Stefaan Vandycke

New Developments in Environmental Dredging: From Scoop to Sweep Dredge

Abstract

The Flemish Community is continuously looking to improve maintenance dredging works through careful selection of dredging and disposal locations and through the use of more efficient dredging equipment. Most sediment pollution consist of fine grained sediments. These sediments tend to settle in the entrance channels to sealocks, in harbour areas or other waterways with low currents. Therefore, special attention has to be paid to maintenance dredging procedures in these areas, in order to reduce both the economic and ecological impact of the removal of contaminated fine grained sediment.

To meet these environmental requirements and to achieve a cost-effective solution, a new type of dredge has been developed in co-operation with the Flemish Institute for Scientific-Technological Research Promotion in the Industry (IWT). This scoop dredge has been successfully tested in the access channel to the Kallo Lock and in the adjacent harbour area. Based on this experience and on environmental dragheads of trailing suction hopper dredges, further breakthrough in environmental dredging has been achieved. The sweep dredge combines the advantages of stationary dredges and trailers. The sweep dredge is able to work in shallow water and to remove very thin layers of polluted fine-grained sediments at high concentrations.
The principles of both dredges have been patented worldwide.

This paper will discuss:
– The criteria for dredging and removal of contaminated fine-grained sediments in an economic and ecologically acceptable way.
– The development of the scoop dredge, the results of the dredging operations and the various test and monitoring programmes.
– The development of the sweep dredge and the evaluation of its characteristics.

The author wishes to acknowledge Mr P. Standaert of Dredging International n.v., Zwijndrecht, Belgium and Mr J. Claessens, Flemish Region, Department of the Environment and Infrastructure, Maritime Scheldt Department, Antwerpen, Belgium for their contributions to this paper.

Introduction

Access channels to locks are the major areas of siltation within the Scheldt estuary and, as such, are among the key areas where maintenance dredging takes place. Until recently, this was successfully achieved with the help of sweep beams. This dredging method meets the basic objectives in that it guarantees a safe navigation depth and does so at the lowest possible cost.

The Scoop Dredge ®

Recent environmental concerns, however, have meant that the quantity of fine-grained contaminated material in the estuary should be reduced, as well as the spreading of the contaminated fraction, throughout the estuary.
A new policy for maintenance dredging is now required to meet the following conditions:
– avoid, as much as possible, the resuspension of fine-grained material once it has settled;
– remove large volumes of fine-grained material from the estuary;
– store the excavated material within restricted boundaries, preferably isolated from the surroundings to avoid leakage and diffusion of contaminants;
– limit the volume of material on the disposal site; and
– operate in an economically acceptable way.

The first alternative for the sweeping devices relies on traditional equipment, such as the cutter suction dredge and/or the trailing suction hopper dredge.
However, in respect of the new criteria (see Table I) each has both advantages and disadvantages.

With this in mind, it was decided to develop a new type of dredge combining, as much as possible, the advan-

Upon acceptance of the IADC Award, Stefaan Vandycke (left) shakes hands with Mr Peter Hamburger, IADC Secretary General. Engineer H. Smitz, Chairman of the Paper Committee of the International Harbour Congress looks on.

IADC Award 1996

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11th International Harbour Congress
Antwerp, Belgium
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At the 11th International Harbour Congress organised by the Royal Flemish Society of Engineers in Antwerp, Belgium in June 1996,
Mr Stefaan Vandycke was presented the annual IADC Award by Secretary General of the IADC Mr Peter Hamburger. Mr Vandycke graduated from the University of Leuven in 1988, and has worked at Pauwels Industrial, De Cloedt, Tai Ho J.V., and is presently Superintendent Benelux at the headquarters of Dredging International n.v., Zwijndrecht, Belgium.
Each year at a selected conference the IADC grants an award to a paper written by a young author.
The Paper Committee of the conference is asked to recommend an author who must be under 35 years of age and whose paper makes a significant contribution to the literature on dredging and related fields. The purpose of the award is "to stimulate the promotion of new ideas and encourage yourger men and women in the dredging industry". The IADC Award consists of US$ 1,000, a certificate of recognition and publication in *Terra et Aqua*.

