EMISSION FREE MAINTENANCE DREDGING

At the Port of Rotterdam

Pieter Kingma
Floris van Ingen
Fabio Curzi
Jan Geleijnse

Under the supervision of:

Sebastian Henrion (Boskalis, R&D)
Hilbrand Druiven (Boskalis, I&S)

Prof. Dr. Ir. Cees van Rhee (TU Delft)
Dr. Ir. Martine Rutten (TU Delft)

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Four ways of performing emission free maintenance dredging in the Port of Rotterdam. Each option also includes the necessary steps to take to make emission free dredging reality.

As part of Boskalis mission to become emission free by 2050, four TU Delft students were recruited to perform a 10 week research with the aim of providing the company with an overview of possible emission free methods forfor a yearly cycle of maintenance dredging in fixed areas. These methods were developed, on paper, for the entrance to the Port of Rotterdam. This memo presents an overview of the designed methods and will show you that emission free maintenance dredging is very much within reach! Readers interested in more background are advised to read through the accompanying slide deck and report.

There are three ways of making dredging emission free:

- Compensate emissions by carbon capture.
- Run operations on sustainable energy carriers (dynamic).
- Connect (parts of) the operation to the electricity grid (static).

This research focused on the latter two as those are options where innovation in the work concept method can be made.

SPLITTING UP THE WORK METHOD

An important part of the solution to get to emission free maintenance dredging is to split up the work method into three parts:

- **Collection** of sediment
- **Excavation** of sediment
- **Transportation** of sediment

In this way, each part of the solution can be designed for its specific task, kept small and becomes more energy efficient. The latter two enable the use of the often heavy or bulky green energy carriers. Splitting up the work method also enables the possibility to connect parts that can be static to the electricity grid.

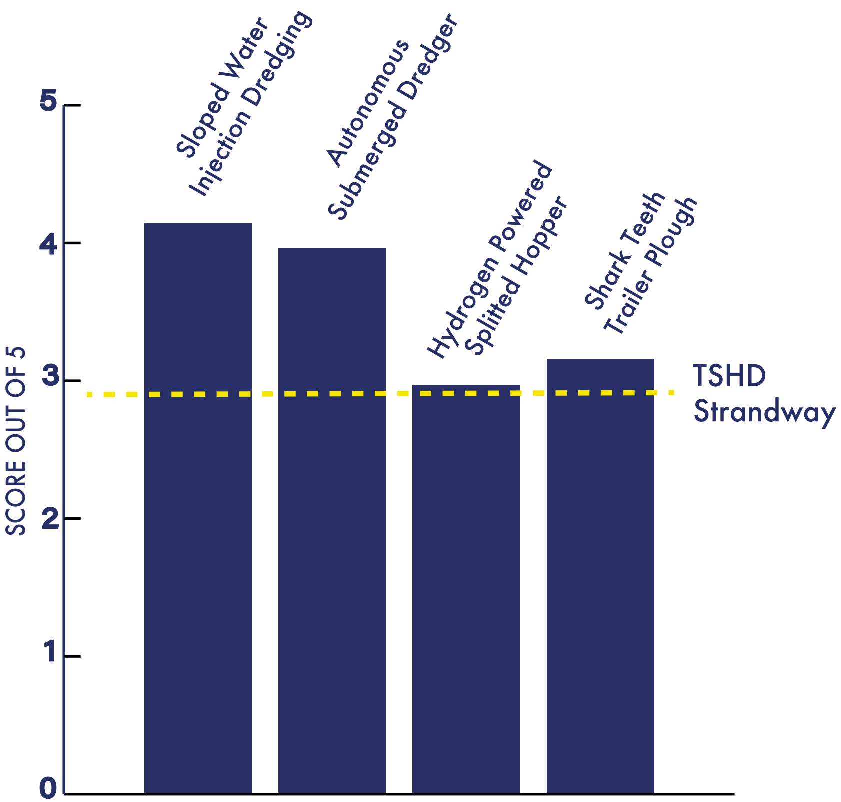
Multiple concepts were developed, all emission free and each handling one or multiple of the three mentioned dredging tasks (collection/excavation/transportation). They were ranked by means of a Multi Criteria Analysis (MCA). The best performing concepts are presented in this memo.

