IREPA LASER
INSTITUT CARNOT MICA
PROCEDES LASER ET MATERIAUX

DED-CLAD® process

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October 2018

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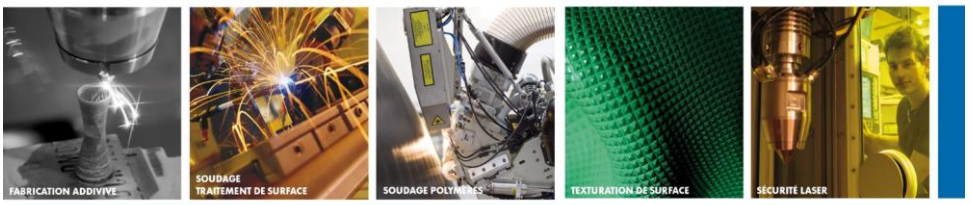

IREPA LASER

Laser Technological centre in France

Industrial laser applications and developments in the field of material processing

- More than 30 years of experience. 47 people.
- Products : feasibility, technical and economic studies, training, industrialization, R&D, …
- ≈ 20 lasers in the lab : YAG, Fiber, diode, Femto, …
  - •with multiaxis workstations and robot
  - • analysis means: 3D profilometer (ALICONA), metallographical, …
- Expertise and fine characterization : INSTITUT CARNOT MICA

Main activities:

- Welding and surface treatment
- Micro-machining
- Training
- **…. And additive manufacturing :**
  - **3 CLAD machines**
  - **+ future SLM machine**
  - **+ future WAAM machine**

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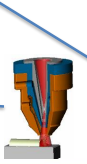
AM STORY AT IIREPA LASER

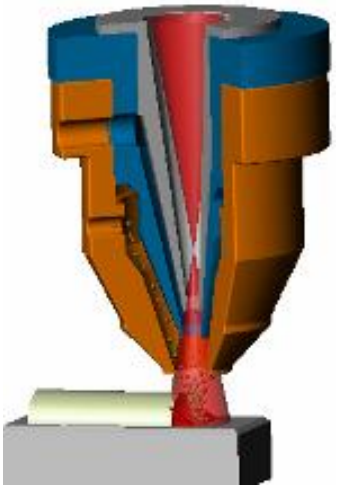
- 1986 — First cladding developments ENSAIS
- 1994 — Coaxial nozzle patent. Licence transfer and nozzle sales
- 2003 — Participation EU project STREP RAMATI
- 2007 — CLAD™ — Simon Sankaré PHD — 1st machine prototype (iMes)
- 2008 — Road map CLAD — First engine parts repairing
- 2009 — Manufacturing + sale of 2 machines (ECN, SIRRIS)
- 2010 — Start of FUI FALAFEL project — Validation aero repair
- 2012 — Installation MAGIC — BeAM — 2017: 40 ETP, 8 machines sold
- 2013 — Start EU project AMAZE – factory of the future
- 2014 — Install. BioCLAD — FALAFEL parts manuf.
- 2015 — 1st machines sold by BeAM
- 2016-17 — Large scale parts manuf.
- 2018 — New project PAMPROD

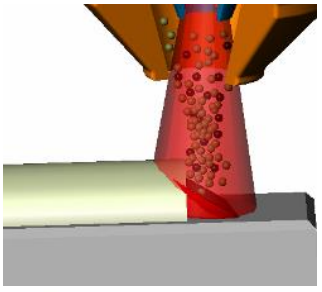


Investment : >5 M€ / staff 8 ETP / 40 % indus sales revenues

LASER CLADDING WITH BLOWN POWDER

- IREPA LASER experience:
  - Coaxial nozzle patented by IREPA LASER
  - Adapted for all kind of laser sources
  - Layer thickness : 0,3mm up to 2 mm/layer
  - Track width: 1 up to 5 mm
    - Powder catchments efficiency ≤ 90%
    - Dilution < 5%
  - High shielding gas quality





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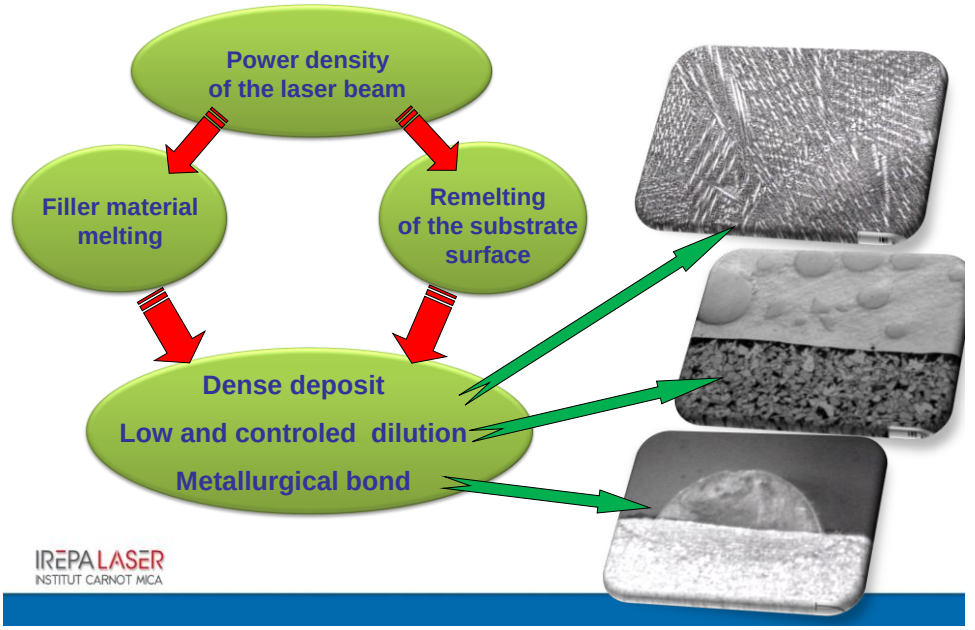
LASER CLADDING

