The Basics of Optimally Loading a TSHD

Introduction

Within the wide range of dredging vessels the trailing suction hopper dredger has an almost unique position. In contrast to cutter suction dredgers. profile dredgers, bucket dredgers and so forth the actual dredging activities of this type of vessel are not continuous. The loading, sailing, discharge to shore or dumping takes longer or not, according to location and the type of vessel.

The operating cycle of a trailing suction hopper dredger can be divided into the following phases:

- ✓ Loading of the hopper.
- ✓ Transport of the soil from dredging location to dumping or shore discharge location.
- ✓ Dumping of the load or discharging it to shore.
- ✓ The return of the empty vessel to the dredging location.

We can only speak of optimum use of the trailing suction hopper dredger when every single phase has been optimised and when the different phases are well adjusted to each other. In this article we first briefly discuss some aspects which are of importance for the optimisation of the separate phases of the dredging cycle. It appears that it is the loading phase that offers the best opportunities for improvement. That is why we go deeper into the method to determine loading and the correct moment to stop dredging. The question is what are the effects of using modern, more extensive than usual measuring and signal-processing techniques in the right way.

Transport

During both vessel transport phases, empty and loaded, savings may be made by sailing with reduced engine output. This is most likely when sailing on shallow waters. That the reduction of fuel costs has to be balanced against the costs of the slightly prolonged cycle time does not need to be emphasised.

Dumping

The time necessary for dumping can be minimised by the most effective fluidisation of the load, pumping water on the load with the dredgepump and by means of water jets. This, of course, largely depends on the type of soil and in most cases the effects on the cycle time are marginal.

Shore discharge

The most effective extraction method is the one where the load is discharged with the highest possible density and speed. Attentive valve operation together with the correct use of water jets and hopper discharge duct water supply is of major importance. Most of the time, however, unloading time is determined by the type of soil, the delivery distance, pump output and the optimal flow-concentration combination that can be maintained.

Separate dumping and shore discharge

When one has to discharge to shore a third possibility can lead to reduction of the cubic meter price in certain circumstances. In general shore discharge with a trailing suction hopper dredger is a costly operation. However, by dumping the soil via the bottom doors and then pumping it to shore by means of a separate small stationary suction dredger a considerable reduction of costs can often be reached.

Trailing suction

The effectiveness of the trailing suction hopper dredger is largely determined by the draghead used, the availability of jet water at the head, the flowrate, the propeller pull available for drag, the adjustment of the draghead and how the flowrate and trailing speed are handled. By playing sensibly with these variables output can be optimised. A considerable amount of time can be saved particularly by searching for the right trailing speed in each situation.

Loading

When loading, a distinction should be made between loading the hopper with fine silt, clay or with granular material. When loading silt the overflow is limited to a few minutes at the most. When it concerns polluted slurry there will be no overflow at all. With the loading of clay and granular material there is virtually always overflow. The answer to the question when the overflow should be stopped is defined by factors such as: type of soil and granulation, mixture concentration, hopper geometry, flow rate and the actual liquid/solid loading condition during overflowing. During loading overflow losses can occur which, depending on the situation, can vary between 0% and 100% of the actual dredged material flow.

Measurement of the dredging parameters

A complex of factors determines the effectiveness of the dredging process and loading. To have detailed insight here expensive instrumentation is employed. We might mention the measurement of the mixture velocity and concentration, from which the dredged production is calculated, and the measurement of pump vacuum and discharge pressure and hopper loading. For insight into the effectiveness of the loading of the hopper a load indicator is necessary. Before discussing this further the loading phase will be first explained.

