Centrifugal dredgepumps (III)

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Transporting mixtures by means of the dredgepump

In the previous article in this series we discussed the characteristics of dredgepumps with reference to a number of theoretical principles. Our considerations, however, were based on the transport of water.

Where soil and water mixtures are transported, the pressure head will be higher, and the efficiency of the pump lower, at a given delivery rate and speed, the variation in these two factors being determined by the nature of the soil to be transported and the specific gravity of the mixture. Thus, for a given speed and delivery, a higher driving power is required in order to pump a soil and water mixture.

Curves relating to the pumping of sand and water mixtures are reproduced in Fig. 1. These are based on normal sand with a d_{50} of 200μ. Curves for water and for sand and water mixtures with specific gravities of 1.1 and 1.2 tons/m^3 are given. Where more homogeneous mixtures of soil and water having the same s.g. as the aforementioned sand and water mixtures are transported at the same flowrate, a greater manometric head is attainable. The drop in pump efficiency is less, and as a result the increase in the power required is slightly smaller than would be the case of a corresponding mixture of water and normal sand with a d_{50} of 200μ and an equivalent s.g.

Fig. 2 shows curves for water and mixtures of water and clayey soil with specific gravities of 1.1 and 1.2 tons/m^3. The extent of the increase in the pressure head and the decrease in pump efficiency when transporting soil and water mixtures is largely governed by the nature of the soil concerned. Broadly speaking, the finer the grains in the soil, the more the mixture will behave as a homogeneous fluid.

Pump characteristics

From now on we shall refer to the combined characteristics of the pump and its drive system as the pump characteristics.

There are a number of ways of driving a pump:

1. By a diesel engine, direct or via reduction gearing.
2. By a diesel engine, via an electric or hydraulic "shaft".

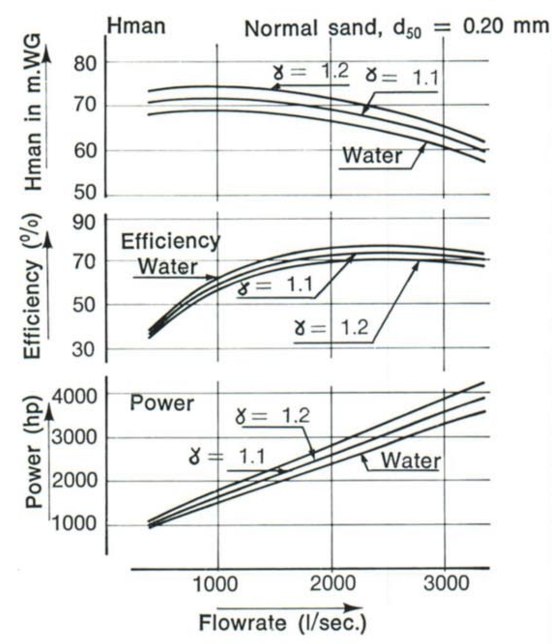
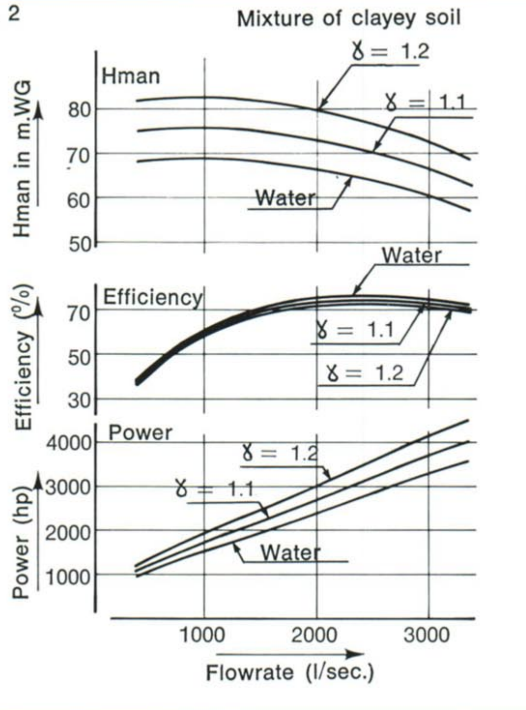


Fig. 1

3. By a "constant-power" system, either electric or hydraulic.
4. Electrically, via non-synchronous motor(s) connected to a high-current circuit.

