Centrifugal dredgepumps

Introduction

This is the first in a series of articles which will appear in successive issues of *Ports and Dredging* and which deal with various subjects connected with centrifugal dredgepumps.

Although the articles have been planned as a series, each will cover a specific subject such as historical development, pump characteristics, pipeline characteristics, etc.

General considerations

The continuous transport of soil through pipelines became possible largely as a result of the development of the centrifugal dredgepump. Its function is to transport a mixture of soil and water.

The feasibility of transporting a substance — in this case a combination of soil and water — by means of a pump is determined by the properties of the substance.

Soil types vary greatly throughout the world, and consequently the demands imposed on the transport operation and the means by which this is realized also differ widely from area to area. The aim in all cases is to achieve the highest possible production, i.e. yield of solids. In an ideal situation, it would be possible to pump sand without water, at a high rate of production and with little or no wear.

In order to achieve continuous production, it is in all cases necessary to pump not only a mixture of soil and water, but also all manner of debris. This fact imposes additional demands on the dimensions and other aspects of the installation, and in many instances such demands affect the flow pattern in, and output of, the pump.

The greatest advantage of the pump installed in a suction dredger lies in the fact that continuous production can be achieved with a single unit. It is true that skilled operators are vital on a suction dredger, but this also applies to other types such as the bucket dredger.

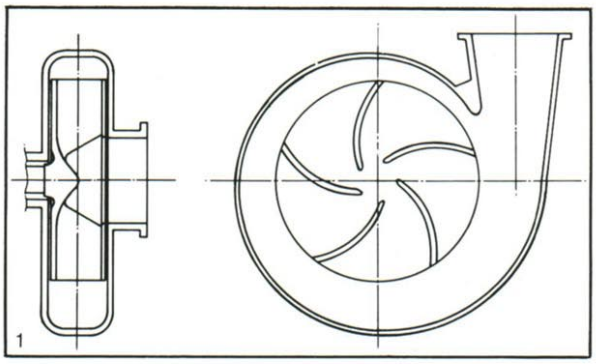
Dredging requires relatively little labour, but demands high investment.

Dredgepump versus water pump

As produced for dredging purposes, the centrifugal pump covers virtually the entire range of such operations. It is derived from the radial centrifugal pump (see Fig. 1).

Large bore

The principal feature which distinguishes the dredgepump from the water pump (Fig. 2) is its much larger bore and the absence of restrictions. The bore is smallest on the inlet side of the impeller. Access to the housing is provided at this narrow point in order to enable debris, which in spite of all precautions still causes blockage, to be removed easily. This is usually done by removing the inspection cover on the expansion piece situated on the suction side of the pump, immediately before the suction cover.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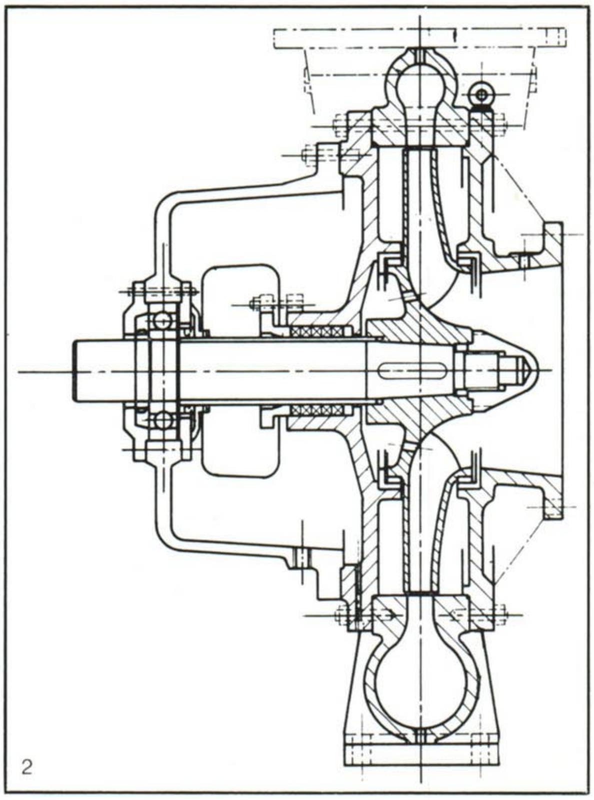
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In many modern pumps, the expansion piece is designed for rapid removal. The inspection cover then serves only for brief examinations and for the controlled draining of the pump housing and the adjoining section of the pipework. For other operations, such as the extraction of debris, minor welding repairs, the filling in by welding of cavities caused by scouring in the volute of the pump housing or on the impeller, or major inspection, the expansion piece is removed altogether from the pipework.

