

7. Grab or Clamshell dredger

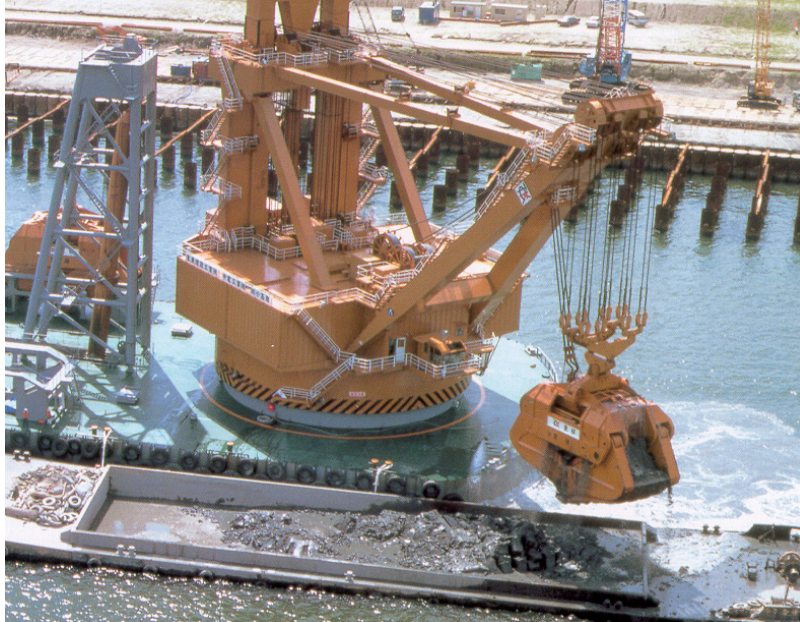


Figure 7- 1: Large grab in the world (200 m^3)

7.1. General

The grab dredger is the most common used dredger in the world, especially in North America and the Far East. It is a rather simple and easy to understand stationary dredger with and without propulsion.

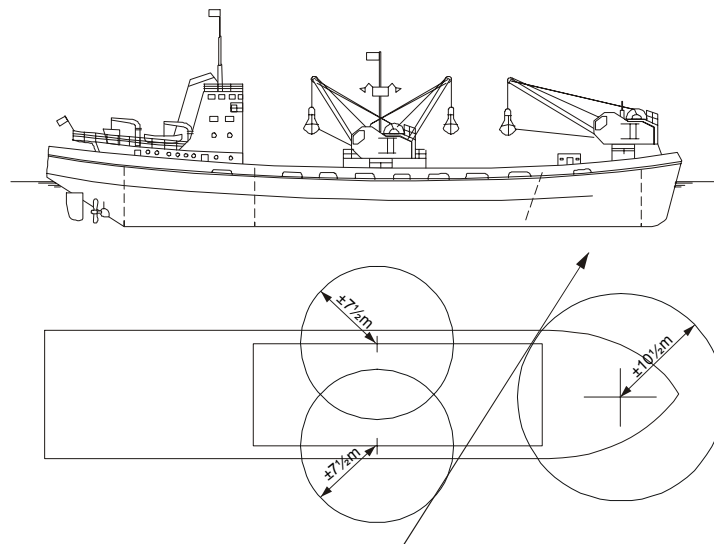


Figure 7- 2 Self propelled grab hopper dredge

In the latter the ship has a hold (Figure 7- 2) in which it stores the dredge material, otherwise barges transport the material. The dredgers can be moored by anchors or by poles (spuds)



Figure 7- 3 Grab bucket reclaimer

The most common types are boom type clamshell dredgers with a boom that can swing around a vertical axis. Beside these, but considerably less in number, are the overhead cranes (Figure 7- 3), with the trolleys, like the ones used for the transshipment of bulk goods in ports.

The capacity of a grab dredger is expressed in the volume of the grab. Grab sizes varies between less than 1 m³ up to 200 m³.(Figure 7- 1)

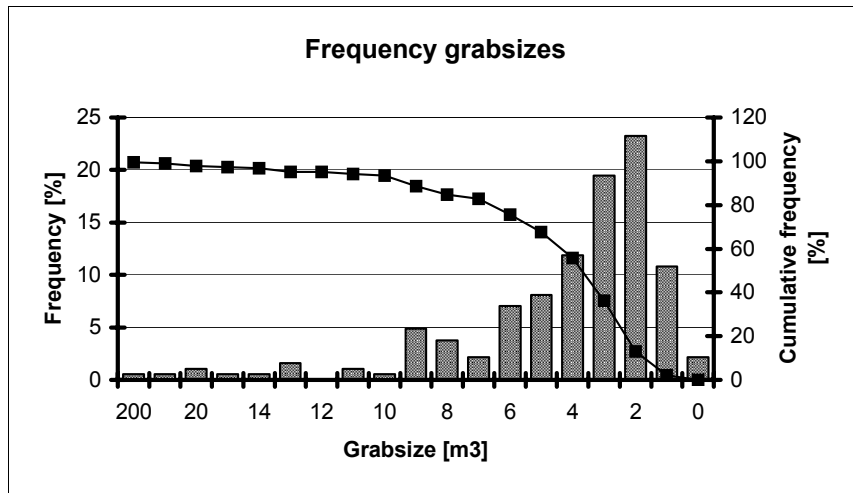


Figure 7- 4

Figure 7- 4 shows a rough overview of the most common grab sizes.

The opening of the grab is controlled by the closing and hoisting wires or by hydraulic cylinders. To ensure that the grab does not spin during hoisting and lowering many crane are equipped with a tag line, running from half way the boom straight to the grab.

7.2. Working method

For clamshell dredgers the method of anchoring and the positioning system plays an important role for the effectiveness of the dredger.

The volume to be dredged at a position decreases with the angle from the centerline. (Figure 7- 5). So dredging areas from -90° to $+90^\circ$ from the centerline is not always effective.

