LOW LIFE-CYCLE COST

CENTRIFUGAL PUMPS FOR UTILITY APPLICATIONS

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Once considered the theoretical concept of academics, rarely applied in practice, life cycle cost analysis is fast becoming the accepted method for the evaluation of both capital projects and items of replacement plant. Indeed to assist pump users in the evaluation of whole life costs, the Confederation of Pump Manufacturers has in 1999 issued a specification (LLC) for establishing and reducing Life-cycle costs.

The developed world has become acutely aware of the effect of its waste and the introduction of levies on CO_2 emissions, now directly taxes the inefficient users of energy. Globalisation is squeezing maintenance budgets and demanding an increased mean time between major service outages.

Initial capital cost is, in most instances, a fraction of the whole life cost of a typical pumping installation. Energy consumption, unplanned downtime, maintenance and replacement parts can easily equate to in excess of 95% of the total life-cycle cost.

The increasing recognition amongst pump users that post installation costs clearly outweigh capital costs and are therefore the only true economic indicator applicable to capital purchases, prompted SPP Pumps Ltd to set up a combined Marketing & Engineering team to develop a range of low life-cycle cost utilities pumps.

Life-cycle Cost Analysis

What are the real costs associated with procuring, operating and maintaining water utility pumping plant? What are the largest, most variable or most invisible costs? Life-cycle cost can be broken-down for analysis purposes into a number of key components.

- Initial Capital Cost
- Operating/Energy Costs
- Replacement/Wear Part Costs
- Maintenance & Repair Costs
- Disposal Costs

Initial Capital Cost

Capital cost is the most visible cost and has historically been the primary selection criterion for most items of capital equipment. Pump users are now becoming increasingly aware of post installation costs and their impact on the total cost of ownership. Lowest capital cost purchases rarely prove economic in the longer term and given that the initial capital cost of a centrifugal pump, inclusive of installation, typically equates to between 5%-20% of whole life cost, placing more emphasis on post installation cost will clearly prove much more economic.

Operating/Energy Costs

Energy costs can easily equate to as much as 90% of the whole life cost of a pumping installation, dependant on installed power and equipment utilisation. Analysis of operating costs, in terms of energy consumption, is relatively straightforward, given that pump utilisation and demand profiles are understood and predictable. The wire to water efficiency of existing or proposed installations can be compared and the results projected over the estimated lifetime of the installation. This should be a fundamental component of any tender assessment process or existing asset review procedure. The attached chart clearly depicts the cost of inefficiency, whilst providing visibility into the post installation savings associated with installing the most efficient equipment for a given duty.

Less visible however, is an installations capacity to operate at or near optimum efficiency throughout its operational life. A degree of degradation in hydraulic performance is inevitable with time. This degradation in performance is primarily a result of wear and erosion of internal clearances. Wear rings limit uid re-circulation between the high and low-pressure areas within a centrifugal pump. A combination of erosion from high velocity uid passing between the wear ring surfaces and mechanical wear, resultant from shaft de ection widens the clearances allowing an increase in internal re-circulation. Significantly, highlighting the importance of optimum pump selection, this process will be accelerated if the pump operates at a duty point less than 70% or more than 115% of best efficiency ow. The resultant loss of performances usually leads to the pump running for longer periods to deliver a given quantity of uid. Erosion of hydraulic profiles and increases in the relative roughness of surfaces in contact with the pumped uid, will also significantly impact on pump performance.

Replacement/Wear Part Costs

The replacement of major components within a pump, whether as a result of wear, erosion or following a component failure is often a very significant contributor to whole life costs. A replacement rotating assembly will typically equate to 70% of the costs of a replacement pump. It is not uncommon for all components forming the rotating assembly to require replacement within the lifetime of a installation. The selection of a conservatively engineered pump, manufactured from high-grade materials should negate this, substantially reducing maintenance costs and increasing the mean time between failure and major service outages.

Maintenance & Repair Costs

The cost of regular monitoring and preventative maintenance is a necessary component of an installations whole life cost and historical evidence shows that regular maintenance is a lower cost option than unplanned emergency repairs. When calculating the cost of maintenance, installation downtime and resultant loss of productivity should be considered. Savings associated with increased mean time between failure and service outages will offset any higher initial capital costs incurred when installing a well-engineered pump, designed for ease of maintenance.

A well-engineered installation should be so designed as to offer good bearing and seal life and facilitate all but a major overhaul insitu, without recourse to disturb either pipework or prime movers.

