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"Compared to 1981 what an engine can do is rather remarkable."

The return of the CIMAC World Congress to Helsinki after 35 years is a great opportunity to take stock of progress over a period which is approximately the life-span of a large engine. We seek the views of Robert Ollus, President of the 2016 CIMAC World Congress, Technical Project Director, Marine Solutions, Engines within Wärtsilä Corporation and prominent member in the CIMAC National Member Association in Finland.

Robert Ollus gained an M.Sc. in Machine Design & Internal Combustion from the Helsinki University of Technology in 1995. He has worked for Wärtsilä for more than 20 years with Wärtsilä, mainly in product and combustion development, including testing & validation. In October 2012 he was elected the Chairman of the CIMAC National Member Association in Finland.

MTZindustrial _ Can you give our readers an overview of what has changed in the large engine industry between 1981 and 2016?

OLLUS _ This question comes at a good time, because at the end of 2015, large four-stroke diesels took a major step forward and a large engine built in 1981 might still be in operation today, so let's pinpoint a few facts in engine development first, which obviously is closest to my heart and probably also to your readers'.

Around 1981 engine shaft efficiency was in the area of 40 to 42 %, and now it is above 50 % for both diesel and gas engines. That's a 25 % increase in engine efficiency, but only one of the milestones we can point to. In combination we have been able to reduce raw NO_x emissions by 50 %, and if we equip our engines with SCR we are looking at 85 to 90 %.

Another key ingredient which is also remarkable is engine load factors, namely BMEP multiplied by mean piston speed. In 1980 we were talking about 150 and today 300, meaning we have been able to substantially increase power density. On the BMEP side, 18 bar was typical in 1980 and today it's more than 30 bar.

Moving to firing pressures which, of course, are one of the aspects which most affect basic engine architecture, such as base frame bearings and crankshafts and so on, at the time of the first Helsinki CIMAC Congress delegates would hear about 130 to 140 bar and now they will hear of 250 bar and above - almost double.

And, of course gas engines have made their mark.

Yes, gas-diesel, spark-ignited gas and dual-fuel engines did not exist before but are now almost a commodity. So if we look at what our retiring engine could do compared to one just leaving the factory, it's rather remarkable, and we can do it with wider range of engine types. This is a special source of satisfaction, because university Professor told us that an internal combustion engine would never pass 50% shaft efficiency and we have been directly involved in disproving this "fact"!

What about the technologies that enabled all this?

Obviously I have to point to the achievements of the turbocharging and fuel injection industries. Turbocharger pressure ratios have been raised from below 3 to above 6 on single-stage turbochargers and now even up to 12 with two-stage turbocharging. Today, a large engine without turbocharging could only produce 20 % of the output we now achieve and, of course, with much higher emissions and far lower fuel efficiency.

The advances in turbocharging allow us to inject more fuel for more power and Fuel injection equipment suppliers have responded with pressures that have risen from around 800 bar to over 2000 bar (3000 bar in the lab). And while

> **"Around 1981 engine shaft efficiency was in the area of 40 to 42 %, and now it is above 50 % for both 2- strokes and 4-strokes."**

common rail is an area of immense progress, we have introduced fuel injection equipment for a whole range of fuel viscosities and types. For example, with our suppliers we have even mastered orimulsion, an immensely difficult fuel to run and engine on.

Then, looking at the way engines operate, these developments have led to substantially higher compression ratios, more variable fuel injection rates and timing and extreme Miller Cycle in combination with variable valve timing.

And, while the new engine types and their systems are largely enabled by digital controls, let's not forget something as basic as the "anti-polishing ring", a very simple device that has had a dramatic effect on engine life, clearly reducing lube oil consumption and the problem of bore polishing.

In 1981 adapting to HFO was still a big preoccupation. Now things look like going full circle, back to distillates.

Not only distillates, but also renewables. At the beginning of the 1980s we had almost only distillate fuel, and we spent about a decade adapting engines systems to HFO, but now things are going back to cleaner liquid fuels, and intrinsically clean natural gas and bio-fuels.

Indeed, there is a major swing in the fuel trend, and we are seeing many more low-sulphur fuels, of course, and certainly more alternative fuels coming onto the market. From an engine builder standpoint, we need to cope with the fuels users want to use, and thanks to the work we put in on HFO, we have the tools to do this. The whole HFO adaptation process was great preparation for "straight-run" liquid bio-fuels and the hydro-treated version coming to the

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marine market.

At what point did legislation become the prime development driver?
The emissions story is shorter but because of that more dramatic. From 1981 to 2000 there were no NO_x limitations and then things IMO Tier 1 in 2000 brought an immediate 20 to 30 %. Emphasising how rapidly things accelerated, in 2011 IMO Tier II prescribed around 45 % lower NO_x, and you started to see a real impact on fuel injection and turbocharging, on compression ratios and the adoption of Miller timing.

It was also realised that gas and dual-fuel engines represented a viable, low emissions alternative to diesel. With gas engines available to us, we are coping with IMO Tier III, which demands a 90 % reduction below the non-regulated baseline. To trade with North America whose coast is the only emissions control area where IMO Tier III applies, we know that we need SCR on diesels, which becomes a very important technology because it is very difficult to avoid if you don't use gaseous fuel.

