top engineer

The Elomatic Magazine 1 · 2017

8 September 2017 will be a major turning point for global ballast water treatment.
– Olli Leino

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Intelligent Engineering – what's the story?

From time to time every organisation needs to ask itself where it is going and whether it is being true to its values and vision. What is the so-called company story we share with our customers, employees, partners and society at large? What do we do and, most importantly, why do we do it?

At Elomatic we are currently reviewing our story. This is important now as we are approaching a rather big milestone, namely our 50th birthday, which is just around the corner in 2020.

One should guard against trying to make up a good sounding story just to impress. You cannot pretend to be something you are not.

In reviewing the story and checking it for relevance in a changing world, external parties can provide new and fresh perspectives, while internal voices have to be listened to carefully.

One way of telling the Elomatic story would be to say that we help and support our customers in the joint struggle against the most significant challenges of our time. These include environmental wellbeing, resource sufficiency and questions related to technology upheaval. To meet these challenges we design sustainable and responsible solutions, thereby ensuring that our customers' business operations are increasingly seamless, safe, sustainable and competitive. We call this *Intelligent Engineering*. It sounds good doesn't it, but is the story true?

One place to look for an answer is this publication. The authors all contribute to it voluntarily because they are passionate about a topic, and crucially, not because they think it will back up management's story. The core messages of the authors' are clear:

- The design of the most efficient and effective ballast water management systems will help us prevent the spread of destructive invasive species.
- Alternative fuels and other methods of reducing maritime emissions will contribute to improving the air we breathe in our cities.
- Recent advances in computational fluid dynamics allow us to optimise increasingly complex systems, thereby reducing material use and streamlining operations.
- A new generation of energy audits enables industry to significantly cut back on energy usage, bringing gains to operational efficiency and profitability.
- By actively taking part in developing innovation and valuing innovators, management contributes to long-term success and allows employees to find better solutions to the challenges of our times.

These messages provide a solid backbone to the bigger story we want to share with you, that of *Intelligent Engineering*.

Patrik Rautaheimo
Editor-in-Chief
CEO

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Cover: Olli Leino, Product Manager, Ballast Water Management at Elomatic Espoo Office.
Cover photo © Olli Tuomola / Elomatic.

Ballast Water Treatment

– IMO Convention entering into force

Text: Olli Leino

On 8 September 2017 the International Convention for the Control and Management of Ships' Ballast Water and Sediments will enter into force. In short, it means that all ships with ballast water operations in international traffic will have to comply with the convention. The threat posed by organisms transported in ballast water has been very topical over the last decade or so, and is set to dominate retrofit activities in the coming years.

Ballast water is used to adjust a vessel's floating position, draught and stability. In the nineteenth century, rocks and sand were used as ballast. Water, however, is easier to transfer around a vessel with pumps and is always available wherever ships are sailing.

A vessel's ballast water capacity depends on the ship size and type. Typically, tankers and bulkers have the largest capacities and passenger vessels have smaller capacities. In tankers the capacity is around 40–50 % of deadweight tonnage. Therefore, a tanker with a 100,000 tonne cargo capacity has a ballast water capacity of around 50,000 tonnes.

So what is all the fuss about? Ballast water is actually just normal sea or lake water. Besides hydrogen, oxygen and little bit of seasoning, salt mainly, it includes a variety of living organisms. These organisms can and will cause problems when introduced into other ecosystems and need to be dealt with.

The problem, however, is that once invasive species are integrated in their new surroundings it may be impossible to remove them. Prevention is definitely better than cure; ballast water has to be disinfected before it is discharged.

Is ballast water still a problem?

A common claim is that invasive species have already been transported around the globe and, therefore, their continued transportation does not pose a threat. This could not be further from the truth. According to estimates, around 3–5 billion tonnes of ballast water is transported around the globe annually.

Every year invasive species are introduced to new areas. Some are innocuous, while others may seriously harm the environment, human health and local economies.

There are reasons why ballast water related problems are relatively new, even though ballast water use is not. In some cases, ballast water used to be pumped into oily tanks for transport, which the invasive species did not survive. The downside of this was the oily water discharge into the sea. The other enemy of invasive species is time: the longer the voyage, the lower the survivability of living organisms.

The Suez and Panama canals have, however, led to shorter voyage times and therefore the survivability of organisms has increased. Globalisation and increased international trade has seen a great increase in the transportation of goods, which has raised the amount of ballast water and invasive species transported.

Ballast water related problems differ from oil spills. Oil spills are usually recognised soon after the accident, after which counter measures can be introduced immediately. The difficulty with ballast water is that the resultant harmful effects are hard to see before it is too late.

A very simplified rule of thumb is that the damage from an oil spill is immediate and dissipates over time, while the damage caused by ballast water

Photo © Petr Jílek, www.fotopetrjilek.cz

Zebra mussels transported in ballast water have caused billions of dollars damage.

grows exponentially. Double-hulled tankers go a long way in preventing oil spills. Ballast water, on the other hand, is routinely discharged and therefore necessitates treatment.

The IMO Convention

The subject of ballast water and invasive species is not new. Discussions and deliberations on the topic have been held for several years in different forums. One of the first milestones achieved was the adoption of the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (BWM convention) in February 2004.

Over 12 years later, in September 2016, the criteria regarding 30 states representing 35 % of the world's merchant ship tonnage was fulfilled. This means that on 8 September 2017 the convention will enter into force.

Thereafter, all ships with ballast water operations in international traffic will have to comply with the convention. This will be achieved, at first, with ballast water exchange, and then by treating the water by installing a ballast water treatment system after the first International Oil Pollution Prevention certificate renewal survey (IOPP).

The IMO convention sets limits for the amount of living organisms and bacteria in ballast water that is discharged. The convention does not apply to ships that are not designed to carry ballast water, ships with permanent ballast water in sealed tanks, warships, or ships in non-commercial service.

Documented history of damages

History provides examples of the damage that invasive species can cause. In the Great Lakes of North America, zebra mussels were introduced via ballast water and have spread rapidly. The mussels have caused billions of dollars damage, for example, by clogging cooling water intake pipes. In 1991 cholera spread via ballast water to Peru and killed thousands of people.

Invasive species can supersede original species, or the newcomers may prey on local species and therefore have a serious impact of the balance of ecosystems. When invasive species are transported to new areas they may not have natural enemies and therefore can reproduce without limits.

Water treatment

Water treatment is actually not a new subject either. Both waste and potable water are treated on ships and especially on land facilities.

Ballast water treatment is usually done in two phases: pre-treatment

Photo © Martin Hablützel, www.unterwasserfoto.ch

◄ *Picture 1. Zebra Mussels are one of the "ten most unwanted" and have become an invasive species in many countries around the world. They disrupt ecosystems and damage harbours, waterways, ships and boats as well as water treatment and power plants.*

► *Picture 2. Crude oil tanker pumping ballast water in Lagos, Nigeria, Africa.*

with a filter and main treatment with either chemicals or ultra-violet light (UV). Chemicals or UV are the most common methods. Other methods include e.g. de-oxygenation, ultrasound, cavitation and heat treatment. For simplicity sake, only UV and chemical treatment methods are described here. Chemicals can be added separately from a tank, or they can be made from sea water that is treated with an electric current (electrolysis).

Filtration is normally done for both UV and chemical systems. It is an effective method to remove larger particles. The mesh size is around 20–50 µm. After filtration the ballast water goes through the UV reactor or the chemical is added to the ballast water. UV treatment is usually done a second time during de-ballasting.

After treatment the water should fulfil the IMO limits set for microbes and viable organisms in water to be discharged into the sea.

Installation of BWTS

There are several factors that need to be taken into consideration during the concept design of a ballast water treatment system (BWTS) on an existing vessel. Answers need to found, among others, to the following questions. What is the right system for our vessel? Will the system fit on the vessel? Will there be enough electricity available for the system? How will the ballasting capacity be affected? Do the ballast water pumps have to be replaced?

After the concept is ready, the installation needs to be planned. A successful installation includes good planning, accurate and efficient engineering and proper project management.

The installation usually takes place during dry-docking, which takes around two weeks. The schedule is extremely tight: one extra day's off-hire is highly expensive and should be avoided at all costs.

It is in this regard that the role of successful design and planning earns its rightful place as a key success factor in ensuring that vessels meet the IMO convention standards as planned. The 8th of September is fast approaching…

Photo © Igor Yu. Groshev, SPb, Russia

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Olli Leino graduated as a Naval Architect from the Aalto University School of Engineering in 2013. He completed his master's thesis for Elomatic by developing a concept vessel that uses no ballast water with the help of creative problem solving methods.

His expertise areas are project planning, design, engineering and project management of ballast water treatment retrofits. He blogs about the topic of ballast water and has authored a quick guide to ballast water treatment retrofits.

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New generation of ene

– tools for large companies

Text: Teemu Turunen and Jussi Jääskeläinen

rgy efficiency audits

Photo © Kimmo Syvari

In recent years energy efficiency audits have been at a turning point in large companies. In many places they have been conducted at least once according to the Motiva model, in addition to which, the EU Energy Efficiency Directive and Finnish legislation have introduced new demands for auditing. As a result, many companies have started looking at new ways of surveying their energy efficiency potential.

Most large industrial companies have conducted energy audits in the last five years as prescribed by the EU Energy Efficiency Directive. The obligation has pushed many companies to implement an ISO 50001 energy efficiency management system. ISO 50001 compliant systems require auditing, but companies have more room to influence the scope and frequency of the audits.

The audit has to be conducted about every four years (depending on choice of model). It is, therefore, important to consider which implementation method best suits a company's operations.

Factory and production plant audits traditionally cover entire facilities.

Once such comprehensive audits have been conducted, other approaches may provide a more cost effective way of achieving good results. In selecting the audit model, at least the following factors need to be considered:

1. Have any changes been implemented at the plant/factory since the last audit?
2. Are there changes in the pipeline at the facility that will affect energy efficiency?
3. Did the previous audit produce concreate optimisation measures?
4. Was staff know-how increased in conjunction with the audit?
5. Is the energy efficiency level directly correlated to the process efficiency?

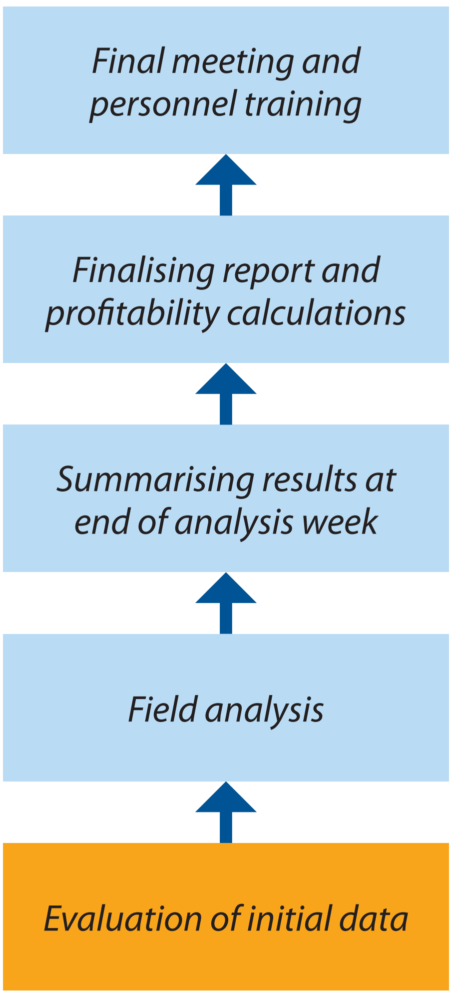


Figure 1. Audit phases

Audit models for different needs

Energy efficiency audits can roughly be divided into the following three main categories:

- Standard-based energy audits (e.g. audits according to the Motiva model)
- Sub-process audits/mill service system audits
- Customised energy audits

Standard-based audits are often cumbersome to implement for an entire facility, even if only a monitoring audit is conducted.

