Rheological measurements in the cone mixer for the specific control and evaluation of fresh concrete properties

TECHNISCHE UNIVERSITÄT DARMSTADT

Prof. Dr.-Ing. **Harald Garrecht**
Dipl.-Ing. Dipl.-Ing. (FH) **Christan Baumert**
Dipl.-Ing. (FH) **Andreas Karden** MBA BEng

Institut für Massivbau
Fachgebiet Werkstoffe im Bauwesen

3-stage concept for concrete production

TECHNISCHE UNIVERSITÄT DARMSTADT

1. mixture development

- calculation with software BétonLab Pro

2. mixing and Measurement

- production of the concrete in a cone mixer
- measurement of the rheological properties

3. assessment of the batch

- requirements fulfilled ?
- no → control / regulation →
- yes → application

subsequent addition

changes in the formulation

cone mixer (Kniele)

BétonLab Pro
recipe development

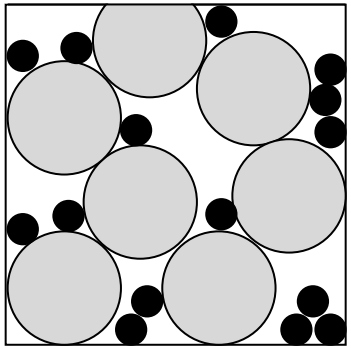
TECHNISCHE UNIVERSITÄT DARMSTADT

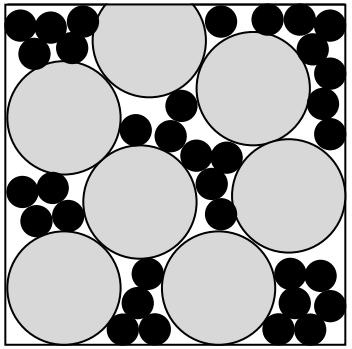
software input

- grading curves of the materials
- demand of water and superplasticizer
- mineralogical composition
- compaction tests

optimization for

- sustainability
- compressive strength
- yield stress and plastic viscosity
- mixing-time (stabilization-time)





HVFA-recipe
targets

TECHNISCHE UNIVERSITÄT DARMSTADT

		reference	optimized recipe 1
CEM I 52,5 N HS/NA	kg/m³	180	180
Fly Ash KM/C	kg/m³	309	309
SP Sika 20 HE	kg/m³	6	4
Water	kg/m³	112	113
Sand 0/2	kg/m³	640	577
Gravel 2/8	kg/m³	746	245
Gravel 8/16	kg/m³	391	955
Stabilization-time	sec.	-	210

initial situation

- without super-pozzolanas
- high plastic viscosity in standard mixers

targets

- compressive strength: 130 N/mm²
- low plastic viscosity
- short mixing-time
- low energy consumption
- lower demand for SP