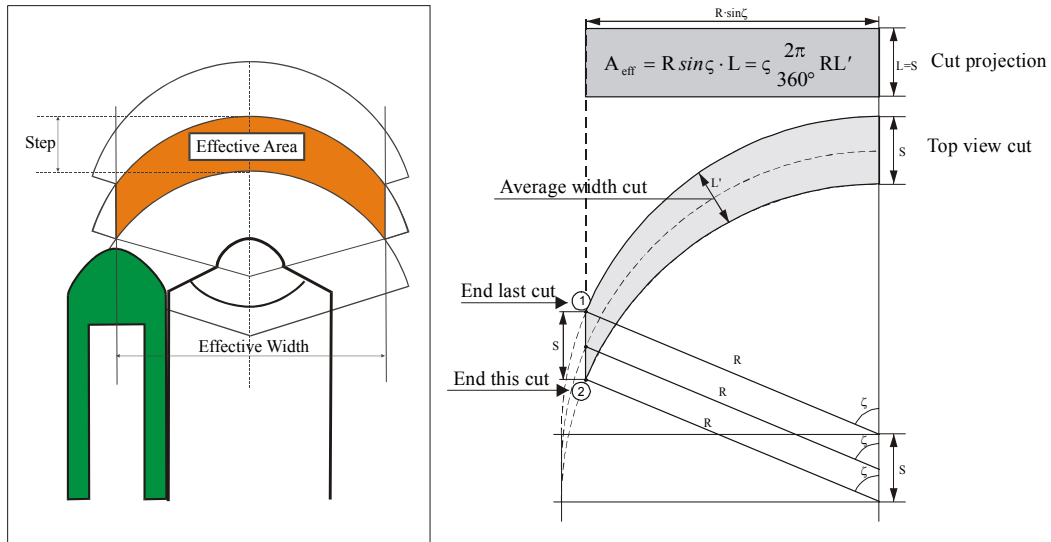


Figure 7- 5 Effective dredging area

In figure 8.5 a top view and a projection of the dredging area area is shown. The width of the dredging area is $R \sin V$ and the width of the cut is L , so the surface of the effective

dredging area is $A_{eff} = L \times R \sin V$ which equals: $A_{eff} = V \frac{p}{90} RL \phi$.

The mean dredging efficiency as function of the swing angle of the crane being $\frac{L \phi}{L}$

follows from equalization of both equations: $\frac{L \phi}{L} = \frac{\sin V 90}{V} \frac{p}{2}$. See Fig.8.6

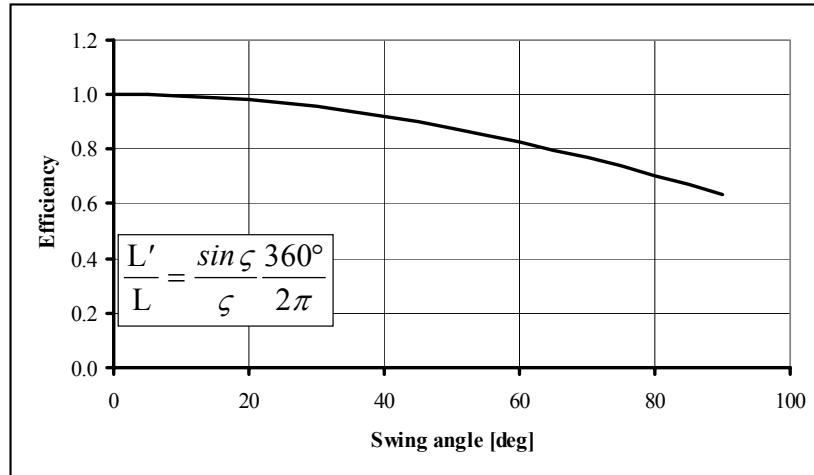


Figure 7- 6 Swing efficiency

It is important to localize every bite of the grab by means of a positioning system. This helps the dredge master to place the next bit after the foregoing.

The dredging process is discontinuously and cyclic.

- Lowering of the grab to the bottom
- Closing of the grab by pulling the hoisting wire
- Hoisting starts when the bucket is complete closed
- Swinging to the barge or hopper
- Lowering the filled bucket into the barge or hopper
- Opening the bucket by releasing the closing wire.

Releasing the aft wires and pulling the fore wires does the movement of the pontoon. When the dredgers have spud poles, this movement is done by a spud operation, which is more accurate than executed by wires.

The principle of this hoisting operation is given in the Figure 7- 7 below.

For a good crane-working behavior the cable cranes have two motors:

- The hoisting motor, which drives the hoisting winch and
- The closing motor, which controls the closing and the opening the grab.

In order to avoid spinning of the clamshell a so-called tag wire is connected to the clamshell.

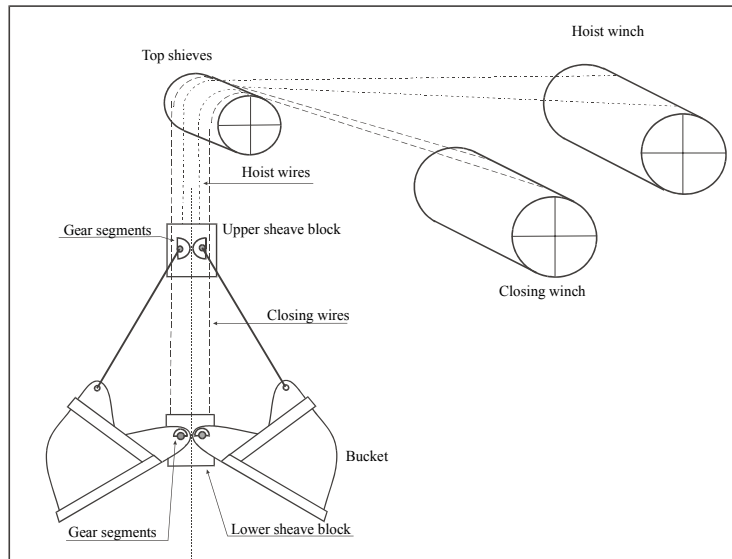


Figure 7- 7 Hoisting system of cable cranes

The crane-working behavior is than as follows:

| no. | Cycle part | position jaws | Hoisting winch | Closing winch |
|-----|------------|---------------|----------------|---------------|
| 1 | ease | open | eases | eases |
| 2 | dig | closing | hoists | hoists |
| 3 | hoist | closed | hoists | hoists |
| 4 | swing | closed | rest | rest |
| 5 | ease | closed | eases | eases |
| 6 | dump | opening | eases | rest |
| 7 | hoist | open | hoists | hoists |
| 8 | swing | open | rest | rest |

7.3. Area of application

The large grab dredgers are used for bulk dredging. While the smaller ones are mostly used for special jobs, such as:

- Difficult accessible places in harbors
- Small quantities with strongly varying depth.
- Along quay walls where the soil is spoiled by wires and debris
- Borrowing sand and gravel in deep pits
- Sand and gravel mining
- Dredging in moraine areas where big stones can be expected.