Sub-process audits and mill service system audits, on the other hand, can focus on a chosen system or entity which results in optimisation suggestions that are sufficiently concrete. The targets of such audits include, for example, electrical motors, pumping systems, compressed air systems, steam and condensation systems, cooling systems, air conditioning, heat recovery, and heat transfer systems.

In such audits process efficiency or even maintenance needs can be taken into consideration, while field analyses can identify much broader cost savings than traditional models.

The third audit model is customised energy audits, of which a saving potential study is an example. Based on initial data, it focuses on optimisation areas with the most potential and examines the selected targets in sufficient detail. The implementation of a customised energy audit could be done as displayed in Figure 1.

In the first phase existing materials are reviewed comprehensively, possible changes since the last audit are identified, and scheduled energy efficiency investments as well as those under consideration are checked. Field analyses are typically done in one week by the plant staff in cooperation with an energy audit consultant. Site inspections generally include:

- Site measurements for chosen targets
- Data logging for chosen targets
- Checking connections and operations of audited entities
- Smaller tests/trial runs
- Interviewing plant staff
- Analysis of results and reporting

A description of the facility's energy efficiency, measurement results, suggested actions as well as potential savings calculations are added to the final report already during the site inspection. Typically, the goal is to have 90 % of the report complete by the time the final site inspection meeting is held. In order to reduce reporting time MS PowerPoint can be used. The benefit of this reporting method is that part of the materials can later be used for training purposes.

After the site inspection the report is finalised and, if necessary, calls for offers are sent out to equipment suppliers in order to provide more detailed profitability calculations.

Rapid developments in tools that can analyze big amounts of data will reduce the need for site measurements and increase the processing of existing data.

What does the future of auditing hold?

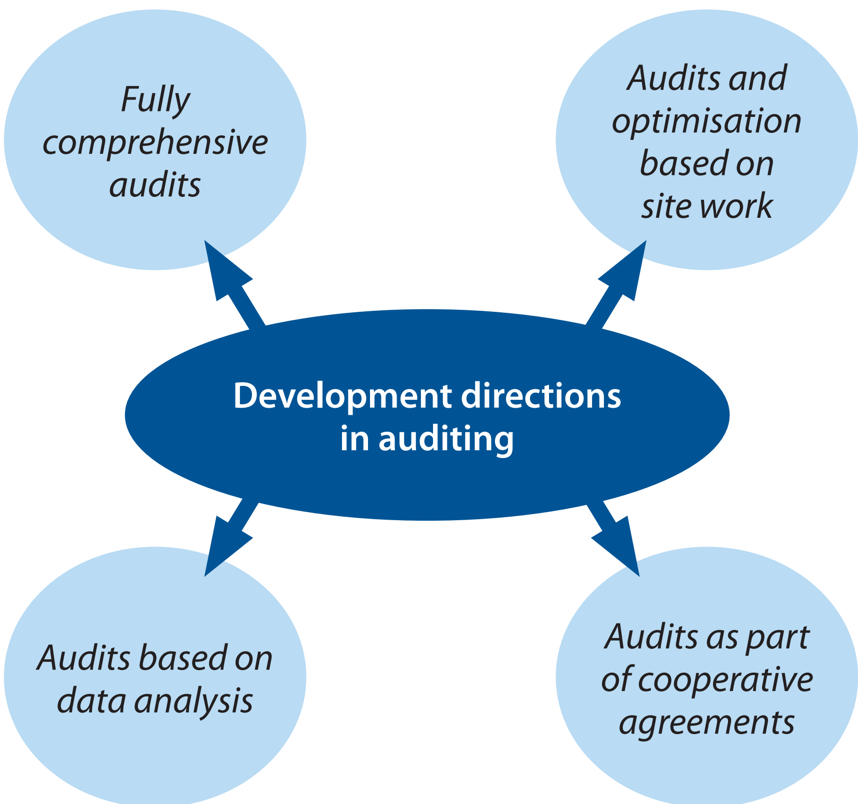
Audits have traditionally been implemented via site measurements; the data produced is used to identify targets where efficiency gains can be achieved. The identified targets are then checked for feasibility.

In future, large enterprises will collect even greater amounts of data, which paves the way for new auditing approaches. Rapid developments in tools that can analyze big amounts of data will reduce the need for site measurements and increase the processing of existing data. See Figure 2 for development directions in auditing.

In this kind of approach data collection from different systems is essential. It creates the opportunity to unveil new phenomena and increasingly deep analysis of processes. Auditing will consist of data mining that produces new data sets, which can also be utilised in development spheres outside of energy efficiency.

A second clear developmental direction is a trend to implement ever more comprehensive audits. When optimisation work is started, it is irrelevant whether savings are generated in energy, material efficiency, maintenance costs or by augmenting process performance. When adequately efficient tools are available to handle data, fully comprehensive audits become possible. It should be remembered, however, that this approach requires greater know-how about the auditing target or process and that the audits need to be conducted as a team by site staff and a consultant.

▼ *Figure 2. Development directions in auditing*



Energy and material audit model implementation: Case – Metsä Board

In 2016 Metsä Board implemented energy and material efficiency audits at all its sites in Finland. The audits produced clear efficiency optimisation measures for each target and an overall picture of the efficiency of its Finnish operations.

The starting point at Metsä Board was very good:

- ISO 50001 energy efficiency system in use
- Energy audits conducted for each site
- Energy and mass balance models implemented at several sites
- Dedicated person responsible for energy efficiency at each mill
- Several energy efficiency projects implemented over the years

However, several process changes had been implemented since the previous audits: new power plants were introduced at some mills while production changes were introduced at others. For these reasons, the energy and material efficiency situation required updating, but Metsä Board wanted to implement a less intensive audit model than the Motiva model. The goal was to benefit from existing materials and surveys to the maximum and to conduct them with mill staff with a focus on the most potential entities.

Optimisation of mill service systems and production process

The audits identified over 30 energy efficiency measures with an overall efficiency potential for electricity of 7,500 MWh and for heating of 61,000 MWh. In terms of cost savings this amounts to 1.5 M€ a year. Several maintenance observations and procedures that affect material efficiency came to the fore. The efficiency optimisation measure breakdown is illustrated in Figure 3.

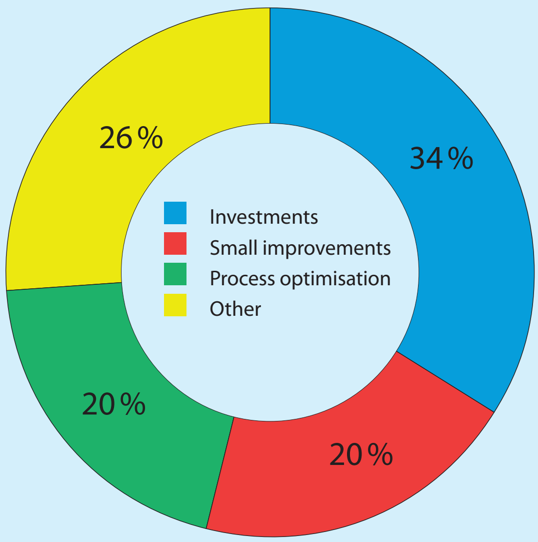
Implementation and deeper process focus

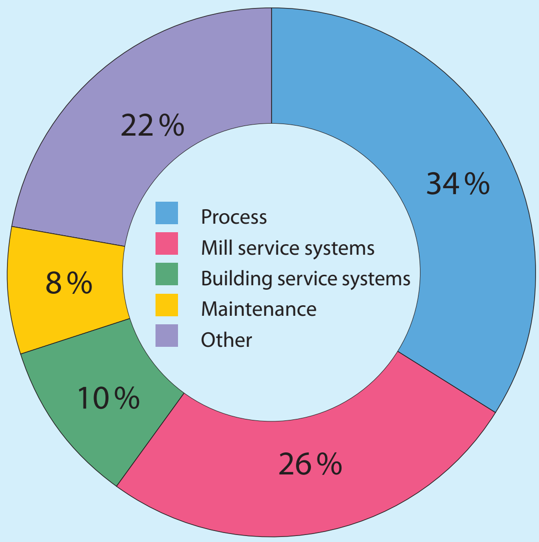
The next step is focusing on implementation of the optimisation measures and conducting surveys to gather more detailed information. Most savings measures and small improvements can be implemented quickly with little effort.

A more detailed supplementary survey will be conducted for the entity comprising the dryer series, steam and condensation system, warm water tank and heat recovery. Another interesting target for further investigation is the utilisation of low-temperature heat sources to heat the process water of the board production line.

"The latest energy and material efficiency audits have helped us to develop a new way of gaining energy efficiency and a less intensive way of analysing data. In the first year we reviewed all seven Metsä Board mills in Finland and identified over 30 optimisation targets. In 2017 seven projects have been started up based on the observations, of which the effect on cost efficiency is over a million euros a year," says Metsä Board Energy and Material Efficiency Manager, Matti Korhonen.

▼ *Figure 3. Breakdown of efficiency optimisation measures by focus area and target.*





▲ *According to Metsä Board Energy and Material Efficiency Manager, Matti Korhonen, material and energy efficiency audits implemented at the company in 2017 have a cost-efficiency effect of over a million euros a year.*

A third development direction is audits based extensively on site work. Many companies have seen a reduction in the resources available for efficiency development and in many cases, for example, maintenance has been outsourced. This model runs the risk of missing the big picture, which can leave even good efficiency optimising measures unimplemented. A counter to this problem may be surveys/audits that cover the target on site in great detail, device by device, after which efficiency measures are introduced immediately after the survey/audit.

This can be done, for example, with cooperative agreements where an outside party takes responsibility for selected energy efficiency targets or the entirety. It is important, however, to keep matters at a sufficiently concrete level to avoid energy efficiency work that gets bogged down in scheduled meetings and document maintenance. The best end results are achieved if the service provider offers experts with diverse professional backgrounds to ensure that optimisation measures are brought from the design phase all the way to implementation.

Summary

Although interest in audits and analyses in companies has decreased in recent years, this type of information processing should not be completely discarded. By implementing projects based on needs and taking care that results are concrete enough, we can ensure that audits remain an effective way of developing operational efficiency and profitability.

