LATEST DEVELOPMENTS IN VOSTA LMG SUCTION SYSTEMS

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ABSTRACT

This paper outlines latest developments in suction systems, focusing on various types of high efficiency/performance dredge pumps, standardization, and local manufacturing of parts. The increasingly strong demand for dredges has created the need to provide reliable and standardized suction systems with short delivery times. For the application of most modern/state of the art designed dredge pumps in high-performance suction systems, local manufacturing in the country of customer provides the benefit of sourcing at reasonable prices.

Dredge pumps, which can either be single or double walled, are the center unit of the suction system and the key to top dredging performance. By applying a gap sealing, including a newly developed adjustable liner on the suction side, suction performance can be improved. Movement of the liner in direction to the impeller nose provides a constant minimum of gap. At the same time, a new compact seal for suction sealing systems is developed and in operation.

Even under highest operating pressure, the lifetime of double walled dredge pump is increased because of smart pressure compensation between inner and outer casing. Standardization of parts for all types of dredge pumps is applied for shell, impeller, liner, shaft and bearing housing, with the objective to reduce the number of dredge pump parts, to enhance interchangeability, to safeguard shortest delivery time and delivery from stock, and effectively, to lower operating costs.

Keywords: Dredge pumps, lifetime, sealing systems, standardization of parts, interchangeability

INTRODUCTION

Over the last decade, the world dredging fleet has experienced a continuous and accelerated growth. New techniques and design tools have improved dredging and sailing performance dramatically, reducing cost during dredges' lifetime. An enormous increase in new building activities for all types of dredges, especially in the so called low cost regions (e.g. the booming markets in China and India which generate potentials for dredging technology), triggers questions about the development of state of the art dredging technology as well as dredging equipment.

For decades, VOSTA LMG has been implementing dredging technology and dredging equipment into dredges in foreign yards worldwide. By combining local resources in shipbuilding with high quality dredging equipment, cost-efficiency and profitability of various types of dredges have been improved.

Suction systems including high performance dredge pumps with variable drives are key in ensuring best dredge performance. Double walled dredge pumps are increasingly used in situations with high operation pressure; highly wear-resistant material is applied to increase the lifetime of the dredge pump's inner casing.

Furthermore, VOSTA LMG has developed a new dredge pump suction side, resulting in a design with an adjustable throat liner which is moveable by a hydraulic pump in combination with a highly flexible pressure hose in front of the dredge pump. Adjusting the throat liner to a minimum gap regularly provides for a more stable suction performance.

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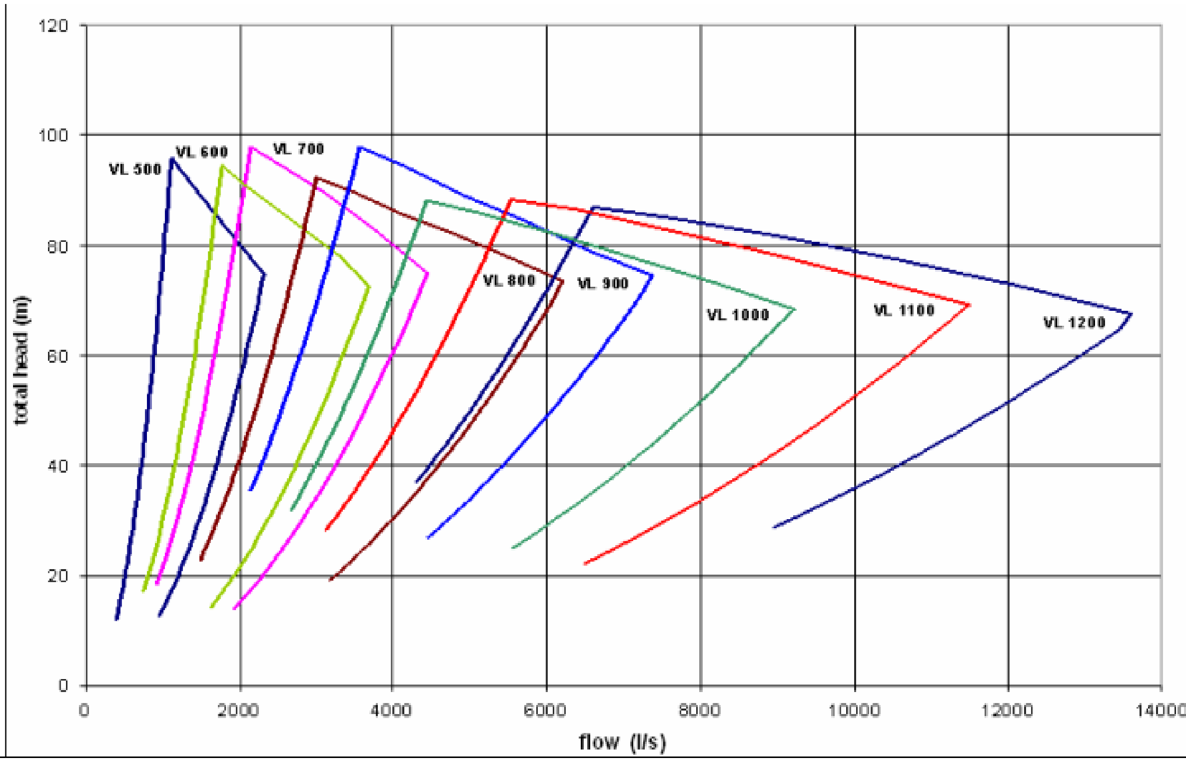
Following market trends and requirements, a new dredge pump line was developed, focusing on standardization of dredge pump parts for multipurpose operation, usable for Trailing Hopper Suction Dredges and Cutter Suction Dredges, as well and considering local manufacturing /casting of dredge equipment.



