DRAGHEADS

CONTENTS

1. INTRODUCTION

A good combination of draghead and soil type can contribute significantly to improve the dredging capacity. But the question is; what is a good combination? In the following, an effort is made to give the most suitable draghead for a particular type of soil.

2. TYPES OF SOIL

Based on grain size and mechanical properties the soil types that can be dredged with a draghead can be divided in three groups:

1. The group of coherent transformable soil types with a grain size of less then 16 μm, for instance clay and loam.
   The extent of the difficulty for the dredging process is determined by the cohesion of the soil. Without a special aid for the draghead, this type of soil can not be dredged efficiently.
2. A mixed type of soil, with a grain size between 16 μm and 63 μm, for instance silt.
   It is in fact the transitional area between soils with coherent properties and soils where the grain structure becomes of importance. These soils are lightly pliable but when water is added they disintegrate. For the suction process the density, initial shear stress and viscosity are important.
3. The group of incoherent materials, with a grain size between 63 μm and 64 mm. For instance sand and gravel.
   The dredgeability of these soils is determined by the permeability of the soil packet and the grain mass of the material.

3. AVAILABLE PRESSURE

The amount of energy one has available to loosen the soil, bringing it into the suction pipe and transporting it upwards, is determined by:

p_z , the absolute pressure at the entrance of the impeller.
For most dredgepumps, the minimum value of the absolute suction pressure $p_{z,min}$ lies between 15 and 25 kPa, depending on pump design and speed, the mixture velocity and the solids concentration[1)].
Below this limit, cavitation will set in.

p_{arm} , the atmospheric pressure.

p_{stw} , the static pressure generated by the surrounding water.

If we for instance assume a dredging depth z of 17 m, a barometer reading of 1000 mbar and a minimum value of 20 kPa [1)] for the absolute pressure at the entrance of the impeller, then the available pressure (=energy) amounts to, see also figure 1:

$p_{atm} + p_{stw} - p_z \approx$ 1000 mbar + 17 mwc - 20 kPa $\approx$ 100 + 170 - 20 $\approx$ 250 kPa

From figure 1 it will be clear that when pressure losses at the draghead p_{drh} are high, there will be only a small amount of pressure available for vertical transport p_{vrt}. Resulting in a lower achievable mixture density and velocity, and therefor a lower achievable production.

1) The normative vacuum p_{vac} and $p_{z,min}$ are related as follows:
$p_{vac} = p_{atm} - p_{z,min}$, resulting in
p_{vac} = 1000 mbar - 20 kPa = 80 kPa for the example.

