

Stefaan Vandycke

Dredging Stiff to Very Stiff Clay in the Wielingen Using the DRACULA® System on a Hopper Dredger

Abstract

Dredging stiff to very stiff clay with a hopper dredger has always given a number of operational problems resulting in reduced or limited production. Thus when the dredging of clay was required, mechanical and stationary dredgers such as a cutter, clamshell or bucket dredger were used. However, when the dredging area is an extremely busy waterway and when the dredging area is exposed to rough sea conditions, an alternative had to be considered.

The patented DRACULA® system (DRedging And Cutting Using Liquid Action), which integrates high-pressure waterjets in the draghead of a conventional hopper dredger, offers a solution. This article describes the use of the DRACULA® system and the experiences during the deepening of the Wielingen where Bartoen clay was dredged.

The author wishes to acknowledge the support of Franky Warnier, Principal Engineer, Flemish Government, Department Coastal Waterways, Belgium and Elie Raes, Works Manager, Baggerwerken Decloedt N.V., Oostende, Belgium, with this study. This paper first appeared in the Proceedings of the 30th PIANC-AIPCN Congress held in Sydney, Australia and is reprinted here in a slightly adapted version with permission.

Introduction

Dredging stiff to very stiff clay with a hopper dredger has always given a number of operational problems resulting in reduced or limited production. Thus when the dredging of clay was required, operational people always used mechanical and stationary dredgers such as a cutter dredger, clamshell or bucket dredger. However, when the dredging area is one of Europe's

busiest waterways like the Wielingen and when the dredging area is exposed to rough sea conditions, an alternative has to be studied. When a stationary dredger is used, the operational time would be reduced by interruptions in order to clear the dredge area for passing ships. Owing to the exposed nature of the dredge area a seagoing dredger would be necessary and even then the operational time would be limited because of the number of stops owing to bad weather and rough seas.

The patented DRACULA® system (DRedging And Cutting Using Liquid Action) offers a solution. The DRACULA® system integrates high-pressure waterjets in the draghead of a conventional hopper dredger. As a result of the waterjets a number of classic problems when dredging clay are overcome. The clogging of the draghead was reduced, almost eliminated. The penetration of the draghead was no problem and there were no propulsion limitations for the hopper dredger, thus a normal trailing speed could be maintained. The overall pipe production during dredging was also increased.

This paper will describe the use of the DRACULA® system and the experiences during the deepening of the Wielingen where "Bartoen clay" was dredged.

THE CONTRACT

The contract consisted of deepening and maintaining the access channel to the port of Antwerp with about 1.5 to 2 metres up to an average depth of H -15.4 metres over a width of 500 metres. This job had to be done as part of the 48-feet programme in the Dutch part of Wielingen. The 48-feet programme will allow ships with a draft of 48 feet to reach the port of Antwerp within one tide. This will give the shipping movements to Antwerp more flexibility and make all ship movements less tide-dependent.

The client was the Flemish Government, represented by: Ministry of the Flemish Community, Department Environment and Infrastructure, Administration Waterways and Seas, Section Coastal Waterways.

This part of the Wielingen channel is known as "GEULVAK 13" situated between Eastings 526.655 (3° 23') and 533.600 (3° 29').

The dredging tolerances were limited to 30 cm in minus or in plus. This means that the maximum dredging depth is H –15.7 metres. If this depth is exceeded the client can demand a refill of the area to the maximum dredging depth. The minimum dredging depth is H –15.1 metres.

Over the total distance of approximately 7 km there was one area of about 1.5 km with stiff "Bartoen clay". In the rest of the channel there were areas with a mixture of sandy material, silt and soft clay.

The estimated volumes to be dredged during the tender phase are shown in Table I.

Table I. Estimated volumes to be dredged during the tender phase.

Soil type	Total volume in situ (m ³)
Quaternary (holocene) sand	1,100,000
Quaternary (holocene) sand en clay	20,000
Quaternary (holocene) clay	20,000
Tertiary sand	20,000
Tertiary clay (Bartoen clay)	990,000
Total	2,150,000

There were several disposal areas available. The disposal location is dependent on the type of soil (see Table II).