tages of both cutter and trailer types. It was decided that:
– a stationary dredge is better suited to dredge on the limited area of the access channel;
– rehandling of the material (dredging into the hopper and on-shore for reclamation) has to be avoided;
– reclamation to a well-designed disposal or treatment area has to be the basic sollution;
– rotating devices are not to be used for fear of creating turbidity;
– the silt has to enter the dredge as far as is possible, at in-situ density; and
– accurate horizontal and vertical positioning during dredging is essential.

These goals can be achieved by the combination of characteristics taken from the draghead of a trailing hopper suction dredge (low turbidity, high density and with no rotating device) and the movement and pumping characteristics of a cutter suction dredger (accurate horizontal and vertical positioning; no-rehandling and reclamation through a closed pipeline).

To implement this, the stationary dredge *Brabo* was converted into a scoop dredge. The *Brabo* has a total installed power of 6 865 hp and overall dimensions of 88 x 15 x 4 m, with a draught of 2.65 m. It is equipped with one ladder pump and two delivery pumps. All movements for dredging and walking are controlled by two walking spuds and two side anchors.

The Scoop-Head ®

A two-sided functional draghead was mounted to allow dredging in two opposing swing directions. This was achieved in practice by the use of a turning blade that scrapes the material from the water bottom into the suction head of the dredge. At the end of the swing, the blade is turned in the opposite direction, the dredge walks forward (between 1.5 and 2.5 m) and the draghead continues scraping in the opposite direction. It is because of this functional scraping that the draghead has been named the "scoop-head" (Figure 1).

The outer casing prevents dilution with water and the creation of turbidity in the surrounding water. On top of the scoop-head, an adjustable water inlet system has been installed to prevent clogging and to ensure a regular feed of silt into the scoop dredge. Since this dredge can work at depths varying from 3 to 28 m, the angle of the scoop-head to the ladder is adjustable with the help of a support frame.

The presence of gas bubbles in the dredged material provokes cavitation of the ladder pump and reduces the performance of the ladder and delivery pumps. Therefore, a specially designed degasification system was added to the basic scoop dredge which draws off

Table I. Comparison of advantages and disadvantages of CSD and TSHD.

CRITERIA	**CUTTER SUCTION DREDGE**	**TRAILING HOPPER SUCTION DREDGE**
RESUSPENSION IN DREDGING AREA	HIGH RESUSPENSION	LOW RESUSPENSION WHEN OVERFLOW IS OMITTED
EXCAVATION FROM THE ESTUARY	GOOD	GOOD
RESTRICTED STORAGE	POSSIBLE	POSSIBLE
ADDITION OF WATER FOR TRANSPORT	HIGH	LOW
COST	REASONABLE	HIGHER THAN A CUTTER

gas and some silt just before the ladder pump. This mixture is collected in a vacuum tank from where the silt is pumped back into the suction pipe. A vacuum is maintained in the vacuum tank by means of waterjets and a set of venturi nozzles.

Evaluation of the Scoop Dredge

A pilot project was set up from January to April 1993. During this time the new method was used for the maintenance of the whole access channel of the Kallo Lock on behalf of the Maritime Scheldt Department (Flemish Community).

Some 500 000 dry tons of silt had to be extracted with the scoop dredge and hydraulically transported over a distance of three to seven kilometres through a closed pipeline to the diffuser pontoon *Demer*. This disposed the silt in underwater pits in the Antwerp Waasland Harbour without disturbing the dock water.
Taking into account the fact that from the original excavation of the channel (completed in 1982) until 1990, the normal maintenance dredging works were limited to only the actual navigation channel, the characteristic of the silt to be excavated was very variable, from almost liquid mud in the navigation channel to almost firm material in the lower layers at the edges of the channel where almost 15 m of mud had accumulated. As a consequence, the dredging cuts were rather irregular.