SIZES (related to inlet diameter D1)

500 550 600 700 750 800 900 1000 1100 1200

Figure 1. VOSTA LMG pump selection chart.

NEW STANDARD DREDGE PUMP LINE

Based on long term experiences in design, construction and operation of dredge pumps, VOSTA LMG has developed a new dredge pump line focusing on various sizes in standard application. Goal of this development was to create multipurpose types to fulfill different requirements for operation in TSHDs and CSDs as well. CFD (Computer Fluid Dynamics) analyses were carried out to optimize the casing and impeller for both applications.

Results

- High efficiency over a wide flow range
- Low NPSH (Net Positive Suction Head)
- Lowest energy consumption
- Minimal wear

Optimized operation points can be achieved by using flexible drive systems for submerged dredge pumps placed on a cutter ladder or on side suction pipes, as well as for inboard dredge pumps driven by speed regulated motor

Standard Dredge Pump, Single Wall

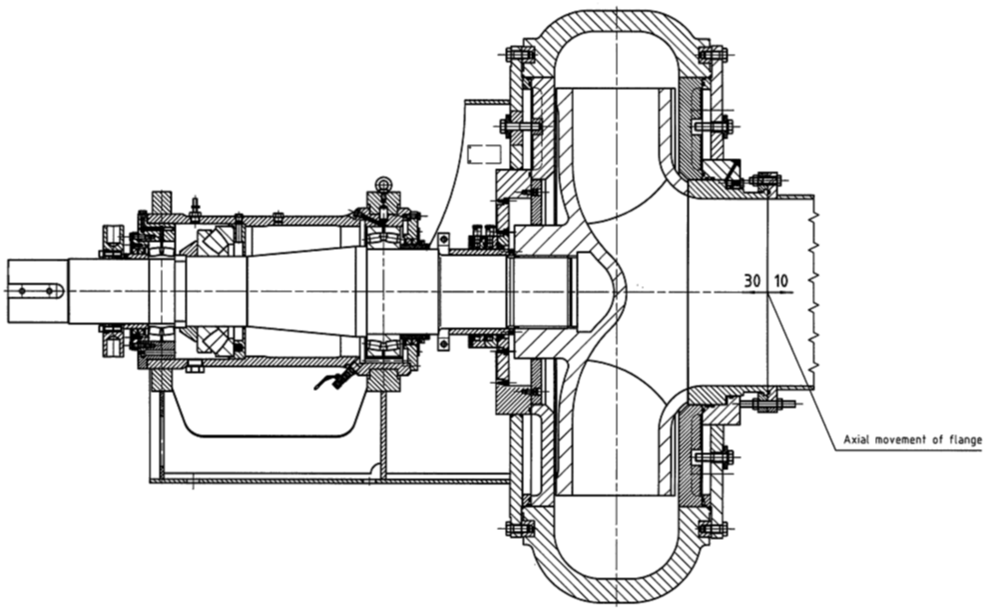


Figure 2. Cross section of a standard single wall dredge pump with identical hub and suction linerand with an adjustable throat liner.

Standard Dredge Pump, Double Wall

Double walled dredge pumps are used for powerful TSHDs and CSDs in order to work efficiently under high operating pressure up to 30 bars outlet pressure. To increasing lifetime for the dredge pump inner casing high wear resistance material with HRC 55 - 63 has to be used. This can be achieved by providing a compensating pressure in the space between outer and inner casing. In addition to minimizing the loads on the inner casing, the wall thickness of the inner casing can be worn down completely.

Normally the wear and following loads of used material limit the maximum operation pressure of dredge pumps. Limitation occurred by using so called weak material with higher percentages of elongation. Since the loads on the inner casing are minimized, extremely hard material – high wear resistance – can be used.

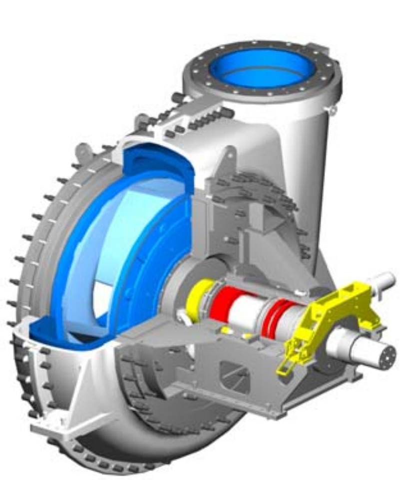


Figure 3. Double wall dredge pump, shaft side.

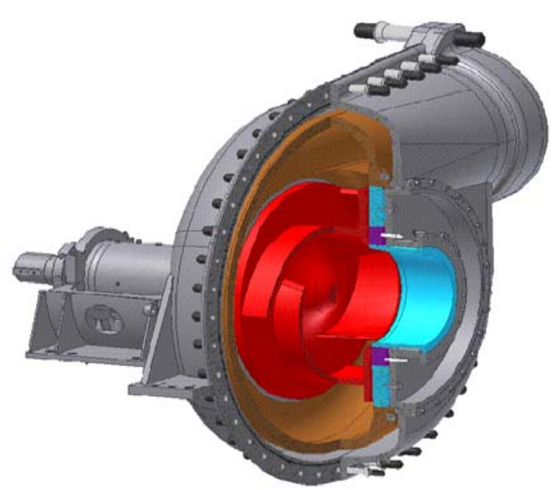


Figure 4. Double wall dredge pump, suction side.

Outer Casing

Figure 5. Double wall dredge pump during assembling of inner casing.

