Cost efficient centrifugal pump use and maintenance in the beet sugar industry

Kosteneffizienz bei Einsatz und Instandhaltung von Kreiselpumpen in der Rübenzuckerindustrie

Hannu Huttunen and Pekka Halme

Investment, use and maintenance of centrifugal pumps in the beet sugar industry are often based on the lowest purchase costs of pumps available. In the long run higher initial cost could be justified considering all the relevant criteria in pump selection. Such criteria are material , energy savings in terms of better pumping efficiency, reliability, lower maintenance labor costs and quality aspects. The most important tool in making a pump or a pumping system selection should therefore be life cycle cost analysis (LCC). Some future trends in pump development, operation and maintenance are also outlined.

Investition, Einsatz und Instandhaltung von Kreiselpumpen in der Rübenzuckerindustrie richten sich oft nach den niedrigsten Anschaffungskosten der verfügbaren Pumpen. Auf lange Sicht können allerdings höhere Anschaffungskosten unter Berücksichtigung aller relevanten Auswahlkriterien gerechtfertigt sein. Kriterien sind Material, Energieeinsparung aufgrund besserer Wirkungsgrade, Zuverlässigkeit, geringere Instandhaltungskosten sowie Qualitätsaspekte. Das Kriterium bei der Auswahl einer Pumpe oder eines Pumpensystems sollte daher eine Analyse der Lebenszykluskosten (LCC) sein. Einige zukünftige Tendenzen bei Pumpenentwicklung, -betrieb und -instandhaltung werden ebenfalls dargestellt.

1 Investment and maintenance strategies

1.1 Investment and maintenance strategies in general

In modern times all investment and maintenance philosophies and strategies should be based on life cycle costs (LCC) of a pump or pumping system [1]. Most pumping LCC costs results from the pumps operation costs. Capital or investment costs are only significant in investment terms for pumps with less than 10 kW input power and even then 80% of the LCC costs are operating costs. For pumps with power rating over 150 kW almost all the LCC costs are operating costs (Fig. 1).

In Figure 2, there is a practical graphic example of the age spread of centrifugal pumps in a Finnish beet sugar factory. As can be seen, the lifetime of a pump in a beet sugar factory varies between 4–50 years depending of pump application. Variations or sudden peaks indicate capacity expansions or other big new investments. The calculated average pump age is about 15.3 years. (It may be even higher, because ages of all pumps could not be found.) All investment calculations should therefore be based on pump lifetimes of at least 10 years in normal applications and in some cases, like water pumping, up to 40–50 years.

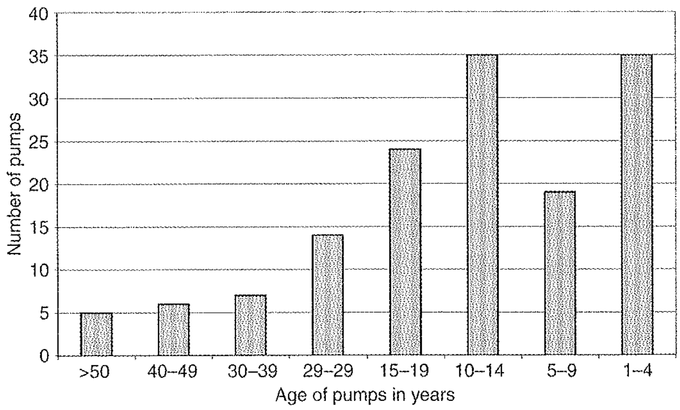

Fig. 2: Age of pumps in a Finnish beet sugar factory

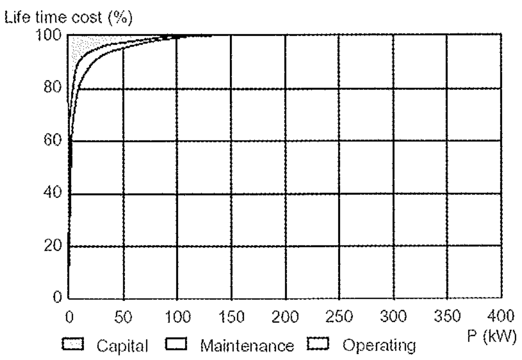

Fig. 1: Distribution of costs for a continuously pumping process pump depending on input power of the pump

1.2 Investment and maintenance LCC calculation

Comparison of three pumps with differing materials of construction and sealing systems: Table 1 shows an elementary calculation example for life cycle costs. Prices and other values are more or less imaginary, but the main purpose is to show that low initial investment cost does not tell the whole story.

