Industrial Case
Soot sludge drying together with bio-based material

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WP2 Bioenergy in bioeconomy
Task 2.2
D2.2-6

Participants of the study

- Andritz Oy and Pohjolan Voima Oy as BEST-programme partners made an industrial case study to dry industrial sludge and use it as fuel in a powerplant boiler.
- The study is based on several drying tests both lab scale and pilot scale.
- Tests were carried out at Aalto university in Espoo, at OFI institute in Vienna and at Andritz Gouda in Waddinxveen.

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Background

- Fresh soot sludge DS 5% is a by-product coming from industrial process.
- Fresh sludge is combusted in a powerplant boiler and it needs heavy fuel oil as support fuel. This combustion is a continuous process.
- Drying of soot sludge is unique process and the experiences worldwide are very limited or null.
- Banked soot sludge is considered as waste which has to be destroyed. Banked soot sludge DS 30-70% is also combusted in the same powerplant boiler. Banked sludge is feeded in to the boiler on batch basis. This makes it difficult to keep the CO-emissions of the boiler in the range of the environment permit limit.

Purpose of the study

- The idea was to mix the fresh soot sludge and banked soot sludge to saw dust and dry the mixture to DS 55-60% to improve the combustibility and increase the caloric value of the fuel. The other idea was to avoid or at least reduce the consumption of HFO as support fuel and in this way to cut fuel costs.
- The purpose of the study was to prove the feasibility of this concept and to find a suitable commercially available drying process and equipment.

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Lab scale tests

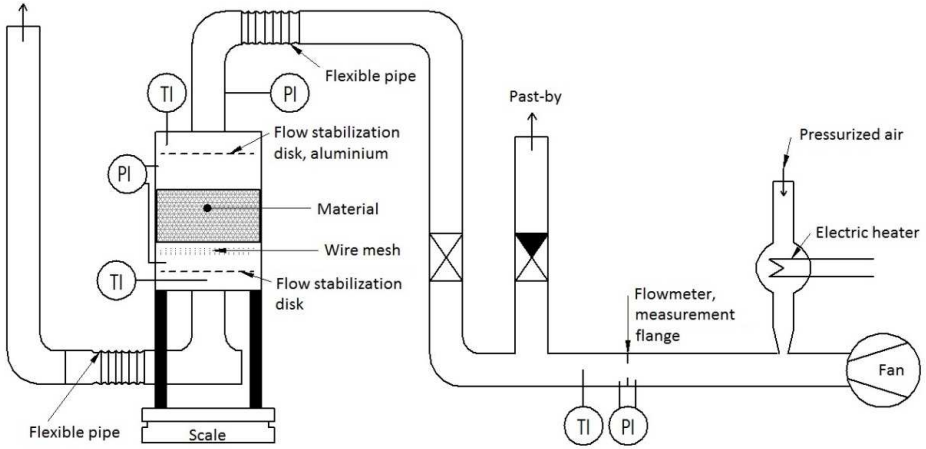
- The target of lab tests was to determine the mixing and drying parameters for pilot scale testing.
- Lab scale tests were carried out at Aalto university.
- Lab scale drying tests were carried out with fresh and banked soot sludge separately.

Test rig

- A fixed-bed batch dryer
- Air used as the drying gas
- Air flows through a drying chamber and a bed from top to bottom
- Chamber lays on a scale which measures and saves the mass of the wood chip sample on the computer after a time interval of 10 seconds
- The drying curve is defined on the basis of the mass change

Technical data of the test rig:

- maximum power of the heating unit 30 kW
- maximum temperature of the drying air ~ 200 ℃
- maximum air velocity per free sectional area of the drying chamber ~1 – 1.2 m/s
- height of the drying chamber 800 mm and diameter 400 mm



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50 % saw dust (volume) and 50 % fresh soot sludge (wet)

