Fines2EAF

Laboratory experiments to test the performance of the cement-free bricks utilized in EAF

University of Oulu

Dsc.Eng Matti Aula

Dsc.Eng Mamdouh Omran

MSc. Ahmed Abdelrahim

Proff. Timo Fabritius

Background

Cement-free bricks offer many advantages over cement bricks in EAF:

- Takes less energy to melt
- No silica input to furnace

Drawbacks:

- Mechanical properties typically worse

→ Possible dust problems

- Binder can combust
- Properties vary highly depending on the binder and recipe

→ Utilization of cement-free bricks in EAF requires better understanding of their behaviour in EAF than the cement bricks

Background

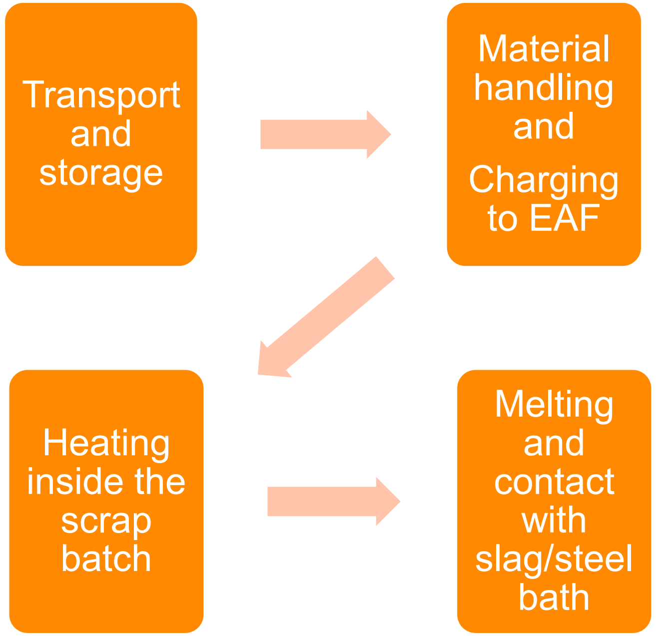
Why perform laboratory scale tests?

- Many possible recipes and binder systems

→ impossible to find optimal recipe without small-scale tests

- Avoid problems in industrial scale
- Obtain guidelines how to handle the bricks without excessive generation of fine particles

Design of laboratory test plan



– **The tests should be designed to simulate the conditions the bricks will be subjected to in EAF**

1. **Storage and material handling**
   - Aging properties
   - Effect of moisture
2. **Charging and handling:**
   - Mechanical properties in material handling
   - Charging to furnace (drop height)
3. **Behaviour during heating**
   - Evolved gases and dust emissions
   - Binder system temperature stability
   - Softening behaviour
   - Solidus and liquidus temperature
   - Reduction behaviour (self-reducing bricks)
4. **Melting behaviour**
   - Dissolution in slag

Storage

- Research question:
- Do the brick properties deteriorate in presence of moisture during aging?

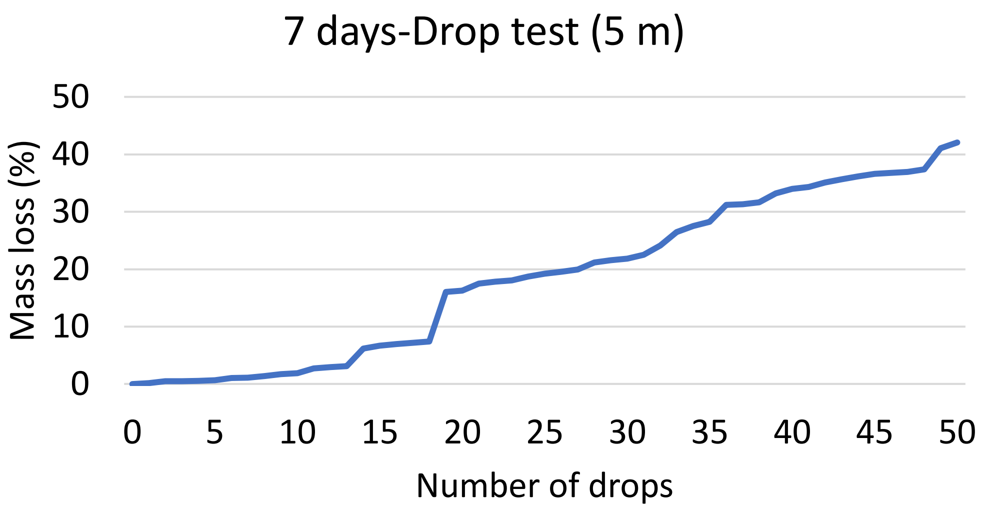
- Aging properties depend highly on the raw materials of the bricks
- Free CaO especially troublesome
- Test methods for aging:
  - Compare mechanical properties of the 1 day and 7 day bricks
  - Storing bricks in humid conditions
  - Sample preparation with wet grinding and cutting (reveals hydrofilic properties)