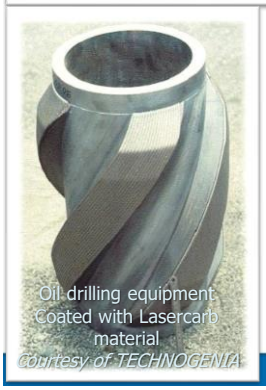


INDUSTRIAL APPLICATIONS


Subpart of extrusion die for brick
Coated with Lasercarb material
Courtesy of TECHNOGENIA

Anti-abrasion
Anti-wear


Farm equipments
Courtesy of TECHLASE


Oil drilling equipment
Coated with Lasercarb
material
Courtesy of TECHNOGENIA

INDUSTRIAL APPLICATIONS

Repairing of worn parts

Crankshaft repairing
Courtesy of TECHLASE

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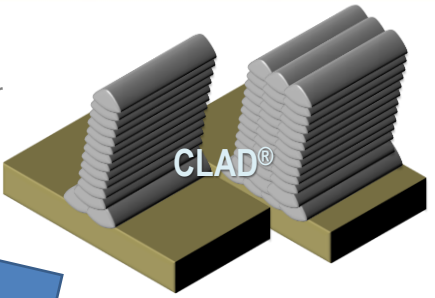
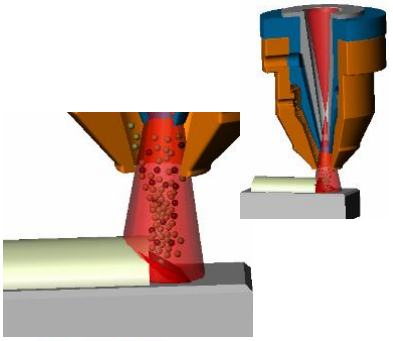
FROM LASER CLADDING TO AM-CLAD®

- **CLAD® nozzle:**
  - Coaxial nozzle patented by IREPA LASER
  - Layer thickness : 0,3mm up to 2 mm/layer
  - Track width: 1 up to 5 mm
    - Powder catchments efficiency ≤ 90%
  - Excellent gas schielding





- ➔ 3 thesis
- ➔ 4 engineer school projects
- ➔ 5 National projects
- ➔ 5 European projects
- ➔ 25 years of development
  (since first cladding nozzle development)

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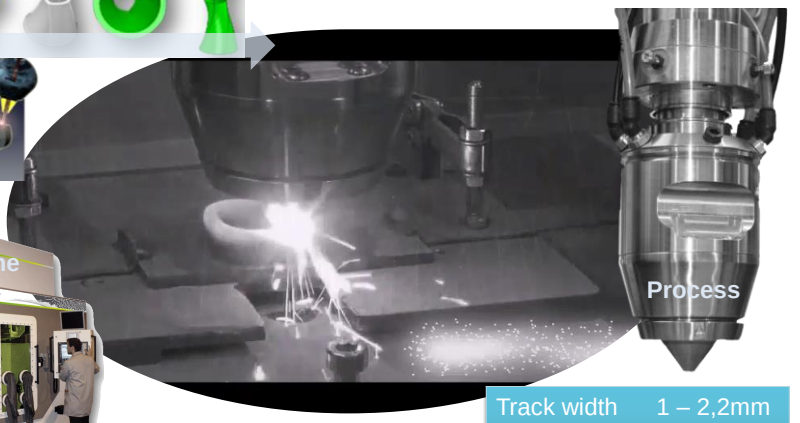
CLAD® Process
Construction by Laser with Additive and Direct Process

Power CLAD Software



Track width	1 – 2,2mm
Accuracy	±0,2mm
Build up rate	**120 cm³/h**

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BeAM
BE ADDITIVE MANUFACTURING

BeAM
About Us

Taken over by AddUp
GLOBAL ADDITIVE SOLUTIONS

MANUFACTURER OF DED ADDITIVE SOLUTIONS

Private company

Created in December 2012

45 employees worldwide

Headquartered in Strasbourg, France
Subsidiaries in Cincinnati, OH, USA and Singapore

Spin-off of IREPA LASER, a French-based R&D centre with 15 years of experience in DED