Table 1: Pump investment and maintenance life cycle calculation

Application	Raw juice pumping
Beet slicing capacity	12,000 t/d = 500 t/h
Campaign length	90 days
Raw juice density	1,06 kg/dm³
Mass flow rate	110 % on beet = 550 t/h = 519 m³/h
Volumetric flow rate	144 L/s
Head	30 m

Pump A		Pump B		Pump C	
Pump material	Stainless steel	Pump material	Stainless steel	Pump material	Cast ironPump
lifetime	15–20 years	Pump lifetime	15–20 years	Pump lifetime	7–10 years
Sealing system	Dynamic seal	Sealing system	Double mechanical seal	Sealing system	Gland packing
Prices		Prices		Prices	
Pump complete	13.000 EUR	Pump complete	13.000 EUR	Pump complete (life time 7–10 years)	7.900 EUR
				2nd pump after 7–8 years	7.900 EUR
Electric motor	2.300 EUR	Electric motor	2.300 EUR	Electric motor	2.300 EUR
Dynaseal	2.700 EUR	Double mechanical seals (life time 5 years)	3.000 EUR	Gland packing	0 EUR
Installation costs	500 EUR	Installation costs	750 EUR	Installation costs	750 EUR
Sealing water system	0 EUR	Sealing water equipment/ system	500 EUR	Sealing water equipment/ system	500 EUR
Total investment	**18.500 EUR**	**Total investment**	**19.550 EUR**	**Total investment**	**19.350 EUR**
Operational costs		*Operational costs*		*Operational costs*	
Additional electroenergy during campaign	90 EUR/a	Additional electroenergy during campaign	0 EUR/a	Additional electroenergy during campaign	10 EUR/aWater
costs	0 EUR/a	Water costs	30 EUR/a	Water costs	80 EUR/a
Annual sugar losses during campaign	0 EUR/a	Annual sugar losses during campaign	0 EUR/a	Annual sugar losses during campaign	40 EUR/a
Operational costs per year	90 EUR/a	Operational costs per year	30 EUR/a	Operational costs per year	130 EUR/a
Maintenance costs		*Maintenance costs*		*Maintenance costs*	
– flushing and cleaning	4 h/a	– cleaning, disassembly, repair	8 h/a	– cleaning, disassembly, repair	16 h/a
– cost of man hour	20 EUR/h	– cost of man hour	20 EUR/h	– cost of man hour	20 EUR/h
– spare parts	100 EUR/a	– spare parts	300 EUR	– spare parts	200 EUR
Maintenance cost per year	180 EUR	Maintenance cost per year	460 EUR	Maintenance cost per year	520 EUR
Operational costs in 15 years	1.350 EUR	Operational costs in 15 years	450 EUR	Operational costs in 15 years	1.950 EUR
Maintenance costs in 15 years	2.700 EUR	Maintenance costs in 15 years	6.900 EUR	Maintenance costs in 15 years	7.800 EUR
Total lifetime costs	**22.550 EUR**	**Total lifetime costs**	**26.900 EUR**	**Total lifetime costs**	**29.100 EUR**

2 Pump selection

2.1 Dimensioning

Accurate dimensioning is important, because there are considerable efficiency losses and, in extreme cases, danger of cavitation if duty point is far from BEP (best efficiency point). Computer programs like PUMP-FLO® by Engineered Software are adapted to individual pump manufactures needs.