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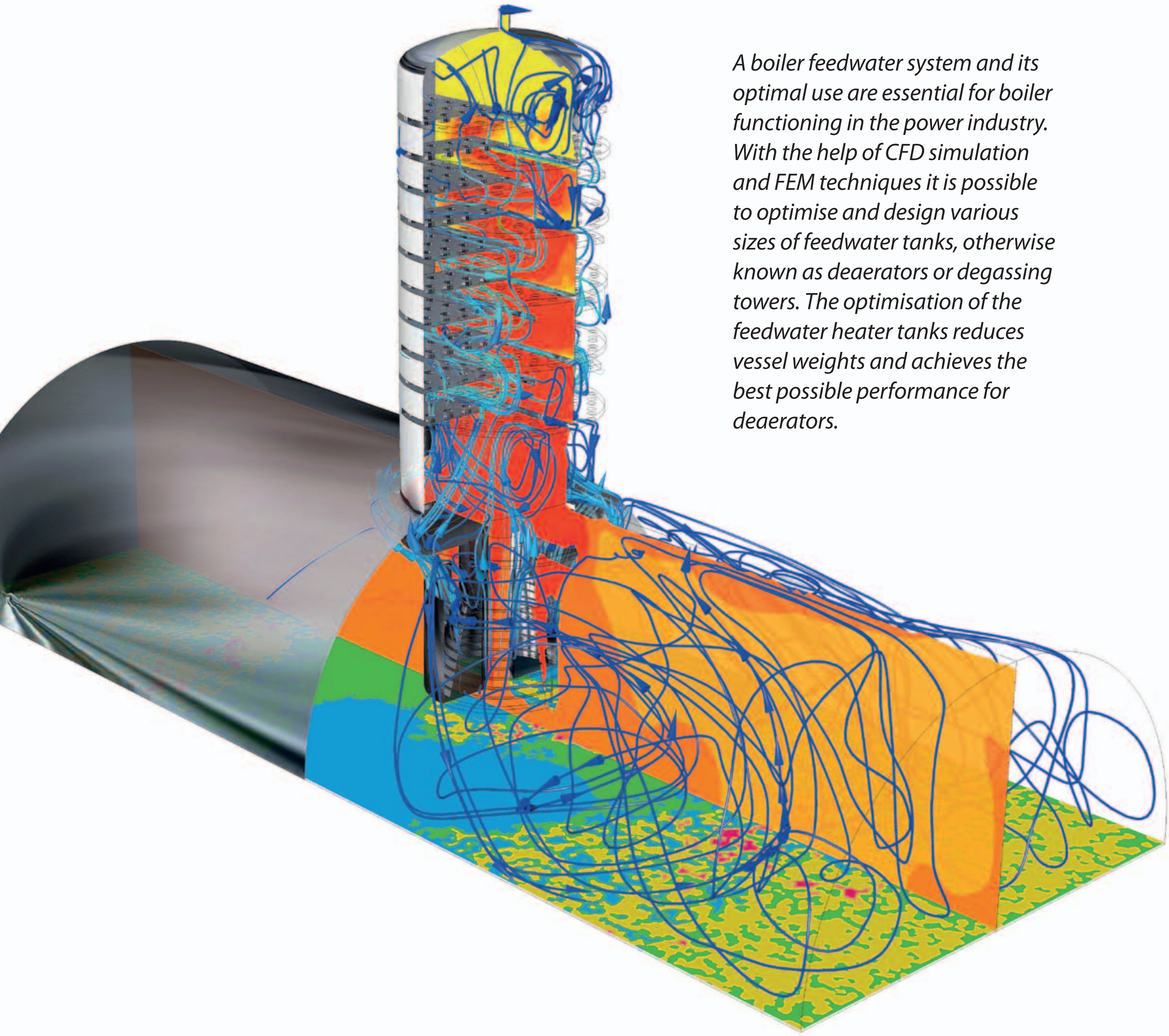
CFD modelling for performance optimisation of feedwater heaters in the power industry

Text: Amir Shakib-Manesh

A boiler feedwater system and its optimal use are essential for boiler functioning in the power industry. With the help of CFD simulation and FEM techniques it is possible to optimise and design various sizes of feedwater tanks, otherwise known as deaerators or degassing towers. The optimisation of the feedwater heater tanks reduces vessel weights and achieves the best possible performance for deaerators.



CFD and FEM techniques are new approaches in optimising feedwater heaters, instead of traditional experimental data that is commonly used in this regard. The CFD technique uses multiphase flows with phase changing, including buoyancy and turbulence in order to optimise the performance of the deaerator tower and main feedwater heater tank.

Basic process design of steam deaerators

The main purpose of a deaerator is to preheat demi-water and eliminate dissolved oxygen. This is essential as oxygen causes corrosion in power plant systems. The removal of dissolved oxygen can be done chemically (e.g. sodium sulphite, hydrazine or tannin) and physically (with a deaerator tower), or using a combination of the methods. See Diagram 1 for an example of a boiler feedwater process in a thermal power plant.

The amount of dissolved oxygen in demi-water depends greatly on the system temperature and should be carefully observed during simulations. Moreover, other gasses are also present in the feedwater tanks, mostly nitrogen, as well as steam and liquid water injected as droplets and condensation that can instantly flash into steam.

It is not just oxygen that needs to be vented out of the feedwater tank; other non-condensable gases have to be ejected at the same time. The steam/gas mixture amount that needs to be released can be estimated with a well-designed and simulated deaerator considering partial pressures and thermodynamic laws.

The connecting steam line to the feedwater tank has to be designed and steam flow rate calculated before and through the control valve prior to the deaerator, while steam dryness must be improved by controlling the steam pressure.

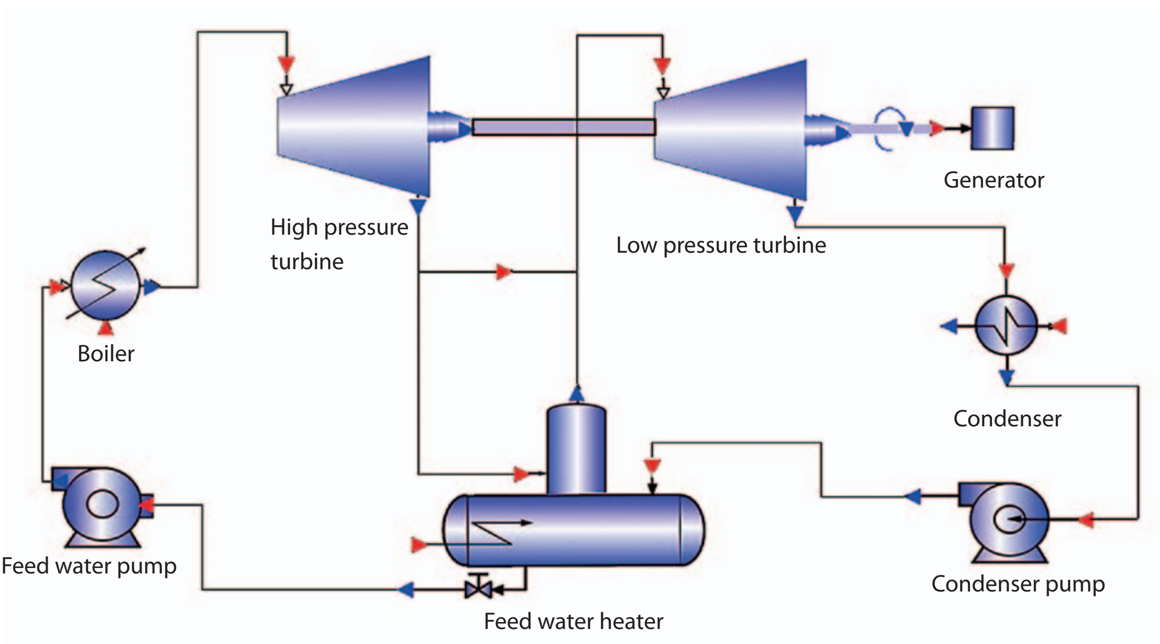
The steam can be blown from the after-cooking section and/or the bottom of the vessel to heat up the make-up water as well as the whole tank to ensure that the outlet feedwater is warm enough. This can be used for preheating the vessel and flashing process as well as controlling the outlet temperature.

Usually, a feedwater tank is overpressured and, in case of a sudden shutdown or other emergency, may also be designed to even withstand full vacuums. In the latter case, an emergency valve is also rated and chosen for the vessel.

Mechanical detail design of steam deaerators

The chemical, thermodynamic and mass balances of the deaerator are accomplished as part of the main design process. However, the main vessel and degassing towers are designed with 3D models and all detailed drawings are prepared based on FEM stress analysis and pressure vessel standard calculations (e.g. PED/EN-13445 or ASME VIII). The designs are inspected, stamped and approved by inspecting authorities. The finite element analysis can include static, and if needed, dynamic structural design for indoor or outdoor installation, as well as seismic and other connecting nozzle design calculations. All designs are synchronised with the other power plant equipment and piping systems.

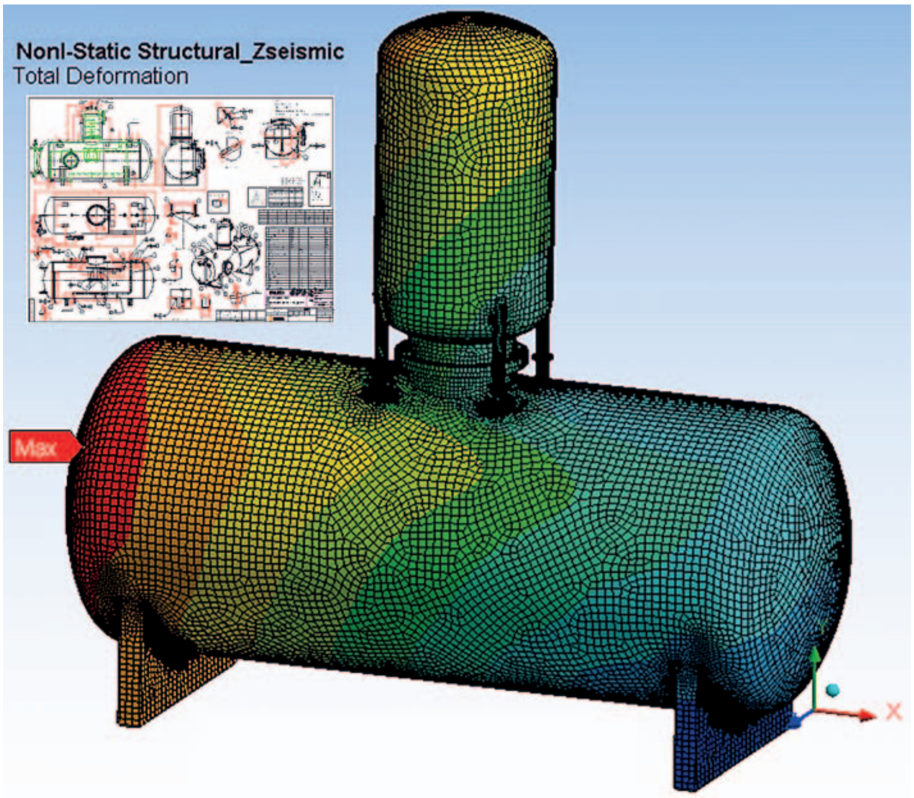
▼ *Diagram 1. Process diagram of boiler feedwater and location of feedwater tank in a thermal power plant.*



