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The Filter

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Wind power

Foam, the whole truth - up to now!

In this article "The Filter" talks to five of Europe's experts on lubrication oils about the question of oil foaming in gearboxes. Their views throw new light on this phenomenon. Our panel of experts are: Per Holm of Mobil Oil Denmark I/S, Hubert Gergorius of Castrol Industrie GmbH, Jørgen Olsen of Hydro Texaco Denmark A/S and Hermann Siebert of Kluber Lubrication Munchen KG. We finish the article with a summary of notes on oil foaming from Jesus Tarradillos of Fundacion Tekniker the Spanish arm of Noria Corporation, the world's biggest oil consultants.

Per Holm

Hubert Gergorius

Jørgen Olsen

Hermann Siebert

Probably the best place to start is to take a look at air, figuratively that is. All our experts agreed that there is always air in lubrication oils. The question is what form it takes. There is free air for example, that could be an air pocket in a line or the air in the cavity of a gearbox and there is dissolved air.

It is dissolved air that interests us. In mineral oils there is normally a volume of 9-10% of air completely dissolved in the oil. When an operating system is functioning this air can change from its dissolved form into small bubbles. "Dissolved air is not readily drawn out of solution" explains Jørgen Olsen of Hydro Texaco, "It becomes a problem when temperatures rise rapidly or pressure drops. When a system starts up or when it overheats, this air changes from a dissolved phase into small bubbles. If the bubbles are less than 1 mm, in diameter, they remain suspended in the liquid phase of the oil, particularly in high viscosity oils. This causes air entrainment, which is characterised as a small amount of air in the form of extremely small bubbles dispersed throughout the bulk of the oil". In the opinion of Mobil's Per Holm, "Air entrainment also occurs by agitation that finely disperses air in oil". In his experience

"This is the most likely source of entrained air in a gearbox. It can also however come from a small leak that allows air to bleed into the system", he added.
The other form of dissolved air is what many call **foam**. This can be defined as a collection of closely packed air pockets that are surrounded by a thin film of oil that normally float on the surface of the oil. The difference between these two types of dissolved air is where many of the misconceptions attributed to "the problem of foaming" originate. Both types can have negative repercussions for operating systems but according to our panel of experts, in general terms it is air entrainment that produces the biggest problems. Before taking a look at some of these let us take a closer look at foaming.

Foam can best be observed when a turbine is stopped
According to Castrols' Hubert Gergorius, systems in operation have air but do not usually have foam. It is when the system is stopped that the air within the oil rises to the surface and when foam can be observed. In wind turbines for example: "By the time you have stopped the turbine, reached it and removed the observation plate as much as 15 minutes could have elapsed, which has given time for the air to rise and form bubbles on the surface. This is the classical observed foam that could have a depth of anything between 10 and 50 mm. If you run the turbine immediately for a short while the surface foam will disappear. It is rather like stirring boiling milk to remove the foam", he said. Hydro Texaco's Jørgen Olsen's description agrees with this, "By looking into transmissions with high viscosity oils, you often see bubbles coming up through the oil up to 10 minutes after a shutdown of the gearbox. Of course this depends on the present temperature and other factors like the speed of the gears", he added.
If foam is constantly present within an operating system there will be clear signs like oil level control problems, possible turbine shutdown through overheating and oil leaks through breathers and other accesses and these have to be treated immediately. No operating system can be adequately lubricated by foam and the foaming may be a symptom of more serious problems like oil contamination from sealing materials, other incompatible lubricants, cleaning compounds, process fluids, greases or airborne contaminants and in some cases filters. If these problems are not treated quickly and adequately the operating system could be permanently damaged."
According to Per Holm of Mobil Oil, "Another factor that affects foaming within a gearbox is the type of oil lubrication system that is used. "If oil is re-injected back into the gearbox by jets (splash system) in order to get a maximum distribution of lubricant over the moving parts, the jets must be set up well to avoid an atomising effect which adds too much air to the lubricant".
In Jørgen Olsen's opinion, "It is a good idea to ask a lot of questions if a foam problem has to be solved. First evaluate the overall system. Then take a look at the fluid. Finally, see if the bubbles are being introduced through, or generated by any of the components. In all lubrication related problems, it is important to treat the root cause and not just the symptom", he stressed.