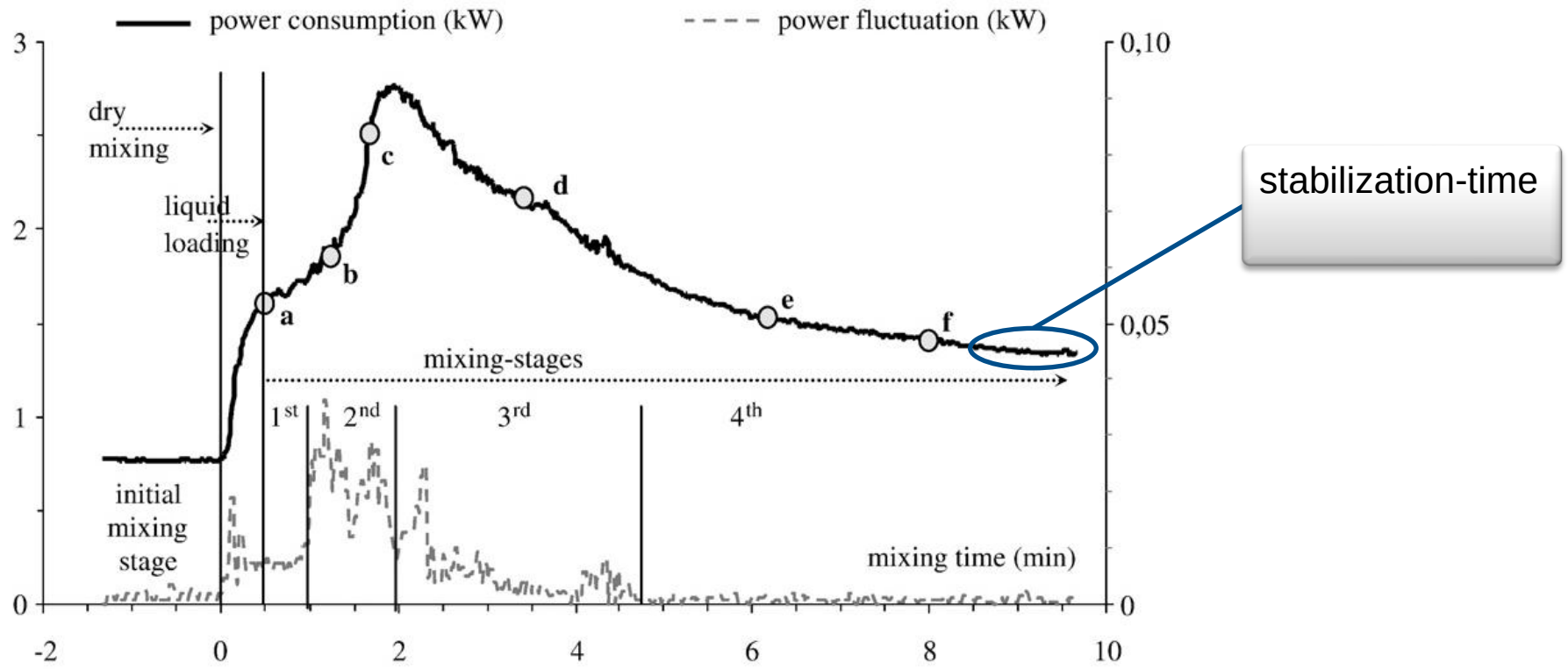
advantages

- cost-optimized
- sustainable
- durable

Mixing-time
stabilization-time

TECHNISCHE UNIVERSITÄT DARMSTADT

energy consumption and fluctuations during the mixing of a UHPC in a twin-shaft mixer



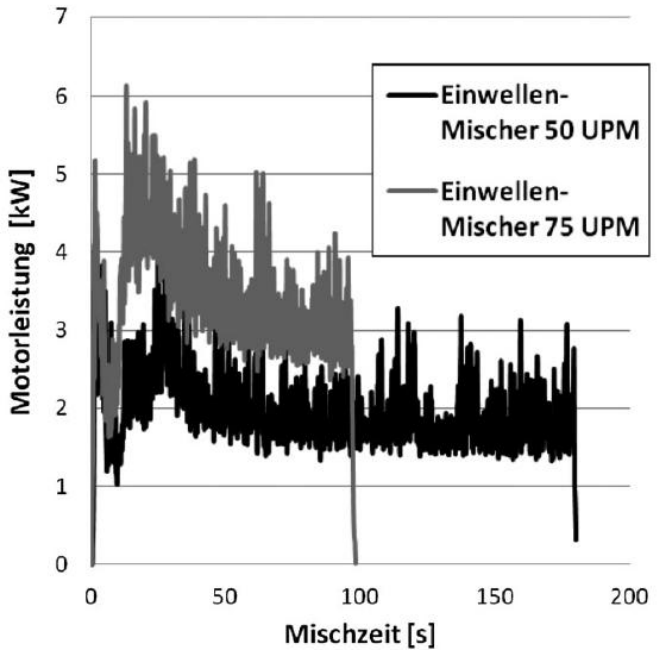
Quelle: Cazacliu, B.; Roquet, N.: Concrete mixing kinetics by means of power measurement. Cement and Concrete Research, 39 (2009), p. 182–194

Possible solutions
for standard mixers

TECHNISCHE UNIVERSITÄT DARMSTADT

increasing agitator speed

- example: single-shaft compulsory mixer (Elba)
- machine-froude-number = max. 1,9 (75 rpm) << 7



Possible solutions
locally increased agitator speed

TECHNISCHE UNIVERSITÄT DARMSTADT

additional high-speed agitator

- for example in a turbine pan-type mixer or a planetary mixer (Pemat)

intensive-mixer type Eirich

- SPP 1182 – UHPC
  - ➢ better fresh concrete properties
  - ➢ shortened mixing-times

Possible solutions
suspension-mixer

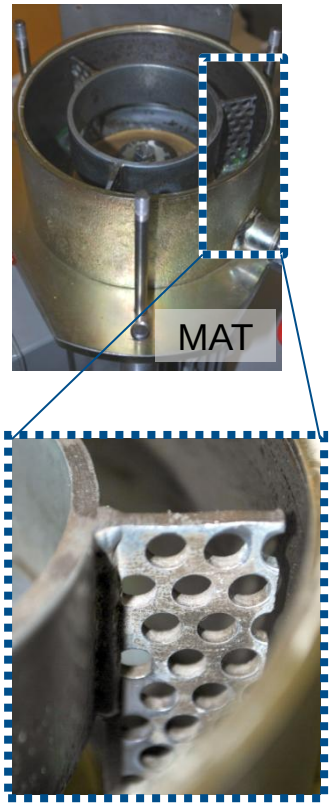
TECHNISCHE UNIVERSITÄT DARMSTADT

advantages

- mixing energy selectively in lime or mortar
- very high agitator speed
- very high machine-froude-number
- very high mixing quality and decreased energy consumption

disadvantage

- additional mixer



Possible solutions
multi-stage mixing-regime

TECHNISCHE UNIVERSITÄT DARMSTADT

1. stage

- production of lime (32 Vol.-%) or mortar (56 Vol.-%)

by:

- very high agitator speed
- very high machine-froude-number

production of the subset:

- intensive
- fast
- energy-efficient

2. stage

- addition of gravel in a very flowable suspension
- with low agitator speed

→ requires only one mixer
→ example: ready-mix applications;
lime or mortar in a truck-mixer with control of consistency (Grace)