The production of a grab depends strongly on the soil. Suitable materials are soft clay, sand and gravel. Though, boulder clay is dredged as well by this type of dredger. In soft soils light big grabs are used while in more cohesive soils heavy small grabs are favorable.

The dredging depth depends only on the length of the wire on the winches. However the accuracy decreases with depth. For mining of minerals dredging depths can reach more than 100 m.

7.4. Important design aspects

7.4.1. Type of grabs

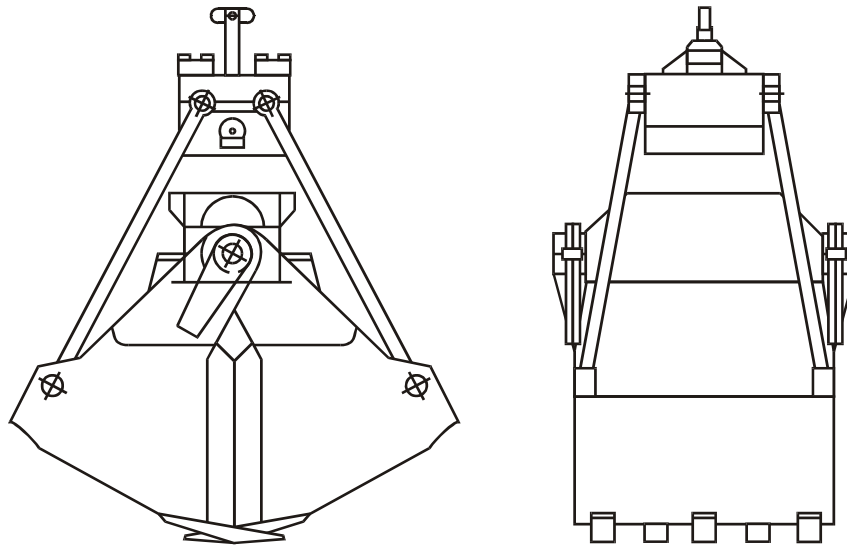


Figure 7- 8 The clamshell

The clamshell most common and is used in silty, clayey and sandy materials. In mud the jaws in general have flat plates without teeth. In sand, clay and gravel, the jaws are fitted with in each other grabbing teeth.

The two halves, shells, rotate around a hinge in the **lower sheave block** and are connected with the **upper sheave block** by rods. The closure/hoist cable is reefed several times between the head and the disc block to generate enough closing force. In mud the jaws in general have flat plates without teeth. In sand, clay and gravel, the jaws are fitted with in each other grabbing teeth. For the removal of contaminated soil closed clamshells are used to avoid spillage.

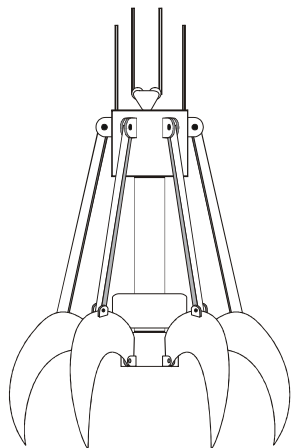


Figure 7- 9 Orange peel grab

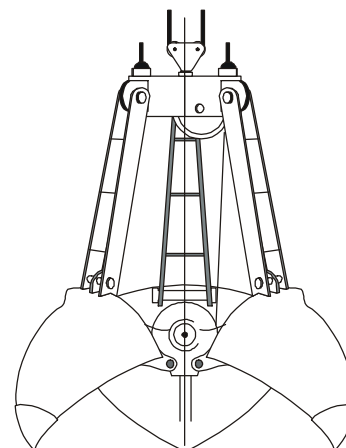


Figure 7- 10 Cactus grab

The orange peel grab (Figure 7- 9) is often used for the removal of large irregular pieces of rock and other irregular pieces. This type of grab has 8 jaws that in general do not close very well.

The **cactus bucket** (Figure 7- 10) is used in the occurrence of both coarse and fine material at the same time. This grab has 3 or 4 jaws that close well in the closed position and form a proper bucket.

The size of the bucket depends on the required production capacity of the crane.

7.4.2. Size and weight of the clamshell

The size of the grab depends on the capacity of the crane. The construction weight is determined, besides by the size also by the required strength and therefore by the type of soil to be dredged. So a grab suitable for the dredging of silt will be relatively large in volume and light in weight, while for the dredging of heavy clay or rocks a relative small but heavy bucket will be used. However, because the hoist force remains constant, with increasing weight of the grab the load weight must decrease. For this reason the efficiency of the grab is expressed as:

$$\eta = \frac{\text{paying load in tons}}{\text{paying load} + \text{grab weight}}$$

Research done in Japan has found the following relation between the ratio of the mass of the material in and the mass of the bucket: $K_g = L \sqrt{\frac{B}{2M_{bucket}}}$. Figure 7- 11

With

- B = Width of grab [m]
- M_{bucket} = mass of grab [kg]
- L = length of fully opened grab [m]
- M_f = mass of grab fill [kg]

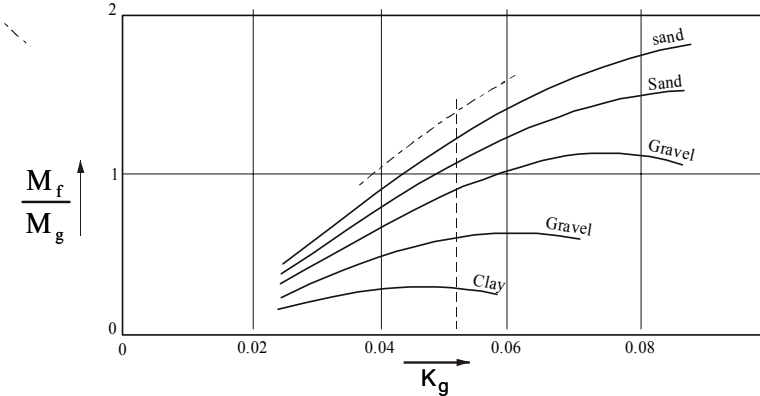


Figure 7- 11 Fill mass and bucket mass ratio

7.4.3. Main winch drive

The winch drive systems are mainly electric (direct current or thyristor-controlled d-c motor connect to the 3 phase board net system) and has the 4 quadrants system. (Figure 7- 12)