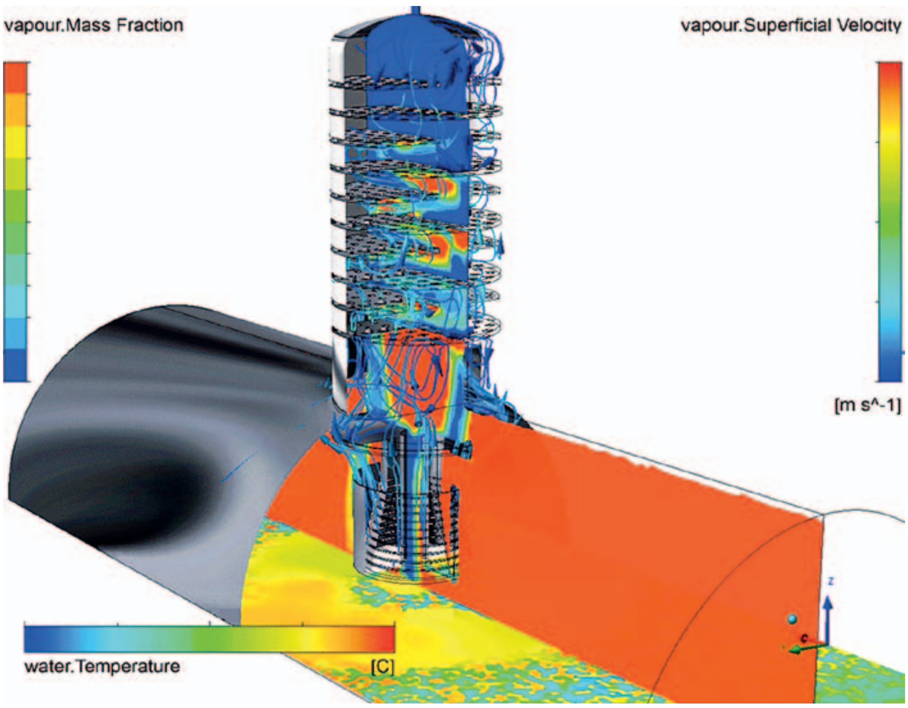
CFD for optimisation of feedwater tanks

The CFD model of a tray type deaerator for a feedwater heater tank has produced promising results. The performance of the deaerator can be significantly boosted by optimising the tray, tower and vessel dimensions.

Factors included in the CFD model can be turbulence, two phases with phase change, energy and heat transfer, buoyancy models, as well as steam and water tables. The simulations usually contain several million elements and require supercomputers with over hundreds of CPU nodes in order to perform the calculations. The heat transfer surface has to be well distributed in the tower trays so that various internal flow regimes' mix well.



Picture 1. A snapshot of feedwater heater tank finite element method (FEM) results with deformation contours due to seismic loads. The inset figure is a stamped detail drawing of the deaerator tank.

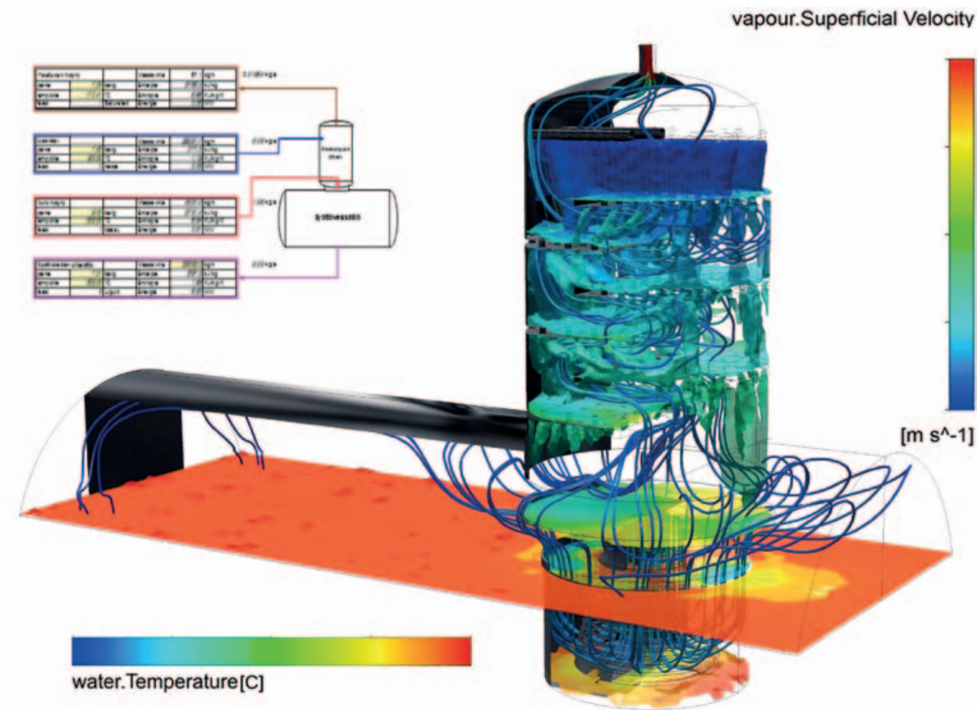


Picture 2. A section view snapshot of a feedwater heater tank with Computational Fluid Dynamics (CFD) results such as streamlines, vapour mass fraction and velocity contours.

Improvements in computational fluid dynamics (CFD) techniques have created a unique opportunity to optimise highly complicated multiphase flow process devices such as feedwater heaters.

Several parameters such as tank volume and liquid level, temperature, density, velocity and partial pressures and pressure drops of each substance and/or material phase are carefully monitored during the simulations. During the deaerating process, a significant part of the steam and non-condensable gasses has to be vented out of the tower, while the rest starts to condensate on the bottom well of the tank.

▼ *Picture 3. A snapshot of a feedwater heater tank with Computational Fluid Dynamics (CFD) results such as streamlines, water surface temperature contours and water mass fraction iso-surfaces. The inset indicates the process diagram of the heat transfer and mass balance of the deaerator.*



The use of the CFD technique, for instance, allows the monitoring of steam and liquid water droplet temperatures and their flows in the tower as well as their final thermodynamic conditions.

Conclusion

Recent versions of computational fluid dynamics techniques have created a unique opportunity to optimise highly complicated multiphase flow process devices such as feedwater heaters, which have traditionally been rated by experimental values. By optimising feedwater heaters we are able to reduce vessel sizes, improve performance, and minimise production costs.

About the author

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Dr Shakib-Manesh has worked in the field of energy, mechanical and process engineering as well as CFD consultancy since 1993.

He has successfully stress-analysed and managed projects for the design of hundreds of pressure vessels, tanks, towers and industrial devices around the world. He specialises in CFD, heat transfer, and energy efficiency of feedwater tanks. His main competence area is computing complex CFD flows, acoustic, noise and explosion simulations, as well as interactive structural stress analysis with FEM methods for power plants and the paper and process industries.

His latest book, entitled "Computational Flow Dynamics of Complex Fluids", was published in 2011.

Mr. Shakib-Manesh joined Elomatic in 2011 and currently works as a Leading CFD/FEM Specialist in the Technical Analysis department at the Elomatic Jyväskylä office.

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Sulphur Emissions

Does one ship pollute as much as 50 million cars?

Text: Tomas Aminoff

A recent eye-catching headline that did the rounds in LinkedIn's marine community suggested that one ship emits as much sulphur as 50 million cars. Another frequently seen statement is that the sixteen worst offending vessels create as much pollution as all the cars on the planet combined. Can this really be true? Was shipping not supposed to be the most environmentally friendly mode of transportation out there?

When I read the article, I felt a strong desire to open Excel and run a few simulations of my own on the topic. Before that, some research about the article and the boundary conditions was required. The original source was an article published in the China Daily Asia on 20 May 2016, titip emissions choking the region".

The article claimed that "Cargo ships typically use highly polluting bunker fuel, which is comprised of around 3 percent sulphur – much higher than ultra-low sulphur diesel. One large container ship at sea emits the same amount of sulphur oxide gases as 50 million diesel-burning cars."

In order to reproduce the figures I used a large modern 14,000 TEU container vessel and compared it with a 2017 Ford Focus diesel. The parameters used in the calculation are presented in Table 1. With these boundary conditions, the result is very close to the original statement in the article and any discrepancies can easy be explained.

The result of the calculations indicates that the vessel actually emits sulphur emissions equal to that produced by 59 million new diesel cars. The difference compared to the claims in the China Daily Asia article can be explained by the used engine power, efficiency and daily utilisation.

Correcting some flaws

The original assumptions clearly contained some flaws. The next step, therefore, was to adjust the figures to better reflect the situation today.

First and foremost, the vessel speed was reduced from approx. 23,5 knots to approximately 18,5 knots. By doing this the main engine load was decreased from around 75 % to 40 %. The amount of sulphur in the HFO was also reduced to 2,45 % to better mirror the world average for 2015.

On the other hand, specific fuel consumption had to be increased for the main engine by 7 % and the auxiliary engine by 5 %. This was done to reflect the tolerances provided by engine manufactures. At the same time, an increase in the vehicle's fuel consumption to 7.1 l/100 km was included. This was the consumption figure displayed by a car used on the day of doing the calculations. The car was admittedly not a new Ford Focus with a diesel engine, but is still an average-sized car with a moderate-sized engine and thus reflects the existing fleet in a balanced way. All the changes are shown in Table 2.

▼ *Table 1: Reference case (ship to car ratio: 58.7 million)*

	14000 TEU Container vessel			Car		
Engines	1 x 2-Stroke ME + 4* 4-S AE			77kW 1.5l Diesel		
	Main Engine	*Auxiliary Engine*				
Installed power	48900	5*3360	kW		77	kW
Average load	75 %	2 engines at 75 %	kW			
Hours per day	24	24	h	**Distance per day***	55	km
SFOC (iso)	160	182	g/kWh	**Consumption**	3.8	l/100 km
LHV (iso)	42700	42700	kJ/kg	**Daily consumption**	2.09	l/day
LHV (fuel)	40600	42700	kJ/kg	**Density**	0.832	kg/l
Consumption	148.02	22.01	tonne/day	**Daily consumption**	1.739	kg/day
S in fuel	3.00 %	3.00 %		**S in fuel**	0.005 %	
Sulphur	5.10		tonne/day	**Sulphur**	0.000087	kg/day

** Source: Driving and parking patterns of European car drivers – a mobility survey.*

▼ *Table 2: Modified case (ship to car ratio: 18.8 million)*

	14000 TEU Container vessel			Car		
Engines	1 x 2-Stroke ME + 4* 4-S AE			97kW 1.6l Petroleum		
	Main Engine	*Auxiliary Engine*				
Installed power	48900	5*3360	kW		97	kW
Average load	40 %	2 engines at 75 %	kW			
SFOC (iso)	172	191	g/kWh	**Consumption**	7.1	l/100 km
LHV (iso)	42700	42700	kJ/kg	**Daily consumption**	3.91	l/day
LHV (fuel)	40600	42700	kJ/kg	**Density**	0.720	kg/l
Consumption	84.74	23.12	tonne/day	**Daily consumption**	2.812	kg/day
S in fuel	2.45 %	2.45 %		**S in fuel**	0.005 %	
Sulphur	2.64		tonne/day	**Sulphur**	0.000141	kg/day