Fig. 2



Dredgepump driven by a diesel engine

This is the most common arrangement. The characteristic of a typical diesel engine is shown in Fig. 3.

At nominal operating speed, the maximum load coincides with the nominal full-torque point A. The governor range AC is the so-called constant-speed range, within which the engine load is below the nominal full-torque point. In this range, the engine speed usually rises slightly as the load drops. This is a result of the control of the speed by the governor, and is referred to as the speed drop of the governor; the extent of the drop depends upon the type of governor fitted.

If the engine load increases as a result of the pump calling for more than the nominal power, the speed drops and the engine operates in the full fuel flow range (line A-B). On most engines, the torque will rise somewhat as the speed decreases, because the charging efficiency of the fuel pumps then becomes somewhat higher. More fuel per stroke is injected, and if full combustion occurs the torque increases. In many instances the exact position of the line A-B is not known, and an approximation is employed in which the torque is held to be constant throughout this range. One then works on a section of the so-called constant-torque line (N/n = constant). This explains why the full fuel flow range AB is sometimes referred to as the constant-torque range. At a given moment (point B), however, insufficient air is available to produce complete combustion, and the engine "stalls", i.e. the torque drops sharply, and heavily polluted (incompletely burned) gases are emitted: the "smoke limit" has been reached. Rapid wear and damage to the engine are now imminent.

The position of point B depends to a great extent on the degree of supercharging and the nature of the supercharger. Where a high degree is achieved. point B will be situated closer to the nominal full-torque point. This contrasts strongly with the situation on normally aspirated engines, where the speed may drop to 60%-70% of the nominal figure.

The characteristic of a pump driven by a diesel engine is reproduced in Fig. 4. This consists of two parts, the governor range and the full fuel flow range. Within the governor range, the engine runs at maximum speed; this is not absolutely constant owing to the speed drop of the governor, and usually rises somewhat as the load decreases. Maximum speed can only be maintained up to the point where the nominal torque of the engine is reached, namely the nominal full-torque point.

In this case, the Q-H curve, which relates to the maximum speed from the no-load condition to full

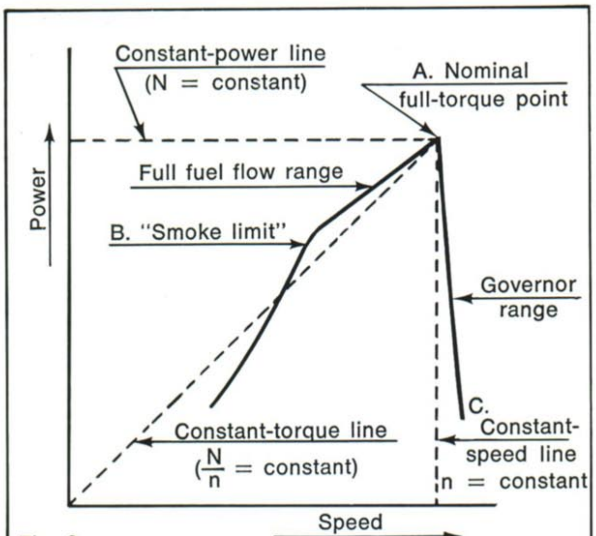
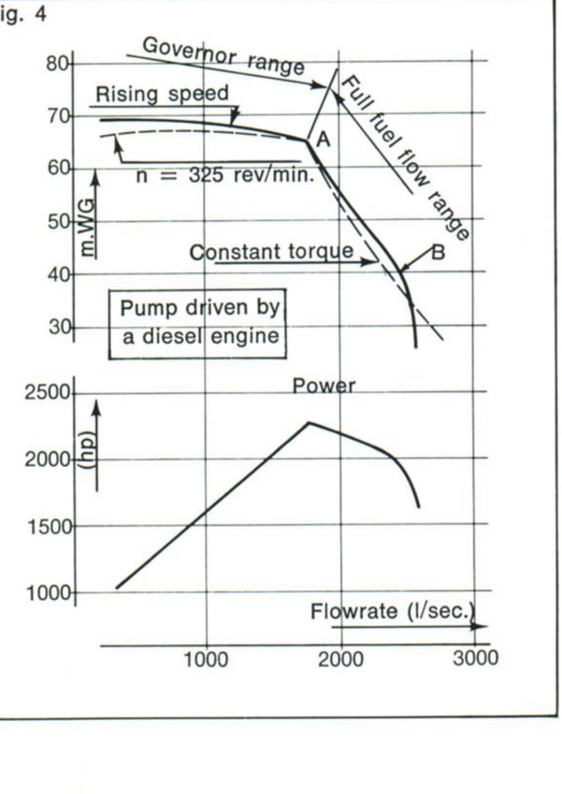