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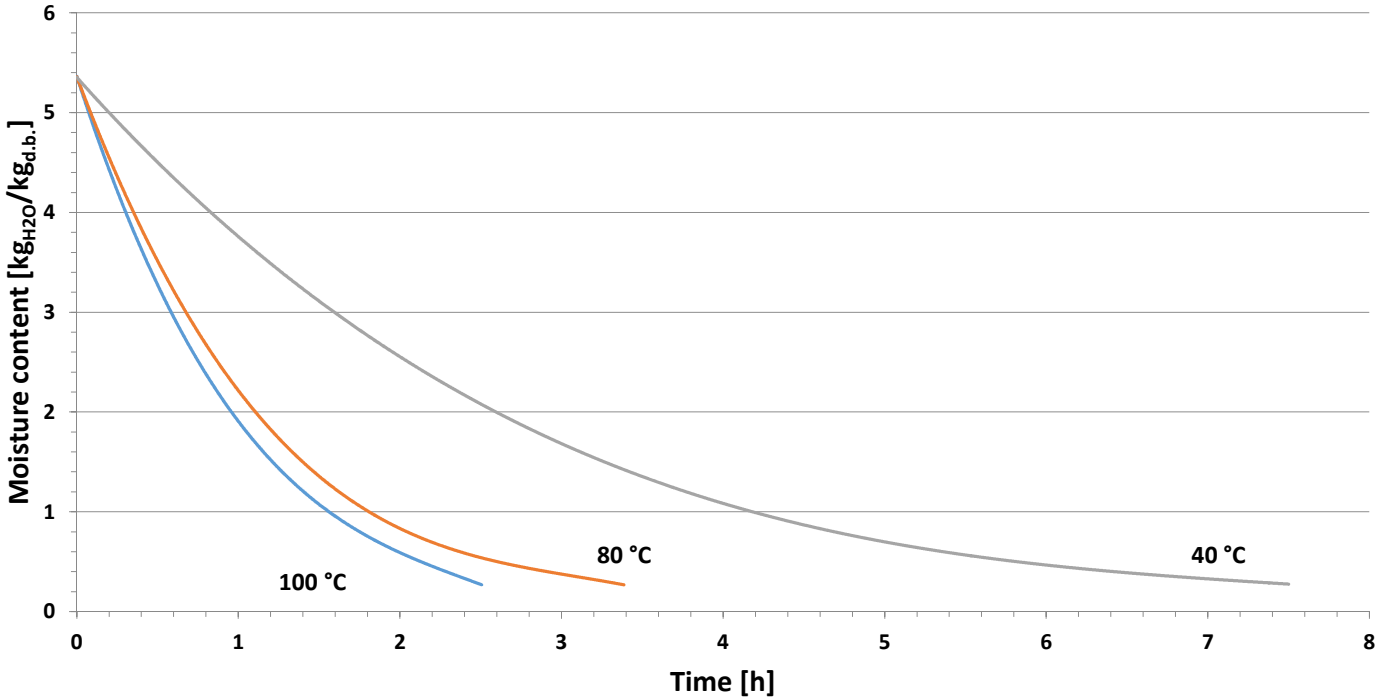
Figure of the air temperatures for the bed height of 200 mm

- Drying curves of different air temperatures (40 °C, 80, 100 °C):
  Mixture ratio of 50 % sawdust and 50 % soot sludge,
  air velocity of 0.75 m/s and bed height of 200 mm



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Conclusions - drying fresh soot sludge at Aalto

- Mixture ratio of 50 soot/ 50 sawdust (vol %) → acceptable drying time
- Mixture ratio of 70 soot/ 30 sawdust (vol %) → the material does not dry evenly, forms 'cakes'
- Mixture ratio of 30 soot/ 70 sawdust (vol %) → too low amount of soot to be dried
- Enhance in air velocity does not have remarkable influence on drying time → air velocity of 0.75 m/s can be enough
- Bed height of over 200 mm → acceptable drying time, material dries quite evenly when mixture ratio is 50/50
- Air temperature of at least 80 °C gives acceptable drying times
- When bed height is lower (200 mm) even lower air temperature (let say 60 °C) could be enough to dry mixture of 50/50

