Laser material processing in the aero engine industry

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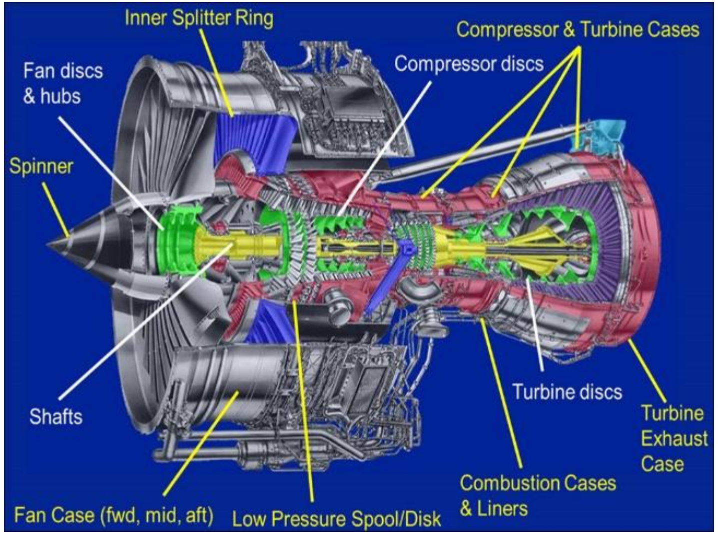
Prima Power Laserdyne

- Prima Power Laserdyne is based in Brooklyn Park, Minnesota and is supplier of precision multi-axis laser material processing (cutting, drilling, welding and AM)3D systems for various industries i.e.
  - Aerospace
    - Aircraft
    - Land-based power generation turbine engines
  - Medical
  - Automotive
  - Electronics

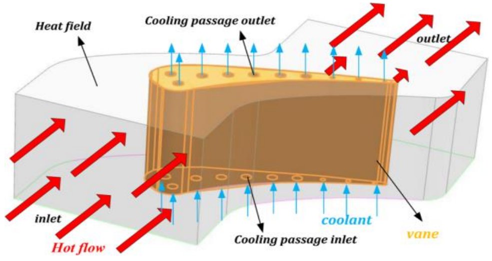
Introduction

Laser machining processes are widely used in the manufacture of aero engine components. This brief talk provides examples of well-established, cutting-edge and emerging laser machining processes.



Laser drilling

- In the aero engine industry, laser drilling is a long- established and the most widely used among laser-based manufacturing processes. The high processing speed of laser drilling has relegated competing processes like EDM to secondary roles.



Aero Blade (1st stage)	**Single Crystal Ni-based super alloy** - CMSX4 (Ni 62%, Co 9%, Cr 7%, Al 6%, Ti 1%, Ta 6.5%, Mo 0.6%, W 6%, Re 3%, Hf 0.1%)
Aero Vane (1st stage)	**Directionally Solidified Ni-based super alloy**
IGT Blade (1st stage)	**Single Crystal Ni-base super alloy** - DS MarM247 LC - PWA1483 (Ni Bal, 9.0 Co, 12.2 Cr, 1.9 Mo, 3.8 W, 0 Re, 5 Ta, 4.1 Ti, 3.6 Al) - (PWA1484 (Ni Bal, 10 Co, 5 Cr, 1.9 MO, 5.9 W, 3.0 Re, 8.7 Ta, - Ti, 5.65 Al, 0.10 Hf)) - IN738LC - SC Rene N5
IGT Vane (1st stage)	**Single Crystal Ni-based super alloy – TBC coating** - SC ReneN5 - DS CM247LC (R1) marM247 LC R2 & 3 - SC IN939
Combustor	**Nickel or Cobalt Alloy with TBC** - HastelloyX (Cr 20, Fe 18, Mo 9, Co 1, W 0.5, Mn 0.5, Sn 0.7, C 0.015, Ni Balance) - Haynes 188
Transition Duct	**Nickel or Cobalt Alloy with TBC** - IN617 with TBC - Nimonic 263 with TBC

IGT (Industrial Gas Turbines)

