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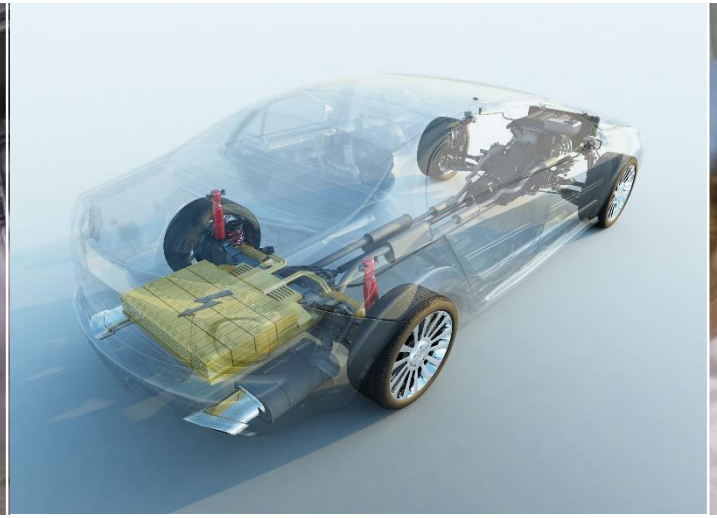

Influence of Super Reactive Alumina on Rheological Behavior of Free Flowing Castables at Low and High Shear Rate

Nabaltec: a leading supplier of eco-friendly flame retardant fillers and specialty alumina

Christian Dünzen, David Janousch
Unitecr 2022

Abstract

The rheological behavior of refractory castables is often only described by the simple spreading test. However, castables with very low water contents are well known to exhibit a strongly dilatant behavior, even though the viscosity at high shear rate is usually not measured. The study described in this paper intends to illustrate the effect of a Super Reactive Alumina on the shear rate dependent rheological behavior of castables. A pure alumina ULCC was modified by gradually replacing the Reactive Alumina (D_{50}: 2.5 µm) by a Super Reactive Alumina (D_{50}: 0.8 µm). While the spreading test is used to determine the flowability at low shear rate, a simple setup was created to measure power consumption of the mixer and thus allowing conclusions to be drawn about the viscosity of the castable at a higher shear rate. It is shown, that the spreading diameter remains almost unchanged for Super Reactive Alumina contents from 20 % to 60 %. Mixer power consumption, is continuously decreasing, when the content of Super Reactive Alumina is raised from 20 % to 100 % stepwise. The results offer a solution to reduce castables viscosity, especially at high shear rate. This study illustrates how Super Reactive Alumina continuously changes the rheological behavior of a castable from rather shear thickening to rather shear thinning by increase of its percentage.

How to get the full article

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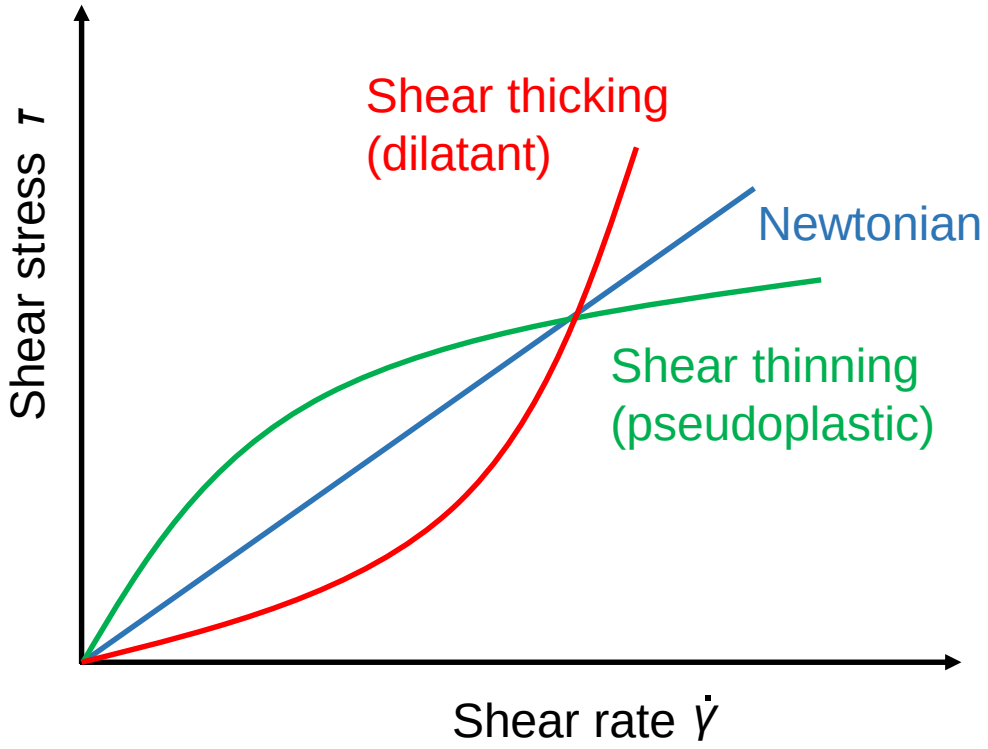
Introduction - Viscosity



