A boost to sustainable growth:

Innovative dredging at Sepetiba Bay

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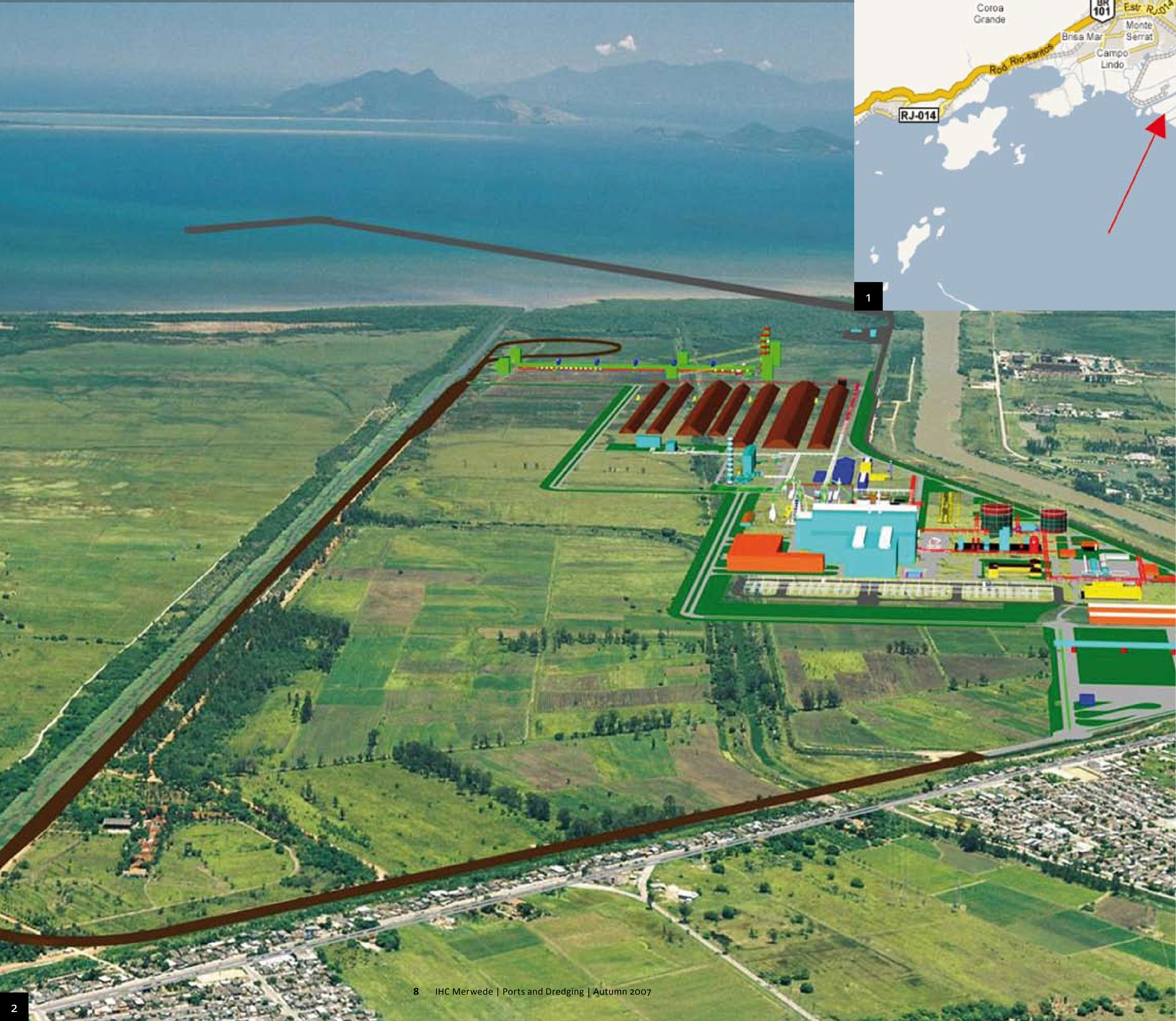
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1 Sepetiba Bay and location of steelworks West of Rio de Janeiro

2 Artist's impression of the project

From commodities to added value

After the well-known recent mergers in the heavy steel industry, German steelmakers ThyssenKrupp AG with their nearly 200,000 employees worldwide and annual revenues of approximately 47 billion Euro, had to invest significantly in order to meet the new standards.