Pictures of moist and dried material: 50 % banked soot and 50 % sawdust

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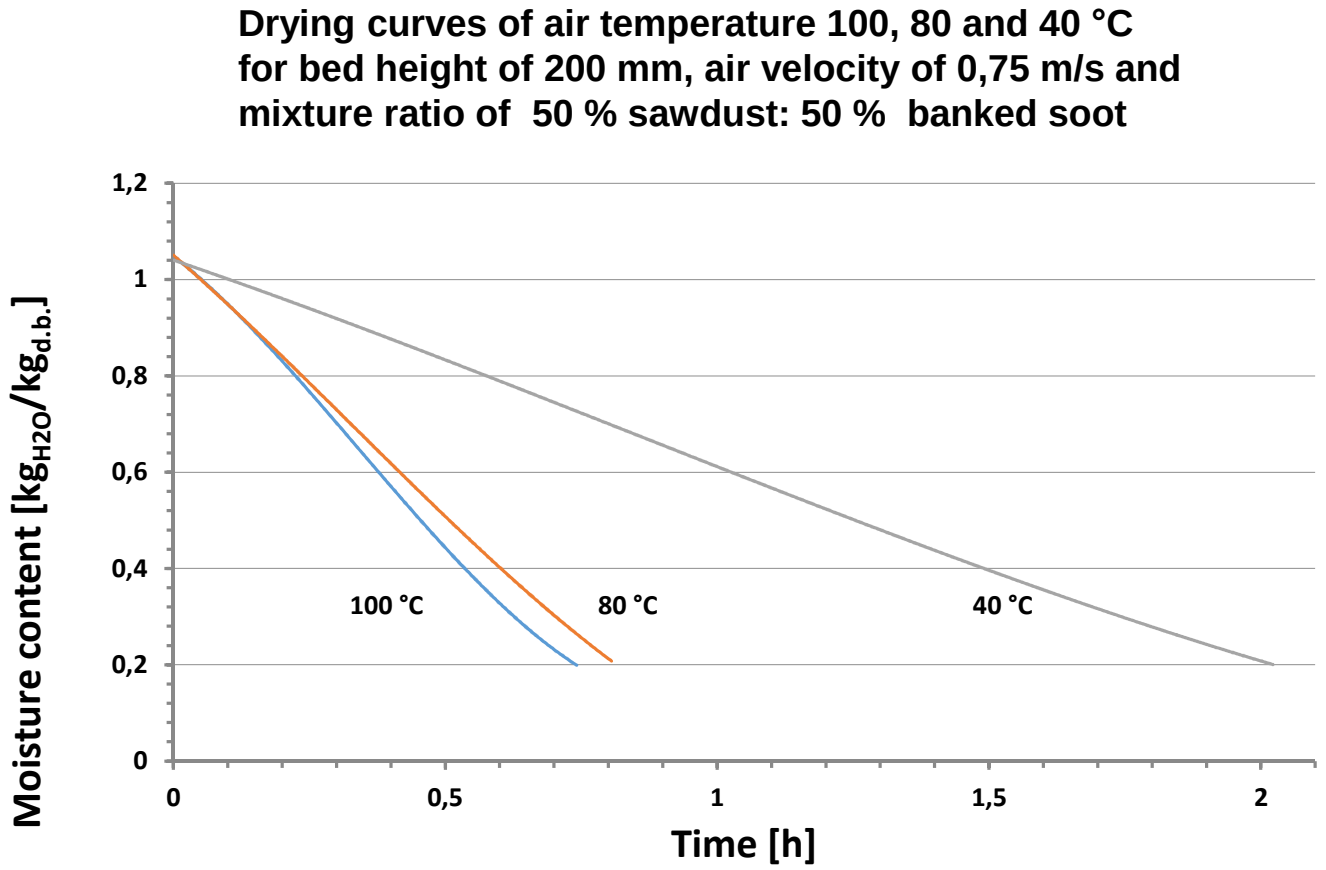
50 % banked soot: 50 % sawdust



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Conclusions - drying banked soot sludge at Aalto

- Drying is possible with the mixture ratio of 50%:50% and with the 100% bed of banked soot

  → the beds dried evenly

- The increase of the amount of the banked soot increases the drying time:

  - 80°C: $50\%_{soot}$ →$100\%_{soot}$; 0.7h → 1.2h

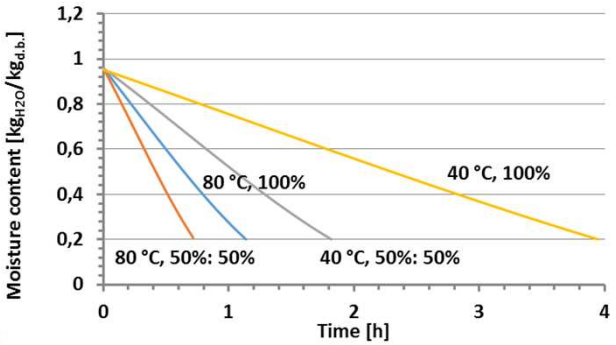
  - 40°C: $50\%_{soot}$ →$100\%_{soot}$; 1.8h → 4h

- Drying with the lower air temperature (40 °C) gives reasonable drying times for both the bed of 50% banked soot and for bed of 100% banked soot.
- The increase of air temperature from 80 to 100 °C does not notably affect the drying time.
- It would be reasonable to dry only banked soot without mixing sawdust in it in order to dry more soot at once.
- The pressure drops over the bed of 100% banked soot and the bed of 50% banked soot and 50% sawdust are high: ~1100-760 Pa.