The purpose of the expansion piece is to enable the suction-side cover, the impeller and the pump housing to be dismantled and subsequently reassembled. The length of the expansion piece is governed by these operations.

In the majority of installations, the removal and refitting of the impeller — the hub of which projects towards the shaft side, while the tool used for extraction projects on the suction side — demands the most room. This is because the impeller has to be moved along the front of the pump housing. Normally, an expansion piece consists of a length of pipe with a loose flange at each end (see Fig. 3).
These flanges are fitted with large rubber O-rings. Fig. 4 shows a rapidly removable expansion piece in a suction line.

This consists of two loose flanges resembling an "L" in cross section and a "floating" length of pipe. Each of the flanges incorporates three rubber O-rings, two of which provide a seal between the flange and the (cylindrical) pipe, and the third a seal between the flange and the mating flange. Expansion pieces of this type are held in position with only six, or at most eight, bolts — three or four at each end.

Not so long ago it was common practice to replace the expansion piece by a stone trap, a circular or square tank introduced in the suction line immediately before the pump inlet. The incoming pipe entered the trap at a fairly low point, while the outgoing pipe, to the pump, was situated somewhat higher; frequently the pipes were also offset laterally. The trap was provided with an inspection hatch.

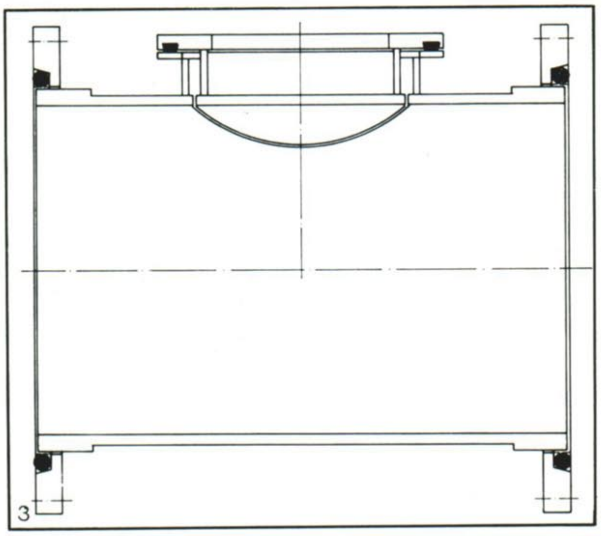
The drop in mixture velocity which occurred in the trap and suction line by-pass allowed stones and other heavy or bulky pieces of debris to settle, and these were removed from the trap when the pump was stopped.

The presence of a stone trap, however, added very greatly to the resistance, and therefore in medium installations, in which the pumps are much more robust and thus less easily damaged by stones and other forms of debris, traps are no longer employed. This means that the "foreign matter" lodges just before or in, the impeller inlet; however, the presence of an expansion piece on the suction side enables it to be removed without difficulty.

If the minimum bore were to coincide with a point nearer to the impeller — for example, if the impeller shrouds were to be made narrower — it would be necessary to dismantle the pump in order to remove large pieces of debris. This would be unacceptable.

There is also the point that jamming of debris between the impeller outlet and the cutwater must be prevented in view of the high risk of consequent fracture of the housing.

