Innovation Design Efficiency Applications Sustainability

EFFICIENCY
FROM REGULATIONS
TO RESEARCH

SEA LAND
ELECTRIC PUMPS

Outline of the presentation

- Energy consumption by origin
- From components to system of components
- How-to improve the efficiency of pumps
- Market trends & developments in pump technology
- Current research on pumps

Energy consumption by origin scenario - I European Union overall

- EU total energy consumption:

1792 Mtoe (~**20900TWh**)

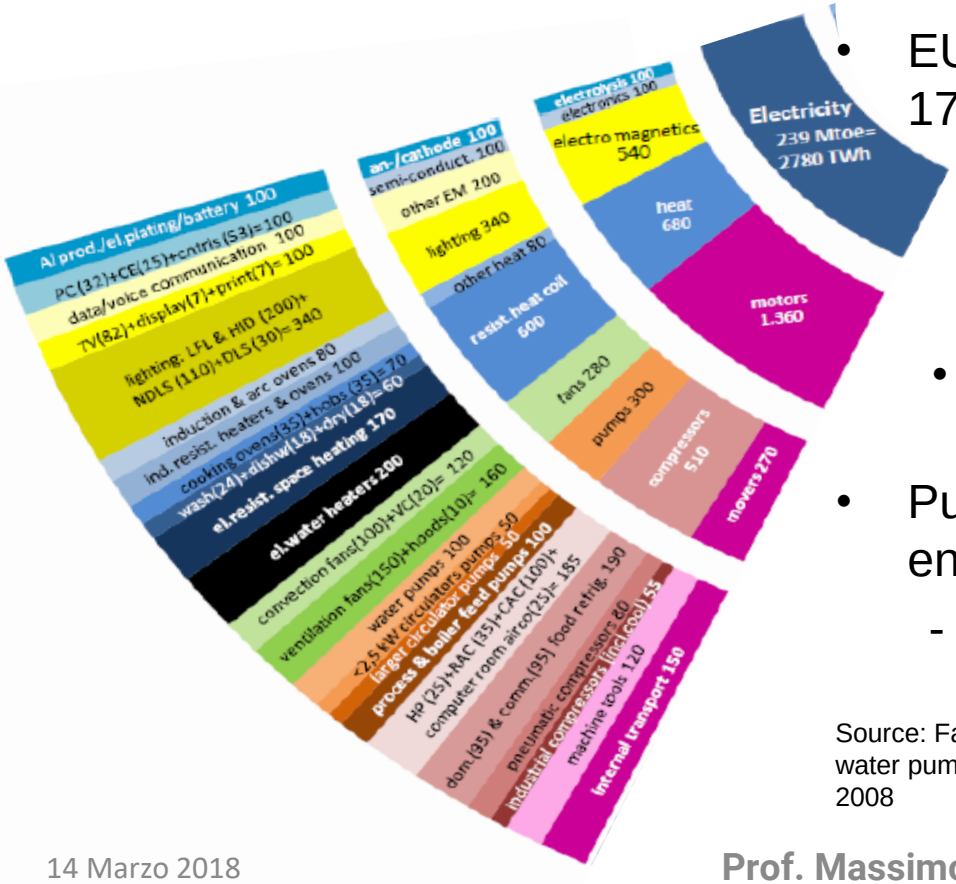
- What about pumps?

YOU ARE HERE!

- And, more in detail…

Source: Falkner, H., Lot 11 - Water pumps (in commercial buildings, drinking water pumping,food industry, agricolture). Report to European Commission, 2008

Energy consumption by origin scenario - II
Pumps in European Union



- EU total energy consumption: 1792 Mtoe (~20900TWh)
  - Electricity consumption is ~13% (~2780TWh) of the EU total energy consumption
  - Electric motors uses ~50% (1360TWh) of the entire electricity
- Pumps require 22% (300TWh) of the energy used by electric motors
  - i.e., ~ 1.5% of EU total consumption

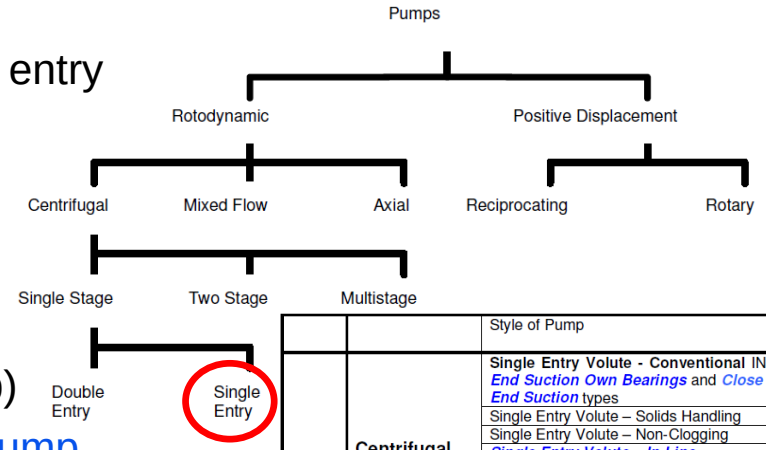
Source: Falkner, H., Lot 11 - Water pumps (in commercial buildings, drinking water pumping,food industry, agricolture). Report to European Commission, 2008

Energy consumption by origin scenario - III
Share of pumps energy consumption

- Rotodynamic-Centrifugal-Single stage-Single entry
  - **"end suction close coupled"**

  - **"end suction own bearing"**

  represent **50 %** (~150TWh) of the total energy use of pumps in the EC (Europump)
- 17M of mass produced commodity types of pump
  - i.e., water pumps for Commercial Buildings, Drinking Water, Agriculture and Food Industry**.**
- These pump types represent ~46% (137TWh) of the total energy use of pumps in EC
  - the three **"End Suction" types** account for **73%** of this energy consumption.



