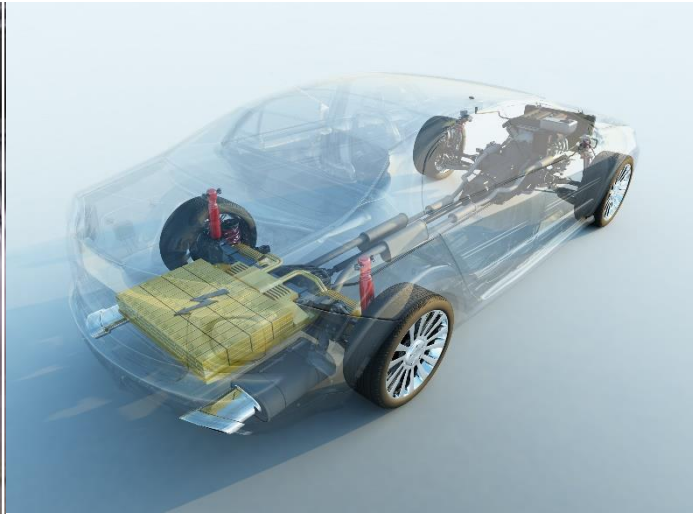


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# **VISCOSITY CHANGES OF AN ALUMINA BASED CASTABLE DURING MIXING AND THE EFFECT OF BIMODAL REACTIVE ALUMINAS**

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

Christian Dünzen, David Janousch  
2021

## Abstract

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 rheological phenomena of a castable that occur during mixing and thus, at high shear rate. A pure alumina ULCC with a bimodal matrix was used. The bimodal matrix was either composed of two Reactive Aluminas, with particle sizes ( $D_{50}$ ) of 2.5  $\mu\text{m}$  and 0.8  $\mu\text{m}$ , or of pre-homogenized Bimodal Reactive Aluminas consisting of the same particle sizes. While the spreading test is used to determine the flowability at low shear rate, a setup was created to measure power consumption of the mixer and thus allowing conclusions to be drawn about the viscosity at higher shear rate. What's more, the power consumption plotted against the mixing time results in characteristic curves. Basically the mixing process can be divided into distinct stages, such as wet out point, when particles start to form a coherent mass with very high viscosity, continuous decline of viscosity followed by a reincrease of the same. These events are discussed with regard to dispersion and coagulation as well as electro-chemical interactions between cement and deflocculant. It is shown, that a Bimodal Reactive Alumina disperses much faster than a bimodal mix of two Reactive Aluminas. What's more, the described power consumption monitoring is proposed as a viable method to ensure the preparation of castables mixed to the optimal viscosity.

## How to get the full article

Ch. Dünzen, D. Janousch

VISCOSITY CHANGES OF AN ALUMINA BASED CASTABLE DURING MIXING AND THE EFFECT OF BIMODAL REACTIVE ALUMINAS

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Ch. Dünzen, D. Janousch

VISCOSITY CHANGES OF AN ALUMINA BASED CASTABLE DURING MIXING AND THE EFFECT OF BIMODAL REACTIVE ALUMINAS

Refractories WORLDFORUM 13 (August 2021) [3]