Design Criteria

Decades ago, VOSTALMG started a development program "design of optimized double wall dredge pumps".

Target	Gain
Minimization of pump weight	Reduction of pump price and easy maintenance
Minimal pump size (allowing deepest location of pump on dredge)	Optimization of the suction performance
Maximum stiffness/minimal deflections of suction/shaft cover	Optimization of suction/shaft seal function
Minimal number and size of bolts, and other parts	Optimization of handling of pump parts
Minimization forces to inner casing	Optimization of lifetime of inner casing

Requirements Concerning the Strength and Stiffness

The following strength requirements are checked and optimized with the aid of FEM calculations.

1. *sufficient strength*: Sufficient strength is necessary for withstanding all the acting main loads during normal operation and possible peak loads during non-stationary operation.
2. *minimal system deformation:* Minimum system deformation is required to realize minimum deflections of the pump covers on suction- and shaft side. Minimal deformation contributes significantly in increasing the lifetime of the seals on suction and shaft side
3. *symmetrical system deformation:* Symmetrical system deformation is required for a proper function of the suction- and shaft seal, for the same reasons mentioned in the previous item.
4. Non-symmetrical deformation results from a non-symmetric shape of the outer casing, which encloses the inner casing with a constant distance. Furthermore a constant wall thickness will lead to non-symmetrical deformation as well, due to the fact that during nominal operation the pressure forces are lower at the beginning and higher at the end of the spiral shape.

Results FEM Calculations

Some of the FEM calculation results, calculated for a maximum operating pressure of 28 bar, are shown here

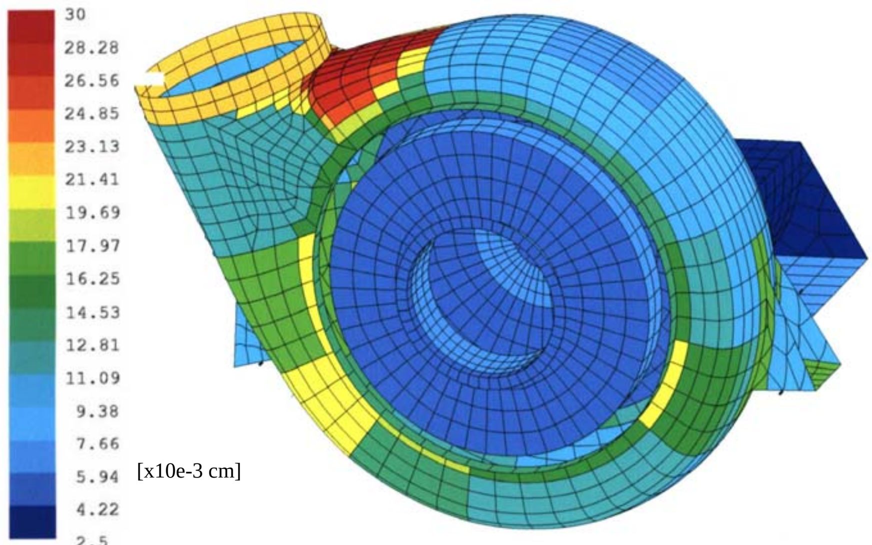
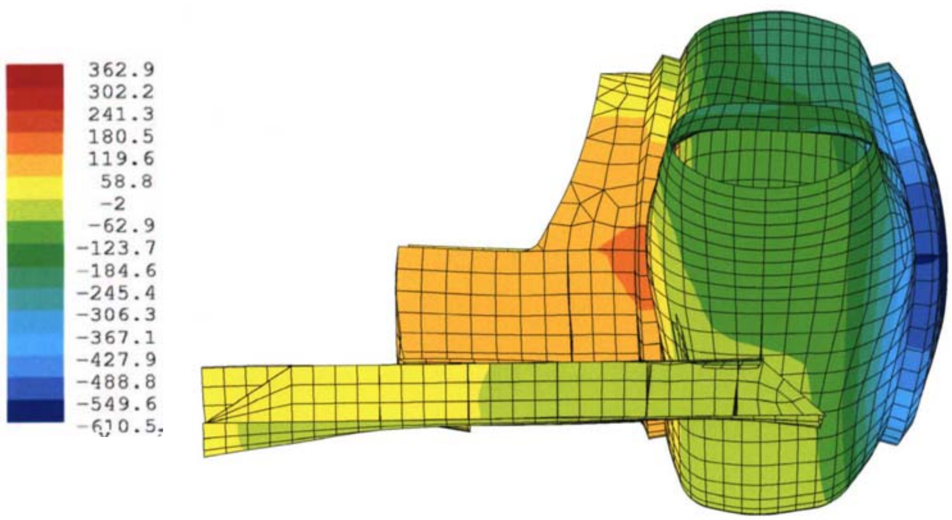


Figure 6. Wall thickness variation on suction side.



[x10e-3 N/mm²]

Figure 7. Deformations side view (dimension in μm).

STANDARDIZATION OF DREDGE PUMPS

Standardization of parts for submerged dredge pumps, as well as for inboard dredge pumps in single wall or double wall design are executed for shell/inner casing, impeller, liner, shaft and bearing housing complete, with the objective to reduce the number of dredge pump parts, enhance interchangeability, safeguard shortest delivery time and delivery from stock, and effectively, realize lower operating costs.

Main Targets

- max. reduction of dredge pump parts
- minimum of main assembly groups
- interchangeability between those groups
- reduction of cost price
- shortest delivery times
- delivery from stock
- improved market position

The objective of this R&D project was to reduce the number of main components, in order for dredge operators to be able to employ equally sized dredge pumps with identical components, as well as differently sized dredge pumps with identical components for their various equipment. Maximum possible performance parameters were to remain the same.
Size and model variety was considerably reduced by optimising the interaction between the casing and rotor discs, as well as the respective adjustment of the outer shell casing, resulting in a distinct cost reduction for the required components, especially for wear parts for first delivery as well as spare parts.

