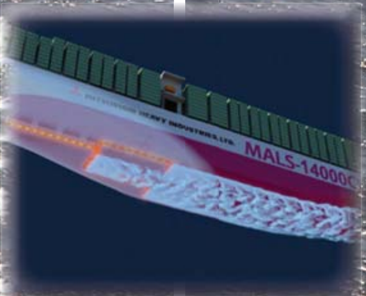
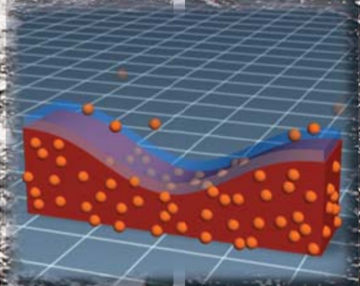
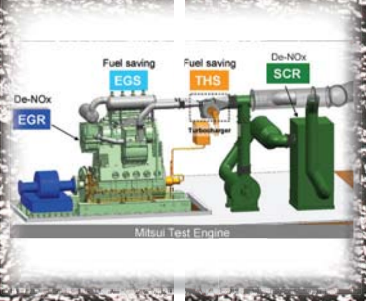
Eco-Ship Technology

In association with ClassNK







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Technology key to greener future

It is with great pleasure that we welcome you to this Eco-ship technology review. Ever since the Kyoto Protocol was agreed in 1997 the shipping industry has been gearing up for change. Slowly at first the operators of vessels across the globe began to realise that simply carrying on as normal was not an option.

Following the global economic crisis of 2008 change has accelerated and ClassNK has been at the forefront of this technological revolution financing projects that will see significant reductions of greenhouse gas emissions from modern vessels and even some older ones. This supplement outlines a few of the projects that the class society is involved in. There are, however, many more research projects under way, both in Europe and Asia that will help to improve the efficiency of ships and shipping as a whole, but perhaps few programmes will be as comprehensive as the research and development currently being undertaken in Japan.

It is our understanding, at The Naval Architect, that more projects are planned by ClassNK and its industry partners and this investment has apparently started a trend as other senior classification societies pledge to invest more into technology that will eventually make the shipping industry one of the cleanest around.

We hope you enjoy reading about these new developments from Japan and we look forward to bringing you the latest developments as they happen in the future.

Making maritime R&D a central part of ship classification

By Noboru Ueda, Chairman and President, ClassNK

Noboru Ueda says ClassNK is committed to becoming a more proactive partner in maritime

Over these past few years we have seen numerous changes take place in the maritime industry, with nearly every sector of our industry forced to redefine itself in the face of new challenges and opportunities. One of the most important areas where we are witnessing these changes is, of course, the importance of R&D and the incredibly rapid development of new maritime technology.

In some aspects, classification has always played a role in driving maritime R&D and innovation. Our class rules, which are the foundation of all our services, are themselves the product of more than a hundred years of working with shipyards and operators; and countless hours of careful and dedicated research covering not only ship design and engineering, but structural materials, machinery and marine equipment.

In the past however, our research was focused solely on the development of newer and better rules in order to ensure greater safety. Just as the role of classification societies has grown over the years, however, expanding from our origins as ship evaluators to rule makers, surveyors, and recognised organisation of flag states, so too has our approach to research and development.

Where once we focused purely on rule development and safety, we are now proactively working to address a variety of challenges including green technology and IT innovation. I believe this change is absolutely essential for class societies to continue to contribute to the safe growth and development of the maritime industry in the years ahead.

For us at ClassNK, the necessity of this change was made apparent by the shipping boom and subsequent crash that ended in 2008. In what seemed like a matter of days, the Baltic Dry Index fell from more than 11,000 to less than 1,000 and has continued to remain low to this day. On the shipbuilding side, ship prices plummeted by nearly 50%, and continued to fall until just recently.

Even as charter rates and ship prices have remained low, however, the same could not be said for the price of bunker fuel. While the price of bunker oil fell during the crash, it quickly rebounded to near record highs.

Beyond the market, the industry has also had to deal with the effects of new legislation and regulations such as new conventions for ballast water management, and revolutionary new initiatives for GHG reduction such as EEDI. These regulations have forced both shipyards and shipping companies to confront a new wave of challenges requiring new ship designs, new operating principles, and new technology to be developed.

It was against this backdrop that I sat down with the Board of Directors at ClassNK, and we decided we had to act. So we began to discuss what has become one of the most important decisions we have made in the 113 year history of our organisation.