- Shear rate is well defined and constant in the measurement container.
- Hardly appliccable for refractories

Experimental procedure – Measurement setup

- Viscosity at low(er) shear rate:
  - Flow spread

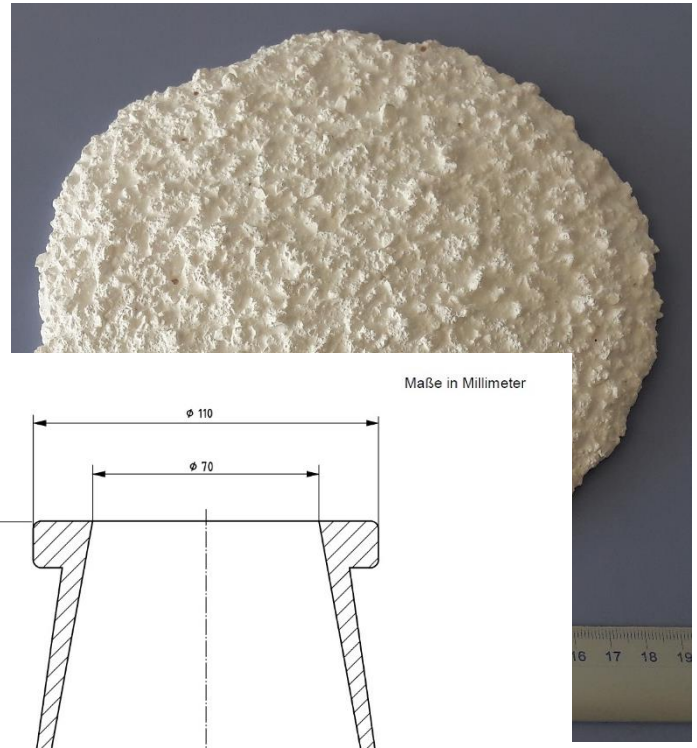
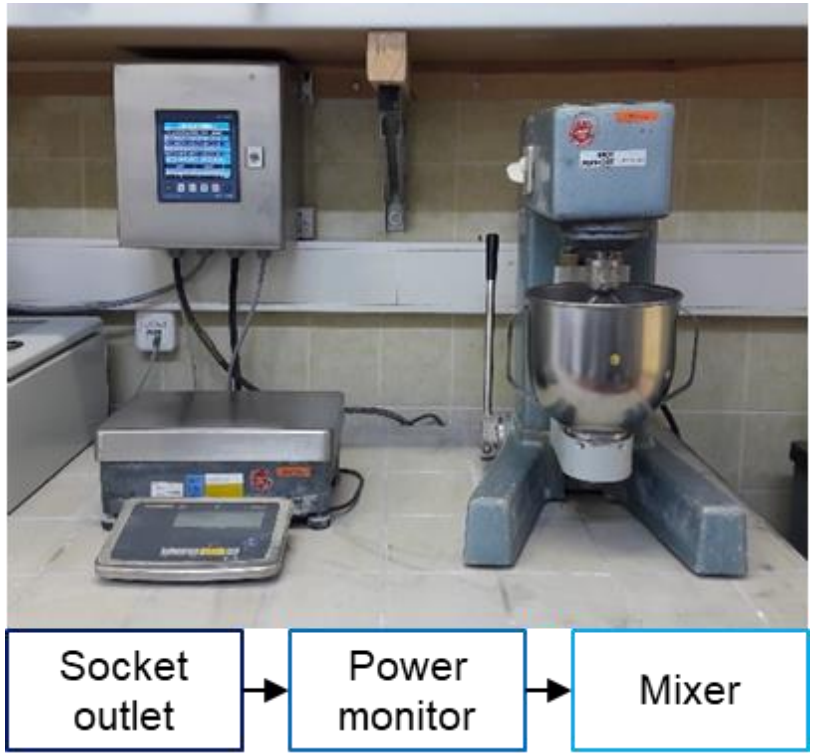


