Further development of the inclined coil pump

by David J. Hilton

The coil pump is simple and efficient, and can be adapted to many different types of power sources. Another stage in the development of the coil tube pump has led to further simplification of the design and improvement in efficiency.

THE COIL PUMP is remarkable in its simplicity: it has only one moving part. The coil pump works by picking up air and water alternately. The pockets of air become compressed and a manometric pressure is set up between each adjacent coil. When added together, the individual pressure differentials are sufficient to force the 'slugs' of water to the top of the delivery pipe. The maximum pressure head that can be achieved depends upon the number of coils and the mean diameter of the coil.

The design of the pump has gone through various stages. In the form described by Morgan[1], Stuckey and Wilson[2], Mortimer and Annable[3], and others, the axis of the pump was horizontal and the pump incorporated a rotating seal. This feature represented a significant drawback to the design, and made manufacture of the pump almost impossible for most village workshops.

The inclined coil version

A significant development in simplifying the pump and easing its manufacture was brought about by inclining the axis of the coil, as described by Reimer[4] and Hilton[5]. This dispensed with the need for the rotating seal, sine the coil and inclined delivery pipe were now joined to form one component. This also meant that the delivery pipe could also be used as the drive shaft, enabling the pump to be driven from dry land as an alternative to the coil element being driven directly by stream power. The inclined coil pump is therefore more versatile, in that it can be powered by either pedal, animal or wind.

Measurement of pump performance by one authority, however, indicated that the overall efficiency of a large diameter pump could be well below that which was desirable, and under certain circumstances was as low as 20 per cent. The indications were that significant energy loss was taking place from the churning of the water caused by the coil's support structure.

A further problem with the pump was that the lower shaft bearing had to support a considerable weight, leading to some difficulty in the design of the bearing support structure and significant bearing friction where simple bushes were used.

Developing a floating drum

A further improvement has been found in using a watertight cylindrical drum as the coil support structure. The drum performs three functions.

First, it supports the complete weight at the lower end of the delivery pipe which was previously supported by the lower bearing. The lower bearing is thus eliminated, and the only requirement is to provide a vertical guide to control the general direction of the pipe. (This can be done by two wooden stakes or poles. See Figure 1.) Second, the drum follows the water level, ensuring that the coil at the entry point remains 50 per cent submerged even though the water level varies. Finally, it forms a coil support structure with a smooth rotating surface which of itself produces only skin friction but no form drag or churning.

The coiled tube can either be wound on the outside of the drum or on the inside. From the point of view of minimum losses, the ideal solution is to wind the coil on the inside of the drum, as shown in Figure 1. This version is, however, just a little harder to manufacture and there is the possibility that poor welding or careless assembly can lead to a leak occurring, and the drum sinking as a consequence.

When the coiled tube is wound on the outside of the drum, this greatly simplifies manufacture (see Figure 2), although the coil itself does tend to churn the water to a certain extent. With this version it is, however, easier

A watertight cylindrical drum supports the coil.

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to ensure that the drum remains watertight.

The size of the drum is quite critical. Firstly the drum must have the correct volume to support the required weight, while maintaining 50 per cent submergence at the inlet end of the coil. Secondly, it should be of as small a diameter as possible to minimize skin-friction losses. Fortunately, in many applications it is found that a standard 200-litre oil drum can satisfy these two requirements admirably.

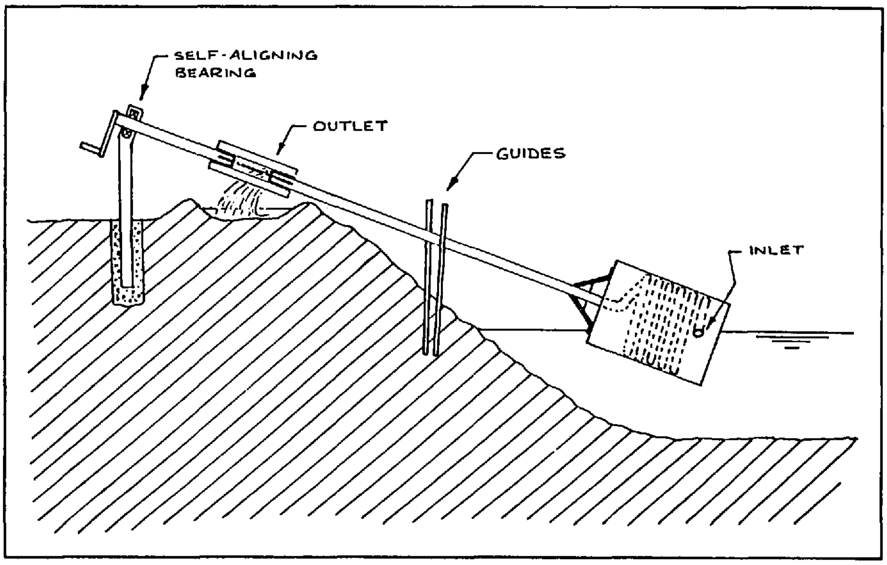

Figure 1. The inclined coil pump showing the coil wound on inside and labelled parts.

Practical experiments

In 1988, experiments were carried out by the author at the Asian Institute of Technology, Bangkok, with a variety of pump configurations. Tests were performed with pumps in which the coil was wound inside the drum (see Figure 1), and one in which the coil was wound externally around the oil drum (see Figure 2).

In most cases a standard 200-litre oil-drum was used, but two pumps were tested with a drum diameter of 750mm. Pressure heads were between 1m and 2.4m. The maximum pressure head that any pump could achieve was given by:

maximum pressure head = k x number of coils x coil diameter where k is approximately 0.5.