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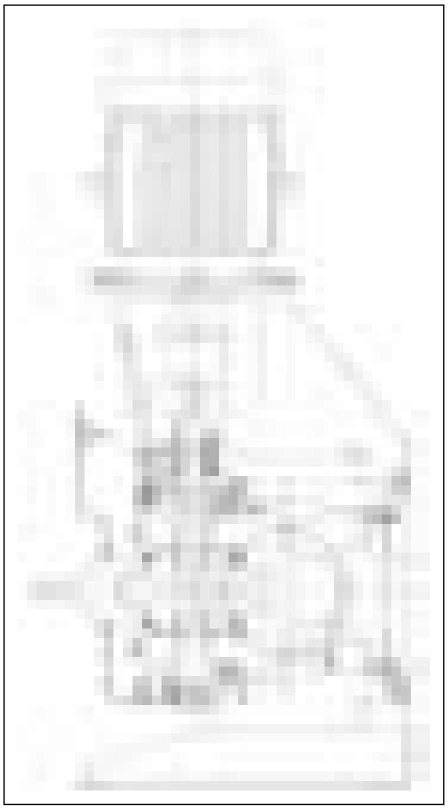
Features

Having identified the key constituent parts of whole life cost, what key features would be required of a low life-cycle cost centrifugal pump? The majority of pumps employed on utility type applications fall into the category of either, Horizontal Split Casing, Vertical Suspended Bowl or End Suction Pumps. Only the latter are regularly manufactured to recognised international standards e.g. ISO 5199. The requirement for low life-cycle cost pumps was identified as being mainly for branch sizes 150mm and above and not really applicable to the majority of End Suction Pump applications. The following key areas were identified following discussions between pump users and designers.

Mechanical Design

A significant change has taken place over the last decade in that the switch from soft packed glands to mechanical seals for shaft sealing on utility applications is near universal. The benefits of this change however have not been fully realised, as mechanical seal life is generally proportional to certain key aspects of pump performance, not least shaft de ection, vibration levels and seal chamber design. The vast majority of utility pumps available today have their design roots in the packed gland era. In many instances this is leading to premature bearing and seal failures, as many pump shafts are quite simply too exible without the support of numerous packing rings and neck bushes.

This is arguably the most significant factor, influencing the mean time



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between failures of utility pumps. Mechanical seals and bearings are intolerant of shaft deflection and residual unbalance. Therefore I suggest that a pump designed for low life-cycle cost would have a shorter span between bearings and an increased shaft diameter when compared to a similar pump designed in the packed gland era. Specifically shafts should be so designed, as to limit shaft de ection at the limits of the operating range of say, 50% - 115% of best efficiency ow, to a maximum of 0.05mm at the seal faces. Bearings likewise should be designed to provide a minimum L10 life of 50,000 hours at these limits.

Hydraulic Design

With the aid of 3-Dimensional Computational Fluid Dynamics, pump manufacturers are now able to produce hydraulic designs that achieve the theoretical maximum efficiency for a given specific speed or impeller geometry. The challenge is then to consistently replicate these designs in material form. High quality manufacturing techniques and procedures are therefore essential, particularly as pump casings and impellers (the most dimensionally critical components of any centrifugal pump) tend to be produced as castings. Only foundry techniques that ensure a high standard of dimensional accuracy and surface finish should be employed in low life-cycle cost pump production.

Efficiency Degradation

The maximum benefit of installing an energy efficient machine will only be realised if performance levels can be maintained for long periods of time between overhauls. Performance degradation is inevitable, however a combination of good hydraulic and mechanical design can have a positive impact in this area and prolong optimum efficiency for much longer periods of time.

Important hydraulic designs considerations are:

- Maintenance of optimum clearances between the impeller outside diameter and the volute cut-water, which will avoid vane pass cavitation.
- Optimisation of impeller geometry with satisfactory suction specific speed values, this will limit internal re-circulation and facilitate a wide band of operation (30%-115% of best efficiency ow).
- Apply internal hydrophobic coating (low electronic affinity) in order to reduce the relative surface roughness value of the pump casing; Thus maintaining the relative surface roughness values at a more constant level, unlike that of a bare metal casing, which will oxidise once put into service immediately impacting on hydraulic performance.

Mechanical design considerations:

- Minimisation of shaft de ection will ensure no contact between impeller eye ring and sealing/wear rings surfaces, thus maintaining as new clearances for longer periods.
- Often overlooked but highly important is wear ring design. A labyrinth profile will help to provide a staged pressure drop across the wear ring, rather than simply allowing high velocity uid to ow across wear ring faces rapidly eroding internal clearances.
- High-grade materials of construction for the pump impeller with good erosion/corrosion properties will ensure that the relative roughness of hydraulic surfaces remain reasonably smooth throughout.

Packaging the Pumpset

When packaging a low life-cycle cost pump with a suitable prime mover, it is important to ensure that the same fundamental design principles be applied to the prime mover, baseplate/ mounting assembly.

The benefits of a superior hydraulic design and first class component quality can easily be forfeited by coupling the highly efficient pump to a lower efficiency driver. Likewise bearing and seal design lives will not be realised if the pump and driver are connected via a exible and inadequate baseplate or mounting frame.

The mounting arrangement as well as being rigid should facilitate a high degree of insitu maintenance. Mechanical seals and bearings should be accessible without recourse to disturb either driver alignment of connecting pipework. This dictates the use of spacer type couplings, if drive end bearings and seals are to be maintainable insitu.