Bild 2 — Trichterform 2, Höhe 80 mm

DIN EN ISO 1927-4:2012

- Viscosity at high(er) shear rate:
  - Mixer Power consumption monitoring

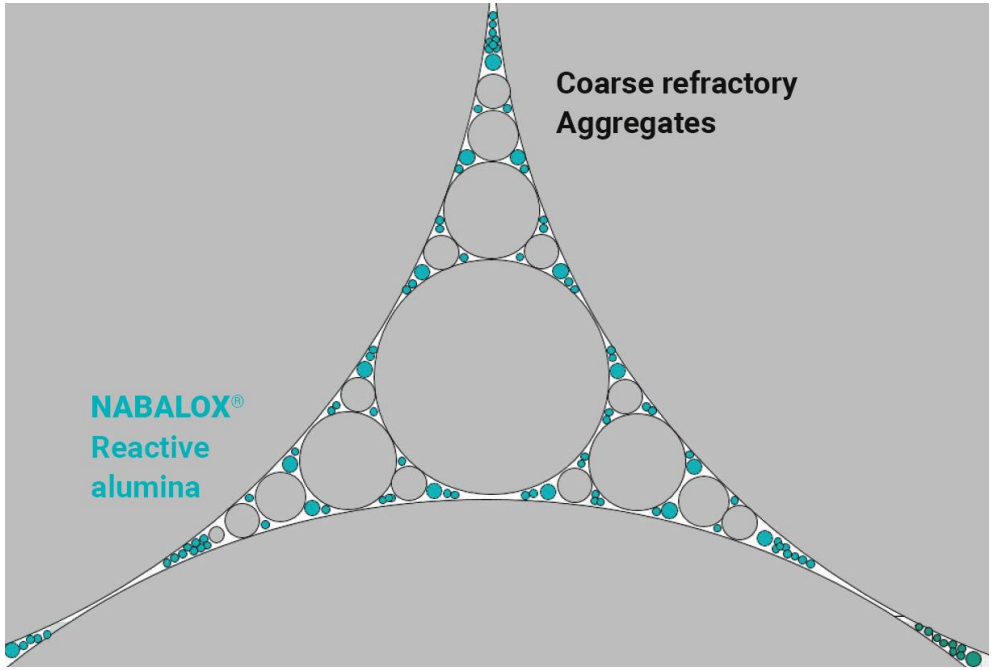


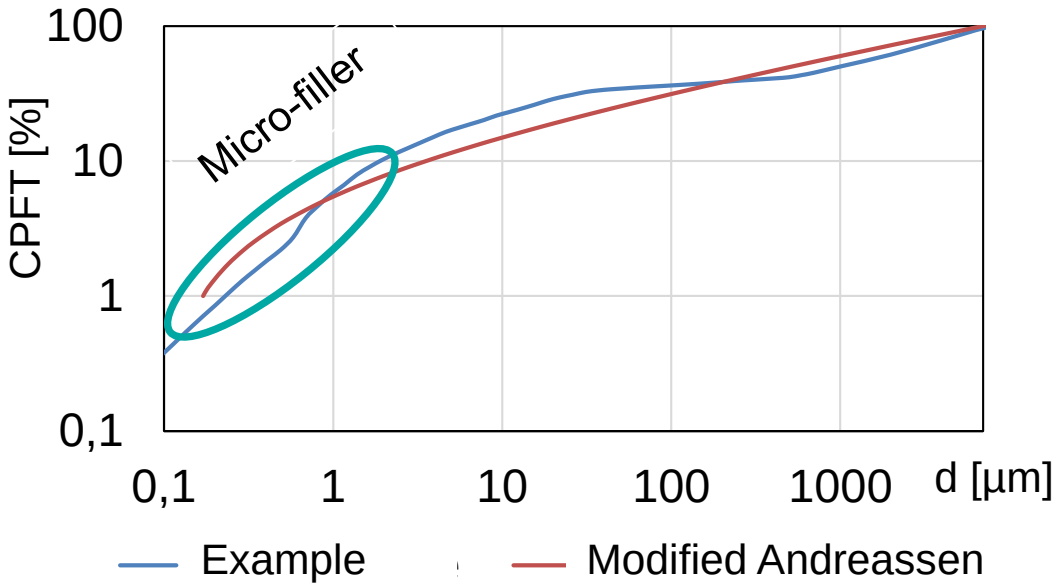
Self created; details in the paper

- Conclusions to be drawn about viscosity
- Flow spread is inversely (!) proportional to viscosity