First industrial machines delivered in early 2016

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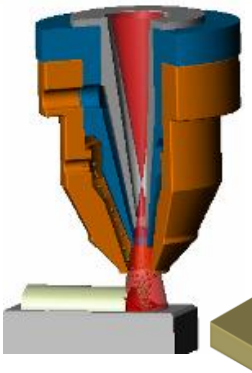
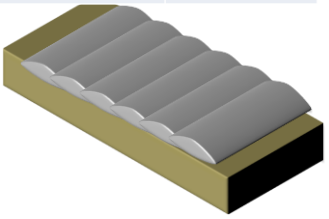
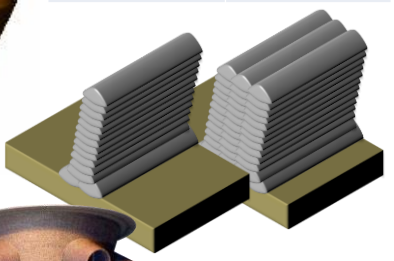
LASER CLADDING VS CLAD®

Layer thickness	0,5 ➔ 2 mm
Track width	3 ➔ 5mm
Efficiency	> 90%
Dilution	< 5%



Layer thickness	0,2 ➔ 0,7 mm
Track width	0,3 ➔ 3 mm
Efficiency	20 - 90%
Dilution	5% ➔ 20%





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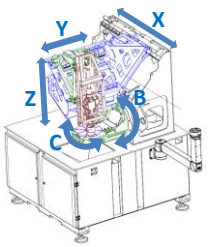
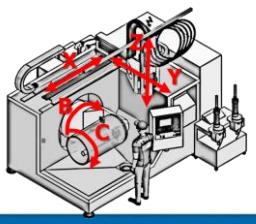
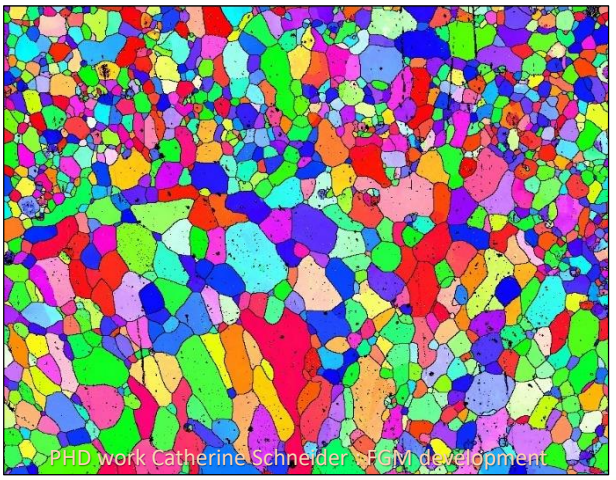
MACHINES

	MAGIC	BioCLAD
Continuous 5 axis	✓	✓
Travel stages [mm]	X1500xY800xZ760	*X400xY250xZ200*
Max load	300 kg	50kg
CLAD heads	2	1
Lasers	Fibre 500W Diode 2000W	Fibre 600W
Gas enclosure	*12 m³* *O2<20 ppm* *H2O<40 ppm*	*1,5 m³* *O2<20 ppm* *H2O<40 ppm*
Powder feeders	2	1





Materials development



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MATERIALS …… ➔ WELDABILITY

materials	grade	State of CLAD® development	CLAD® results
Steels	Low carbon steel	Parameters ok	👍
	Alloy steel (low Ceq)	Parameters ok	👍
	Tool steel (CPM10V, M2)	Cladding ok	👍
Stainless steels	SS304L, 316L	Parameters ok	👍
	APX4	Parameters ok	👍
	17-4 Ph	Parameters ok	👍
	SS440, …	Setup in progress	👍
Ni base alloys	Inco 718, 713	Qualified on aero parts	👍
	Inco 625, 738	Parameters ok	👍
	Nimonic C263, 75	Parameters ok	👍
	Rene 77, 142	Parameters ok	👍
	Waspalloy	Qualified on aero parts	👍
	CMSX4	Setup in progress	👍
Ti base alloys	Ti6Al4V	Parameters ok	👍
	Ti6Al2Sn4Zr2Mo (6242)	Qualified on aero parts	👍
	CpTi	Parameters ok	👍
Co base	Stellite 6, 12, 21, 25	Cladding ok	👍
Al alloys	Al alloys (Si, Mn, Mg …)	Difficult to process	👎
Cu alloys	Cu alloys (Zn, Sn, Al, Ni, …)	Difficult to process	👎
Au alloys	Au alloys	Difficult to process	👎
Others	W	Difficult to process	👎
	WC	Ok with Ni matrix	👍
	Mo	Setup in progress	👍