** Source: Driving and parking patterns of European car drivers – a mobility survey.*

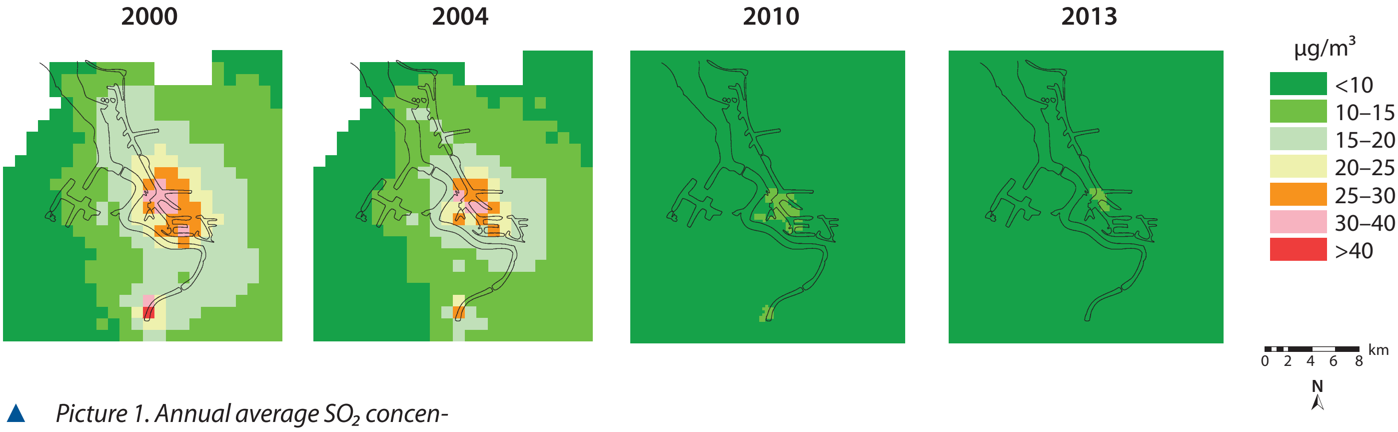
After all the modifications were introduced the result indicated that one large container vessel in the open sea emits as much sulphur as about 19 million cars in city traffic.

Does it really matter?

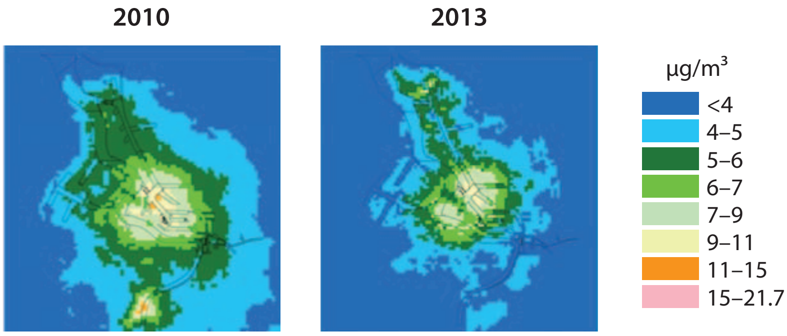
This begs the question whether these figures are relevant? Does it matter whether one ship emits as much sulphur as 59 million or 19 million cars? The answer is no.

Firstly, in 2017 China will adopt new emissions regulations for on-road fuels, which are the same as those governing EU road traffic. This will cut the amount of sulphur emissions by cars from 50 to 10 ppm, which will result in a five-fold increase in the number of cars to one ship ratio, from almost 19 million to 93 million. Furthermore, in countries like Germany and Sweden the sulphur rate in diesel is typically 2–3 ppm, which would further double the number of cars to approximately 185 million.

At this point we should remember our maths lessons from school. While the numerator is greater than zero and the denominator is approaching zero, the sum approaches infinity. This indicates how different results can be achieved by selecting different, yet correct input values.



▲ *Picture 1. Annual average SO_2 concentration in the port of Antwerp in 2000, 2004, 2010 and 2013. The level of SO_2 concentration in the port and city declined so dramatically that the map colour key had to be changed from 2010 onwards (on the right) to allow for SO_2 levels below 10 µg/m^3. In order to allow a meaningful comparison, the 2010 and 2013 maps from the Flemish Environment Company were redrawn (above) according to the 2000 and 2004 map key for this publication.*



▼ *Table 3. Operating profile and emissions during one port stay*

	18 knots Service speed		14 knots Approaching + Maneuvering		Harbor	
	Main Engine	*Auxiliary Engine*	*Main Engine*	*Auxiliary Engine*	*Main Engine*	*Auxiliary Engine*
Engine load	40 %	2 * 75 %	20 %	2 * 75 %	0 %	3 * 75 %
Hours per roundtrip	2	2	2	2	0	24
Consumption (tonnes)	7.06	1.93	3.65	1.93	0.00	34.67
S tonne/stay	0.173	0.047	0.090	0.047	0.000	0.849
S tonne/stay	0.220		0.137		0.849	
Share of S	18 %		11 %		70 %	

As the majority of emissions originate while vessels are berthed in harbours, it is both easy to pinpoint the problem and take corrective actions.

So what would be a better way to compare emissions and decide on the required actions? Rather than trying to achieve results that have more shock value than relevance, the focus should be on emissions that have the largest impact on air quality and human health. Only after this can one make meaningful conclusions.

Tracking sulphur oxide emissions

The challenge with SOx emissions is to get a clear picture of how local the emissions are. While it is known that SOx emissions can travel in the air over great distances, the majority of SOx emissions from a vessel's exhaust is emitted in the form of SO_2, which has a rather short lifespan. On the other hand, part of the SO_2 emissions is transformed into SO_4, which remains in the atmosphere for longer periods. It is also known that SOx contributes to particulate matter (PM), which is a great health concern. Local wind and weather conditions also play an important role in dispersion. Data from the Port of Antwerp's 2015 sustainability report can be used to reach a (basic) conclusion in this regard.

Measurements in the port region indicate that increased concentrations of SO_2 are rapidly diluted. After 10–20 nautical miles the concentration of SO_2 drops to less than one third of the original concentration. Thus, while fighting air quality issues over populated areas and especially in harbour cities, the focus should be on the last two hours of the voyage before the harbour call, the harbour stay itself, and the first two hours after departure.

When the same container vessel makes a harbour call according to the profile in Table 3, the greatest contribution by far to SOx is from the port stay itself. It not only accounts for more than 70 % of the emissions, but is also where the emissions are closest to the populated area and therefore have the greatest impact on city air quality.

The fact that the majority of emissions originate while vessels are berthed in harbours, makes it not only easy to pinpoint the problem, but also easy to take corrective actions. The EU's 0.1 % sulphur in fuel requirement while berthing in European harbours is a very powerful and simple tool to dramatically reduce sulphur emissions. The process is fairly simple as only vessels' auxiliary engines need to switch fuel. The result of the reduced sulphur amount in fuel at the port of Antwerp between 2000 and 2013 is clearly visible in Picture 1.

Similar patterns for nitrogen oxide emissions

Nitrogen oxide (NOx) emissions were not included in the example calculations, but one can nevertheless conclude that NOx emissions will behave similarly to SOx emissions. Most emissions that reach harbour areas are from the last few hours of trade and during harbour stays, where the majority of emissions originate from the auxiliary engines. It would, thus, be a logic step to implement lower NOx level limits (e.g. IMO Tier 3) while a vessel is in port. It would be technically feasible to implement in the form of NOx reducers or catalysts for medium speed engines. These are proven technologies and rather compact and affordable. When SOx and NOx are heavily reduced PM is similarly decreased.

Other options would be to shift to fuels that are totally or almost sulphur-free, such as LNG, methanol or ethane, all used today to different degrees in shipping, or to shift to shore power. All these alternatives would reduce SOx, NOx and PM. As with other measures, focusing efforts on harbour stays alone minimises the associated costs and technology challenges.

There are several proven methods available to dramatically cut sulphur emissions in locations where the impact on air quality and human health is most significant. By directing emissions reduction activities and measures at the most critical areas, the best input/output ratio for efforts and their associated costs can be achieved.

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Tomas Aminoff graduated from the Helsinki University of Technology in 2002 with a major in Marine Engineering. He has worked for 15 years for a major marine equipment supplier with special focus on alternative fuels, machinery solutions and portfolio management. Tomas has extensive knowledge of LNG as a marine fuel and has played an important role in introducing several gas powered engines to the market. Today, Tomas works as a Senior Consultant in Elomatic's Marine Consultancy and Life Cycle Solutions department.

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Life Cycle Costing

– predicting life cycle costs as part of maintenance management and investment planning

Text: Anita Vuorenmaa and Riina Brade

Photo © depositphotos.com/06photo

How does one achieve optimal plant operation in relation to maintenance? Production would like to maximise equipment performance and management would like to minimise maintenance costs. Although operational reliability is important for all, maintenance actions are often postponed, and preventive maintenance and change planning are cut in the name of cost-efficiency. Life Cycle Costing (LCC) is a tool that can be used to predict life cycle costs as part of maintenance management and investment planning.

One cornerstone of long-term maintenance is the identification and optimisation of the life cycle costs of investments as part of purchasing decision-making. The predictability of costs and the profitability of production can be enhanced by using the techno-economic LCC model for production lines and equipment.

LCC is a highly useful tool for making investments and selecting equipment and systems, as the model takes into account both the investment cost and the life cycle costs, allowing the option with the lowest overall cost to be selected. The life cycle profits of technical solutions should also be included in the comparison, if the options being compared differ in their operational reliability, capacity or quality of production.

As awareness of costs and malfunctions increases in the organisation, the LCC model can be developed further and also be used to control the maintenance of existing production lines. An LCC model based on malfunction history can be used to predict and prepare for future changes. Preparation makes for efficient preventive maintenance and stoppages, and allows the timing and amounts of spare part orders to be optimised.

The history of Life Cycle Costing begins in the 1960s, when the United States Department of Defence started improving the efficiency of weapons system investments. The significance of maintenance costs during an investment's service life was noted time and again. In the 1990s, there was a shift towards so-called reliability-focused maintenance, where the effectiveness of maintenance was improved by utilising the experiences of an investment's primary users. This resulted in better productivity and increased reliability.

Maintenance costs as part of production line life cycle costs

LCC can be used in manufacturing environments to estimate the life cycle costs of equipment and production lines. Budgeted life cycle costs also offer important information for product pricing purposes.

Life cycle cost can be divided into three main phases: the procurement phase, the operational phase and the decommissioning phase. Costs accumulate over each phase of the life cycle of the equipment or production line, adding up to the final Life Cycle Cost.

Procurement

- design and planning costs
- initial investment

Operation

- operational costs
- maintenance costs

Decommissioning

- decommissioning costs

At the procurement phase, the largest cost item is the initial investment, which includes the purchase price of the equipment, but also other expenses, such as installation, testing and software. However, effort should be put into the planning phase as well, as the decisions and choices made at this stage will have far-reaching effects on the whole life cycle and the associated costs.

Unlike the initial investment, operational and maintenance costs recur throughout the investment's life cycle, comprising either relatively constant expenses – like the cost of energy, supplies and operating personnel – or cost spikes caused by for example, work, materials and lost production due to stoppages and maintenance. Modernisation and overhauls show up in the life cycle model as rare large spikes, compared to other maintenance operations.