		Style of Pump
ROTODYNAMIC	Centrifugal	**Single Entry Volute - Conventional** INCLUDES ***End Suction Own Bearings*** and ***Close Coupled End Suction*** types
		Single Entry Volute – Solids Handling
		Single Entry Volute – Non-Clogging
		Single Entry Volute – In-Line
		Double Entry Volute
		Two Stage Volute
		Multistage Radial Split INCLUDES ***Vertical Multistage pumps***
		Multistage Axial Split
		Multistage Barrel Casing
		Single Stage Well
		Multistage Well INCLUDES ***Submersible Multistage Well pumps***
	Mixed Flow	Volute
		Bowl
	Axial Flow	Well
POSITIVE DISPLACEMENT	**Rotary**	Progressing Cavity
		Sliding Vane
		Peristaltic
		Screw
		Lobe
		Gear
	Reciprocating	Diaphragm
		Plunger
		Piston
	Open	Archimedean Screw

Source: Falkner, H., Lot 11 - Water pumps (in commercial buildings, drinking water pumping,food industry, agricolture). Report to European Commission, 2008

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From components to system of components - I the component, i.e., the pump

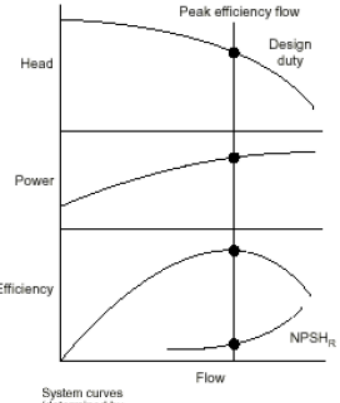
- Reductions in the **weight of the products** is something that manufacturers would wish to do anyway, but **will not have a significant impact** on the overall eco impact of the products.
- The eco impacts from the **Production, Distribution and End-of-life phases** of pumps **are very small** or insignificant compared to the USE phases.
- This justifies the **focus on energy efficiency** as the primary means for improving the eco performance of pumps.
  - Pumps, like each component, have a component efficiency: $\eta_{comp} = \frac{P_{comp}}{Pcomp + dP_{comp}}$

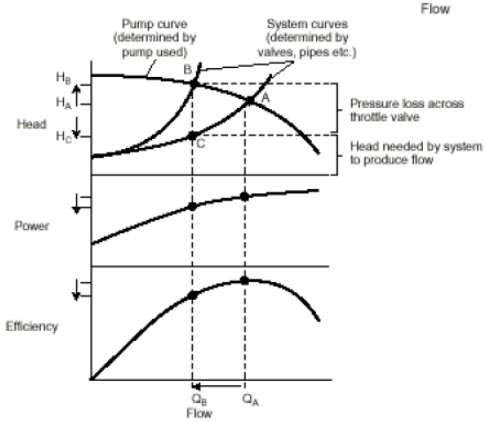
➔ $\eta_{pump} = \frac{P_{pump}}{P_{pump} + dP_{pump}}$

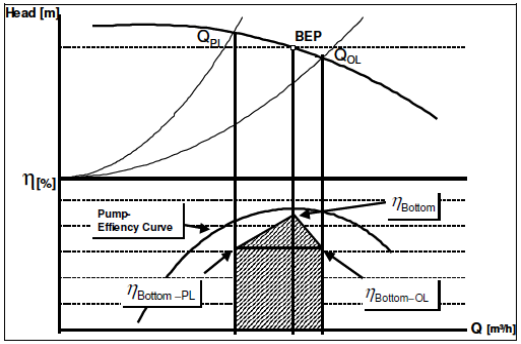
Source: Falkner, H., Lot 11 - Water pumps (in commercial buildings, drinking water pumping,food industry, agricolture). Report to European Commission, 2008

From components to system of components - II the component, i.e., the pump

- In most real life applications, pumps will spend much of their time working some **way from** their design point.
- Classification of pump performance **must accounts account for this** to avoid pumps passing the simple (rated flow) efficiency threshold, but actually performing very poorly when operated away from this point.
- The “house of efficiency” scheme addresses this issue by setting efficiency criteria for **not only 100%** flow, but also sets slightly lower efficiency **thresholds at 75% and 110%** of rated flow that a pump must also exceed.







Source: Falkner, H., Lot 11 - Water pumps (in commercial buildings, drinking water pumping, food industry, agricolture). Report to European Commission, 2008

From components to system of components - III the system, i.e., the future?

- **Pumping system:** system of components (motor+transmission+pump+piping+…) making available to the users the power P
  - like a component, it has:
    - Losses dP_{sys}
    - Efficiency $\eta_{sys} = \frac{P}{P+dP_{sys}}$
  - Losses occur in:
    - motor dP_{mot}
    - transmission dP_{mech}
    - pump $dP_{pump}(dP_{mech'}, dP_{hyd}, dP_{vol})$
    - piping dP_{pipe}
    - etc.