Therefore, a certain level of foaming is always present and can be caused by a number of factors. For foam to be a problem it has to be excessive and will produce recognisable signs. If foaming reaches this level then remedial action should be taken immediately and it is the root cause that should be treated and not just the symptom.

Bubble size and oil viscosity and the problems of entrained air
It is generally agreed that air entrainment can be a more serious problem and although it is a form of foaming, it is much more difficult to control. When the entrained air reaches a certain level, there are so many minute pockets of air trapped within and evenly dispersed throughout the oil, that the overall level of lubrication of an operating system is reduced. This can lead to accelerated component wear, pump cavitation and fluctuations in flow rates, these in turn affect cooling systems and operating temperatures can rise. And as if all this was not enough, oil oxidation is increased drastically reducing the lifetime of the lubricant.
Not all is gloom and doom however; the major oil companies have done a great deal of work on keeping air entrainment under control. Jørgen Olsen commented, "Although studies show that basic mineral oils foam most at 280-290 cSt you normally find that they have a very good foaming tendency and stability. There can be some variation depending on the source of the crude oil and the distillation process used. It has been seen that where foam is generated mechanically a change to synthetic oil PAO (polyalphaolefin) or hydrocracked oils may help", he concluded.
This is a fact also borne out by experience in the market place. According to Kluber Lubrication's Hermann Siebert, "We have been selling a synthetic oil with great success to the wind turbine sector due to its low foam levels".

Air entrainment is a serious problem and can be identified by increased noise levels and can result in damage to pumps, increased gear wear, reduced oil flow rates, accelerated oil degradation and increased operating temperature as a result of reduced oil cooling.

Popping the bubbles with antifoaming additives can help
All the major manufacturers of lubricant oils have experimented with anti-foaming additives. These work by spreading across the surface of an oil bubble and shearing the oil film until it ruptures. The most common antifoam additives are based on silicone that is much denser than the surrounding fluid and much denser than any bubble. This means that bubbles are slowed down during their way to the surface and this prevents the foam from being built up. To be effective however, according to Jørgen Olsen, "They must be insoluble in the oil and to ensure long term foam performance silicon antifoaming additives must be less that 5 to 7 microns in size".
However there is a tendency for silicone antifoaming additives to cling to surfaces such as gearbox housings and thus reducing their effect. Filters can also heighten this clinging characteristic because they provide huge additional surfaces for the silicone to attach to.
Simply applying more anti-foaming additive is not the answer either. According to Jørgen Olsen, "to avoid foam from a system it was previously a common practice to add an after-market additive, usually silicone-based. Generally foam went away quickly, only to return. More antifoam was added, and the cycle repeated until the system became so overloaded with the additive that the oil had to be dumped".

In some industrial gear oils acrylate copolymers are used. The optimum particle size to ensure efficient product performance and long-term foam stability in formulated oils is 1 to 10 microns. There is a great deal of research underway to develop a new generation of antifoaming additives that are less sensitive and more effective.

Antifoaming additives are being studied and developed for a new generation of low foaming lubrication oils.

Fine filtration and its effects on foaming

Most of our experts agreed that the benefits of 3-micron absolute, fine filtering such as reduced component wear and tear, removal of water and resins and in general the promotion of longer oil lifetimes, far outweighed the disadvantages of foam creation in certain circumstances.
Mobil Oil's Per Holm felt that there must logically be an effect on foaming additives that have particles greater than the finest filtration limit of the filter, but he said, "I believe that it is more complicated than this. In a test with a 12 micron filter it removed the entire antifoaming additive on the spot, whereas in other tests with a 5 micron filter nothing was removed. We are still trying to figure out the best way forward including fine filtration, but we see the extra foaming these filters can cause as a minor problem".
Tests carried out by Hydro Texaco were not so conclusive explained Jørgen Olsen. "Together with CJC we tested a depth filter with an industrial gear oil with a viscosity of 320. Two test beds were established. One was with a filter element and the other without. Samples were taken from both beds at the same time during the tests. The analysis showed an increasing foam tendency on the test bed with the filter and an unacceptable level of foaming after 7 days. This test illustrated that something was affected in the lubricant after a very short time period, but unfortunately the test did not continue to see the long-term effect of depth filter filtration. However, on the other hand from thousands of installations with an off-line depth filter in gear systems apparently foam as observed is not a problem, so far", he concluded.
For Hermann Siebert of Kluber, foaming is not a big issue from the point of view of the difference made by fine filtering. "Foaming of oil is influenced by a complex number of circumstances. Some oils foam more than others. Some types of gear meshes create more foam than others. Some types of oil circuits produce more foam than others. Some types of filters create more foam than others. Some operating temperatures create more foam. It requires ongoing test programs on many different fronts, before we will get step-by-step answers that will lead to comprehensive and viable solutions to all these variables", he stressed.
According to Hubert Gregorius of Castrol however, there are a number of possible solutions that have to be explored and none of which affect the use of fine filtration. He said that, "There are undoubtedly many factors that contribute to unacceptable levels of foaming or air entrainment and they can be just as easily associated with poor maintenance as generic factors such as filters, gear design, distribution systems and oil characteristics.
I believe that we have to start looking at lower oil circulation rates, larger oil volumes, adequate breathers, avoidance of sharp edges and flow restrictions and the use of lower oil viscosity", he concluded.