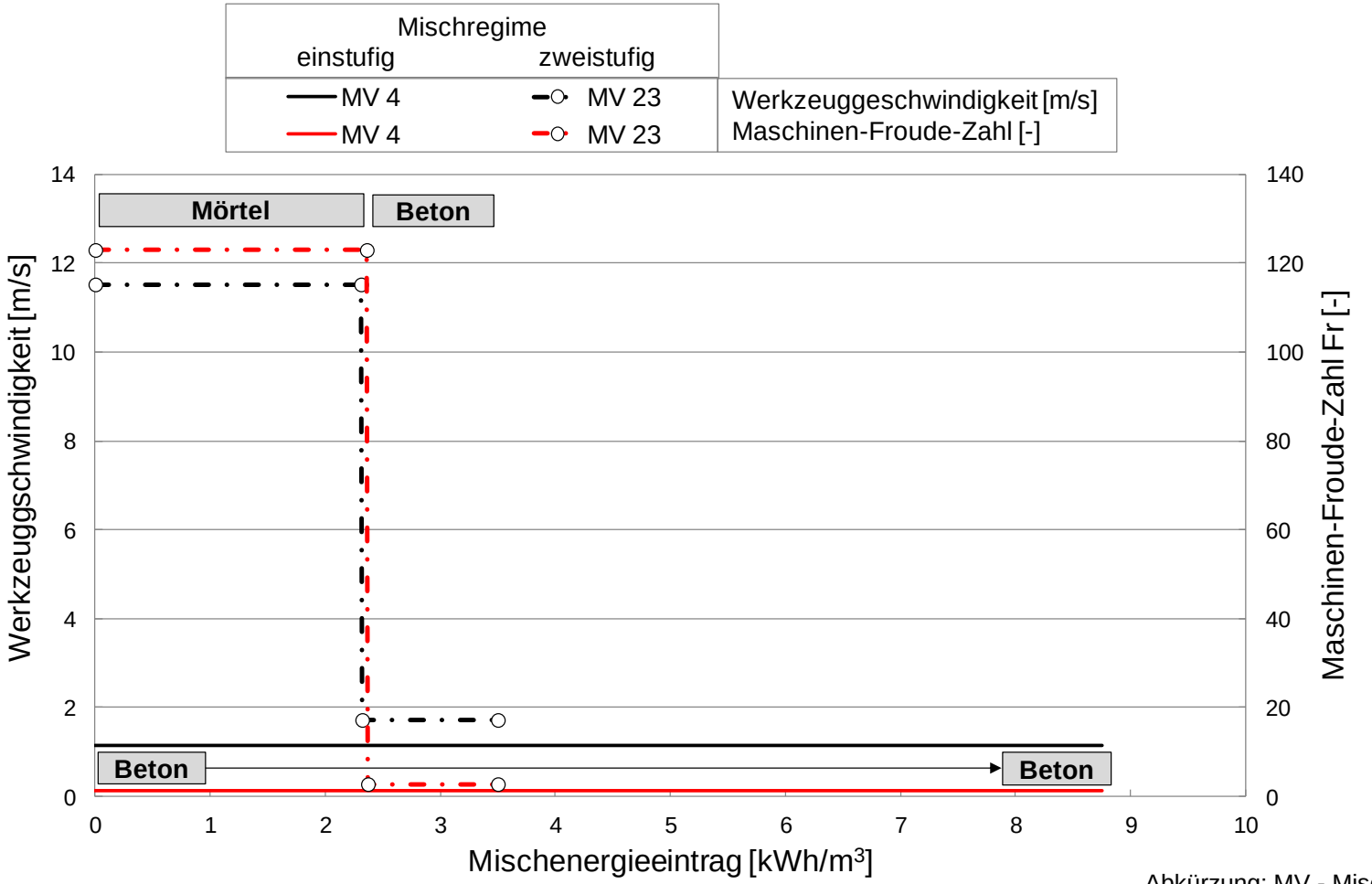
Calculated stabilization-times
for multi-stage mixing-regimes

TECHNISCHE UNIVERSITÄT DARMSTADT

		reference	optimized concrete recipes					
			1	2	3	4	5	6
CEM I 52,5 N HS/NA	kg/m³	180	180	180	180	180	180	180
Fly Ash KM/C	kg/m³	309	309	309	309	309	309	-
SP Sika 20 HE	kg/m³	6	4	4	4	4	4	4
Water	kg/m³	112	113	113	113	113	113	113
Sand 0/2	kg/m³	640	577	577	289	-	-	577
Gravel 2/8	kg/m³	746	245	-	-	245	-	245
Gravel 8/16	kg/m³	391	955	-	-	-	955	-
Stabilization-time	sec.	-	210	166	143	122	178	235