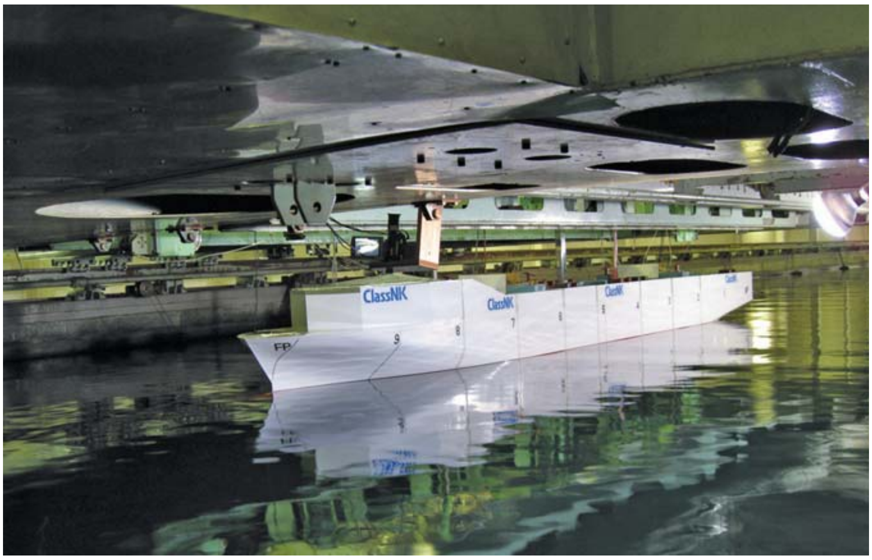
That day we made a commitment to be more than a just regulator for the maritime industry, and become a better and more proactive partner in maritime. We made kick-starting innovation and driving the industry forward as one of our organisation's primary goals.

Where the industry lacked human and technical resources for carrying out the innovation required by new regulation and new market paradigms, ClassNK would step in.

Where the industry lacked research and financial resources, ClassNK would fill the gap. We would join hands with shipping companies, shipbuilders, and manufacturers, and work together to develop the solutions for a brighter future for the maritime industry.

In doing so we would establish a more proactive, more supportive, and better role for classification societies in the maritime industry.

ClassNK plans to continue offering its full support to the Joint R&D for industry programme well into the next decade, if not further



In order to achieve this vision, we greatly increased the size and scope of our research activities. Whereas prior to the crash in 2008, R&D expenses comprised some 8% of our total revenue each year, today they amount to some 15% of our total revenue. This year alone we will spend more than 40 million US dollars for maritime research and development, a figure unmatched in the field of ship classification.

Beyond just committing our financial resources however, we wanted to improve the innovation process itself. Far too often we had seen inspiring new technologies fail to address the differing needs of shipowners, shipbuilders, and manufacturers. What appeared to be great benefits on paper failed to become reality on actual vessels.

We decided the way to address this problem was to work hand in hand with the companies developing these new technologies, and where possible bring multiple companies from across sectors together. In this way we could ensure that not only would each project have the necessary resources, but also that innovations become practical solutions for the problems faced by the wider maritime industry.

It was with the goal in mind that we launched our *Joint R&D for Industry* programme in 2009. As part of this programme we hear proposals for new research from companies throughout the maritime industry, and provide research and financial support to projects we feel have the potential to provide benefits to the entire maritime community.

As it can take many years to develop a technology from its initial stages to practical application, our commitment is also long term. It is my belief that we can best support research by taking a long term view, and so we not only support projects over several year spans but also plan to continue the *Joint R&D for Industry* program extend well into the next decade, if not further.

Over the past few years, this programme has grown from strength to strength, and now accounts for more than half of our research budget each year. As of the end of September 2013, more than 130 projects have been completed as part of the programme, with another 105 in progress and roughly 63 more in various stages of planning.

This supplement with the Royal Institute of Naval Architects covers some of the very first fruits of this program, and I am excited and honoured to work with such an esteemed organisation to bring you the very latest on new green technologies in the maritime industry. I very much hope the information contained herein is beneficial to you and your company, and helps promote the continued growth and development of our industry around the world.

One of the ClassNK-sponsored programmes was Nippon Paint Marine's A-LF Sea low resistance coating, pictured being applied here

Leading the line

Tokyo-based classification society ClassNK has made the shift from local player to global leader through its development of new technologies. ClassNK senior management took the decision to support a Japanese initiative to develop new technology to reduce maritime GHG emissions

When the Japanese government approached ClassNK with a plan to spark innovation in the Japanese maritime sector and promote new green technology, it was an easy choice for the Tokyo-based classification society.