Fine filtration is not a major contributory factor to the type of oil foaming that could be considered serious although it may be a contributory factor along with a number of other elements in certain circumstances. The problem is more complex and one where a number of factors still have to be studied before any conclusive assumptions can be drawn.

When diagnosing foam or air entrainment problems, according to Jørgen Olsen, "It is important to use a systematic approach and to avoid treating the symptoms rather than the cause", he stressed.
Most of our experts agreed that work on reducing oil foaming and air entrainment continues apace and that the search is for a product that can reduce foaming to a minimum whilst working more effectively with complementary products like off-line fine filtration. Another challenge is to increase the lifetime of oils particularly for low maintenance locations such as offshore wind farms. We can only assume that the first company past the post with such important advances will in the words of one of our experts, "create a milestone in the long history of lubrication oil development"!

Summary of notes on the issue of Oil Foaming.

Jesús Tarradillos
Fundación Tekniker

There are many possible causes of unacceptable levels of foam. Some relate to the conditions of the oil and others are mechanical in nature. A mechanical problem may be associated with over agitation from high return/drain flows or a low oil level. If foam collapses quickly when a machine is at rest, then a mechanical problem should be suspected.
The factors to eliminate foam are:

- *Filling method.*
- *Preventive and proactive maintenance programmes.*
- *Tank design.*
- *Selection of lubricant.*

• Filling the tank is critical and it is recommended to do this with a hose introduced into the tank to avoid the introduction of air. When you fill a new tank, the air may be trapped in dead areas which will mean that a purge will be necessary. The best procedure is to empty the tank with a vacuum pump and maintain the vacuum while the tank is filled.

• The preventative maintenance tasks recommended are to revise sealings and joints, make visual inspections, check oil levels and revise filters.

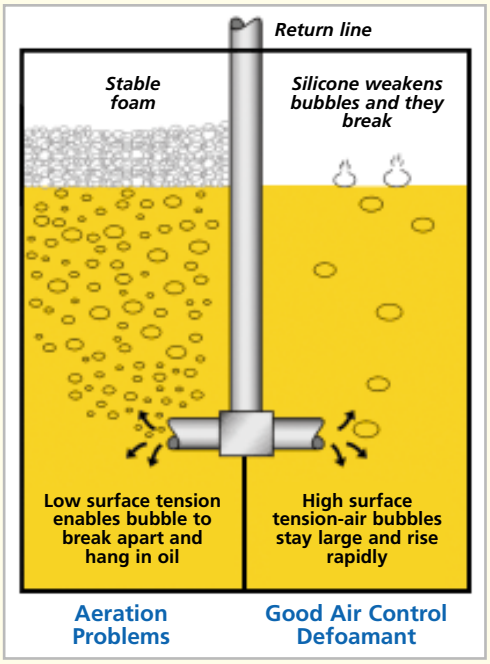
• Proactive maintenance is an effective tool to eliminate foam by:
- *Cleaning control.*
- *Elimination of humidity.*
- *Good filtration of oil.*
- *Removal of contaminants as quickly as possible.*

If, after introducing good maintenance practices, foaming persists the point where air is entering the system has to be located and closed.

• The design of the tank can be a major contributory factor to oil foaming, among the principal problems are:
- *The return line is above the level of the oil.*
- *The tank is too small. The tank has to have a capacity between 5 and 10 times the volume of the pump.*
- *The oil level of the tank is low.*
- *The moving parts introduce air into the system.*

• The adequate selection of oil. There are great differences in the comportment of one oil and another. Some oils can accumulate large quantities of retained air but release it quickly, while others only allow small quantities of air but release it very slowly. The ideal oil has to be highly resistant to air and should not retain air bubbles after they form. The oils that best obey this model are the synthetic and hydro-cracked oils.