A closer look at the loading phase

During the loading of the hopper it goes through the following phases:

- ✓ First the mixture is pumped into the hopper until it is completely full and starts to overflow. As long as the hopper does not overflow no overflow loss will take place and a maximum material collection will be achieved.
- ✓ Overflow at a rate (m^3/s) equal to the flow rate. The water in which the solid material had settled, flows over the overflow(s) in their highest position or over the side of the hopper until the ship has reached the maximum admissible draught and with that its maximum loading capacity. The overflow losses are still relatively low.
- ✓ Overflow at a rate (tons/s) equal to the pump production. The vessel is kept at a constant draught (constant load). With a pumped-in concentration which is higher than the overflow concentration the out-going volume stream must be larger than the incoming one. Because of this the liquid loading level will drop gradually. At the same time the solid loading level will rise because of settling. This leads to a lower liquid section as a result of which the mixture transport from inlet pipe to overflow speeds up and becomes more and more turbulent with, as a result, decreasing settling and even erosion. This explains the increasing overflow losses until the pump production directly leaves the hopper. The loading efficiency has then decreased to 0% (or sometimes even less).
- ✓ End of loading and overflow of the remaining water. Far before the point that 100% of overflow loss is reached the crew will have stopped drawing material in. There is still residual water on top of the load which can be discharged after some time by overflowing so

that the vessel can sail to the dumping site or shore connection without unnecessary load and at reduced draught.

The load indicator as aid for optimal loading

When loading a trailing suction hopper dredger one mostly uses a recording load indicator. The current type is based on measurement of the sinking of the vessel hull and shows the progress in the time of the displacement. Fig. 1 schematically demonstrates such a recording. From this displacement curve one can derive the most cost effective point at which to stop loading. For this purpose one usually chooses by feel the point on the displacement curve whereby it does not increase further. As a further help one sometimes also uses the "tangent method" that will be discussed later. Because of its limitations this method is only useful when dredging silt and with trailing dredgers with a so-called "high specific gravity hopper" (high load capacity - hopper volume ratio).

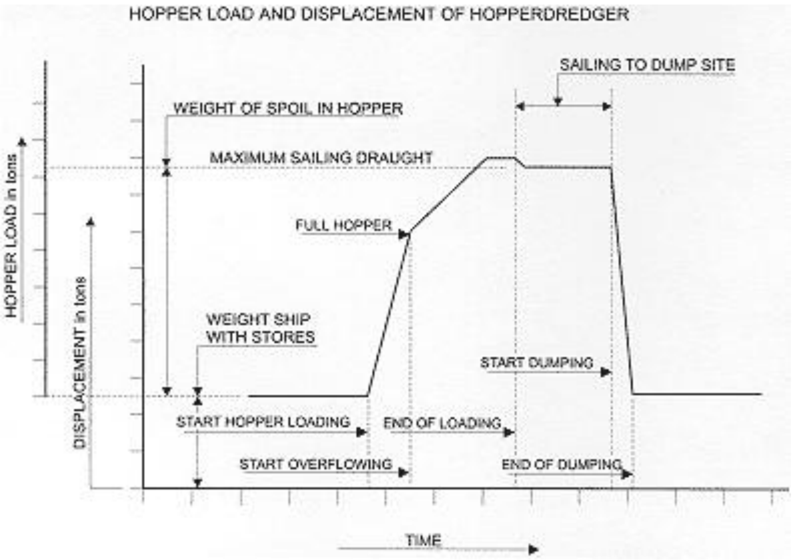

Fig.1

The load indicator based on vessel hull displacement has some clear limitations. Together with some general critical aspects these are:

- ✓ The load indicator shows the displacement of the vessel hull and thus the weight of the total hopper contents that can be derived from it – consisting of dredged material mixed with water. However, from the displacement curve the 'paying' load cannot be derived.
- ✓ On reaching the maximum hull displacement and with that the maximum weight of the hopper contents, that part of the load that pays - the solid or dry material - is not maximised. Besides the settled (solid) material, the load consists of a mixture with a considerable amount of water which can still be replaced by an amount of paying solid material of approximately the same weight.
- ✓ That is why with most trailing dredgers it is impossible to derive the optimal final point of loading of granular material from the hull displacement curve. More information is needed.
- ✓ Sometimes the trim of the vessel hull is insufficiently taken into account which results in a less specific indication of the displacement. This effect can also be the result of non-optimal positions of the sensors or flexing of the vessel hull.
- ✓ To accurately define displacement pressure measurement is used. This can be done by means of pressure meters in the bottom of the ship or indirectly and mostly less accurately by means of bubble points.