Further, it should be noted that it is not mandatory to employ different dredge pumps for different operation requirements. Specially designed suction systems/ dredge pumps that meet specific requirements are available for any application.

In addition to this new range of standardised dredge pumps, the following types of dredge pumps were further developed:

- submerged dredge pumps with impeller in semi axial design
- inboard dredge pumps for high pressure applications usable in serious operation
- inboard dredge pumps with improved suction performances
- dredge pumps with long term lifetimes for the wear parts

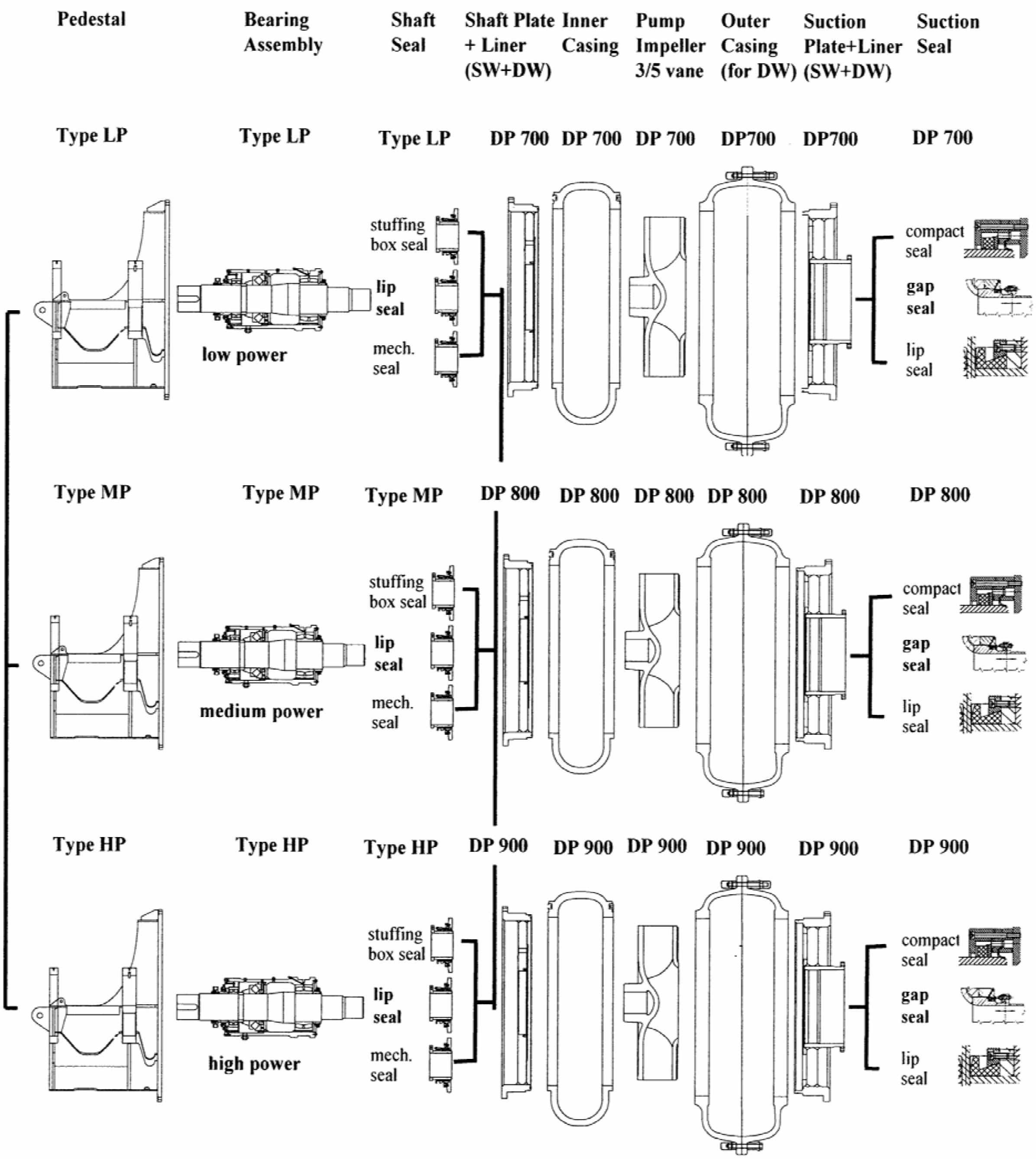
Not only the equipment itself, but also the purchasing and sourcing function of parts and components as well as raw materials is playing an increasingly important role, which has also affected the development and standardisation of dredge pump components: In order to manufacture and source globally, a less complicated dredging technology is encouraged.

This is especially true for the new design of casing and rotor disc components which are to be manufactured/ casted from different materials in different geographical regions.

INTERCHANGEABILITY

For a fast reaction to market requirements the development of standard components for dredge pumps is more and more important to offer alternatives acc. to special customer requests without changing the standard pump design. For standard parts suitable for mounting in several pump types, especially the so called “mechanical parts” are adequate as complete pump bearings with pump shafts, shaft seals and bearing pedestals.

The wear parts, as pump impeller, pump casing and covers and all type of suction seals are suitable for the special pump size only. This modular concept of dredge pump standard parts is shown in detail in the following. This concept is made for pumps in single (SW) and double wall version (DW) with alternatives as shown below (for lower or bigger pump sizes it is provided accordingly).



