Summary:

Start of cooperation with OSE Germany: 24.09.2018

Date of interim report / status: 08.11.2018

Active tasks:

Documentation: holistic documentation with all the basics and the detailed description of all components and backgrounds	**In progress**	Johannes
Sludge removal: concept for sludge removal and implementations in reaction chamber	**In progress**	Vaishnavi Victoria
Recycler: concept for recycler system and implementations in the process	**Starting**	Hans

Presentation of results in this interim report

Simulation (Master thesis): optimization of fluid-dynamic boundary layer for functionality and optimization of efficiency	**In progress**	Isabel

Separate presentation of results

1 Topic: Documentation

1.1 Description and aim

Holistic documentation with following topics:

- Why the Zinc Air Cell is important? Which potential?
- State of the art? General information to fuel cells?
- Which other research and development activities worldwide?
- Differentiation to other systems of ZAC?
- Description of the system and all components with the background ideas (focus on every part)?
- Which development states and which results?
- View to the future?

1.2 First steps

- ✓ Collection of information, reading the input data
- ✓ Start of the documentation

1.3 Next steps

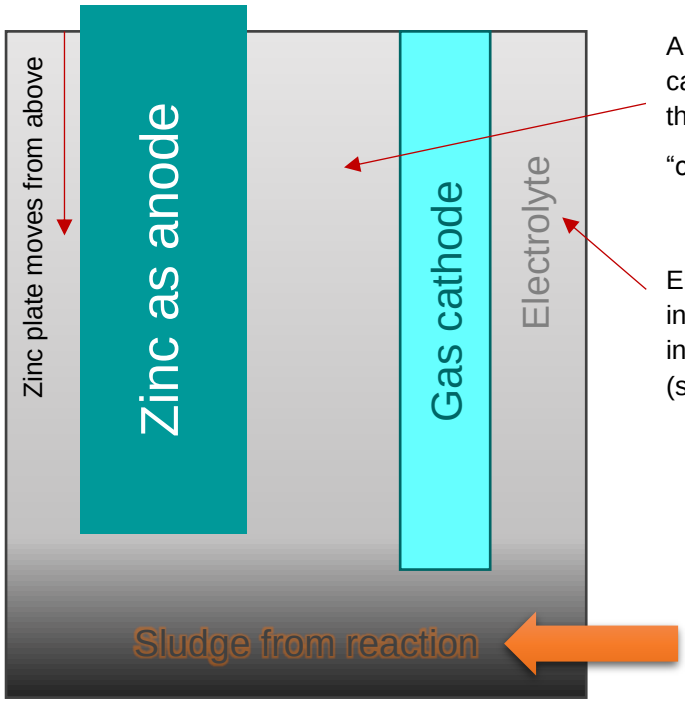
- Writing of first chapters and sending to Oliver for check

Open point:
Planned: documentation in English
Idea: documentation in German first, then translation?

2 Topic: Sludge removal ZAC+

2.1 Description and aim

The chemical reaction in the Zink Air Cell, schematic sketch:



Area of reaction between zinc anode and gas cathode (the main reaction takes place in the three-phase boundary of the gas cathode)

"cold combustion": oxidization of zinc

Electrolyte: KOH (potassium hydroxide)
in the upper area more, clean electrolyte &
in the lower area deposition of the reaction sludge
(sludge of zinc oxide has a larger molar mass)

Aim:
Removal of the sludge of zinc oxide from the KOH electrolyte)

Figure 1: Description and aim
Schematic sketch of the reaction ZAC+

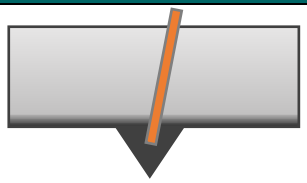
The result from the aim are to topics:

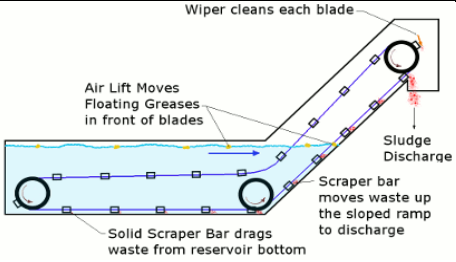
1) Main topic: concept for removal of the sludge
2) Side topic: concept for deposition (see chapter 2.4)

2.2 Research: common concepts for sewage sludge removal

First step:
Sewage plants and some other technical systems have a similar problem regarding the sludge removal.
For the idea-making process a research for existing concepts is useful, see following table:

Table 1: Research sludge removal
Ideas from existing systems

ITEM	Idea	Description	Sketch	From System
1a	Hose/tube for suction	Removal with a hose in the area of deposition, realized with a pump or another solution with under pressure		F. e. sludge pump for garden pond

1b	Industrial vaccum ceaner	These cleaners use vaccum to suck out the sludge and to separate it from the liquid.		https://www.big-brute.co.uk/applications/4110/recovering-waste-oil.htm
2	Sludge conveyor	The conveyor consist of spirals inside that is driven by the helical geared motor. As the spiral moves, the sludge is transported. The conveyor can be vertical or diagonally **Remark:** perhaps the auger could be connected with the zinc plate inlet (with the sinking of the plate the auger is moved) – self-sufficient system		https://sodi-mate.de/portfolio/schlamm-foerder-schnecke-cs/ Videos, see: https://www.youtube.com/watch?v=KRxhinJp-ME or: https://www.youtube.com/watch?v=kKM7Xue-JcUY
3	Shovel	Shovel can be used to remove sludge. It is a manual clean up method. It is not expensive in genera.		F. e. used in garden pond or fishponds
4	Conveyor belt with raw or grooved surface	The bottom exists out of the conveyor belt. The conveyor with the special surface belt moves the sludge out of the fluid and deposits the waste into barrels for disposal.		F. e. for earth, mud or other materials, used in mining or others
5	Conveyor belt with a certain surface out of shovels	The sludge scraper (shovels) removes sludge, from the bottom of reservoir, the conveyor belt moves the sludge out of the fluid and		https://www.stingrayparts-washer.com/parts-washer-option-sludge-scraper.html

		deposits the waste into barrels for disposal.		

In general, the sludge removal can be realized - depending on the selected concept and the practicability:

- Manually as needed
- Automatically, continuously
- Automatically, sporadically, f. e. by use of a timer
- Automatically, sporadically as needed coupled with the zinc inlet

https://data.epo.org/publication-server/rest/v1.0/publicationdates/19790711/patents/EP0002704NWA1/document.html

2.3 Requirements for the sludge removal for ZAC+

The weighting of requirements is divided into three categories:

- Must (M): requirements to be fulfilled under all circumstances
- Should (S): requirements to be fulfilled with certain deviations
- Wish (W): requirements that should be fulfilled as far as possible, even if this involves additional work

Table 2: Requirements for the sludge removal
Technical and economical requirements for the solution sludge removal for ZAC+

ITEM	Technical / economical / others	Category M / S / W	Requirement	Description of requirement
1	Technical	M	No leakage regarding electrolyte	The reaction chamber and the electrolyte cycle must be without leakage; The recycler is the next step of development, the reaction chamber with the sludge removal is separated in the first step. From the system consisting of anode, cathode, electrolyte and the reaction product, the zinc oxide sludge, only the sludge must be removed for reprocessing.
2	Technical	M	Adaptable to the size of ZAC System and the free installation space	The size of the ZAC system needs to be determined. The area of reaction should be free. Perhaps the reaction camber needs an extension on one side.
3	Technical	M	Large collection volume	The volume of the collection area must be big enough in compromise with the concept of removal (continuous or discontinuous) and the amount of sludge in a several process time. The collection area must cover the full area of the bottom or a system for steer the sludge to a several area must be found.