MULTI CRITERIA ANALYSIS

For the MCA, four categories were considered

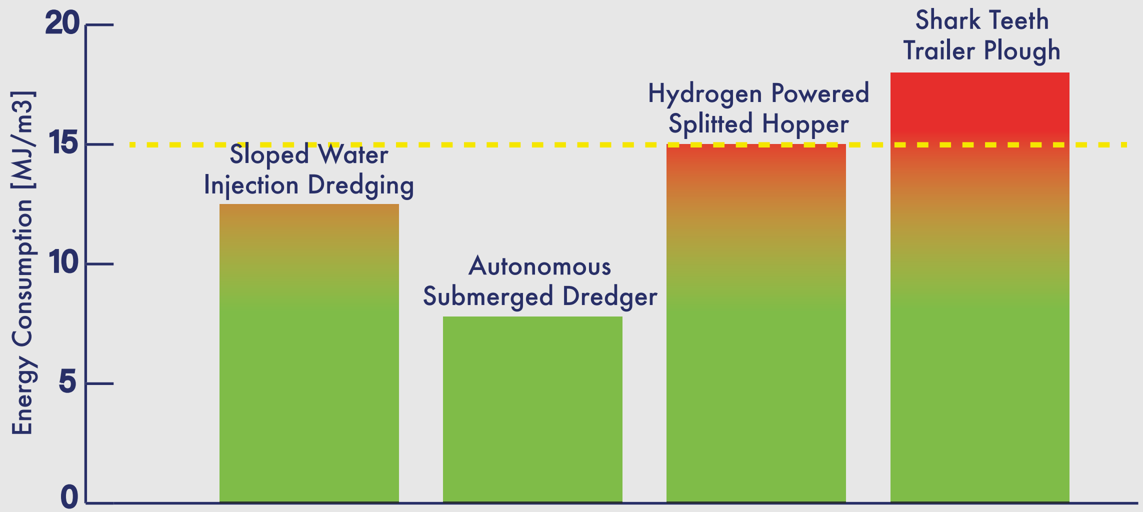
1. Sustainability 40 %
2. Interference, Risk & Safety 25 %
3. Reliability 25 %
4. Cost 10%

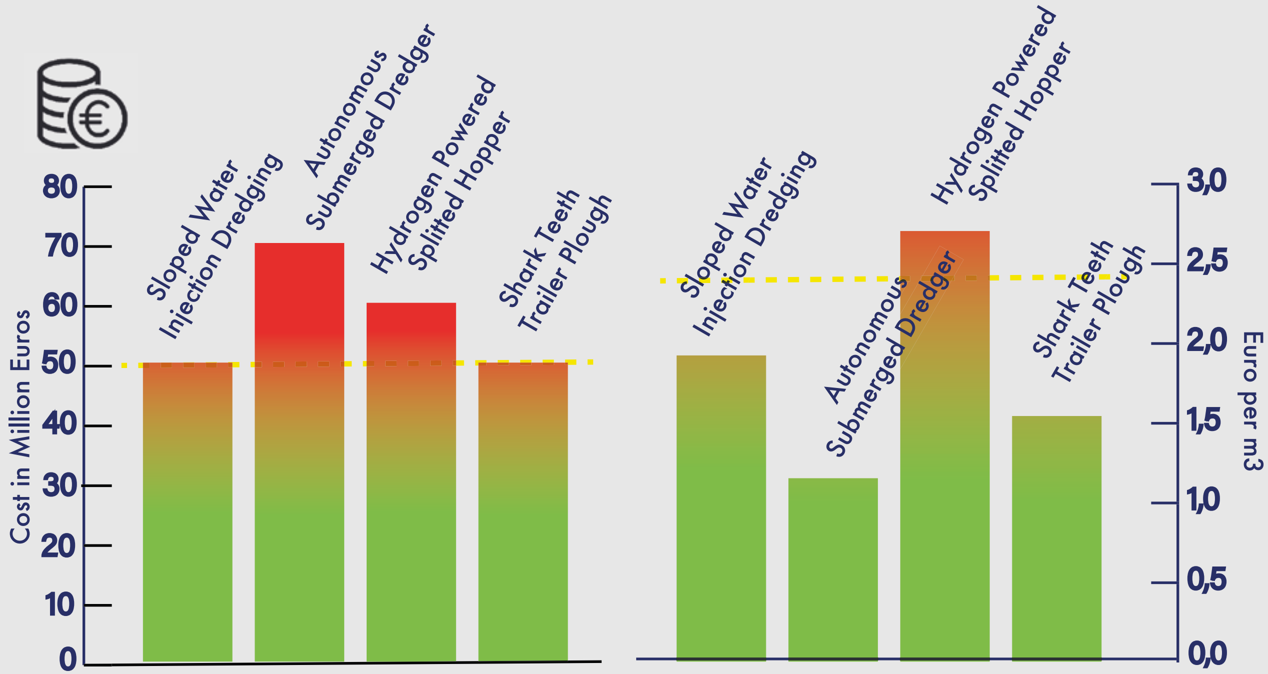
This page presents a summary of the results of the best scoring concepts. The reader is referred to the report for more detail.