  → Higher electricity consumption of the fans

  → Bed of 100% banked soot gives slighty higher

  pressure drops than the bed of 50% banked soot



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Belt Dryer pilot scale test at OFI

- The target of the was to find out the suitability of belt dryer to dry the mixture to the required DS. The test was carried out at the OFI institute in Vienna, Austria, where the suitable belt dryer for testing purposes is located.
- Mixture features [vol%] 50$_{soot}$ / 50$_{sawdust}$

Dry stubstance	29,77	%
Bulk density	628	kg/m³
Sieve analysis	sieve size	distribution
	mm	mass - %
	8	2,42
	4	9,79
	2,5	7,43
	2	3,86
	1	23,18
	0,5	20,23
	0,25	16,88
	<0,25	15,93
	mass loss	0,29

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Belt Dryer pilot scale test 1,

belt speed 75%, layer thickness 100mm, time 13 min

Sample		1	2	3	4	5	Mean value
Time		09:50	10:00	10:10	10:20	10:30	
Dry substance input	%	29,68	29,86				29,77
Dry substance output	%	47,14	47,91	51,6	50,53	46,51	48,74
Recirculation air	°C	39,01	42,24	40,56	37,89	38,71	39,68
	m³/h	764,02	877,97	861,99	849,60	845,39	839,79
Outgoing air	°C	32,39	35,40	34,73	34,00	35,13	34,33
	m³/h	493,78	568,21	558,51	549,07	551,12	544,14
Incoming air	m³/h	0,06	0,06	0,06	0,06	0,05	0,06
Drying temperature	°C	93,56	103,82	102,26	105,64	106,75	102,41
Outgoing air zone 1	°C	30,73	34,71	34,97	35,21	35,44	34,21
	%	84,11	96,69	97,75	97,97	98,13	94,93
Outgoing air zone 2	°C	32,14	35,66	35,30	35,55	35,72	34,88
	%	75,46	89,16	91,55	93,97	94,33	88,89
Outgoing air zone 3	°C	32,92	36,88	36,73	36,94	37,47	36,19
	%	76,92	90,46	91,43	91,00	89,25	87,82
Pressure drop	mbar	6,81	7,63	8,05	8,42	8,23	7,83
Ambient	°C	15,20	17,24	17,38	17,67	17,83	17,06
	%	45,30	54,01	56,72	58,15	58,06	54,45
Heiza inlet temperature	°C	153,52	173,98	174,00	175,48	176,38	170,67
Heiza return temperature	°C	139,72	158,18	158,21	159,76	160,65	155,31

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Out going air = vent gas, mainly H_2O

Belt Dryer pilot scale test 2,

belt speed 50%, layer thickness 100mm, time 20 min

Sample		6	7	8	9	Mean value
Time		11:00	11:10	11:20	11:30	
Dry substance input	%	29,68	29,86			29,77
Dry substance output	%	60,04	60,16	58,93	62,09	60,31
Recirculation air	°C	42,23	42,17	43,10	41,74	42,31
	m³/h	854,76	844,88	833,60	831,12	841,09
Outgoing air	°C	36,28	37,04	38,64	37,62	37,39
	m³/h	562,64	559,97	558,90	558,92	560,11
Incoming air	m³/h	0,07	0,07	0,06	0,05	0,06
Drying temperature	°C	100,82	102,39	102,44	104,60	102,56
Outgoing air zone 1	°C	35,14	35,23	35,38	35,15	35,23
	%	98,51	98,59	98,65	98,24	98,50
Outgoing air zone 2	°C	35,18	35,32	35,58	34,91	35,25
	%	92,54	92,69	92,21	88,91	91,59
Outgoing air zone 3	°C	38,08	37,59	37,65	36,81	37,53
	%	80,68	85,82	85,16	83,79	83,86
Pressure drop	mbar	7,50	7,48	7,44	7,68	7,52
Ambient	°C	17,42	17,62	17,93	17,85	17,70
	%	52,13	53,97	53,45	54,59	53,53
Heiza inlet temperature	°C	174,17	174,27	174,24	178,89	175,39
Heiza return temperature	°C	158,45	158,58	158,64	163,33	159,75