The imbalance vibrations caused by the trapped pieces are minimized by the fact that the mass which is in imbalance is located as close as possible to the centreline of the impeller.
To obtain the largest possible bore, the impeller should have as few blades as possible. For an efficient pumping action, however, it is desirable



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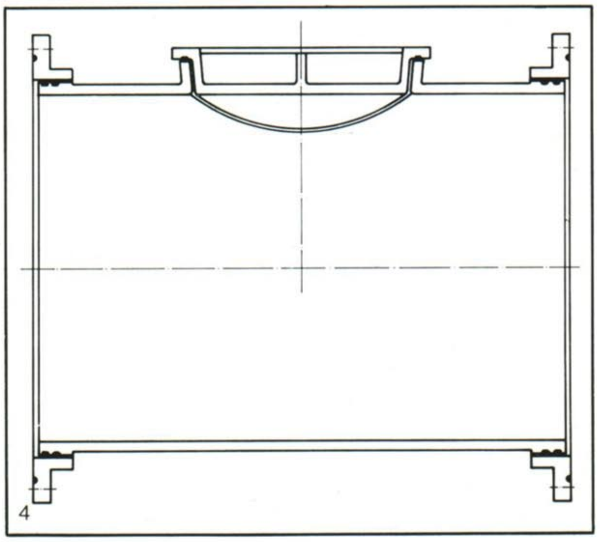

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to employ a large number of blades. The solution thus lies in a compromise, and in most cases this is manifested in an impeller with 3, 4 or 5 blades, depending upon its dimensions and the bore required. In some instances the number is even reduced to 2. For special applications, units with 2 or 3 normal blades and 2 or 3 "half-blades" are used; the smaller blades normally commence at a point approximately midway between the inlet and outlet diameters of the impeller.

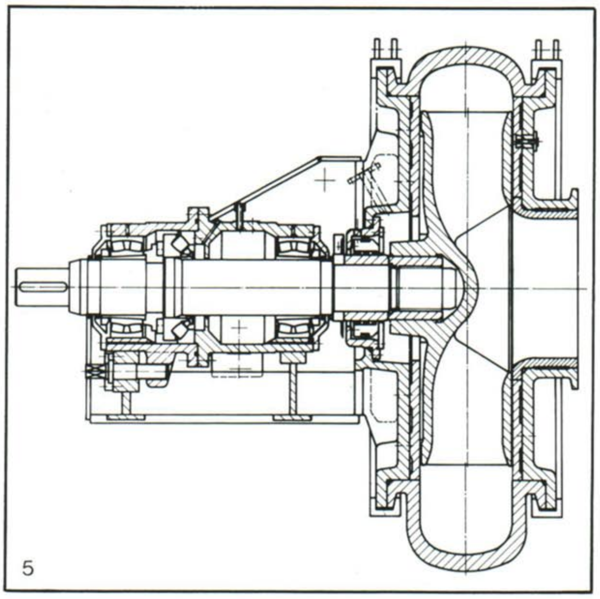
In order to achieve the smoothest possible passage of mixture, reduce contact between objects and the blades, and minimize wear, overlapping of the blades is usually avoided; indeed, impellers in which an uninterrupted diametric view can be obtained through the blades are fairly common.

To assist the passage of the mixture, the inlet angle is made as large as possible. In this connexion, it must be realized that varying the inlet angle, while retaining the familiar design and dimensions of the impeller, would have serious consequences for the behaviour of a pump (position and shape of pump efficiency curve, delivery pressure and cavitation pattern).

In the interest of favourable suction and flow characteristics and a large inlet diameter, the bore of the suction-side cover is frequently radiussed in the area adjacent to the impeller. This, however, implies either sacrificing blade area at the inlet, by employing shorter blades, as shown in Fig. 5, or lengthening the blades so that they project far into the inlet, as shown in Fig. 6.