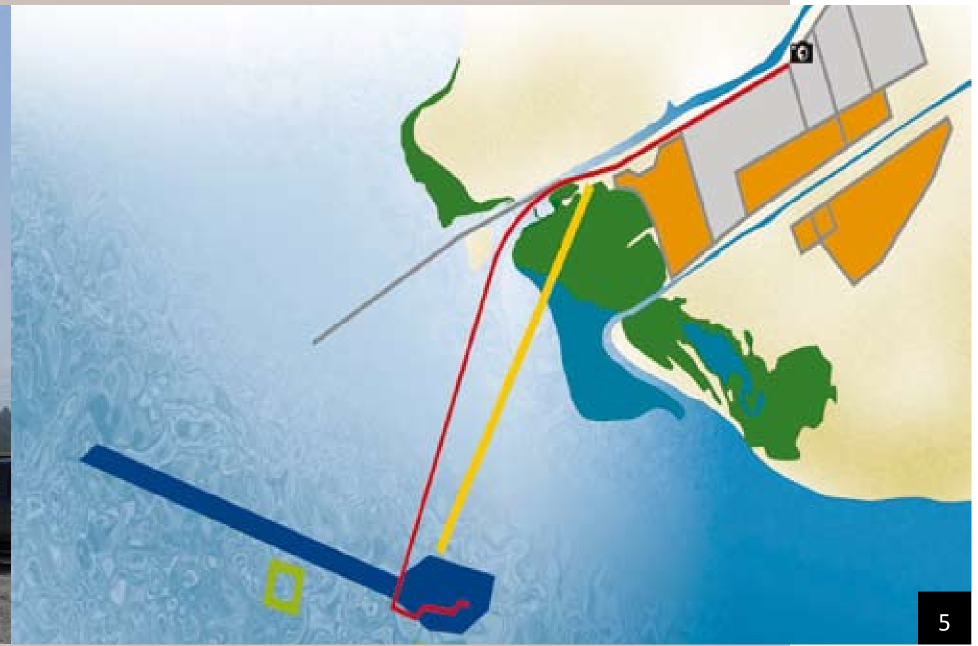
At the other side of the globe, having survived the economic and domestic shocks of 2001-2003 without sincere collapse, Brazil is hard-working to create a better life for their 190 million people who earn an estimated annual € 6,500 at average. One attempt to enhance Brazilian standard of life involves trying to make profit out of the growing demand on iron ore, driven by current world economic growth, especially in countries as India and China. Brazil is one of the so-called BRIC countries, containing enormous natural resources. Among them are bauxite, gold, iron ore, manganese, nickel, platinum, tin and much more. Within this complex, iron ore is one of Brazil's economic drivers, with estimated annual iron ore and pellet production of 220 million tons, of which a growing part is used for the domestic crude steel and steel products industry. Brazil's iron ore reserves are believed to be about 20 billions of tons. A great lot of them concentrate in the State of Minas Gerais with an area that roughly equals France, inhabited by nearly 18 million people. In the southeast, Minas Gerais borders on the large markets and ports of São Paulo and Rio de Janeiro, having in that way an outlet for their rich resources. Minas Gerais owns approximately 70% of Brazil's iron ore reserves.

Now it is well-known that exporting commodities do not enhance living standards on the long term as price margins on commodities are usually small. So Brazil is hurrying to set up more and more industries that allow them to add value to their mineral resources and to produce semi-finished products, which pursuit only can be for the good benefit of Brazilian people, who will find employment, income and social improvement in this way.

ThyssenKrupp decided to rise huge steelworks at Sepetiba Bay, a location near Rio de Janeiro at Brazil's coast, with real good access to the Atlantic Ocean (*figure 1*). ThyssenKrupp AG and one of the world's largest mining companies, Companhia Vale do Rio Doce (CVRD) joined forces and planned to build a two hundred hectares factory, comprising among others a stockyard, a sinter plant, two blast furnaces, a steel making plant, and a coking plant (see *figure 2*, viewed from a north-eastern point), a 3 billion Euro investment. In these steelworks so-called steel slabs will be produced. Slabs are semi-finished products for export to ThyssenKrupp's production facilities at Duisburg and in the USA. Now one can guess what had to happen further: a large area of land should be reclaimed, a jetty, loading berths and roads had to be developed, a 16-meter deep entrance canal to the Atlantic should be made. Guess also which small countries come in sight now... Not only for having the only European port, Rotterdam, that can process the huge slab transport freighters, but also for having a long tradition in dredging and land reclamation: The Netherlands and Belgium.

Innovative approach of dredging and reclamation works

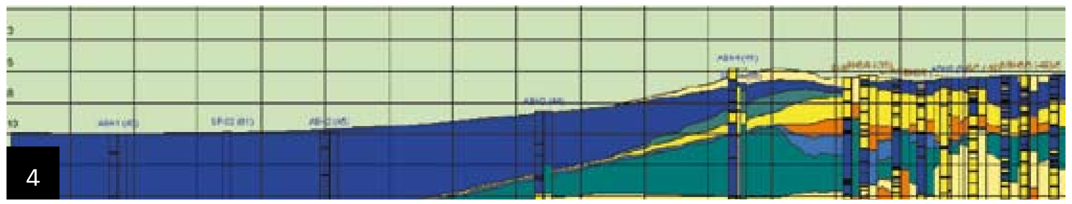
High-ranking dredging contractors Boskalis International BV, an operating company of the Royal Boskalis Westminster NV, and Dredging International NV were awarded the contract for all 'wet' dredging works. For more than one reason they entered into a Joint Venture (JV), but the most important reason aimed at delivery guarantees. For ThyssenKrupp AG and CVRD the delivery term of the steel factory is of highest priority (March 2009 production should be operational with an estimated 5 million tons of slab production). So the dredging contractor had to be sure to have available a large Cutter Suction Dredger immediately at start of the works. Both contractors have such dredgers, so a kind of certainty was built-in. The JV was registered as a Brazilian enterprise (*figure 3*). As became a winged word at JV meetings: "Brazil is not a country for beginners."



It's time to attend the dredging works as such. From the day of signing the preliminary contract in June 2006, an unusual approach was required. As it was the intention to supply the entire reclamation with sand that had to be dredged out of the entrance canal and the turning basin for the slab freighters, a lot of soil investigation had to be executed yet. Furthermore, there was to do detail-engineering for the dredge works due to the tight time schedule of the tender. Thus ThyssenKrupp/CVRD and the JV agreed on an Early Works Agreement, which allowed them to start mobilisation of the equipment, bring up dredgers, execute soil investigation and extended engineering at shared risks. It was a unique co-operation of customer and contractor, based on trust and mutual respect. After accomplishing this phase, the definite contract was signed in September 2006, dredging could start.

Brazilian government put stringent rules on the project, intended to enhance wealth and economic power of the region, as well as social and ecological state at the same time. This thinking may be hailed as a serious attempt to reason from sustainability. So, dredging with 'green fingers' was at stake. The JV succeeded in doing so in an innovative way, applying three measures, viz. *environmental dredging*, *selective dredging* and '*volcano-discharging*'.