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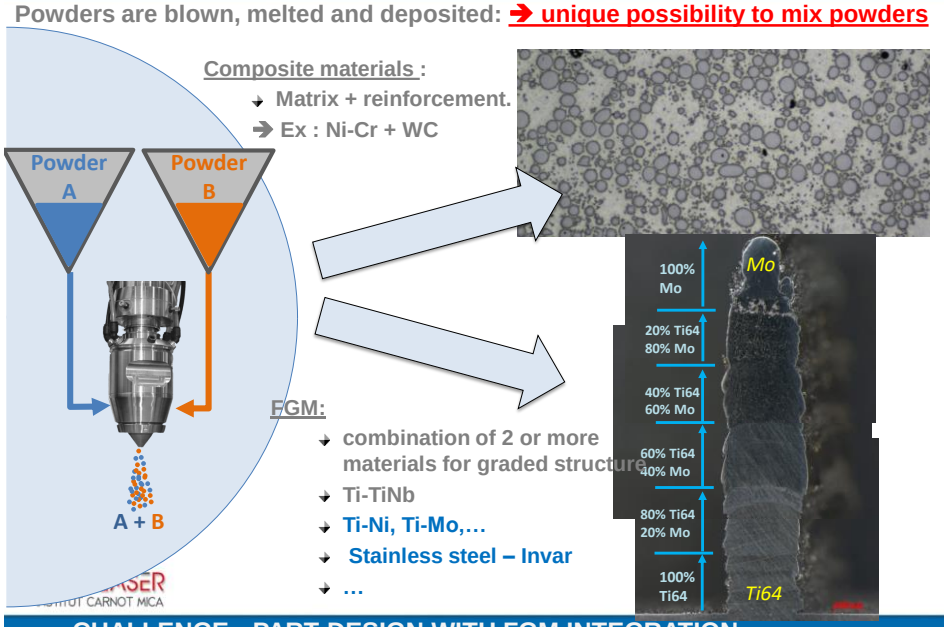
NEW MATERIALS WITH LMD-CLAD®

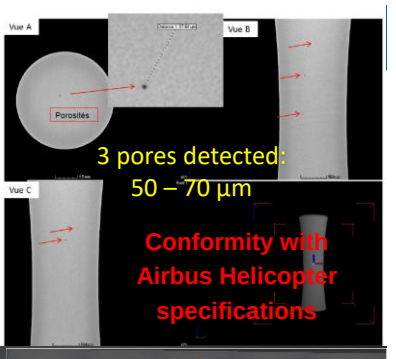
Powders are blown, melted and deposited: ➔ **unique possibility to mix powders**

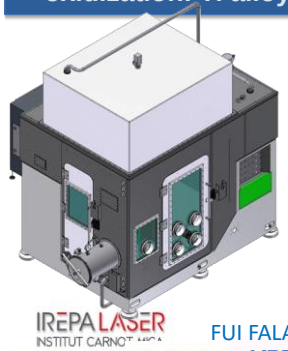


CHALLENGE : PART DESIGN WITH FGM INTEGRATION

METALLURGICAL & MECHANICAL PROPERTIES

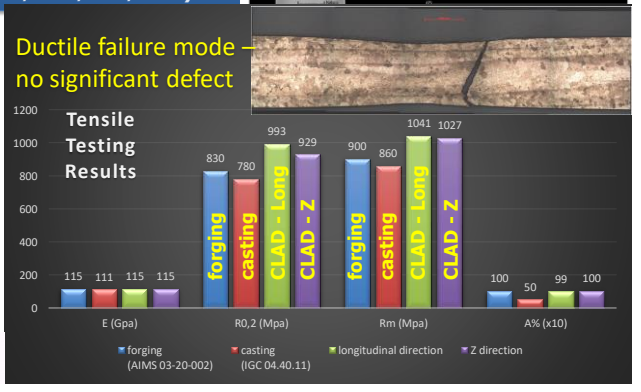
- Very low level of pores (<0,01%) and defects
- Fine microstructure (rapid solidification), excellent mechanical properties
- Local or global gas shielding to avoid oxidization: Ti alloys, (Al, Mo, Nb, Ta..)





FUI FALAFEL

AIRBUS HELICOPTERS AIRBUS GROUP



APPLICATIVE POTENTIAL OF CLAD® PROCESS

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APPLICATIVE POTENTIAL OF CLAD® PROCESS

Repairing of worn or damaged parts

Fonctionality adding on existing valued parts

Manufacturing of functionnal parts

Preform manufacturing to be machined

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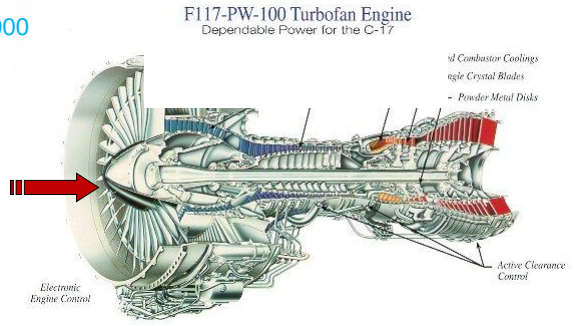
APPLICATION EXAMPLE OF THE CLAD® TECHNOLOGY

SEALING RING

ROTATION SPEED: 30 000 TR/MIN



- Repairing of the worn knife edges of sealing parts
- Collaboration with a company specialized in engine maintenance
  - Company : Chromalloy France
  - 100 people
  - Essentially repair for Pratt & Wittney : PW100/ PT6/ JT15 APU (901)

