Deep dredging engineering to the extreme

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Abstract: In recent times the development of custom-build / deep-dredging installations has taken a major step forward, showing particularly in the increased number of deep-sea dredging installations available nowadays. The use of such equipment is successfully demonstrated in special offshore dredging projects such as the excavation of glory holes and pre-trenching for pipelines. Besides these special projects there is also an increasing attention for deep-dredging capabilities for land reclamation works. The ever increasing demand for sand, forces the dredging industry to focus on the exploration of the deep sea international waters, instead of the shallow coastal waters.
These kind of operations place high demands on the dredging equipment. High trailing forces, submersible dredgepump units with high powers and the demand for accurate positioning of the draghead require high-quality engineering. To build such installations, known engineering boundaries have to be moved and special high-tech solutions are needed.

This paper describes various aspects of the design process and the technique of custom build deep-sea dredging installations. Before the different parts of a dredging installation can be designed, first the system constraints have to be determined. Design criteria such as load conditions, maintainability, wear management and maximum dredging depth have to be laid down. The maximum dredging depth for a particular ship is traditionally determined by its length. On the drawing board, alternatives to cope with this fixed relation have been developed.
After the system constraints have been determined, the engineering process goes to the next level: product design. Specialized engineering tools to determine dynamics and workability help the engineer to design specific deep-dredging components such as pressure compensating systems and high tech bearing connections.

Keywords: trailing suction hopper design, deep sea dredging, increase of scale, maintainability, workability, suction pipe dynamics, product design.

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1 INTRODUCTION

In the past ten years both the dredging depth as well as the size of the hoppers themselves increased. The growing size of the hoppers was mainly pushed by the requirements of large scale land reclamation projects. The maximum dredging depth was pushed due to various reasons. First one can think of the limited availability of sand in coastal waters. The sand has to be dredged further of the coast, which usually means a larger dredging depth and a more hostile environment.
Secondly and thirdly, the dredging depth increased due to special offshore projects such as pre-trenching for pipelines or excavation of glory holes.

To reach the ever increasing dredging depths, suction pipes consisting of more than the traditional two pipe sections (upper and lower) are used. As a consequence the dynamic behavior of such an installation will become more critical. This is also driven by the fact that due to the high overall investment costs for both the jumbo dredge as for the underwater pump installation a malfunction of one of the components resulting in down time will lead to serious losses. Determining how and when such an installation can be safely used is one of the key factors in designing these installations.

In order to be capable of efficient deep dredging it is eminent to have a submerged dredgepump. Deep dredging without a submerged dredgepump will lead to very low production rates. Unless these rates are acceptable a submerged dredgepump will be part of the suction pipe.
The dynamic behavior and workability are described in section 2. Section 3 subsequently describes in more detail some of the specific features and components of deep dredging installations. The main conclusions are given in section 4.

2 WORKABILITY

Given the design of a vessel and its dredging installation, limits exist in which this equipment can work. When working offshore, limiting factors for the workability may be high waves during adverse weather conditions.
To be able to determine at what weather conditions it is still safe to continue dredging is a major advantage when:

- planning and budgeting of offshore projects for a given vessel and its dredging installation, or
- guaranteeing the vessel is capable to complete a specific job given a fixed time schedule, or
- optimizing the design of a vessel and its dredging installation,

2.1 HOISTING OPERATION

The hoisting operation is the situation where the suction pipe is out of the water, above the waterline, besides the hull of a hopper dredger. During this operation the suction pipe is free to move due to the vessel's motions. This results in a swinging motion of the suction pipe. When the motion amplitudes become too large, the suction pipe might hit the vessel's side or its gantries resulting in damage. This swinging motion is a kind of resonance behavior in which large motion amplitudes can built up quickly.

In order to determine the limitations to the workability due to this swinging motion, an analytical tool was created (ten Heggeler, 2001). In this tool all relevant parameters, such as the wave response characteristics of the vessel, cable lengths, winch speeds and also the capacity of the buffers on the upper pipe and draghead, were included. Special tests were executed to determine the damping characteristics of the suction hoses. With this tool the workability of a hopper dredger regarding the hoisting operation can be quantified. Figure 1 shows a wire frame sketch of the model.