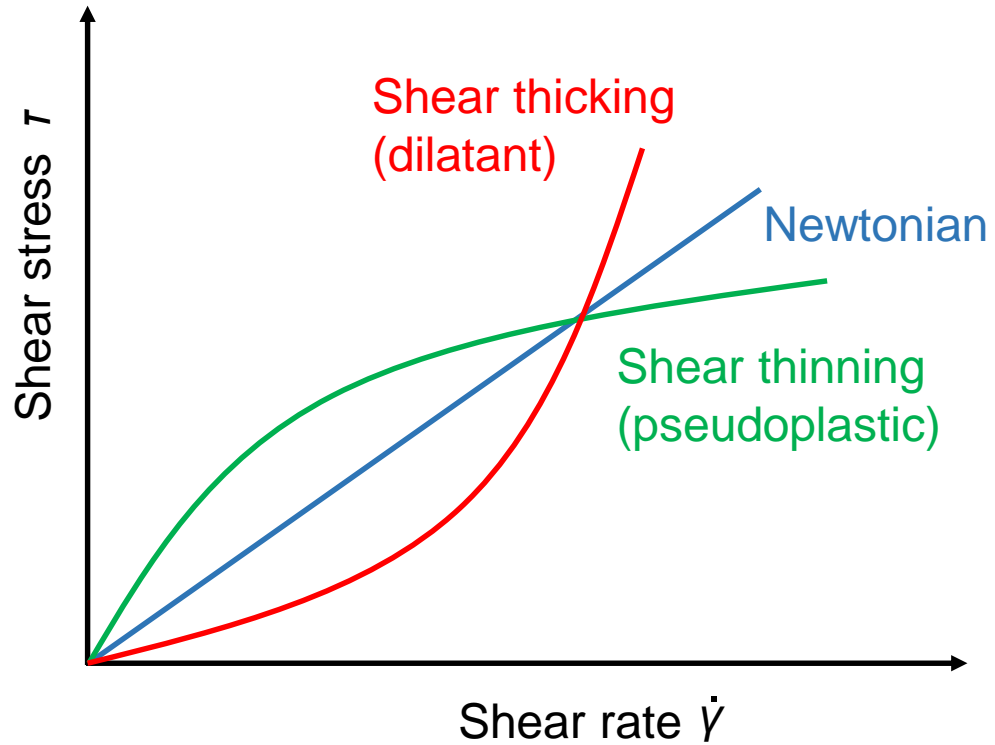
Göller Verlag, Baden-Baden

Pages 33 - 37

## Table of Contents

- Introduction
  - Viscosity
- Experimental procedure
  - Measurement setup
  - Raw Materials
- Results and Discussion
  - P-t-Plots
  - Effect of Reactive Aluminas
- Summary
- Outlook