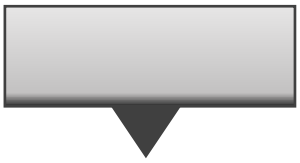
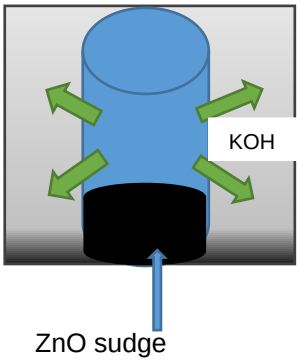
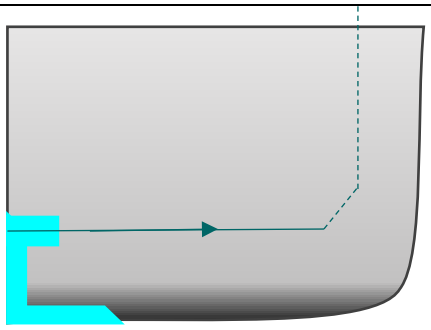
4	Technical	M	No influence of the reaction or the liquid flow or other parts	The removal system must be outside the reaction zone. The sludge removal system must be without changing influence about the fluid flow (f. e. no turbulences). The removal system must be without influence on other parts: no damage, no abrasion.
5	Technical	S	Easy to implement in the existing system	The solution must be easily produced / obtained and implemented in the existing system.
6	Technical	M	No susceptibility to clogging	The removal system must be able to remove the sludge without clogging the removal system. F. e. the diameters of tubes must be big enough.
7	Technical	M	Material resistance to the elements in the system	The materials of the removal system must not be corroded or disintegrated by those of the elements in the ZAC system: no damage, no corrosion, no delamination, no decomposition.
8	Technical	M	Galvanic separation	The removal system must not interfere with the galvanic separation.
9	Technical	M	No chemical reaction of the components of the removal system with the rest of the system	The materials of the removal system must not react with those of anode, cathode, oxygen or electrolyte.
10	Technical	S	Maintenance-free	The sludge removal system should be maintenance-free: no exchange of parts, no repairs, no refilling of resources.
11	Technical	W	Automation	Ideally, the process runs automatically and does not have to be done manually.
12	Economical	M	General availability of materials and parts	The materials used must be generally available for everyone and the price must be low.
13	Economical	M	Cost efficient	The materials must be cost effective: low price.
14	Economical	M	Long lasting (lifetime)	The removal system should be long-lived for permanent use, like the complete system.
15	Economical	S	Easy to build for users	The system must be easy to build that interested people can rebuild the system.
16	Others	W	Use of ecological harmless materials	To realize this project, only eco-friendly materials must be used.

2.4 Concepts for Deposition

As second topic, here are ideas for the deposition listed. An extensive rating is not planned. The choose for a concept is only to justify below.

Remark: The kind of deposition area must be designed after choosing a concept based on the final evaluation and can be a combination of the following ideas.

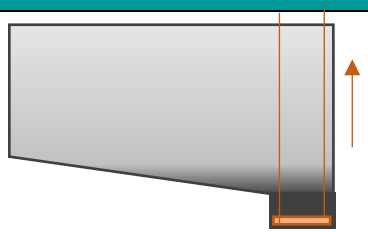
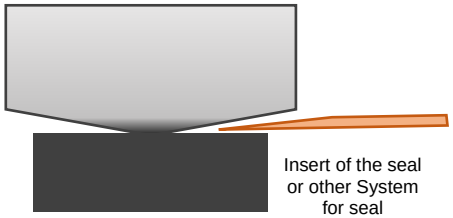
Table 3: Research sludge removal
Ideas from existing systems

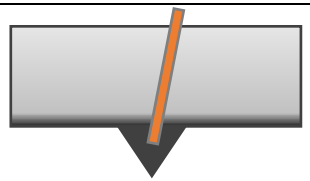
ITEM	Idea	Description	Sketch	From System
1	A kind of funnel	For deposition at a lower area of reaction chamber; like a storage area for the sludge in flow calms area → for the deposition, part one of the removal		F. e. wastewater treatment See: http://diglib.tugraz.at/download.php?id=576a781b42b3c&location=browse
2	Slope	The bottom of the reaction camber is a slope. The sludge is collected on one side.		
3	A kind of cylinder type container that contains thin pores, standing at the bottom	For deposition at a lower area of reaction chamber: The mixture of KOH and ZnO falls into this cylinder. At the sides of the cylinder, due to thin pores, the electrolyte flows out and the ZnO sludge gets settled at the bottom. But it doesn`t cover the complete bottom.		
4	A system for pushing / scratching the mud together	With a kind of shovel or something like this scratching the mud at the bottom together to the removal system or to the outlet		

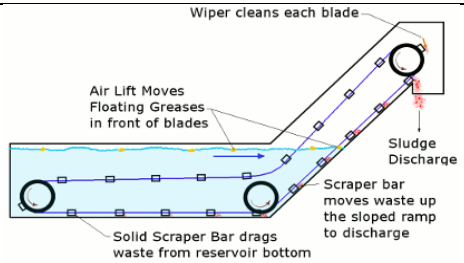
2.5 Creation of concepts for removal with rating

Based on the ideas of the research: creation of new concepts and rating of concepts from the research and of the new concepts regarding to the applicability

Table 4: Creation of concepts for sludge removal ZAC+
New concepts and adaptation of established concepts, see Table 1