➔ **System efficiency**:

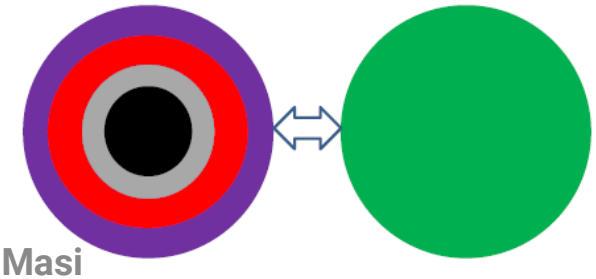
$$\eta_{sys} = \frac{P}{P+dP_{pipe}+dP_{pump}+dP_{mech}+dP_{mot}+\cdots}$$

- **Now** we are at **components level**, what is **the next step**?

MEErP 2011 - Methodology for Ecodesign-related Products - Project Report Contractor: COWI Belgium sprl -in association with-. Van Holsteijn en Kemna B.V. (VHK). Prepared for the European Commission, DG Enterprise and Industry. Unit B1 Sustainable Industrial Policy under specific contract SI2.581529, Technical Assistance for the update of the Methodology for the Ecodesign of Energy-using products (MEEuP), within the framework service contract TREN/R1/350-2008 Lot 3

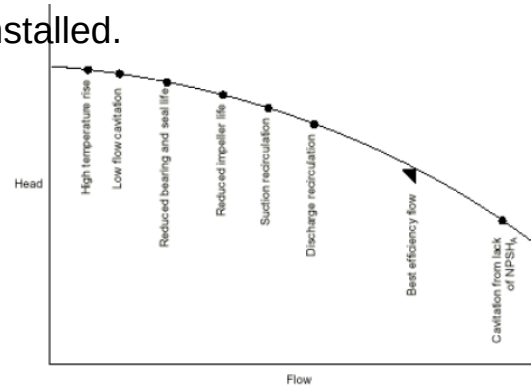
EXAMPLE: Ventilation from product=strict to product=systems

- Motor
- Drive + Motor
- Fan + Drive + Motor
- Central Ventilation Unit: Casing, Filters, Unit Controls, Heat exchanger (recovery), Fan(s) +Drive(s) +Motor(s)
- Mechanical Ventilation System: Central Ventilation Unit(s) + Ductwork + Terminals + Distribution controls + possibly additional functionality (pre-heat, humidification, etc.)
- Natural Ventilation (or hybrid) Systems ←→Mechanical ventilation systems

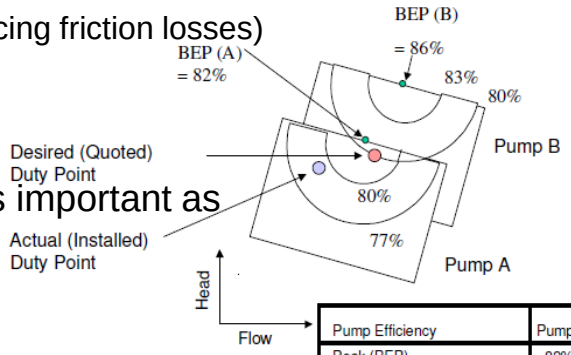


From components to system of components - IV
Reducing pump system energy consumption

- **Correct specification and design of the system** in which the pump is installed.
  Better System Design : **10%**
  (pipework sizing, minimising velocities, reducing friction losses)



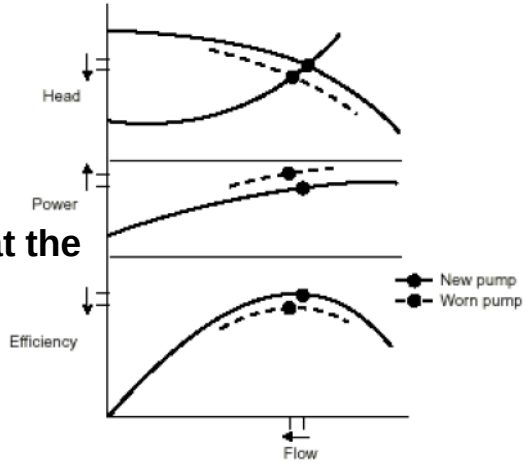
- **Correct Selection of Pump**
  Selecting better sized pump: **4%**
  correct selection of pump is at least as important as the selection of pump by highest BEP.



Pump Efficiency	Pump A	Pump B
Peak (BEP)	82%	86%
At desired (quoted) duty point	81.5%	80%
At actual (installed) duty point	79%	<77%

- **Control of the system**
  Better System Control: **20%**
  (use of Variable Speed Drives can make energy savings > 50% in some systems)

- Effective **maintenance of the pump**.
  Better installation / maintenance: **3%**



Beyond the pump itself, **large energy savings are to be found by looking at the system**