The Filter would like to take this opportunity of thanking our panel of experts for their invaluable contribution to this article. – The Editor



Dutch developer Nuon looks to optimise generation from its spanish acquisition

Dutch wind farm developer and turbine manufacturer, Nuon moves to optimise the energy production of its recently acquired Spanish wind farm operation, Desarrollo Eólicas, to take full advantage of green energy premiums available to the company in the Dutch market.
To do this, the company is studying the possibility of retrofitting its 500 turbines located in Spain with C.C. Jensen off-line filtration systems to reduce maintenance and downtime and prolong the life of gears and bearings.
According to Dutch law and as a government measure to stimulate investment in renewable energy sources, Dutch producers of green energy are allowed to charge a premium price for energy generated in this way. This applies to energy generated and entering the European grid in any EC member state and allows Nuon the benefits of the premiums back home in Holland. It is logical therefore that the company should be looking for wind farm generation capacity in other countries apart from Holland.
At the moment C.C. Jensen has 10 mobile off-line filters being used in various locations as part of an extensive test program.
"Up to now the results have been spectacular and we have every confidence that Desarrollo Eólicas will join the ever growing number of developers looking to fine filtering to increase their profitability. We naturally hope that when they decide, that it will be C.C. Jensen that do the job". Ulf Bertelsen, Managing Director of C.C. Jensen, Spain, commented.

Green energy generation gets premiums from the Dutch government

DeWind move to CJC off-line filtration

In a significant step forward for C.C. Jensen in the German market, Karberg & Hennemann has completed an important deal with DeWind AG, the Lübeck based manufacturer of wind turbines.

The deal for 125 units will see the retrofitting of 65 off-line filters type HDU 15/25 PV fitted to DeWind D4, D6 and D8 turbines. The rest will form part of an original equipment programme for the new versions of the D4 and D6 and possibly also the new D8 (2 MW) turbine which is in its final stages of development.

Meinhart Hansen on site with DeWind

"We are really pleased to have won this contract against strong competition", commented Meinhart Hansen, sales engineer at Karberg & Hennemann, the German manufacturer of CJC in Hamburg. "Our filter was tested for over a year before the contract was finally confirmed. We all hope that this will be the start of a long and fruitful relationship with DeWind".

DeWind, which since May of this year is part of the U.K. based global industrial group

DeWind wind turbine

FKI Plc, shipped its 400th turbine in September 2002 and has ambitious plans for the near future. Among these is the development of the D9 wind turbine which will have a generation capacity of 3,500 kilowatts for both onshore and offshore applications. The prototype is due to be erected in 2003/2004.

Seeing is believing

Thomas Møller Andersen

The best way to convince potential clients of the effectiveness of fine filtering is to let them see for themselves, according to C.C. Jensen's key account manager for wind energy, Thomas Møller Andersen.

This is why the company initiated a programme of free testing for any client interested enough to allow Jensen's technical team install a filter system and analyse together with them the results of the exercise.

"One of the initial doubts expressed by clients is always the downtime needed to install a system," explained Andersen. "As we now have this down to as little as two hours, this is no longer a barrier".

A test programme has no particular time limit and C.C. Jensen has in fact completed programmes up to as much as two years to finally convince a client of the long-term viability of its systems. Normally a test programme will require oil samples to be taken from the gearbox before the test program start-up; after 2 days, one week, one month and then every month until the client is convinced that the improvements gained are constant. In one industrial application tests were taken over a period of 7 years and showed a staggering reduction in maintenance time of over 60%. All the samples taken are analysed by an independent laboratory (normally Filtrex, a Dutch specialist) and test reports produced. These are used progressively to compare results, as oils become cleaner.

"We offer the tests with absolutely no obligation on behalf of the client" said Andersen. "One of the really positive spin-offs for the client is that his learning curve increases with every visit and every sample analysed, until at the end of the study a client will know literally as much as we do about the techniques and benefits of fine filtering. Some of our largest contracts with highly demanding clients have been won through this process. We have a mission as well as a sales objective. That mission is to convince the client of the added value of effective filtering for wind turbine lubricating oils, but you can't beat the old adage that seeing is believing".

