05. November 2014 Workshop

"Challenges on Additive Manufacturing for High Energy Physics"

Metallic Additive Manufacturing@CERN

Work done in the Mechanical & Materials Engineering (MME) group from 2013 to 2014

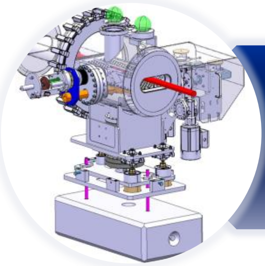
- MME group
- Tests made over the last year
- Some open questions
- Cu and Nb development
- Conclusion

Thomas Sahner EN-MME

EN-MME Group: Mechanical & Materials Engineering

~172 Headcounts

Domains of Activities



Engineering & Design

Measurement

- Internal **Design Office** facilities, ~42 designers (Staff and Industrial Support)
- CATIA / SmarTeam, ANSYS
- **Mechanical measurements lab**

Fabrication

Machining & Maintenance

Preparation & Subcontracting

Assembly & Forming

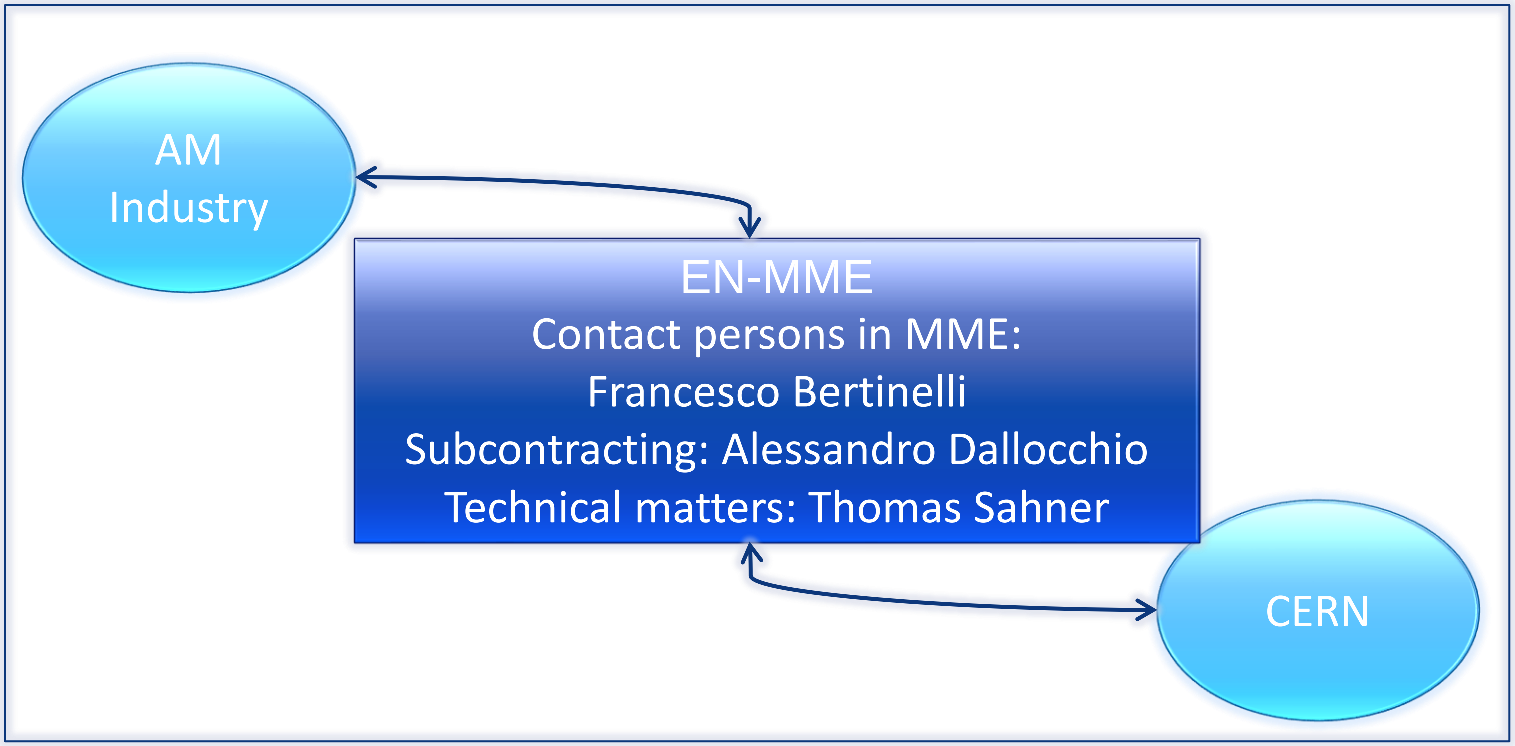
- 4000 m2 of internal workshop facilities, 50 technicians (Staff and Industrial Support): CNC machining, sheet metal work & welding, electron beam & laser, vacuum brazing
- External **subcontracting service**
- Free access Users workshop