Table II. Location of disposal area by type of soil.

Soil type	Disposal area
Sand	Coast of Vlissingen
Sand	Coast of Zeeuws Vlaanderen
Holocene Clay	Belgian disposal area S3 or R4
Bartoen Clay	Schone Waardin (Vlissingen)
Holocene Silty Sand	Belgian disposal area S3 or R4

For the realisation of the capital dredging hopper dredgers were chosen. The main problems to be expected were the tolerances to be realised and the dredging of the very stiff Bartoer clay. For the dredging of the Bartoer clay one hopper dredger was equipped with a DRACULA® draghead.

The choice of hopper dredgers was based on two factors:

- The dredging area is very exposed to rough sea conditions. Working with a stationary dredger would mean a great deal of down time, because of bad weather conditions even when a sea-going cutter dredger would be used. The nearest ports for shelter are Zeebrugge and Vlissingen which are both at some distance from the dredging area.
- Owing to the shipping traffic, a stationary dredger and floating pipelines would obstruct passing ships. There would be a great amount of down time as a result of having to clear the dredging area for passing ships.

The complete dredging area was split up into different dredging areas depending on the type of soil in the area. This would allow optimal the use of the different hopper dredgers in combination with the disposal areas and the type of soil:

Sand area I:	from E526.655 to E528.085
Sand area III:	from E528.085 to E529.500
Clay area:	from E529.500 to E531.000
Sand area II:	from E531.000 to E533.600

To execute the job two types of hopper dredgers were used:

- Hopper dredger type 8500 m³ (*Antigoon*) in areas with mixed sandy soil.
- Hopper dredger type 3500 m³ (*Jade River* + DRACULA® draghead) in areas with mainly (tertiary) clay.

SOIL CHARACTERISTICS

The soil data are based on a soil investigation campaign executed by the Dutch Government (Rijkswaterstaat) in 1985. Based on this investigation three sub-bottom profiles were made along the dredging area.

Holocene

The Holocene clay varies in thickness from 20 cm on the south side of the channel to 1 metre on the north side. Towards the east side the clay layer is covered with approximately 1 metre of sand.

Tertiary

The tertiary clay is located on the east side of the dredging area and covers the full depth of the dredging area. Some layers of sand are present between the clay layers. This clay is the most critical soil to dredge in the Wielingen. Some numbers below show the characteristics of the clay:

In situ density γ_{situ} :	2 T/m ³
C_{pt} :	2 Mpa
Liquid Limit LL:	55%
Plasticity Limit PL:	22%
Plasticity Index PI:	33%

These numbers indicate that the Tertiary Bartoen clay is very stiff and will form clayballs when pumped.

THE DRAGHEAD

For this purpose DEME has integrated high pressure waterjets on the draghead and patented the system. The system was named DRACULA® which stand for DRedging And Cutting Using Liquid Action. The purpose of these jets is on the one hand to reduce the resistance that the draghead has to penetrate into the hard soil, and on the other hand to prevent the draghead from getting clogged with clay during dredging. These two facts will be described in more detail below.

High pressure waterjets are now very commonly used in a large number of industries. The pressures that are used can reach as much as 3000 bar with a standard high pressure pump. Waterjets are used for stripping paint, cutting concrete, cutting steel plates, and so the thought arose, why not use them to cut the soil during a dredging process?

A study and some tests with scale models indicated that for cutting clay in submerged conditions a pressure of 300 to 350 bar was needed. This was only true for conditions not deeper than 30 metres. So for the DRACULA® draghead pressures of 380 bar were used. This should be sufficient to cut even the hardest clay at a trailing speed of 2 to 2.5 knots.

Reducing the cutting forces

When dredging hard soils the only force that makes the points of the draghead penetrate into the soil is the weight of the draghead and of the suction pipe. When this is not sufficient, the draghead will not penetrate and will drag on top of the surface without cutting any soil. This will result in a very low mixture density and in a low production of the hopper dredger.

To assure a maximum efficiency of the waterjet the nozzle had to be integrated into the points of the draghead. This way the waterjet will cut the soil only moments before the point penetrates the soil. As a result the forces needed to penetrate the soil are reduced, and the cutting efficiency is increased.