The former usually has an immediate and negative effect on the suction properties and cavitation pattern of the pump. Extending the blades results in an inlet with excellent flow characteristics and good suction properties, but of very small volume. The impeller has now become highly susceptible to debris and lumps of solid material, the removal of which may well necessitate frequent stoppages. Generally speaking, it is necessary to accept a compromise between the most favourable blade shape and the largest possible effective inlet. In most cases, the latter requirement will predominate. An aperture of one-third of the inlet diameter of the impeller is the accepted minimum.

In the pump shown in Fig. 6, the bore of the suction-side cover has a very pronounced radius, and the blades project deep into the suction inlet.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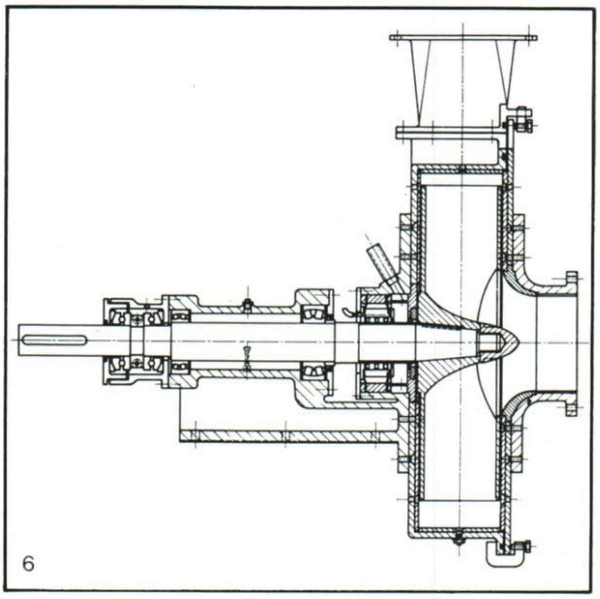
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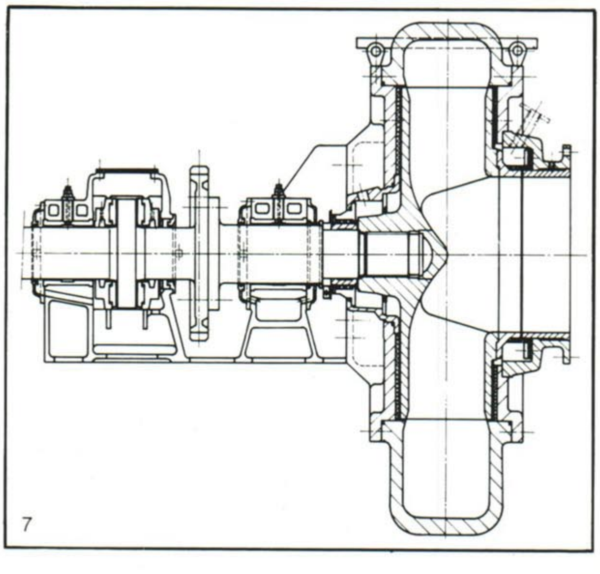
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This arrangement is suitable where washed sand with a predetermined grain size is to be pumped. Reducing the width of the impeller where its diameter is increased will result in a further improvement of the flow pattern.
The most common arrangement, in which very little radiussing of the bore is employed, is shown in Fig. 7. In many such pumps, the blades are taken somewhat deeper on the shaft side. Practice has shown that, where a mixture containing large lumps of stone and other debris is handled with a pump of this type, the impeller tends to act as a trap for such material, and that in many instances this results in the burning away of horizontal areas of the extended blades adjacent to the suction inlet and the shaft-side cover. This in turn has an adverse effect on the suction characteristics and cavitation pattern of the pump. In many designs, account is taken of the possibility of burning away of the blade in these areas, and allowance is made for this to occur without causing any significant suction problem.

Dredgepumps are designed with considerably larger volutes than water pumps. This is done chiefly to limit the peripheral velocities in the volute and thus to minimize wear on the housing, while ensuring that any wear which does take place is as uniform as possible.