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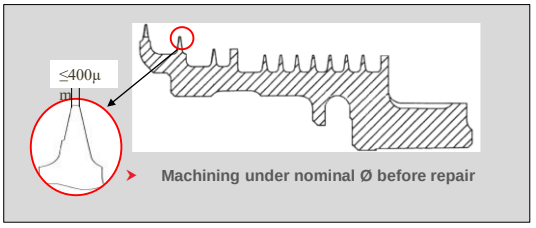
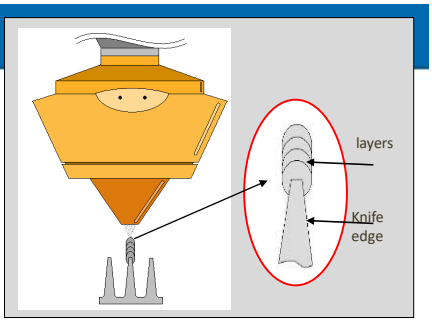
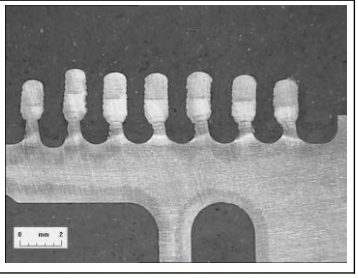
REPAIRING PROCESS



- Machining under nominal Ø before repair



material	Cross view of a repaired part Before final machining
Part : **Ti alloy** Heat treatment after repair	
Powder : **Ti-6Al-2Sn-4Zr-2Mo**	
Grain size : **45 – 75 µm**	
Track width : **1,12mm** Hardness : **400Hv**	

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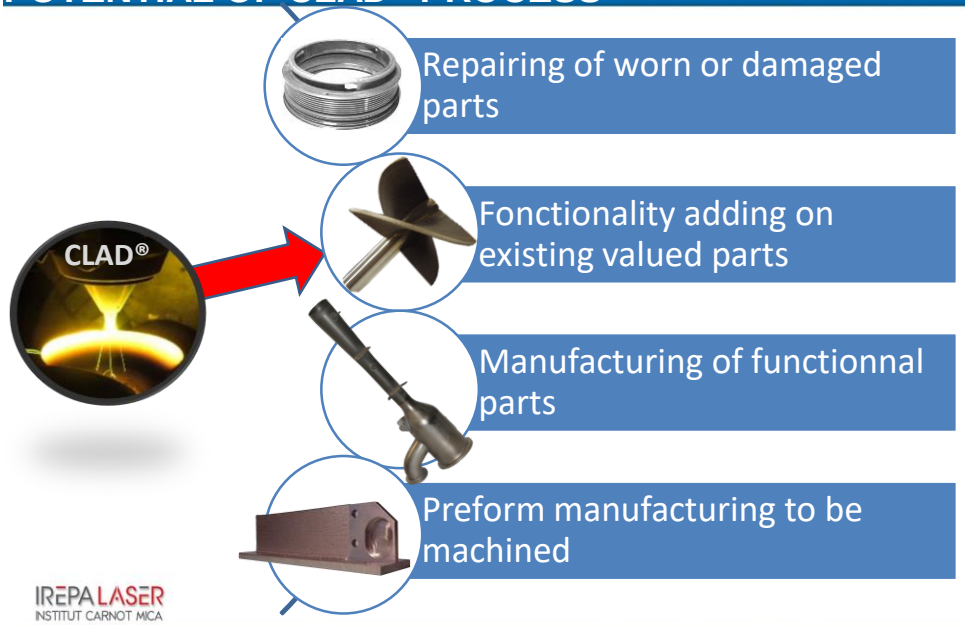
CONCLUSION ON REPAIRING APPLICATION

- Success story
  - 1st contact : 2008
  - 1st repaired part : 2009
  - Process validated : 2010
  - Parts qualified : 2011-2015 (1200 parts repaired)
  - Parts in production at CFR : 2016
- 2 machines BeAM bought by CFR
- Process validated and qualified by the motorist (various materials)
- Technology transfer to :
  - Spin-off BeAM for pilot production
  - And then to the customer
- Technology transfer on other parts

POTENTIAL OF CLAD® PROCESS



EXAMPLE: FUNCTIONALITIES ADDING

Manufacturing of 2 blades on a machined steel cylinder

Manufacturing of a centring pin on a machined Ni base ring

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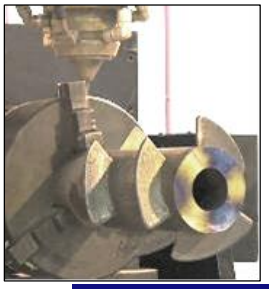
EXAMPLE : BLADES ON A SHAFT



Part dimensions :

Ø tube : **80mm**
Material : SS **316L**
Construction :

- 2 tracks width (**≈ 5 mm**)
- total height **20 mm**
- Inc. Z **0,70mm**

Construction time for 1 blade :

4min26s

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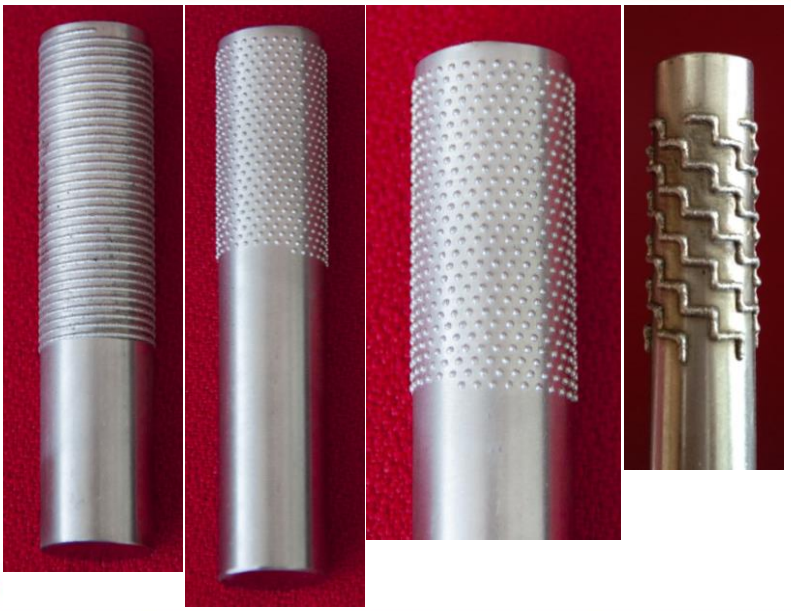
EXAMPLE: MACRO-TEXTURING ADDING