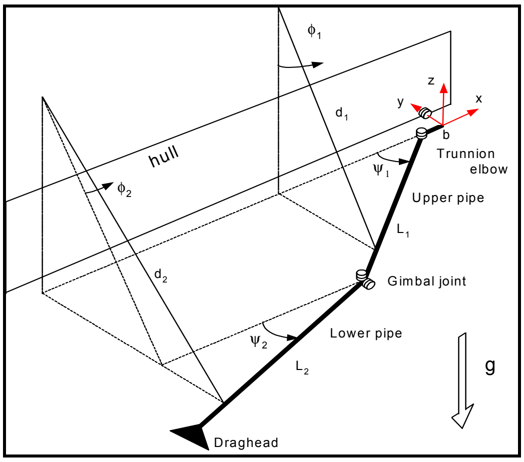

Fig. 1: Wire frame sketch model

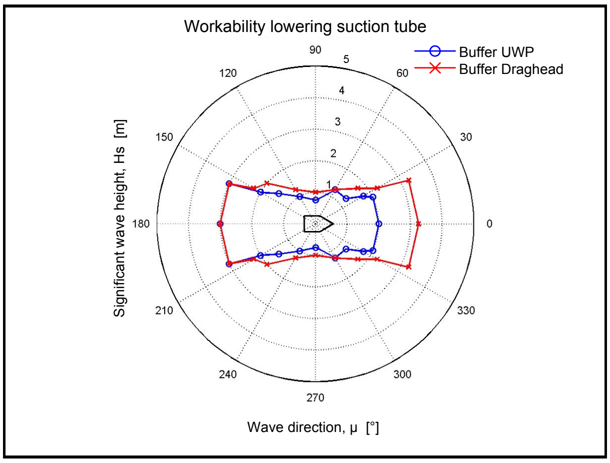

Fig. 2: Workability lowering suction pipe

With the aid of this tool not only a prediction can be given considering the workability of the system, but it can also be used to determine the size and placement of buffer elements on the suction pipe. When the buffers collide with the ships hull and the buffering capacities are exceeded, the hopper can no longer lower the suction pipe into the water without risking the suction pipe damaging the vessel.

In the centre of Fig. 2 the hopper dredger is plotted, the circles indicate the wave height and the two lines show the limiting wave height verses the orientation of the vessel in the waves. For a wave direction of 30 degrees the limiting wave height for the buffer unit on the upper pipe is 1.8m, and for the drag head 2.2m. It can be seen that the buffer at the upper pipe is not necessarily the limiting factor for all wave directions.
The figure shows the results for the lowering operation of the suction pipe. These calculations can be done for the hoisting operation as well. When these two situations are compared, the lowering situation (when the vessel is empty) limits workability earlier than the hoisting operation.

As the example illustrates the model is a very useful design tool for optimizing new dredging installations and further more it can be used to analyze existing installations as well.

2.2 DREDGING OPERATION

The dynamics of a suction pipe can limit the workability of a hopper dredger in another way. When dredging, the vessel moves with the waves keeping contact with the ground through its suction pipe. To do so the motions of the vessel are compensated by the swell compensator. With increasing wave heights the demand on the swell compensator in terms of stroke and speed increases. When the waves become too high the swell compensator can no longer compensate for these motions and contact with the sea bottom is lost. An accompanying risk is that a hopper dredger can stand on its suction pipe. This can happen especially when the suction pipe is at a steep angle in combination with a relatively slow forward speed. Due to large vertical motions of a vessel in the waves the suction pipe can straighten itself. When the vessel is moving downward again due to the waves, a negative speed of the draghead can occur across the sea bed. If this negative speed is not compensated enough by the forward speed of the vessel, the change is that the vessel stands with its full weight on the suction pipe, with all the consequential damage.
Especially for deep dredging operations like pre-trenching for pipelines or the excavation of glory holes the reduction of workable time can be significant. In these situations the wave conditions are more challenging. An extra complication, for example with trenching, is that one is often not free to choose the sail directions to minimize the ships motions, in order to reduce the motions of the vessel on the waves.

