State of the Art of Niobium Machining for SRF Applications

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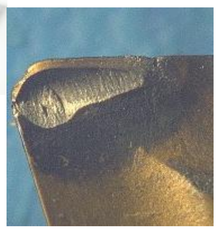
ENGINEERING DEPARTMENT

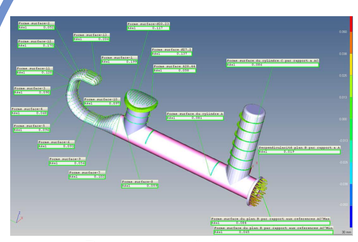
- Practical / empirical knowledge of Niobium machining
- "Behave like" annealed OFE copper (long chips, adhesive, abrasive, soft…)
- Tendancy to stick ➔ low cutting speed, HSS tool, high rake angle
- High flow of cutting fluid



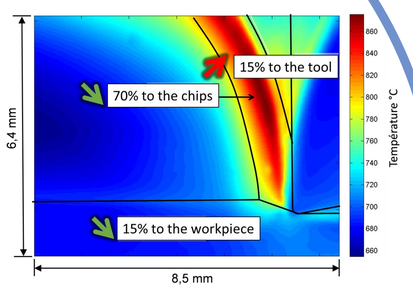



Increasing complexity, knowledge to be managed

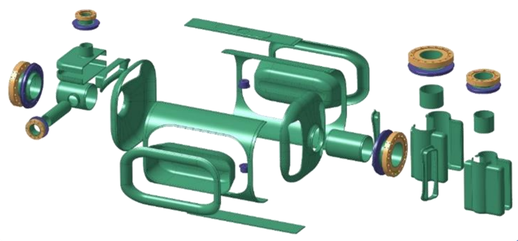
Niobium is difficult to machine because…



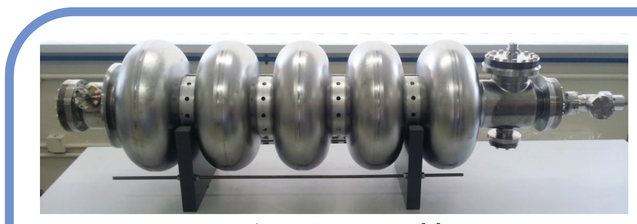
Part precision
(shape 0.3mm, Ra 0.8µm)



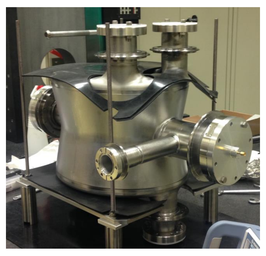
Material properties [4]



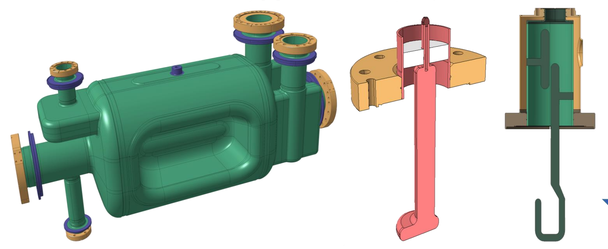
Part shapes and complexity



Superconducting Proton Linac [1], 2013




DQW crab cavity [2] and HOM couplers, 2017



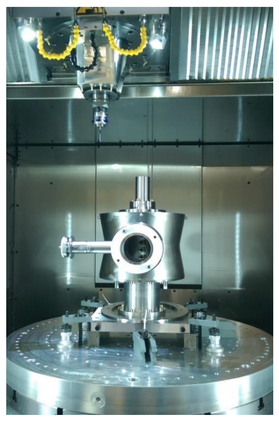
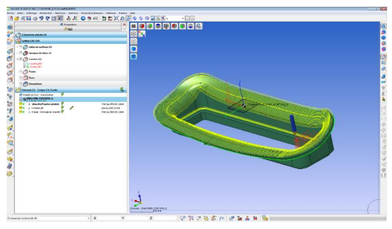
RFD crab cavity [3] and V/H-HOM's, 2019

Complexity, number of parts, accuracy

1/ Environment mastering

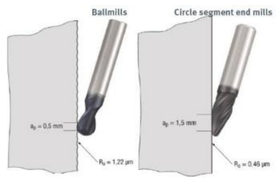
State of the art machine and equipment, regular accuracy checking, adequate clamping and metrology intertwined alignment, optimization of toolpath and CAD/CAM workflow.