Environmental dredging: there were some spots in a canal near the factory's location as well as at some parts of the newly to be dredged canal in the bay, covered with a layer of contaminated soil. This layer has been removed. The contaminated soil was stored in so-called Confined Disposal Facilities (CDF), being newly dredged pits, starting at 18 meters of depth. Then the contaminated soil was covered and confined by a layer of clean soil.



Selective dredging: to meet the requirement that most of the material for the landfill should be obtained from the dredging works, Boskalis and Dredging International developed a really innovative method of operation, consisting of two parts. First, they agreed with their customer that they had to dredge selectively, as it had proven from the soil investigation (*figure 4*) that sand has really been hidden at random within the soil of the bay, especially in the area of the turning basin, which was the main sand 'deliverer'. Yes, it would retard the operation a bit, but would also guarantee the utmost yield of sand. So dredging started selectively for as long as 75 days and patience was rewarded with a host of sand.

Volcano-discharging: then the second creative plan came into work. Of the resting soil, as much sand particles as possible should be saved for reclamation, so was the agreement. How could the JV guarantee meeting such a requirement? Well, they developed a new method of rainbowing, which they call volcano-discharging: at the end of the delivery pipeline they spew out the mixture under a certain velocity and angle. As a result of this meticulous design, the heavy sand particles fall relatively fast and cover only a defined area, while lighter particles as mud, pet, silt, etc. flow a bit farther and gather at the border of the settling area, where they can be removed relatively easy. It is this innovation which gave the customer full trust that the JV could do the job in time.

3 The Joint Venture's (DEBRA) office in Brazil

4 One of the soil charts of Sepetiba. Note the stratification of sand (yellowish and orange fields) at random.

5 The Dredging Project. Grey area = landfill with dikes; orange area = silt deposit; green squares = CDF; yellow line = jetty; red line = discharge pipeline; grey line = return water line.

6 Boskalis' old warrior BEAVER ST LAWRENCE

7 Dredging International's *éminence grise* at work

As it is important that the people who actually build the factories can work on dry feet, first a layer of sand is deposited on a layer of wild vegetation, which carries the sand in first instance. The sand is discharged to a one-and-a-half meter level and settles, while the rest of water is pumped back. So dry feet can really be obtained and building of the particularly scheduled factory can start. The rest of the sand is pumped to dry depots, from which it is removed by 'dry methods' to further supply the terrain after first consolidation and piling.

Total amount of soil to be moved in the 'wet' operations is approximately 10 million m^3, reclamation area about 200 hectares (*figure 5*). Soil properties vary between sand with grain size (d_{50}) of 600μm and clay with a shear strength of 100 – 150kPa. Length of the mixture discharge pipeline is approximately 10 kilometres. Installed power on the mixture transport chain approaches 18,000kW, 3,000kW is kept in spare.

Deployment of dredging equipment

At start of the works, Boskalis' grab dredger ELISA digged the necessary pits for vessels and boosters. Then Boskalis' BEAVER ST. LAWRENCE (*figure 6*), a Beaver 1500 dredger, built at IHC Sliedrecht 1983 and equipped with a special ecological head, started removal of the contaminated layer. With its installed 1,200kW it discharges the soil through a discharge pipeline of 1,500 meters of length to the Confined Disposal Facilities.

As Boskalis' heavy cutter suction dredgers were not available in time, the JV gave her fruits and Dredging International's *éminence grise* VLAANDEREN XIX (*figure 7*) was put in. This self-propelled, heavy cutter suction dredger, built at the IHC yard at Kinderdijk and commissioned 1978, was carefully prepared for the challenging job. Among others the newest generation of IHC Systems' Automatic Cutter Controller (ACC) was hoisted on board. This ACC has been developed in close co-operation with Dredging International and should cope with the control demands we will learn about below.

VLAANDEREN XIX's powerful 1,750kW cutter drive and 8,500kW applied on one ladder pump and two inboard pumps are assumed to give a first kick to the pumped mixture over a distance of about 2 kilometres.

At the end of those kilometres, Boskalis' double booster station COSEL (*figure 8*) is found, supplying 5 500kW to another 2 kilometres, to the end of which Dredging International's booster station DI 509 has been coupled, adding 4 500kW more to the rest of the pipeline, measuring roughly a final 6 kilometres. In case of emergency, Boskalis' booster station NIEUWE MERWEDE is able to add an additional 3 000kW to the discharge process, or replace one of the other stations.

A small local cutter dredger, called URUGUAY, removes silt from the side silt deposits and pumps it to a 115 hectares final silt deposit, which had been assigned and prepared for that purpose.

A considerable control demand

Remember for a few seconds the ingredients for dredging in Sepetiba: ten kilometres of discharge pipeline and six dredge pumps of different power in series at irregular distances, of which three on board of a single dredger (*figure 9*). Anyone with even an amateurish view on 'control' could deduce that a huge control demand is glaring. All these pumps should maintain a certain mixture velocity in the pipeline to prevent settling, all pumps should be protected from under- and overload. Not in the least: production should be made. Add as a special flavour the necessity to limit water quantities at the reclamation site in order to prevent application of yet more return water pumps and an unpleasant brew is cooked. If this challenge should be tackled by man, a lot of (miss-) communication would be involved, as every pump operator should know all data and parameters of all other pumps – and should be able to remember and process them during about 2 000 seconds, the mean runtime of a particle trough the pipeline! One can imagine that at the end of a communication cycle one or another of the pumps already has been overloaded, the pipeline already clogged. Even when cell phones or multi-channel radios were used …