Main Features:
- shaft/suction seal acc. to customer requirement (standard version in bolt print)
- material of wear parts acc. to customer requirement (weldable, high wear resistant, rubber lined)
- pump impeller in 3/5 vane version (adjustments of impeller diameter acc. to special requests)
- liner at suction and shaft plate identical at standard pump design (adjustable suction gap seal)
- pumps available in clockwise and counterclockwise rotation
- single wall dredge pumps designed up to a max. pump discharge pressure of 12 bar
- double wall dredge pumps designed up to a max. pump discharge pressure of 30 bar

Figure 8. Interchangeability of dredge pump components.

NEW SEALING SYSTEMS

For fulfilling the increasing requirements regarding availability, lifetime, and maintenance of dredge pumps, the most important factors are not only to realize high efficient pump performances with a minimum of wear, but in addition the lifetime and reliability of sealing systems become more and more important. Experience in the application of different existing sealing concepts has shown that the systems in their original version as standard delivery of appropriate sealing suppliers are not suitable for the use in dredge pumps.

The operation of sealing systems in dredge pumps is significantly different from the use in standard pumps. Especially the abnormal wear of all parts are in contact with the flow medium, not to be avoid complete also for components of the sealing systems, the special load affecting the pump shaft and pump casings, as a result of vibrations and shocks are to be taken into consideration at a sealing design for a dredge pump.

Due to the lack of experience with regard to the appropriate sealing suppliers, and the fact that a sealing design based on the theoretical knowledge only is not enough to be applied in real conditions, a test under realistic conditions is definitely necessary.

Unfortunately is it not realistic to make any tests onboard a working dredge pump of an existing dredge, because the reliability of a dredge pump especially depends on the reliability of the sealing systems. This is why it is extremely important for seals to be free of faults.

Therefore a seal test on a test rig in a lab or factory seems to be the best way to verify the operation of a new developed sealing system. In the past we have also learnt that a test of a prototype seal scaled 1:1 is an essential prerequisite for a safe transfer of the results to the final size, because the deformation of the sealing elements as a result of the total load is depending on its size. Changes of these inner deformations can be significant for proper operation or a damage of a seal in special cases. In the same way the deflections of the main parts of the seal as a result of the deformation of pump shaft and covers are significant as well and also have to be taken into consideration.

So the following general conditions for a test rig design are to be considered:

	scale		
• Size	1:1	for realistic (inner) deformation of parts	
• Loads	1:1	pressures, speeds, etc.	
• Outer deformation	1:1	in axial direction due to	pressure load of pump cover (deflection)
			axial load of pump shaft (bearing play)
		in radial direction due to	radial load of pump shaft (bending, bearing play)

Due to the insufficient design and reliability of the existing test rigs of the appropriate sealing suppliers, a new construction of a suitable test rig with the following advantages has been introduced at the factory of VOSTA LMG:

- Carrying out of prototype tests when ever required
- Carrying out of tests for improvements whenever required
- Direct sales of product forwarding best prices to the customer

Picture 1.2.1 the test rig is shown in detail. Power and speed of drives, and size of casings as well allows to test seals of the following type and size:

1.	shaft seals	shaft diameter	200 up to 600 mm	pressures up to 30 bar
2.	suction seals	suction diameter	200 up to 1300 mm	pressures up to 10 bar

By using this test rig, VOSTA LMG is in the position to test any kind of sealing of appropriate dredge pumps of suction diameter 300 up to 1300 mm

VOSTA LMG Test Rig

Test Arrangement:

- Sealing casing with 2 seals in back to back

- Sealing water system with 1 and/or 2 sealing pump pressure up to max..30 bar
- Pressure regulating system
- Sealing casing adjustable in height for simulating radial deflections
- Sealing casing adjustable in length for simulating axial deflections

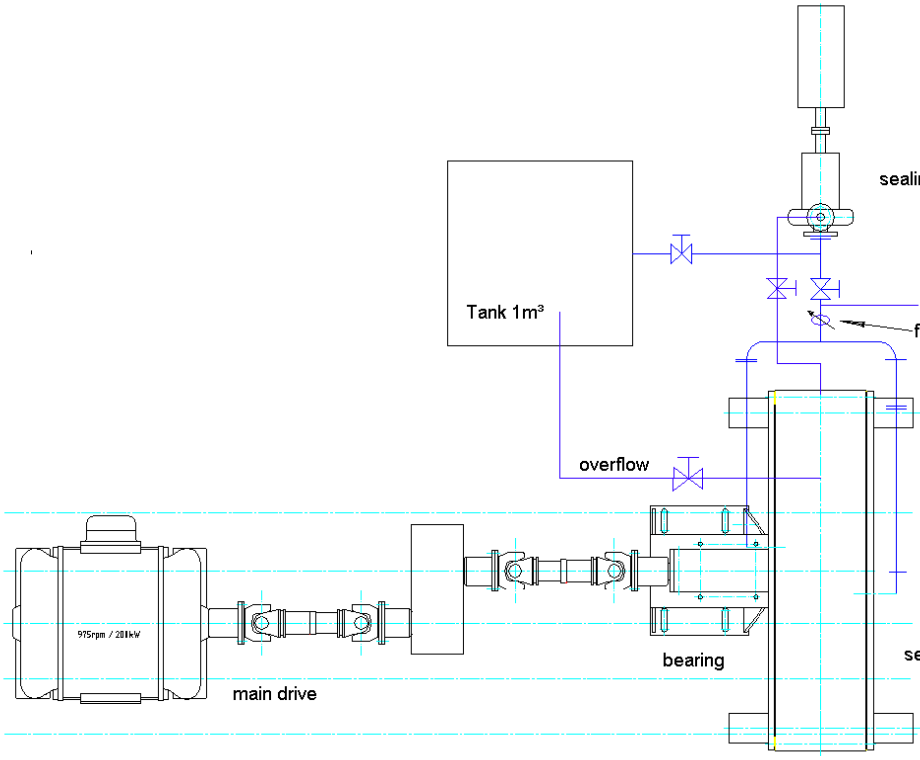


Figure 9. Test rig for sealing systems.