Component	Diameter (mm)	Wall Thickness (mm)	Angle from Surface (deg.)	Number of Holes
Blade	0.3 - 0.5	1.0 - 3.0	15	25 - 200
Vane	0.3 - 1.0	1.0 - 4.0	15	25 - 200
Afterburner	0.4	2.0 - 2.5	90	40,000
Baseplate	0.5 - 0.7	1.0	30 - 90	10,000
Seal Ring	0.95 - 1.05	1.5	50	180
Cooing Ring	0.78 - 0.84	4.0	79	4,200
Cooling Ring	5.0	4.0	90	280

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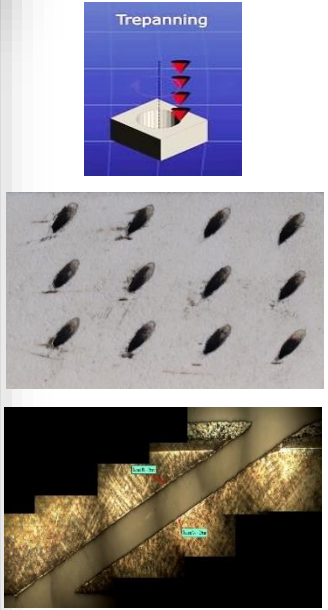
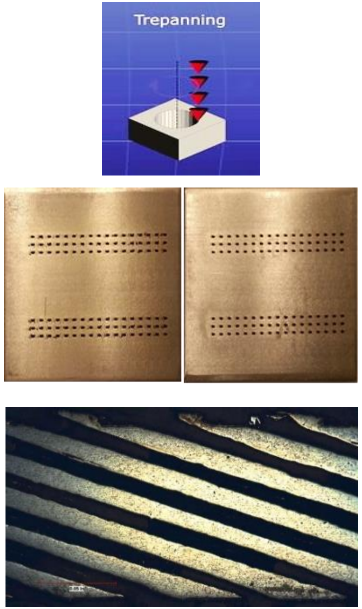
Laser drilling

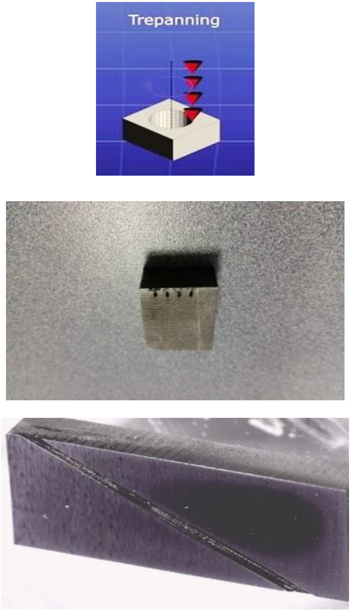


Inconel 718 coated (3.0mm + 0.65mm thick coating); 0.7mm diameter hole; average recast layer 29µm

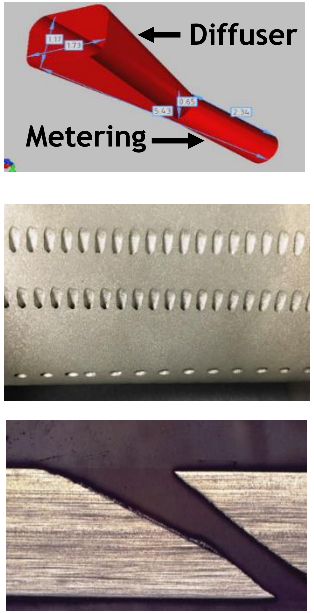


3.2mm thick Hastelloy X; 20 degrees to surface; 0.2mm dia.; actual hole depth 9.42mm; aspect ratio 47:1