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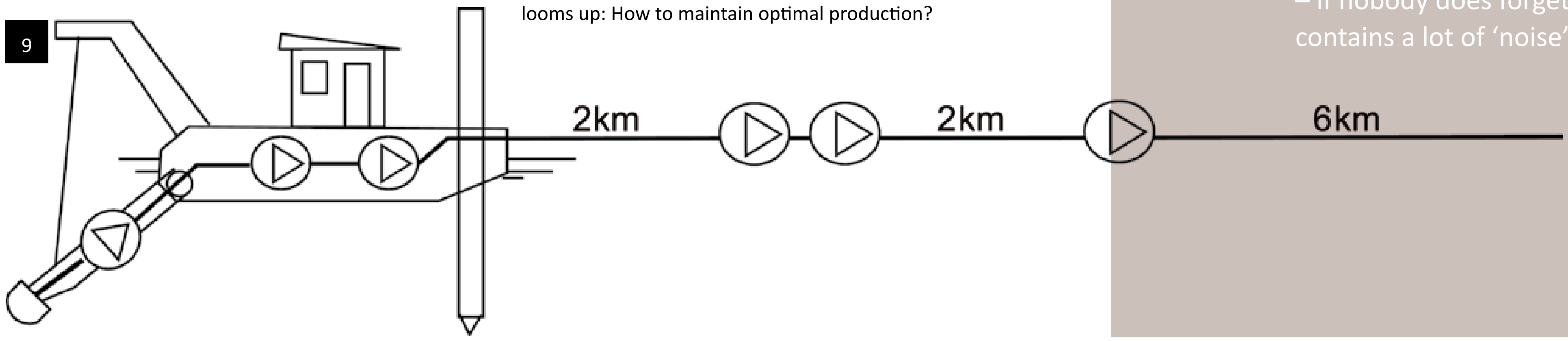
Now the JV could profit from a recent Boskalis development. Boskalis has available a kind of semi-automatic booster pump controller (*figure 10*). It comprises two PID controllers that react on low incoming or high outgoing pressure, and it furthermore limits minimum and maximum allowed pumpspeed and fuel rack position. When one of these parameters becomes decisive, the controller alters the speed of the concerned pump. Each unit communicates with the others by a reliable radio telemetry link. On VLAANDEREN XIX a similar unit has been installed, however with an extension that allows the dredgemaster to adjust setpoints for any pumpspeed in the chain, if the individual booster operator gives free 'his' booster to remote control. So a first technical solution for the control challenge was found. In any case, individual pumps could not longer be overloaded at suction or discharge characteristics. However: now the burden of maintaining flow is entirely put on the dredgemaster aboard of VLAANDEREN XIX – who has a lot of things more to do … and must be a versatile magician in processing so much data. After all, what happens to a dredge pump in the chain when speed of one of the preceding pumps is altered, or speed of the next neighbour, or … ?

While this is the first reason to look for a more comprehensive solution, there is yet another one. Assume: in a miraculous way it would happen that one centipede-magician-dredgemaster could really maintain flow in the discharge line, then a more serious demand looms up: How to maintain optimal production?



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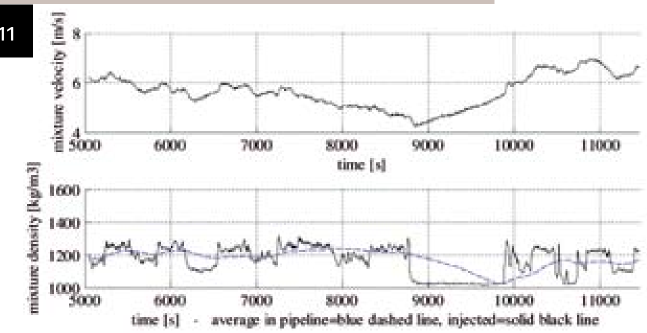
8 Double booster COSEL

9 Schematic diagram of the hydraulic transport chain

10 Booster radio telemetry local/remote control and display unit

11 Vulnerability of conventionally controlled hydraulic mixture transport



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It is common knowledge that production of a dredge-chain is established by the product of mixture velocity and mixture density. In the same way pump power is determined by mixture flow and pressure in the pipeline, which in its turn is a derivative of the average mixture density in the total length of the discharge pipeline. Now what happens if such a chain is fed by a cutter suction dredger? Production of such a dredger varies considerable along the swing width, dependent on position, swing speed and soil properties – which are extremely variable in Sepetiba as we remember. So, the dredger feeds the discharge line with substantial varying 'lumps' of high density now, low density then. The discharge pipeline accumulates these differences and has a certain flattening effect, so one can speak about 'average density in the pipeline' with a certain pretence of saying the truth – if nobody does forget that this 'average' contains a lot of 'noise' yet.

Now assume the process generally running in balance on nearly nominal power, however a gradual and slow increase of average density is growing in the pipeline. Production increases as do required pump speed and power, however without alerting the operator (who cannot observe these parameters for so long time) until one of them reaches its maximum value. Now the pumps cannot longer maintain mixture velocity. Loss of production occurs, and if the dredgemaster is not very alert to this phenomenon, mixture velocity approaches critical velocity, the value at which settling in the pipeline starts, narrowing the pipeline cross-section and so even initiating the risk of clogging. The only thing the dredgemaster now can do is stop swinging. This action will decrease input mixture density and so decreases total average mixture density in the pipeline. The operation would succeed most times if not unfortunately spoiled by another physical phenomenon: if density in a dredgepump body decreases, its output pressure also decreases by definition, which in its turn has a fresh decreasing effect on the flow in the discharge line. So, with a little bit of bad luck, such a rescue operation can become the gateway to disaster – meaning total clogging of the discharge line. This effect is clearly shown in *figure 11* at approximately 8 800 seconds. Anyway, an entire loss of production for the subsequent 15 minutes or so is also evident from this practice-originated graph, as density drops to 1 000kg/m^3, meaning: one is pumping clean water. In conclusion one may say that the actual control task simply cannot be done by man properly. DEME's engineers believed that performance could profit from the application of more sophisticated control, and started looking for an algorithm with the assistance of IHC Systems.