To determine these limiting wave conditions a 2 dimensional model calculates the responses behavior of the suction pipe. In this model data as; the wave response characteristics of the hopper dredger, the inertia of the suction pipe, routing of the hoisting wires and the characteristics of the swell compensator and wire strainers are included.

From the output of the model follow the limiting wave conditions which are valuable information for both the designer and the operator of the system. It can be used to improve a design or to help the dredging contractor to estimate the amount of time needed to perform a certain job.

3 PROFIT DEFINING TOOL

Suction pipes consisting of more than the traditional two pipe sections (upper and lower) are used to reach the ever increasing dredging depths. From a dynamic and handling point of view, it would be better to use two large pipe sections, instead of three or four. However, if one zooms in on this problem, a simple example will show that this will lead to immensely heavy pipe sections: the maximum moment is one of the determining factors in calculating the strength of a suction pipe section. If one doubles the length of a suction pipe, the maximum moment will quadruple. To withstand this additional bending moment, the moment of inertia should be increased. This means adding extra material (which in itself will lead again to an increase in bending moment). From this example, it is clear that their will be a limit to the maximum length of a single suction pipe section. As a rule of thumb, the maximum length of each pipe section usually does not exceed 30 to 35 times the diameter.

Not only the weight of a suction pipe section will increase largely when the individual length increases, also the accompanying gantries, deck reinforcements and necessary powers for the winches will increase. From this point of view, it is evident that their will be a trade off between the number of pipe sections and the maximum allowable (or desirable) weight of a complete suction pipe.

Not only does the suction pipe of a deep dredging installation needs to be long enough to reach its design depth, it also has to accommodate the submerged dredge pump. This dredge pump is driven by an oil filled electrical motor. Some of the deep dredging installations are designed in such a way that the submerged dredge pump does not work in series with the inboard dredge pump(s) but is capable of filling the hopper all by itself. This has lead to enormous pump units. In 1998 IHC delivered the 5.000kW submerged dredge pump unit for the TSHD Volvox Terranova. This design was unique, because the pump was driven not by only one electrical motor but by two. Also, the pump unit was situated in the lower pipe instead of the upper pipe. With a total weight of more than 400 tons and a maximum dredging depth of 105 meters, this is still one of the largest installations in the dredging industry.

The largest installation up till now is the one for the TSHD Vasco Da Gama. With a weight of 370 tons for the upper pipe section alone, a maximum design dredging depth of 155m and a submerged dredge pump power of 6.500kw, this design is clearly in the vanguard of today's technology. Not only is the suction pipe the largest of its kind, also the trunnion and the pump gantry are the largest in their kind. The latest one has a reach of more than 10m and roughly weighs 250 tons. It is designed for a nominal load of 320 tons, with a staggering maximum load of 750 tons.

Fig 3. Lifting the upper pipe with submerged dredge pump unit of the Vasco Da Gama

The most recent deep dredging installation is the one delivered for the TSHD Pearl River. Originally, the Pearl River was only capable of a dredging depth of 50m. But after increasing the total length and capacity of the vessel itself, it was ready for a deep dredging installation of 3.400kW with a maximum dredging depth of 120m.

Dredging installations of this size are profit defining tools. To make them work, some intricate engineering is required to produce a perfectly operating tool. The outcome if this engineering are components which in itself are unique, and, when put together, form a complete deep dredging installation.

Some if these unique components are:

- Special designed sliding piece bearing, to transfer the high trailing forces into the ships hull.
- Pressure compensator system, to maintain a constant overpressure inside the oil filled electrical motor.
- Special impeller connection (Threaded Slip Protection, TSP), to be able to use white cast iron impellers and to reduce handling time when exchanging a worn out impeller.
- External cooling of the electrical motor, to reduce the weight of such a motor.

4 CONCLUSION

This article highlights a few elements of the design process of a deep dredging installation and the characteristic features of these installations. It illustrates that successfully designing and building a deep dredging installation requires a thorough knowledge of all the different levels of the design and building process. A process that requires a close co-operation between the builder and client as the success of the final product relies heavily on the experience and expertise of both.

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