In the centre of the area, the navigation channel had to remain open to shipping for most of the time, resulting in a great deal of idle dredge time whilst the floating pipeline was opened and closed for navigational purposes.
The pilot project was extensively monitored to:
– determine the productivity and the quantities of silt removed;
– monitor the performance of the dredging process and make suggestions for immediate and long-term improvements to equipment and methodology; and
– check the environmental performance of the overall system.

During the project, 550 000 tons of dry material were removed, representing about 1.1 m m^3 of in-situ mud, from the access channel. Productivity was 695 tons of dry material per operational hour or at an average in-situ density of 1.3 tons per cubic metre, 1 400 m^3 an hour for a pumping distance of 7 kms.

The performance of the dredging process was monitored by the continuous measurement of more than ten important parameters, such as concentration, velocity, swing speed, pulling force, pumping depth, and so on. From this monitoring programme, it was concluded that the dredging process can perform at almost the same level as a normal draghead, but that the concentration decreases during anchor relocation activities, during spud relocation, when the width of the cut is variable, and during the start up and slow down of the process.

The reduction of these idle times will be of major importance for the overall efficiency of the scoop dredge.

As far as an environmental performance is concerned, the efforts were focussed on the evaluation of the turbidity generated at the dredging site. During the monitoring programme, attention was paid both to the short and medium term (48 hours) increase in turbidity (Figure 2).

During the control measurements, the background turbidity was 22-24 mg/l at the surface, increasing to 40 mg/l at the bottom. The influence of the dredging activities could not be measured at a distance of 50 m

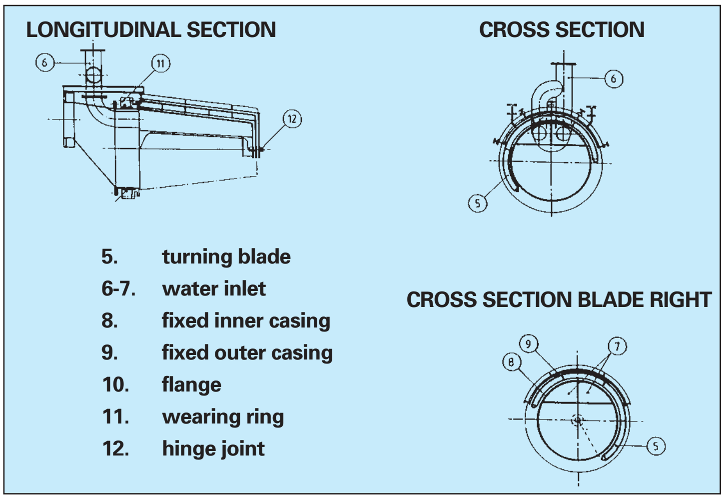

Figure 1. The scoop-head (general lay-out).

from the dredge, but in the immediate surroundings of the scoop-head (a distance of 5 to 10 m) a turbidity increase of 2 to 5 mg/l was measured representing less than 10 per cent of the background turbidity.

Prior to a second maintenance programme in spring 1994 a dredge pipeline of about 1 000 metres had been drilled under the access channel by using directional drilling technology. This pipeline crossing avoids idle time due to stops for navigation. As expected, the operating efficiency and performance improved considerably.

In this second programme another 400 000 tons of silt (800 000 m^3) were removed.

To evaluate better the environmental performance of the scoop dredge a second test location was established in the docks itself. Indeed, the daily siltation of 1.5 cm in the access channels made it impossible to evaluate the accuracy of the dredge.

These tests (April 1994) were attended to by the Dutch Hydraulics Laboratory of Delft and University of Leuven. The results were very encouraging when measured against the set criteria:
– accuracy (vertical) better than 10 cm at 15-19 m water depth;
– mean turbidity increase less than 10 mg/l near the dredge;
– spillage was between 3-7 cm;
– safety good, because no personal contact with hydraulically pumped material;
– no stops for debris.

During the next phase of silt removal in the access channel with the scoop dredge, further attention will be paid to minimise the waterflow in the 7 km long discharge pipeline to reduce the pumped volume.