Fig. 3

Fig. 4


load — within which units the governor controls the engine — has in fact ceased to be a constant-speed curve. As the load decreases, the speed rises slightly; the pressure head at the declining flowrate then shifts to higher Q-H curves, causing the pressure head in the pump characteristic to increase. This increase diminishes the risk of settling of the solids in the pipeline and assists stable operation. Failure by the pump designer to take account of this increase in speed in the governor range can increase the tendency towards cavitation and adversely affect the decisive vacuum level of the pump. This becomes clear if we recall that, at lower flowrates, the pressure rise over the impeller steadily increases.

If, when the nominal full-torque point A in Fig. 4 is reached, the driven machinery calls for more torque, a limiting device on the fuel control rod of the engine will prevent more fuel being injected into the cylinders. If the load increases, the engine, and with it the driven machinery, will slow down. On most diesel engines, the torque does not remain absolutely constant when the speed decreases (although for simplicity it is frequently assumed that it does), but initially rises slightly. The pump characteristic in the Q-H diagram rises fairly steeply in this full fuel flow range.

When the speed of the installation drops, the pump is operated on a lower constant-speed line on the Q-H diagram. The torque then increases slightly, while maximum fuel continues to be injected.

The pump now operates at a working point having a lower pressure and a higher delivery, and corresponding with the slightly higher torque and reduced speed. As the torque increases somewhat, the curve becomes flatter, and thus more favourable, than at constant torque.

The full fuel flow range extends from the nominal full-torque point to the smoke limit, the speed at which the engine can just continue to run satisfactorily. If the speed falls below this limit, the torque falls away sharply. At a scarcely increasing delivery, the pressure head in the Q-H curve of the pump will very soon commence to fall.

If mixture is pumped, a situation as shown by the curves in Fig. 5 will obtain.

As a result of the increased manometric head and

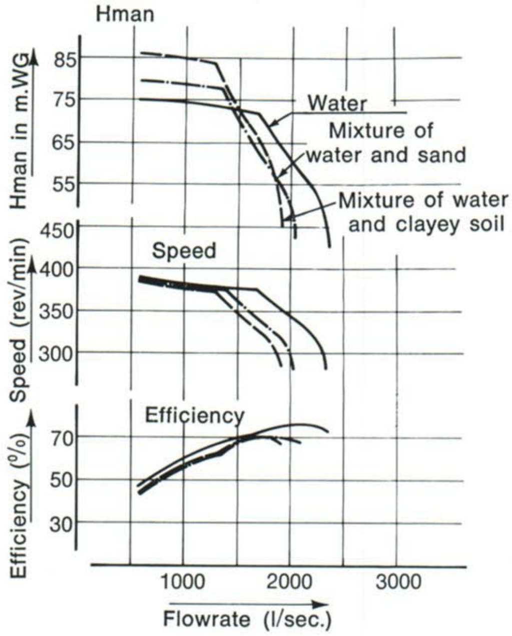
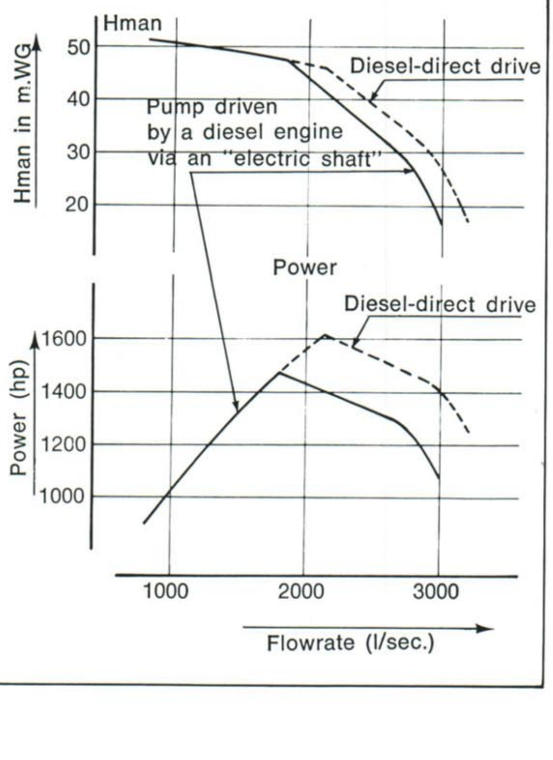