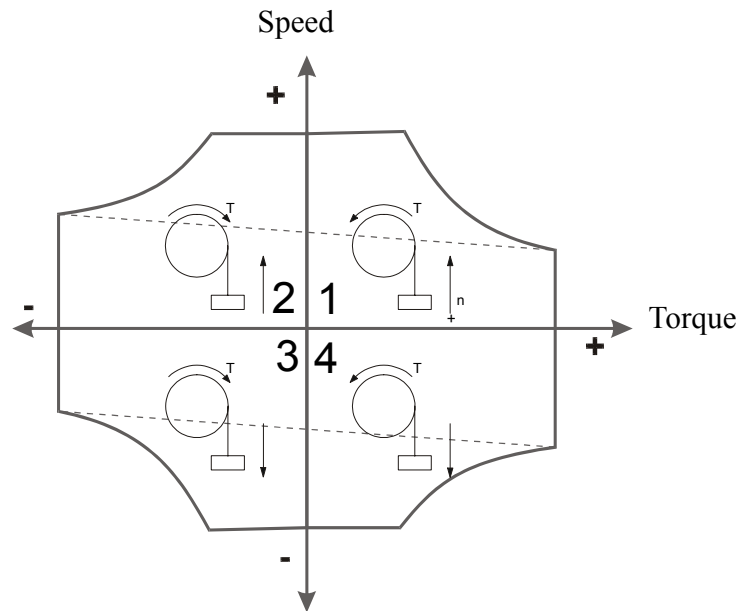


Figure 7- 12 Four quadrants system

7.5. Main Layout for pontoon type floating dredgers

Non self-propelled grab dredgers consist of simple pontoons on which the crane is positioned. The deck is heavy reinforced not only for foundation of the crane but also where heavy loads can be expected, in particular where the grabs are stored. Winches for the movement of the pontoon are placed on deck as well as the accommodation for the crew when necessary

In many cases a standard crane is placed on the pontoon. The boom of the crane is movable with a simple wire system. During dredging the boom is kept in a fixed position as much as possible. This avoids the need for a horizontal load path.

The length of the pontoon is in many cases longer than necessary in order to keep barges along side.

The positioning of the pontoon is either by anchors (4 to 6) or by 2 or 3 spud poles.(Figure 7- 13) In the last case 2 fixed spuds are situated at on the sides of the pontoon and one walking spud aft.

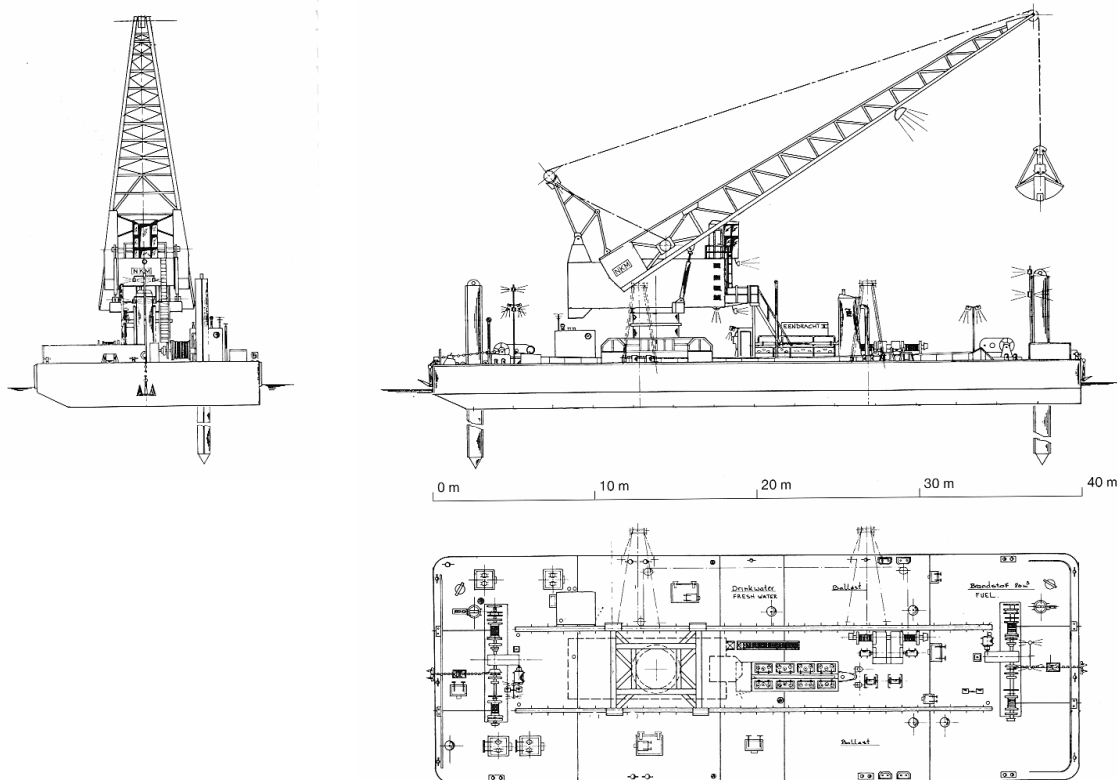


Figure 7-13 Plan view of Grab crane Eendracht, BOSKALIS

An idea about the lightweight in relation to grab size is given in (Figure 7-14) and is in the order of 100 times the grabsize.