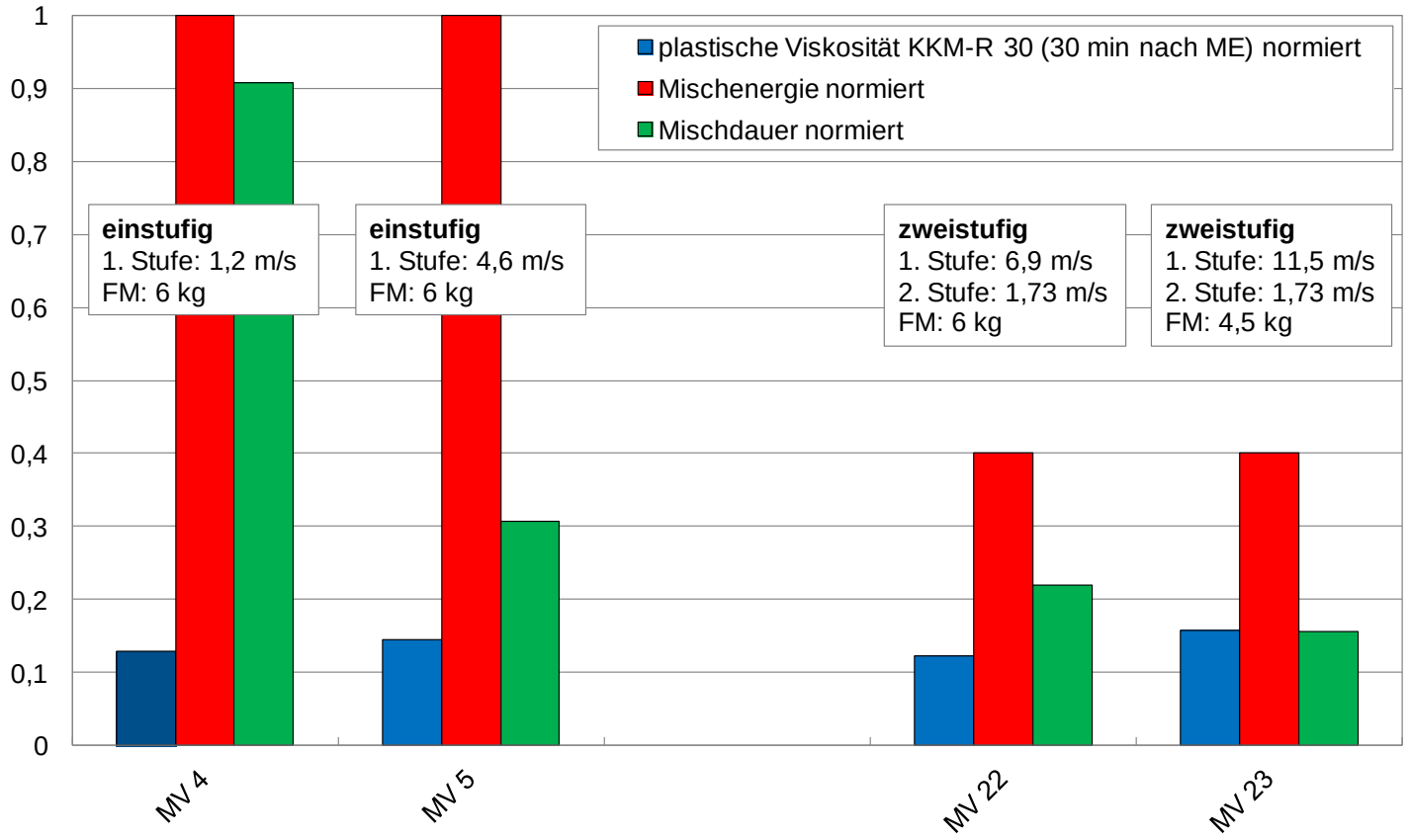
Results of mixing experiments

agitator speed – energy – froude-number



Abkürzung: MV - Mischversuch

Results of mixing experiments
viscosity – energy – mixing-time



MV: Mischversuch

Rheological measurements in the mixer
possibilities

TECHNISCHE UNIVERSITÄT DARMSTADT

Viscoprobe

- additional device

„Wattmeter“

- too insensitive for self-compacting concrete
- problems if small gap between agitator and vessel

→ Concept for conical mixer

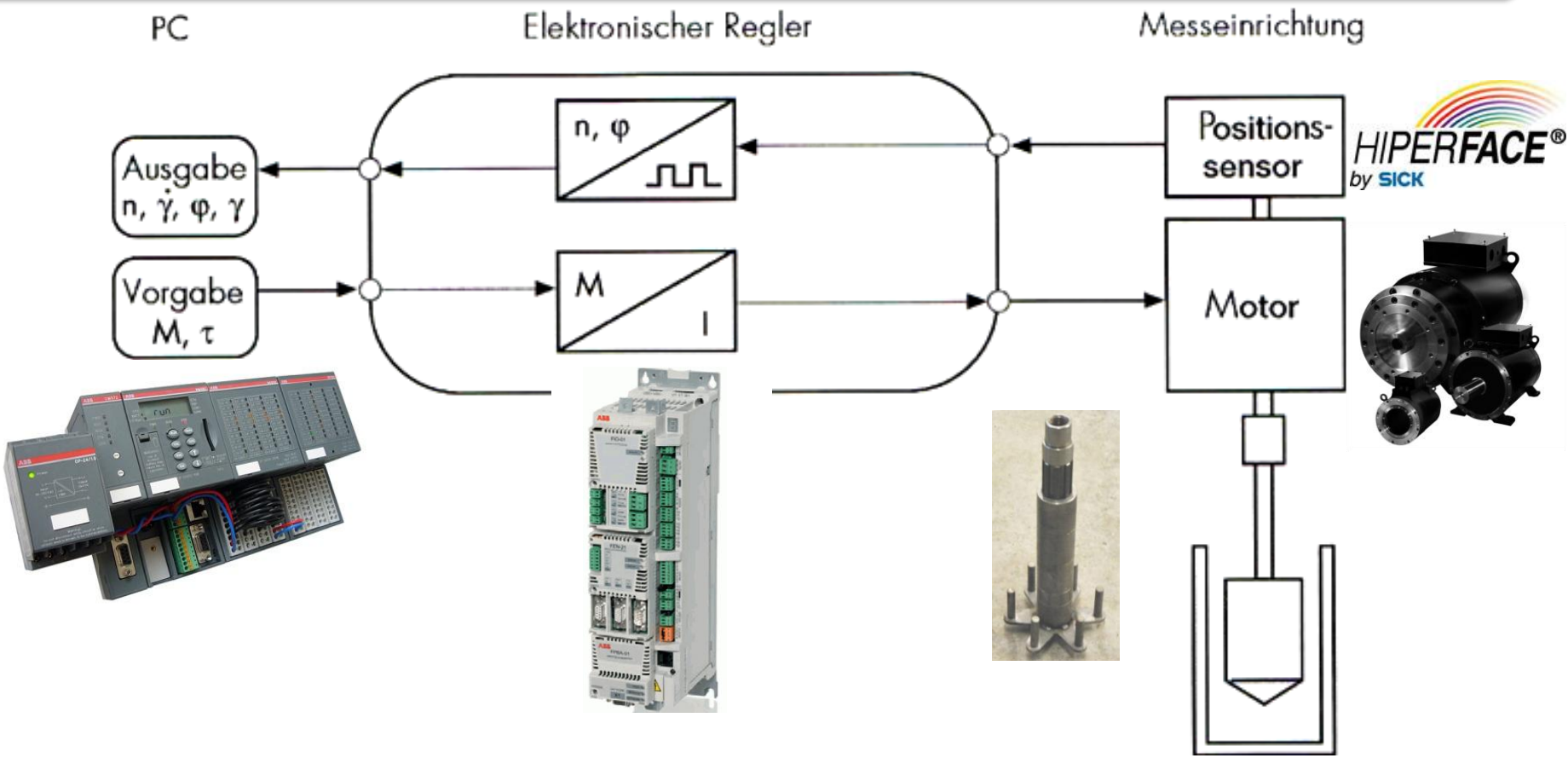
- large gap between agitator an vessel
- measuring raw-data with high accuracy