- ❖ Relevant for real usecases
  - ❖ Mixing
  - ❖ Casting

Experimental procedure – Raw Materials

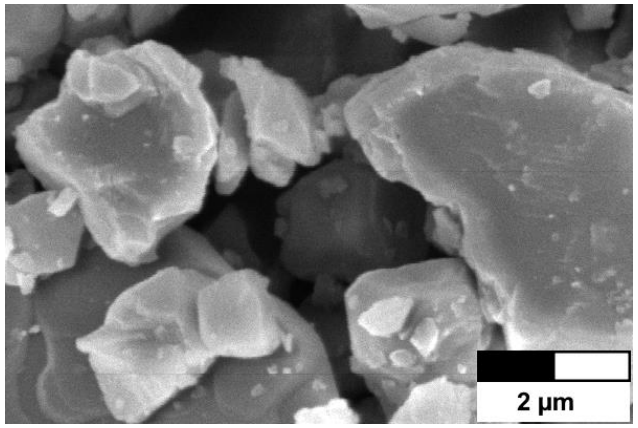


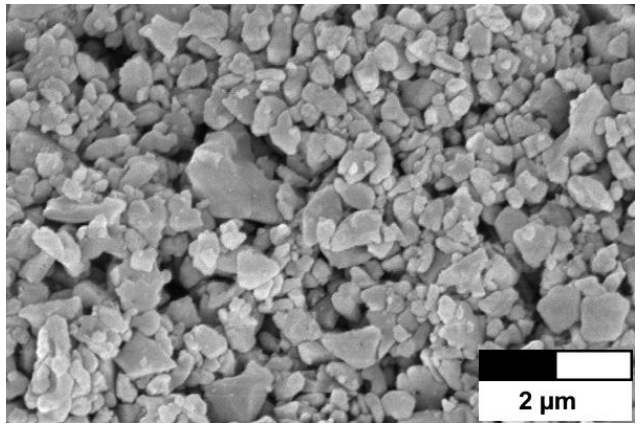


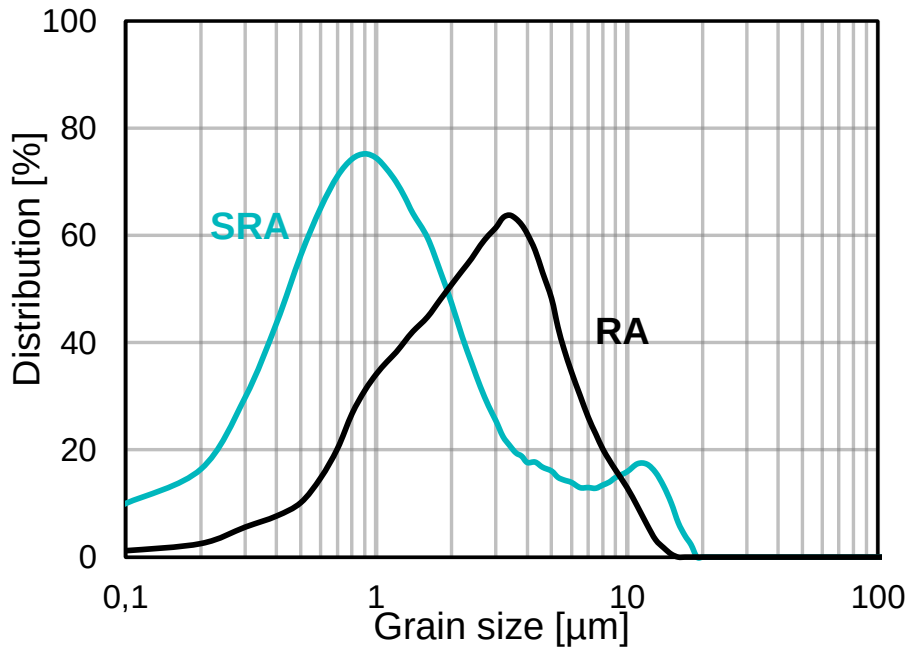
- Gap filling effect of Micro-filler
- Maximization of packing density
- Particle sizes 2 µm to <<1 µm
- Reactive Alumina vs. Silica fume

Experimental procedure – Raw Materials – Monomodal Reactive Aluminas

		RA	SRA
NABALOX ®		NO 625-10	NO 713-10 RF
D_{10}	[µm]	0.62	0.19
D_{50}	[µm]	2.32	0.85
D_{90}	[µm]	5.9	4.4
S_{spec} (BET)	[m²/g]	1.5	7.6
Na_2O	[%]	0.1	0.08
Al_2O_3	[%]	99.8	99.7