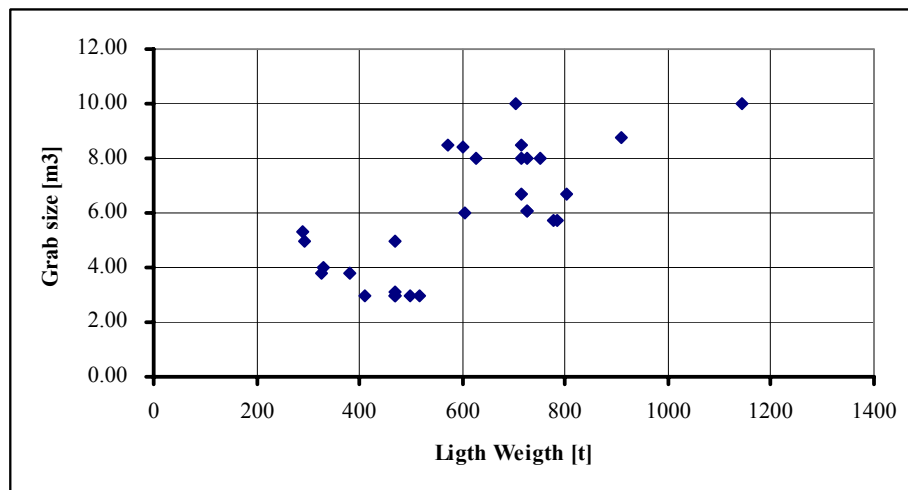


Figure 7-14 Light weight of grab dredge pontoons

The lightweight of the pontoon is low compared to that of the other dredgers. The relation between light weight and pontoon volume is shown in Figure 7- 1

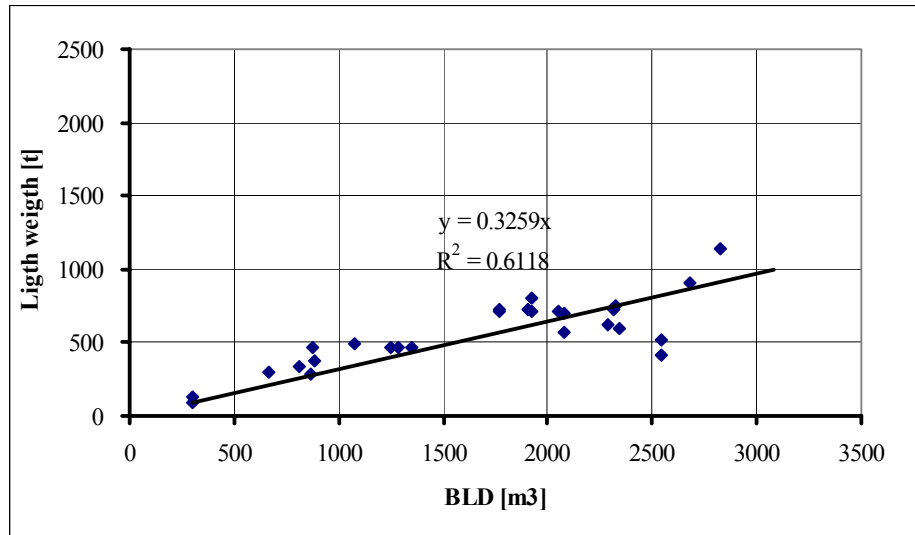


Figure 7- 15 Pontoon volume

The L/B and B/T ratios of the pontoons are respectively between 2 and 3 and 4 to 6. ()

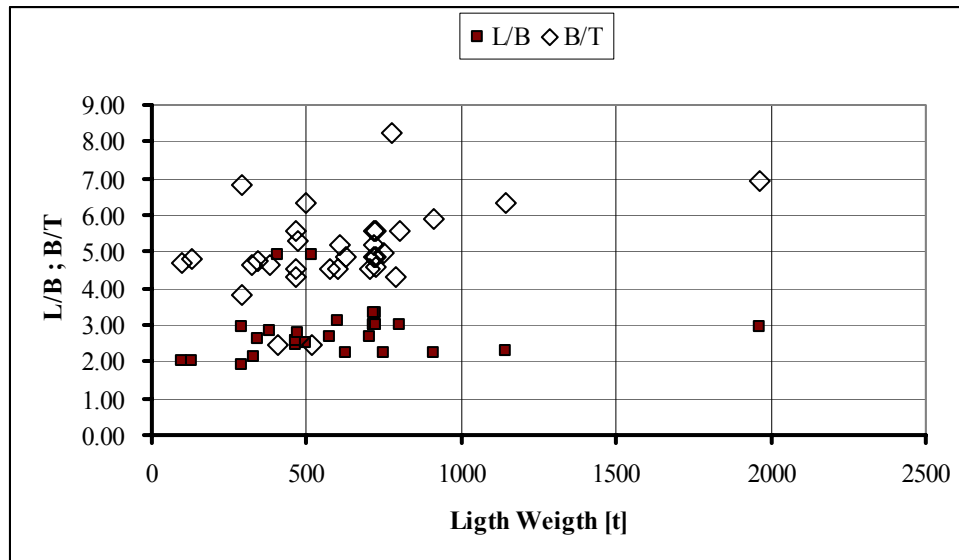


Figure 7- 16 Pontoon numbers

Special attention needs the stability of the dredge because of the varying and eccentric loads. Free fluid levels should be avoided.

7.6. The theory of excavation

The most interesting part of the dredging process takes place during the digging in the soil of the closing grab.

When the grab falls on the soil the yaws penetrate vertically into the soil. This is called the initial penetration.

If the closing cable is pulled up, the lower sheave block and the upper sheave block are pulled together and as a result the grab closes. During this process the hoisting cable is kept slack to allow the grab penetrate deeper into the soil. In very soft soil, like silt or soft clay, the hoisting cable is kept tight to prevent a too large penetration.

The movement and the accompanying forces are described in the proceedings of the Wodcon 1992 in India of Steven Becker: The Closing Process of Clamshell Dredgers in Water-Saturated Sand.

The calculation of the path of the grab and the occurring forces is done by solving the equations of motion with the aid of the cutting theory for sand and/or clay. The friction forces on the sides of the yaws must however be taken into account.

During the excavation the cutting edge follows a certain path through the soil (**the digging curve**) due to the weight of the grab. During this movement the lower sheave block moves upward and the upper sheave block downward (see also figure 7.8).

If the cable grab is outlined as shown in figure 7.9, than the **closing curve** of the grab, not being the digging curve, can be determined as function of the opening angle λ .