2.2 Selection of materials

Process conditions dictate the choice of materials to ensure resistance to chemical and mechanical corrosion and wear. Process conditions are normally manageable, but there are certain points to regard attention in the beet sugar process:

- abrasive conditions found in beet washing, extraction, pulp pressing and milk of lime production;
- chemically demanding conditions such as extraction;
- hygienic conditions like those found in the sugar house.

In abrasive conditions wear a resistant pump might be more cost effective, because it needs no rubber lining or coating procedures after the campaign. At the beet end and juice purification cast iron is an option if the conditions are not too abrasive or there is no chemical hindrance. Normally pH value is high enough, between 6 and 11. As a standard stainless steel is used because of the foodstuff manufacturing nature of the process, GMP = Good Manufacturing Practices and quality requirements, ISO 9000. In many cases better material saves costs in maintenance labor costs.

2.3 Sealing solutions and lubrication

There are many different sealing systems: gland packing or stuffing box, single or double mechanical seal and Dynaseal [2]. For lubrication, there are two alternatives: grease or oil lubrication. The lubrication system may also be centralized, which is easier to control and saves lubricant. In some cases over-lubrication with grease can be even harmful. In high temperatures oil lubrication should be used because its additional cooling properties and can guarantee longer lifetime for bearing units.

3 Use of pumps under process conditions

V-belt drives and control valves are being increasingly replaced by direct-coupled electric motors equipped with variable frequency drive (VFD). This is because VFD offers many advantages over valve control. The most important is energy saving, in many applications this may be as much as 25–30% [3]. An additional advantage is the ability to control the process over a wide range of flow conditions combined with optimal energy usage.

4 Maintenance

4.1 Maintenance in general

According to *Piotrowski* [4] maintenance can be categorized in four different ways:

- breakdown or run-to-failure maintenance;
- preventive or time-based maintenance;
- predictive or condition-based maintenance and;
- pro-active or prevention maintenance.

Kapseu et al. [5] give a very good presentation about pump maintenance and factory productivity in cane sugar industry. There is only one thing in the article, where the authors disagree with him, the idea of many spare pumps used as standby, which should safeguard the production. Modern heavy-duty process pumps do not need spare pump, except in absolutely critical process stages, where start-up must take place in seconds instead of minutes. It is possible to save a lot in investment costs in analyzing the process for the 'real world' need for spare pumps. If the pump design includes the back pull-out concept with incorporated modules and spare parts, in most cases it is possible to change an impeller, for instance, in about 30 min.

In beet sugar industry the two main maintenance philosophies are time-based and condition-based respectively. Sugar industry cannot afford run-to-failure maintenance, because down time, which is involved in sugar manufacture, always means substantial energy losses and sugar losses in the form of leakage and lost production. In practice, it also means up to 30% higher maintenance costs than time-based maintenance.

Condition monitoring is based on the failure process and the phenomena occurring during the deterioration of a piece of machinery, as described in Figure 3. Condition-based maintenance is the main concept adopted in developed, modern beet sugar factories. The condition of machines is measured by different monitoring methods such as: vibration measurement and analysis, infrared thermometry, oil analysis and tribology, ultrasonics and motor current analysis. *Dunn*'s article [7] is a good overall description about different condition monitoring practices and the business approach to condition-based maintenance.