Measuring systems:

Speed and Power measuring system

- Sealing water flow measuring system for measuring leakages
- Pressure measuring system
- Automatic Measurement storage system

Shaft Sealing HYDROSEAL

Design Philosophy
- working free of maintenance
- highest operating pressures, pump speeds
- existing shock and pressure loads
- maximal radial and axial shaft deflections
- minimisation of pump efficiency loss
- maximisation of lifetime
- optimisation of handling

Operation Conditions

pressure:	0 - 30 bar
velocity:	0 - 10 m/s
load factor:	0 - 300 bar x m/s
radial deflection:	2 mm maximal
axial deflection:	10 mm maximal

In the diagram the leakage and power consumption of the seal as function of the load factor is shown. This factor is chosen as a characteristic value giving the load of any kind of seal, calculated by the circumference speed multiplied with the pressure at the seal. The two curves (brown and blue) are showing the differences between the starting and final design of the seal.

For realizing this the design (shape and material) was improved step by step to optimize the power consumption and lifetime of the seal. As shown in the diagram a certain leakage for cooling and lubrications purposes has to be guarantied over the whole operating range.

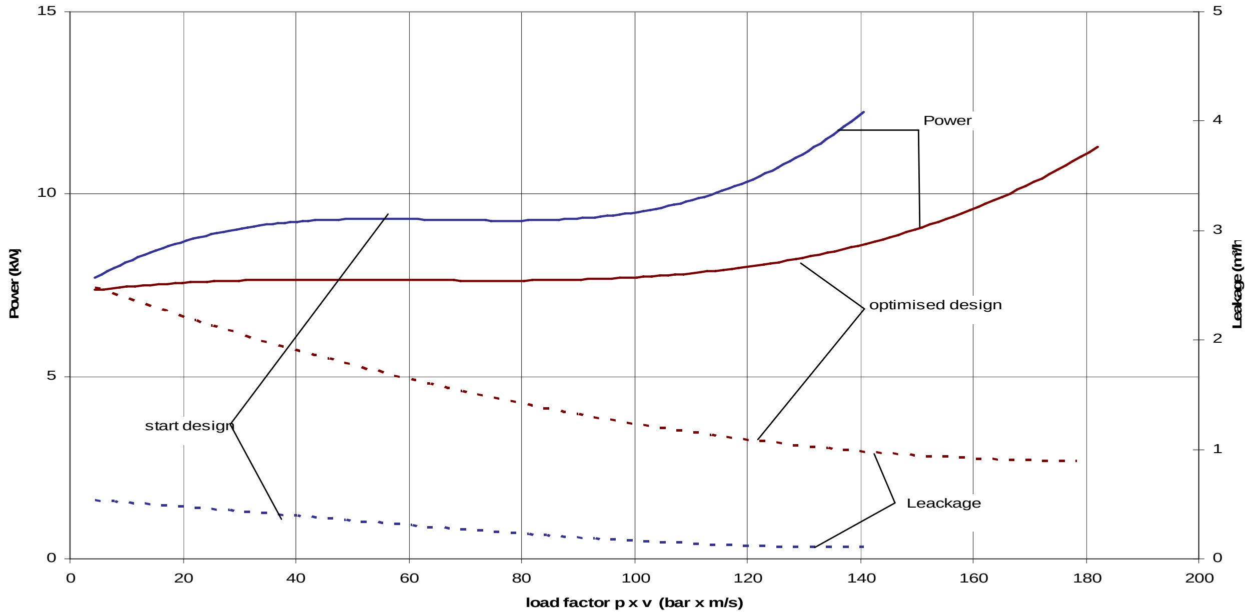


Figure 10. Test results.

SYSTEM	HYDROSEAL
pressure limit	**300 kPa**
circumferential speed limit	**10 m/s**
nom. radial deflections	**1,5 mm**
nom. axial deflections	**10 mm** limited by liner profile length
lubrication of seal	**Leakage** due to special liner design
power consumption	**Low** due to - minimisation of friction
leakage	**Low** due to - optimisation of shape liner surface
pump efficiency	**Loss below 0,3%**
cost of seal	**Medium** due to - rubber lips seals - profiled shaft sleeve in stainless - steel with hard lining - low weight and number of parts - auxiliary flushing water equipment
safety against radial deflections due to shock loads	**0,5 mm** (exhausting the max. nominal deflection of 1,5 mm) - support rings with big gap to liner shape of rubber lips steep
lifetime	**High** due to**:** - high thickness of rubber lip seal - high wear resistance of liner - low leakage (low flow of particles)
sensitivity against shock loads in general	**Low** due to restrictions regarding - shaft deflections (radial and axial) - big thickness of lip seal
auxiliary equipment	**Low quantity** of clean flushing water required

Suction Sealing Compact

Design Philosophy Suction Sealing
- working free of maintenance
- highest operating pressures, pump speeds
- existing shock and pressure loads
- maximal radial and axial shaft deflections
- minimisation of pump efficiency loss
- maximisation of lifetime
- optimisation of handling

Operation Condition
- pressure: 0 - 10 bar
- velocity: 0 - 20 m/s
- load factor: 0 - 200 bar x m/s
- radial deflection: +/-10 mm
- axial deflection: 30 mm max.