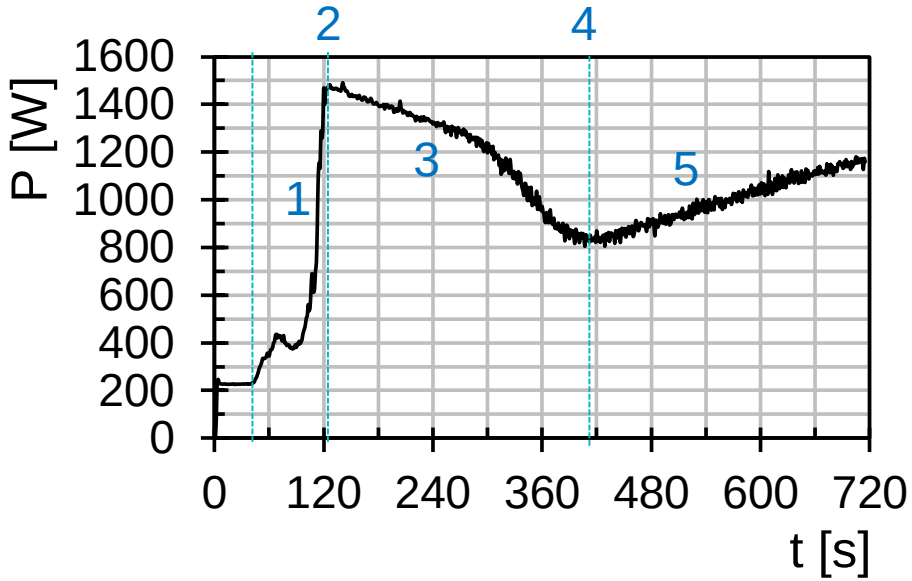
- Combination of RA + SRA
- Bimodal Matrix

Experimental procedure – Raw Materials – Test castable

Tabular Alumina	3 – 6 mm	[%]	24
Tabular Alumina	1 – 3 mm	[%]	16
Tabular Alumina	0.5 – 1 mm	[%]	15
Tabular Alumina	< 0.5 mm	[%]	7
Tabular Alumina	< 0.3 mm	[%]	5
Tabular Alumina	< 325 #	[%]	12
Calcined Alumina	3.5 µm	[%]	5
RA	2.3 µm	[%]	(1-x)·13
SRA	0.8 µm	[%]	x·13
CAC (Secar 71)		[%]	3
PCE (Viscocrete 225 P)		[g/100g]	0.1
Water content		[ml/100g]	4.0

Results and Discussion – P-t-Plots

P_{max}: Mixer power consumption at Maximum (2)
P_{min}: Mixer power consumption at Minimum (4)
P_{end}: Mixer power consumption after 12 minutes
t_{max}: Mixing time to Maximum (2)
t_{min}: Mixing time to Minimum (4)
F_{min}: Flow spread at Minimum (4)
F_{end}: Flow spread after 12 minutes