While it would be easy to say that supporting some of the Japanese maritime industry is in ClassNK's best interests, according to ClassNK Executive Vice President Yasushi Nakamura, the society's contribution was driven by something deeper.

"In Japan, we are surrounded by some of the world's largest shipowners, machinery manufacturers, and very advanced shipyards; and we wanted to support their efforts to develop new technology and reduce GHG emissions. But as a four-year global organisation we were most excited about the potential for the new generation of technologies we were helping develop to be used by shipowners and yards around the world," says Nakamura.

In all, the programme supported 22 different projects with funding provided by the Japanese government, industry participants and ClassNK. In the end ClassNK invested more than US$25 million in the programme over its four-year run, serving as both the first major investment and major success for ClassNK's *Joint R&D for Industry* programme since its launch in 2009.

"Obviously with a national project of this size not every new technology is going to be an incredible success and achieve wide use in the industry. One technology, for example, might work well on a bulk carrier, but not on a container ship. Another technology might be technically feasible, but not economically practical. But by supporting a wide variety of projects we can help both drive innovation and achieve practical results at the same time," explained Nakamura.

Yasushi Nakamura says ClassNK wanted to support the industry to help reduce GHG emissions

He went on to say: "One good thing about this programme in particular is that it covered a broad range of technologies from advanced concept designs to very practical improvements of machinery already in use today."

One such concept design that has already shown a lot of promise, though it has yet to enter production, is the Minimal Ballast water Ship (MIBS).

Tank tests for the MIBS vessel, developed by shipbuilders Namura Shipbuilding and Oshima Shipbuilding, showed the design decreased fuel consumption by 15% compared with a standard VLCC. This was achieved by changing the hull design to reduce displacement and thereby reduce the power requirements.

Japanese researchers say this design is a stepping stone to a vessel design that dispenses with ballast water altogether, with the obvious benefits of lower fuel consumption and no ballast water treatment system, which saves on capital costs and energy consumption.

Perhaps the most significant new design will prove to be a highly efficient container ship developed by IHI MU (now JMU), IHI and engine manufacturer Diesel United. The vessel, which has been tank-tested, has a twin skeg design and features an improved propulsion system performance, as well as a reduction in emissions through the use of renewable energy. The total decrease in power requirements for the design is said to be 25% compared to existing vessels.

Of course only a handful of projects are focused on comprehensive designs, with the rest primarily focused on a variety of new and improved technologies.

Another significant success in the testing tank has been a contra-rotating propeller design developed by JMU. During testing the system returned fuel savings of 12%.

Other projects include a non-hub vortex propeller designed with a minimal blade area; a turbo-ring attachment for propellers that reduces torque and consequently increases propeller thrust; a hybrid power management system that uses a shaft generator and controllable pitch propeller; optimisation of the combustion process in large, low-speed, marine diesel engines and finally highly efficient waste heat recovery systems for small size diesel engines.

Of these technologies not all are complex systems. A simple energy saving device developed as part of the programme is STeP, the Spray Tearing Plate, Naikai Zosen Corporation in cooperation with the National Maritime Research Institute (NMRI).

The STeP offers fuel efficiencies of 3% by reducing the bow wave, thereby reducing the vessel's water resistance.

Research has shown that STeP is effective in water with a wave height in excess of 2m and the plate, which is added to the bow of a vessel, has already been tested on a PCTC and a cutting edge RoRo vessel.

However, Nakamura says that four projects in particular are drawing the attention of shipowners around the world. "These four projects stand out because they represent new and improved technologies that have undergone verification testing in operational conditions, and are already being applied to commercial vessels. Combined with their potential to be retro-fitted, these four technologies are the ones we think will have the greatest impact on the industry in the short-term."

Of the four projects featured in this magazine one of the most successful research programmes was conducted by Nippon Paint Marine which has developed low friction paint, known as A-LF-Sea.

"The initial idea came from observations of the skin of a tuna fish," explained Nakamura. "Tuna are very fast over short distances and in large part this is due to the coating on their skin. The natural coating on a tuna's scales attracts water and it adheres to the skin smoothing the surface and reducing drag."

A-LF-Sea works in a similar way; under a microscope a coating of paint it will appear bumpy and A-LF-Sea attracts water to these microscopic craters filling them and smoothing the surface.

Nakamura says that the overall savings achieved by the paint were as much as 6-8% when it was tested on a pure car and truck carrier. Costs for coating a standard vessel with Nippon Paint Marine's A-LF-Sea are around twice the level of conventional paint, but with the fuel savings at up to 8% the payback time of between one and two years is realistic.