Rheological measurements
in the cone mixer

TECHNISCHE UNIVERSITÄT DARMSTADT

„Direkte Ansteuerung des Drehmoments bei der Versuchsart Schubspannungsvorgabe“

Quelle: Mezger, Rheologie Handbuch

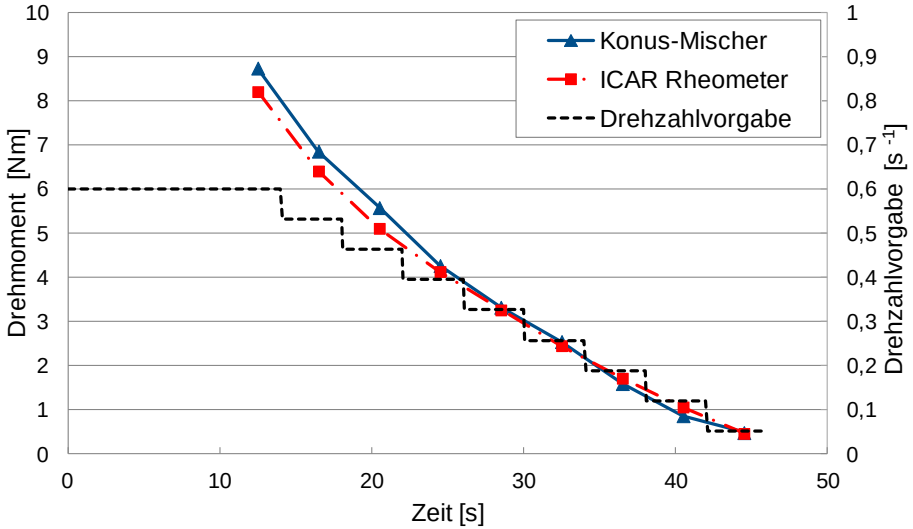


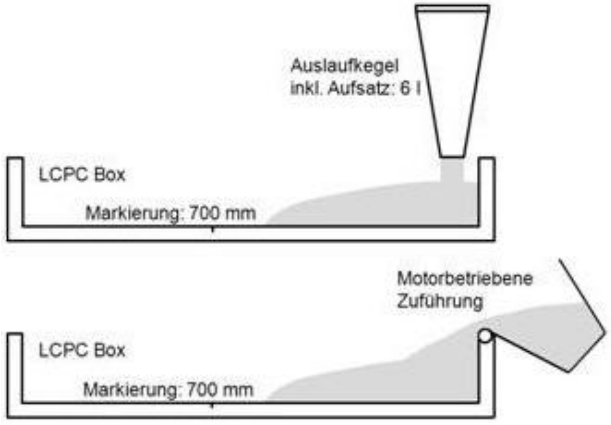
Calibration of the cone mixer
with ICAR-rheometer

TECHNISCHE UNIVERSITÄT DARMSTADT

Comparison of raw-data
– measurement profile:
(down ramp with speed control)