ITEM	Idea	Description	Sketch	Pro	Contra	Applicability
New concept ideas						
1	A kind of easy lift	A collection box for the ZnO sludge is lifted using a simple lift device. It hast to be emptied at defined intervals, depending on the amount of sludge.		+ Easy system + If needed: automatization possible + Easy construction possible + Material generally available	- Manual process - Needed working space for the removal process - Can influence the fluid flow - Amount of sludge must be observed	Applicable, if: ○ Easy lift concept ○ Working space for removal is available
2	Detachable area with sealing element	Through the opening at the lowest point, the ZnO sludge sinks into the collection chamber. This can be closed with a seal. Then the collection chamber can be opened for sludge removal.		+ No working space in the area of reaction chamber needed + Collection chamber with a lot of volume for less removal frequency + No influence of reaction or fluid flow	- Realization of seal - Manual process - Amount of sludge must be observed	Applicable, if: ○ Space for collection chamber ○ Realization of seal
Concept ideas, see Table 1						

1	Hose/tube for suction ~~/ vacuum cleaner~~	Removal with a hose in the area of deposition, realized with a pump or another solution with under pressure or vacuum With the end of the hose, sludge can be removed at the lowest point.		+ Cost effective solution + Easy construction of the hose/tube and the fixture + Material generally available	- Chances of the liquid flowing through the hose/tube - Only usable when the process in the reaction chamber stop - Automation only possible, when coupling with process stop in reaction chamber - External energy would be required for the pump - The hose/ tube must be fixed in the system - Suction of mud and more electrolyte then with the other systems - Costs for the pump system - Amount of sludge must be observed	Applicable, if: ○ Supply of external energy ○ No need such a high accuracy of separation ○ Easily available material / pump system ○ Cost efficiency ○ Process in the reaction chamber can be stopped
2	Sludge conveyor	The conveyor consist of spirals inside that is driven by the helical geared motor. As the spiral moves, the sludge is transported. The conveyor can be vertical or diagonally.		+ Efficient separation of the sludge + Done in less time and continuous as it is automated + Any mounting position (from 0 ° pitch up to 90 ° pitch). + Low maintenance + Variable length	- Could be expensive - Motor or any idea for engine needed - Heat generated from the motor must be considered – outside the electrolyte - Space for installation	Applicable if: ○ Enough installation space ○ Cost efficiency ○ Concept for engine

3	Shovel	Shovel can be used to remove sludge. It is a manual clean up method. It is not expensive in general.		+ Cost efficiency + Easily available + No implementation of an additional system	- Manually process, only when the process in the reaction chamber stop - Labor Intensive - Needed working space for the removal process - Amount of sludge must be observed	Applicable if: ○ Allow human intervention ○ Process in the reaction chamber can be stopped ○ Working space for removal is available
4	Conveyor belt with raw or grooved surface	The bottom exists out of the conveyor belt. The conveyor with the special surface belt moves the sludge out of the fluid and deposits the waste into barrels for disposal. The intake must be at the lowest point or over the complete area of the bottom of reaction chamber.		+ Efficient separation of the sludge + Continuous process + Automatization + Effluent flow of electrolyte can be realized by design of the conveyor belt for less outtake of electrolyte + No observation of the amount of sludge	- Could be expensive - Engine or concept for running needed - Might require Large space for installation - Automatization needed -	Applicable if: ○ Enough installation space ○ Cost efficiency ○ Concept for engine
5	Conveyor belt with a certain surface out of shovels	The sludge scraper (shovels) removes sludge, from the bottom of reservoir, the conveyor belt moves the sludge out of the fluid and deposits the waste		+ Efficient separation of the sludge + Continuous process + Automatization + Effluent flow of electrolyte can be realized by design of	- Could be expensive - Engine or concept for running needed - Might require Large space for installation - Automatization needed	Applicable if: ○ Enough installation space ○ Cost efficiency

		into barrels for disposal. The intake must be at the lowest point or over the complete area of the bottom of reaction chamber.		shovels for less outtake of electrolyte + No observation of the amount of sludge		○ Concept for engine

2.6 Next steps

- Based on the applicable concepts: technical-economic evaluation according to VDI 2225 (sheet 3) with strengths-weaknesses-diagram is in progress.
- Construction of the chosen concept

3 Topic: Recycler

3.1 Description and aim

The zinc oxide (ZnO) produced during the reaction process of the cell must be recycled again to zinc in order to close the cycle. The recycler system must be developed.

3.2 First steps

- ✓ Collection of information, reading the input data
- ✓ Training with Open CAD

3.3 Next steps

- Requirements
- Collection of concept ideas
- Technical-economic evaluation of concept ideas
- Choose of one idea
- Construction of concept