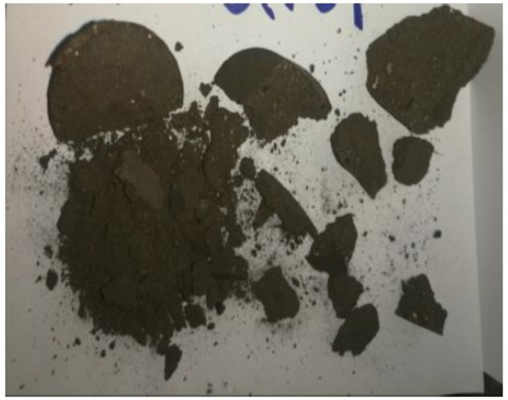
Charging and handling

Research question:

- Are the mechanical properties of the bricks good enough to withstand handling and charging to EAF?
- Very high bond strength not necessarily optimal, can require high energy to melt
- Test methods material handling
  - Drop tests (number of drops, height)
  - Tumbler tests
  - (Compressive strength)

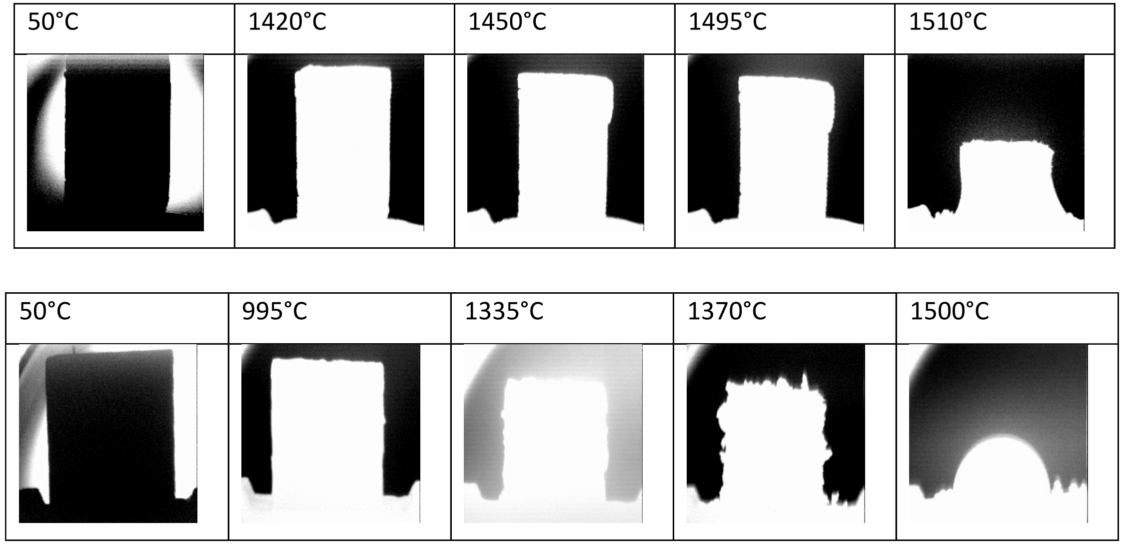
Drop tests





- Drop tests are very important for determining handling properties
- Brick dropped consequtively from certain height and the mass loss is measured
- Good screening method, can be used to reduce the amount of brick recipes tested further
- A brick can give very good compressive strength but perform poorly in consecutive drop tests
- Important to perform from heigh relevant to EAF charging or silo storage (for example 5 meters)

Heating behaviour



Research questions:

1. Does the brick retain it’s shape in the heating?
2. Are excessive amounts of fines formed?
3. How high is the volatilization of the brick?
4. Does reduction occur in the brick?