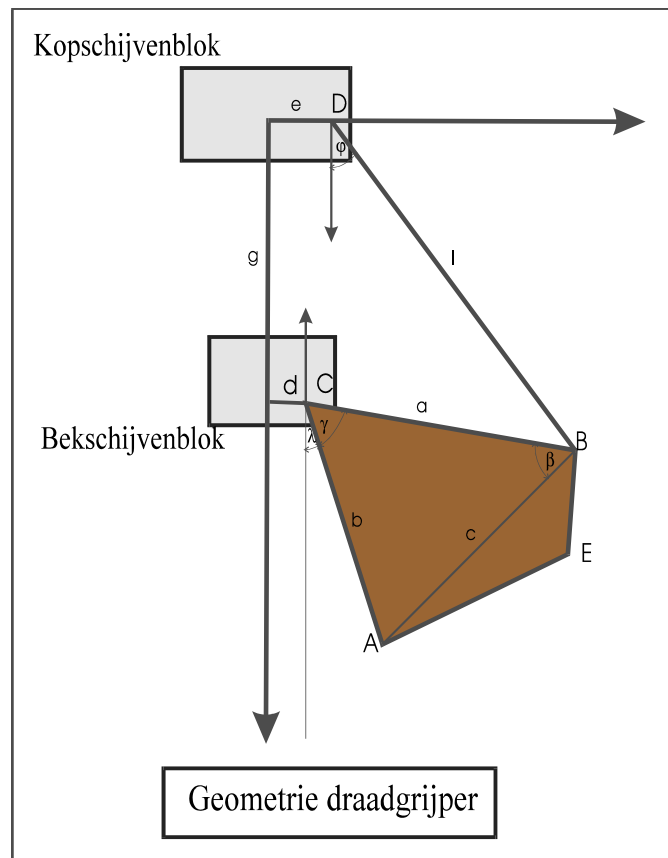


Figure 7- 17 Geometry of cable clamshell *Engels!!!*

In the above shown scheme (Figure 7- 17) can be distinguished:

$$x_c = d + b \sin \lambda = e + l \sin \phi - a \sin(\gamma + \lambda)$$

$$y_c = g + b \cos \lambda = l \cos \phi - a \cos(\gamma + \lambda)$$

and

$$x_a = x_c + b \sin \lambda$$

$$y_a = y_c + b \cos \lambda$$

Furthermore, $x_c = e$, with which the relation between λ and ϕ can be determined:
 $x_c = d = e + l \sin \phi - a \sin(\lambda + \gamma)$, so that x_a and y_a can be calculated as function of λ .
 The closing curve shows the path of the grab yaws compared to the grab head.(.)

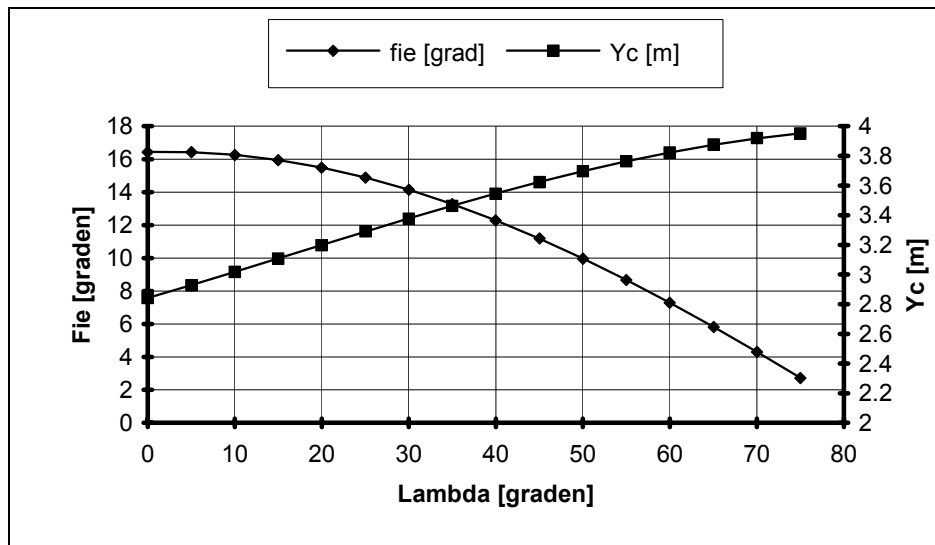


Figure 7- 18 Rotation and vertical movement of the grab and rod

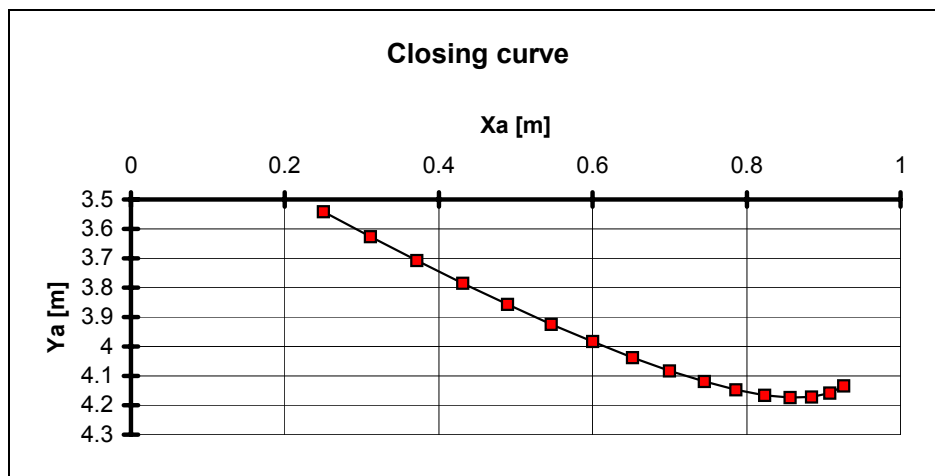


Figure 7- 19 Closing curve

Such a curve is fully dependent of the dimensions of the rods and the grab. For a good working of the grab the underside of the grab, the line AE, may not cross the path of the closing curve. In the below figure also the path of the point E is shown, while in the movement of the grab is shown when closed, half closed and open. Also the closing curve is drawn.

