Adiabatic Film/Transpiration Cooling Effectiveness of an Additively Manufactured Structures

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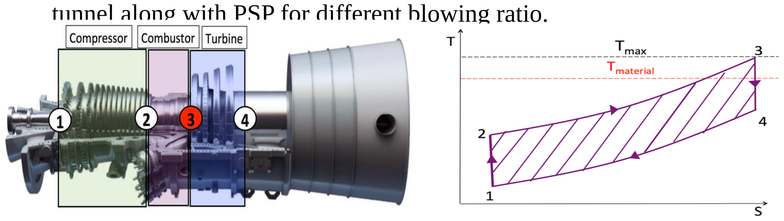
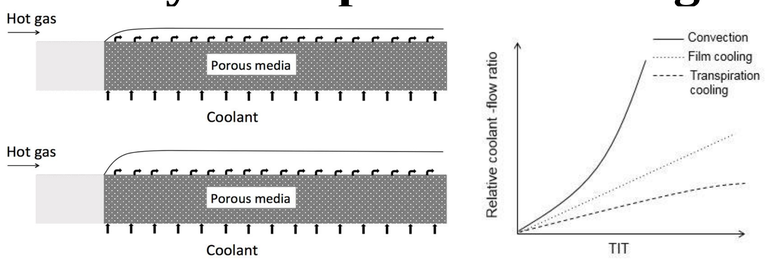
Objective

- In this study, leading edge of blade section along with transpiration cooling and S-shaped NPR structured are printed by using IN718 powder in EONINT M270. Printed material is further tested in wind tunnel along with PSP for different blowing ratio.



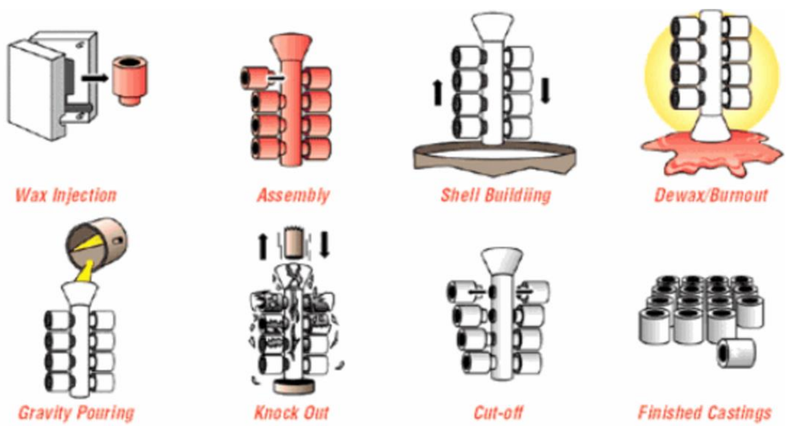
(a) Highest temperature at turbine section (b)T-S diagram for Brayton cycle

Why Transpiration cooling



(a) Transpiration cooling (b) Comparison of other cooling techniques

Why Additive Manufacturing

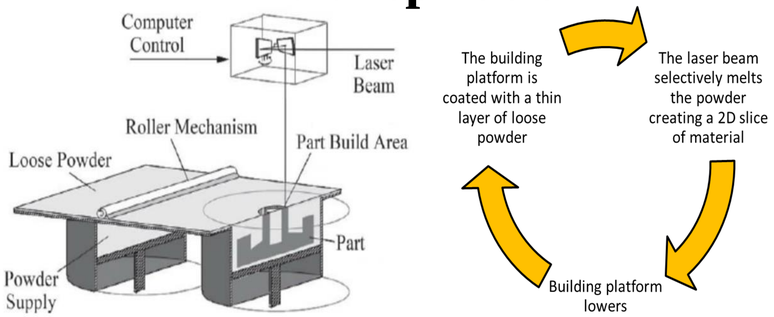


Conventional manufacturing – casting process to manufacture simple cylindrical surface

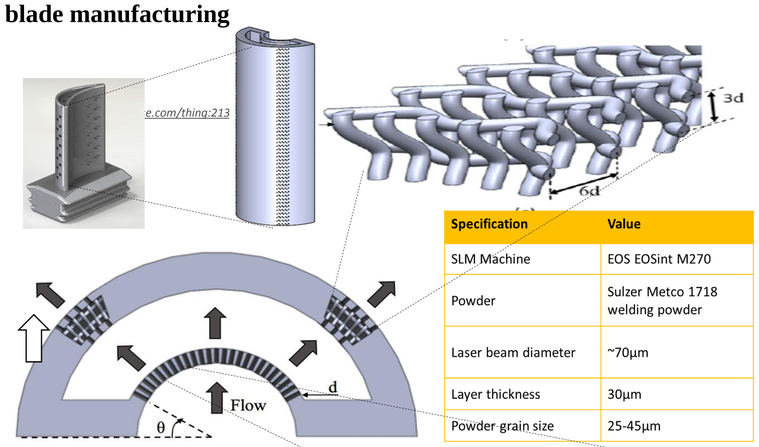
Why NPR Structures

NPR (Negative Poisson Ratio) or auxetic structures change shape under loaded conditions, as a result of which effective stress is reduced and life of the part increases. Additive manufacturing allow a pathway to making such parts.