Materials & Metrology

- **Material selection, analysis & metallurgy**: microscopy, mechanical testing
- NDT: US, radiography, tomography
- 350 m2 of internal metrology facilities: CMM

With our experience in advanced manufacturing methods and our knowledge about additive manufacturing we want to support your questions in 3D printing.

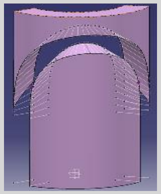
We are your contact between CERN and industry and vice versa.



Metallic Additive Manufacturing@CERN

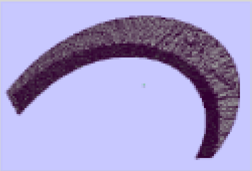
AM technology is an integral part of the Upcoming LHC high luminosity upgrade. It is now being used in the development of many magnet types: From the LHC standard Nb-Ti , the high field Nb_3Sn , and future high temperature superconductors HTS. The parts must resist Nb_3Sn reaction processing at temperature of 650°C, metallic End Spacers in SST are replacing the old fiber glass parts.

Calculation in ROXIE



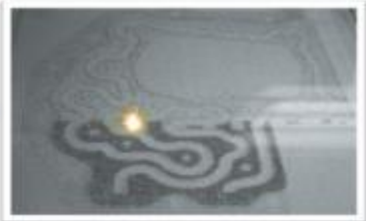
Import of data in CATIA

Préparation of the final model in CATIA



Export of the STEP or STL

Design Phase



Production

Final parts

Depending on the availability of the 3D printer, can be done today within a couple of days.

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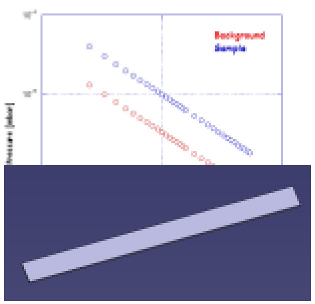
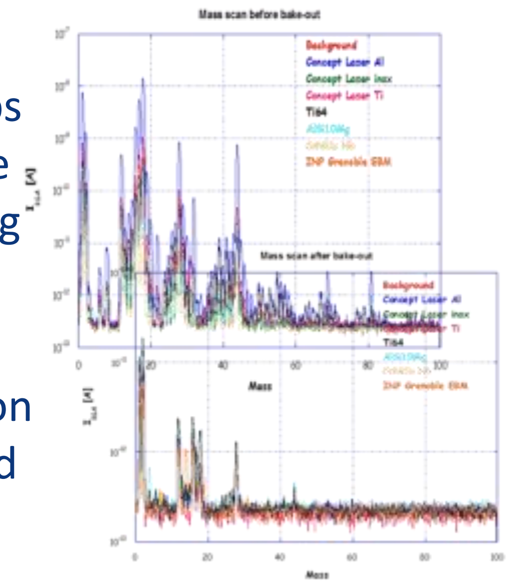
All the following tests are performed with parts in in AISI 316L, AlSi10Mg and Ti6Al4V, manufactured in Laser and Electron Beam melting technology.

To create and maintaining clean high-vacuum environments, outgassing is a significant problem for UHV systems.