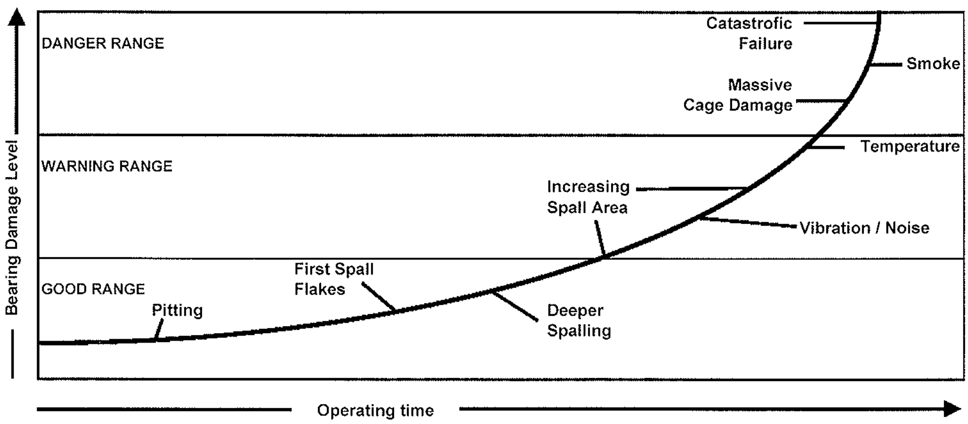

Fig. 3: The failure process [6]

4.2 Maintenance labor "consumption" and costs

Development of manpower usage in a Finnish beet sugar factory shows a tremendous increase in efficiency during a 30-year period (Table 2).

The development demonstrated above is due to continuous rationalization, improving of methods and a shift from run-to-failure through time-based and condition–based maintenance towards pro-active maintenance. It also includes investment in better pump construction, design and materials plus eliminating all unnecessary stages of pump maintenance support work such as haulage of pumps off site.

Table 2: Maintenance man-minutes per ton sugar produced

Manpower usage	1970	1980	1990	2000
Number of pump maintenance workers	9	7	4	3
Approximate working in h/y	12,000	9,000	4,000	3,000
Beet slicing capacity in t/d	1,500	2,900	4,100	6,800
Sugar production per year	12,000	28,000	41,000	75,000
Pump maintenance in min/t sugar	60	19	5,9	2,4

Pro-active or prevention maintenance, is gaining more and more emphasis. It combines the best points of the three other methods, but the basic philosophy also includes very thorough analysis of the cause of failure (Root Cause Analysis) and continuous improvement of the process, machinery and methods of operation to eliminate problems from reoccurring. Disadvantages of the approach are that it requires extremely knowledgeable employees or outsourcing of the work to a knowledgeable contractor. The costs of maintenance could be reduced to only 30% of run-to-failure maintenance.

5 CIP (cleaning in place)

CIP after the campaign reduces maintenance costs, if pumps can flushed and left in their places until the next campaign. This requires that the pumps are made of appropriate material and the pipelines are adjusted to recirculation of cleaning fluids and final rinsing with water. This may require additional piping start-up costs, but savings in maintenance and personnel costs can be notable.

6 Future trends in pumping

Pump suppliers will show focus and commitment to both technical and technological development to improve products and develop new innovative applications specifically adapted to the sugar industry

6.1 Product development trends

- Increased reliability: Adopting the one pump concept leading to fewer spare pumps. Spare pumps are installed only in critical applications. Reliability of the pumps is the key factor, but the investment cost savings in long run are worth investigation.
- Lower energy consumption: better pumping efficiency; lower NPSH (Net Positive Suction Head).
- Less maintenance: new materials such as special steels for different specific needs and innovative plastic and/or fiber materials.
- More specific products to even narrower individual industry sectors: better hydraulic designs in special applications and broader application range in terms of temperature or other process variables.

6.2 **Application development**

- Replacement of normal centrifugal pump by gas-removing centrifugal pumps in some applications [8, 9].
- Replacement of positive displacement units by centrifugal pumps in some applications [10].
- New pumping applications based on technology transfer from other industrial sectors.

6.3 **Methology development**

- Partial or total outsourcing of maintenance works;
- Reduction of cleaning and maintenance costs by developing CIP (cleaning in place) during or after the campaign;
- Application of computer technology in maintenance planning and control;
- Better exploitation of Internet and other network connections in purchasing and maintenance procedures, *e.g.* spare parts inventory updating (e-commerce);
- On-line condition monitoring of pumping systems during processing using ever more sophisticated electrical and electronic devices;
- More advanced process control strategies and automation systems require better pumps and pumping control including piping and flow control capabilities;
- System analysis for process performance deterioration: flow performance and trend prediction based on material and energy balances;
- Simulation technology in the orientation and training of operators.