The earliest housings were square in cross section.
This resulted from the fact that they were manufactured from simply formed plates (see Fig. 6). The 1950s saw more general introduction of cast pump components, but these forerunners retained the old squarish, flat shape which had initially simplified manufacture and replacement.

Such curvature as they possessed was rendered necessary by the casting methods employed. The results could be described as cast versions of the original pump housings. A number of housings of this type are still in existence.

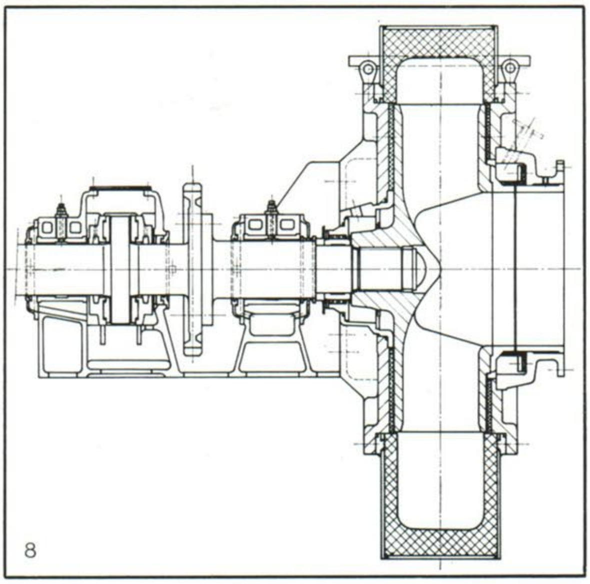
Modern cast pump housings, in which exotic steels and steel alloys are used, are designed in the form of volutes, which are much more a compromise between the optima from the points of view of wear and flow characteristics. Accordingly, they vary in cross section almost from hemispherical to elliptical and are amply curved at their extremities (see Figs. 5, 9 and 10).
Viewed in the direction of rotation, the area of maximum wear in the housing is just beyond the cutwater. This is frequently of an intensely local nature and is manifested in vortex-shaped cavities caused by scouring.
The shape of the cutwater is the principal factor which influences wear at this point; others are the outlet angle and the profile of the blades at the periphery of the impeller.

Notions concerning the size of the gap between impeller and cutwater have also changed with the passing of time. Modern dredgepumps have a considerably larger gap in order, amongst other things, to prevent debris — particularly stones — becoming wedged between the impeller and the cutwater. In earlier units, the gap was markedly smaller and the cutwater accordingly had to be replaceable. Except for housings with plastic or rubber liners, in which the cutwater is much more vulnerable, no provision is made for replacement nowadays.

The cutwater itself has also undergone changes. The square design of yesteryear has given way to a well-rounded diametrical cross section, while the cross section which coincides with the axis of the pump is seen to be elliptical.
In modern pumps, the gap between the cutwater and the impeller is of the order of 20-40% of the inlet diameter of the impeller.

If the quantity of sand and water mixture which can flow, in countercurrent, on either side of the impeller is to be reduced to a minimum, the distance between the impeller and the suction and shaft side covers must be as small as possible. The means employed to this end include the incorporation of "counterblades" in the shrouds of the impeller; these exert a certain pumping action and thus oppose the backflow (see Fig. 5). In the light of practical experience, however, the value of such additional blades must remain open to doubt.