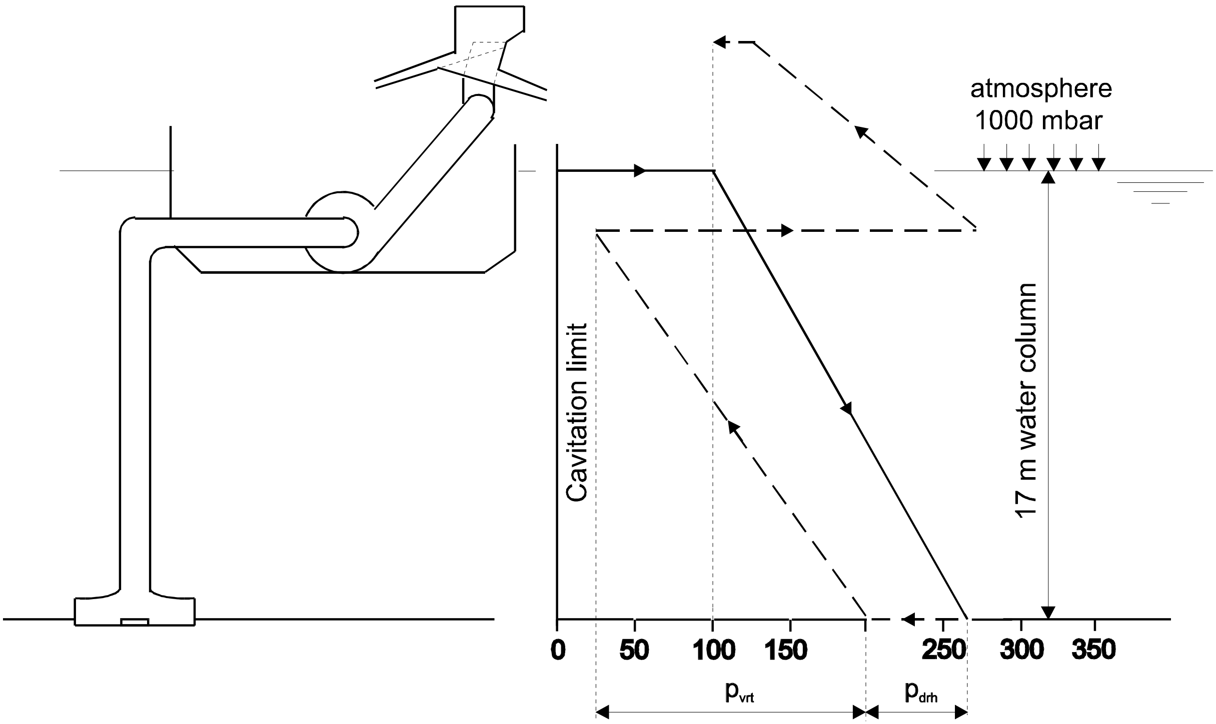

Figure 1: Available pressure.

4. THE EXCAVATING PROCESS

4.1 Excavation by erosion

If water with a high velocity is directed along a loose bottom structure, forces will be exercised on the grains on this bottom. The grains will be cut loose and taken up by the current. This phenomenon is called erosion, it is usually limited to the surface of the bottom. The depth of erosion depends on the velocity of the water along the bottom and on the bottom structure.
An increase in water velocity causes a local decrease in pressure and an increase in pressure difference over the soil packet. As a result of the pressure difference a current through the soil packet occurs. If the pressure difference is sufficient enough, the mutual cohesion between the grains wil be broken and the grains will be carried away by the water current. The erosion effect therefore extends in depth, but at the expense of higher water velocity and therefore higher pressure losses at the draghead.

In figure 2 the water velocity along the bottom of loose sand is given in relation to the grain of the soil type. This figure shows that in order to erode clay high velocities are necessary, due to cohesive forces. For silt, with a less cohesion (Yield-stress) and less grain mass lower velocities are necessary. This soil will erode fast.
For sand and gravel the grain masses are playing a role in the erosion process increasing the required water velocities. Furthermore with increasing grain diameter the water velocity also has to increase in order to prohibit settling.

The most common dragheads, which work according the erosion principle are the California

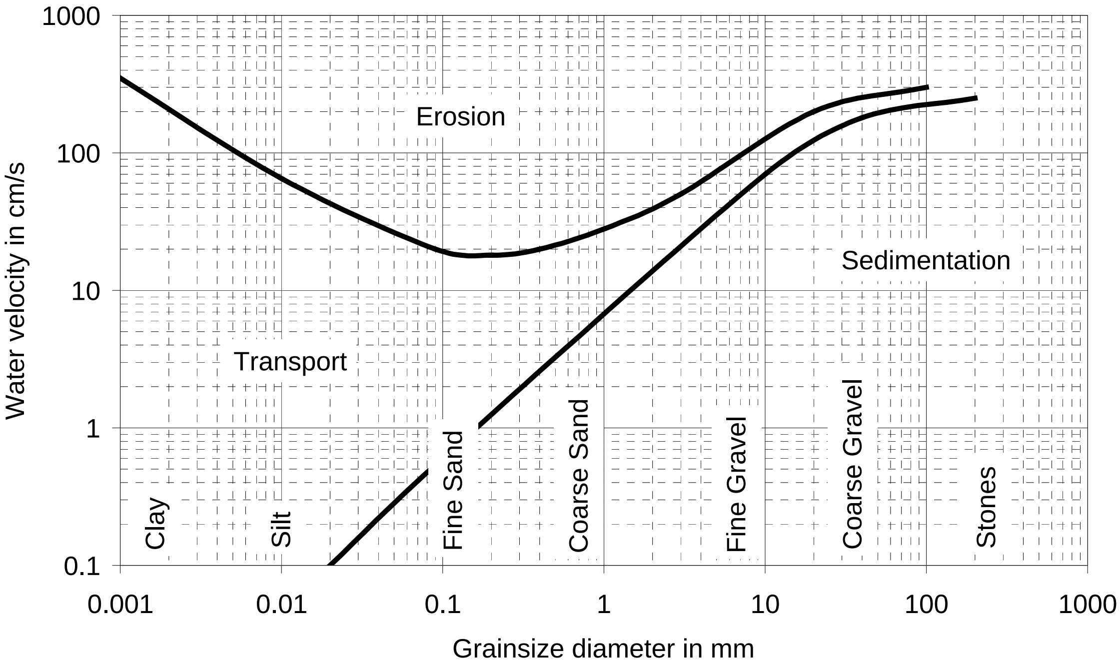

Figure 2: Relation grainsize and erosion, transport and sedimentation.