Manufacturing of helix and dots on a machined stainless steel cylinder (Ø20mm)



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APPLICATIVE POTENTIAL OF CLAD® PROCESS

- Repairing of worn or damaged parts
- Fonctionality adding on existing valued parts
- Manufacturing of functionnal parts
- Preform manufacturing to be machined

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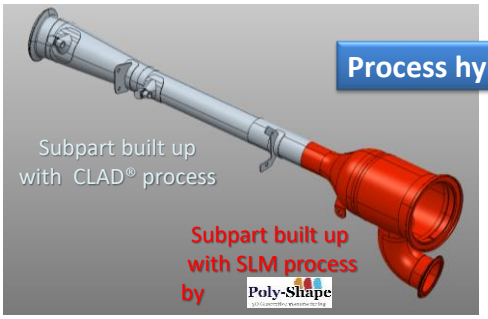
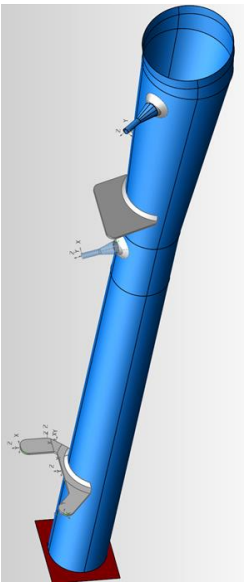
TRUMP : PREPARATION



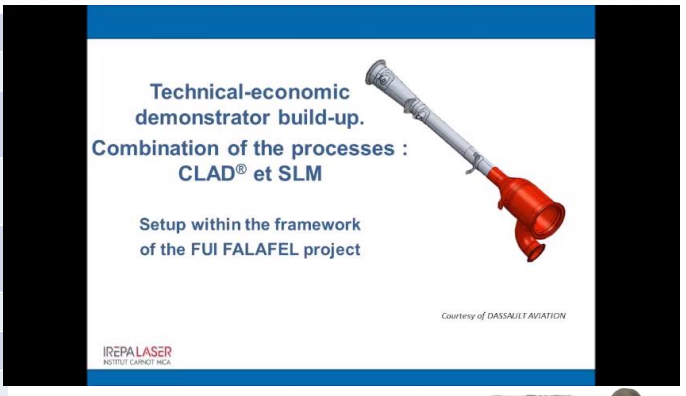


- Material : Nickel Based alloy (Nimonic C263)
- Manufacturing started on SLM subpart
- Part adaptation to the process:
  - Thickness variation eliminated
  - Modification of the cones geometry
  - Corner radius added for the mounting lugs

IREPA LASER INSTITUT CARNOT MICA *FUI FALAFEL*

TRUMP: PRODUCTION

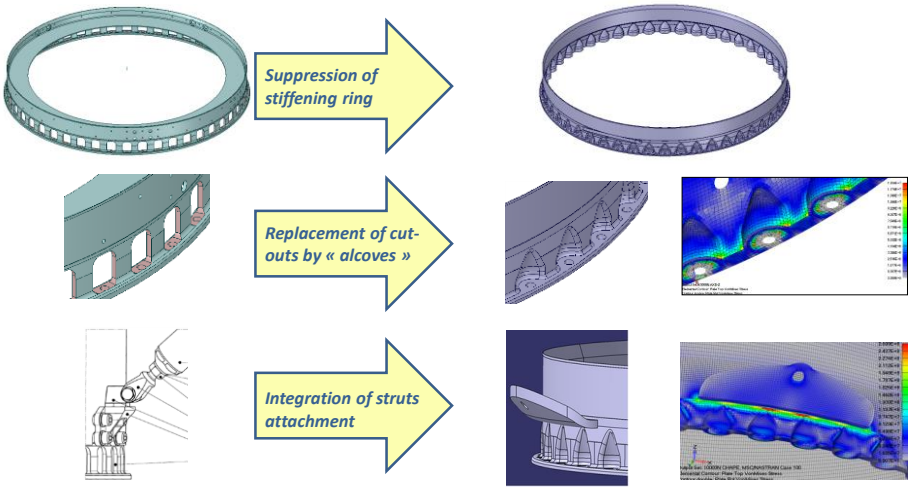
Material	C263
Wall thickness	0.8 mm
Build up time	3h46min 2h46 + 1h
Deposited mass	520 g
Powder efficiency	21%
build up rate	18 cm^3/h
Roughness	Ra5
Powder to be recycled	1900 g



Industrial demonstrator: airduct Ti64 FUI FALAFEL 2014 – IREPA LASER Dassault Aviation Courtesy

IREPA LASER INSTITUT CARNOT MICA *SLM subpart made by* Poly-Shape

OPTIMISATION AND ADAPTATION TO THE CLAD® PROCESS



The mechanical performances (strength, Stiffness) have been checked by F.E.M.