At low speeds the quantity of water pumped per revolution was found to be almost exactly equal to the volume contained in half of one coil. Thus, for example, a 50mm tube coiled inside a 200-litre oil drum (570mm diameter) gave an output of 1.7 litres per revolution, while a coil of 62mm tube gave an output of 2.9 litres per revolution when wound on the outside of the oil drum. Where a drum diameter of 750mm was used, a coil of 75mm wound on the inside gave an output of 4.1 litres/revolution. Pump flow rate increased proportionately with speed up to around 40 rpm. At the speed increased further, the flow rate increased, but the volume delivered per revolution gradually dropped. Finally a speed was reached (between 80 and 100 rpm) at which the pump ceased to operate.

When the coil was wound on the inside of the drum, the efficiency was found to be between 50 and 58 per cent within the low speed range. This is quite satisfactory when compared to other types of small handpumps.

The power range is therefore suited to human (hand or leg), animal or wind power. For instance, a handpump delivering 2.9 l/rev (at 35 rpm) provided a flowrate of 101 l/min. If the pumping head is 1.6m and the overall efficiency is 50 per cent, this requires a power input of 53 watts. A windmill, coupled directly to a pump delivering a 4.1 l/rev and rotating at 60 rpm requires a power of around 160 watts, which is easily attainable.

Although the coil diameter should be as small as possible to minimize skin friction and churning, there is a practical limit to how tightly a flexible tube can be coiled. Plain polythene or rubber tubes tend to flatten or to kink easily when coiled. It is therefore advisable to use plastic tube which has stiff reinforcing rings molded into it (that is tubing similar to that normally used for suction intakes).

Using this type of tubing, it has been found that a tube diameter up to 50mm can be used on the inside of a 200-litre oil drum, and a tube diameter of up to 62mm can be wound around the outside. Tube diameters of 75mm and above normally require greater drum diameters.

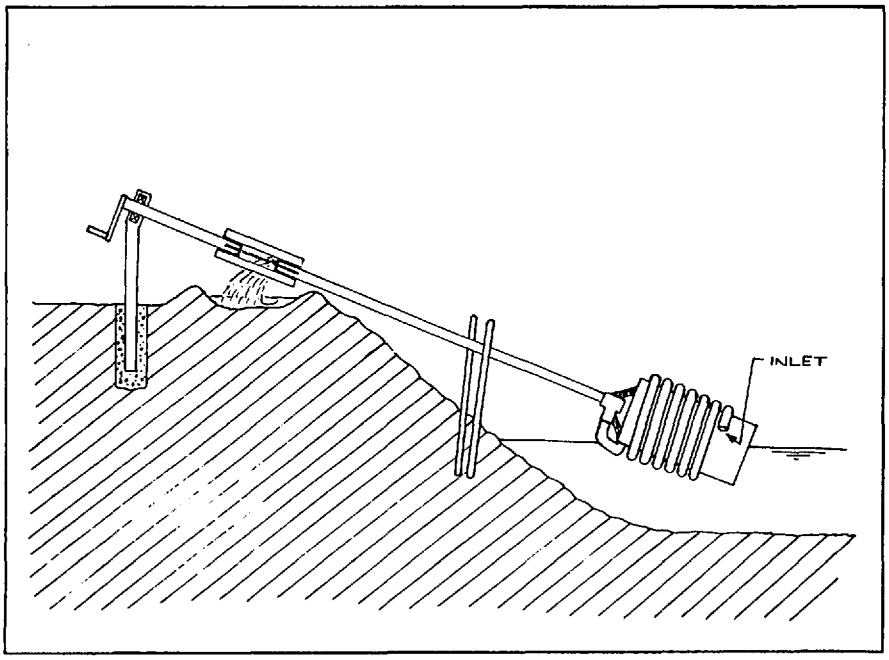

Figure 2. Same as above but with coil wound on outside.

Constructional details

It is important that the delivery pipe is attached rigidly to the drum. This can be done by welding brackets and stiffening strips to the drum lid, incorporating a standard pipe socket.

When fitting the coil to the inside of the drum, a short piece of pipe must be welded to the drum at the entry point. The pipe must be of the correct diameter to allow the flexible plastic tube to be fitted over it and clamped with a hose clamp. At the coil outlet, a 90° and a 45° elbow should be used to connect to a short radial pipe, which then is connected to the delivery pipe

Pedal power provides ample energy to run the pump.

via another 90° elbow. It is advisable to use silicone rubber sealant on all clamped pipe joints. After assembly, the drum lid should be carefully welded on to form a complete seal.

If the coil is to be fitted externally, the coil must be carefully clamped to the outside of the drum with appropriate clamps. Connection to the delivery pipe is easily done through a 90° elbow and a T-piece which has one end closed off.

Applications

The pump should find widespread application wherever water is to be lifted one to 4m from a river, irrigation canal or storage pond. When operated by hand, it compares very well against reciprocating pumps, since the rotary motion is smooth and therefore less tiring. It is also well suited to operation by a windmill, especially if the wind comes predominantly from one direction. The windmill rotor can be mounted directly on to the shaft without the need for any transmission (obviously great care must be taken in any such attempt).

Perhaps the greatest advantage of the pump's design is that the requirements for maintenance are virtually nil. The only component requiring attention is the one self-aligning bearing at the top of the shaft. If a fully sealed ball-bearing is used, and given some protection from the rain, then the pump should give many years of service without requiring any maintenance.

References

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