Typical for cable grabs is that, when they are hanging in the hoist cable, the cutting edge first moves downwards, followed by the upward movement caused by of the movement of the lower sheave block

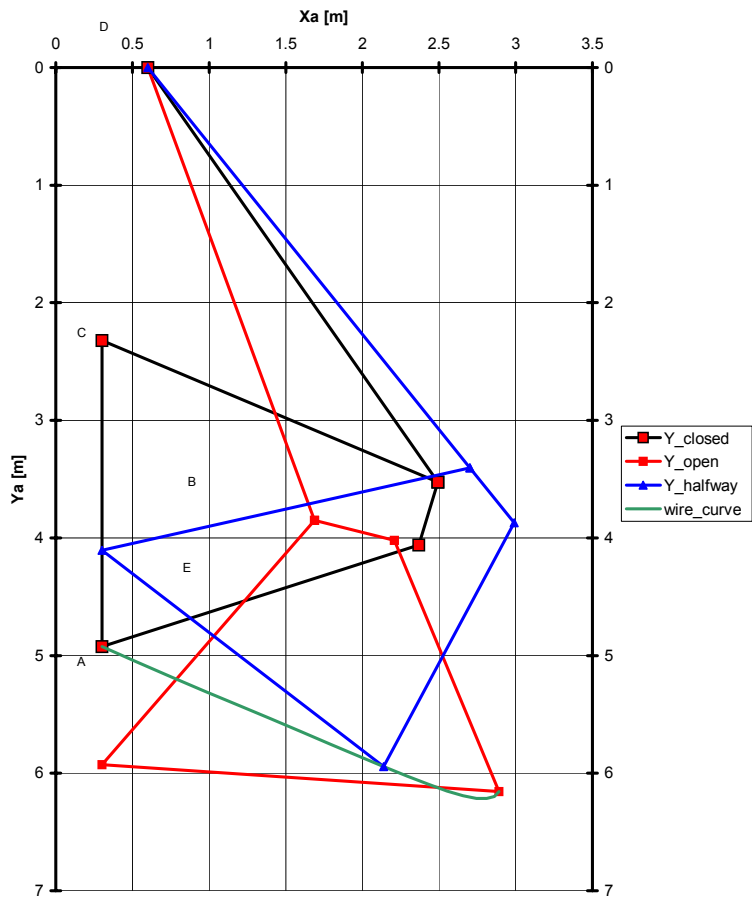


Figure 7- 20

comment: wire curve is closing curve

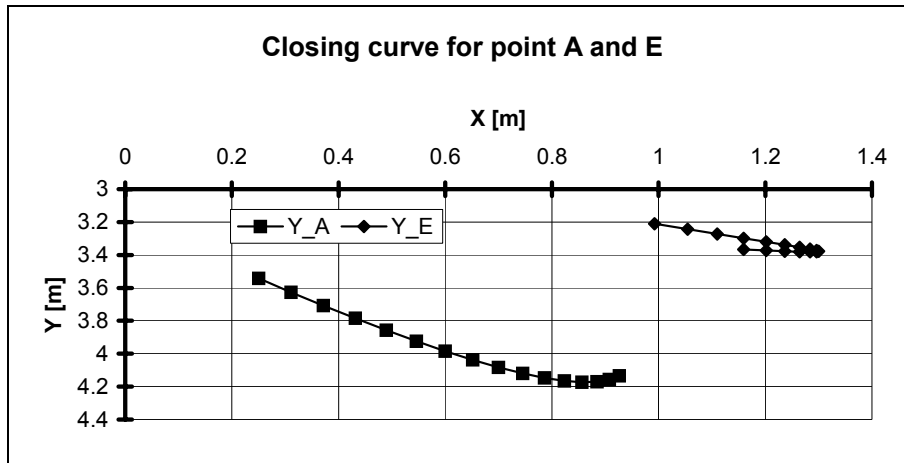


Figure 7- 21 Closing curve for the points A and E

For grabs where the rods are replaced with hydraulic cylinders the closing curve is like the one in the below picture.(Figure 7- 22)

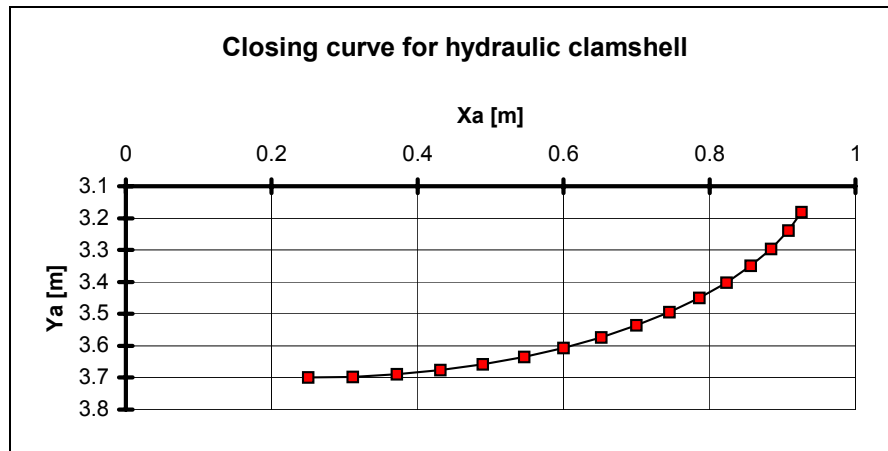


Figure 7- 22

The cutting edge of the grab continues a downward motion when the grab hangs in the hoist cable.

The closing curve is very important when dredging contaminated soils. Storage of these soils is very expensive, so digging uncontaminated soils have to be avoided as much as possible. There for grab dredgers dredging these soil types use horizontal closing grabs as shown in

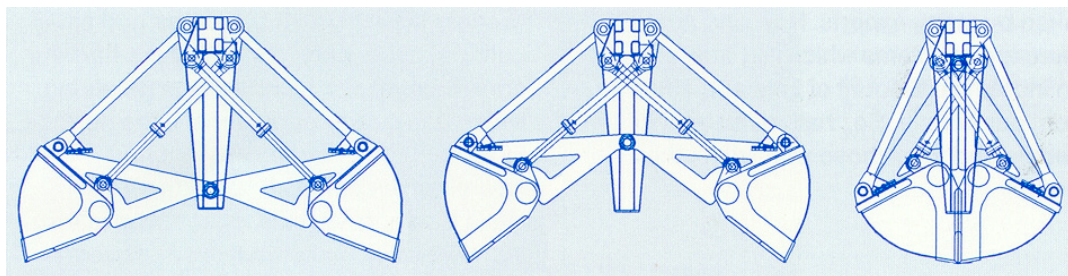


Figure 7- 23 Horizontal closing hydraulic grab (Boskalis)

For production purposes the determination of the closing curve is insufficient. For this the excavating of digging curve is necessary. This is determined by calculating the forces on the grab jaws and the disc blocks at every moment of the closing process.