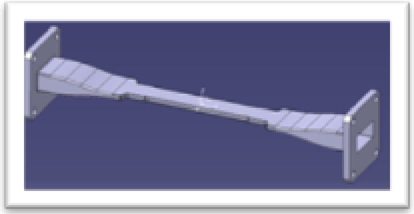


For each material and manufacturer several test strips (125x10x1mm) are analysed on their pumpdown rate and contaminations. The pumpdown curve is showing a typical time-dependent pressure drop in the vacuum system.



The analysis of mass spectrometry is showing traces of hydrocarbon contamination. A bake-out at 150°C for 15h is showing an improved result.

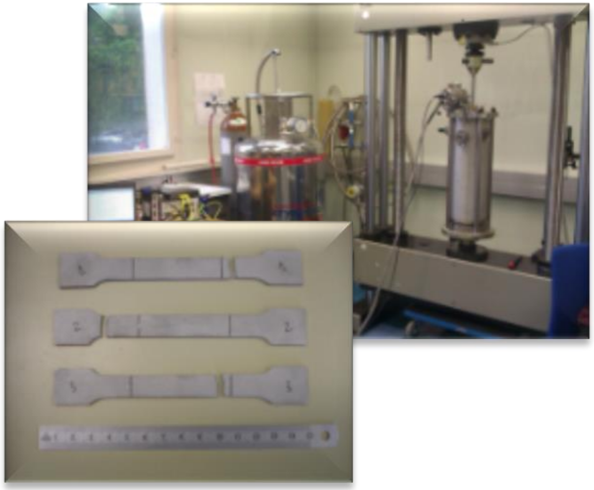
For the leak tightness we used 5 RF parts with a wall thickness of 0,6mm on a leak detector.
The leak rate is below 10-10 mbar l/s which is a very tight system.



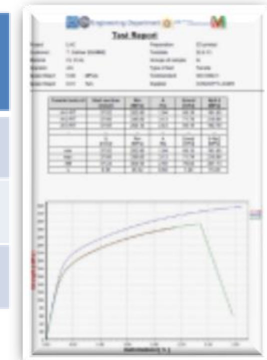
Further investigations are under way!

Test performed by Ivo Wevers

Standard tensile testing with tensile bars in our mechanical test laboratory.
3 specimen from each manufacturer in each of the materials are tested on room temperature.

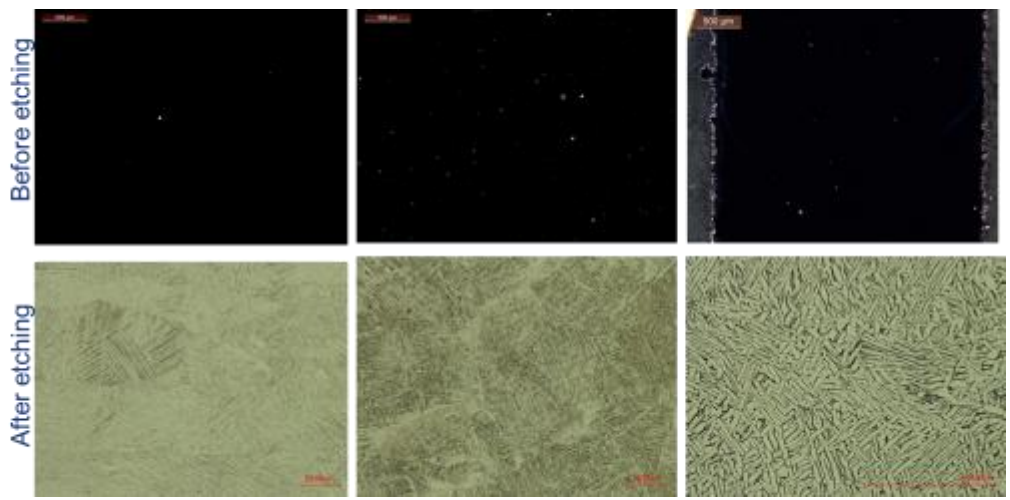


Traction Test	Rm [Mpa]	Rp0.2 [MPa]	A [%]	Emod [Gpa]
AlSi10Mg	310 - 325	170 - 220	2 - 3	75 - 103
316L	570	470	15	200
Ti6Al4V	1.100 -1.300	900 - 1.200	5-15	110