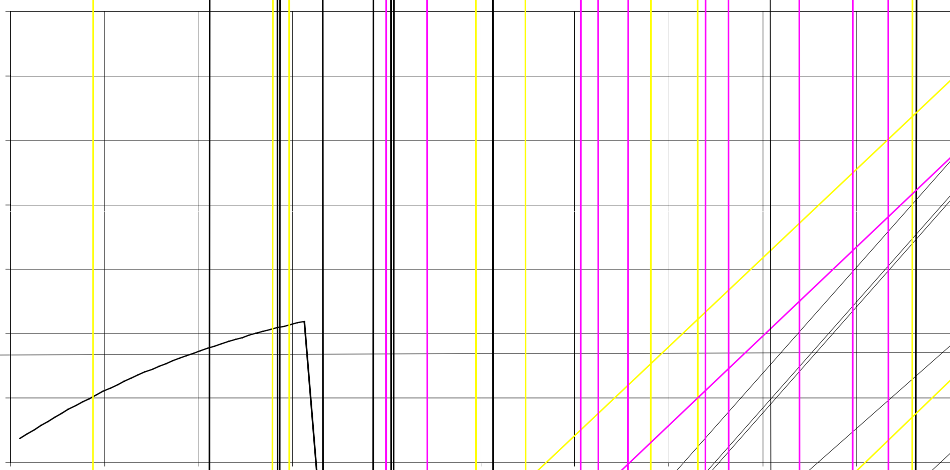


Figure 11. Test results.

Figure 12. Test results.

At the two diagrams power consumption and leakage over load factor is shown separately for different sealing systems. All tested seals are based on elastic sealing elements chosen to withstand the deformation of the surrounded pump parts, in general classified into two working principles (sealing to axial and radial surfaces). The radial compact rubber profile is a new developed seal type and finally chosen by VOSTALMG for standard suction seal due to the following:

- low leakage (high efficient seal with low wear as a result of passing particles)
- low power consumption
- low sensitivity against deformation of surrounding parts