And on land?
The situation in the early 1980s was roughly parallel on land. Then the World Bank introduced emissions limits for new power plants from 1998 to 2000 as a condition of loans, with around 25 % NO_x reduction. This was followed by the second level from 2001 to 2008 with a 35 % reduction and today we have World Bank Level 3 prescribing 50 % reduction which goes hand in hand with marine up to IMO Tier II.

What will the next emissions goals?
Particulate matter and methane slip are moving into the legislators' focus and we will face challenges with particulates because particulate traps are untried and will be hard to implement on large engines.

We are at a crossroads with NO_x, because one thing that has surely changed is awareness of greenhouse gases. This means that if this industry is pressed too hard on NO_x there is a CO_2 downside as the NO_x-SFC trade-off comes back into force. NO_x below IMO Tier III using SCR or lean burn gas engines could again start to impact greenhouse gases, because we are now balancing two types of regulated emissions, and one of them is analogous with fuel consumption.

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"The Vaasa area, where Wärtsilä is based was home to many small, local boat engine builders."

So where does the answer lie?
In an holistic approach to the design of large engines and their applications. IMO has responded with the Energy Efficiency Design Index (EEDI) and CIMAC in a very timely way with the new Working Group 20 System Integration.

Although we have just had the quantum leap on four-stroke diesels of Miller plus two-stage turbocharging, which has improving NO^x, fuel consumption and power density by big margins at one go, the EEDI prescribes efficiency gains for ships of 30 % in 10 years and this will not be done on the engine side alone.

"What CIMAC does is drive the entire engine industry to ensure cross-learning and e an industry-wide response to our challenges."

Nonetheless, it's a good challenge. Engine developers love solving problems and this is definitely one we can get our teeth into! Driving for best energy utilisation in an application is in our blood, and EEDI is doubly important at the moment, because the low price of oil means we need an incentive to look at fuel consumption.

But remember – and this is a big point – both the Diesel and Otto processes are best-in-class in terms of energy conversion. This supports the view that we do have a good product with excellent value-adding, and increasing thermal efficiency is our daily goal in engine development. So, in fact all our work, every day, is supporting greenhouse gas reduction.

Moving to the present, can you say some words about CIMAC's role in the industry?
CIMAC drives the entire engine industry to ensure cross-learning and cross-fertilisation and to ensure industry-wide responses to our challenges. CIMAC has a clear role which doesn't exist anywhere else – nobody else is providing a forum for this cross-fertilisation and CIMAC works not only for marine applications but also between marine, power plant and rail.

Happily, this has led to more and more enterprises and organisations seeing the benefits of the CIMAC family and this is going hand-in-hand with a change from a country-based CIMAC structure to a corporate-based structure as the world globalises and multinational companies become the norm.

And what is the value of the Helsinki Congress?
The massive exchange in information every third year brings everyone up-to-date and from my own standpoint, I have always seen Congresses as a perfect opportunity for benchmarking. This may sound egocentric, but a competitive edge can only be maintained if you constantly develop and seeing if you are ahead or behind are both good motivators to do better, which can only be good for engine users and the environment. If you are ahead you have the confirmation that the direction you have taken is correct and you can build on your advantage. If you are behind the message is to regroup and accelerate to catch up before the next Congress.

For customers, operators and other large engine stakeholders, the Congress is the place to be to find out what is going on – I wouldn't miss it for the world!

Now, I would like to put on your Wärtsilä and Finnish hats, and talk about Finland's rise in the large engine industry since the 1981 Congress.
Where Wärtsilä was born in Vaasa there were a lot of small, local boat engine builders. Based on these skills, Wärtsilä took on several licenses, for example Sulzer, which enabled us to learn large engine building, based on the small engine skills and we went on to prove this decisively.

If you look at how many Wärtsilä products and technologies came to market it is astonishing. Major milestones include the Vasa 32 producing low NO_x on HFO; gas-diesel engines; dual-fuel engines with micropilot and low pressure gas admission; all culminating last year with the Wärtsilä 31, which has set records with its high efficiency, power density and low NO_x emissions.

Many factors came together but it could not have come about without strong long-term investment into R&D determined efforts and people who with determination and drive that took charge and were given authority, because there was no alternative to growth for survival.

We have a saying in Finland that "shy boys never kiss beautiful girls". You have to be brave, and if you look what our small company did in those early days, you wonder how it was done by a small company in a small village. Our people possessed great drive and energy, and we operated with a clear, long term strategy and had the stubbornness - another typical Finnish virtue - to stick to the plan.

It also had to do with education and a love of engines. In Finland, I believe that engines are in our blood, which is probably why we have a history of great rally drivers. But we also have to acknowledge the contribution of our Universities. A few men of vision brought combustion engineering into colleges to complement manufacturing expertise with theoretical knowledge. This is more and more important when developing engines that work closer to their performance limits than ever before. These men established Bachelor and Master level qualifications in a full range of internal combustion engine related science, such as physics, chemistry and thermodynamics.

What are the key values?
We are a global company with Finnish roots that has not forgotten its roots. So, while 16,000 of our 19,000 employees work outside Finland, we continue to work with several local sub-suppliers.

Energy, excitement and excellence are our values, and we try to apply these at the customer level. We try to be the player with ground-breaking technologies, constantly searching for solutions that add value to the customer. This has not always been crowned with success, but it is part of bringing new technologies to market that you will take some pain. Nonetheless, we estimate that of the world's entire energy consumption, 3 % derives from Wärtsilä engines, which is not bad for a country our size.

INTERVIEW: Jonathan Walker