LCC will often reveal the considerable impact that unrealised production and maintenance have on life cycle costs: unplanned stoppages caused by repairs and malfunctions, as well as planned stoppages for preventive maintenance, cleaning and so on, will incur downtime costs that add up to a significant portion of life cycle costs. For this reason, improvements targeting these events will reduce costs; the positive development of costs can be seen by monitoring the model's results.

Increased malfunctions and losses caused by the aging of a production line can also often be discovered when maintenance and malfunction records are reviewed. Downtime and maintenance cost data is very beneficial and should be used to optimise preventive maintenance and to plan overhauls, as this helps control the overall costs. All in all, compared to a simple maintenance system, the added value of the LCC model lies in how it takes into account profits lost during downtime.

The costs at the end of an investment's life cycle are caused by the decommissioning of the production line or equipment. The time is right for decommissioning, when maintenance costs reach a level where it is no longer profitable, based on the investment calculation.

One way to perform the investment calculation is to analyse how much a new equipment purchase could save annually in significant maintenance and downtime costs, compared to the value of the one-time investment. Naturally, decommissioning may also be necessary to increase capacity or implement new technology. There are costs associated with dismantling, scrapping and toxic waste processing, but the equipment and materials may also have a salvage value, though that is often difficult to estimate beforehand.

LCC calculation tool to manage life cycle costs

An LCC calculation tool is a useful instrument for managing life cycle costs and enhancing production. It is important that the following limits are defined at the start of the LCC calculation:

- the time span for modelling
- the number and extent of cost factors
- the level of detail for costs

For example, it is usual for costs to be calculated at the annual level and for a time span of 20 years or so. The analysis breaks down the typical significant cost factors for each phase of the life cycle, and the model is customised according to the characteristics, needs and information available in each case. For instance, maintenance costs can be divided into repairs and preventive and restorative maintenance.

The expert's role is to identify the essential cost factors together with the customer and prepare the risk assessment based on the information they have received. The model is primarily used for planning new investments, but with sufficient maintenance and operational history available, the model can also be adapted for existing production lines and thus be used to predict their future cost trends.

The LCC model can take into account a given interest rate and inflation, and provide results already converted to their present value. The accumulation of total costs, as well as the cost of different annual phases and throughout the whole life cycle can be graphically visualised (see overleaf). The model gives a clear overview of the individual factors that incur the most cost; useful information for selecting investments and improving efficiency. See Figure 1.

As predicting future costs always involves uncertainty, the calcula-

Maintenance costs are a major part of a product's life cycle costs. It is important that they are identified and managed.

BASIC INFORMATION	
Interest rate %	6
Inflation %	0,3
Life cycle in years	20

Year	0	1	2	3	4	5	6	7	
I Planning	35000	0	0	0	0	0	0	0	
II Initial investment	1500000	0	0	0	0	0	0	0	
III Operation	0	9000	9000	9000	9000	9000	9000	9000	
IV Maintenance	0	47500	46000	46000	46000	46000	46000	46000	
V Decommissioning	0	0	0	0	0	0	0	0	
Total €	1535000	56500	55000	55000	55000	55000	55000	55000	
Cumulative €	1535000	1591500	1646500	1701500	1756500	1811500	1866500	1921500	19215

DISCOUNTED VALUES									
Interest rate %	6								
Inflation %	0,3								
Year	0	1	2	3	4	5	6	7	
I Planning	35000	0	0	0	0	0	0	0	
II Initial investment	1500000	0	0	0	0	0	0	0	
III Operation	0	8515	8056	7621	7210	6821	6453	6105	
IV Maintenance	0	44939	41173	38952	36852	34864	32984	31206	
V Decommissioning	0	0	0	0	0	0	0	0	
Total €	1535000	53453	49228	46573	44062	41686	39438	37311	
Cumulative €	1535000	1588453	1637681	1684255	1728316	1770002	1809440	1846751	18467

Front Page | **Summary** | Planning | Investment | Operation | Maintenance | Decommissioning | Sensitivity Analysis

Year	0	1	2	3	4	5	6	7
Spare parts		2000	2000	2000	2000	2000	2000	2000
Spare part storage		3500	3500	3500	3500	3500	3500	3500
General mechanical, electrical and automation components		2500	2500	2500	2500	2500	2500	2500
Equipment for measuring maintenance; other testing and maintenance equipment		1000	1000	1000	1000	1000	1000	1000
Internal maintenance personnel costs		5000	5000	5000	5000	5000	5000	5000
Training for maintenance personnel		3000	1500	1500	1500	1500	1500	1500
Documentation and other management costs		1500	1500	1500	1500	1500	1500	1500
Annual maintenance contracts		25000	25000	25000	25000	25000	25000	25000
Other external maintenance services		4000	4000	4000	4000	4000	4000	4000
Modernisations or modifications for other use								
Renovations								
Total €	0	47500	46000	46000	46000	46000	46000	46000

Front Page | Summary | Planning | Investment | Operation | **Maintenance** | Decommissioning | Sensitivity Analysis

▲ *Figure 1. An overview of the calculation chart for the Elomatic LCC model. The model specifies all the major cost factors involved in different life cycle phases and functions. For example, maintenance requires several actions, materials and equipment.*

tion's sensitivity to changes is sometimes tested using a sensitivity analysis, which is a way of testing how strongly a change in the initial data affects the result. A typical example of this would be calculations testing what effect the rate of interest has on the final result. As a rule, the impact of the cost factors selected for sensitivity analysis needs to be more than 10 % of life cycle costs.

Challenges in applying the calculations

The calculation of LCC allows the differences of various options to be compared and a choice to be made between investment alternatives. The model is straightforward to build and utilise, particularly for new investments, where the annual operational and maintenance cost estimates should be prepared together with the equipment or system supplier. In practice, this could be an Excel file attached to the request for tenders that the supplier can fill out to indicate the required operational, preventive maintenance and spare part recommendations and estimate the equipment's operational costs and service life.

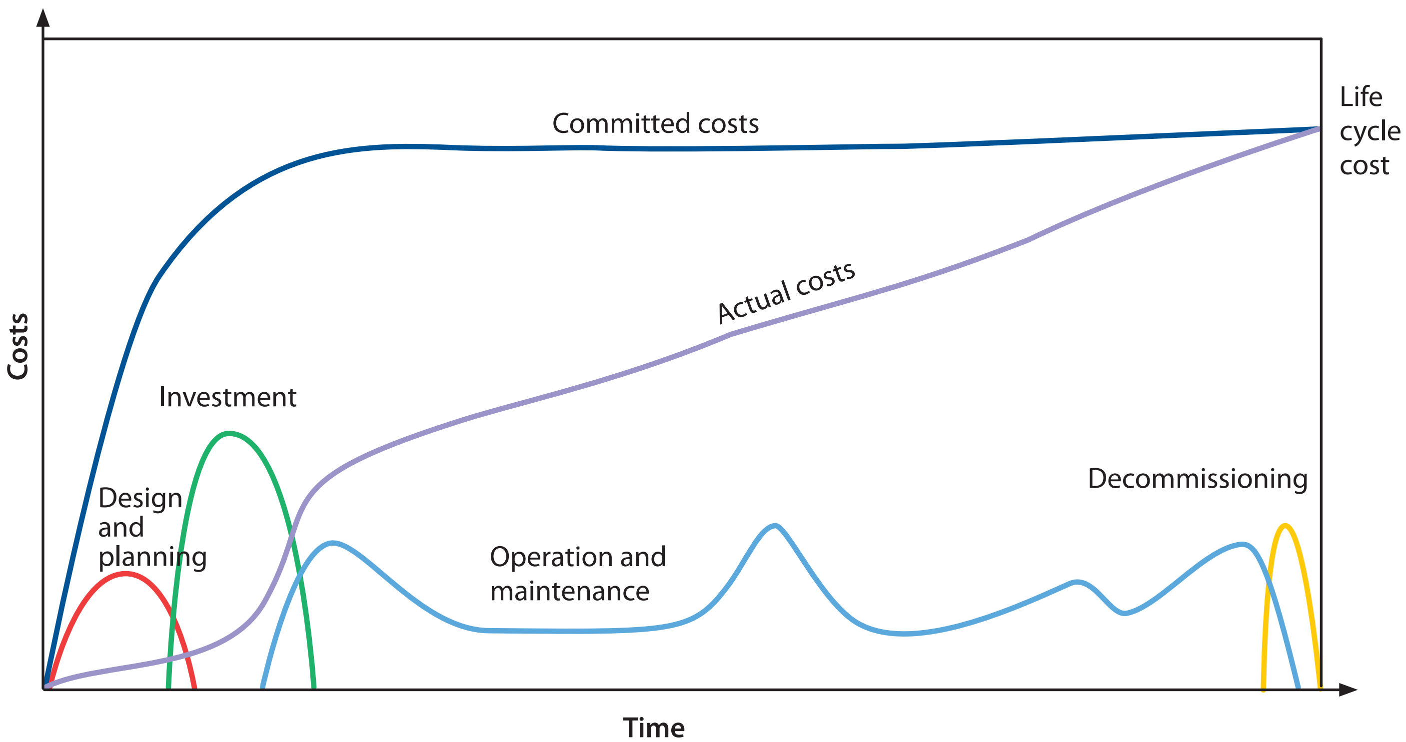
LCC is more challenging in the case of existing production lines, when the objective is to predict the remaining service life and future maintenance costs. This requires the creation of a cost model based on sufficient records of malfunction and actual downtime.

In this case, the model is primarily used to prepare for more significant maintenance and modernisation work, as well as to procure the necessary spare parts and materials. A projected cost level can be included in the model to act as a warning threshold; exceeding the threshold means that it is necessary to update the maintenance or replacement measures.

In our experience, it is an intense undertaking to create a cost model and gather information for existing production line systems. The malfunction history of an individual production line consists of its devices and components that require information to be gathered from different sources and systems. There must also be adequate historical operational and maintenance data for the line – ten to twenty years minimum – to allow the reliable statistical prediction of trends.

Furthermore, the production units rarely specify operational costs by device or even by production line. This often results in theoretical calculations that produce a rough model. The reliability of the cost model can be improved by utilising the user experiences gained from the production line ("reliability-focused maintenance") and the line's efficiency data (e.g. total OEE efficiency, including disruptions and their causes) over a long period of time.

▼ *An indicative graph of the life cycle costs for a production line. The cumulative life cycle cost is the sum of the costs related to different phases.*



The idea of the LCC model is to analyse the costs that are critical to the efficiency of maintenance by exploring the use of personnel, downtime and material purchases. To identify changes that involve maintenance, it is important to acquire sufficient historical data to identify malfunction and maintenance frequency trends.

Automated data collection systems are recommended, once the appropriate measuring locations and methods have been specified. Effective and suitable data collection requires a good understanding of how knowledge of maintenance and malfunctions can improve the management and efficiency of operations.

Undeniable benefits

Today, the life cycle of industrial investments ranges from a few years to decades. However, the funding for investments is shrinking and is focused on shorter repayment periods, i.e. return on investment is sought as soon as possible. The risk here is that urgent and short-sighted decision-making is still focused on the purchase price and not on finding the investment option with the lowest life cycle cost.