The drawing in Figure 1 gives a cross-section of the visor of the DRACULA® draghead and shows how the nozzle is integrated inside the dredgepoint. For this purpose a special hollow dredgepoint has been developed (Figure 2). The point has a channel inside, through which the high pressure line is mounted.

Preventing clogging

When dredging clay the draghead will easily be clogged with clayballs that get stuck inside the draghead

IADC Award 2002



Stefaan Vandycke

Presented at the 30th PIANC-AIPCN Congress, Sydney, Australia September 22-26 2002

At the 30th PIANC-AIPCN Congress, held this past September in Sydney, Australia, Stefaan Vandycke was presented with an IADC Award for young authors. This was the second time that Mr. Vandycke as been so honored. Mr Vandycke graduated from the University of Louvain, Belgium in 1988 as an Engineer in Electro Mechanics. He joined Pauwels Industrial in Evergem in 1990. From 1992 to 1993 he worked at De Cloedt, Oostende and in 1993 joined Dredging International (DI). At DI he served in a number of positions as superintendents of projects in Hong Kong and Germany, and is now head of the department for special projects and new applications.

Each year, at selected conferences, the International Association of Dredging Companies grants awards for the best papers written by authors younger than 35 years of age. At each of these conferences, the Paper Committee is asked to recommend a prize-winner whose paper makes a significant contribution to the literature on dredging and related fields. The purpose of the IADC Award programme is "to stimulate the promotion of new ideas and encourage younger men and women in the dredging industry". The winner of an IADC Award receives US\$1000 and a certificate of recognition, and the paper is then published in *Terra et Aqua*.

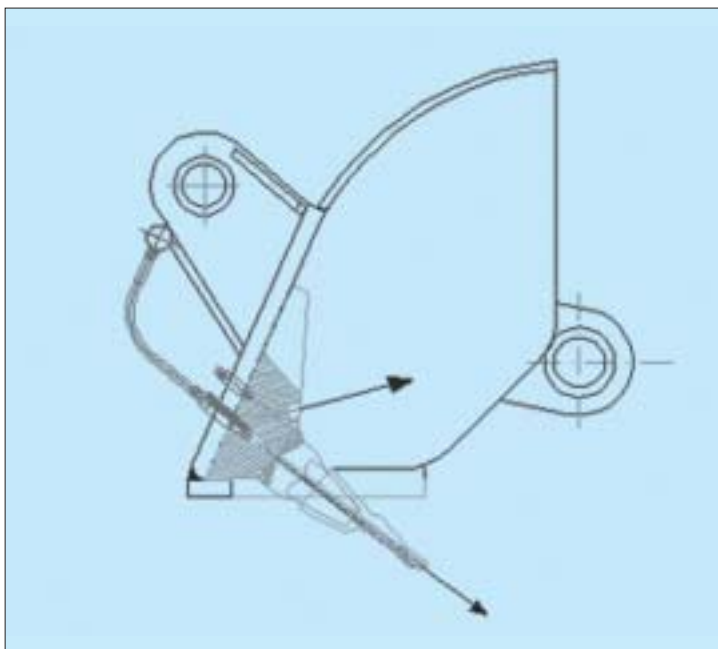
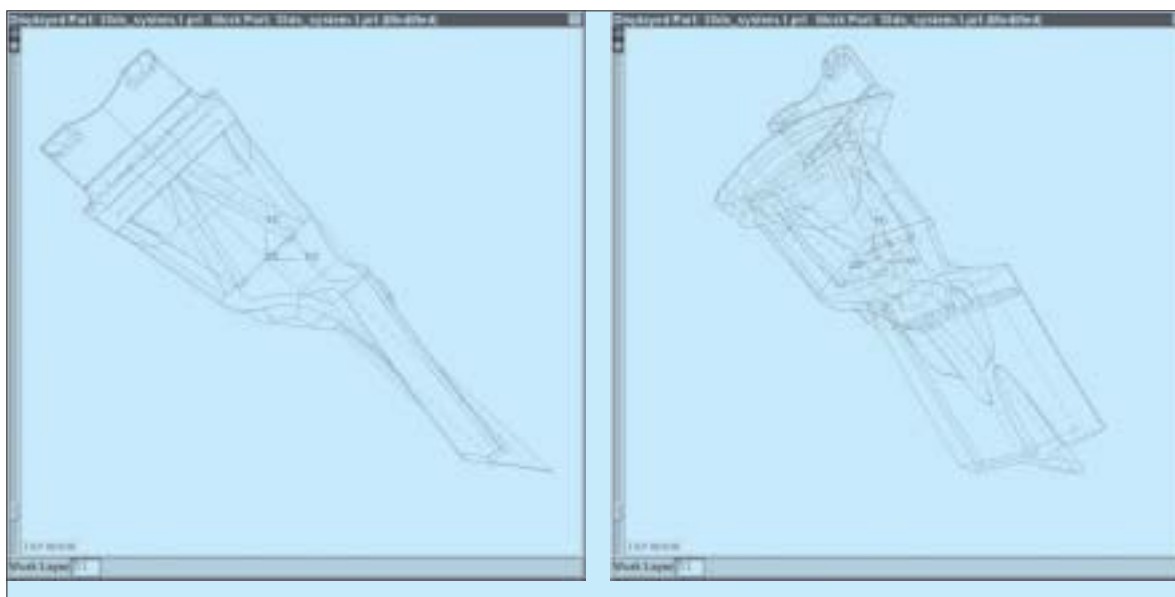