The optimal load indicator

The limiting aspects mentioned above can be met by an optimal load indicator:

- ✓ By measuring the displacement of the vessel by using pressure meters in the bottom. These should be installed in such a way that under every possible sea condition a reliable trim can be derived. Possibly the displacement can be defined on the basis of four instead of two sensors so that both listing and flexing can always be taken into account.
- ✓ By programming the load indicator with extensive ship's tables for water displacement as a function of draught and trim which tables list all possible draught and trim conditions.
- ✓ By measuring the volume of the mixture inside the hopper, taking into account the trim and listing conditions.
- ✓ By continually determining the actual volume or weight of the paying load from water displacement and hopper volume.
- ✓ By including in the graphic presentation an aid for determining the optimal point to stop loading.
- ✓ By equipping the load indicator with an indication of mutual inconsistent trim positions that are defined on the basis of draught and hopper level. By this means erroneous sensors can be monitored.
- ✓ By a provision for the automatic control of overflow during loading at maximum draught.

The actual hopper contents is derived from the level of the fluid load in the hopper. To measure this ultra-sound measuring techniques are used as a rule. The actual weight in the hopper is derived from the difference between the actual displacement and the displacement of the empty vessel. From the hopper volume and the weight of the hopper contents the volume and weight of the paying load can be derived. The paying volume or weight is determined by an adjustable reference density (for instance in situ, water-saturated sand, dry material). For signal processing, calculations and presentation a micro computer system is used. The same functionality can, of course, also be included in a modern integrated and computerised dredging control system. The definition of the paying load takes place on the basis of the following equations:

$$Vol_{pl} = \frac{Wgt_h - Vol_h * SG_w}{SG_{pl} - SG_w}$$

$$Wgt_{pl} = SG_{pl} * Vol_{pl}$$

In which:

Vol_{pl} = Volume of paying load
Sg_{pl} = Specific Gravity of paying load
Wgt_{pl} = Weight of paying load
Vol_h = Volume hopper
Wgt_h = Weight of hopper contents
SG_w = Specific Gravity outboard water

The progress of the weight of the paying load is graphically shown in Fig. 2, together with the displacement curve. From the curve for the paying load the optimal loading point can be derived. In the next paragraph the background and working method will be explained.