References

1 Pump Life Cycle Costs: Executive summary. Hydraulic Institute, www.pumps.org

2 *Hokkanen, J.* (2000): Dynamic seal in the sugar industry: Enhanced operational reliability and lowest total costs. Int. Sugar Journal 102, 586–591

3 *Kuoppamäki, R.* (1999): Saving electrical energy in pumping. Eucepa Conference, Stockholm, 8–11May

4 *Piotrowski, J*: Pro-active maintenance for pumps. Pump-Zone, www.pump-zone.com

5 *Kapseu, C.; Kombou, E.S.; Allain, M.; Bertrand, E.; Tedga, N.* (1995): Pump maintenance and factory productivity. Int. Sugar Journal 97, 117–120

6 *Board, D.; Cartwright, B.*: Using predictive maintenance to gauge bearing and gear damage in rotating machinery. www.energy-tech.com

7 *Dunn, S.* (2002): Condition monitoring in the 21st century. Plant Maintenance Resource Center, www.plant-maintenance.com

8 *Seppänen, L.* (1998): Self-priming, gas-removing pumps in sugar industry. Int. Sugar Journal 100, March, Buyer's Guide, BG1–BG4

9 *Rübsam, A.* (2000) Plobmfreies Pumpen gashaltiger Medien und Energieeinsparung durch Dichtungssysteme. Zuckerind. 125, 342

10 *Kupiainen, S.* (2001): Pumping of viscous technical sugar solutions with centrifugal pumps. Zuckerind. 126, 875–879

Received on 5 April 2002

Efficacité des dépenses consenties lors de l'installation et de l'entretien des pompes centrifuges en sucrerie de betteraves (Résumé)

L'investissement, l'utilisation et l'entretien des pompes centrifuges en sucrerie de betteraves sont souvent basés sur les coûts d'acquisition les plus bas des pompes disponibles. Sur le long terme, un coût initial plus élevé peut se justifier si on considère tous les critères significatifs dans le choix d'une pompe. Ces critères sont le matériel, les économies d'énergie en termes d'une meilleure efficacité de fonctionnement, la fiabilité, de moindres coûts d'entretien ainsi que les aspects qualitatifs. Le critère le plus important lors du choix d'une pompe ou d'un système de pompage devrait être une analyse des coûts d'un cycle de vie (LCC). Quelques tendances futures dans le développement des pompes, leur mise en service et leur entretien sont également soulignés.

Eficacia económica del empleo y del mantenimiento de bombas centrífugas en la industria azucarera de remolacha (Resumen)

Inversiones, empleo y mantenimiento de bombas centrífugas en la industria azucarera de remolacha, muchas veces, están sujeto a los gastos más bajos de adquisición e instalación de las bombas disponibles. A largo plazo, sin embargo, se podrán justificar gastos iniciales más altos, si se toman en cuenta todos los citerios de selección para bombas. Tales criterios son: material, ahorro de energía por mejor eficacia/rendimiento, fiabilidad, menores gastos de mantenimiento y aspectos de calidad. La selección de una bomba o de un sistema de bombas deberá así basarse en el análisis de los costes de todos los ciclos de vida (LCC, life cycle costs). Se presentan algunas tendencias a nivel del desarrollo, del servicio y del mantenimiento de bombas.

Authors adresses: *Hannu Huttunen,* Senior Process Specialist, FMF/Food, Sulzer Pumps Finland Oy; e-mail: Hannu.Huttunen@sulzer.com, www.sulzerpumps.com; Pekka Halme, Maintenance Manager, Finnsugar Sucros Ltd. (Danisco Sugar); e-mail: Pekka.halme@danisco.com, www.daniscosugar.com.

Reprint from vol. 127 (2002) 376–379

Zucker Industrie Sugar Industry

Verlag Dr. Albert Bartens KG, Lückhoffstr. 16, D-14129 Berlin