Nippon Paint Marine has not been the only company looking to reduce vessel water resistance. Mitsubishi Heavy Industries (MHI) has developed an air lubrication system which it says will save owners a considerable amount of money through fuel efficiency.

The Mitsubishi Air Lubrication System (MALS) has already been fitted to flat bottomed module carriers operated by NYK-Hinode Line and has achieved exceptional results with these ships. Nakamura says the real prize will be the application of this technology to a wider variety of commercial vessels. MALS will undergo its first commercial vessels on a bulk carrier newbuilding to be built by Oshima Shipbuilding for grain major ADM starting next year, but MHI has its sights set on other vessel types as well.

MALS has also been fitted to the Japanese owned ferry, *Ferry Naminoue*, which operates at around 20knots and has a slender shaped hull. "Fuel efficiency savings on Naminoue were lower than on the flat bottomed vessels the system has previously been installed on, but the experience gained from this ferry project will give MHI a significant benefit as it looks to apply the system to larger slender body vessels," says Nakamura.

According to Nakamura, one key benefit from this project is that this technology will not just be limited to MHI's shipyards. "MHI is very progressive, and they understand this technology has incredible potential not just for their own shipyards, but for other shipyards as well, and their partnership with Oshima Shipbuilding is a good example of this. We hope that the use of this technology will spread to yards in other countries throughout Asia and around the world as well."

In addition to the coating and air lubrication systems which concentrate on reducing water resistance the two other projects highlighted in this supplement seek to increase engine efficiency.

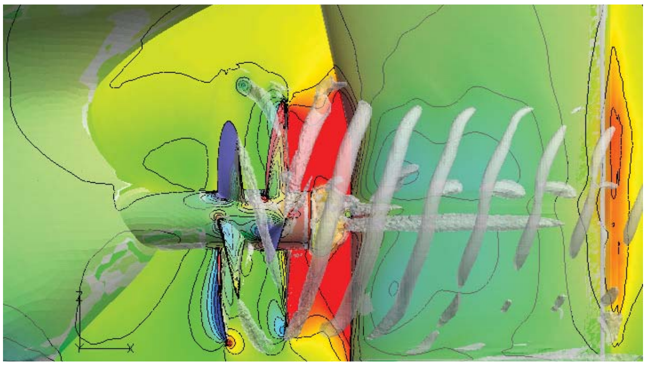
A new hybrid turbocharger, also developed by MHI with NYK, MTI & USC, combines an electric generator with the turbocharger system. The hybrid system is capable of providing all the electrical needs of a standard capesize vessel during regular operations, reducing fuel usage and making it possible to reduce the size (and cost) of the generators that are installed on the vessel.

The final technology is a series of improvements that shipbuilder and engine manufacturer Mitsui Engineering & Shipbuilding (MES) has developed for marine diesel engines. The improvements, which include optimising combustion and the use of exhaust gas separation and recycling, can greatly improve the effectiveness of existing diesel engines.

"While these technologies may not be as revolutionary as air-lubrication systems, or as easily implemented as new paint, they represent practical technologies that shipowners implement on vessels today. It is this combination of both dramatic new technologies like the MALS systems and very practical technologies like engine combustion optimization that I think reflect the real importance of this programme."

The *Ferry Naminoue* is fitted with MHI's MALS air lubrication system : (Picture MHI)

Japan's 22 Maritime GHG Emission Reduction Projects



Project #2 Picture Credit JMU

Project #3 Picture Credit Naikai Zosen Corp.

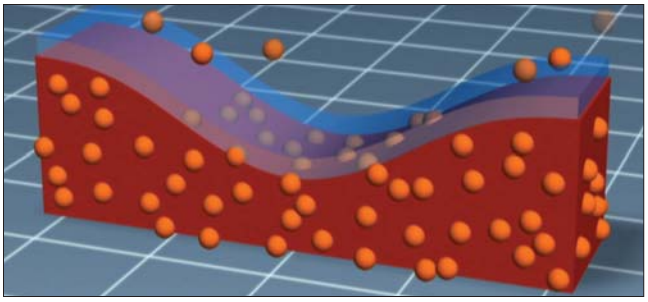
Project #4 Picture Credit JMU

Project #3 Picture Credit Naikai Zosen Corp.