A new generation-ACC

IHC Systems already had developed a new generation of their automatic cutter controller during the building stage of Dredging International's 26,100kW self-propelling cutter suction dredger d'ARTAGNAN in 2005. Two factors favoured development of this new generation. First, IHC Systems and Dredging International have a long track record of cordial co-operation in developing presentation and automation of trailing suction hopper dredgers. And second, as Dredging International had not invested in new-building of large cutter dredgers for nearly twenty years, their engineers were not bound to any control or presentation 'tradition' and could open-mindedly co-operate in things that are really innovative. In this way an ACC came into existence in which brand new presentation concepts were integrated, as well as considerable enhancements in control techniques, for example improvement of adaptive control by application of Extended Kalman Filters. All these new developments were of course built on the proven IHC Systems control concept of PLC's for data gathering and process control, SCADA packages for presentation and adjustments, models and mathematics running under a higher language.

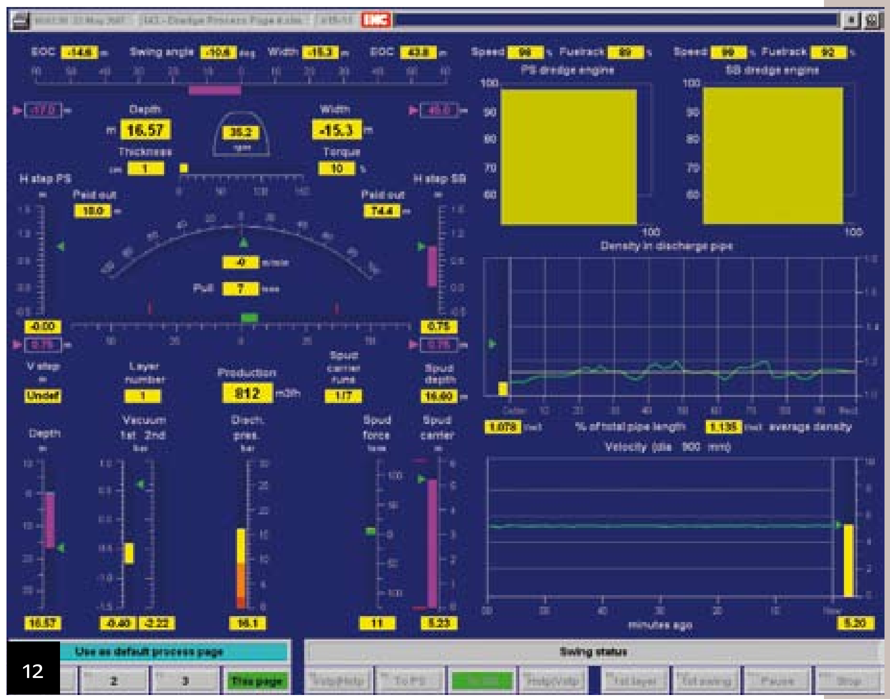
With this new generation ACC, IHC Systems had available a basic platform for meeting the Sepetiba control challenge. The SCADA image (*figure 12*) clearly shows the evolution in thinking on presentation during last years, which may be described as much more thinking from the process and from the operator's data capturing and processing capacity, than thinking from what happens technically. This development is only at its beginning in the dredging world, and one may expect a lot of further innovations in this field in the coming years. After all, the real impetus of innovation is the close co-operation and mutual trust between any party involved in applying a product or system, in this case between IHC Systems and their respected partners in the dredging world.

An (artificial) intelligent solution

Engineers realized that in relation to required pump power there is one decisive parameter corresponding to any given mixture velocity in the pipeline. They called it *maximum allowed density*, applying this term on *average* mixture density in the pipeline. Now this average density is relatively easy computable, could even be calculated for any desired pipe-piece in the trail, based on IHC Systems' integrated velocity/density measurement aboard VLAANDEREN XIX. Unfortunately not so with the *maximum allowed density* and the critical velocity, as these parameters depend on pump and pipeline behaviour, that is to say: on average grain size (d_{50}) and pump wear. Should it be possible to calculate these values online, then *maximum allowed density* would be available as a setpoint for the ACC which then could control swingspeed in order to supply the pipeline with just that 'lump' of density that keeps the average mixture density exactly at the desired value corresponding to instantaneous mixture velocity, optimum production and optimum utilization of available pump power.

Now an exciting new element was introduced, called Artificial Intelligence, commonly abridged AI. One definition of AI runs as follows: *"AI is the sub area of informatics in which computer programs are developed for the execution of tasks which – as was common belief ten years ago – exclusively require human intellect."* (N.J.I. Mars, University of Twente, The Netherlands). More understandable for common people and all together more specific, one can say: *AI is that kind of computer programming that tries to urge computers 'reasoning' instead of computing.*

Well, IHC Systems did just that. After first analysis it became clear that three important process parameters in the Sepetiba pumping chain could not be calculated, nor be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approached mathematically with any kind of accuracy. These parameters are: *density influence on pump pressure, dredgepump wear* and *average grain size*. IHC Systems' employees gave birth to the clever idea of obtaining these parameters by reasoning, i.e. by developing software that could estimate them *online*. Naturally, in order to get clear *what* was to be estimated, they necessarily had to develop two ingenious mathematical (!) models first: a *pump model* and a *pipeline model*. It is fascinating stuff.