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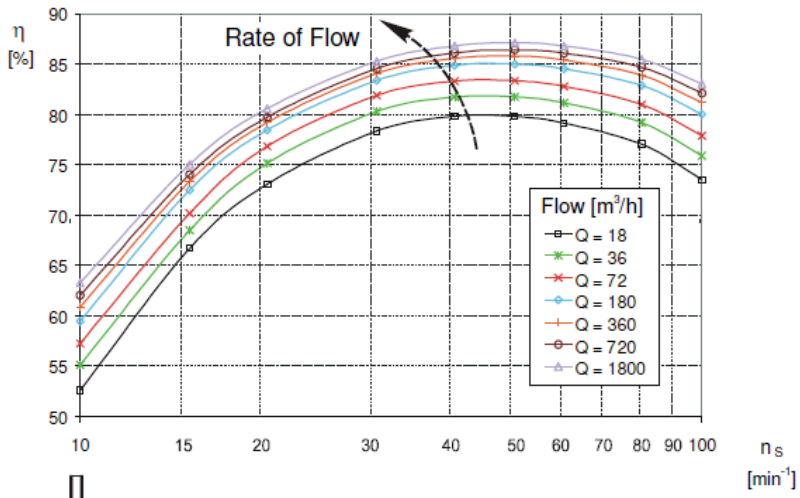
How-to improve the efficiency of pumps - I Introduction

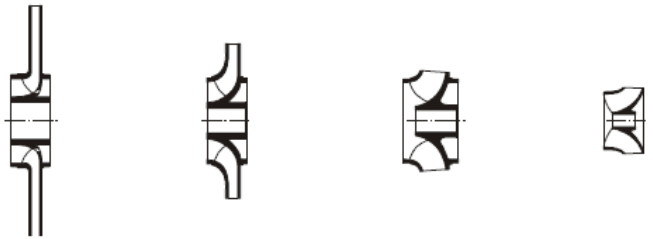
- technical understanding of the types of methods that can be used by manufacturers to improve pumps (purely theoretical indications of the effects of modifications to an idealised pump)
- The possible gain of efficiency strongly depends on:
  - the absolute size of the pump;
  - the initial state of pump parts;
  - the issues of operating reliability*;
  - the technical requirements of production and assembly*;
  - the system constraints*

  *dominate the design process of the pump
- Absolute size of the pump

$$n_s = n \cdot \frac{Q^{1/2}}{H^{3/4}}$$

n_s [min^{-1}], n [min^{-1}], Q [$\frac{m^3}{s}$], H [m]





single stage end suction standard industrial pumps

Source: European Commission - SAVE Study on improving the efficiency of pumps, 2001, AEAT-6559/ v 5.1

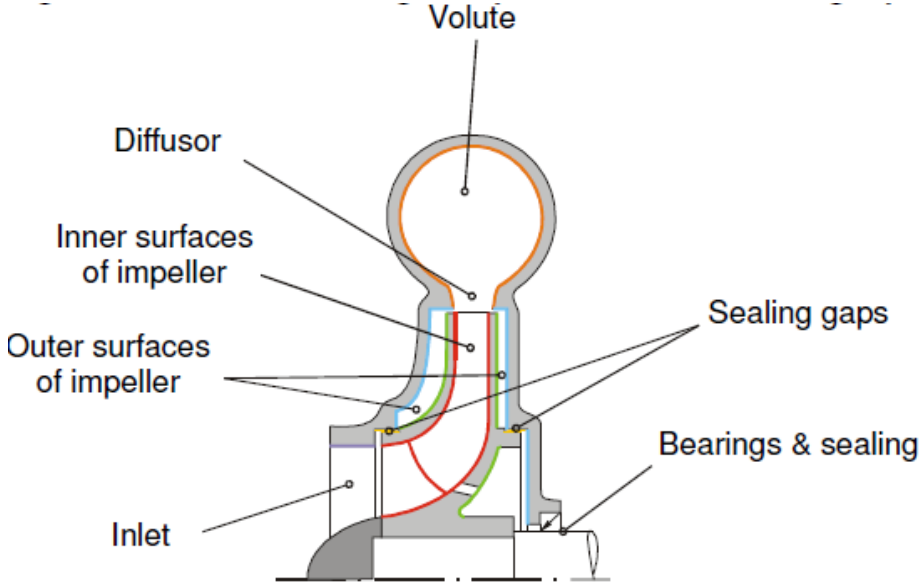
How-to improve the efficiency of pumps - II Design Factors Affecting Pump Efficiency

- Pump manufacturers have the know-how to carry out hydraulically correct designs
  - pump efficiency had not changed significantly since 1990

➔practically attainable overall efficiency is mainly influenced by:

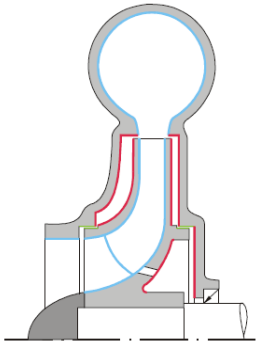
  - surface roughness
  - internal leakage
  - mechanical friction