Uncoated 2.2mm thick Hastelloy-X; 30 degree from surface; hole dia. 0.50-0.75mm



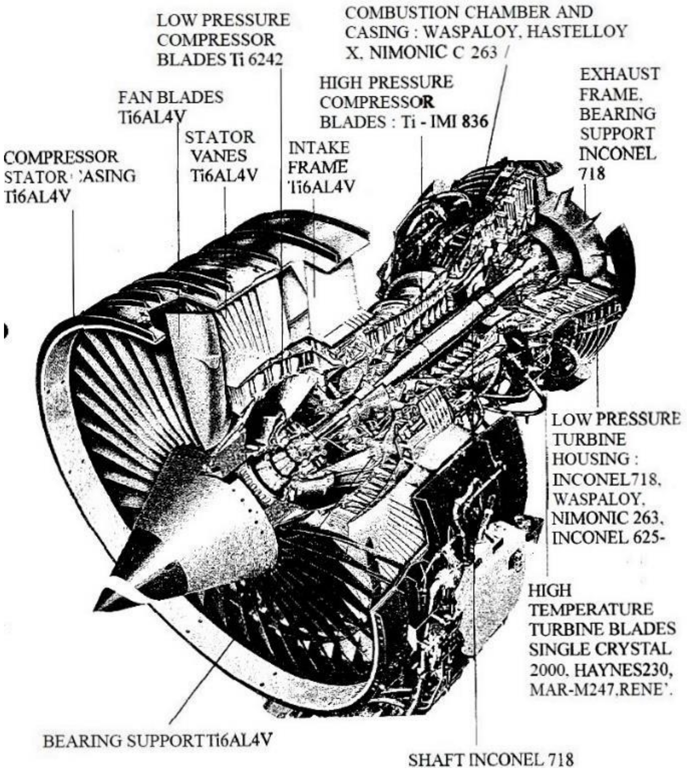
10mm thick Waspaloy; 0.6mm dia.; 30 degrees from the surface actual hole depth 20mm; oxygen assist,



Fan shaped hole; Inconel 718 (TBC). Film cooling holes increase efficiency of cooling air by 30%, reducing the amount of air required for cooling.

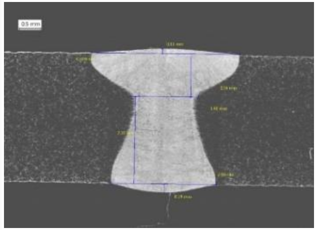
Laser welding

- The requirements for welded aircraft parts have become increasingly severe, especially in terms of the reproducibility of the geometry and metallurgical properties of the weld bead. The main requirements are:
  - No/ minimum porosity
  - No cracking
  - No top and under bead undercut
  - Top bead seam width of certain size
  - Waist (center of the weld) of certain size for butt joint
  - Interface width (> thinnest sheet) for overlap joint
  - Bottom bead seam of certain size
  - Oxidized free top and bottom bead

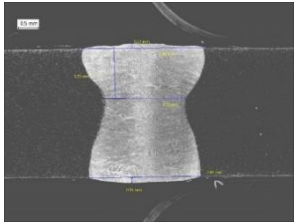


Laser welding

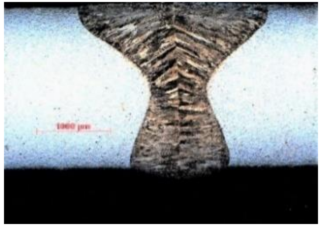
Autogenous welds



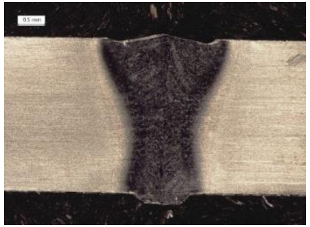
Hastelloy X; 3.2mm ; butt joint; N_2 shield gas



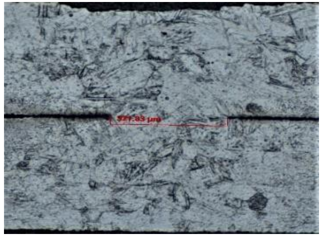
Haynes 230 alloy; 3.2mm ; butt joint; N_2 shield gas



Inconel 718; 2mm; butt joint; N_2 shield gas

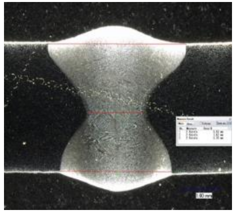


Ti-6Al-4V;3.2mm; butt joint; Ar shield gas

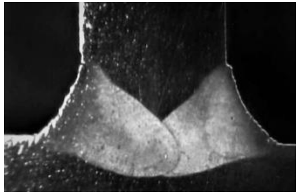


CP Ti; 0.8mm; overlap joint; Ar shield gas

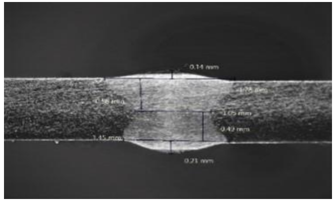
Laser welding with filler wire



3.2mm thick Inconel 625 ; butt joint; welded with 1.2mm diameter 625 wire; N_2 shield.