- The basics for the pump model are the well-known calibrated Q-H diagrams, empirically taken at pumping water instantly after construction of the pump. Any deviation of this characteristic would originate from pump wear and density influence, so was the logic. Now, pump differential pressure is function of the flow through the pump and pump revolutions, values which are available on board as well as is the density in the pump, which can be derived from the density measurement and the time span within which the measured 'lump' passes the pump itself. So these three measured values are imported. Then the model can exactly predict the theoretical pump differential pressure at any time, and …. any deviation of this predicted pressure from the measured pressure value is assigned to two postulated unknown factors, a density influence factor f_{solids} and a wear influence factor f_{wear}. The mentioned deviation is fed to two Extended Kalman Filters (EKF), which are able to filter non-linear signals without the perpetual dilemma of more common filters: either unwanted phase shift, or unwanted damping. Moreover both EKF's by definition calculate their own gain factors, which in turn are indicators for exactly the online values IHC Systems was so eager to estimate: f_{solids} and f_{wear} ! Besides, due to configuration and mathematics of an EKF, after a number of measurements it will come more and more close to the real values of the estimated parameters. This point is called steady state, and the phenomenon is named adaptivity.

- A similar ingenious procedure was followed to 'cook' an *online* estimator for the grain size. Pipeline resistance – which is expressed as a pressure value – depends on some known factors as pipe diameter and – length, some measured values as mixture density and velocity, and … on the big unknown: average grain size. A mathematical model in which the average mixture density is imported, gives theoretical mixture flow and pipeline resistance as results. Both values are compared to their empirical values, fed to their own EKF and, applying Jufin-Lopatin equations for pipeline structures, two new estimations come out: the average grain size d_{50} and the critical velocity v_{crit}, again two parameters so desperately looked for. Again adaptivity.


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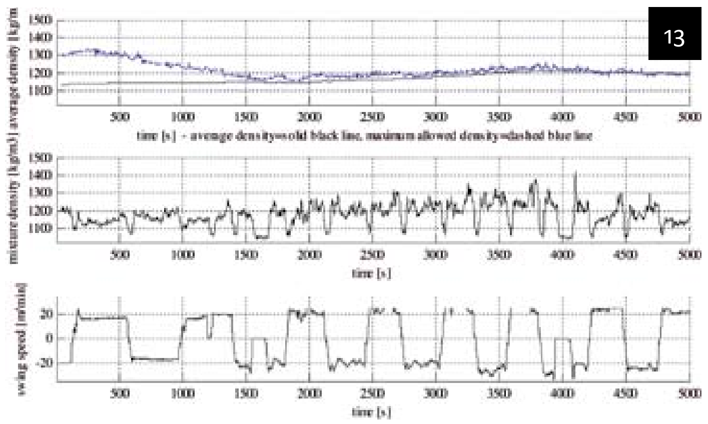
With the availability and adaptivity of these estimated parameters, any aspect of the pumping process has been fixed and it is to expect that really stable pump control shall be possible for the whole chain. Well, it is – and it is not only *possible*, it is *magnificent* as can be seen in *figure 13* and *14*! These graphs, sampled in Sepetiba practice, clearly show that IHC Systems succeeded in solving the control problem. After a



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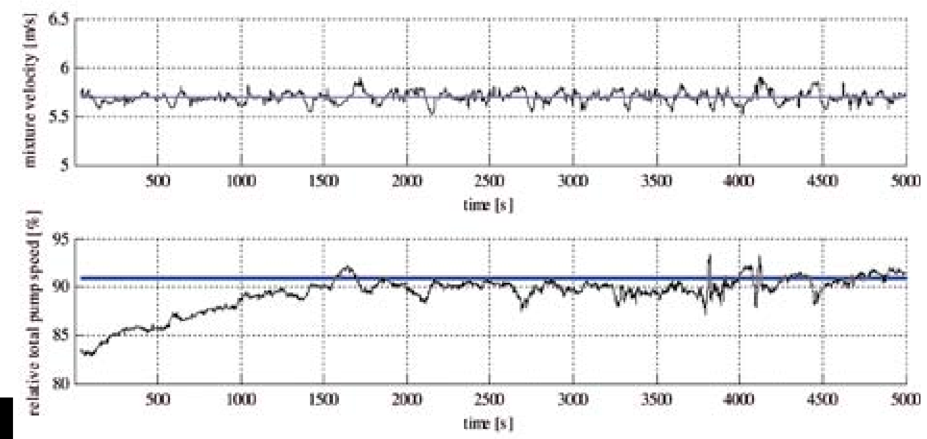
'learning-process' of about one hour only, the control system stabilizes maximum allowed density and mixture velocity within a few percents. Another (not-shown) graph tells the same story on discharge pressure.

Now the greatest challenge can be addressed. Once it is possible to maintain reliable mixture density, -velocity and pressures in the pipeline, control margins grow considerably and attention can be given to optimization of *production*. For this purpose IHC Systems loaded an extra software shell around cutter control, mathematical models and estimators, aimed on maximizing production, and taking into account pump limitations such as maximum pump power, pump torque, pump speed, pipeline pressure, system wear and so on. Once having available these estimations and pump limitations, production can automatically be increased by manipulating the setpoints for mixture velocity and maximum allowed density. So the simple outcome of the whole story is only a set of two setpoints aboard of VLAANDEREN XIX.

In *Ports and Dredging 153* (IHC Holland, 2000) P.M. Vercruijse demonstrates that prediction of the solids effect on pump and pipeline characteristics with the assistance of common mathematical models such as Stepanoff & Wilson, Durand & Coriolos, Giber, and Fürböter almost immediately show deviations of 20-50% from reality. And he stipulates the problem that these insufficient mathematics tend to cause "… conservatism in the design and operation of hydraulic transport installations, which, for instance, may result in unnecessarily high capital and operating costs resulting from the installation of excessive pump power …"

Well, the course of this article shows that such *real* problems in the dredging world can innovatively be solved if people/companies involved are dedicated to join forces, go with each other and work innovatively in mutual trust and appreciation.