Backflow on the suction side results in extremely heavy wear, particularly of the fearing plates and wearing rings on the suctionside cover; in addition, it is accompanied by a loss of efficiency.
Backflow on the shaft side results principally in wear of the pump shaft and silting of the shaft seal; this is followed by wear and leakage of the seal, necessitating repair or replacement of the shaft and seal. It is for this reason that a gland pump has been incorporated on the shaft side of dredgepumps since their inception.
The gland pump was connected to the "water chamber", a space immediately before the shaft seal on the pump housing. Its function was to flush the space with clean water, keeping the shaft seal free of sand. The water also partially flushed the aperture between the shaft-side impeller shroud and the wearing plate on the shaftside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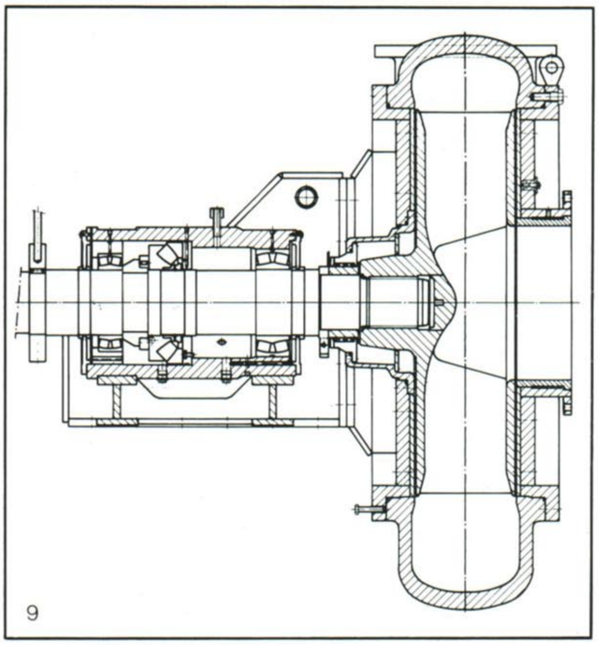
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cover. It is of great importance that the water chamber should be amply dimensioned so that its buffer capacity is adequate for varying operating conditions.
With the passing of time, innumerable types of shaft seal have been devised. Among these was a protective bush which fitted on to the shaft, and with which the seal made sliding contact.
Although shaft seals incorporating stuffing boxes are still employed, the most up to date types employ supported Simmer rings interspersed with grease (see Figs. 7, 8, 9 and 10). The grease pump is driven from the pump shaft.

Some seals, however, are of the "floating" type. In these, a flexible element is introduced between the Simmer sing housing and the backplate of the water chamber, which forms part of the shaftside cover (see Fig. 5). With this arrangement, the Simmer ring seal is better able to follow the movements of the shaft.

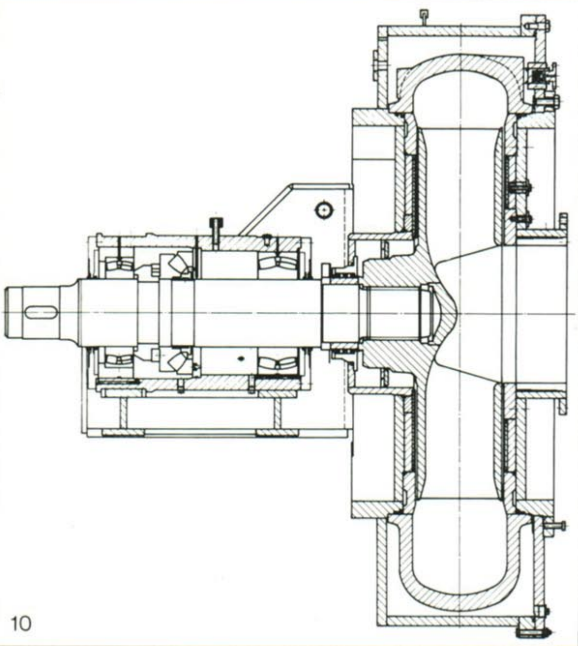
Many attempts have been made to seal the aperture on the suction side; a large number of devices have been developed to this end, but practically all of these have been failures.
Nowadays, one of two reasonably satisfactory methods is employed. The first of these involves keeping the aperture as small as possible, mainly by a combination of limited tolerances and accurate machining (see Fig. 10). In a number of pumps, most of which are in the smaller category, an additional refinement, whereby the bearing and impeller can be adjusted axially, has been incorporated. With this arrangement, the aperture can be kept to a minimum at all times (see Fig. 5). The second method involves a combination of flushing of the seal on the suction side, by means of a gland pump, and partial closure of the aperture on this side. The principal problem encountered with this system is one of axial and radial movements of the impeller on the suction side, resulting from the action of the dredgepump itself. The seal must be capable of following such movements (see Figs. 7 and 8).