Metallographic observations

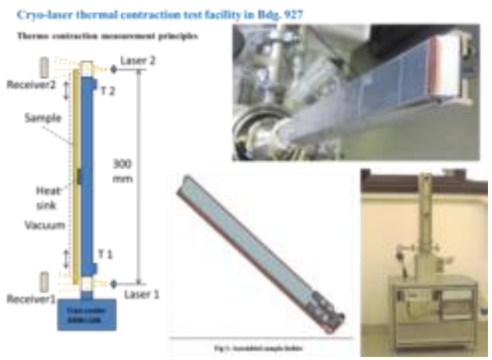
All test showing a poor porosity and a homogeneous metallographic image, depending on the cooling during thermal treatment.



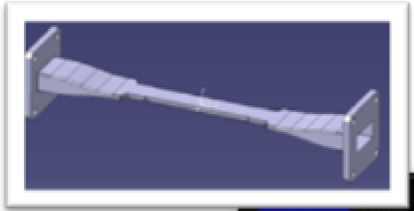
Furthermore the electrical conductivity was measured.

Thermal contraction test with most materials used in additive manufacturing, polymer and metallic, are performed in the Gryo-Laser facility in Build.927.

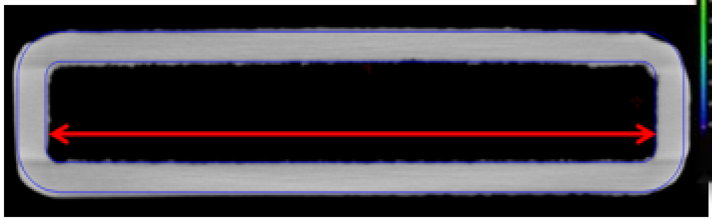
Test performed by V. Datskov and G. Kirby

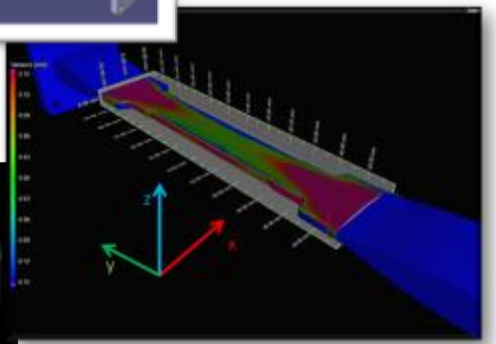


Measuring with 3D tomography is showing that the manufactured dimensions need some improvement. The different parts, even from the same manufacturer, have a different geometry.



The tolerance for the RF part varies between 0.0 and 0.4mm





Some open questions:

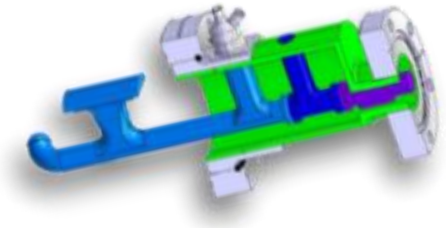
How to improve the quality of the parts ?

Is there a way to reach a better tolerances or Surface Quality? for e.g. In the data chain. CAD-STL- Slicer software or via the machine parameters ?

Quality control ?

How to integrate the AM parts in the quality Policy ?
Do we need new rules for pressure and vacuum vessels?

How to Build and remove the support structures ?

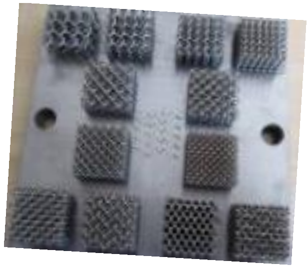


Do we need additional software ?

For FEM analysis, data verification, ……

How to build a Lattice structures ?

Lattice structure can be useful if we need porous or light weight structures.



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We need high purity in Cu for the high electrical conductivity and Nb for the superconductive capabilities at low temperature.