Results FEM Calculation

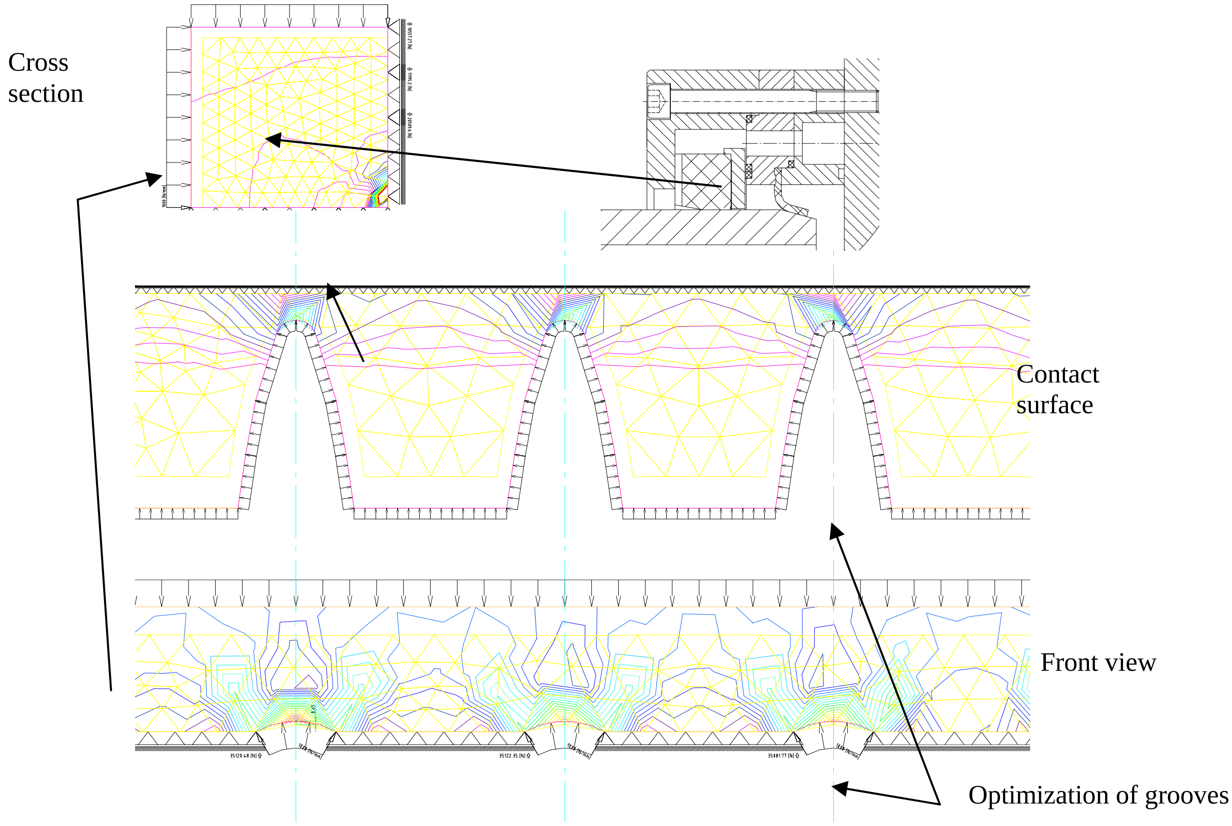


Figure 13. Results FEM Calculation

System	VOSTA.LMG	Conventional (lip) sealing
pressure limit	**100 kPa**	**?**
circumferential speed limit	**20 m/s**	**?**
limit of radial deflections	**10 mm**	**about 1-2 mm**
limit of axial deflections	**low restrictions** only by length of liner	**low restrictions** only by length of liner, evt. groove area on liner surface
lubrication by providing	**hydraulic grooves on the profile**	**hydraulic grooves on the liner**
power consumption	**medium** due to balanced load on surface area	**high** due to pressurising the whole lip area
leakage	**minimal, relative constant at increased wear of rubber profile** due to an optimisation of number and shape of grooves	**medium, decreasing at increased wear of liner** due to the shape of grooves on lip or liner
pump efficiency	**drop below 1%**	**drop above 1%**
cost of seal	**medium** simple rubber profile, liner with smooth surface, additional support ring, secondary seal	**medium** complex shape of seal (using a mould), liner with layer, evt. grooves on the liner, low number of parts
measures against gap extrusion of rubber profile	providing a support ring (radial movable) ⇒ **no limitation of radial offset of pump shaft**	minimising of radial play (rotating/not rotating parts) ⇒ **limitation of radial offset of pump shaft**
lifetime	**high** due to: - compact rubber profile - high wear resistant liner (Nihard/white iron) over whole cross section	**medium** due to: - thin lip seal profile - soft material liner with high wear resistant layer with limited thickness resulting in heavy wear after wearing down of layer
sensitivity against shock loads	**no restrictions** due to high the amount of allowed shaft deflections in radial and axial direction	**restrictions** especially regarding radial shaft deflections
sensitivity against blockages of sealing profile	**low** because sealing profile is not fixed in rotation direction	**high** at blockages sealing will be destroyed

Suction Sealing with Gap and Adjustable Throat Liner

Suction sealing between the rotating pump impeller and suction liner will be used more and more by a gap sealing system, with following advantages:

- minimum number of parts
- easy maintenance
- no flushing water on suction side

Providing this kind of seal a minimum gap width has to be provided all the time to minimize the losses due to the gap flow and to guarantee a maximal pump performance. A continuous axial adjustment of the suction gap has to be realised to compensate the wear between pump impeller and the wear parts at the suction cover. In general there are two possibilities to do this:

- from suction side by shifting the suction wear part
  - o advantage: no movement of impeller, bearing assembly and pump shaft
- from shaft side by shifting the pump impeller
  - o advantage: no movement of parts of suction cover

The adjustment from suction side has the advantage that the gap between pump impeller and shaft cover remains constant after adjustment. So, the amount of sand particles getting into this gap and the water chamber where the shaft seal is located is lower.

The gap on suction side has to be adjusted at the smallest diameter possible to have a maximal effect for minimizing these losses (provides for a minimal free passage for flow losses flowing from pressure to suction side). Unfortunately, at this location, the wear is also maximal due to the mixture passing the gap. The main disadvantage of all existing gap seals on the market is the fact that any adjustment from suction or shaft side will be limited by contacting the rotating pump impeller with parts of the suction cover before the suction gap can be adjusted to a minimum.

The new adjustable throat liner was developed to eliminate this disadvantage, realised by shifting the throat liner only located at the minimal suction diameter (no other parts of the suction cover will be moved!). This will be realised by hydraulic shifting of the throat liner and its locating in any position with the help of fixing bolts.

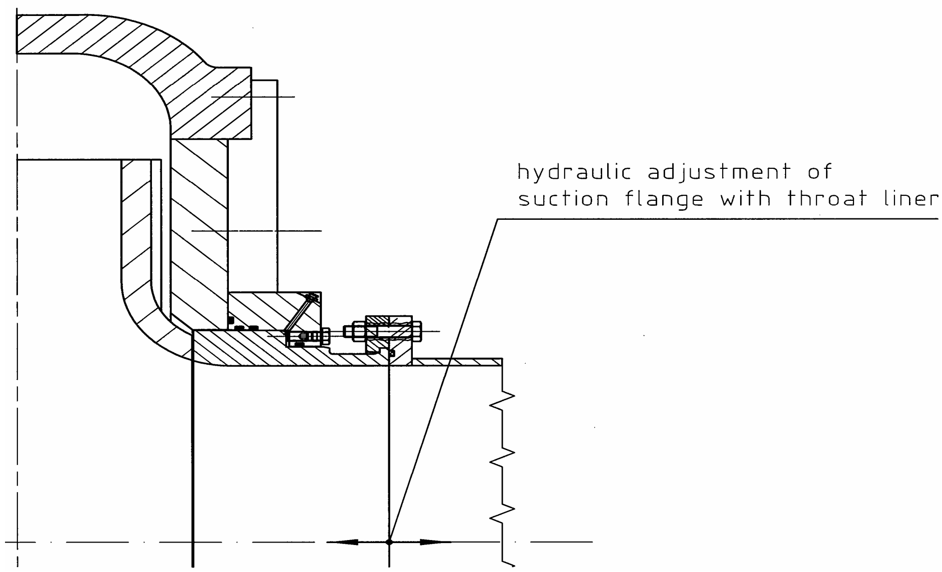


Figure 14. Hydraulic adjustment of suction flange with throat liner.

CONCLUSIONS

In the course of capitalising on opportunities provided by the increasingly global market for dredging technology, VOSTA LMG has increased its level of activities in the growing Southeast Asian markets, especially in China and India, as well as in the Middle East, and has implemented structures and procedures for local manufacturing and sourcing of suction systems/ dredge pumps and related components.

The optimized design for suction systems mainly for multipurpose dredge pumps as outlined in this paper, results in benefits at different levels. Minimisation of the weight, dimension loads and deformation of the inner casing, results in improvement of suction performance and a maximum of lifetime of the wear parts. Among other benefits it is very clear that they directly decrease the costs and increase the overall profit of the end user.

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