- Conical mixer with ICAR-device
- ICAR-rheometer in conical vessel

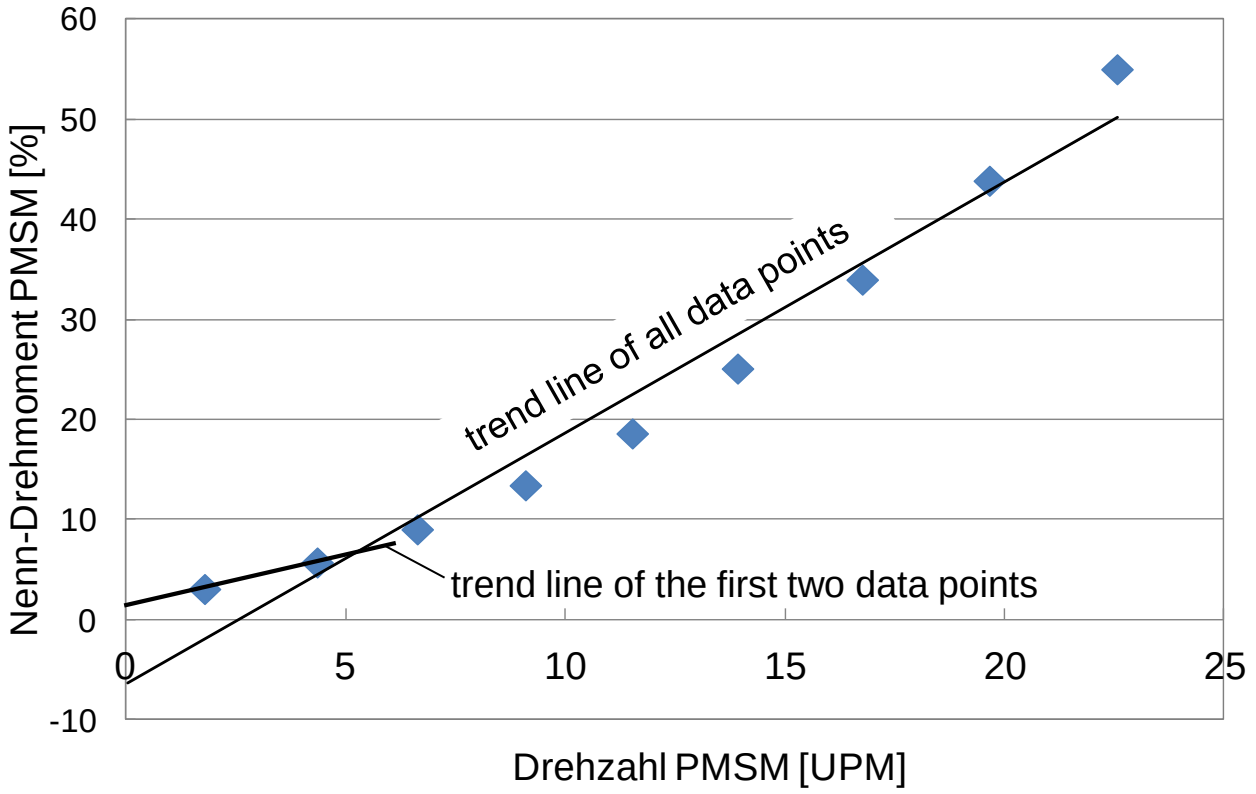




Rheological measurements
in the cone mixer

TECHNISCHE UNIVERSITÄT DARMSTADT

determination of the yield stress with flow curve **(speed-controlled)**

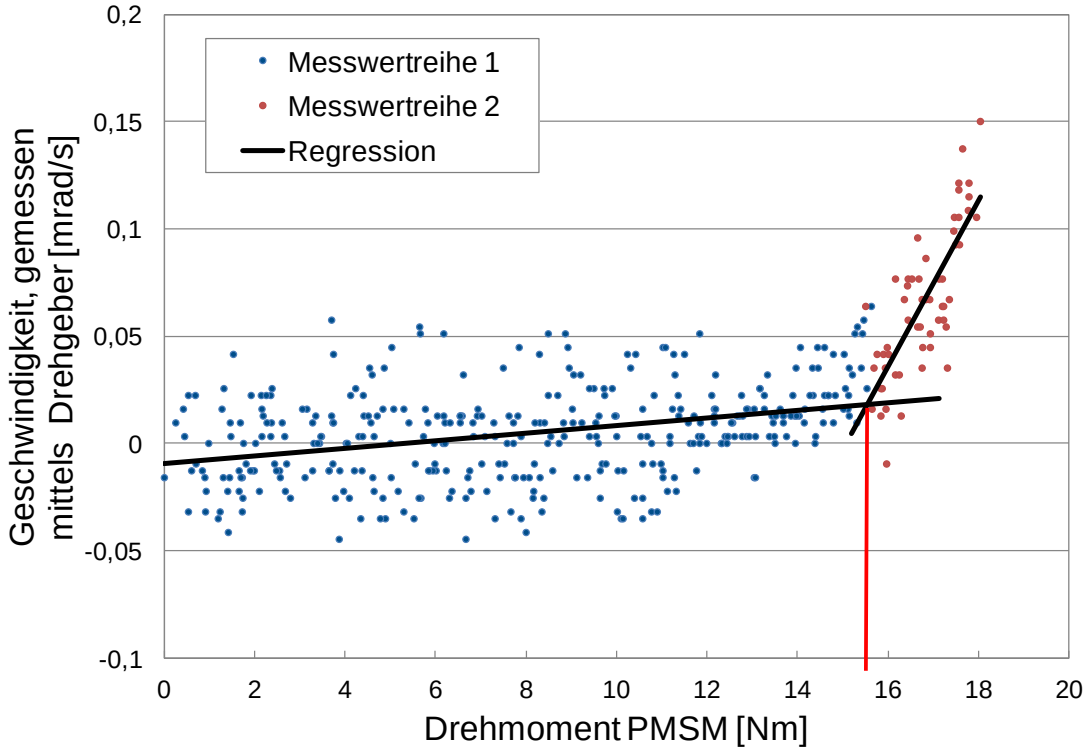


Abkürzung: PMSM - Permanent Magnet Synchron Motor

Rheological measurements
in the cone mixer

TECHNISCHE UNIVERSITÄT DARMSTADT

measurement of the yield stress (torque-controlled)



- linear increasing torque
- measurement of the angular velocity with encoder
- determination of yield stress with tangent method