Custom designed CJC filter test bed

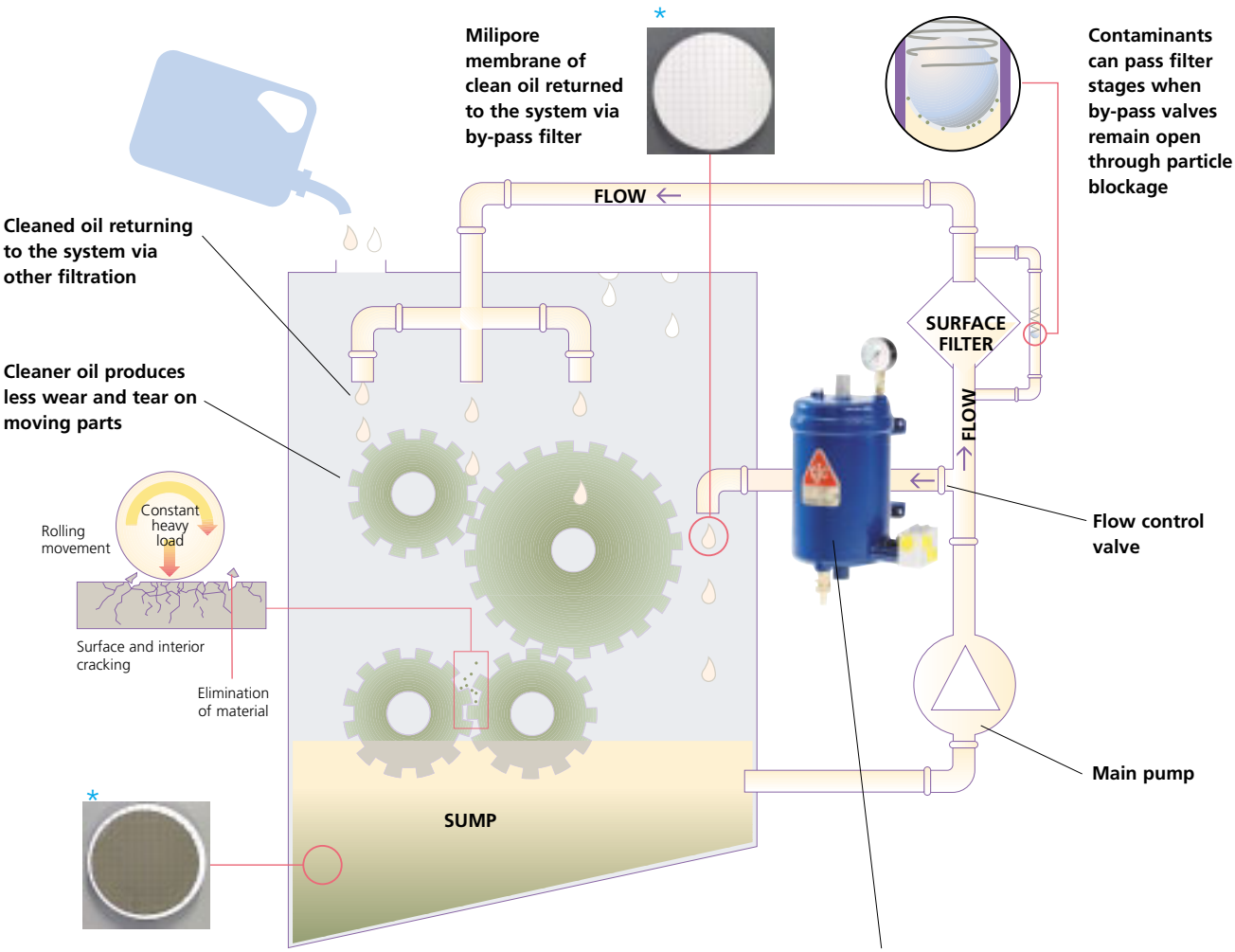
New by-pass filter system gets Vestas vote of confidence

