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Total Ownership Cost model for slurry pumps

The Total Ownership Cost model has been developed to help analyse the total costs attached to the purchase and operation of a slurry pump over its complete life-cycle. The model is most useful for optimising pump size/type on a purely economic basis, for calculating the costs of duty changes and for establishing the savings of pump material or design improvements.

This bulletin details the basis for the TOC model and explains the methodology for calculation. A number of examples are included to illustrate the specific advantage of the approach in providing a measuring tool for pumping cost continuous improvement (ie. cost reduction).

Introduction

In determining the cost of owning an item of capital equipment such as a slurry pump, many different factors need to be considered. Whilst the initial purchase cost is obviously important, it may ultimately only be a small proportion of the overall Total Ownership Cost (TOC) incurred during the lifetime of the pump. Out of the many different items of process equipment which are used in the mining industry, slurry pumps in particular can benefit from the use of a “life cost” approach because of the high relative wear associated with the erosive solids which have to be handled. With an understanding of the cost structure of the plant in which the pump is operating, and predictive or actual data on the wear of the various component parts, it is possible to build a complete picture of the costs of owning the pump.

The TOC model

The TOC of a slurry pump is the sum of the various costs:

1. Capital costs - C_c
2. Energy costs - C_e
3. Maintenance costs - C_m
4. Service water costs - C_w
5. Inventory costs - C_i
6. Availability costs - C_a
7. Overheads - C_o

1 - TOC ($/y) =

$$C_c + C_e + C_m + C_w + C_i + C_a + C_o$$

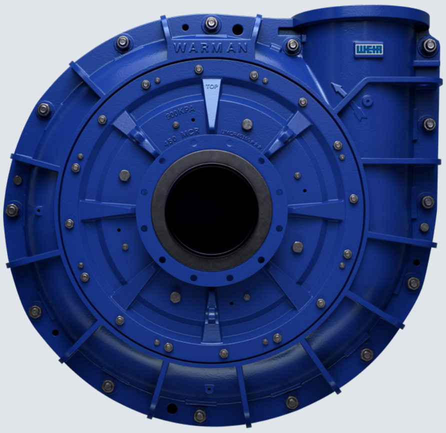
These individual cost categories are described in more detail in the following sections.

Capital cost

When purchasing a slurry pump the money that has to be out-laid includes not only the amount paid to the supplier for pump, motor, drive (eg. gear box) and base plate, but also the capital costs attached to the installation and the supply of services such as gland water and power cabling. The actual cost of the pump(s) may only be a relatively minor portion of the overall expense. For larger installations (>100 kW) pump price may be less than 30% of the capital spent on the total installation.

Other factors which affect the installation cost include the pump and drive "footprint" size which may in turn impact on the process plant floor layout and the physical size of the plant.

Centrifugal seals may offer certain capital advantages where suitable gland water is not readily available.



Warman® MCR® slurry pump

For example, in a plant in Northern Canada, the cost of a seal water supply system for some remotely sited pumps able to withstand freezing conditions was over $5m.

The use of standby pumps is another area which has a significant impact on capital costs for the plant. If maintenance strategies can be developed to avoid the need for standbys without causing direct plant downtime, then not only is there a reduction in pump costs, there is also savings in capital for valving and piping as well as the associated maintenance.

The usual method for accounting for capital items on the plant balance sheet is to depreciate them. Either a production linked approach (giving greater upfront writedown) or a "straight line" depreciation is commonly used [1]. Using the latter approach over a 5 year period, the capital cost of the installation is:

2 - $\mathbf{C_c = 0.2 \times c_i}$

where: c_i = total capital cost of installation ($)

Other ways of accounting for capital items which are not considered here include using Opportunity Cost or Cost of Capital.

Energy Cost

The amount of energy a pumping installation consumes depends on the pump efficiency, the drive train losses and the motor and/or motor controller electrical efficiency.

Pump efficiency is the biggest determinant of power costs. A slurry pump's efficiency is reduced by the presence of the solids and an Efficiency Ratio (ER) is used to correct the published water performance curve (refer [2] for detailed calculation of ER). The design of the pump may also have a small influence on ER [4]. The power absorbed by the pump (P_p) is determined by:

3 - $\mathbf{P_p = (0.98 \times H \times Q \times SG_m) / (e_w \times ER)}$

where: H = head developed (m of slurry)
Q = flowrate (L/s)
SG_m = specific gravity of slurry mixture
e_w = pump efficiency on water (%)
ER = f (d50, SGs, CW)

Other factors which influence power consumption are the transmission losses from the motor to the pump. This may be up to 5% for a V belt drive or of the order of 2% for a gearbox speed reducer. Most direct drive coupling losses are negligible. The total transmission losses (Pt) are:

4 - $\mathbf{P_t = (1-e_t) \times P_p}$

where: e_t = 0.95 for belt drive or 0.98 for gearbox

Actual power consumption of the complete pump and drive unit will depend on motor efficiency and the power factor. Motor efficiency is a function of the size and to some extent the design of the motor as well as the relative load as a fraction of the rated full load power. Power factor is just a function of the type and size of loads at the particular pump site and is generally in the range 0.85-0.9 (although can be lower with motors < 10kW). Power input to the electric motor (P_m) is then:

5 - $\mathbf{P_m = (P_t + P_p) / (e_m \times PF)}$

where: PF = site power factor
e_m = electric motor efficiency at duty point

This figure may need to be further corrected if a variable frequency controller is used as unit efficiency is of the order of 95%. This is somewhat compensated for by the power factor correction available with the drive. In simple terms, overall unit electrical power input (P_i) can then be determined from:

6 - $\mathbf{P_i = P_m / e_c}$

where: e_c = controller efficiency at duty point

The total energy cost for operating the pump can then be calculated from the power input and the cost per unit of the electricity supply:

7 - $\mathbf{C_e = P_i \times c_e \times h_o}$

where: c_e = unit power charge ($ / kWh)
h_o = total operating time (h/y)

Maintenance Cost

Maintenance is a major cost factor for slurry pumps and includes the cost of replacement parts, the labour that is required during overhaul, the service time that is consumed during routine inspection, monitoring and lubrication as well as the (hire) cost of cranes or other equipment. Alternatively if some of the maintenance services are contracted out, then these need to be added as a direct cost.

Analysis of part usage is generally restricted to the common wearing parts such as impeller, liners, shaft sleeves, stuffing box or expeller ring and expellers. Different classes of materials, including ceramics, metals and elastomers can be used for these different wear parts. The optimum selection of a material depends on a number of factors including particle size, density, pH, etc [5]. Bearing assemblies should also be included so as to highlight the effect poor maintenance can have on component life and overall costs.

The total maintenance cost (C_m) is:

8 - $C_m = c_p + c_r + c_d + (R_l \times h_w)$

where: c_p = total parts costs ($/y)
c_r = rebuild or contract mtce costs ($/y)
c_d = direct maintenance costs, incl cranes ($/y)
R_l = labour rate ($/h)
h_w = total time for overhaul and servicing (h/y)

Service Water Cost

The costs associated with the use of water to flush the gland of a slurry pump can be split into two components, the supply cost and the removal cost. The former depends on the type of pump, its size and gland type, the latter depends on the particular process and commodity being handled.

The amount of water consumed by the pump firstly depends on the type of seal for which a number of different styles are available.

The mechanical seal and expeller or centrifugal seal can be operated without any water injection, but sometimes use small amounts to help reduce wear in particularly erosive duties. "Full flow" glands use a lantern restrictor at the front of the stuffing box into which water is injected, whilst "low flow" glands use a ring of packing in front of the injection point which limits the amount of slurry dilution [6]. This water has to be supplied at a supply pressure which is generally 70kPa above the discharge pressure of the pump.

The power required to deliver the water to the gland (Pg) can be approximated by:

9 - $P_g = 0.02 \times (H + 7 / SG_m) \times Q_g$

where: H = head developed by pump (m slurry)
Q_g = gland water flowrate (L/s)

The energy cost (cge) is then:

10 - $c_{ge} = P_g \times c_e \times h_o$

To the above energy cost needs to be added the actual consumption cost for the water. In remote areas the supply of suitable gland water may be very costly due to the need for sinking bores and pumping long distances by pipeline back to the plant. Even when more readily available from mains supply, water can be relatively expensive to purchase in large quantities. The total water consumption cost (cc) is:

11 - $c_c = 3600 \times Q_g \times c_{gw} \times h_o$

where: c_{gw} = cost of water supply ($/L)

With tightening environmental standards in some cases requiring complete liquid containment on site, any slurry dilution can incur substantial cost penalties. In the alumina industry in particular, the costs associated with drying hydrate may be up to $2.20/kL [7]. The total cost of unwanted dilution water is:

12 - $c_d = 3600 \times Q_g \times c_{rw} \times h_o$

where c_{rw} = cost of removing the water ($/L)

From this the total service water cost can be calculated by summing the three terms:

13 - $C_w = c_{ge} + c_c + c_d$

Inventory Cost

Holding stock ties up capital which could otherwise be spent on revenue earning activity. Pump users hold stocks of spare parts largely to ensure that they are available immediately in the case of an unplanned shutdown or to ensure supply in the case of extended lead-times. The cost of holding stock depends on the average value of the stock held and the cost of capital(related to prevailing interest rates). In turn, average stock levels depend on the reorder points and the lead time for replenishment. This is as well as direct expenses such as store building depreciation, power, rent, transport and labour. Total inventory costs are then:

14 - $C_i = (S_{av} \times i_c) + (h_i \times R_s)$

where: S_{av} = average stock value ($)
i_c = cost of capital (%)
h_i = store labour time spent on pumps (h/y)
R_s = store labour rate (incl. direct o/heads) ($/h)

Availability Cost

If pump unavailability directly causes plant downtime or reduced recoveries then this cost needs to be accounted for. The cost attributed to lack of pump availability is:

15 - $C_a = c_{do} \times h_a$

where: c_{do} = cost of downtime ($/h)
h_a = time the plant is unavailable over a year (h)

Overheads Cost

In many mining sites there are considerable overhead costs as a result of having to provide accommodation and messing facilities, administration, HR, as well as the meeting of OH&S and environmental and other statutory requirements. Overhead costs can be factored in as a percentage of direct labour or as an addition to the labour rate. Using the latter method:

16 - $C_o = (h_i + h_w) \times c_{ov}$

where: c_{ov} = overhead rate for direct labour ($/h)

TOC calculation example

The easiest way to calculate the TOC is to use a spreadsheet set-up to take site data for costs and duties and which determines the ownership cost in the various categories. Using a spreadsheet also allows easy comparisons between alternatives and scenario analysis for a variety of different materials, designs and duties such that the immediate impact on costs can be seen.

The TOC (in $/y) for each individual pump is calculated by summing the individual cost terms. If the pump has a standby then the actual operating hours per year for each pump must be used in calculating the part consumption and number of changeouts, etc.

TOC calculation example

Total ownership cost	Cyclone feed cost ($)	Cyclone feed cost (%)
Capital	26,800	13%
Energy	129,946	61%
Water	392	0%
Maintenance	50,617	24%
Inventory	1,699	1%
Availability	0	0%
Overhead	3,944	2%
TOC ($/Y)	213,400	
TOC ($/T)	0.13	

The overall TOC can be normalised for tonnes solids handled by the pump ($/t/pump) or for tonnes processed by the plant ($/t overall) as shown in the example.

Cost reduction

In most applications the largest costs are for Energy, Maintenance and depreciation on Capital. In looking to reduce costs these areas should be given priority.

Specific strategies for cost reduction should explore the following options:

Energy:

- Maximise use of high efficiency (HE) style impellers for fine slurries
- Ensure the gap at the front of the pump impeller is adjusted to a minimum to reduce recirculation and increase efficiency
- Utilise reduced eye impeller and low flow volute to increase pump efficiency at flows less than 60% of standard impeller best efficiency point
- Maximise use of low NPSH style (HN) impellers where pumps may be prone to cavitation
- Where justifiable use purpose designed duty point impellers to increase efficiency

Maintenance:

- Optimise selection of materials (ceramics, elastomers and metals)
- Choose materials to give part life same as or multiple of shortest life part
- Ensure pump is selected to operate at correct flow with respect to BEP
- Use reduced eye impellers for coarse particle slurries at flows below 60% of BEP
- Use “thick liners” when pumping coarse abrasive slurries
- Work on improving shortest life part first
- Ensure maintenance and operations personnel are properly trained
- Utilise off-site maintenance or Rebuild Centre to reduce overheads
- Use rubber liners to ease handling, reduce need for cranes and reduce back strains

Capital:

- Don’t install standby pumps
- Use centrifugal or mechanical seals where dedicated gland water system is expensive
- Use CV drive arrangements to reduce the floor space requirement

Conclusion

Slurry pump TOC analysis is a useful tool for continuous improvement of pump costs. It enables a reference to be determined using all the costs that are incurred. Changes to the pump or system can then be planned with an estimate of the potential savings in mind, and a measured base from which to judge results.

TOC analysis is also useful for comparing different pumps at the time of purchase to ensure that the lowest cost (not price) unit is selected.

References

[1] Australian Accounting Standards No. 4 (AAS4)

[2] Weir Minerals Technical Bulletin No.22, Weir Warman Ltd, Sydney, (November 2005)

[3] Pump Life Cycle Costs: A guide to life cycle cost analysis for pumping systems. Europump and Hydraulic Institute, First Edition 2001.

[4] Walker, C I, Wells, P J and Pomat, C, “The effect of impeller geometry on the performance of centrifugal pumps”, Int Conf on Bulk Materials Handling and Transportation, I E Aust, Wollongong, Aust, (July, 1992).

[5] Walker, C I and Bodkin, G C, “Erosive wear characteristics of various materials”, Proc. of HYDROTRANSPORT 12, BHR Fluid Eng, Brugge, Belgium, (September, 1993).

[6] Warman Pumps Assembly and Maintenance Instructions, Supplement M9, Gland Sealing, (June, 1996).

[7] “Cost of dilution to Alcoa’s refineries”, 1st Warman User Group Workshop, Perth, Appendix 1, (May, 1995)

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