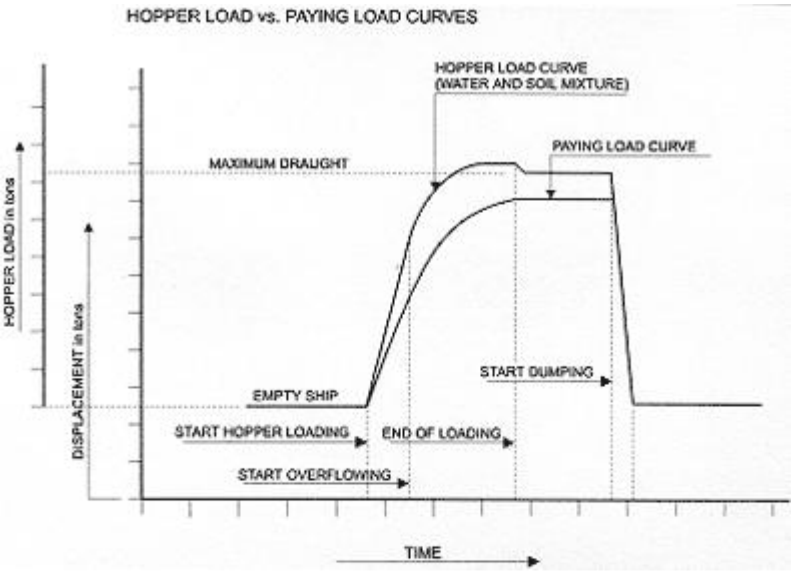

Fig. 2

Determination of optimal duration for hopper loading
(by means of the tangent line method to the paying load curve) Contrary to the displacement curve (weight hopper contents), from this "paying load curve" the optimal point to stop loading can be defined. The point where the volume or weight of the paying load per cycle-time unit is at its maximum is regarded as the optimal loading point. That is why a maximum output cost ratio occurs at the optimal loading point. Graphically this point can be defined as follows: As starting point of the new, we take the time of the previous cycle when dredging stopped. When following the new loading curve every point of that curve can be linked to the starting point of the cycle at the 0-level of the paying load. The tangent of the angle this line makes with regard to the time axis then corresponds to the relation in that point between the paying load and the duration of the cycle up to that moment. At the point where this connection line hits the loading curve, the angle, and also the ratio between output and costs, will be at a maximum. By increasing overflow losses the growth of the paying load per time unit decreases. So from that moment on the paying load curve runs below the tangent line. That is why every next point will show a lower output per unit time. Stopping dredging is thus imperative. The course of affairs as outlined here is shown graphically by means of Fig. 3.

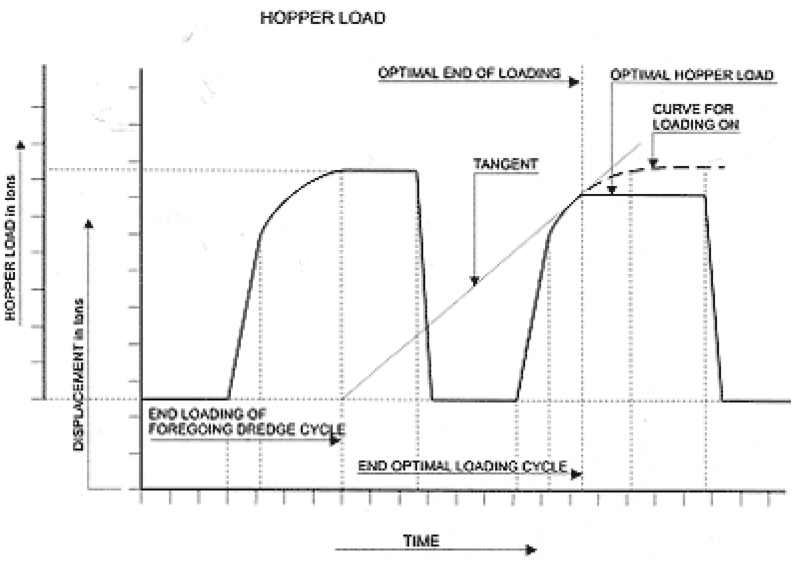

Fig. 3

Optimal loading by using optimal equipment

From the foregoing it can be deduced that optimal loading is only possible when using equipment that is optimally suited for this task. This implies that the equipment should at least be able to present on a monitor the time progress of the paying load in the hopper, plus an indication of the loading optimum. An example of such a presentation is again shown in both figures below. Fig. 4.1 shows the cycle with a short sailing distance, while Fig. 4.2 shows the cycle with a long sailing distance. In these diagrams for the definition of the loading optimum the tangent line method has been applied both on the displacement curve (dashed line) and on the paying load curve (unbroken line). The differences have been made visible