draghead and the IHC visor draghead, see figure 3.
From figure 1 and 2 it can be seen that dragheads which work on the erosion principle will not be satisfactory for clay and coarse material; the required water velocities and therefor the pressure losses at the draghead are high, resulting in a strongly reduced amount of pressure available for vertical transport and therefor a low achievable production.

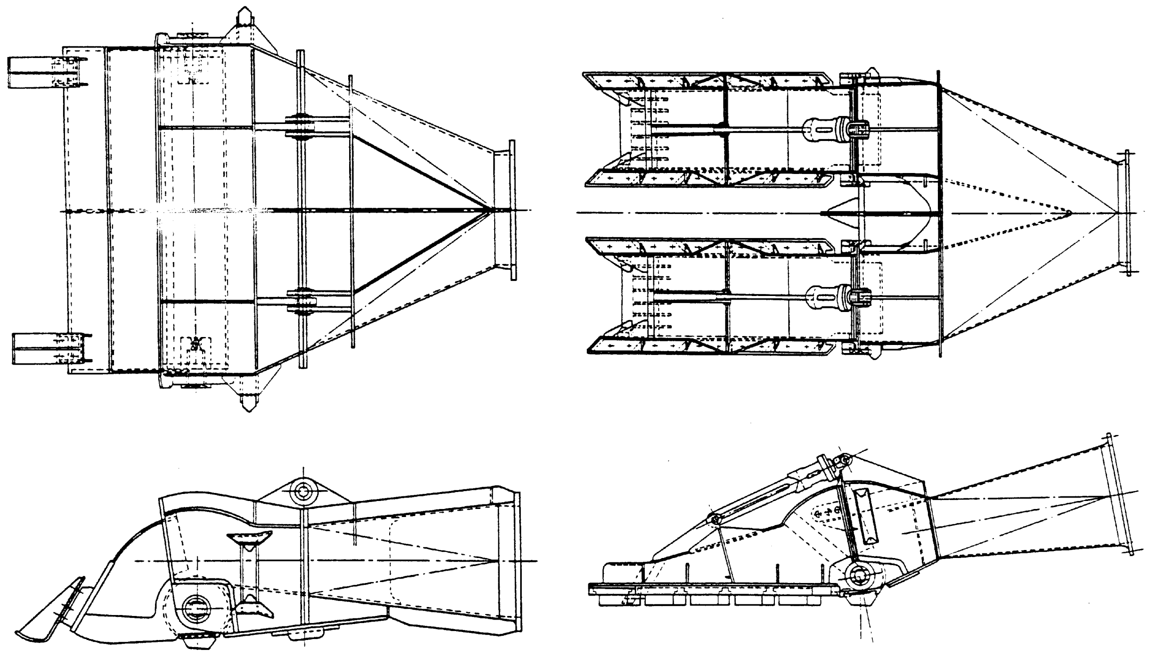

Figure 3: IHC and California draghead.

4.2 Cutting devices

The cutting device on a draghead can consist of a blade or a number knives. The IHC excavating draghead shown in figure 4 is a modified California draghead (cheese cutter type).
When pulling this draghead along clay it cuts long slices of about 15 cm in thickness. The water current behind the cutting device generated by the suction action, transports the slice.
When using this type of draghead in fine compacted sand the cutting blade loosens the sand by eliminating the appearing pore underpressure.
Thus when using this type of draghead in clay or fine compacted sand the necessary energy for loosening the soil is supplied by the propulsion of the vessel in stead of the available pressure, resulting in a larger amount of the available pressure left for the vertical transport of the soil and therefor a higher achievable production.
When dredging coarser, less compacted types of sand the usage of cutting devices (blade or knives) gives a comparatively less increase in production. In these types of soil with a higher grain mass the required water velocities, and therefor the pressure losses at the draghead, are high to prevent settling of the material.
As a result of the use of propulsion power to loosen the soil the maximum achievable sailing speed while dredging will be reduced.