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Out going air = vent gas, mainly H_2O

Belt Dryer pilot scale test 3,

belt speed 60%, layer thickness 100mm, time 17 min

Sample		10	11	12	13	14	Mean value
Time		11:45	12:02	12:18	12:30	12:45	
Dry substance input	%	29,68	29,86				29,77
Dry substance output	%	55,47	59,62	53,51	50,66	50,02	53,86
Recirculation air	°C	40,40	39,51	40,84	40,77	42,04	40,71
	m³/h	783,04	747,75	738,95	726,89	729,53	745,23
Outgoing air	°C	35,83	35,38	36,70	36,48	37,90	36,46
	m³/h	543,26	528,88	526,15	524,85	525,97	529,82
Incoming air	m³/h	0,05	0,06	0,07	0,06	0,06	0,06
Drying temperature	°C	105,09	104,57	105,48	105,09	105,03	105,05
Outgoing air zone 1	°C	36,12	35,91	35,75	35,53	35,12	35,69
	%	99,13	99,08	99,26	99,38	99,48	99,27
Outgoing air zone 2	°C	35,97	35,91	36,19	36,66	37,42	36,43
	%	93,35	94,32	94,41	93,07	88,39	92,71
Outgoing air zone 3	°C	38,13	37,77	38,05	40,17	40,99	39,02
	%	87,19	89,38	88,20	79,29	73,73	83,56
Pressure drop	mbar	7,53	7,98	8,21	8,29	8,11	8,02
Ambient	°C	17,90	17,78	17,84	17,97	18,01	17,90
	%	58,22	59,68	61,56	63,96	64,39	61,56
Heiza inlet temperature	°C	177,78	178,23	178,05	177,25	176,71	177,60
Heiza return temperature	°C	162,03	162,60	162,62	161,94	161,48	162,13

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Out going air = vent gas, mainly H_2O

Belt Dryer pilot scale test 4,

belt speed 60%, layer thickness 90mm, time 17 min

Sample		16	17	18	19	20	Mean value
Time		13:05	13:20	13:35	13:50	14:05	
Dry substance input	%	29,68	29,86				29,77
Dry substance output	%	46,19	51,97	50,38	53,6	50,5	50,53
Recirculation air	°C	43,86	43,16	42,76	44,47	44,97	43,84
	m³/h	745,35	751,57	742,63	735,56	735,97	742,22
Outgoing air	°C	38,44	38,23	38,25	40,03	39,93	38,98
	m³/h	532,57	533,63	532,32	531,48	533,25	532,65
Incoming air	m³/h	0,06	0,06	0,08	0,06	0,05	0,06
Drying temperature	°C	103,74	103,73	104,56	102,36	102,62	103,40
Outgoing air zone 1	°C	35,17	34,12	34,19	34,09	34,35	34,38
	%	99,62	99,64	99,68	99,74	99,78	99,69
Outgoing air zone 2	°C	37,65	36,85	36,62	37,90	39,02	37,61
	%	84,92	84,90	86,56	81,57	75,05	82,60
Outgoing air zone 3	°C	40,77	40,20	39,05	41,50	42,09	40,72
	%	73,31	71,69	77,52	68,34	62,55	70,68
Pressure drop	mbar	7,51	7,45	7,62	7,56	7,39	7,51
Ambient	°C	18,09	17,68	17,65	17,83	17,98	17,85
	%	64,12	55,44	56,89	57,62	54,64	57,74
Heiza inlet temperature	°C	176,50	174,45	173,55	173,71	174,58	174,56
Heiza return temperature	°C	161,20	159,24	158,36	158,63	159,46	159,38

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Out going air = vent gas, mainly H_2O