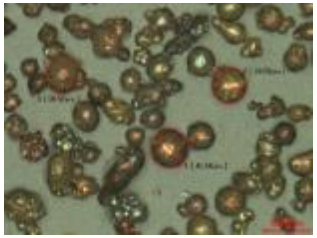
Part of the project is financial supported by our Knowledge Transfer unit and together with KT we could establish several collaboration agreements with the AM industry. It is possible to develop the project into a EU financed R&D project.

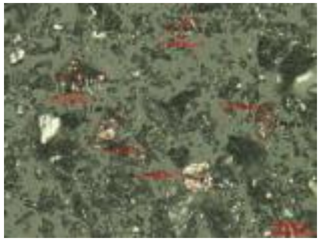

KNOWLEDGE TRANSFER Group

KT fund
Submission Form

Please send the submission form to
KT-fund@cern.ch

The first step was done by the analysis of the different powders on the market and the selecting of the appropriate supplier.


Copper


Niobium

The second step was done by the production test of some "simple cubes" in Copper and Niobium in Laser technology.


COPPER

COURTESY OF CONCEPT LASER


NIOBIUM

Next step is an advanced manufacturing program in Laser and EBM with first results In Cu expected before the end of 2014. For Nb we are working on the program.

After the development of Cu and Nb we intend to integrate 3D printing capabilities in our workshop and apart from the price of a printer the costs for additive manufacturing fabrication depends basically on these parameters:

Part/Machine costs: Volume of the part, build platform, cost of materials, height of the part, height of supports, number of slices

Man Power: 0,1-0,5 Full-time equivalent (FTE)

Space requirements: Approx. 25-30m2 for the machine, container, generator/stocking room

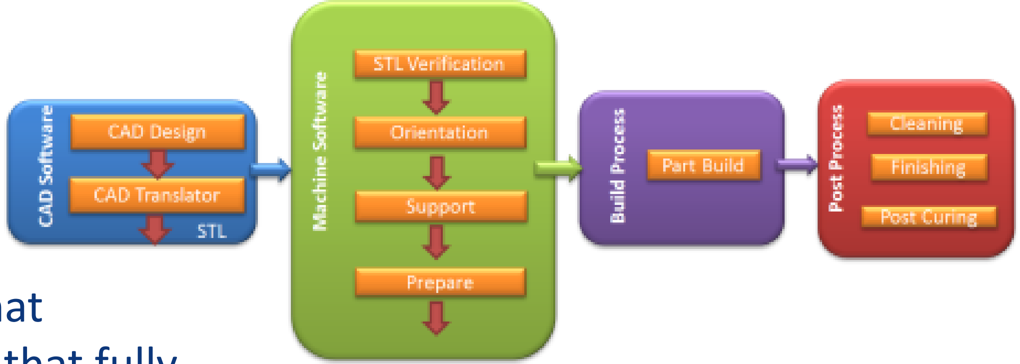
Auxiliary equipment (temporary): Electro erosion, milling machine, furnace and compressed air

Peripherals & Consumable: Lifting and transportation device for material handling, cleaning and handling, recoaster blades, waste bags

Maintenance: Software and machine maintenance

Conclusion

"The additive manufacturing brings together a whole range of technologies which we have to understand"



However, to further the adoption of these emerging AM technologies, there is a need for "Design for Additive Manufacturing" methodologies, tools, and guidelines that empower designers to realize products that fully capitalize on the novel processes capabilities. A first training session for designers was organized to change their approach in the design of the parts.

We have every day new ideas at CERN and the 3D printing can open the door to these ideas but we *have to learn to think different and AM is not a solution for all.*

When we compare the AM technology with the traditional way of "subtractive methods" there are many advantages but mainly in a field of manufacturing where the object complexity and a small quantity are the driving force behind the technology.

Thank you to my colleagues:
Ofelia Capatina, Said Atieh, Ignacio Aviles Santillana, Floriane Leaux,
Ivo Wevers, Alexej Grudiev, Raphael Leuxe

Thank you for your attention
and
Let’s do things together !