Remote manipulations and application of unconventional repair technologies in the FCC tunnel

RIGA TECHNICAL UNIVERSITY

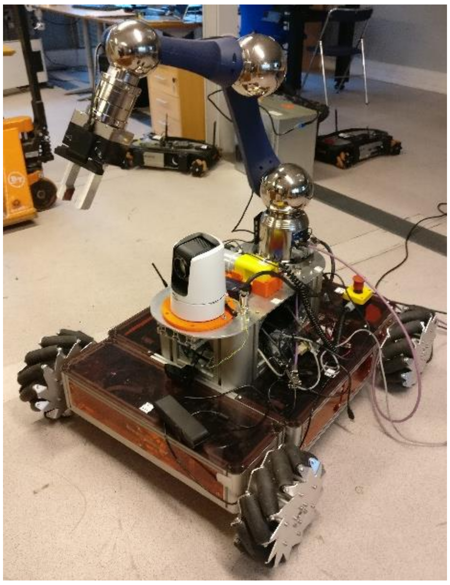
Prof. Toms TORIMS toms.torims@rtu.lv & Prof. Leonids RIBICKIS leonids.ribickis@rtu.lv

Following the FCC study and its recent developments, it is evident that due to the nature, size, scale and complexity of the environment, the deployment of **conventional repair methods and technologies will be insufficient** in the FCC.

Human intervention will be limited or even counterproductive because of the safety issues, time constraints and related costs. At the same time, it appears that the FCC infrastructure will be so large and complex that the potential for failures or malfunctions will increase exponentially. Therefore, the **FCC may face an unprecedented amount of technical glitches and problems to resolve**.

The prospective solution for the FCC is remote manipulations and unconventional repair technologies. However, this will largely depend on the general maintenance and repair strategy chosen for the FCC: preventive or predictive maintenance, or run-to-failure?

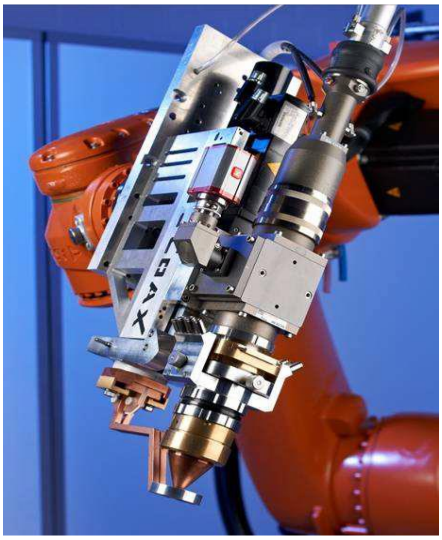
Advanced robotic and remote manipulation systems, along with novel in-situ repair technologies, offer tangible repair results. Hence one of the solutions for the FCC is a remotely controlled robotic platform performing **in-situ additive manufacturing repairs**.



/Courtesy of Dr. A. MASI – CERN/

Additive manufacturing for FCC

This could be performed at **micro and macro levels**, i.e. both in the accelerator structure and the actual civil engineering installations.



/Courtesy of Fraunhofer IWS – Dresden/

Laser cladding provides for
- ✓ rapid design changes – very flexible
- ✓ direct generation of complex parts made from eventually any material

Surface cladding
- ✓ 100 μm to 2 mm thickness
- ✓ 100 μm to 2 mm single truck with cladding area range of sq/m

Repairs
- ✓ 100 μm to 2 mm single truck with
- ✓ Multi-layer build-up
- ✓ Exact material delivery

Additive manufacturing
- ✓ 3D material build-up
- ✓ 30 μm to 1 mm lateral resolution

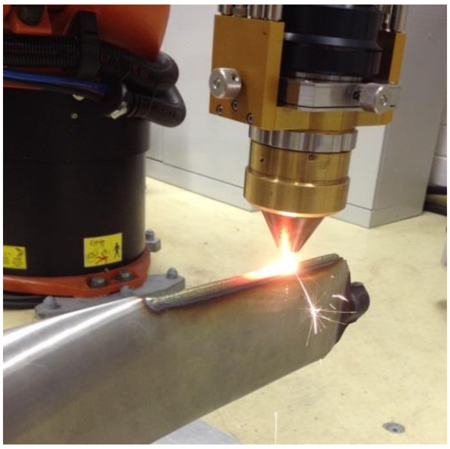
Preliminary analysis of certain challenges

Since there are numerous challenges to overcome, the new concepts have to be developed to address environmental, safety, technological and operational issues.

Environmental
- ✓ Radiation
- ✓ Supper high magnetic fields
- ✓ High voltage
- ✓ Oxygen deficiency
- ✓ **Fire safety / optical - laser**
- ✓ **Powder release in the tunnel**
- ✓ Recycling

Operational
- ✓ Difficult to access
- ✓ Very limited space
- ✓ Distance from the access points
- ✓ Time to access and solution to the problem
- ✓ Time schedule – recovery
- ✓ Reliability of technology

Technological
- ✓ Very delicate equipment, high precision and fine tolerances
- ✓ Complex assemblies
- ✓ Magnitude from micro to macro levels
- ✓ Variety of materials, often difficult to process and repair
- ✓ Novel and "unknown" materials



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Potential for FCC
- ✓ Fire safety – is different from welding – less heat and very local impact
- ✓ Flexibility – type and material
- ✓ Large variety of materials, including composite - everything that tolerates laser melting
- ✓ Could be applied to unknown and novel materials
- ✓ From nano to macro
- ✓ Fast reaction – time-to-action
- ✓ No human intervention – automation and remote manipulation
- ✓ Reliable technology
- ✓ Can work in hazardous environment
- ✓ Offers a new concept/philosophy

Important is that the aforementioned concepts could be used not only during operation but also in the construction, installation and testing phase of the FCC.