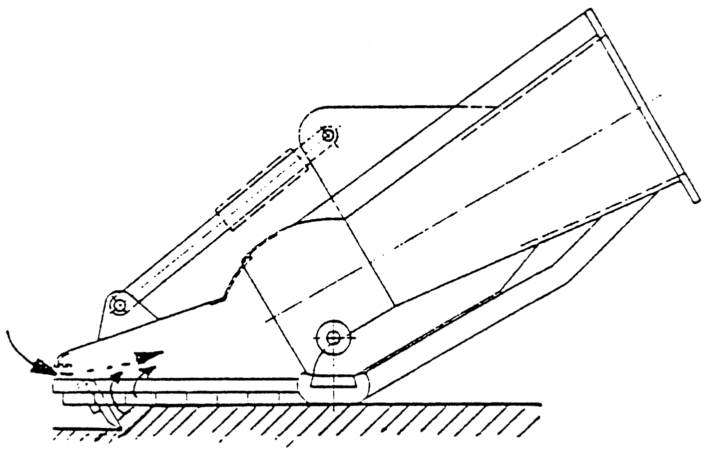

Figure 4: The IHC excavating draghead.

4.3 Water-jets

Another commonly used aid is the water-jet. For the IHC draghead, at the bottom water under high pressure is provided through openings in the sliding surface, figure 5.
The water-jets bring about a fluidisation of the bottom, which especially in compacted fine sands causes the pore underpressures to be eliminated, and the grains to be split up and therefore enabling an easier erosion process: The energy for loosening the sand is provided by a water-pump which contributes the pressure and the flow rate, resulting in a larger amount of the available pressure left for the vertical transport of the soil and therefor a higher achievable production.
When dredging clay however the effect of the water-jets does not go any further then making furrows in the plastic material without increasing production.
In coarser, less compacted sand-types the production increase is comparatively less due to the fact that the higher grain mass require higher water velocities, resulting in higher pressure losses at the draghead.
A disadvantage of the water-jets is the complicated situation to guide the watertube along the trunnion slide and the cardan.

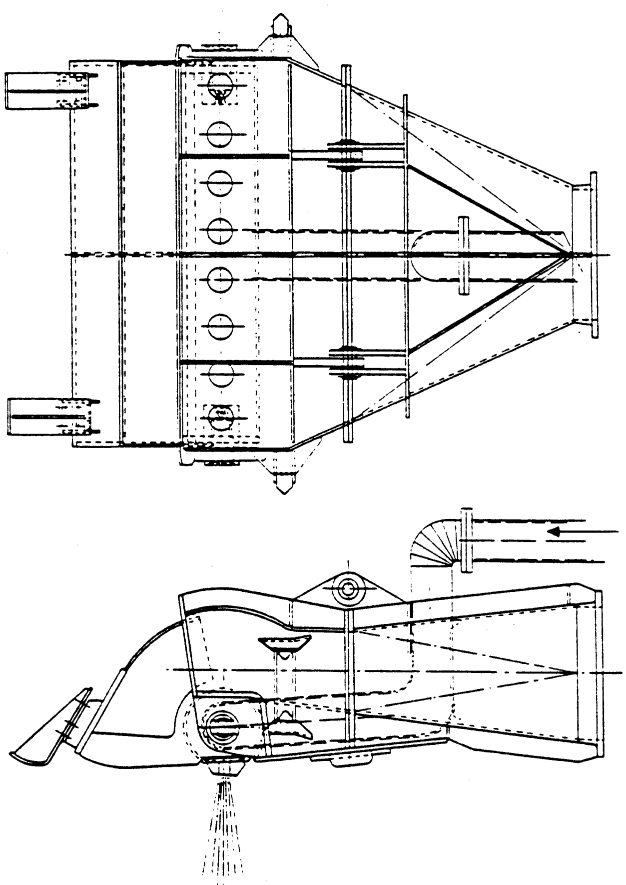

Figure 5: Draghead equipped with water-jets.

4.4 A combination of cutting devices and water-jets

As the dredging industry generally works in a wide variety of soil types, the draghead has to be suitable for both sands and plastic soiltypes. Therefor the dragheads used by the dredging industry nowadays are equipped with both cutting devices and waterjets.
This combination has all the characteristics as described in 4.2 and 4.3 except when dredging fine compacted sand: In this type of soil the water-jets bring about a fluidisation of the bottom after which the cutting device acts like a spoiler which guides the material into the draghead. Therefor only a minimal amount of propulsion power will be used for loosening this type of soil, resulting in a negligable reduction in maximum sailing speed when dredging.