C.C. Jensen has launched an absolutely new filtration system specifically designed to be fitted to already operational wind turbines. It is called the by-pass filter and is codified as the HDU 15/25 VY. This article explains this new development in detail and looks at its potential in a rapidly growing market.
Knowledge and awareness of the importance of oil cleanliness is rapidly increasing and therefore filtration technology has moved forward with better and better solutions. One of the most recent and major developments has been fine filtration. Many turbines and most 600 kW turbines were installed before 3-micron fine filtration technology was available or recognised as being one of the most efficient ways of protecting gearboxes and bearings against accelerated wear and tear whilst at the same time reducing maintenance costs and non-productive down time.
It was soon discovered that a product to meet the requirements of this highly lucrative market had to meet very strict criteria to make it a viable economic option for the major turbine manufacturers. When it is a question of thousands rather than hundreds of installations the cost/quality ratio has to be fine-tuned to maintain all the benefits of fine filtering, but at an acceptable cost. The most important criteria were therefore the following:

- A highly competitive price.
- A product that could be installed quickly and cheaply.
- An obtained oil ISO code better than 19/17/14.
- Low maintenance.

C.C. Jensen's engineering design team started working on the problem in late 2001 and developed a product ready for client testing programmes in approximately 3 months. To ease installation and reduce the sales price, the independent pump and motor that are features of the more complete off-line system, were removed and the oil was driven through the filter using the pressure in the turbine gearbox cooling system. The only limitation of this method was that the oil only flowed through the filter when the turbine was functioning. However, given the patented design and composition of the

A driagram of a typical by-pass filter installation



by-pass filter insert, changing periods are extended to as much as 12 months. With this and other factors it was decided that these limitations were acceptable, especially given the reduction achieved in unit cost and the still excellent level of oil filtration achieved. In fact in the ensuing test program the by-pass filters were also found to extend the life of the existing in-line filters. Finally the new filter design was rationalised to allow an installation time of only a few hours.

In 2002 a test programme was initiated at Vestas; the world's leading wind turbine manufacturer in order to prove the efficiency of the system. Based on the test results, Vestas decide to use the CJC by-pass filter that will now be available to all owners of Vestas wind turbines of the size 600-660 kW. The CJC off-line filter will still be fitted to the V52, V66 and the V80 Vestas turbines.

"The major competitive advantages of this new product include not only the quality of the filter and its ability to remove very small particles, water and resin, but also the life of the filter element which is 12 months. Other key factors include the price of the filter and the installation time", highlighted Thomas Møller Andersen, key account manager for wind energy at C.C. Jensen.

"Customers are fast becoming aware of the importance of fine filtering in cutting maintenance costs, wind turbine downtime and other costs related to inefficient filtration of lubrication oils and the resultant accelerated wear and tear on machine parts. We are even beginning to see longer lifetimes for the oils filtered by our products", he said.

"Over the last three years some eight thousand CJC filters have been installed in the wind turbines of a number of different manufacturers. We are naturally delighted that such an important company as Vestas has also granted us an important vote of confidence", he concluded.

Used CJC filter element showing its powerful ability of particle removal including wear metals

Messages from America

SeaWest's Scott Eatherton

It is always refreshing to talk to our colleagues across the Atlantic, and my recent discussion with Scott Eatherton of Sea West Windpower, one of the U.S.A's main wind energy developers, was no exception. According to Scott, the need for efficient oil filtration for wind turbines is recognised. He was complementary about C.C. Jensen off-line filters and said, "We have been waiting for a filtration system of this quality for many years.

The big problem we are facing right at this time is to convince the wind farm owners of the dollars and cents advantages of off-line filtration. At the moment we are working on how we can evaluate the potential savings. We as engineers know that taking out contaminants bigger than 3-microns reduces wear and tear and can lower maintenance costs. We also know that cleaning oil efficiently to take out water and resins reduces oxidation and can lead to longer life for the oil. We know that gearbox and bearing manufacturers herald any system that makes them look good by increasing the life and reputation of their products".

From the point of view of the turbine owner Scott continued, "They are naturally interested in reducing downtime to a minimum. They are also interested in amortising their investment in the shortest possible time. They are interested in lowering costs on things like storing and disposing of used oil, inspections and ecology taxes, maintenance periods, insurance etc. The problem is relating something like fine filtration to the generation of these benefits. I don't see this as a permanent problem, because there are enough off-line filters now installed to give us, in the not too distant future, the data we are lacking. It also helps to know that important manufacturers are now fitting this type of filtration as original equipment. We will also have within the next year or two a viable international standard for gearbox care and maintenance that will go a long way to convincing people of the good practices necessary to maximise lifetime and minimise maintenance, and one of these will certainly be efficient filtration.