Therefore the following forces have to be known, both in magnitude and size.

- the weight of the grab parts
- the cutting forces of the material to be dredged
- the forces needed to transport the soil backwards in the grab-shells
- the inertia forces of the grab shells

ad 1.

The determination of the weights and the inertia forces of the different grab parts will not give many problems.

ad 2.

For the determination of the cutting forces the linear cutting theories can be used, with the remark that the cutting angles change during the closing. By dividing the excavating process in a large number of discrete steps these theories can be used well.

ad 3.

This problem is the most difficult one. As long as the soil is shoved backwards in the grab shell, the forces can be calculated with the passive soil theory, dependent on the way the shear planes run. If however, except for backwards, the soil is also pushed above than this happens from two sides. As far as is known there has not been any research of the than acting deformations and therefore there has not been developed (yet) a theory. For the calculation of the excavation curve can be referred to the earlier mentioned article of Steven Becker that is realized in cooperation with the section dredging technology.

The calculation of the excavation curve is as follows:

Due to the weight and the drop speed the grab will penetrate initially into the soil.

To calculate this penetration the empirical formula of Gebhart can be used:

$$F_c = 0.14 \cdot e^{0.0019d_m} \cdot K_f \cdot 1.26^{(\rho_s-1)} + 0.21 \cdot 10^{-3} e^{(0.0175d_m)} \cdot (B-900) + 1.21 \cdot 10^{-3} \cdot e^{(0.0145d_m)} \cdot (h-300)$$

in which:

| | | |
|----------|---|--|
| d_m | = | average grain diameter |
| K_f | = | the grain shape factor |
| B | = | the width of the grab mouth |
| h | = | the initial penetration |
| ρ_s | = | the situ density of material to be dredged |

calculate the position, velocity, and acceleration of the grab.

determine the shear planes.

determine the passive earth pressures.

determine the horizontal and the vertical cutting forces.

calculate the acceleration of the grab from the equilibrium of the forces.

The remaining part of the dredging process like hoisting, opening and easing are totally determined by the winch characteristics and the swing velocity of the crane.

7.7. The production capacity

7.7.1. Influence of hoisting power

The production capacity of a grab dredge crane depends strongly on the size and the weight of the grab as shown in the previous section.

When however, it is assumed that the weight of the grab is not decisive during the closing process, than the specific energy concept can be used for the calculation of the required closing energy.

When the grab volume is equal to V_g , with an average efficiency of w , the closing time is T_c , the average fill rate of the grab is F and the specific energy of the soil equals SPE , than the required closing power equals:

$$P_c = \frac{V_g \cdot SPE}{F \cdot w \cdot T_c} = F_c \cdot v_c$$

With F_c and v_c the closing force and the closing speed of the closing wire.

The closing force F_c should be smaller than the closing force that can be delivered by the closing winch.

7.7.2. Influence of the soil type

The to be dredged soil type determines for a required production capacity, the required excavation energy and therefore grab weight in relation to the grab volume, the necessary closing force and the hoist force. As mentioned before the application area of grab dredge cranes lies mainly in the non-cohesive soils and soft clays. Nevertheless boulder clay is sometimes also dredged, although with low productions.

7.7.3. The dredging depth

The maximal dredge depth

For a certain production capacity the grab volume has to increase with increasing depth, since the total cycle time increases. If this is not the case the production will decrease hyperbolically.

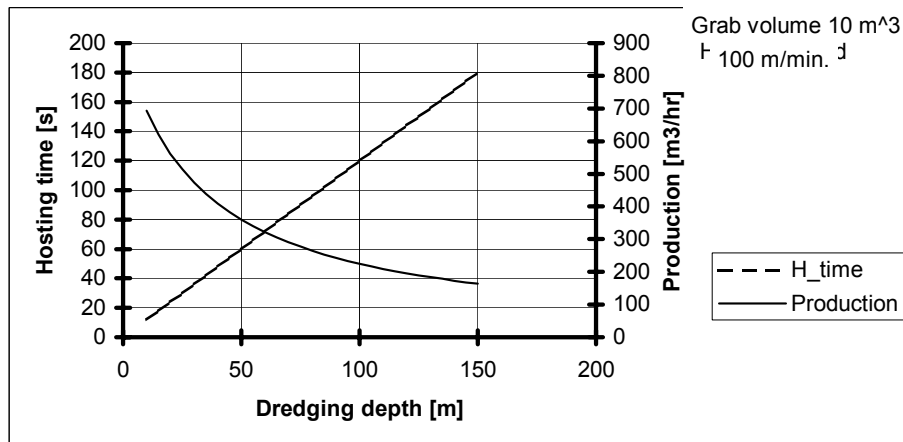


Figure 7- 24 Influence of dredging depth on hoisting time

Figure 7- 24 is an example of the production decrease as a result of increasing dredging depth of a 10 m^3 grab with a hoist velocity of 100 m/min and a non-hoist time of 40 seconds .

The maximum dredge depth also determines of course the size of the winch drums for the hoist and closing cables of the grab.

The minimal dredge depth

The minimal dredge depth is determined by the required draught of the pontoon and the related keel clearance. However it could well be that the minimal dredging depth is not determined by the pontoon, but by the barges that transport the dredged material.

7.7.4. The discharge of the material

The dredged material is usually transported with barges. But as already mentioned in the general considerations there are dredge cranes placed on self-propelled hoppers, so the material is transported by the dredger.

For grab dredge cranes that are used for the winning of sand and gravel, the discharge of the material to the separator installation is done with conveyor belts.