Figure 1. Cross-section of the DRACULA® draghead with jets through the point.

construction. This is especially the case with softer and more sticky clay. To prevent this, the clay should be prevented from forming clayballs and should be cut in to as small as possible pieces. Therefore high pressure jets were also placed just above the points inside of the draghead.

The large lump of clay that is formed by the point is immediately cut in to small pieces by the waterjet just above. The direction of the jet is towards the suction mouth so that the clay particles are directed towards the suction mouth, thus preventing the draghead from clogging (Figure 3).

Figure 2. Transparent view of the hollow dredgepoint used on the draghead.



Pre-cutting (ripping)

A third application of the waterjets on the draghead is to use the waterjets as a kind of hydraulic ripper. The waterjets are placed next to the existing low pressure waterjets on the heel of the draghead. They are directed vertically in to the soil. This gives a similar effect as a ripper: the soil is cut by the waterjet and will create cuts into the clay surface. The results are that both the cutting forces of the points are reduced because the soil is already cut and because the clay is cut in to smaller pieces, thus the waterjets reduce the risk of clogging.

HIGH PRESSURE PUMPS

To utilise this system, high pressure pumps were installed on board the hopper dredger. A flexible system, which could be used on different hopper dredgers, was chosen. The pumps are mounted in a 20' container and can operate as a stand-alone unit. Each pump is driven by a CAT 3412 DITA diesel engine of 558 kW. The pumps have the following capacity: 759 l/min @ 380 bar.

The pumps which were used are piston pumps so the water has to be pumped to the high pressure pump using an inboard centrifugal pump which feeds the water at a pressure of ca. 8 bar. The water is then filtered to 75 μ before it enters the high pressure pump. The nozzles used were between 1.7 mm and 3.3 mm. As the total flow is limited the nozzle diameter depends upon the number of nozzles and upon the number of pumps. As a rule it can be said that one pump can feed ca. 20 nozzles of 2.0 mm. For the Wielingen, on the TSHD *Jade River*, two pumps were used in parallel operation (see Figures 4 and 5).

At these operational conditions the water under 380 bar is leaving the nozzle at a speed which can reach 250 to 300 m/s. This creates a hydraulic cutting power sufficient to cut the stiff clay layers in the soil. The pumps are placed on deck and the high pressure water is fed to the draghead by flexible lines on the suction pipe. As the flow is limited, the flexible lines have a small diameter and are easy to manipulate.

RESULTS

During the dredging of the Wielingen an intensive monitoring programme was set up to determine the effectiveness of the DRACULA® draghead.

The following parameters were monitored:

- the influence of the jets on the pipe production;
- the influence of the jets on the cycle production;
- the influence of the jets on the propulsion power; and
- the influence of the jetting location.