Belt Dryer pilot scale test 5,

belt speed 50%, layer thickness 90mm, time 20 min

Sample		21	22	Mean value
Time		14:30	14:45	
Dry substance input	%	29,68	29,86	29,77
Dry substance output	%	52,93	56,57	54,75
Recirculation air	°C	47,34	47,27	47,30
	m³/h	755,82	748,23	752,02
Outgoing air	°C	41,09	41,80	41,44
	m³/h	549,66	544,42	547,04
Incoming air	m³/h	0,07	0,07	0,07
Drying temperature	°C	99,40	100,35	99,87
Outgoing air zone 1	°C	34,94	34,58	34,76
	%	99,81	99,81	99,81
Outgoing air zone 2	°C	38,83	38,99	38,91
	%	77,23	77,93	77,58
Outgoing air zone 3	°C	43,47	43,86	43,66
	%	60,35	60,02	60,19
Pressure drop	mbar	6,43	6,65	6,54
Ambient	°C	18,38	18,31	18,35
	%	59,76	64,25	62,01
Heiza inlet temperature	°C	173,72	175,24	174,48
Heiza return temperature	°C	158,47	159,77	159,12

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Out going air = vent gas, mainly H_2O

Belt Dryer pilot scale test 6,

belt speed 42%, layer thickness 90mm, time 24 min

Sample		23	24	25	Mean value
Time		15:20	15:45	16:10	
Dry substance input	%	29,68	29,86		29,77
Dry substance output	%	58,58	56,93	57,73	57,75
Recirculation air	°C	52,31	52,16	50,85	51,77
	m³/h	734,51	731,92	720,11	728,85
Outgoing air	°C	45,67	44,68	41,86	44,07
	m³/h	544,85	545,25	546,72	545,61
Incoming air	m³/h	0,07	0,07	0,07	0,07
Drying temperature	°C	105,62	101,32	101,50	102,81
Outgoing air zone 1	°C	35,67	35,66	34,00	35,11
	%	99,83	99,84	99,70	99,79
Outgoing air zone 2	°C	41,02	41,59	42,62	41,75
	%	70,71	67,04	57,85	65,20
Outgoing air zone 3	°C	44,70	43,03	49,49	45,74
	%	56,58	64,13	40,26	53,66
Pressure drop	mbar	6,48	6,45	6,81	6,58
Ambient	°C	18,36	18,37	18,34	18,36
	%	65,07	66,40	65,71	65,73
Heiza inlet temperature	°C	176,87	175,49	165,20	172,52
Heiza return temperature	°C	161,44	160,27	152,67	158,13

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Out going air = vent gas, mainly H_2O