## Introduction - Viscosity



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

## Experimental procedure – Measurement setup

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

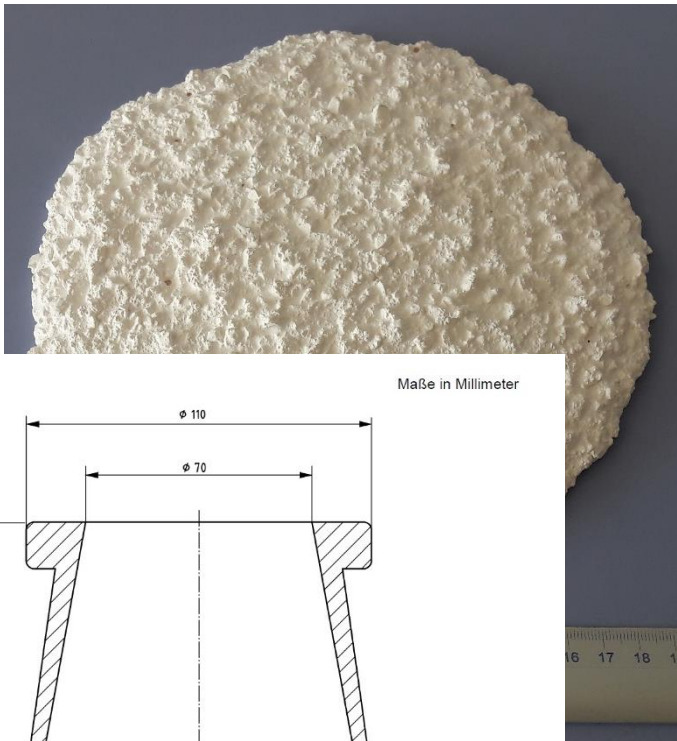


Bild 2 — Trichterform 2, Höhe 80 mm

DIN EN ISO 1927-4:2012

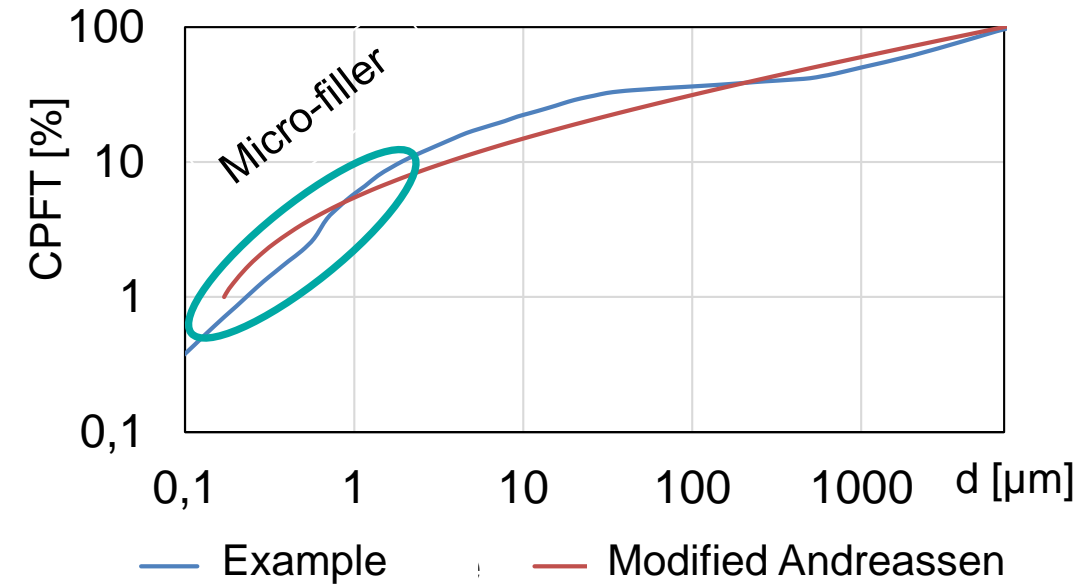
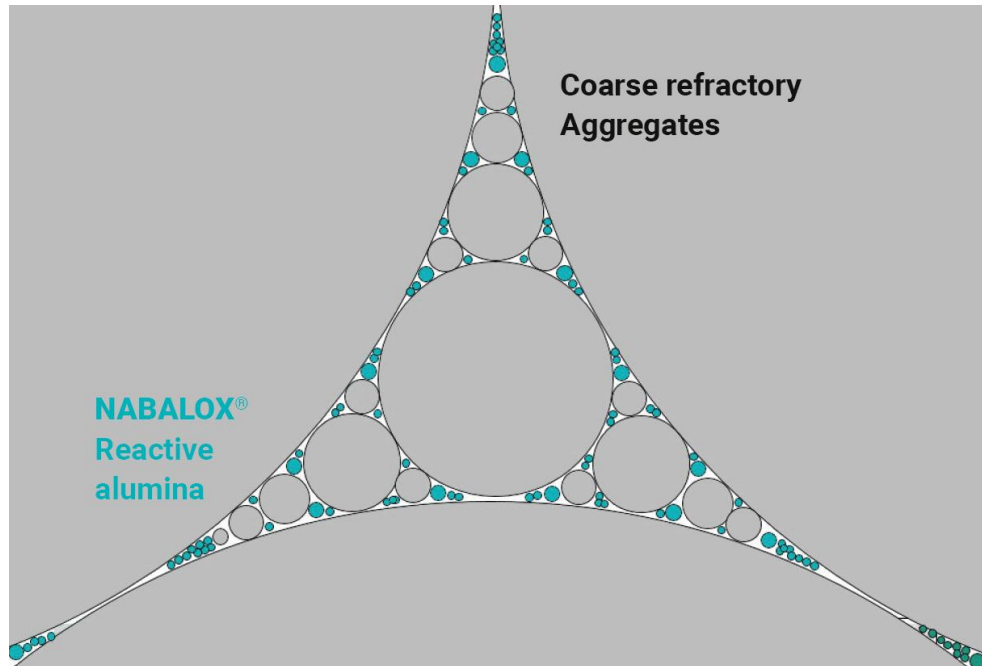
- Viscosity at high(er) shear rate:
  - Mixer Power consumption monitoring