(see separate article on American Gear Manufacturers Association report).

There has always got to be a million dollar question and when I asked Scott how he saw the future of filtration for wind turbines, his reply demonstrated the great emphasis placed on customer service that sets the U.S. market apart from so many others in the world. His reply was as follows: "I believe that we have to make things as easy as we can for the our customers and to do this I believe we need companies who can provide a one stop shop. It has to be called a Clean Oil Service and it would have to provide everything a customer requires in this regard. This would include all types of filter installation and maintenance, oil changes, emergency oil cleaning, disposal of used oil and oil testing and analysis. Anyone that can put all this together in one company with a national network and specialise in wind turbines will have a business with real potential", he concluded.

Oil cleanliness code and Clean Oil Guide goes hand in hand

The American Gearbox Manufacturers Association for their part and filter manufacturer C.C. Jensen for theirs are making concerted efforts to improve oil cleanliness procedures in the wind turbine sector.
The AGMA has been working for some time on the creation of an international standard for gearbox manufacture, care and maintenance for wind turbines and it looks as if it is very close to gaining the international recognition that would make this work. One estimate is that they are as little as a year away from achieving their goal. In the meantime "The Filter" would like to offer its readers the chance of receiving a copy of an interesting report that forms part of this new international standard. It is an 8-page document entitled "Oil Cleanliness in Wind Turbine Gearboxes" and was written by Robert Errichello and Jane Muller of the Montana, U.S.A., based engineering consultancy, GEARTECH. It explains the importance of clean oil procedures and touches on subjects such as: types of contaminants, sources of contamination, methods to minimise internally generated contamination, methods to minimise ingressed contamination, mechanism and debris denting and a really useful summary of measures to ensure clean oil.
C.C. Jensen's contribution is a really useful publication entitled the "Clean Oil Guide". In its 24 pages in full colour, it packs a wealth of information on clean oil practices. It explains what contaminated oil can do to a gearbox and types of contamination, why and how to take oil samples and their analysis, a great explanation of ISO codes and how they work, oil cleaning methods, filtration definitions and much more. The best news of all is that it is free.
"What we really wanted to do was to promote a process of self education for engineers working in the wind turbine industry", explained Ulf Bertelsen, Managing Director of C.C. Jensen's Spanish business and the man behind the guides publication. "And we thought that it was best to start with the basics. The response to the version in English has been so positive that we are about to reproduce the guide in many other languages".

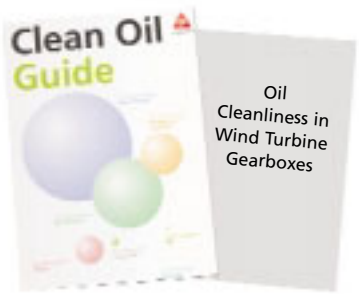
C.C. Jensen celebrates its Half-Century

On the last day of January 2003 C.C. Jensen will celebrate its 50th anniversary.

Managing Director
Carl Aage Jensen

The company still belongs to the founding Jensen family who with a business philosophy based on customer service and combining traditional craftsmanship and modern technology, have created an enterprise that now exports 70% of its production and has an annual turnover in excess of DKK 150 m.
The company is divided into three divisions; the ship window division, the metal castings division and the filter division. All these businesses have their origins in the maritime world, but increasingly the company's filter division has widened its customer base to include off-line filtration for an increasing number of land-based industrial applications.
Undoubtedly, one of the most recent and exciting has been the wind turbine, energy generation sector where the company has become market leader in many countries. In a message to staff and customers, Managing Director, Carl Aage Jensen said, "In C.C.Jensen we believe in planning ahead, but the last 50 years of constantly changing market situations has taught us that plans may have to be modified faster than they are drafted. We will continue to strive for honesty, responsibility and imagination to be the qualities which will help us face the challenges of the future. In this respect, I would like to extend my thanks to everyone who has contributed so positively over the years."

Would you like more information



Any reader wanting a free copy of the GEARTECH report and the Clean Oil Guide (currently only available in English) should send there request by fax using this coupon.

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Participate in THE FILTER

Welcome to the 2nd edition of the international newsletter from C.C. Jensen. Its purpose is to create a platform to disseminate technical information, provide a regular flow of news and stimulate interaction and debate around the most important issues that currently challenge our sector. If you would like to participate with articles or your views on the current issue please send your material to
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