Source: European Commission - SAVE Study on improving the efficiency of pumps, 2001, AEAT-6559/ v 5.1



single stage end suction standard industrial pump

How-to improve the efficiency of pumps - III Breakdown analysis of Pump Losses



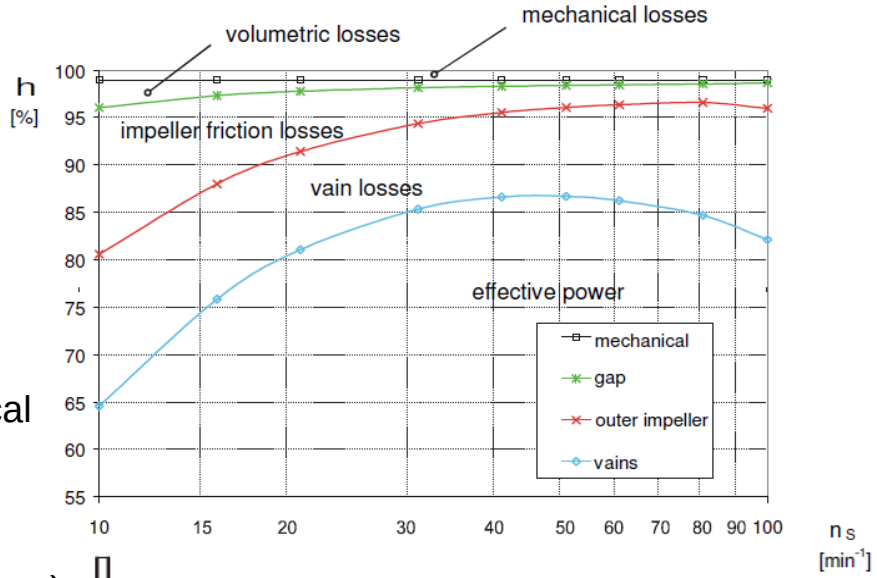
Considered Losses

- hydraulic losses:

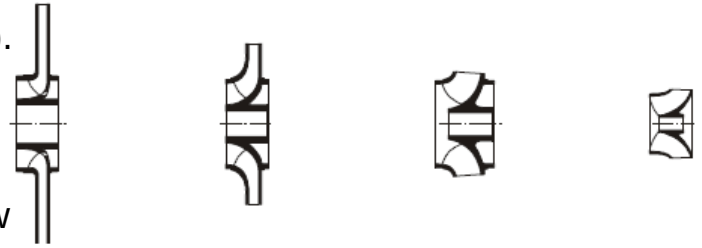
  friction losses
  deceleration losses
  wake losses
  mixing losses (Volute)

- volumetric losses (gap flow)

- mechanical losses



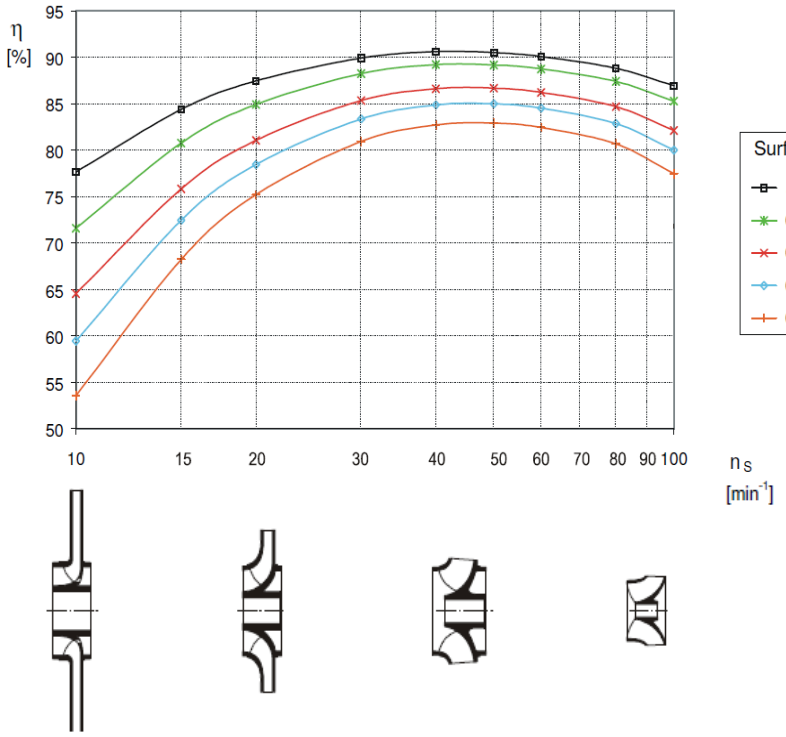
- mechanical losses (anti-friction bearings and mechanical seal) range from 2% to 10% (small pumps) of the input power. These are not capable of significant reduction (without resorting to very sophisticated and expensive solutions, i.e., water lubricated journal and thrust bearings).



➔ Main factors affecting efficiency are the influences of:

- different values of **surface roughness**;
- different **gap clearances** on the internal leakage flow rate

How-to improve the efficiency of pumps - IV
Influence of different values of surface roughness