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

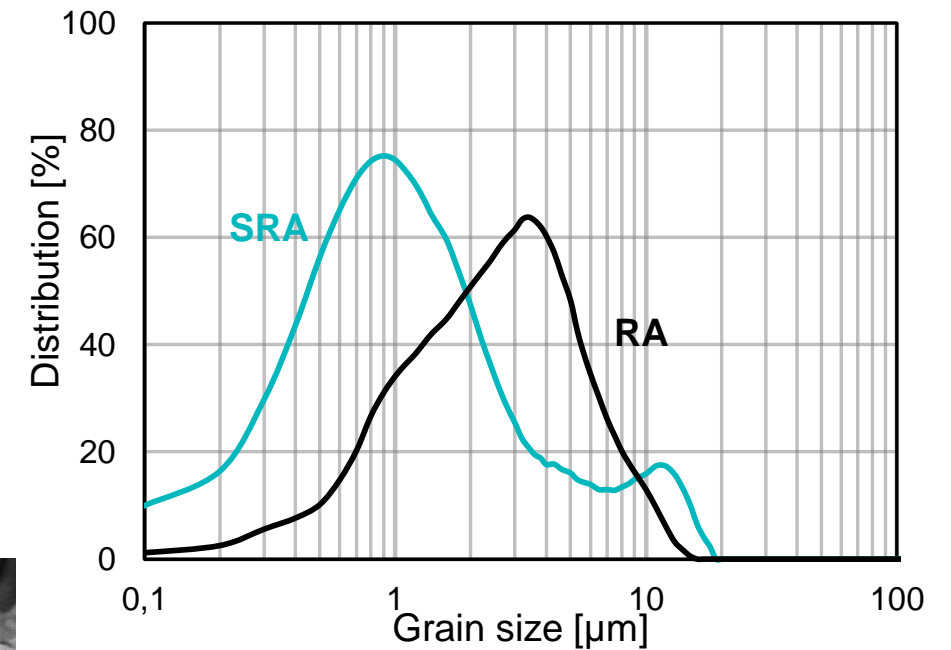
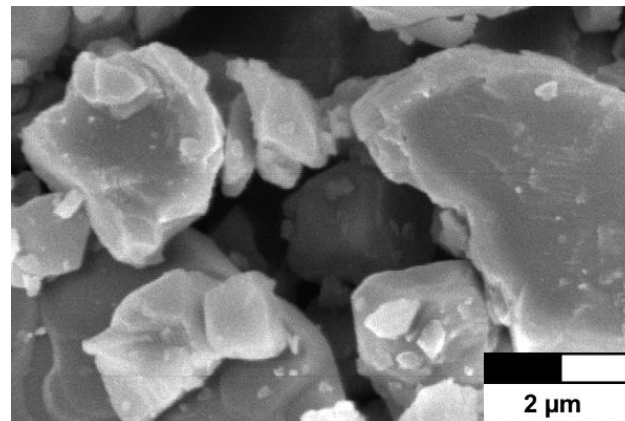
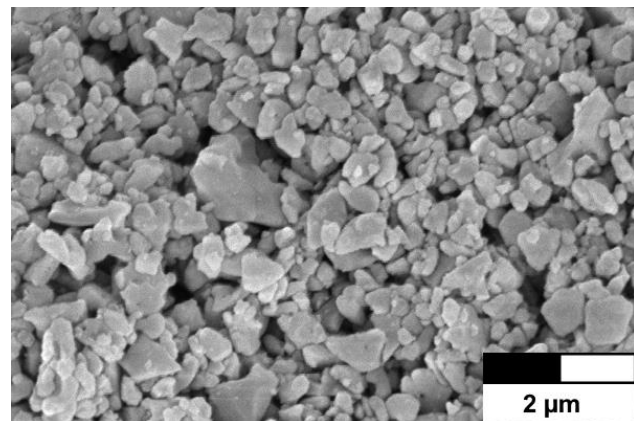
## Experimental procedure – Raw Materials