MULTI CRITERIA ANALYSES FINAL SCORES

ESTIMATED ENERGY CONSUMPTION OF DREDGING METHOD





CAPEX **OPEX**

OVERALL TAKEAWAYS

DO

Split up the process

- Designs become task specific and thus more efficient.
- Less required power enables green energy carriers.
- Oppurtunity to use fixed structures connected to the grid.

Keep the sediment submerged

By not lifting the sediment to the surface, a lot of energy is saved.

Use Hydrogen in Port of Rotterdam

The Port of Rotterdam aims to have introduced a large scale integrated hydrogen network across the Port by 2030. Jumping in on this trend can be very fruitful for both parties.

DON'T

Transport through complex pipelines

When using long and complex pipelines or hoses, a lot of energy is lost due to friction.

Use large permanent underwater structures

A design that did not pass the MCA test, consisted of a large ploughing system on rails. Although energy consumption of such methods is low, they are way too material intensive.

SLOPED WATER INJECTION DREDGING

Use water injection dredging combined with sediment traps to COLLECT the sediment in central locations. EXCAVATE the sediment traps continuously using static pumps.

Water injection dredging (WID) puts settled sediment back into suspension by injecting it with water under high pressure. The water with the suspended sediment is heavier than its surrounding water and therefore moves downhill, getting underneath the lighter water. At the site, multiple permanent pumps are placed at the bottom of the harbour that create downhill conical shaped sediment traps. These pumps are connected to the electricity grid. Following an outward rotating path starting at the pump, a hydrogen powered WID vessel puts the sediment in suspension. If there are no currents interfering, the water with the suspended sediment will end up at the lowest point of the slope: the sediment trap. From there, barges are filled that take care of transportation.

- **Emission free**
- **Case study: OPEX reduction of up to 40 %**
- **Case study: no maintenance for 2 months**
- **Small and maneuverable vessel: low interference**
- **Energy usage is approx. 10 - 15 MJ/m3 (TSHD uses 15 MJ/m3)**

Research

- Next-gen WID vessels on hydrogen
- Modelling sediment transport after injection
- Currents at project site

Operational

- WID running on hydrogen
- Fixed structures connected to grid
- Within 5 years

Current Stage

- Diesel powered
- TSHD empties sediment trap

Costs

- 2 WID vessels: 20 M
- 5 Barges: 10 M
- 10 Pumps: 10 M
- **Total: 40 M**
- **OPEX:** 1.92 euro/m3

AUTONOMOUS SUBMERGED DREDGER

Similar to a robotic vacuum cleaner, this vessel maneuvers autonomously over the bottom of the harbour. It EXCAVATES and TRANSPORTS the sediment remaining submerged.

By performing the dredging of the sediment underwater, the sediment is not lifted to the surface. This saves a lot of energy. The entire process uses half of the energy a hopper dredger would use. The submerged dredger runs on a 10 m3 battery pack, providing 3000 kWh. The fact that it is autonomous eliminates the cost of crew. Autonomy also allows for charging when green energy is available. The bouyancy of the submerged dredger is ensured using air chambers. Stability is ensured by placing stabilizers on the seabed floor during loading.

- **Emission free**
- **Energy usage is 7 MJ/m3 (half of TSHD)**
- **Little interference with traffic**
- **No need for permanent structures**
- **Low OPEX**

Source: C-job

Research

- Underwater navigation software
- Autonomy regulations should change
- Test and overcome possible bouyancy and stability issues during loading
- Charging station connected to smart-grid

Operational

- Multiple small vessels
- Powered by batteries
- Low energy usage
- Low interference with traffic
- > 10 years

Current Stage

- Preliminary design on paper (C-job)
- Technology for autonomous vehicles available

Costs

- 3 Submerged dredgers: 60 M
- 1 Charging system: 10 M
- **Total: ± 70 M**
- **OPEX:** 1.15 euro/m3

HYDROGEN POWERED SPLITTED HOPPER

Splitting the hopper dredger into a separate DREDGING and TRANSPORTING vessel enables the use of hydrogen as energy carrier in the Port of Rotterdam.

The Port of Rotterdam has the goal of becoming the world's number one hydrogen hub. By 2030, a port wide hydrogen network providing green hydrogen should be in place. The downside of hydrogenis that its energy density is low, which means a lot of volume is needed to store the required energy. However, the required tank size is kept small by the facts that firstly, during maintenance dredging, travelled distances are small and secondly, liquified hydrogen will be widely available on site. The split of the hopper dredger into a dredging and transportation vessel also contributes to this.