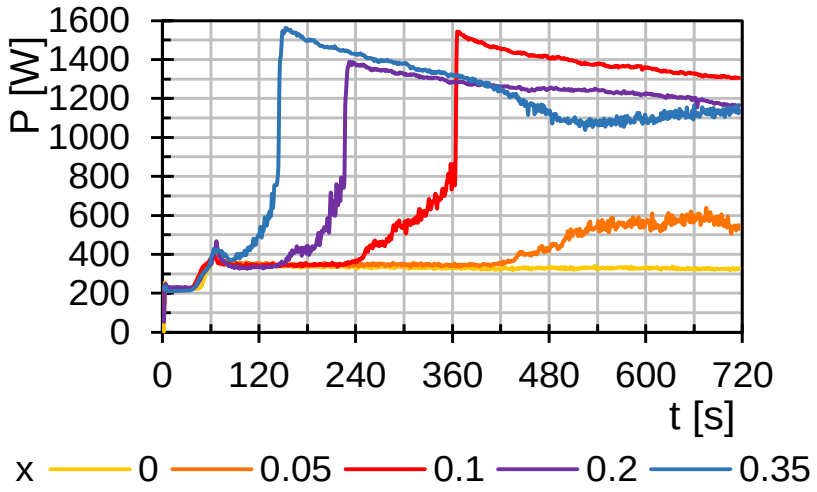


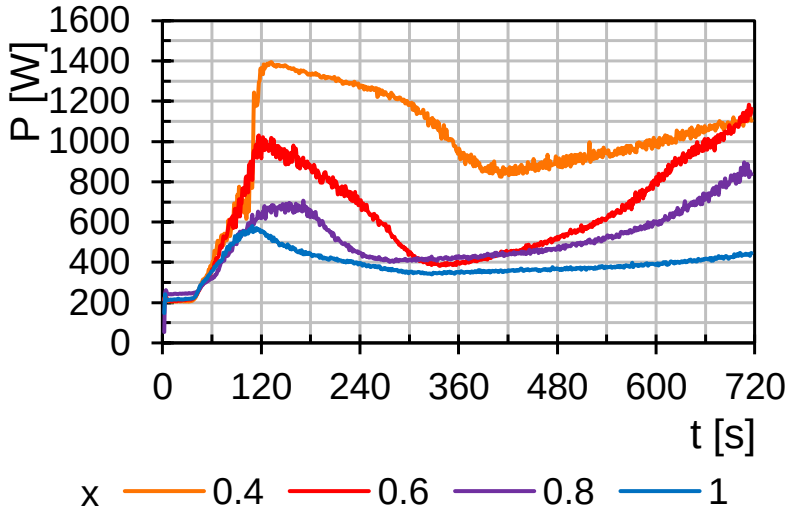
Results and Discussion – Effect of Super Reactive Alumina

x	Mixing behaviour
0	Like dry powder
0.05	Like dry powder
0.1	Turns into a consistent mass after 6 min
0.2	
0.35	
0.4	
0.6	
0.8	
1.0	

↓ Effects occur faster

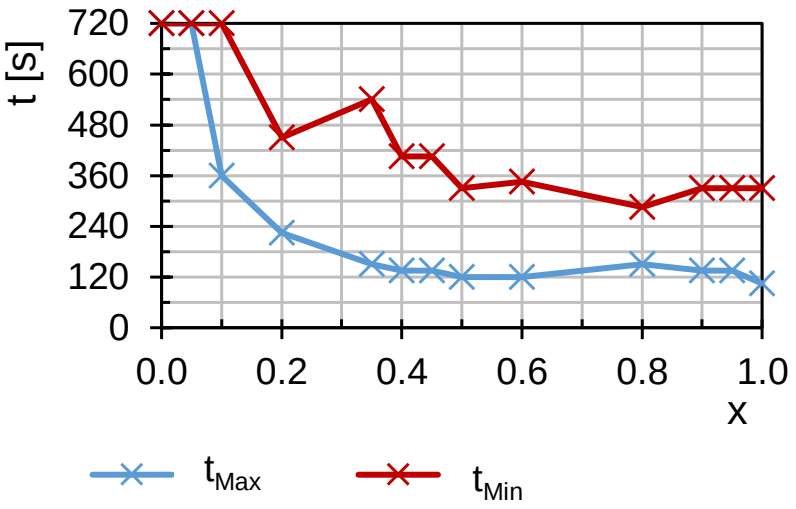
↓ Power consumption reduces



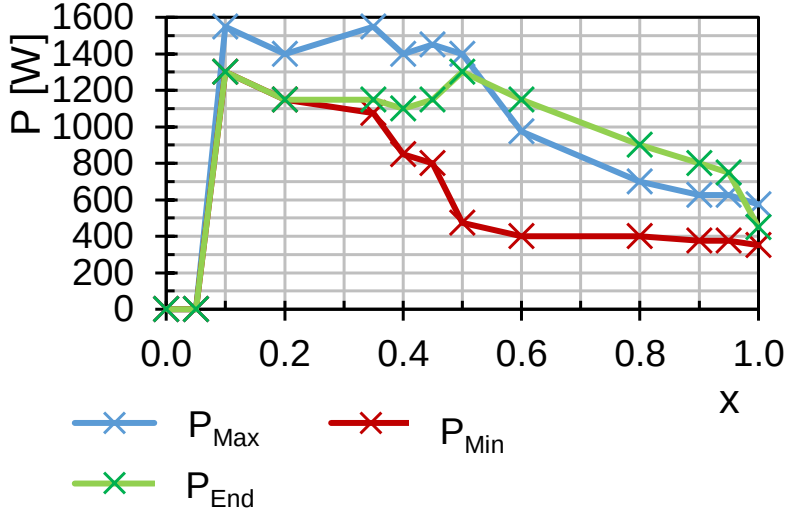


The three parameters t (time), P (mixer Power consumption) and F (Flow spread)