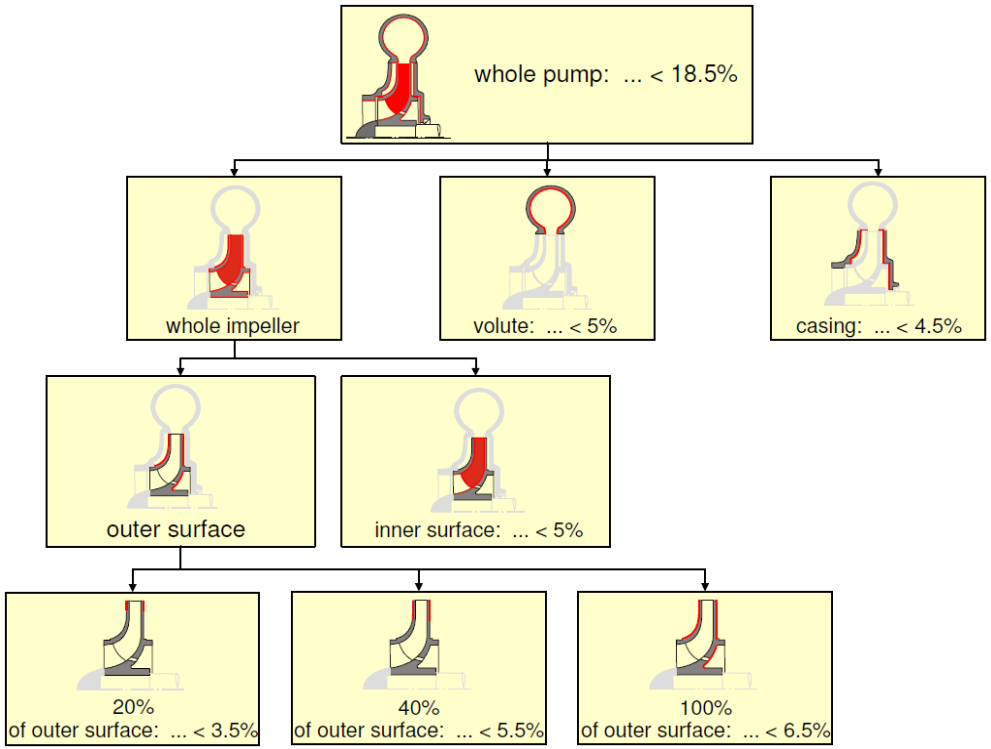


← top quality sand-cast-rough surfaces
← low quality of manufacturing
← widely eroded and/or incrustated surfaces

Surface smoothing of low quality inner surfaces
➔~ 5% minmum efficiency gain
(@ optimum Ns)
➔>20% maximum efficiency gain
(@ low Ns)

Source: European Commission - SAVE Study on improving the efficiency of pumps, 2001, AEAT-6559/ v 5.1

How-to improve the efficiency of pumps - V Influence of Smoothing parts of the wetted Surface



smoothing a whole pump is a **very cost intensive** manufacturing process (especially for small and medium sized pumps produced by a normal sand cast method), but:

1) smoothing of the **inner surfaces** is primarily favourable for pumps with **higher Ns** (>>30 [1/min])
2) smoothing the **outer surfaces** of the impeller front and back shroud (by turning) is a **less costly** procedure

for pumps with **lower Ns** (<30 [1/min]), smoothing of part the outer surface of the back and front shroud (turning process starts at *D*2) leads to

an efficiency improvement ~ **5.5%** when **only 40%** outer part is smoothed
an efficiency improvement ~ **3.5%** when **only 20%** outer part is smoothed

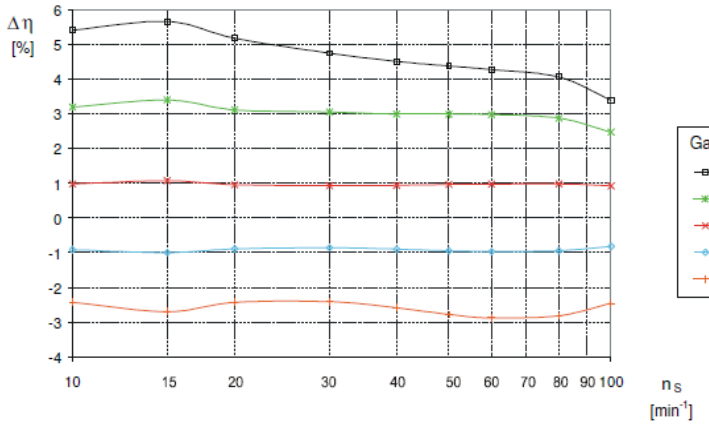
➔there is **no need** to smooth the impeller at **smaller diameters** where turning gets more difficult because of the more complicated impeller contour

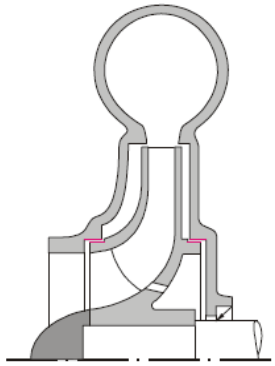
➔ smoothing part of the impeller front and back shroud is a **very efficient** procedure

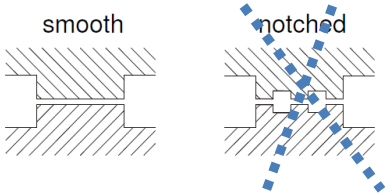
Source: European Commission - SAVE Study on improving the efficiency of pumps, 2001, AEAT-6559/ v 5.1

How-to improve the efficiency of pumps - VI Influence of Gap Clearances on the Internal Leakage

- Volumetric losses are mainly caused by the suction-sided sealing gap which throttles the secondary flow from the impeller delivery to suction (and by the additional pressure-sided sealing gap which usually belongs to the axial thrust balancing system of a single stage centrifugal pump).
- This internal leakage flows strongly depend on the clearance of the sealing gaps.