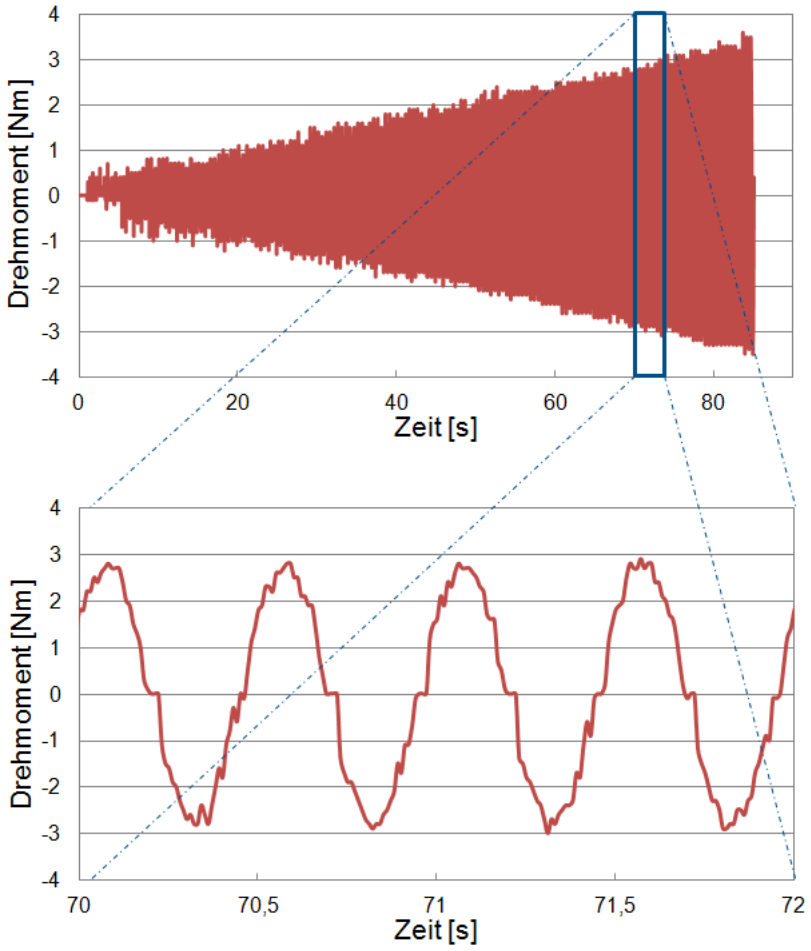
Abkürzung: PMSM - Permanent Magnet Synchron Motor