Figure 2. The scoop-head has no rotating cutting devices, so turbidity and addition of transport water is minimised.

A buffer system is planned just behind the dredge. This makes it possible to slow down the suction (dredging) process without interrupting the reclaiming process.
In this way the buffer system will prevent water from having to be pumped to clean the dredge pipes before stopping the dredge process.

From Scoop to Sweep Dredge

However the scoop dredge has its limitations. Since the height of the dredge head opening is not adjustable, a great deal of water will be pumped when dredging thin layers. In addition the scoop dredge *Brabo* has a draught of 2.65 m and is thus more suited for applications in deeper water.

To improve the performance of the scoop-head for clean-up dredging, attention should be paid to:
- improving the removal of thin layers without excessive water addition during dredging;
- controlling the addition of transport water;
- reducing the minimal dredging depths;
- tuning in the dredged and pumped volumes;
- optimising the process steering (even computerising it);
- visualising and storing of all process parameters;
- implementing the latest technology developed in recent years with trailing suction hopper dredges *(Antigoon, Pearl River)* in silt to cutter suction dredges.

For the development of the new scoop dredge, now referred to as the sweep dredge, the following conditions have been set out:
- the concept of the dredge head is based on the known current characteristics of a classic trailerhead;
- the dredge head can be positioned with high accuracy, horizontally as well as vertically;
- turbidity generation is minimal;
- the dredge can work in low water depth;
- spillage is minimal;
- the thickness of the dredged layer is adjustable between 20 and 60 cm;
- a degasification system must be installed;
- addition of transport water is adjustable;
- the sweep-head is cutting mechanically avoiding (hydraulic) erosion;
- pump suction discharge is always adjustable;
- the suction (dredging) process can be separated from the reclaiming process.

Based on the above-mentioned requirements a classic stationary dredge equipped with a spud carrier and dredging by swinging has again been chosen. In this way a controllable and steerable positioning of the dredge head is possible.

Furthermore it is possible to control and steer the dredged volumes (layer thickness and swing speed).

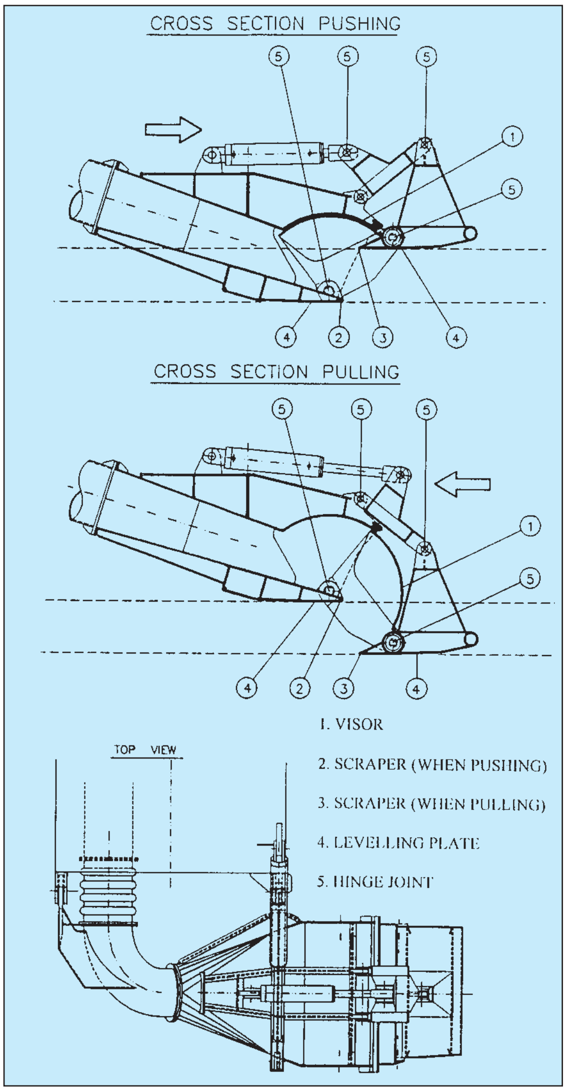

Figure 3. The sweep-head (general lay-out).