Test methods:

- Dilatometer
- TGA-DTA-MS
- Full scale brick TGA

Dilatometry

– Measures change of shape during the heating

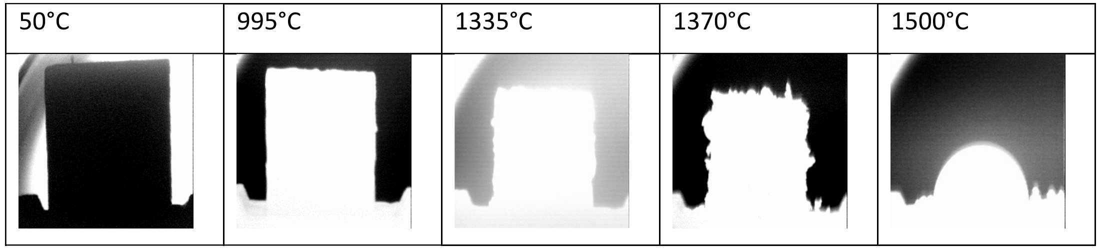
Allows measurement of:

– Softening temperature

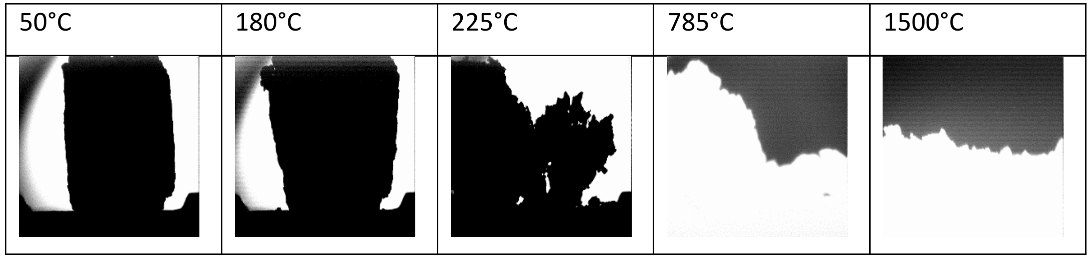
– Solidus temperature

– Liquidus temperature

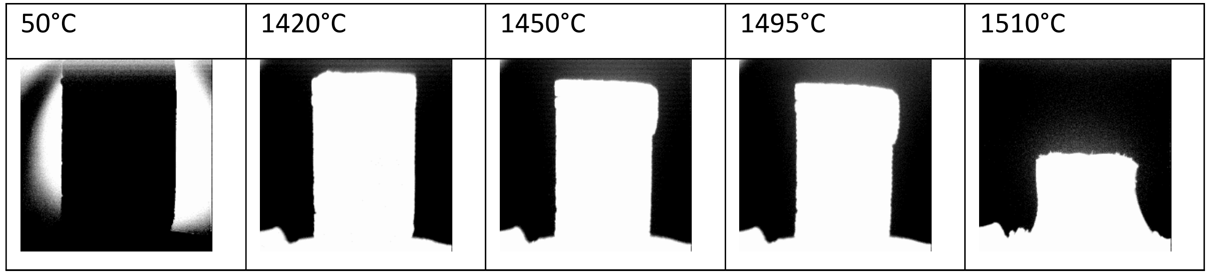
Solidus Liquidus



Failure

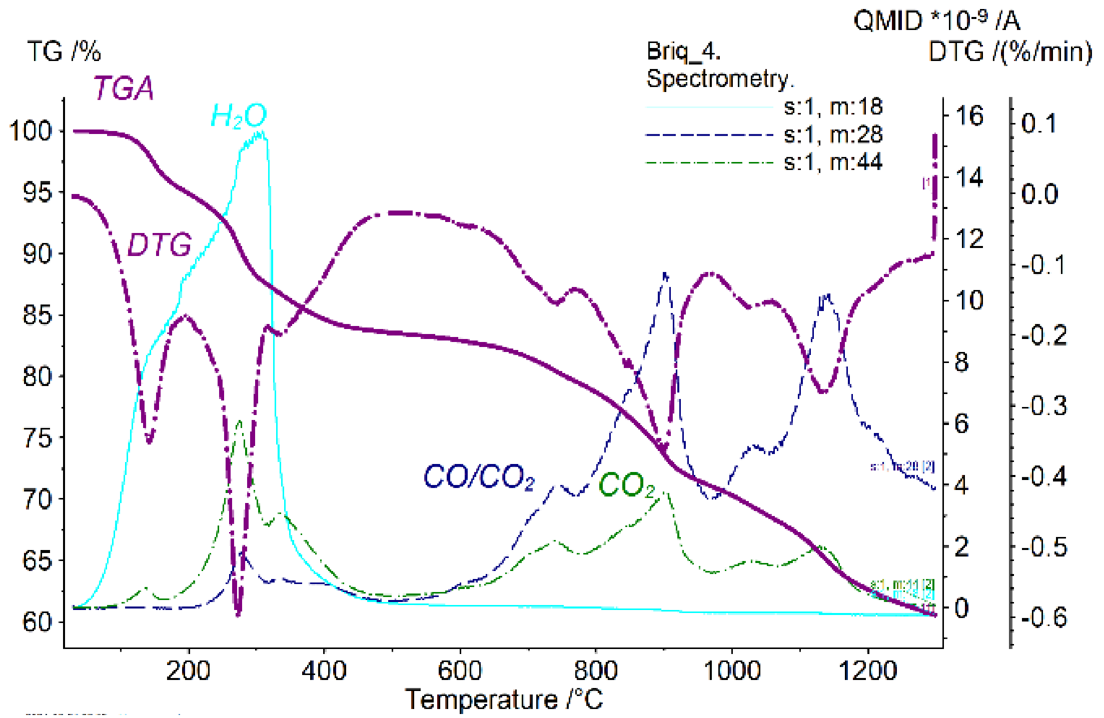


Only softening



TGA-DTA-MS

Example of TGA-DTA-MS for self-reducing brick



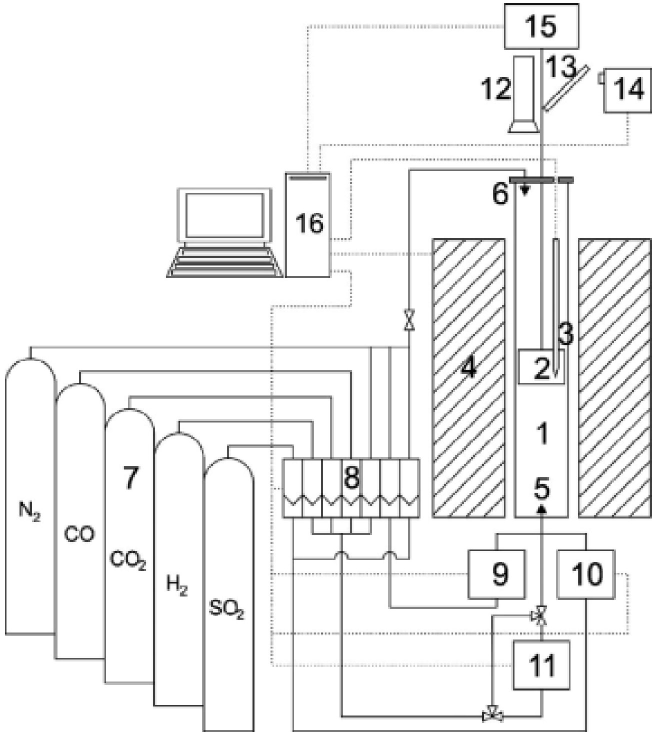
Enables:

- Mass spectrometry measurement of evolved gases
- Measuring change of weight during heating
- Detection of phase change temperatures with DTA

Example of summary of results

Sample	Reaction 1	Reaction 2	Reaction 3	Reaction 4
1	Binder decomposition at 286 °C, fast	Reduction at 800 – 1400 °C		
2	Binder decomposition 200 – 500 °C, slow	CaCO3 decomposition at 600 - 800 °C		
3	Evaporation of free water at 109 - 200 °C	Slow decomposition of binder at 200 - 400 °C	Slow reduction at 700 – 1100 °C	Fast reduction at 1100 – 1250 °C
5	Binder decomposition at 222 °C, fast	Slow water removal at 100 - 500 °C	Decompostion of manganese ore at 670 °C	Reduction at 1100 – 1500 °C

Full scale TGA



Schematic of the appartus

– **Thermo gravimetric analysis for full brick**

Enables:

- Measurement of reduction degree of self-reducing bricks
- Determine the effect of brick size on reduction degree
- Observing thermal shock resistance of the full brick

Features:

- Heating to 1100 C in 35 min
- Reducing atmoshpere
- Camera to see shrinkage

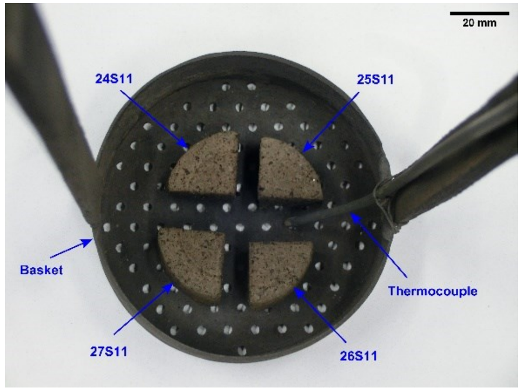
Gas composition

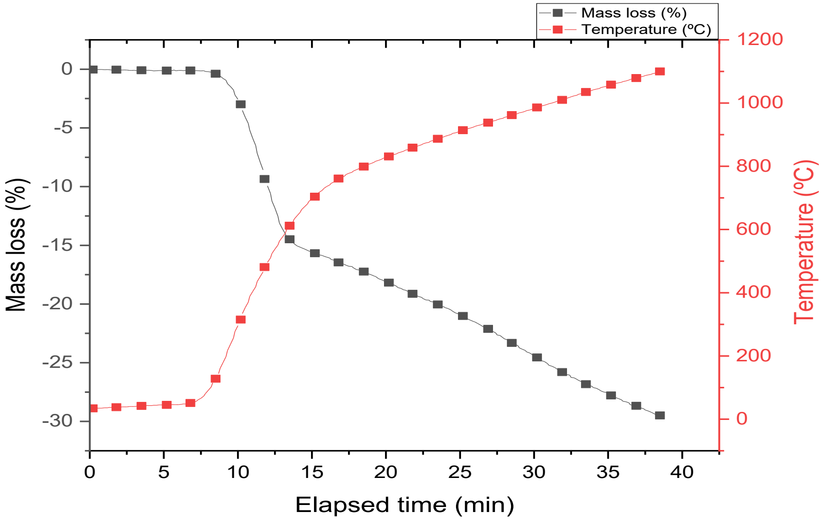
Gas	N_2	CO	CO_2	H_2
(%)	31.00	50.00	15.00	4.00

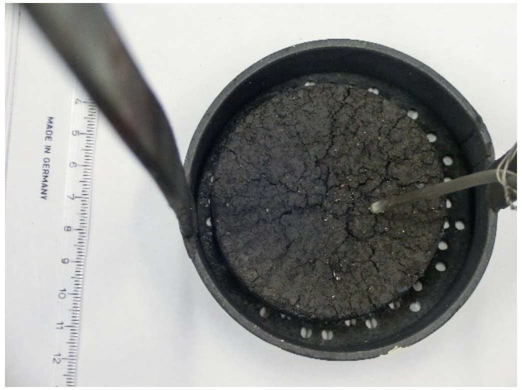
Full scale TGA

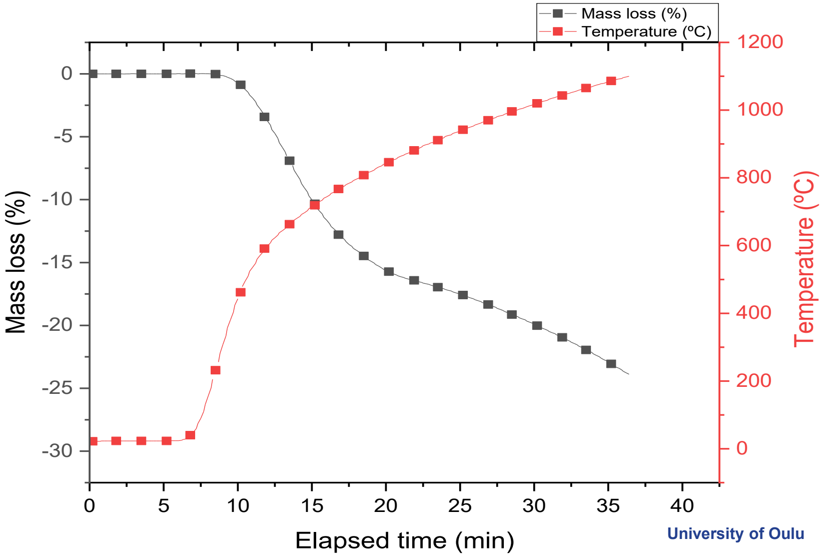
– **Residual analyzed with metallographic analysis (Montanuniverstität Leoben)**