Conclusion/Design Brief

Following the marketing & design review it was decided to develop a range of low life-cycle pumps, for water utility applications, based on the following brief:

A low life-cycle cost centrifugal pump will have hydraulic efficiency close to the theoretical maximum, thus minimising energy costs, identified as the largest single component cost.

In order to meet the demands of the 21st century utility application the pump should show stable characteristics associated with optimum suction specific speed, thus being able to operate reliably and efficiently across a wide range of ow conditions.

Shaft de ection should be kept to the absolute minimum in order to reduce vibration and maximise bearing and seal life. Specifically shaft deflection at the seal face with mechanically sealed pumps should not exceed seal manufacturers recommendations. This calculation should be carried out across all potential operating conditions. The pumps should firstly be designed for mechanical seals, which should be fitted directly onto the pump shaft, facilitating larger shaft diameters and reduced bearing spans..

Pumps should be so designed and pumpsets so configured that mechanical seals and bearings can be removed and replaced insitu without recourse to disturb either pipework or driver alignment. This will substantially reduce maintenance costs.

High-grade materials of construction should be utilised to maximise component life.

Pumps must not only be energy efficient as new, but must maintain a high efficiency for longer period between major overhauls.

SPP's Lowest Life-cycle Cost Series

During October 2004 SPP Pumps Ltd successfully launched their Lowest Life-cycle Cost Series pumps. The range incorporates all of the key features identified by our business partners and design engineers.

Hydraulic Design

The above test curve depicts the hydraulic performance of a 200 mm discharge Horizontal Split Casing, radial vane impeller, from the Lowest Life-cycle Cost Series range. Values of NS 1,191 and NSS 7,886, in imperial units. Note that high efficiency is achieved from 50% of best efficiency ow, peaking at 90% actual efficiency.

Mechanical Design

Vertical Direct Mounted Low Life Cost Axial Split casing Pump

The above section drawing depicts a packaged axial split casing pump. Firstly note the maintenance features of the pump; the motor mounting stool is extended to accommodate a spacer type coupling, sized to facilitate removal of the drive end seal and cartridge mounted mechanical seal insitu, also note that a product lubricated bearing is fitted at the none drive end. An antifriction bearing would be susceptible should the installation ood or the lower seal fail. A double row thrust bearing assembly is chosen for the drive end.

The short bearing span and generous shaft diameter are clearly evident. In order to replicate good hydraulic design in material form, world class manufacturing methodology is required. Note

the internal surface finish on the above double suction impeller. SPP Low Life-cycle cost pumps achieve predicated performance levels with very little variation or need to hand finish components. Austenitic stainless steel is the optimum impeller material combining excellent corrosion and mechanical properties with good castability.

Standard materials of construction for low life-cycle cost utility pumps are:-

- Casing- Cast Iron (option coated)
- Impeller – Austenitic Stainless Steel
- Shaft – Chrome Steel
- Wear Rings – Grade SG Iron

Baseplates

Low levels of vibration and accurate alignment of pump and driver cannot be maintained without a substantial baseplate. A low life-cycle cost baseplate should be rigid, easily grouted in and incorporate motor alignment screws and machined mounting pads to assist with site alignment.

Vertical Suspended Bowl Pumps

Major savings in civil engineering costs can be achieved by suspending a vertical shaft driven or submersible pump directly into a wet sump, as opposed to constructing a wet sump with accompanying ood resistant dry well.

This has resulted in a growth in vertical turbine and submersible pump sales. The majority of these pumps supplied for utilities applications however are not maintainable in-situ and are proving very expensive to repair. Submersible pumps are prone to electrical failure, owing to ingress of water and tend to have limited bearing life. Motor efficiencies also tend to be low when compared to TEFC energy efficient machines.

The majority of vertical suspended bowl pumps require removal from site into a workshop environment for minor service/replacement of bearings and mechanical seals. Major overhaul can often result in a need to replace line shafting and connecting coupling which are screwed together.

When applying the same low life-cycle cost philosophy to suspended bowl pumps, major consideration was given to mechanical seal replacement in-situ and as such a bespoke spacer coupling was developed, capable of transmitting the total thrust generated by the bowl assemblies, through to the headpiece thrust bearing. This facilitates mechanical seal replacement in-situ, without recourse to disturb either the drive motor or thrust bearing assembly.

It was decided to connect all intermediate shafting by keyed couplings thus facilitating disassembly without risk of damaging these expensive component parts.

Shaft lengths were limited and diameters set to ensure all pumps operate well below the first critical speed. An important consideration given the growing use of variable speed drives.

Summary

This short paper serves to demonstrate the concept employed by SPP in the development of a genuine range of low life-cycle cost pumps.

A thorough understanding of the intended application, operation and maintenance of pumping plant is a fundamental requirement when considering such a project. This could not have been achieved without the input of pump users and designers alike. <<

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