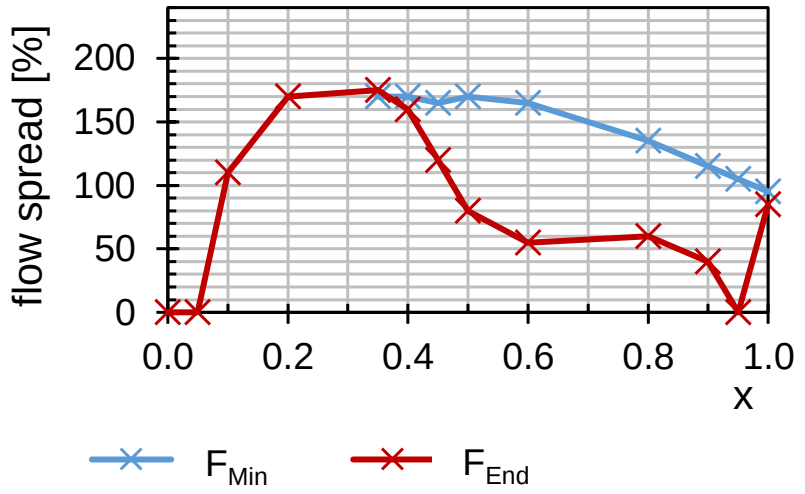
t_{Max} and t_{Min} as a function of x



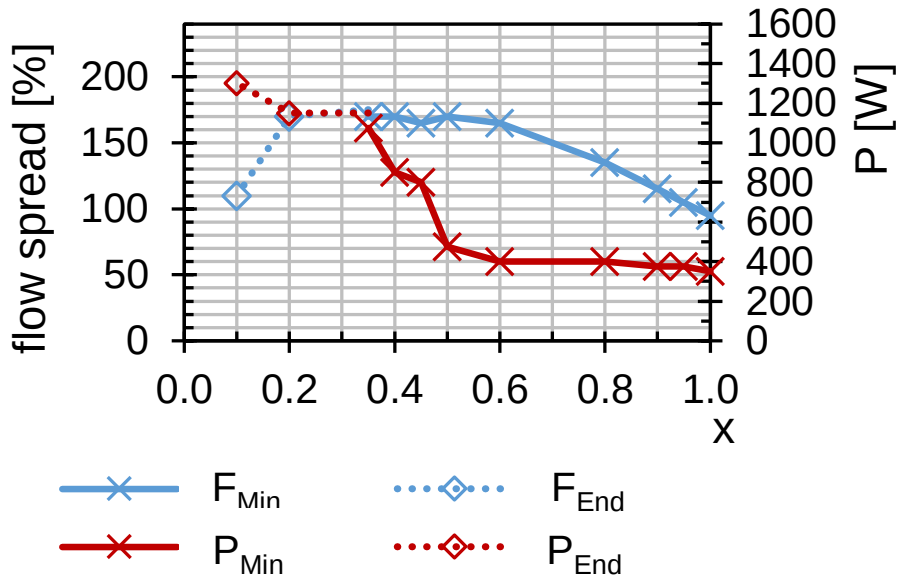
P_{Max}, P_{Min} and P_{End} as a function of x



F_{Min} and F_{End} as a function of x

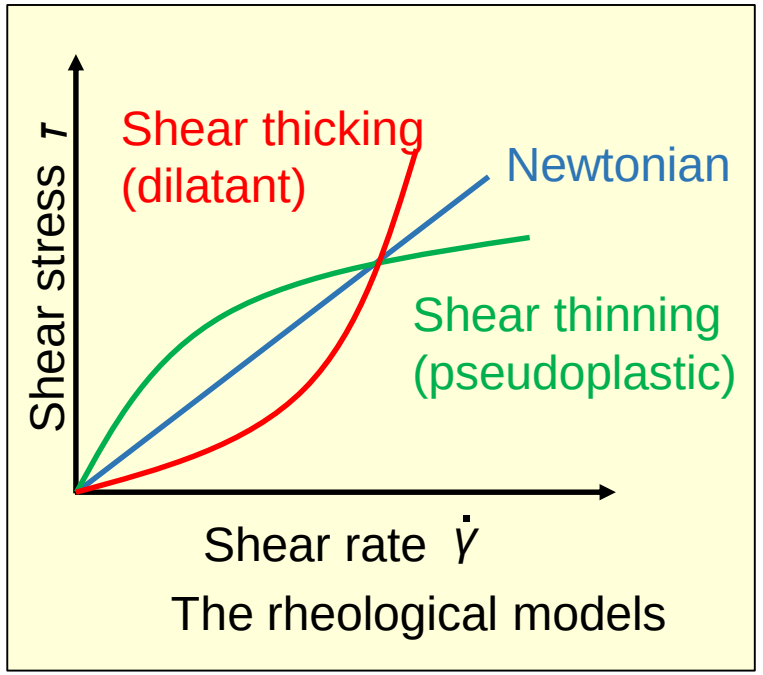


Discussion – Effect of SRA on the shear rate dependant rheology



flow spread and mixer power consumption for optimally mixed castables

- 0.1 < x < 0.35:
  - When x increases:
  - The viscosity at low and high shear rate decreas
- 0.35 < x < 1:
  - When x increases:
  - The viscosity at high shear rate decreases
  - The viscosity at low shear rate increases