AM transpiration



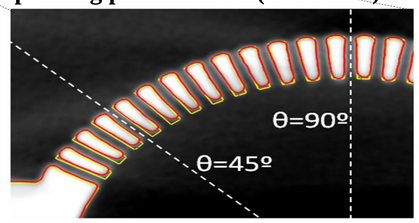
Direct Metal Laser Sintering process(DMLS-EOSINT M270) for turbine blade manufacturing



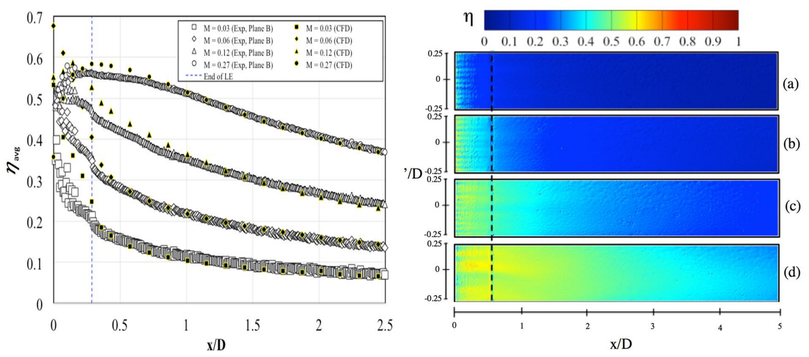
Specification	Value
SLM Machine	EOS EOSint M270
Powder	Sulzer Metco 1718 welding powder
Laser beam diameter	~70µm
Layer thickness	30µm
Powder grain size	25-45µm

Printed leading edge section and printing parameter set(d=0.5 mm)

z/L	Hole center location θ= 90°	θ= 60°	θ= 30°
0.03			
0.25			
0.51			
0.75			
0.97			



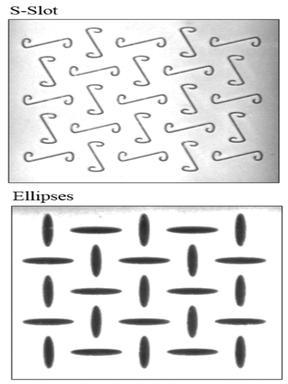
NDE evaluation about concentricity(quality checking)

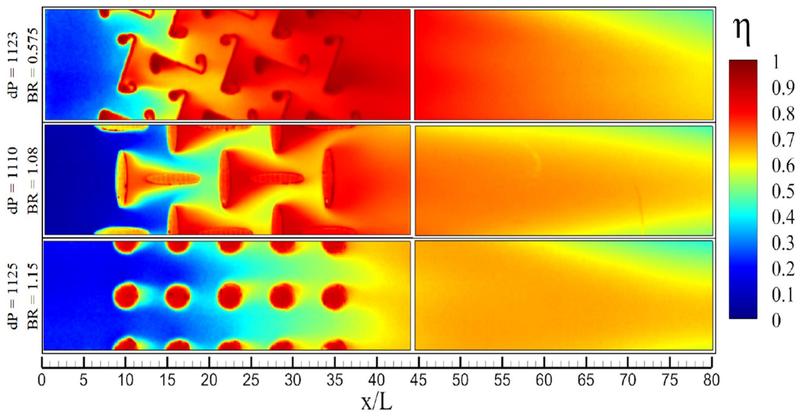


(A)Lateral average effectiveness comparison between experiment and CFD for various blowing ratios(B) Experimental local effectiveness ratios(a)M=0.03,(b) M=0.07, (c) M=0.11, (d) M=0.15[1]

S-Shaped NPR structures

- Study of high performance auxetic geometries designed around a Negative Poisson Ratio (NPR) for combustion liners.
- Utilization of auxetic structures in combustion liners to mitigate for low component life.
- Higher Energy Absorption
- NPR Combustion Liners offer higher quality fracture resistance.
- Effective cooling configuration and acoustic damper





Film cooling effectiveness of S-slot, ellipses and circular holes

- Pressure Sensitive Paint (PSP) non-intrusive experimental technique is utilized to obtain film effectiveness over a surface.
- Film Effectiveness is obtained for each experimental coupons (S-Slot/ Ellipses/ Circle) and compared by averaging the effectiveness in a lateral manner.
- The S-Slot configuration was found to effectively distribute film over a surface at a significant lower mass flow.

References

[1] Calderon L., Curbelo A., Gupta G., and Kapat J.," Adiabatic Film Cooling Effectiveness of a LAM Fabricated Porous Leading Edge Segment of a Turbine Blade." ASME Turbo Expo 2018: Turbomachinery Technical Conference and Exposition

[2]Flores, W., Curbelo, A., Calderon, L., J, Kapat J., ", Adiabatic Film Cooling Effectiveness Measurements of High Performance Combustion Liner Slot Jets " Proceedings of ASME Turbo Expo 2018: Turbine Technical Conference and Exposition GT2019, 2019, June 17 – 21, Phoenix, Arizona, USA

[3]Brandon. E., Calderon. L., Wang.W., Valentin.R., Mingareev. I., Richardson. M., Kapat. J., " Characterization of LAM-Fabricated Porous Superalloys for turbine components", Journal of Eng. For Gas turbine and power.