The Sweep Dredge ®

The existing cutter dredge *Vlaanderen XV* has been rebuild to become a sweep dredge. The most important change was the removal of the cutter and the installation of the sweep-head (Figure 3). Further the dredge was equipped with a purpose built silt degasification system.
The *Vlaanderen XV* has a total installed power of 2 550 kW and overall dimensions of 52 m x 11 m with a draught of 1.75 m. The maximum cutwidth equals 80 m and the maximum swingspeed equals 50 m/min. The principal characteristics of the sweep-head can be deduced from Figure 3.
A visor rather than a turning blade (scoop dredge) visor make it possible to operate in the two opposite swing directions. The same visor makes it possible to adjust the cutheight. The transport of the dredged material is hydraulic.

Figure 4. The sweep dredge during the test programme at Hingene.

Figure 5. Sweep dredge during trials on the Ketelmeer.

In November 1995, the new sweep dredge *Vlaanderen XV* started its first trials on the Brussels Sea Canal at Hingene (Figure 4). Maintenance dredging works are being carried out for N.V. Zeekanaal (Flemish Community).

The test programme involves the evaluation of swing-speed, production, automatisation, and such, and the specific environmental aspects concerning clean-up dredging, such as turbidity generation, spillage, accuracy and selectivity.

The results were very good. From March 1996 through May 1996 the sweep dredge did the maintenance dredging works in the Port of Nieuwpoort. In June the sweep dredge moved to the Ketelmeer in The Netherlands (Figure 5), where very elaborate tests were executed for the Dutch Government (see page 18). Because of the good performance of the sweep dredge, the maintenance works in the Port of Nieuwpoort were resumed with the same dredging equipment.

Process Steering

During the dredging of polluted silt one has to take into account many parameters, e.g. in-situ silt levels, water content and silt density, generated turbidity, desired concentration, production and accuracy and so on. In order to optimise this process only a highly automated process steering system can handle the operation. The dredge was for that reason equipped with a completely in-house developed computer-controlled dredge operator. All data are stored and visualised on a screen during the process (Figure 6).

During the dredging operation no manual intervention is needed any more. For example, the opening of the sweep-head is automatically adapted as a function of the thickness of the silt layer which is measured on-line during dredging.

Figure 6 : Computer controlled dredging operations.

Conclusions

With the development of the scoop dredge and the sweep dredge, two important new tools have been created for the removal of (polluted) soft fine-grained materials from waterways.

The scoop dredge is very well suited to the removal of thick layers of silty sediments even at very great depths (4-25 m). The sweep dredge is suited for depths ranging from 3-14 m and can remove selectively in layers up to 20 cm.
Both dredges do so with a minimum of environmental disturbance and at a competitive cost compared with other traditional dredging equipment, such as cutters and trailers. The sweep dredge is in fact the combination of the latest in-house developed technology both in automatisation, for instance, process control, and in trailing dredge heads for fine sediments.

References

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The Sweep Dredge: High Accuracy Dredging Trials Continue

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turbidity is partly compensated by higher production figures. As with the other trials the three weeks dredging in the Ketelmeer proved not only to be valuable to the initiator (Rijkswaterstaat), but also the dredging contractors gained vauable information which will enable them to optimise the tested dredging equipment for future projects.

Conclusion

The final report (in Dutch) describing the four completed tests is scheduled to be ready in the beginning of 1997. An English language version can be made available depending on the demand. A tremendous effort was put into the trials by all the participants, especially the Survey department of the Directorate IJsselmeer and the crews of the dredgers. For further information on the dredging trials queries can be directed to:
Thomas Arts, Rijkswaterstaat USW, Postbus 2000, 3502 LA Utrecht, The Netherlands,
tel. +31 30 285 7889 and/or Bert Kappe, Rijkswaterstaat RDIJ, Postbus 600, 8200 AP Lelystad,
The Netherlands +31 320 297 480.