5. OPTIMISATION OF THE TRAILING SPEED

In section 4 was explained how we can improve production by making use of water-jets or teeth, equipment which reduces the amount of available pressure used for loosening the soil. Another method to improve the production is the optimisation of the trailing speed.
As the time which the draghead passes on the bottom section increases with a decrease of the ship's speed, a deeply excavated section is obtained. However, the solids concentration consequently drops because the supply of new soil to be dredged decreases. On the other hand, in the event the ship's speed is too great, the soil cannot be excavated op to the expected depth and at the same time the draghead will from time to time loose contact with the seabed; therefor the solids concentration decreases.
These effects result in the existence of an optimum ship's speed for a given combination of type of draghead and soil type, figure 6.

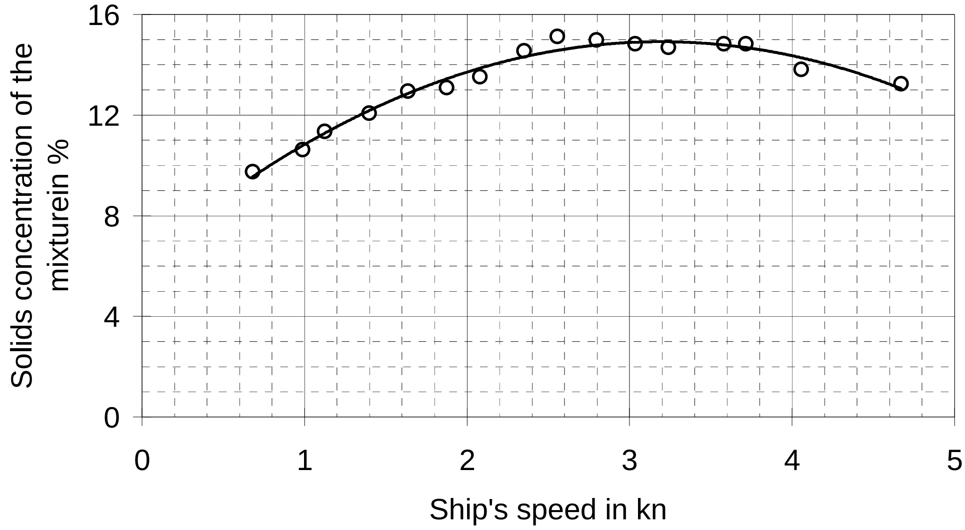

Figure 6: Relationship between ship's speed and concentration.

6. ALTERNATIVE DRAGHEAD DESIGNS

Especially in areas were there has been extracted gravel for some time, there will be a top layer present of poor quality due to the screening of the material.
If one is able to extract a thicker layer or extract the better quality underlying layer without having to extract and dumping the top layer, one would save a lot of energy and reduce the cycle time significantly due to the better quality material extracted.
Extraction of a thicker layer can be achieved by reducing the trailing speed when using traditional types of dragheads which has disadvantages as discussed in section 5, or by using an alternative design draghead as discussed in section 6.1 to 6.3.

6.1 Selective extraction by using a plough

By fitting a plough on the draghead as shown in figure 7, one should be able to extract a better quality material from under the top layer.
Points of consideration when applying this system is an increase in required propulsion power and an increase in tensile forces occurring in the suction pipes.