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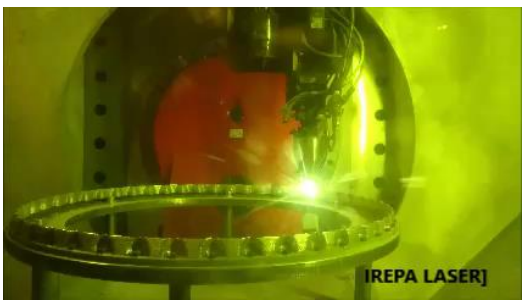
MANUFACTURING STRATEGY

➤ **Ring manufacturing**



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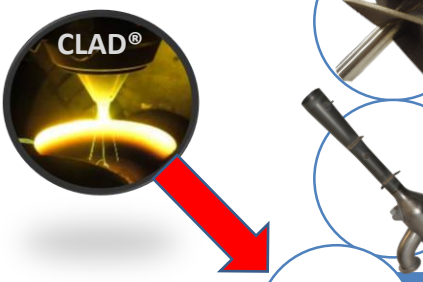
APPLICATIVE POTENTIAL OF CLAD® PROCESS



Repairing of worn or damaged parts

Fonctionality adding on existing valued parts

Manufacturing of functionnal parts

Preform manufacturing to be machined

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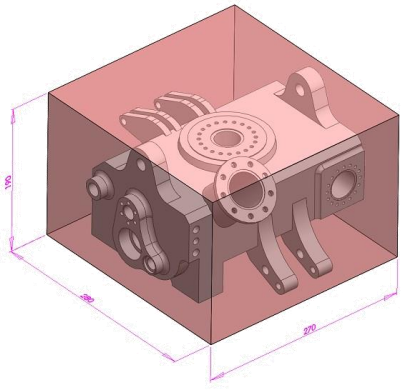
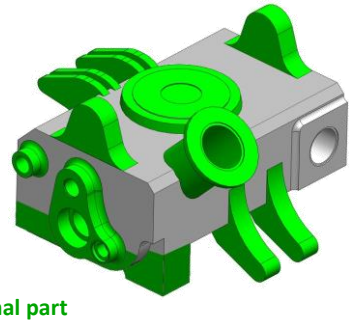
EXAMPLE : PREFORM + MACHINING

- Application example:

- Traditional machining
  - 14 364 cm3
  - 104.7 Kg



- Features added by CLAD
  - 4 543 cm3
  - 33.2 Kg



- Final part
  - 27 Kg

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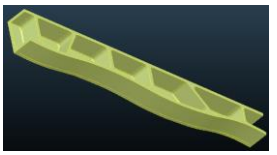
BeAM
BE ADDITIVE MANUFACTURING

THE AMAZE PROJECT

- Additive Manufacturing Aiming Towards Zero Waste & Efficient Production of High-Tech Metal Products
- European project : FP7, 23M€ budget
- coordinator : MTC
- 26 leading institutions in European academia, research and industry
- 5 years : 2013 - 2017



Spar : 14kg, length 1.1m, Ti64

Cyl. Diam 600mm (40-70kg), Ti64

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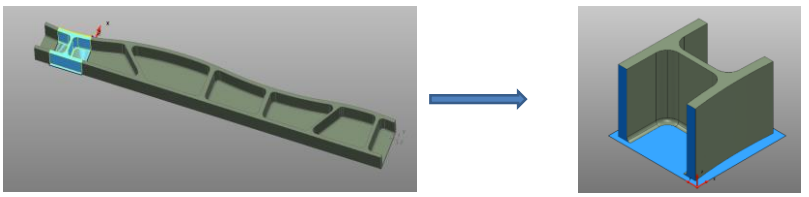
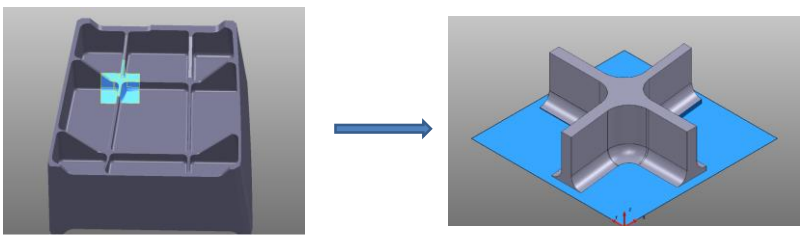
SUB-ELEMENTS

- H-shape (Aircraft Spar Frame sub-element)



- Cross-shape (Aircraft Outboard Rib sub-element)



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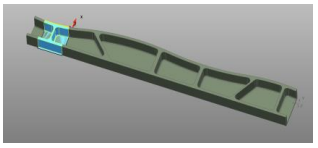
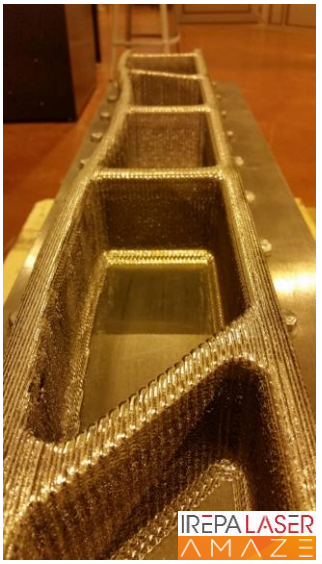
FULL SCALE DEMONSTRATOR - RIB