Fig. 5

the diminished efficiency when pumping a mixture of soil and water, that part of the Q-H curve which falls within the full fuel flow range will shift to the left, the extent of the shift being governed by the mixture concentration and the nature of the ma-

Fig. 6


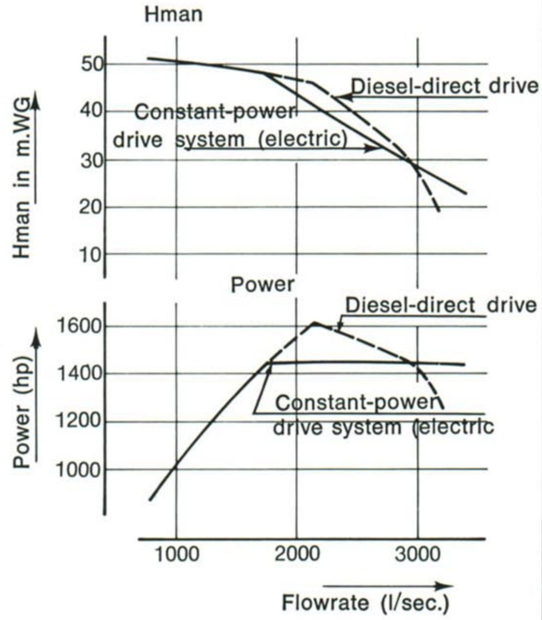
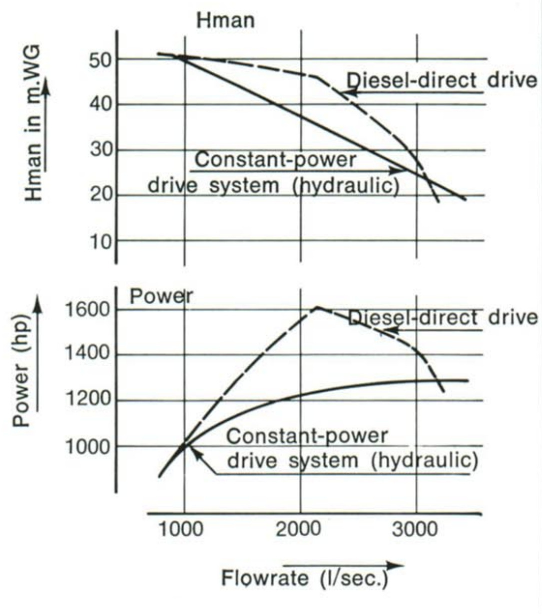


Fig. 7

terial being transported. The nominal full-torque point moves to a position corresponding to a smaller delivery and a higher pressure head. Comparison of the curves for mixtures containing the two types of soil referred to (Fig. 5) shows

Fig. 8



that, within the full-torque range, the pump curve moves farther to the left with a mixture of water and normal sand than with one of water and clayey soil having the same specific gravity. In the governor range, the effect of the rise in pressure is less in the case of a mixture of water and normal sand than of one of water and clayey soil having the same s.g. Generally speaking, it may thus be concluded that the effect of the rise in pressure in the governor range is greater, and that the leftward shift of the curve in the full fuel flow range increases proportionally with the homogeneity of the soil and water mixtures transported; i.e., proportionally with the fineness of the grains.