- **Emission free**
- **Hydrogen tank of 5 - 10 m3**
- **Known and proven technique**
- **Maneuverable vessel: low interference**
- **No need for permanent structures**
- **Conveys with mission of Port of Rotterdam**

Current Stage

- Hopper dredger running on diesel
- No split of activities
- Port of Rotterdam aimes to become world leader in Hydrogen

Research

- Wait for hydrogen developments in Port of Rotterdam
- Increase efficiency of Hydrogen production
- Design and create Hydrogen powered splitted hopper

Costs

- 1 Hydrogen system: 0.55 M
- 1 Vessel: 40 M
- 7 Barges: 14 M
- **Total: ± 55 M**
- **Opex:** 2.7 euro/m3

Operational

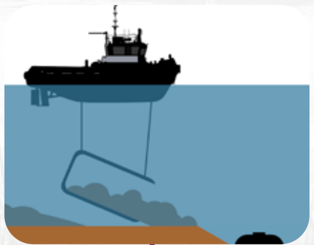
- Dredger powered by hydrogen
- Discharging into autonomous barges
- Within 5-10 years

SHARK TEETH TRAILER

Use a ploughing system that shovels over the bottom and COLLECTS the sediment at a central location from where it is EXCAVATED by a permanent pump. The used container leaves a trench behind that recalls a 'shark teeth' shape.

The ploughing technique is one of the oldest dredging techniques ever used ('Krabbelaar'), back then primarily used as bed levelers. The shark teeth trailer (STT) is a revised form of this method. It consists of a tug vessel powered with hydrogen or by batteries with underneath, a detachable container that scrapes over the seabed and stores the sediments until a pick-up site is reached. Here the sediments are released and pumped into an autonomous barge that will eventually dump the sediment elsewhere.

- **Emission free**
- **Very simple and thus robust**
- **Energy usage ±18 MJ/m3, more than TSHD**
- **Low in maintenance**



Research

- Design of container, find optimal shape
- Filling up process of the container
- Influence of Shark teeth shape on sedimentation
- The exact resistance of the sediment when dragging the container

Operational

- Tugboat powered by hydrogen or methanol
- Sediment is collected at central locations
- Fixed structures pump up sediment

Current Stage

- Not applied on this scale
- Preliminary design based on old harbour maintenance technique

Costs

- 2 Tug vessels: 20 M
- 2 Ploughing system: 4 M
- 8 Barges: 16 M
- 8 Pumps: 8 M
- **Total: ± 48 M**
- **OPEX:** 1.54 euro/m3

EXCAVATION

PERMANENT PUMPS

The great advantage of working with fixed dredger heads (pumps) is that these can be connected to the electricity grid. This enables the use of green energy that was harvested elsewhere.

The technique was used already in the 1990s in the form of the Punaise-pump. The Punaise was a semi permanent structure that was able to dredge with an energy usage of 5.4 MJ/m3. It operates from the bottom and is permanently submerged. During operation, a pit is formed around the Punaise, making it the lowest point in its surroundings. This 'draws' the sediment towards the Punaise. Back in the 90s the Punaise ran on fossil fuel but now it will be changed to run on electricity. Another alteration is that this time the pump is really permanent, attached to the seabed and not easily removable. This prevents problems related to storms. The pump will fill the autonomous barge that is described on the right.

TRANSPORTATION

AUTONOMOUS SPLIT BARGE

Autonomous barges run on batteries and can go whenever there is a surplus of green energy in the grid. The energy provided by the batteries can be complemented by sails. Another possibility to save energy is to fill and sail the barge underwater.

The transport of sediment has a big share in the energy consumption of the dredging industry. Some reports say that it adds up to 50 % of the energy consumption. In the case of the project site in the harbour of Rotterdam, 7.3 MJ/m3 is used for transporting the sediment to the dumpsite at 20 km. This is indeed half of the used energy. Split barges traveling should carry a battery pack of 4.4 m3 for one trip to perform this job emission free.

It is expected that in the near future transportation ships using wing sails will become available. This will bring the possibility of decreasing energy usage for transport by 80 - 90 % (Oceanbird is working on this). A technique that is already used more often is that of the flettner rotor sails. These can decrease energy usage by 8 - 25 %.

A final possibility is filling and sailing the autonomous split barges underwater. Although this technique might be a bit more complicated, filling and transporting the sediment underwater reduces energy usages significantly. The reasons for this are that the sediment no longer has to be pumped up to the surface and secondly that underwater sailing has almost no wave resistance. This can decrease energy usage of the process by more than 50 %.

HAPPY DREDGING **Cheers from fieldtrip Friday at the Maasmond**

Pieter Kingma
Floris van Ingen
Fabio Curzi
Jan Geleijnse