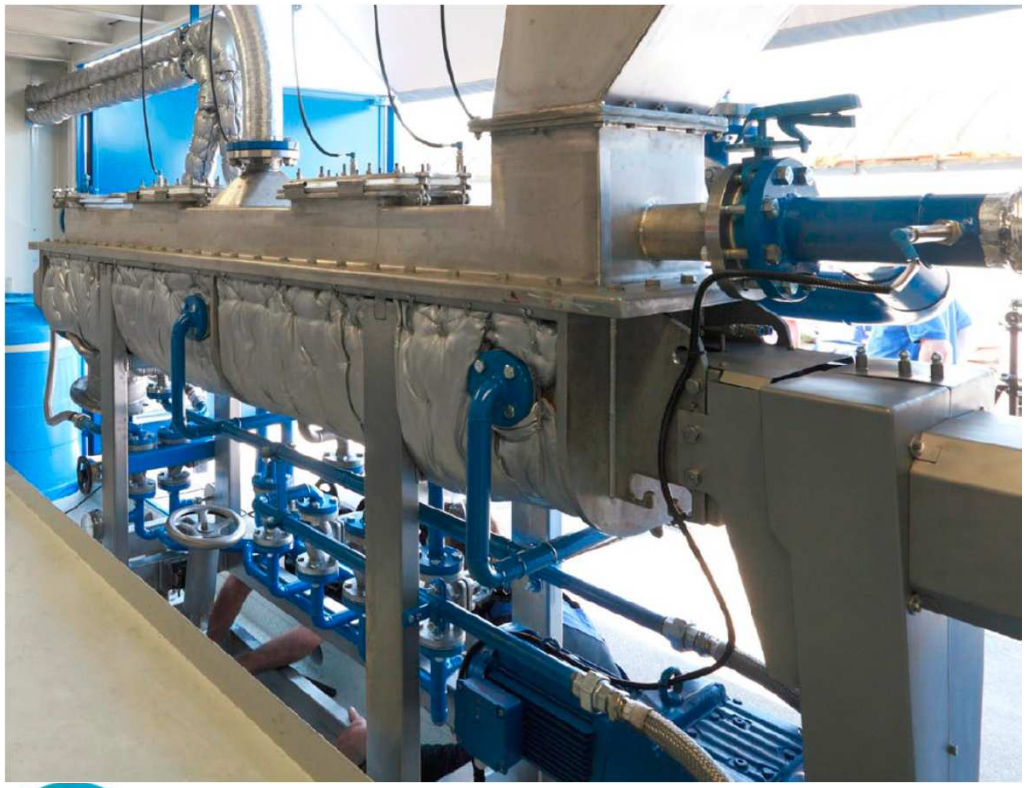
Belt dryer suitability - conclusions

- The performed tests indicated that drying process performed well, but there is a dust problem.
- The sieve anylysis showed 15,9% of the material was smaller than 0,25 mm in particle size.
- The above is expected to cause several problems in industrial scale operations.
- The main conclusion from the dryer test was, that it is not recommended for drying the mixture, because of the dust problem.

Paddle dryer pilot scale test at Andritz

- Due to the fact that belt dryer was not recommended for drying the mixture, another drying technology should be applied. Paddle dryer was decided to be tested.
- Prior to the paddle dryer pilot test a laboratory feasibility trial has been performed to conclude on the possibility to use a paddle dryer to dry mixture. In the trial the mixture was heated on an electrical plate. The temperature of the product was checked, and the mixture behavior, during the drying process was determined visually. The trial showed paddle dryer is suitable to dry the mixture and it is feasible to enter the pilot scale test.
- The target of the paddle dryer pilot test was to determine all relevant parameters such as, K-value, product flow, product temperatures, etc. to prove the suitability of paddle dryer with saturated steam to dry the mixture to the required DS. The test was carried out at Andritz Gouda in Waddinxveen, Netherlands.
- The objective was to determine the most suitable process parameters:
  - check the encrustation of the product on the heated surface of the dryer
  - determine the drying capacity of the dryer
  - determine the slope of the dryer
  - determine the steam pressure - temperature
  - determine the behavior of the product in the dryer

Paddle dryer for pilot testing



Inside view of rotating paddles

Paddle dryer is suitable for
The following processes:

- Drying
- Heating
- Cooling
- Reacting
- Rosting
- Cooking, braising
- Calcining
- Sterilizing
- Solvent stripping
- Melting

Paddle dryer is suitable for drying of sticky materials

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Paddle dryer pilot scale test at Andritz

- One big bag (50soot/50sawdust in vol%) 500 kg of mixture, average DS 28%.
- The mixture was fed manually into the Paddle dryer (batch-wise). The product temperature during feeding of the dryer was 18 °C. Due to the product feed the slope has been set to 1.5° (product outlet lower than the inlet). The sweep gas (air) over the product bed was approx. 125 °C.
- During the drying tests the following data were collected:
- Feed temperature of the product inlet
- Product temperature in the trough at 10%, 26%, 42%, 69%, 96% and 100% of the trough length
- Moisture content inlet and outlet of the product
- Bulk density of inlet and outlet of the product
- Steam pressure
- Product level in the trough
- Inclination of the dryer
- Paddle shaft rotation and power consumption
- Product overflow weir in the trough

Results - Paddle dryer pilot scale test

- In the first set-up the residence time of product in the dryer was approx. 39 minutes. The dryer could handle the defined product flow. Drying of this mixture in the paddle dryer was successful, but the mixture outlet moisture was too low at the outlet DS 87%, the drying process created a high amount of dust.
- Samples were taken after the first test over the dryer length. Some encrustation was observed in the first 50% of the dryer length.
- Due to low end moisture in the first test, it was decided to do a second test with an 50% increased feed rate capacity.
- In the second set-up the dryer was running quite well. Drying of this mixture in the paddle dryer was successful, but the product outlet moisture content was higher than expected. The creating of dust was minimized during this test.
- In this test Andritz-Gouda paddle dryer was found suitable for drying the mixture approx. DS 28% down to approx. DS65%, which is somewhat higher than targeted.
- The results can be used as guidelines for dimensioning of a dryer.

Summary and conclusions of paddle dryer pilot test

- Prior to the paddle dryer pilot test a laboratory feasibility trial indicated it is feasible to enter the pilot scale test.
- Paddle dryer pilot test was performed in Waddinxveen.
- Paddle dryer was found suitable to dry the fresh and banked soot sludge mixed with saw dust.
- All relevant parameters such as K-value, product flow, product temperatures were determined. These gave the guidelines to dimensioning the production scale paddle dryer.
- This study also indicated that paddle dryer has potential for drying another type of industrial sludges.

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