➔ Reduction of clearance can improve the pump efficiency (for instance: ~3% from 0.6mm to 0.3mm)

Source: European Commission - SAVE Study on improving the efficiency of pumps, 2001, AEAT-6559/ v 5.1

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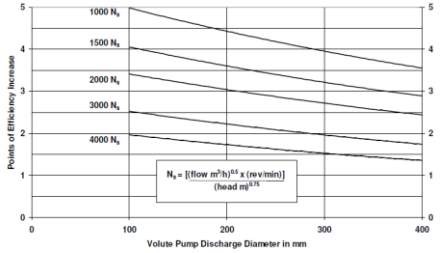
Market trends & developments in pump technology

- Several positive trends are noted, which will lead to a reduction in energy consumption particularly as applied to mass produced pumps and pumpsets for building applications:
  - Greater sales of pumps with **pressed stainless steel** or **plastic** impellers.
  - **Variable speed control** incorporated in integrated packages - give large energy savings often larger than that from the improving of the pump itself.
    - it frees the designer from the specific speed constraints of standard fixed speed induction motors. This enables the efficiency of some pump sizes to be improved by being designed to operate at a more favourable speed and hence specific speed.
    - Europump estimate (May 2007) that the proportion of each class of pump sold with integral VSD control is:
      - End Suction Own Bearings 4%
      - End Suction Close Coupled 5%
      - End Suction Close Coupled in line 30%
      - Multistage water 8%
      - Multistage submersible 1%

  - Pumps available with **built-in condition monitoring**, although sales so far are poor.
  - Some larger pumps will have **friction reducing coatings** on the cast iron volute.



Source: Falkner, H., Lot 11 - Water pumps (in commercial buildings, drinking water pumping,food industry, agricolture). Report to European Commission, 2008

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Current research on pumps: an example - I

Proc. 29th Int. Conf. On Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems. ECOS 2016. Portoroz (SLO)

CFD modelling to aid the design of steel sheet multistage pumps

Federico Fontana[a] and Massimo Masi[b]

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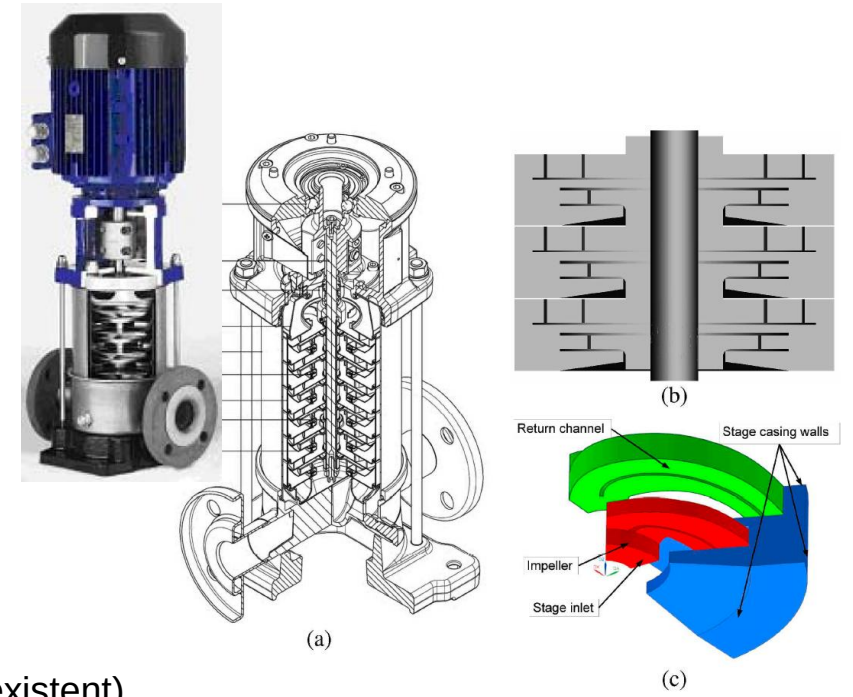


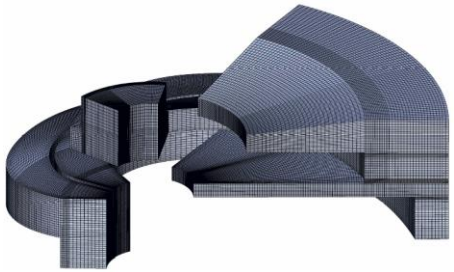
Fig. 1. The pump under analysis: a) view of the multistage pump assembly, b) schematic view of a three-stage assembly, c)geometrical model of the fluid volumes of one impeller channel and one return channel.

Pressed stainless steel sheet multistage pumps

Vertical multi stage - Compact Design

- Main advantages
  - Reliable and cost effective technology
  - Surfaces smoothness
- Main drawbacks
  - unconventional shapes (literature almost non existent)
  - 2D geometry constraint
  - Wide annular chamber betweer impeller and return channels

Current research on pumps: an example - II



CFD modelling to aid the design of steel sheet multistage pumps

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Swirl-less single-stage single-passage