- Gap filling effect of Micro-filler
- Maximization of packing density
- Particle sizes 2  $\mu\text{m}$  to  $\ll 1 \mu\text{m}$
- Reactive Alumina vs. Silica fume

## Experimental procedure – Raw Materials – Monomodal Reactive Aluminas

		RA	SRA
NABALOX <sup>®</sup>		NO 625-10	NO 713-10 RF
D <sub>10</sub>	[μm]	0.62	0.19
D <sub>50</sub>	[μm]	2.32	0.85
D <sub>90</sub>	[μm]	5.9	4.4
S <sub>spec</sub> (BET)	[m <sup>2</sup> /g]	1.5	7.6
Na <sub>2</sub> O	[%]	0.1	0.08
Al <sub>2</sub> O <sub>3</sub>	[%]	99.8	99.7



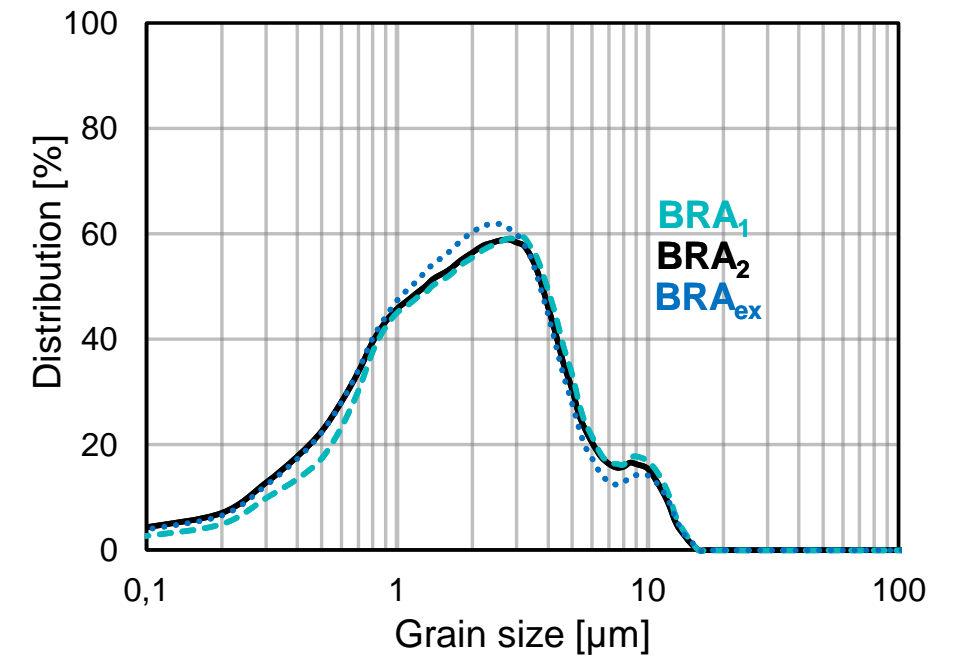
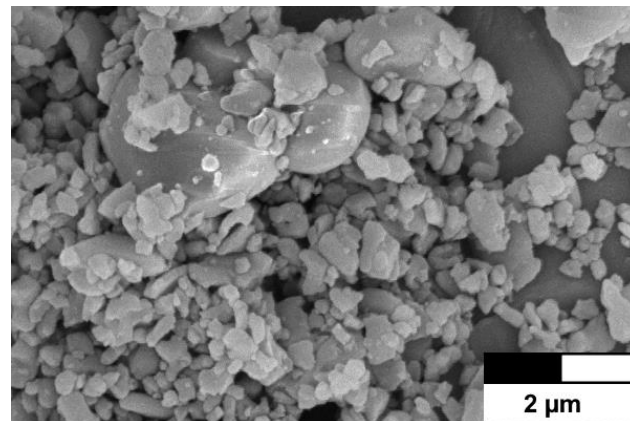
■ Combination of RA + SRA