	Main components	Size	Fe total	Fe2+	Fe-Met	Fe3+
Analysis method			DIN EN ISO 11885. 2009-09	AM_EG. 26 (Titration) *	ISO 5416*. 2006-04	Calculated
BRIQ1	Grinding sludge + oxy-cutting fines +carbon	Cut to four indentical	81.3	26.6	47	7.7
BRIQ2	Grinding sludge + oxy-cutting fines +carbon	Full brick	70.7	45.2	22.3	3.2

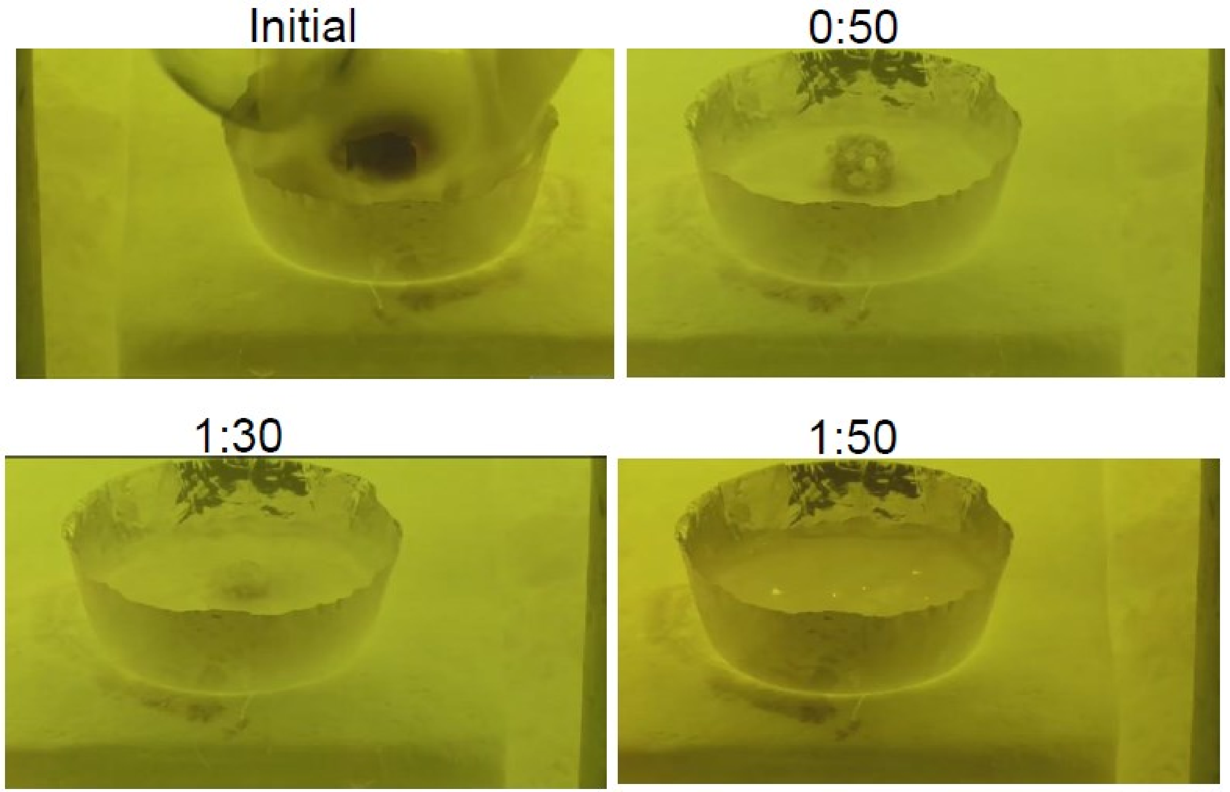






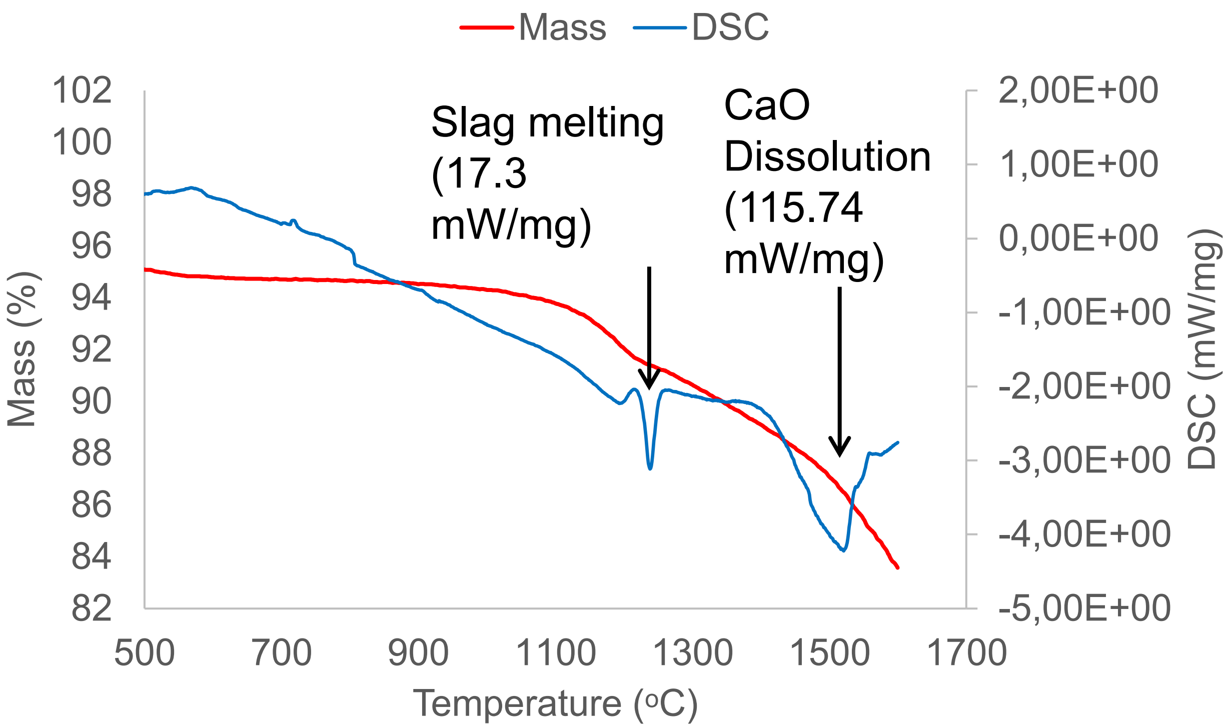


Melting behaviour



- Research question:
  - Do the bricks melt or are the taphole clogging problems possible?
  - Are there fuming problems?
  - How much energy does the brick melting take?
- To accurately test the melting and dissolution behaviour, liquid slag is required
- Laboratory chamber furnaces suitable for such trials
- Features:
  - Synthetic liquid slag in platinum crucible
  - Temperature 1550 C
  - Brick put on the top of the hot slag
  - Melting observed with camera

Calorimetric analysis



Synthetic slag compositions

FeO	SiO2	CaO	MgO	Al2O3
67.51	13.50	9.00	5.00	5.00

- Calorimetric analysis enables measurement of energy consumption