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12 SCADA image of new generation ACC main presentation page

13 Artificial Intelligence-controlled mixture density against swingspeed at Sepetiba

14 Artificial Intelligence-controlled mixture velocity against pumpspeed at Sepetiba

15 SCADA image of VLAANDEREN XIX's pump- and pipeline process page

Lighthouse,

the development of the next generation of double-walled pumps

One of the most important components of the dredge system is the dredge pump. The IHC Merwede double-walled pump is installed in many ships. Over the past year a new design for the outer casing of the double-walled pump has been developed: the Lighthouse.

Double-walled pumps are fitted with an external pump casing which allows the internal pump casing to be made of extra wear-resistant material. The outer pump casing serves as a support structure for the inner pump casing. This means a larger part of the inner casing is available for wear losses. The outer casing also offers optimal security. In case of fracture of the internal pump housing due to excessive wear or a sudden fracture, the outer housing prevents flooding of the pump room. To allow easy access to the wear parts inside the pump, the outer housing is split into two parts (*figure 1*): the cover plate and the outer casing.

Goals

In project Lighthouse, IHC Merwede did not look at the pump as a separate entity, but rather as an integral part of the ship's dredging system. Challenging goals were set in order to generate the 'outside the box' solutions desired:

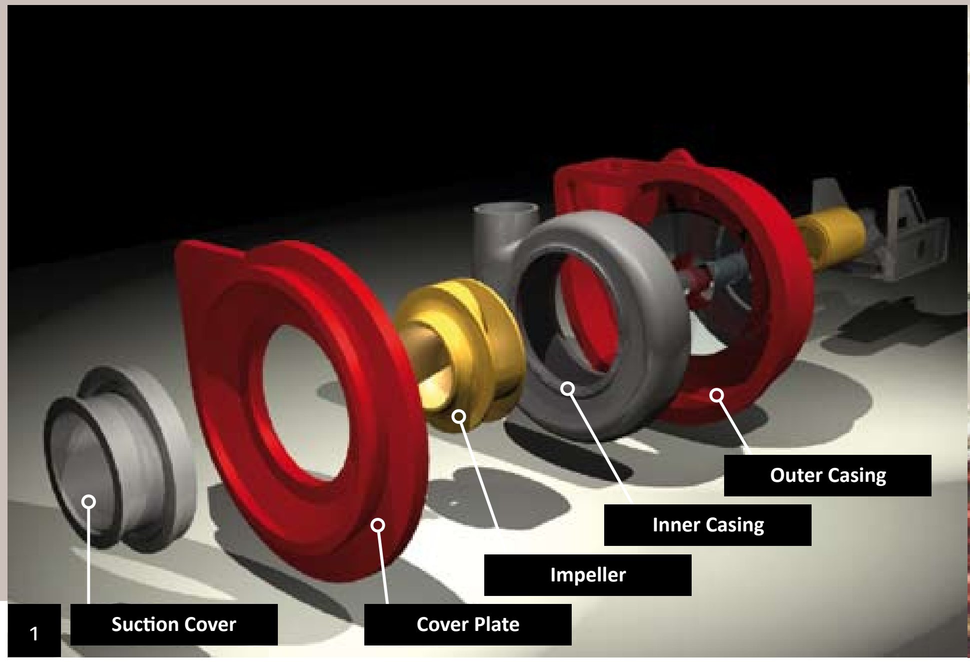
- outer housing mass reduction of 50 %
- significant Reduction of build-in length
- significant Reduction of replacement time for the wear parts.

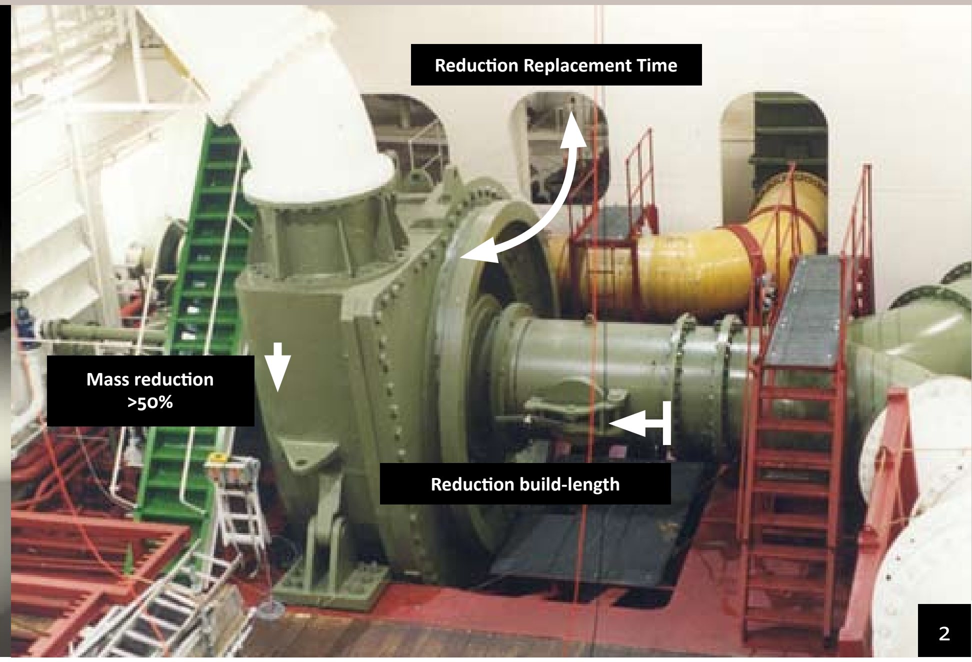
The design was based on the 262 pump in order to allow for comparison of different concepts goal quantification. This pump has an impeller diameter of 2,620mm and is one of the largest pumps available and is used on the NILE RIVER and HAM 318, among other places.