➤ Bimodal Matrix



## Experimental procedure – Raw Materials – Bimodal Reactive Aluminas

	BRA <sub>1</sub>	BRA <sub>2</sub>	BRA <sub>ex</sub>
NABALOX <sup>®</sup>	NO 645	NO 530	AOR EXS 034-17
D <sub>10</sub> [μm]	0.38	0.30	0.33
D <sub>50</sub> [μm]	1.88	1.60	1.60
D <sub>90</sub> [μm]	5.3	4.9	4.8
S <sub>spec</sub> (BET) [m <sup>2</sup> /g]	3.8	4.0	4.7
Na <sub>2</sub> O [%]	0.10	0.10	0.09
Al <sub>2</sub> O <sub>3</sub> [%]	99.7	99.7	99.8

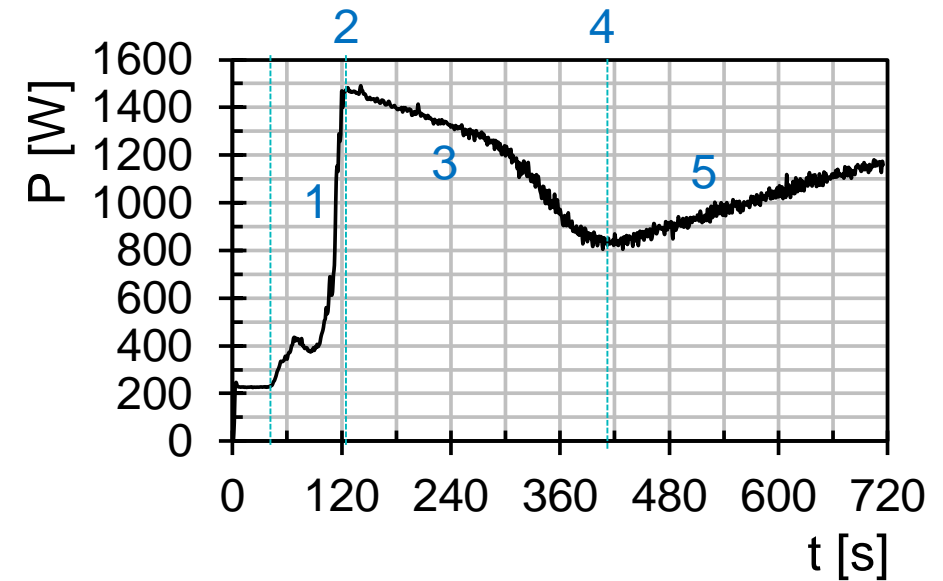


## Experimental procedure – Raw Materials – Test castable

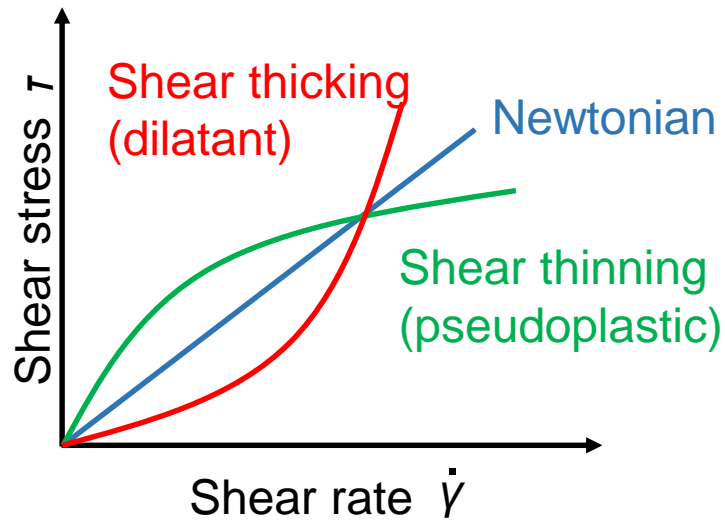
		M1	M2	B1	B2	Bex
Tabular Alumina 0 – 6 mm	[%]	79				
Calcined Alumina 3.5 μm	[%]	5				
RA	[%]	8.4	7.1			
SRA	[%]	4.6	5.9			
BRA <sub>1</sub>	[%]			13		
BRA <sub>2</sub>	[%]				13	
BRA <sub>ex</sub>	[%]					13
CAC (Secar 71)	[%]	3				
PCE (Viscocrete 225 P)	[g/100g]	0.1				
Water content	[ml/100g]	4.0 / 3.7				