Rheological measurements
in the cone mixer

TECHNISCHE UNIVERSITÄT DARMSTADT

oscillatory measurements

- amplitude-sweep
- sinusoidal variation of torque

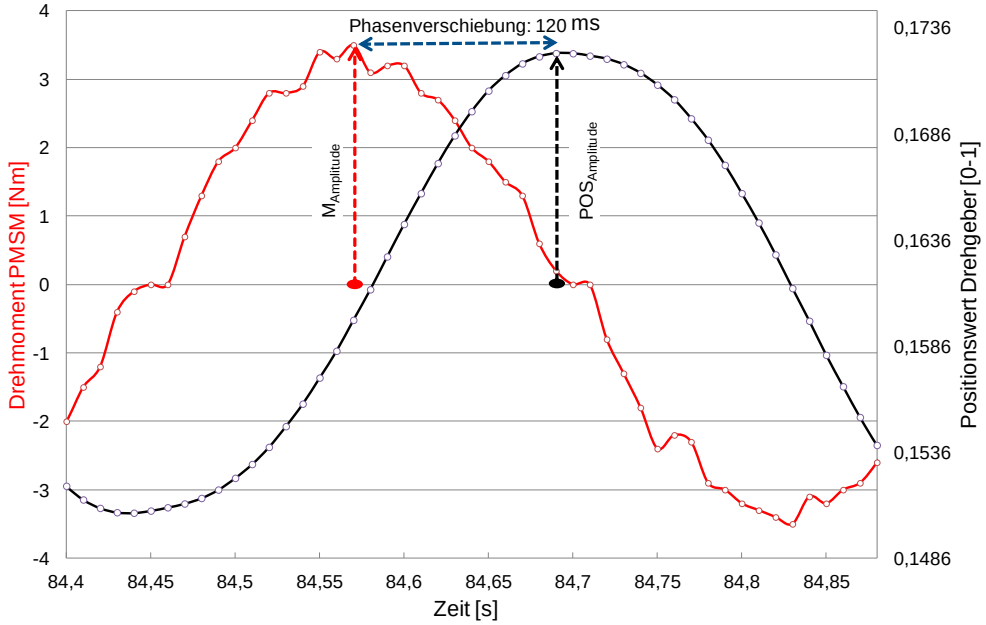


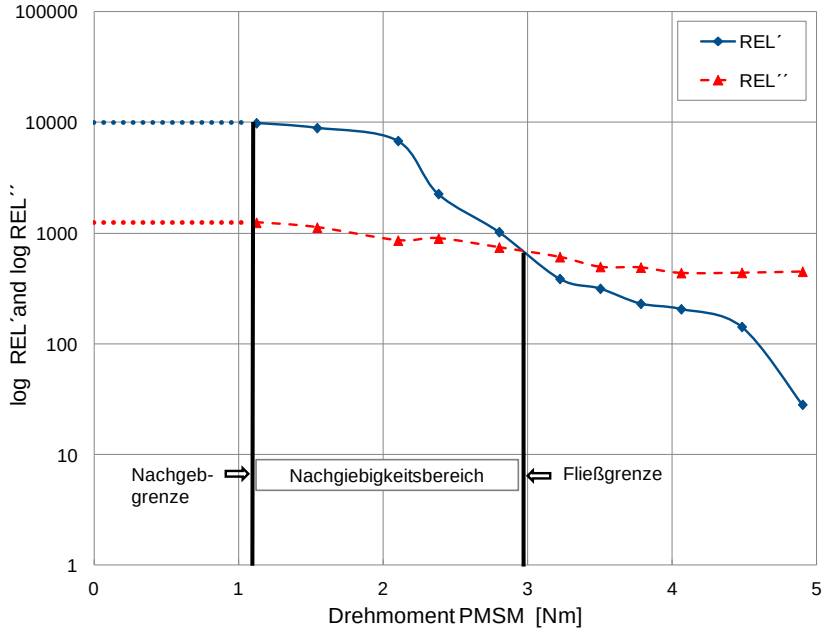
Rheological measurements
in the cone mixer

TECHNISCHE UNIVERSITÄT DARMSTADT

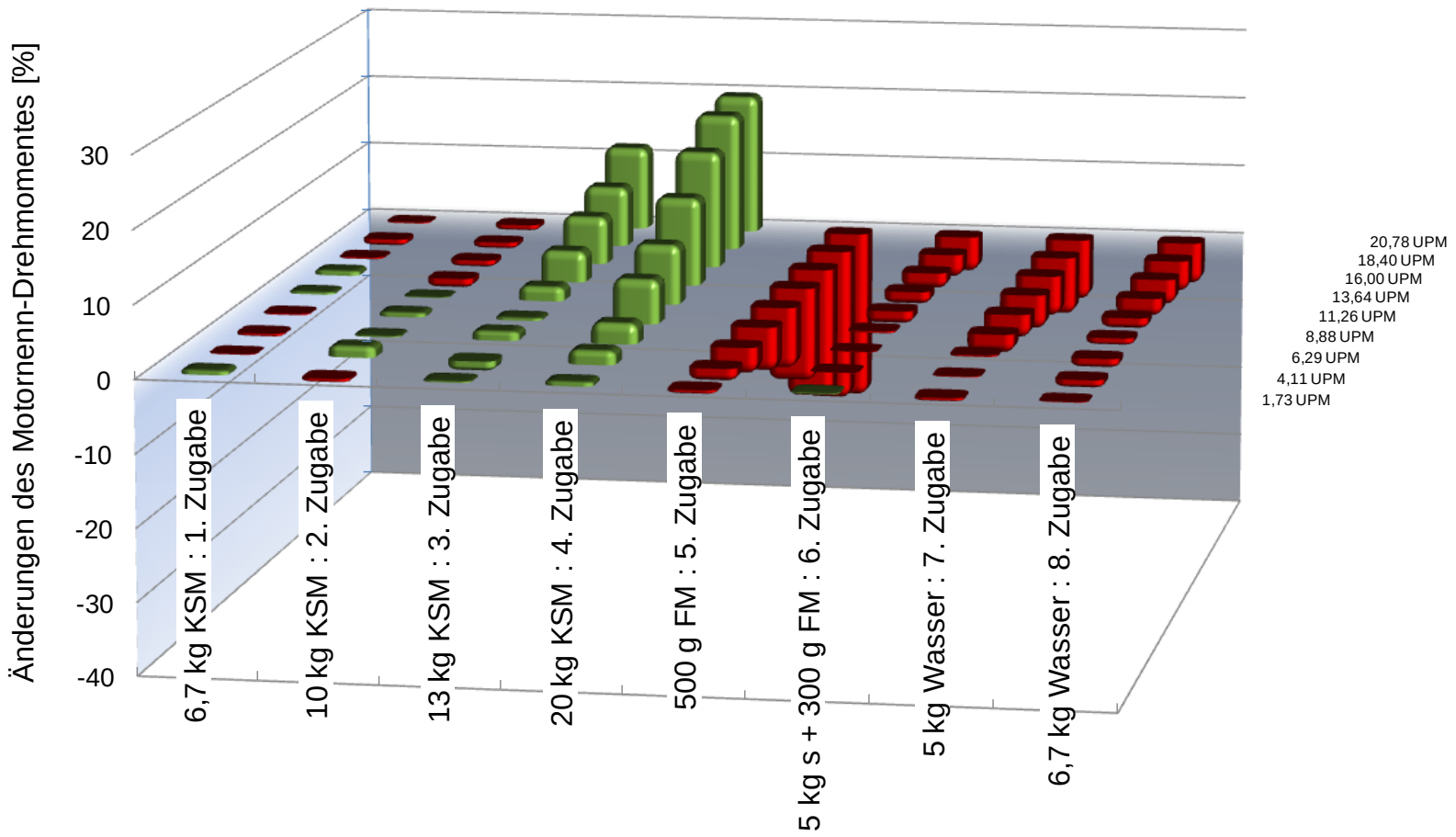
Evaluation of the amplitude-sweep

- phase shift
- calculation of the G´ and G´´ (REL´and REL´´)





Control of the mixing process
with subsequent addition



TECHNISCHE UNIVERSITÄT DARMSTADT

Vielen Dank für Ihre Aufmerksamkeit

Fragen… ?

Thank you for your attention

Questions ?