4mm thick 6065 aluminium alloy (Al-Mg-Si-Cu); double pass Tee joint welded with 0.8mm diameter 6065 wire; N_2 shield



1mm thick Inconel 718 ; butt joint; welded with 1.2mm diameter Inconel 625 wire; N_2 shield

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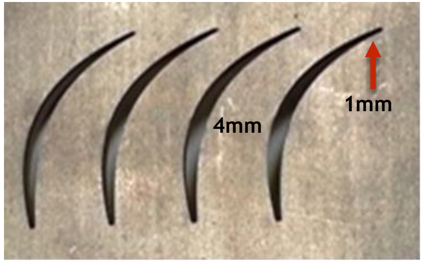
Laser cutting

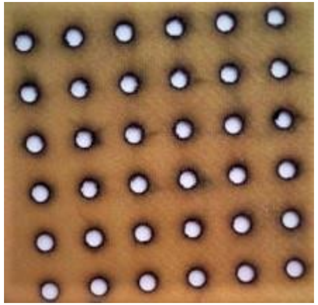
- The laser cutting of 2D and 3D sheet metal is state-of-the-art and is extensively used in aerospace industry.
- Nickel based super alloys are normally cut with nitrogen assist gas to produce oxide free clean edge. Titanium based alloys are cut with argon assist gas.
    - No dross and minimum recast layer
    - Parallel cut edges



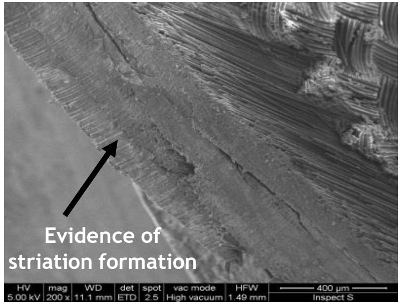
Narrow blade profiles, land based turbine stator ring; 5mm thick; nitrogen assist gas

Laser processing of composite materials

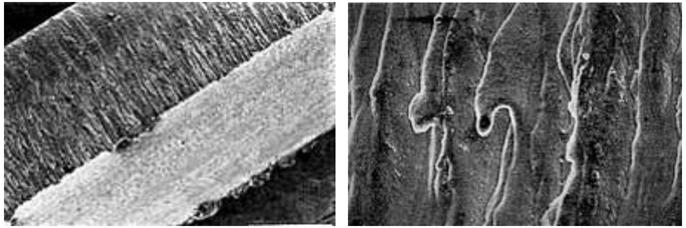
Carbon Fiber Pre- Preg, the amount of burn back on the top surface is only a few tens of microns



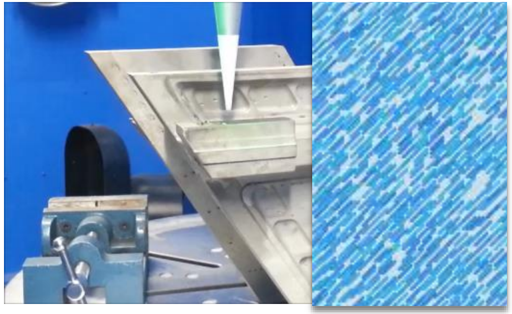
Glass fiber composite; slight charring of the top surface



2mm thick CFRP ; nitrogen assist gas; QCW fiber laser



2mm thick Al-Li alloy reinforced with 20% (wt.) SiC particulate; QCW laser; N_2 assist gas



Drilling of MMC; hole depth 34.95mm (1.38 inch)

Outlook

- New laser processes in in aerospace & space engineering
  - Aerospace engineering
    - Optimized turbines will need even better processes
    - Dissimilar material welding, new alloys, for ultra high reliability electrical systems
    - Higher levels of process interrogation and knowledge.
  - Space engineering, future small spacecraft with requirements for higher performance and lighter weight will necessarily use the advanced materials i.e.
  - Aluminum-Lithium Alloys (welding)
  - Polymer-Matrix Composites (cutting)
  - Carbon-Carbon Composites (cutting, drilling)
  - Metal-Matrix Composites (alloys reinforced with silicon carbide, alumina, or boron particulates or fibers; cutting)

Prima Power

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