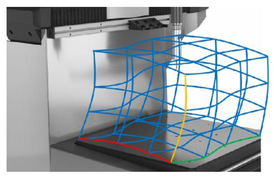


Possible opportunities for advance machining

- Fully climate controlled workshops
- Vibration dampening tools or clamping
- New strategy combined with barrel tools for smoother finishing (not steps nor marks, better roughness)
- Automatic machine calibration and compensation of part positioning (volumetric compensation)

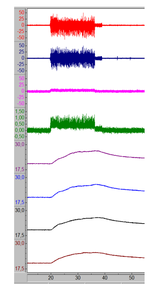




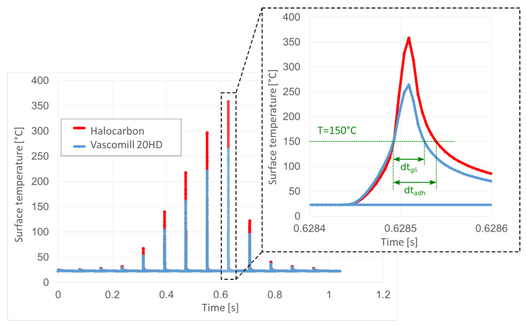
2/ process optimizing

3/ Measure & understand

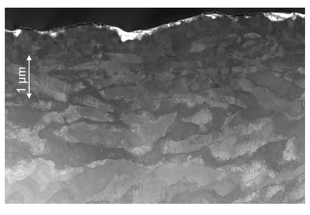
Multiphysic measurement during the cutting process: boring process for cutting forces in all direction and temperature measurement at various depth for heat flux characterisation

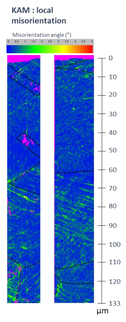



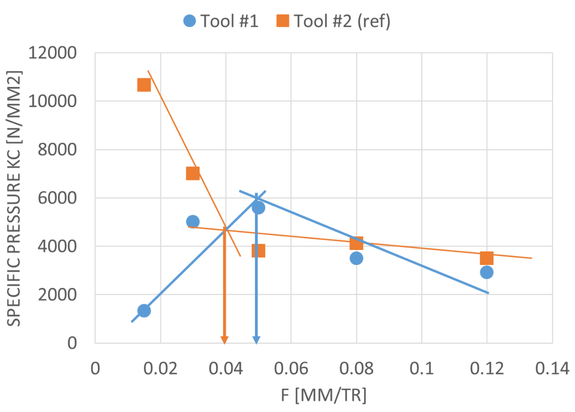
Cutting forces, friction coefficient, FEM modeling of the equivalent strain and heat flux entering the workpiece through final surface [8]



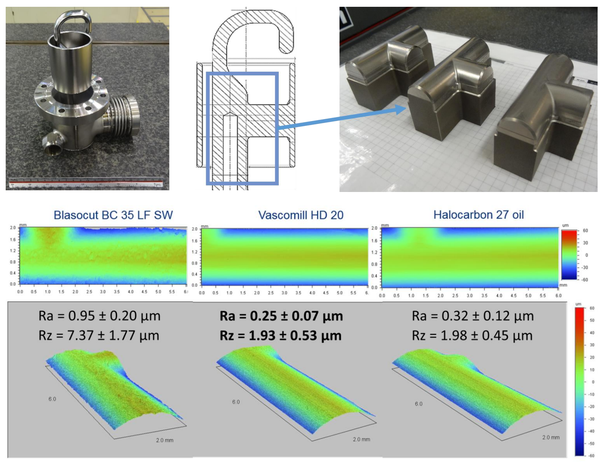
Multi-scale approach for bulk niobium radiofrequency cavities machining and surface integrity impact (microstructure, affected layer, recrystallized layer, impact on RF performance) [9]