This risk can be mitigated with the help of equipment suppliers. Requests for tenders should require the suppliers to estimate the life cycle costs of their solutions. This will make the proposals easier to compare and ensure the overall cost-effectiveness of the decision over the investment's life cycle.

Furthermore, maintenance can integrate the equipment supplier's recommendations into maintenance planning after the equipment has been purchased, ensuring that the value of fixed assets is maintained.

The experience of operating personnel and automatic data collection solutions should be used in the LCC model. It is essential that the organisation can easily update the model based on historical maintenance data.

For larger installation investments, the role of the planning phase is significant in defining the life cycle cost of the installation. The ability of different investments to be maintained should be discussed during the planning phase and the maintenance personnel included in the discussion.

Organisations use LCC to minimise life cycle costs and prepare for future cost spikes. The importance of LCC is emphasised during investment decision-making in particular, as operational and maintenance costs are often a much greater factor in the life cycle costs than the purchase price. In the end, the accuracy of the LCC model depends on how it was defined and how accurate the information is.

Even though maintenance is known to be necessary, it is still often seen as a necessary evil. Too often, organisations resort to partial optimisation of different functions, instead of taking into account the long-term overall efficiency.

Maintenance costs are a great part of a product's life cycle costs, and it is important for everyone to identify and manage them. Without doing so, it is impossible to reach the common goal of efficient plant production (with regard to availability and cost optimisation).

Room for improvement in Finland

There is still room for improvement in Finland's productivity and industrial competitiveness, compared to other EU countries. Economic growth can be achieved by increasing the amount of work or by improving its productivity. Productivity can be improved by employing more effective methods, more efficient machines and new products.

To celebrate Finland's centennial, we should work together to improve the productivity of maintenance and make good use of LCC modelling in investments to minimise life cycle costs and improve the predictability of costs!

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Winning Product Development

Integrating technical analysis, engineering, and industrial design

Text: Petri Seppänen

Traditional product development is time-consuming and costly. It relies heavily on experts in engineering, technical analysis and industrial design that work sequentially and separately in developing initial designs and testing prototypes. The expertise of technical analysts and industrial designers, in particular, is underused in such approaches, in which design can be described as being done from the "outside to the inside". Typically, simulation is used only at the back end of traditional product development. Modern and more efficient approaches integrate these disciplines at the outset of development projects, are simulation-driven, and enhanced with optimisation tools. Such products are designed from the inside-out.

Tom Kelly, from the renowned California-based IDEO product design company, has indicated that in product development the game cannot be won by having better engineers or marketers than the people down the street.

"You can't win. Someone is always going to come along who is better. The magic is at the intersection between anthropology and engineering and marketing or whatever, where you cluster things in a different way, and you say, 'Hey, here is something people need that they didn't know they needed'."

Another interesting and revealing quote on the topic can be found further back in history. In 1955 Henry Dreyfuss, the internationally acclaimed industrial designer proclaimed that "the best products are designed from the inside-out. An honest job of design should flow from the inside out, not from the outside in."

Product development is a series of steps that includes the conceptualisation, design, development and marketing of newly created goods or services. A company's product development strategy is a core success factor in any business and the focal point that drives organisational growth.

So what are the key factors that result in excellent product development? Some may say process. What is more important in creating winning products, however, is making use of multidisciplinary teams that understand Henry Dreyfuss' and Tom Kelley's ideas and also employ modern product development methods.

Increasingly tough competition placing high demands on product development

Product development strategies have become essential because current day business operations are characterised by high pressures to meet customer demands, the eternal quest to implement cost savings and achieve increased competitiveness, as well as the drive to hit ever-shrinking time-to-market windows.

A product development strategy provides answers to global trends. Seiffert & Rainer, 2008, have compartmentalised the development of bigger global trends as follows:

- Progressive innovation politics (China, India)
- Aging of the European workforce
- Increased urbanisation (Asia, South America)
- Environmental awareness (CO_2, consumption)
- Change of transport infrastructure
- Reducing resources

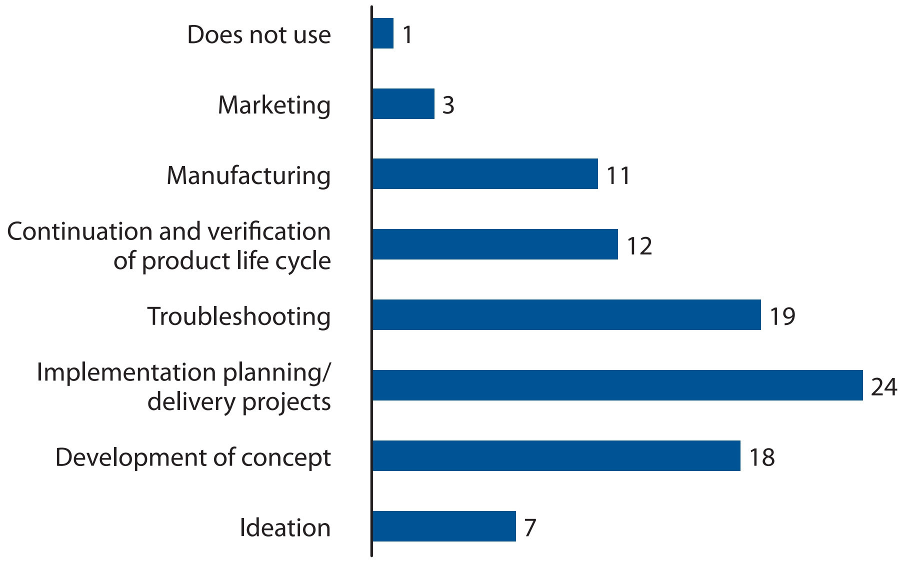
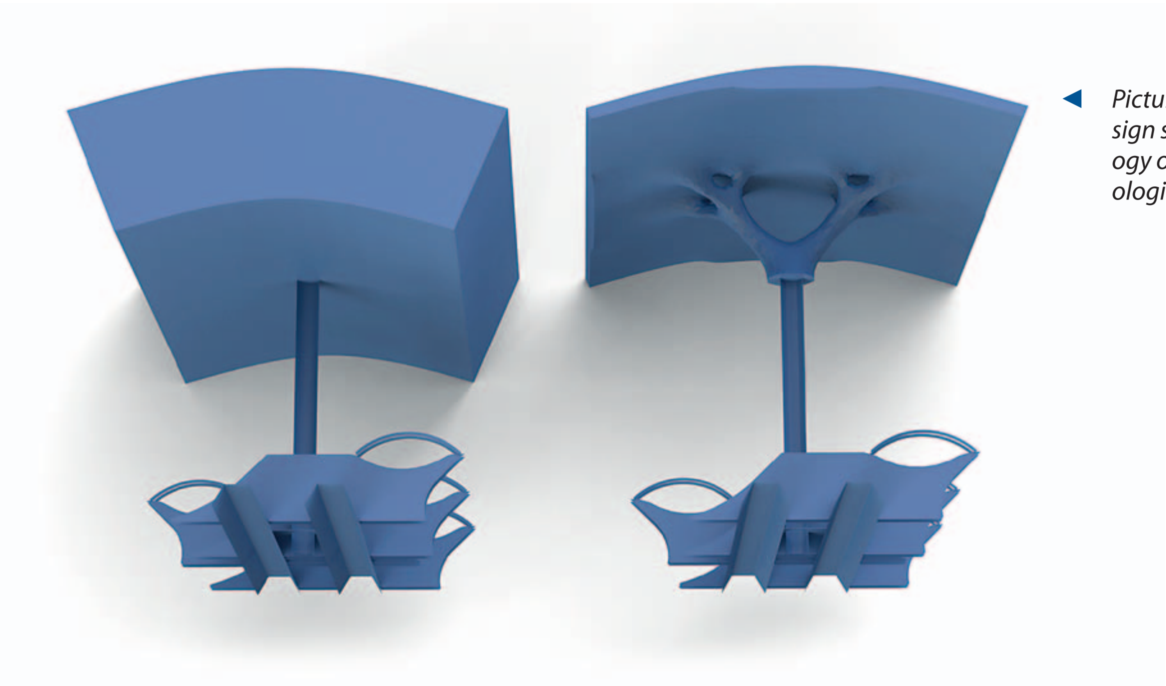


Diagram 1. Simulation and its uses by industrial companies. It is worrying to see how much simulation is used for troubleshooting as the ability to make changes during this phase is minimal.



Picture 1. Bike stand cover with a design space (left). This is used for topology optimisation. The cover with topologically optimised structure (right).

Picture 2. The finite element model of the optimisation case.

The increasingly competitive selling conditions call urgently for high-quality products. In the automotive industry Heissing & Ersoy, 2011, have identified the following global trends:

- 30 years ago, vehicles could be organised into a relatively small number of categories: compact sedans, mid-sized sedans, and premium sedans. By 2020 the number of categories is estimated to be 22.
- Increased number of model variants
- Reduced product life cycles and continouously increasing levels of innovation
- Increased globalisation in manufacturing, sales, and development.

These global trends also affect other sectors. Companies that continue to rely on traditional product development, instead of making use of simulation and other modern product development tools and methods, will be left behind. They will find that their development cycles are longer and that their development costs are higher. Lead time is not the only important parameter; cost and quality are examples of other parameters that are influenced by product development processes.

Multi-disciplinary teams boost product development

Traditional approaches to product development start with the development of an initial design, which is used to develop a prototype for an experimental test. Engineering, industrial design, and technical analysis are used sequentially and the approach is usually based on trial and error. This is, unfortunately, a highly time-consuming process and remarkably costly because industrial design and technical analysis know-how is commonly employed late in the process and is not fully utilised. This means that knowledge is used from the outside to the inside. Simulation tools are mostly used for troubleshooting and validating designs. Diagram 1 outlines the results of a 2016 survey conducted by Elomatic regarding the use of simulation tools in product development.

Traditional product development can be improved by introducing simulation-driven design early in the development process. This replaces manual and iterative work and reduces costs. The cost savings produced by simulation-driven methods can be significant, because product development accounts for 75 % of fixed costs.

Simulation-driven design

Simulation-driven design may sound like just another buzzword, but can actually make a significant difference in product development. Simulation-driven development differs from the typical design process: simulation tools are not used to validate the behavior of the model. Another way of explaining this is that engineers first create a behavioral model (based on boundary conditions), and then use simulation and optimisation tools to generate a geometric model. Put even another way, while typical design processes start with computer-aided design, simulation-driven design processes start with computer-aided engineering.

Optimisation is a key driver in business success

Simulation-driven design can be enhanced with optimisation tools (parametric and non-parametric), such as topology optimisation (see Picture 1). Non-parametric optimisation includes structural optimisation, size-, shape- and topology optimisation.

In topology optimisation no a-priori assumptions on the topology of structures is made. It is the most general area of structural optimisation where an ideal setting for every point in space is determined, and whether there should be material or not. Topology optimisation can be seen as a generalisation of the above areas, since it determines the shape of a structure's boundary, as well as the number and shape of holes it contains.

Topology optimisation has become an important tool in the product development process. It assists designers and engineers to gain insights into alternative topological possibilities. It also provides new points of view for industrial designers to design beautiful, useful and user-friendly products.