## Results and Discussion – P-t-Plots

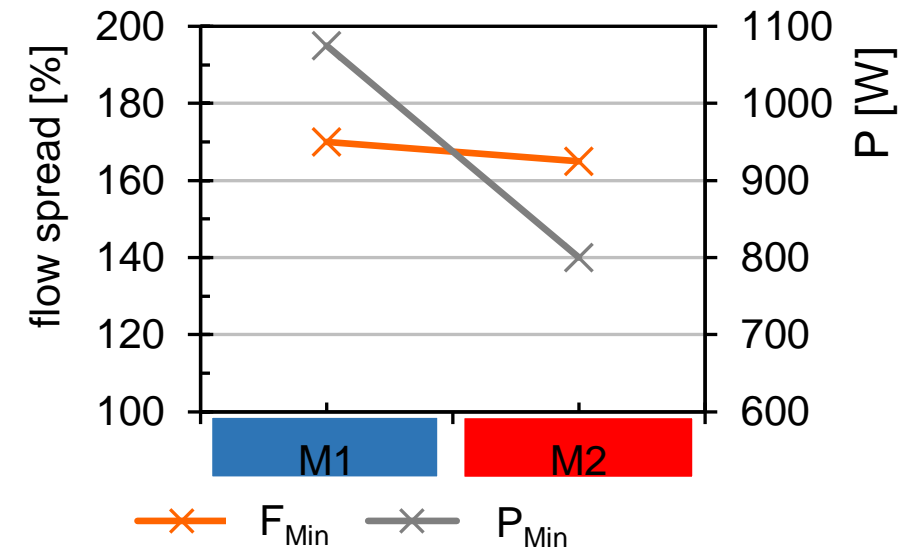
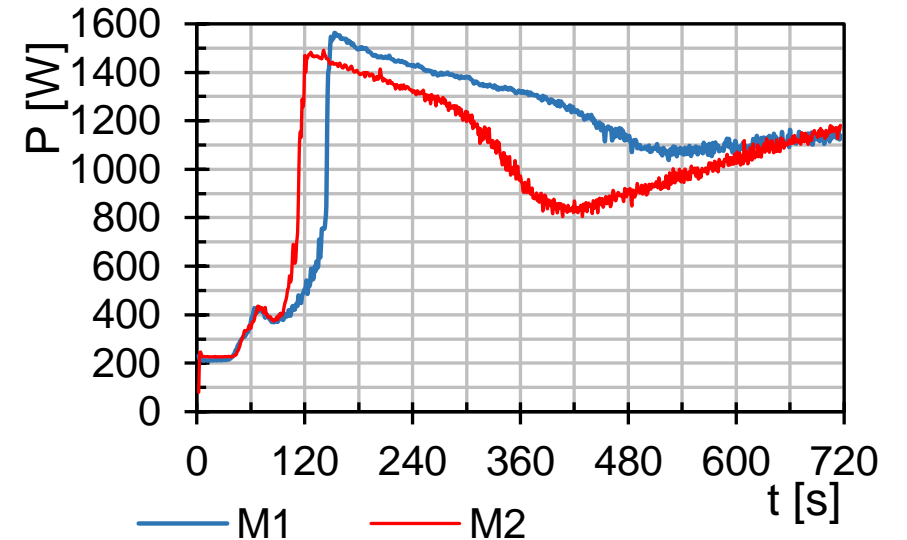
- $P_{\max}$ : Mixer power consumption at Maximum (2)
- $P_{\min}$ : Mixer power consumption at Minimum (4)
- $t_{\max}$ : Mixing time to Maximum (2)
- $t_{\min}$ : Mixing time to Minimum (4)
- $F_{\min}$ : Flow spread at Minimum (4)