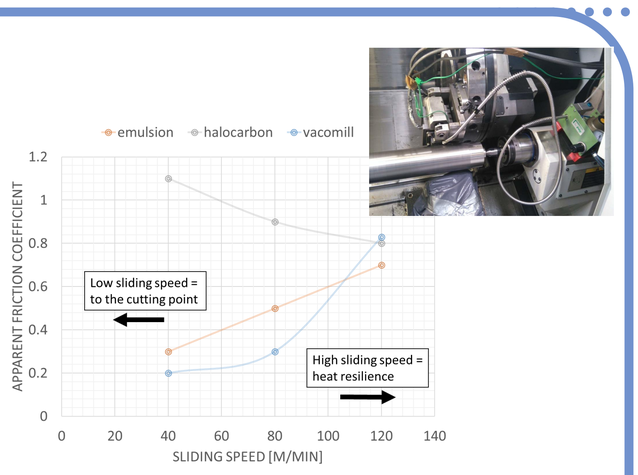




The right tool (Tool material pair standard [5])
Measure of power and force during machining

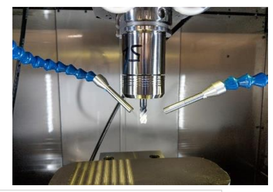
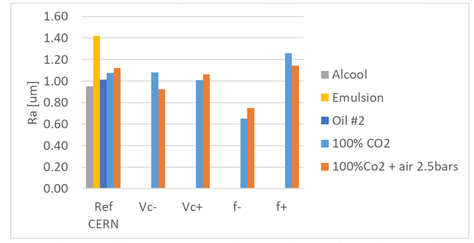


Comparison of surface shape and roughness with various coolant (1: emulsion, 2 oil #1, 3 oil #2) [6]



Thermo-mechanical tribometer [7] (study of friction characteristics of Niobium/tool/cutting fluid interface). Oil and tool contact point characterization

CO2 cryogenic cutting fluid

CO2 cooling allow smooth surface finish without surface contamination

[1] CERN Developments for 704 MHz Superconducting Cavities, Capatina, O. & al, 16th International Conference on RF Superconductivity, Paris, France, 23 - 27 Sep 2013, pp.friob04
[2] Advanced Manufacturing Techniques for the Fabrication of HI-LHC Crab Cavities at CERN, Garlaschè, M., 18th International Conference on RF Superconductivity, Lanzhou, China, 17 - 21 Jul 2017, pp.TUPB013
[3] A New Design for the Hilumi Radio-Frequency Dipole Bare Cavity, Parise, M: & al, 9th International Particle Accelerator Conference, Vancouver, Canada, 29 Apr - 4 May 2018, pp.WEPMK014.
[4] Valiorgue, F.; Brosse, A.; Naisson, P.; Rech, J.; Hamdi, H. & Bergheau, J.-M. Emissivity calibration for temperatures measurement using thermography in the context of machining Applied Thermal Engineering, 2013, 58, 321–326
[5] NF E66-520-1, Domaine de fonctionnement des outils coupants - Couple outil-matière - Partie 1 : présentation générale, Septembre 1997
[6] Trubacova, P., Niobium Polishing for SRF applications, ECC week poster session, Brussels, 2019
[7] Bonnet, C. & al, Identification of a friction model-Application to the context of dry cutting of an AISI 316L austenitic stainless steel with a TiN coated carbide tool, International Journal of Machine Tools and Manufacture 48.11 (2008), p. 1211–1223.
[8] D. Fabre, Etude numérique de l'usinage du Niobium, internal report, 2019
[9] Camelin, A, Approche multi-échelles de l'usinage des cavités RF et impact sur l'intégrité de surface. Master report, 2017