One could say that in simulation-driven and optimised product development, design flows from the inside-out and creates winning products. Henry Dreyfuss would agree I think. By combining Dreyfuss' and Tom Kelley's ideas with modern product development methods, the product development process can be taken to even more efficient levels.

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Petri Seppänen started working at Elomatic as a structural analyst in May 2015. He has worked in consultancy, simulation and design tasks within mechanical design since 2008 and is specialised in multibody simulation (MBS) and optimisation (parametric and non-parametric optimisation). From 2012 to 2015 Seppänen worked as a technical consultant in the automotive industry and consulted OEMS and Tier 1 level component suppliers. Seppänen has also performed pre- and post-sale support for an optimisation program.

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Inventions and inventiveness as part of development projects

Text: Pekka Koivukunnas and Rami Raute

Some inventions are created by chance, while some are not even recognised as being inventions; their full benefit may be left unutilised, even if they are implemented as part solutions. Inventions that change the world and create significant growth for companies, however, are rarely the result of chance. Rather, they spring from a marked effort in strategy and technology leadership.

How should we lead companies with the aid of innovations and inventions in order to deliver significant competitive advantages and clear market differentiation? Technology and market leadership can be analysed with the use of international patent databanks and by comparing the patenting of products that are market leaders.

On the other hand, if a company and its products and patents are not sales or technology quality hits, one can easily conclude that it lacks a competitive advantage. If most development project related signals come from competitors' products, the situation is much the same.

What differentiates innovative companies from ordinary ones?

There a four main factors that differentiate innovative companies from the rest. Firstly, the management of innovative companies clearly expresses the need for new inventions and innovations. It defines concrete challenges and goals for product development staff and highlights challenges that are market- and customer centric and driven by changing operational environments. Management is aware that challenges can be set, even though there is no intention to launch a new product development project.

Big challenges of the "it would be great if…" type, leave the door open to new and great innovations. Innovative companies benefit from the innovative potential of employees on a continuous basis. A skilled innovator is able to process challenges on a subconscious level so that ideas and inventions are "self-created" outside busy daily life.

Secondly, employees in innovative companies generate many suggested solutions for the given challenges and draw up invention disclosures.

Thirdly, management evaluates these suggested solutions (invention disclosures) from the viewpoint of operational goals. Would the invention in practice reach the set goal? In the first evaluation no attention is paid to potential flaws of the invention. Management therefore actively takes part in developing inventions, rather than just screening them. A skilled manager is able to process inventions subconsciously. He/she comes to new insights/realisations automatically while taking care of other duties.

The final differentiating factor is management that shows that it truly values inventors. This recognition motivates real innovators more than money. Recognition gives birth to an innovative environment and culture.

Management as driver of innovations and growth

One of the core goals in innovation is to define management's role as the driver of innovations and growth. Management has to take on the role of a movie director and producer, while the end user sets high goals for the quality of inventions and innovations. Modern product development methods, for example scrum, highlight the aforementioned roles precisely from the end user's perspective.

The evaluation of inventions with the aim of promoting innovation is management's role. Only management that has set goals for innovations and inventions is able to evaluate such achievements. At the outset, management should try to find some feature or possibility that in some circumstances could be functional or beneficial. As indicated before, the focus should not be on identifying possible flaws or risks, but only on identifying possibilities. The flaws will be removed in the invention's processing phase.

When management takes part in evaluating and improving inventions they change the organisational dynamics. The synergies generated ensure that the significance and quality of inventions are driven to a new level over the long term.

Changing innovation cultures

It is relatively simple to change management's orientation to innovation. This is due to the fact it is a small group of people that need to learn to think about inventions and innovation in a new way. But, how does one get the whole company and engineers stuck in traditional ways of working to take part in developing innovations and to support the company's technological success?

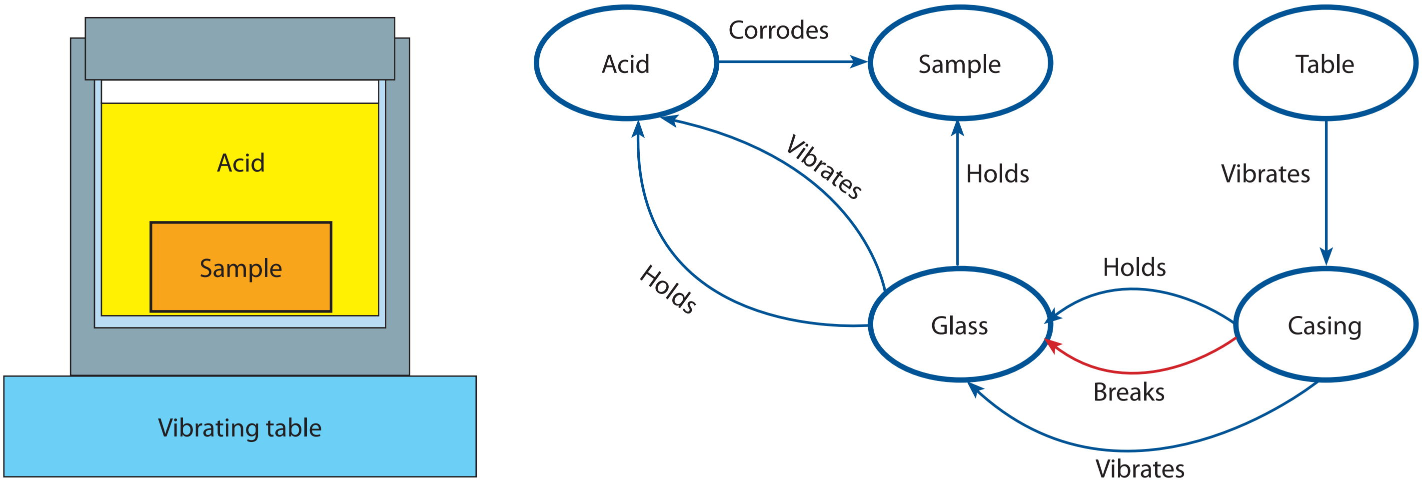
The corporate vision is a key element in this regard. Only a vision that looks sufficiently far into the future challenges the organisation to approach development work in the right way. Leading via a company's vision should be such an integral part of corporate management, that a significant part of development work is evaluated in relation to the vision. For example, if part of the vision states that a company wants "to be a technology leader", one should ask whether the invention in question will achieve this goal.

A vision in itself is not enough. Support is required in the form of methods that integrate the development of inventions and innovations in the company's processes and ways of working. The importance of opinions and the atmosphere in which inventions are created in a company should be understood.

How are inventions generated professionally?

Challenges provided by management and customers are analysed carefully. What is it really about? What problems are associated with it? What was tried before? Attempts are made to find the core issue in a bundle of problems.

It helps to conduct a function analysis to understand a problem. The system's desired complete function is broken down into part functions, for which implementation alternatives are identified separately. Before coming up with



▲ *Figure 1. A function analysis can assist in understanding a problem: the system's main function and supporting functions are analysed. A diagram of the analysis should be drawn that contains the system parts with their desired interactive functions as well as problematic functions, which are the problems that require solving. The functional analysis was conducted on a material testing arrangement. Metal samples are tested in the acid bath. The problem is that the glass lining in the acid chamber breaks every now and then.*

◀ *Innovations are not only required in industrial applications. Elomatic's Innovation team used the TRIZ problem-solving and idea generation method to come up with an idea for an artificial nest to help save the Saimaa ringed seal. They focused particularly on what local natural resources could be used to fulfil the requirements. They identified common reed as a suitable material. Here the team is building a nest on Lake Saimaa. See back page of magazine for story on successful birth of Saimaa seal pup.*

To be successful management has to take an active role in developing innovations and show that it truly values inventors.

your own ideas, it is worth benefitting from existing information resources. The expression – *everything has already been invented* – holds particularly true for part functions. See Figure 1 for an example of a function analysis.

A part function can be made up of two systems components that *affect* each other. Several alternative implementation methods may be identified for each part function. Only if no implementation alternatives are found from already implemented part functions, does one start generating ideas of your own. The reason is very simple: inventing things yourself is slower and more expensive. With professional and systematic work methods, one or several inventions can be generated in a week.

Part functions and their alternative implementation methods can be handled with the help of a morphological matrix. When working individually the matrix can be handled in the mind. However, group work is more efficient when the matrix is visualised with a cloud tool like Realtimeboard (https://realtimeboard.com). Total solution alternatives can be generated by combining the cells of the morphological matrix differently.

TRIZ method – when ready solutions do not exist

Sometimes we are faced with a problem to which there is no ready solution. In such cases the solution has to be invented. In industry the most commonly used method is trial and error. This is known to be a slow and expensive.

TRIZ is a much more efficient and professional method. It defines a problem as a contradictory and seemingly impossible pair of features. Attempts are made to solve the contradiction in the system with the help of existing resources, without adding anything to the system. Compromise solutions are not accepted. In the ideal system the system task and function are fulfilled without the system. For example, AirBnb is close to the ideal "hotel", because the function of a hotel is fulfilled even if no hotel exists.

With the help of the TRIZ method one can relatively quickly and cheaply generate cost-efficient solutions and inventions that can be patented. An example of an invention created with the help of TRIZ is the OptiLoad paper calendering machine. The invention was created by first identifying a contradiction: the roll had to be simultaneously flexible and rigid.

During resource analysis it was noted that a different type of paper calendaring machine had exactly this kind of roll. The invention was thus rather "easy" in the end. The roll in question had been available for over ten years, but only the setting of the contradiction allowed the inventors to "find" the roll. Nobody could have guessed that the patenting of the invention would lead to market leadership that lasted several years and cumulative sales of over a billion euros.

Conclusion

Companies that develop and benefit from inventions and innovations as central elements of management culture are also more agile in taking up new technologies and moving into new business areas. One of the surest ways to achieve success in a changing world is connecting inventiveness development and awareness of inventions to systematic processes as part of a company's core corporate culture.

About the authors

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Pekka Koivukunnas graduated from the Lappeenranta University of Technology in 1985. Since his graduation he has worked in product development, as an innovation consultant, professional innovator, and entrepreneur. He also has experience of patenting and has over 100 patents registered in his name. In 2013 the Finnish Inventors National Federation awarded Pekka the prize of Innovator the Year. He currently works at the Elomatic office in Espoo.

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A step closer to saving endangered Saimaa ringed seal

In 2016 Top Engineer reported on an artificial nest designed by Elomatic's Innovation Team, which was designed to assist Saimaa ringed seal breeding during winters of low snowfall in collaboration with Metsähallitus Parks & Wildlife Finland and the LIFE Saimaa Seal project. There is now conclusive evidence that a seal pup made use of the artificial nest during the first testing period on Lake Saimaa in the winter of 2016/2017.

To breed successfully, Saimaa ringed seals require sufficient amounts of ice and snow as the seals give birth to pups in cave-like nests built of snow. The artificial nest is made of common reed found in and around the lake.

The nest where the pup was born was a combination of an artificial nest and a snowdrift created specially to assist breeding. It is unclear whether the seal was born on the side of the artificial nest or the snowdrift, but the pale, wool-like fur left behind by the pup on both sides of the nest indicates that it made use of both.

This is a particularly positive development as recent winters have seen little snow. The development of the nests will continue next winter.

Photo © Metsähallitus/Timo Seppäläinen