## Results and Discussion – Effect of Reactive Aluminas

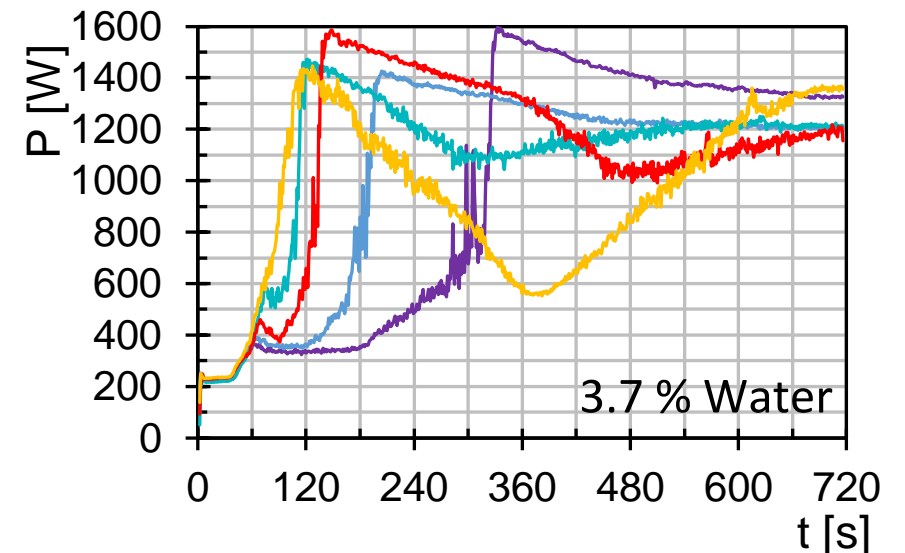
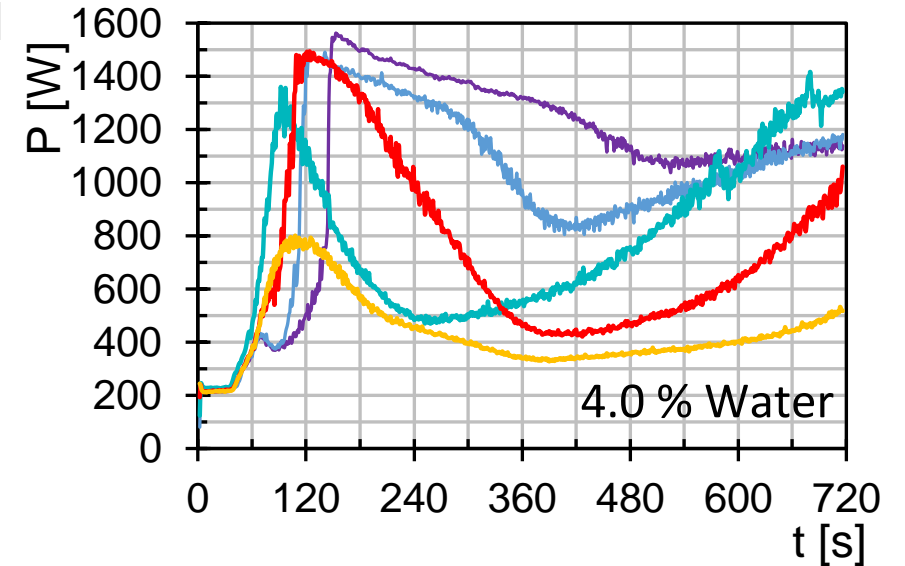


- M2 is less shear thickening than M1



## Results and Discussion – Effect of Reactive Aluminas

- Bimodal reactive Aluminas disperse faster (except BRA2).
  - BRA require less mixing energy to provide their benefits as Micro-filler.
- Viscosity reduction ( $P_{max}$ ) is a result of specific surface.



— M1 — M2 — B1 — B2 — Bex

## 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
  
- Bimodal Reactive Aluminas provide benefit compared to a bimodal mix of two monomodal Reactive Aluminas
  - By shorter mixing cycles
  - By lower viscosity / water demand

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## 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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Nabaltec products make many aspects of everyday life safer, as well as being eco-friendly and thereby an irreplaceable part of your daily routine.