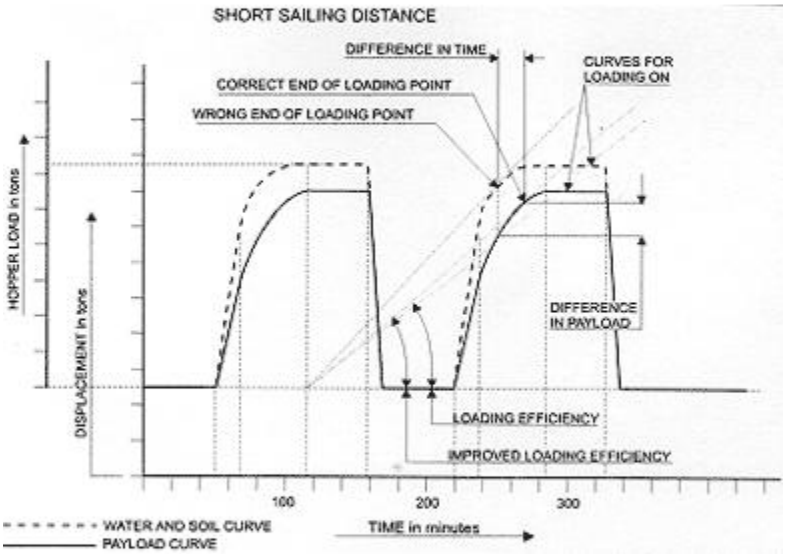

Fig. 4.1

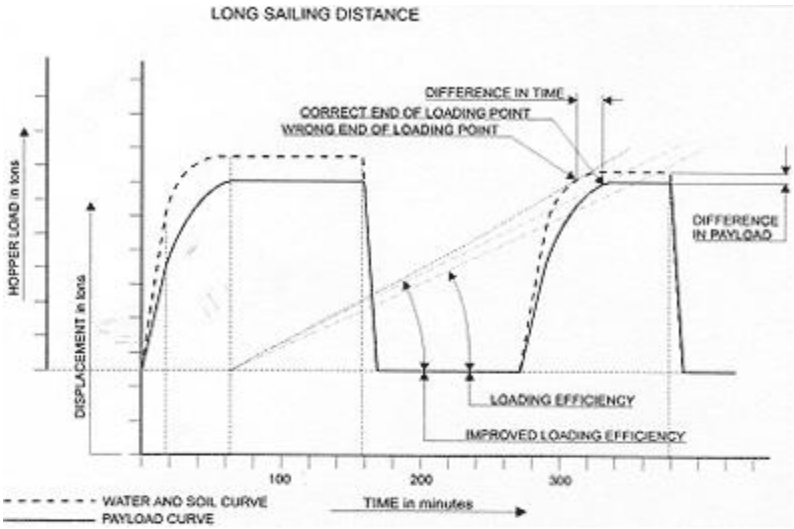

Fig. 4.2

Financial aspects and conclusions

Both in the case of short and long sailing times application of the tangent line method to the paying load curve leads to considerably more favourable ratios between paying load and cycle time. Quantitative comparative research has shown that, especially with short cycle times, loading is ended too early on the basis of the usual loading measurement. Within a cycle time of 120 minutes and a loading time of 60 minutes it appears that when loading moderately fine sand, differences of 10 minutes and more can occur. This means that with the improved method loading can go on up to a point with a higher cycle efficiency. The accompanying output improvement is in the order of 5 to 10%. In the considerations above it is assumed that in the case of loading measurement which is only based on displacement, the tangent line method is always used. In practice, however, it is mostly different.

Because the displacement curve does not give any further information after passing the point of maximum displacement, while one still has the feeling that loading can go on, most of the time loading will go on for too long. This probably causes an even worse loss of efficiency.

These things show that the improved working method described based on the definition of the paying load, will always lead to an improved loading efficiency. In addition to the financial one there is yet another aspect of the improved method for loading measurement which should not be left unmentioned. With clients as well as with controlling authorities there is an increasing effort to measure the actual dredged soil and relocated dry material as a basis for payment. This, together with the determination of the optimal loading time, can contribute to an important increase in the efficiency of the trailing suction hopper dredger.

(Source : *Ports and Dredging 137*, IHC Holland 1991)