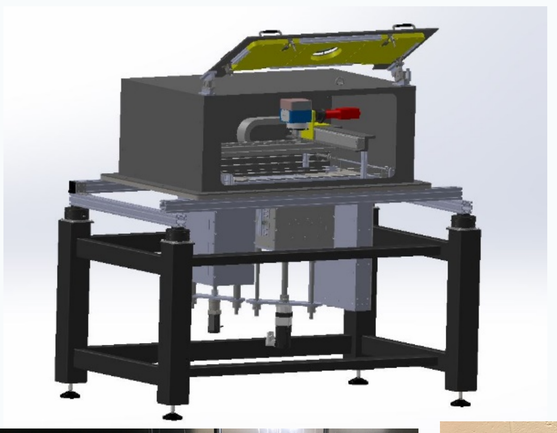
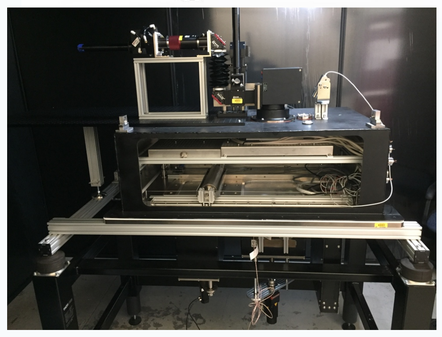


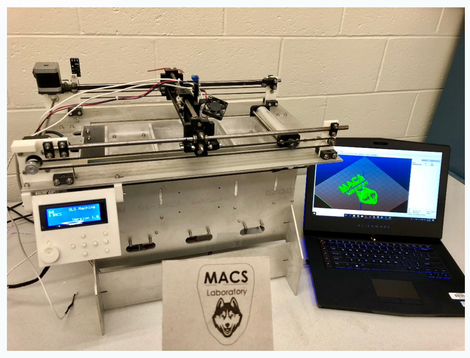
Schematic of LASLM



Designed large-area selective laser sintering system with:
- 15”×15”×12” build volume
- Complementary Cartesian motion stage



Design leverages current in-house built testbed



Slicing and 2D sintering software designed, deployed, and successfully validated on small-scale prototype machine

Summary

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- Process optimization completed for AM of IN939
- Demonstrated AM fabrication of 180 mm diameter IN939 engine component with a commercial SLM system.
- Completed the design of a cost-efficient LASLM and the demonstration of a small-scale system.
- Evaluated the feasibility of in-situ microstructure and mechanical property optimization using selective area forging (SAF).

Milestone Status

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- Completed IN939 process optimization using commercial SLM system (Jan. 2018)
- Completed machine design of LASLM and demonstration of a small-scale system. (Feb. 2018)