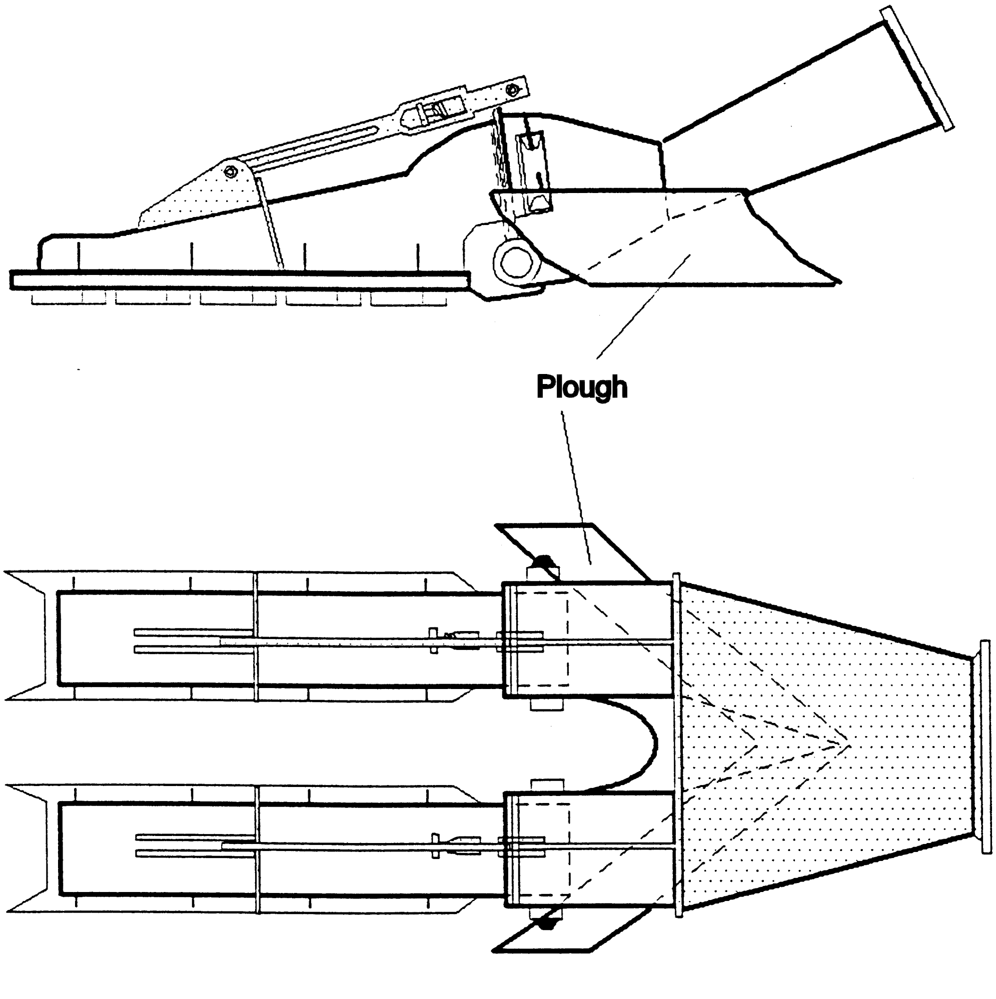

Figure 7: Selective extraction by using a plough.

6.2 Selective extraction by using water-jets

As with fitting a plough one should be able to extract a better quality material from under the top layer by fitting water-jets on the draghead which erode the top layer in front of the draghead, figure 8.

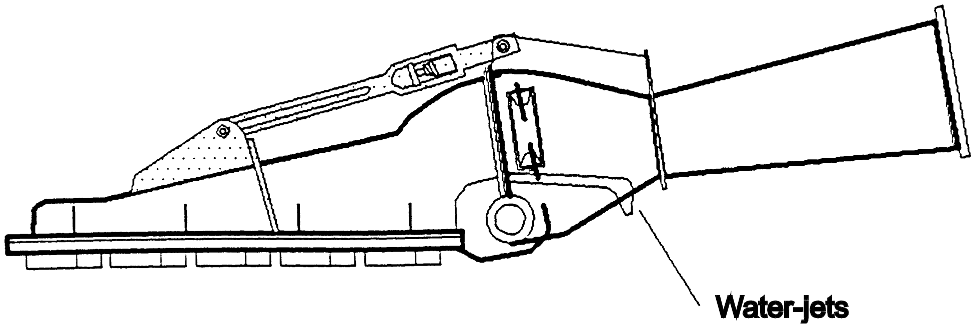

Figure 8: Selective extraction by using water-jets.

6.3 Extracting a thicker layer

The draghead shown in figure 9 uses a deep penetration jet-system (DPJS) which fluidises a significantly thicker layer then a traditional jet-system does. This draghead is therefor able to cut or erode a better quality material resulting in a reduction of the cycle time.

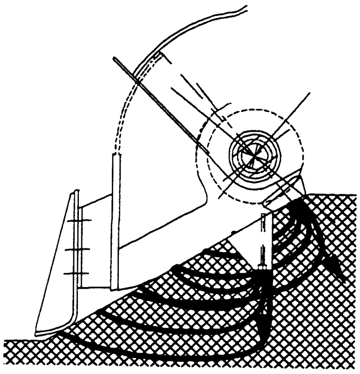

Figure 9: Draghead equipped with a deep penetration jet-system (DPJS).