The rheological models

Summary

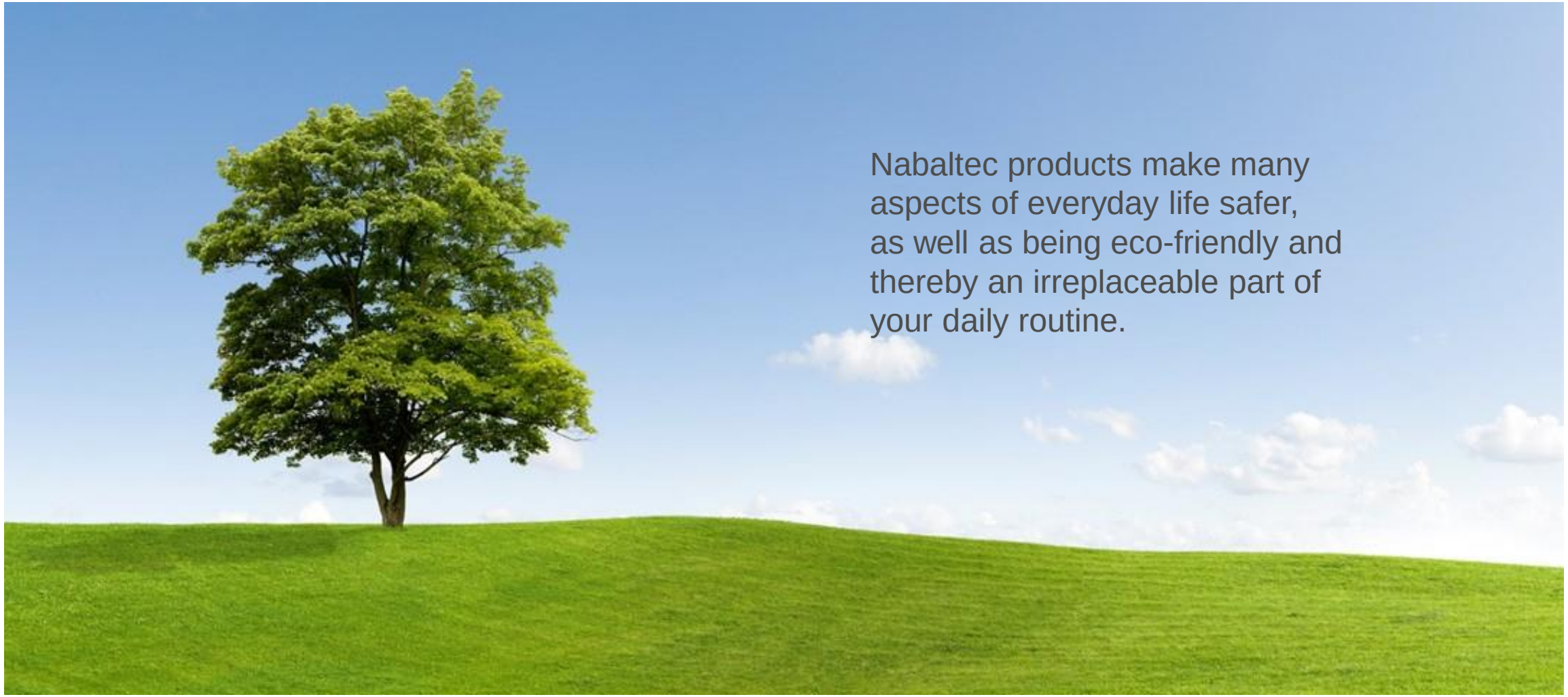
- Mixer power consumption monitoring
  - Reveals numerous aspects of a castables rheology
  - Can prevent over- (under-) mixing
  - Can be a development tool to reduce dilatancy

- Super Reactive Alumina
  - is a tool to influence castable‘s rheology
  - Can turn a castable from shear thickening to shear thinning

Outlook

- Comparison with real viscosity data
- Modification of the setup towards variable shear rate
- Use as a tool for product development

Thank you for your attention! ☺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your daily routine.