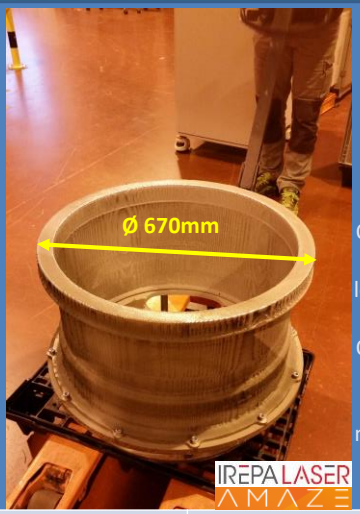
- **Demonstrator: Aircraft spar**



Material	Ti-6Al-4V
Construction	Total : 33h
Weight	14.2kg
Build up rate	97 cm^3/h
PCE (powder)	60%



FULL SCALE DEMONSTRATOR - CYLINDER

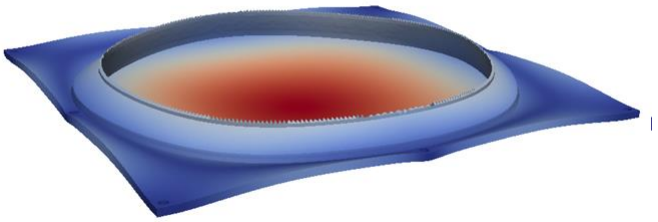


Material	Ti-6Al-4V
Construction	Total : 127h
Weight	≈45kg
Build up rate	≈92 cm^3/h
PCE (powder catchment efficiency)	≈60%

Strategies Optimisation – long duration Process Optimization – Distortion management

Material	Ti-6Al-4V
Construction	Total : 155h
Weight	71kg (109kg used)
Build up rate / PCE	92 cm3/h / 60%
Cost approach	≈ 60 k€

Modeling



Cylinder distortion modeling

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II. ISSUES RAISED BY THE LMD-CLAD® PROCESS

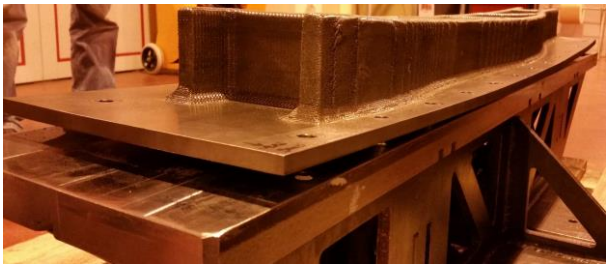
➤ **To know and counteract thermo-mechanical effects**

Crack

Mismatch

Residual stresses, distortion, cracks, mismatch, lack of material… can appear in manufactured part:

- **During building**
- **During cooling**
- **During unclamping**



Distortion in the 'airframe spar' part after unclamping

Screw break during the manufacturing process

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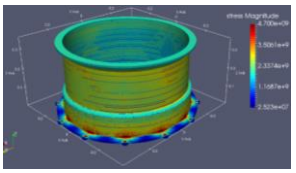
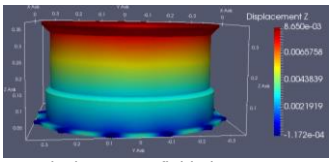
Distortions can cause lack of material, cracks …

CHALLENGE : BIG PARTS MODELLING

C. Application: ESA cylinder in 48hours



Stress field magnitude
Stress: > 600MPa



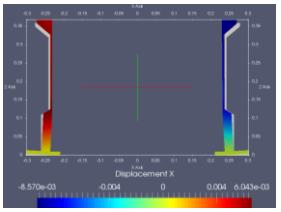
Displacement field along Z axis: 8,6mm

Max external diameter: 660mm

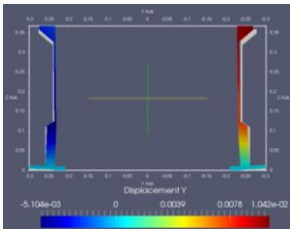
Inner diameter: 592mm

Thicknesses: 20mm at the bottom of the part, 4mm in the middle section and 34mm at the top of the part

Height: 350mm



Displacement field cross section along X axis: calculation vs CAD (8mm)



Displacement field cross section along Y axe: calculation vs CAD (10mm)

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CONCLUSION

- **Various application of CLAD® process**
  - Mature for fine repair
  - Ready for
    - functionalities adding
    - part manufacturing
    - for preform manufacturing
- **Adapted for various sizes:**
  - From small surface texturing
    - → to full scale large parts (>1m or >70kg)
- **Numerous benefits:**
  - Better use of materials
  - Mass saving VS bulk machining
  - Delivery time reduced
  - Unique possibility of features adding
  - Excellent mechanical properties
  - (multi-material)
- But needs part redesign

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THANK YOU FOR YOUR ATTENTION

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