Dredgepump driven by a diesel engine, via an electric or hydraulic "shaft"

The electric "shaft" consists of a non-synchronous generator coupled to the diesel engine and providing current for a non-synchronous motor which drives the pump. The hydraulic "shaft" comprises one or more fixed-delivery hydraulic pumps coupled to the diesel engine and powering one or more hydraulic motors which drive the pump.

The characteristic of a pump with a drive system of this type is shown in Fig. 6. The shift in the curve, in relation to a dieseldirect drive, is caused by a loss of efficiency as a result of the introduction of the electric or hydraulic "shaft".

Drive systems of this type are, for example, employed for laddermounted, submerged dredgepumps; these are generally used where the dredging depth exceeds 20-25 metres.

Dredgepump with "constant-power" drive system

The electrical version of this system consists of a Ward-Leonard installation. The hydraulic version comprises variable hydraulic pumps with constant-power control, which power hydraulic motors driving the dredgepump.

In the majority of cases, the hydraulic pumps are driven by diesel engines.

Where a pump is driven by a system of this type, the curve in the constant power range of the Q-H diagram will be less steep than the constant-torque curve in the diagram. With such systems, the torque increases as the speed decreases. Because the pump characteristic in the constant-power range is much flatter, this curve is therefore more favourable, than one applying to an almost constant torque system such as the diesel engine plus an electric or hydraulic "shaft".

Fig. 7 shows a typical curve for an electric system, and Fig. 8 for a hydraulic system. These graphs afford a comparison between the characteristics of pumps with constant-power and direct drive systems incorporating identical diesel engines. Both were compiled on the basis of a number of measurements taken under practical conditions by the Measurements Service of the MTI.

Like an electric or hydraulic "shaft", a constant-power system is an additional stage in the drive mechanism, the presence of which produces additional losses. As comparison between Fig. 7 and 8 shows, the loss arising from an electric constant-power system is less serious than that produced by its hydraulic counterpart.

In a constant-power installation, the full output of the diesel engine can be utilized. The shorter the delivery pipeline — and thus the smaller the pressure head and the greater the flowrate — the more will the loss be compensated by the gain in power relative to the constant-torque curve of a diesel-direct system. Moreover, the engine continues to run at full speed.

Where a constant-power system is employed, it is not necessary to decrease the diameter of the impeller, since the drive system adapts its behaviour to the circumstances. Full power is available until such time as the minimum speed of the system is reached. In the constant-power range, the actual operating range of the dredgepump installation — which may be compared with the full fuel flow range in a diesel direct system — the advantages of the constant-power system become steadily greater. Within this range, it is now possible to vary the length of the delivery pipeline with the maintenance of full power and without the necessity to modify the impeller.

Drive systems of this type are usually chosen where the pump motor(s) can be fed from a high-current circuit on board or from the shore, or where the dredgepump drive is one of a number taken from a very large diesel engine which operates at a constant speed. An example of the latter is seen in trailing dredgers in which the main engine drives both the propeller and the dredgepump. With this arrangement, a high steaming speed to and from the dumping ground can be achieved, since the power absorbed by the pump during dredging is now available for propulsion.

Dredge driven bij non-synchronous motor fed from the ship's supply

In installations of this type, all working points must be within the permitted power range of the motor, even when pumping mixture, as otherwise the motor will burn out. Motors must be expressly dimensioned for this application. If the motor load decreases, the speed, and with it the manometric head, will increase slightly as a result of the reduced slip of the motor. If the power limit of the motor is reached — for example, because the resistance in the delivery pipeline diminishes — it will be necessary to reduce the size of the pump impeller or to replace it with one of a smaller diameter (see Fig. 9).

A practical application for this system exists in vessels having a high-current main circuit from which all smaller drive systems are powered. The primary source of power on board ships consists of one or more large diesel engines. Land-based installations, e.g. boosters, and those which remain in one place for long periods are often powered in this manner.

Fig. 9