A practical difficulty affecting flushing of the shaft-side seal (and of the suction-side seal. where this is employed) is the cleanliness of the water. The position of the "weir chest" is critical, especially in the case of a barge-loading stationary dredger, or a trailing-suction dredger from which fine particles of sand escape via the hopper overflow. When working in a shallow pit, a wrongly positioned weir chest can cause difficulties.

Replacement and design
Ease of replacement and simplicity of design and construction of all components — many of which are provided with a second, wear-resistant, surface (which in many cases is also replaceable) — constitute the second major distinction between a dredgepump and a water pump.
Initially, efforts were directed towards round, straight and flat shapes, or combinations of these; the reason for this was that all components which would be in contact with the soil and water mixture were given a second — replaceable — "wearing skin".
In the majority of modern pumps, only the suction and shaft side covers are fully protected. This is achieved by means of wearing plates with or

without the addition of wearing rings, while the bore of the suction-side cover also incorporates wearing rings and bushes.
The pump housing and impeller are not lined or coated with protective material; however, these are cast in steels or steel alloys having a high or very high resistance to wear. Housing fabricated from steel plate and lined with rubber or polyurethane are also on the market. Fabricated steel impellers with cast steel hubs are encountered, some of which have a protective coating of plastic (polyurethane) or rubber.

To protect the impeller shrouds and the wearing plates on the pump covers, these are flushed by means of a gland pump.
Originally, a gland pump served only to prevent foreign matter entering the shaft seal; however, recent investigations have shown that, by reason of the pressure gradient which exists throughout the periphery of the impeller, a considerably larger volume of water is required to adequately flush the whole of the area of the wearing plate and the impeller.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The highest pressure is encountered just beyond the cutwater, viewed in the direction of rotation. Research conducted by the MTI has shown that, for pumps of the IHC standard type, the minimum quantity of water required is:

$$Q = \frac{D^2 \times n}{20} \text{ m}^3\text{/h}$$

where:
D = impeller diameter in metres
n = nominal pump speed in rev/min.
The operating pressure of the gland pump should be approximately equal to the maximum operating pressure. A drop in the flowrate of the glandpump should be accompanied by a slight rise in pressure as a function of the Q-H-curve, however, this may not give rise to an area of instability.
The gland pump selects its working point in accordance with the working point of the dredgepump. This fact must not be overlooked when deciding upon the size of the motor which will power the gland pump. The majority of gland pump units consist of a small, foul water-resistant centrifugal pump, driven by a non-synchronous electric motor fed from the general circuit.
Due account must be taken of the power consumed by the gland pump unit when the dredgepump is stationary. The incorporation of a fixed resistance in the circuit enables excessive flowrates, and thus excessive current consumpton, at the virtually constant running speed to be limited; on the other hand, of course, this shift of working point must be considered when choosing the motor.
Where low and medium pressure dredgepumps are concerned, it is not uncommon for a small displacement pump of a type relatively unsusceptible to siltation to be used for flushing purposes. The Mono pump, the characteristics of which render it satisfactory in this respect, is a typical example.

Robust construction

The third factor which distinguishes a dredgepump from a water pump is its far more robust construction, the purpose of which is resistance to wear rather than sheer strength.

Physical features

Apart from these technical features, all centrifugal pumps, whether designed for dredging or other purposes, possess a number of physical features which are manifested in their characteristics.
These, together with the characteristics of the pump drive and the pipeline, determine the possibilities and constraints of the complete installation as a transport unit.
Together, this unit, the nature of the dredging work to be carried out and the conditions obtaining thereto, and the spoil delivery capacity in terms of the solids flow (the "pit supply") plus the capacity of any dilution jet or soil dislodgement installation which may be employed, determine the ultimate capacity of the system as a whole.