Expanding expertise

Due to the functional division in the current design of the pump, the outer housing does not come into contact with the abrasive mixture. This means that materials other than steel can be used, for example fibre-reinforced composites. Since the products in the dredging industry are traditionally made of steel, IHC Merwede needed to expand its expertise. In an early phase of the design process, IHC Merwede teamed up with Airborne Composites. Airborne is specialized in developing and producing advanced composite products and systems. They have expertise in the oil and gas industry as well as the marine industry, and proved to be an ideal partner for the development of a new type of outer casing.

In the marine industry, the use of reinforced composites is relatively new. A fibre is embedded in a synthetic material, called the matrix material. Depending on the requirements, different fibres can be used, for example glass or carbon fibre. The resulting material is well suited for a tension driven design. Specific material properties can be achieved by orienting and concentrating the fibres in a specific way and selecting the right matrix material. By taking advantage of these properties structures much lighter and stronger than steel can be created while maintaining the same stiffness. The use of reinforced composites also allows the creation of shapes and forms not possible in steel.





1 Definition of the parts in a double-walled dredge pump

2 Goals of lighthouse

3 Several different concepts

4 Spiral shape as a solution for opening

5 Impression of the lighthouse

Systematic Analysis

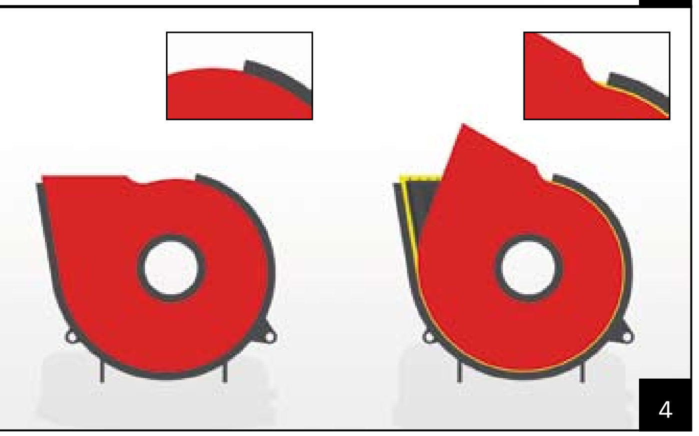
To provide a structured approach for concept generation and to widen the search area for solutions to the design problem, the different functions of the outer housing were defined, namely:

- providing access to the wear parts
- supporting the inner casing
- connecting the two parts of the casing
- watertight sealing of the outer casing parts.

With these functions in mind, several concepts were defined (*figure 3*). The systematic approach used in this project helped to find combinations of 'sub-solutions' that have not previously been identified.

Concept selection

The concepts illustrated in *figure 3* were elaborated in detail and consequently evaluated using a pre-defined set of criteria. The concepts differ in complexity and all have their advantages and disadvantages. Only one concept was selected from this study. In the selected concept, the spiral shape of the pump is used to open the casing. This opening mechanism, as illustrated in *figure 4*, significantly reduces the number of bolts. This allows the case to be opened much faster. Speeding up the cover opening procedure eliminates, the need for a separate suction cover. This results in a reduction of build length and a further mass reduction.



The Concept

Below (*figure 5*) is an impression of the final result of the Lighthouse project. In the final design, glass fibre is embedded in a thermosetting plastic. Some critical parts are further reinforced by carbon fibre. The stiffness of this design is comparable to the traditional steel housing. A special seal system is used to create a watertight seal between the two casing parts. The advantage of this sealing mechanism is that no pre-tension is required. The cover plate is guided by a support frame to ensure a correct alignment and to shorten replacement time.

This design accomplishes a mass reduction for the outer housing of over 70%. Additionally, both build length and replacement time are reduced significantly. Three patents are pending for the lighthouse design. In addition to the spiral shape, the construction method used for the reinforced composite housing and the fibre-reinforced cover plate are patented.

The Benefits

The benefits of reductions in mass, build length and replacement time of the lighthouse can be illustrated using the following examples in which the lighthouse is installed on a 12.000m³ trailing suction hopper dredger and a medium-size cutter dredger.

- Sand is very abrasive, therefore the wear parts need to be replaced frequently. The reduced replacement time will improve the uptime of the hopper. Furthermore, when dredging sand the load capacity is mass-limited. Every ton saved in mass is a ton of additional load capacity for the dredging ship. The return on investment for the lighthouse in this case is expected to be less than one year.

- Silt is much less abrasive than sand. Therefore, the reduced replacement time will have no significant effect on the uptime of the hopper. Also, the load capacity of the hopper is not mass limited, but volume limited. Therefore the mass reduction will have no effect; the reduced build length, on the other hand, does have an effect on the load capacity. If the build length is reduced by only one frame, the length of the hopper can be increased by two frames due to the equal load distribution. The increase in hopper capacity results in an expected return on investment of less than five months.

- For a medium-sized cutter suction dredger in continuous operation in sandy or rocky soil, the mass reduction and the shorter build length will have no effect on the production. The cutter will have a reduced downtime due to the reduction in replacement time for the wear parts. As a result, the return on investment will be less than half a year.

The next step

The development of the lighthouse into a mature product is ongoing. The first step is a full scale test of the most critical parts. A conventional double-walled pump will be adapted for the new reinforced composite cover, including the spiral closing mechanism. This will give us a chance to study the behavior of the most critical part of this product under dredging conditions.

IHC Merwede has acquired an enviable wealth of practical experience and technical know-how when it comes to the design, manufacture and maintenance of pumps for dredging. The combination of theoretical knowledge and practical experience and the cooperation between IHC Merwede and Airborne Composites has yielded the desired result: a much lighter pump with a shorter build length and a shorter build time. These improvements result in uptime and capacity gains. Requirements that ultimately lead to a substantial gain in overall output and, consequently, a reduction of exploitation costs.