Investigation of a novel concept for carbothermic reduction of alumina

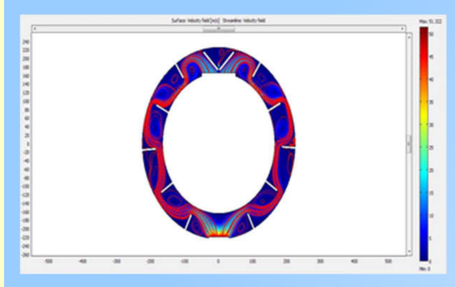
Motivation

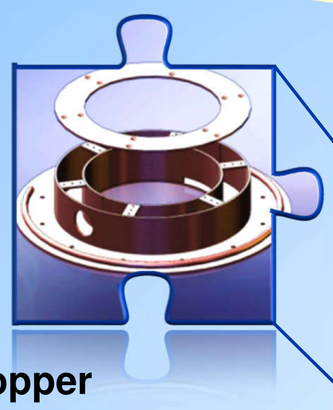
- Conventional Hall-Héroult process is one of the most energy and CO_2 intensive processes
- No alternative aluminium production process was able to prevail in industrial scale
- The most promising alternative is the carbothermic reduction of alumina in an EAF, which is characterized by high flexibility and power density as well as providing the required process temperatures
- A thermodynamic calculation indicates that the aluminium comproportionation reaction is preventing the complete alumina reduction in the liquid phase and leading to vapour losses
  (T = 2250°C; $Al_2O_{3(l)} + 5Al_{(l)} = 3Al_2O_{(g)} + Al_{(g)}$)

→ Suppression of liquid metal formation → Suppression of $Al_2O_{(g)}$ formation → higher alumina reduction yields → processing above 2500 °C → decreasing oxygen content of the system

Al generation over the gaseous phase under protective gas

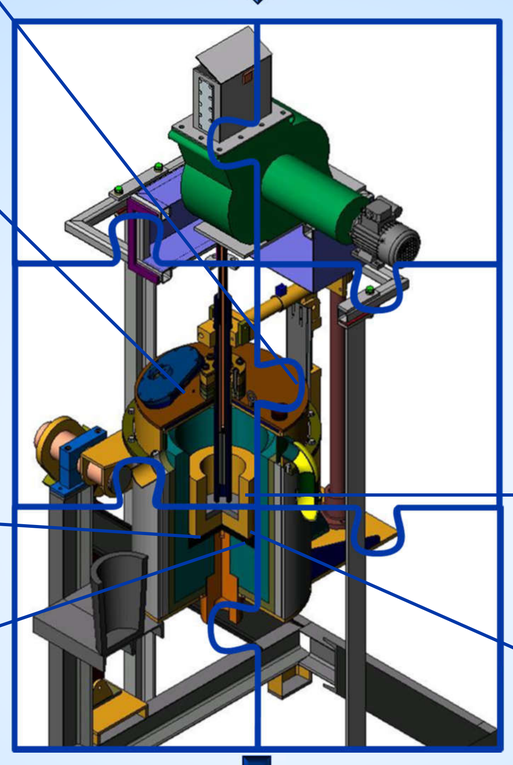
Process development



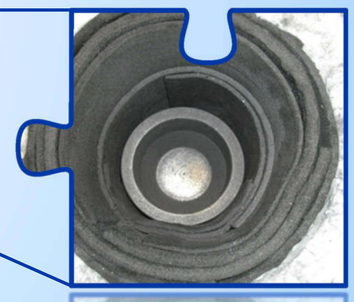


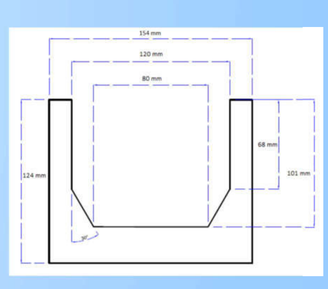
- New water cooled copper condenser
  - Design and calculation of the optimal parameter and conditions using CFD
  - Very fast cooling of the gaseous aluminium to avoid back reactions

- Feeding through rotary valve and hollow electrode



General Data:
- Power supply 25 kW
- Ar is used as protective gas
- Alumina + Carbon were pelletized in stoichiometric ratio ($Al_2O_3 + 3C$)
- Feeding speed was optimized
- Average duration of an experiment: 40 min preheating, 30 min experiment





- Optimization of the flow conditions of the gases at the interior of the EAF
  - 4 different gas inlets
  - Gas flow can be adjusted with the graphite base for rapid and homogeneous transition of the gaseous components to the condenser

- A special graphite felt for thermal isolation
  - Low thermal conductivity
  - High temperature resistance
  - High strength of shape
- Conical crucible design
  - Focusing to feed the initial material close to the arc

Results

Condensed Aluminium

- Fast and clean physical vapour deposition
- Successive optimization of the specific parts led to increasing Al contents in the condensed material

Progress in metal content

5 wt.-% Al

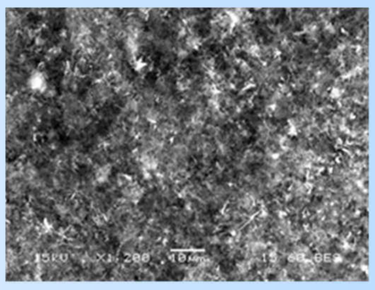
15 wt.-% Al

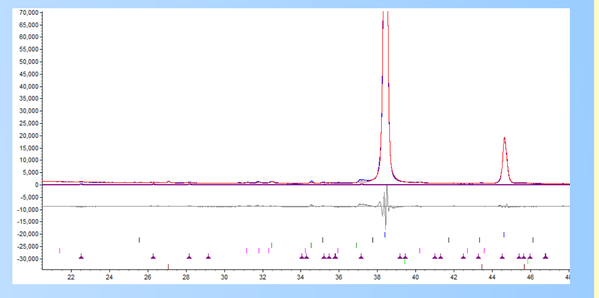
40 wt.-% Al

60 wt.-% Al

>90 wt.-% Al

SEM Analysis





- After realization of the aforementioned processing and optimization steps:
  high amount of Al, no corundum, no graphite, no cubic Al_2O_3, minimal amounts of Al_2OC and Al_4C_3, traces of Al_4O_4C

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