- Bricks with organic binders very difficult to analyze with Differential scanning calorimetry (DSC)
- High volatilization, organic compounds and prone to combustion

→ Hazardrous for delicate DSC equipment

→ Extreme care required in DSC trials

→ Energy consumption more feasible to analyze with pilot scale EAF

Example of test results

	Main components	Binder	Test	Compression	Drop test	TGA- MS	Melting	Reduction	Dilatometry	Sample prep	Suitability for use in EAF	Remark
BRIQ1	Oxy-cut fines + CCD dust	Starch	BRIQ1	++	+	+	NA	-	++	+	Use limited	High fuming
BRIQ2	CaO fines	Starch	BRIQ2	+	+	+	NA	NA	+	+	Suitable	
BRIQ3	Grinding sludge + oxy-cutting fines	Starch	BRIQ3	++	+	+	NA	+	++	+	Suitable	
BRIQ4	Grinding sludge + oxy-cutting fines	Starch	BRIQ4	++	++	+	NA	++	++	+	Suitable	
BRIQ5	MnO dust	Starch	BRIQ5	+	+	+	NA	+	-	-	unsuitable	
BRIQ6	LF Slag	Starch + $NaSiO_2$	BRIQ6	+	+	NA	++	NA	++	-	Use limited	Cannot be stored for long
BRIQ7	Mix residues + LF slag	Starch	BRIQ7	+	+	NA	++	NA	++	-	Use limited	Cannot be stored for long


Thank you
University of Oulu