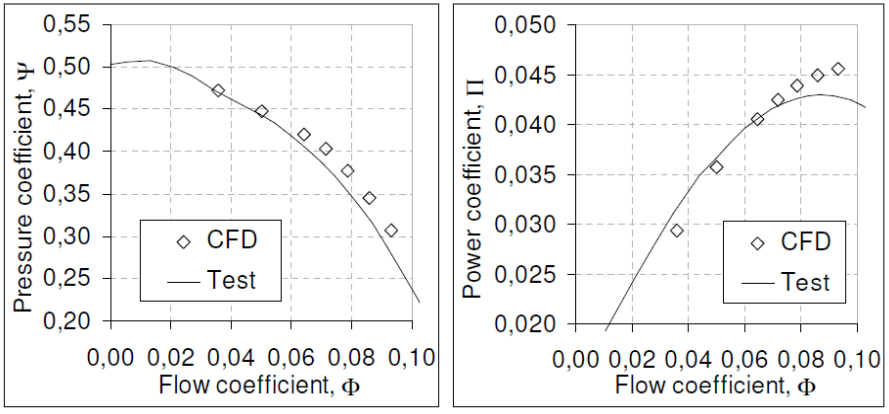

Fig. 4. Comparison between measurements (solid lines) and numerical results of the swirl-less, single-stage model (empty markers): a) head per stage versus the flow rate, b) absorbed power per stage versus the flow rate. The values are presented in dimensionless form.

"corrected" single-stage single-passage

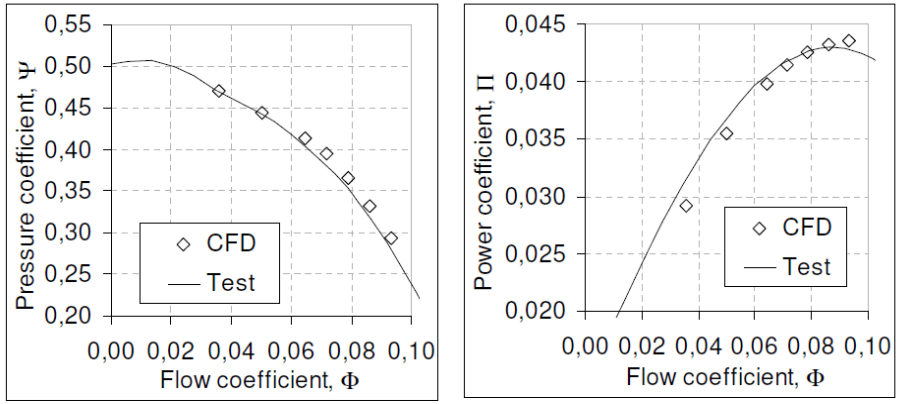

Fig. 7. Comparison between measurements (solid lines) and numerical results of the single-stage model after corrections for pre-swirl (empty markers): a) head per stage versus the flow rate, b) absorbed power per stage versus the flow rate. The values are presented in dimensionless form.

Thank you for your kind attention

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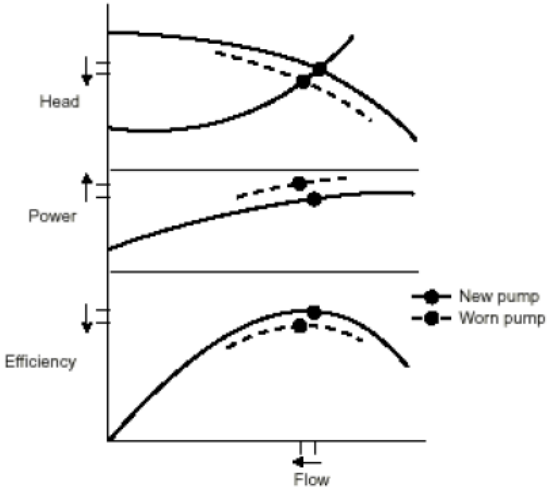
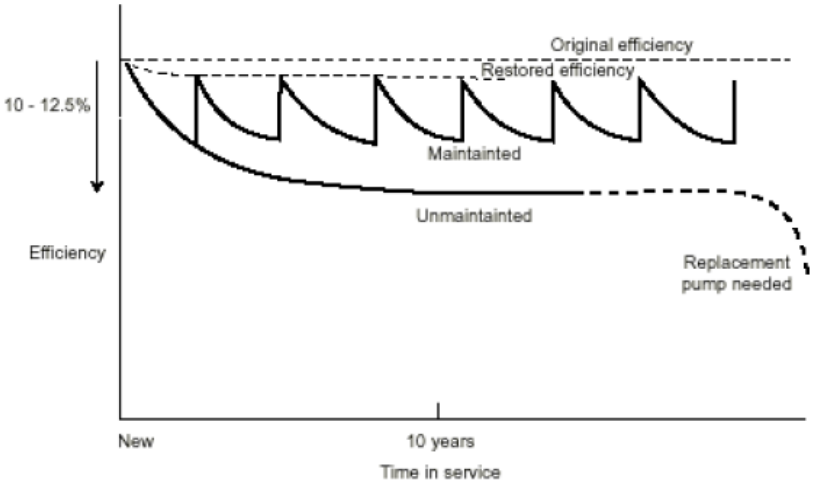
SEA LAND
ELECTRIC PUMPS

Life of pumps

- The lifetime of a water pump will rarely be dictated by obsolescence.
- The pump will usually be replaced when it fails, due to a broken component or an unacceptable drop in output.
- A pump operating under ideal conditions could work for 20 years with minimum maintenance.
- Unfortunately, most pumps lose efficiency due to wear in their wear rings due to operation at part flow and/or roughening of their cast iron volutes by corrosion products. It is not unusual to lose 10% of the new efficiency in ten years.





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