The pipe production

Depending on the jetting location, the pipe production of the *Jade River* increased between 15% and 27%.

The cycle production

An exact figure is hard to determine but it was clear that when the system was not operational, the draghead tended to clog quite quickly. This meant that the dredging operation had to be stopped to clear the draghead. When the jets were on, no clogging of the draghead was observed. The DRACULA® system reduced the down time considerable.

Propulsion power

The *TSHD Jade River* has a great deal of propulsion power (2 x 1730 kW), independent from the dredge

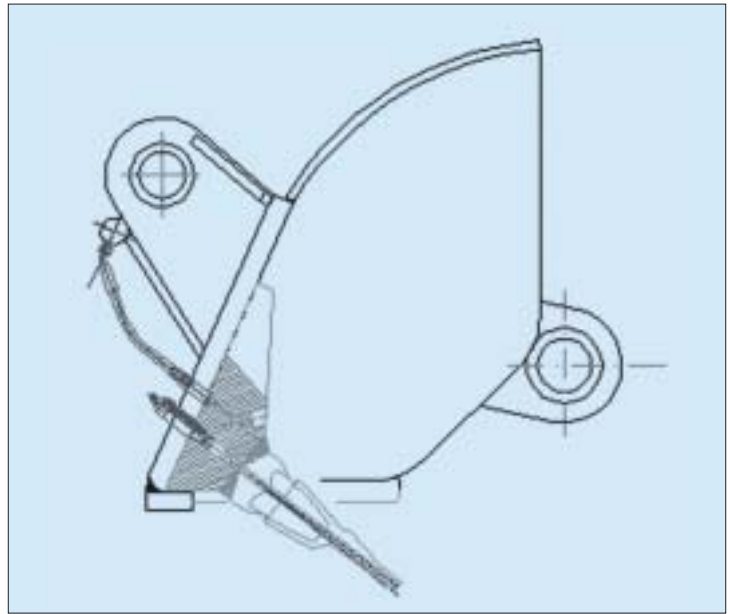


Figure 3. Cross-section of the DRACULA® draghead with jets inside the visor.

pumps. During the project there was never a problem with the propulsion: a trailing speed of 2 to 3 knots was always possible. However, the fuel rack on the propulsion engines was logged and from these data it was concluded that when the system was active, the average fuel rack was 5% less compared to dredging without DRACULA®.

The jetting location

As propulsion was no problem for the *Jade River*, the jets through the points were not really effective. It was observed that the most important increase in pipe production (27%) occurred when the jets in the visor together with the jets on the heel were active.

Figure 4. Photo of the DRACULA® draghead on the TSHD *Jade River*.





Figure 5. TSHD Jade River with the high pressure pumps.

Accuracy

As the dredging tolerances were only ± 30 cm, which is very little for a job with a hopper dredger, there was a risk that in the hard clay areas some tracks would be formed by the draghead. This would have resulted in local overdepths. As a result of the DRACULA[®] system and an adapted working method this was not the case. Figure 6 shows the final survey of the dredging area.

Conclusions

During the project to deepen the Wielingen, based on previous experiences in Liepaja (Latvia), DEMA used for the first time on such a big scale the new patented DRACULA[®] system on a hopper dredger. The results when dredging the very stiff clay were very successful and after solving some technical problems the system proved to be operational on a hopper dredger.

Further tests will be executed for dredging harder soils such as cemented sand using a hopper dredger as an alternative for a stationary dredger like a cutter dredger or bucket dredger.

The results from the Wielingen project proved that for dredging stiff to very stiff clay a hopper dredger is now a possible alternative instead of a stationary dredger. The typical problems that occur when dredging clay with a hopper dredger are largely solved by the DRACULA[®] system.

The deepening of the Wielingen was executed in nine weeks in total using the hopper dredgers *Antigoon* and *Jade River*. During the tender phase the total duration of the job was estimated at 19 weeks using the same hopper dredgers. The success of the project was largely obtained by using the DRACULA[®] system on the *Jade River* to dredge the stiff clay.

Figure 6. General view of the dredging area with the final survey data.