Project	Industry Participants	Target Value	Reported Results
1. Development of minimall ballast water ships	Namura SB, Oshima SB	10%	15% Tank test
2. Development of optimum hull form for contra-rotating propeller	IHI MU, IHI	8-12%	12% Tank test
3. Development of optimum bow design in waves for container carriers	Naikai SB	2%	3% Onboard test
4. Development of highly efficient container ships (Incl. Hull shape + WHR)	IHI MU, IHI, Diesel United	28%	25% Tank Test/Shop test
5. Development of micro-bubble lubrication (air lubrication) system	Oshima SB, IHI MU, Imbari SB, MTI, KHI, IHI, Tsuneishi SB, MES, MHI, USC	4-7%	6% Sea trial
6. Practical application of an air lubrication system to shallow-draft, twin screw ships	MHI, NYK, MTI	10%	10% Sea trial
7. Development of extremely low resistance hull coatings	Nippon Paint, Nippon Paint Marine Coatings, MOL	9-12%	6-10% Onboard test
8. Development of a hybrid turbocharger for marine use	NYK, MTI, USC, MHI	3%	1.8% Onboard test
9. Development of an optimum weather routing system reservation systems	USC	5%	3-7% Onboard test
10. Development of port congestion management and berth reservation system	NYK, MTI	20%	29% Simulation

Project #5 Picture Credit MHI

Project #6 Picture Credit: MHI



Project #7 Picture Credit Nippon Paint Marine

Project #7 Picture Credit Nippon Paint Marine

Project	Industry Participants	Target Value	Reported Results
11. Development of non-hub vortex propellers	Nakashima Propeller	3%	3% Onboard test
12. Development of a propeller attachment to improve thrust efficiency	ShinKurushima Dockyard	3%	3% Sea trial
13. Development of a load fluctuation stabilizer using shaft driven generator and controllable pitch propeller	NYK, MTI, Terasaki, KHI	2%	2% Simulation
14. Development of technologies to optimize combustion in large slow speed diesel engines	MES	9-27%	10-27% Shop test
15. Development of a high efficiency heat recovery system for small size diesel engines	Yanmar, Uzushio	6%	5.7% Shop test
16. Development of a small size dual fuel diesel engines	Niigata Power Systems	15%	20% At shop test
17. Development of efficient maneuvering system for large car carriers	NYK, MTI, Japan Marine Science	12-14%	12-14% Simulation
18. Development of an optimum routing management system	Oshima SB	3% Simulation	3% Simulation
19. Development of detailed data measurement and analysis systems for improved ship operations	NYK, MTI, NYK Trac, Kawaju Techno	2%	2% Simulation
20. Development of next generation sail assisted cargo ships	USC	2.5%	10% Simulation
21. Development of lithium ion battery / PV cell hybrid power systems	MOL, MHI, SANYO	0.6%	0.5% Onboard test
22. Development of Gigacell (high capacity nickel-hydrogen cell) battery / PV cell hybrid power system	Kawasaki SB,KHI, NYK, MT	2%	2% Simulation

Air force lifts MHI

Decreasing hull resistance, caused by friction with water can significantly reduce the power necessary to propel a vessel. Designing an air lubrication system that offers significant net fuel savings has eluded engineers, but Mitsubishi Heavy Industries has found a solution, says Shuji Mizokami

Ideas for air lubrication systems have been mooted for more than 50 years now, but few systems have achieved the necessary net reduction in fuel savings until now.

Energy used to power a blower to create air bubbles on which a vessel rides was significant and the net fuel savings, after the increase in fuel needed to power the air lubrication system was accounted for, were minimal. Up until relatively recently the price of fuel was comparatively cheap meaning the driver for the development of an air lubrication system was simply not there.

Increases in fuel prices in the recent years have changed the economic context in which air lubrication systems are set, while changes in attitudes to pollution have also altered political perceptions.

As the push from economic and political arenas has intensified so engineers have responded with innovations to meet new environmental demands and economic imperatives. Technological advances have raised the possibility of designing systems that can make substantial fuel savings and hence reduce pollution also.

Mitsubishi Heavy Industries (MHI) estimates that as much as 50-70% of the resistance experienced by ships is caused by frictional resistance created between the skin of the hull and the surrounding water, a fact that has fuelled MHI's development of a new air lubrication system as a key method for reducing fuel consumption and CO_2 emissions.

The Mitsubishi Air Lubcrication System or MALS, is MHI's answer to critics of air lubrication technology. The system has already been installed on two module carriers to great effect, achieving a 12-13% reduction in fuel consumption during sea trials. Both of these vessels, the *Yamatai* and *Yamato*, were delivered in 2010, April and December respectively, and both have substantial operational time on which to calculate the effectiveness of the MALS.

Shuji Mizokami believes the MALs can be applied to all ship types

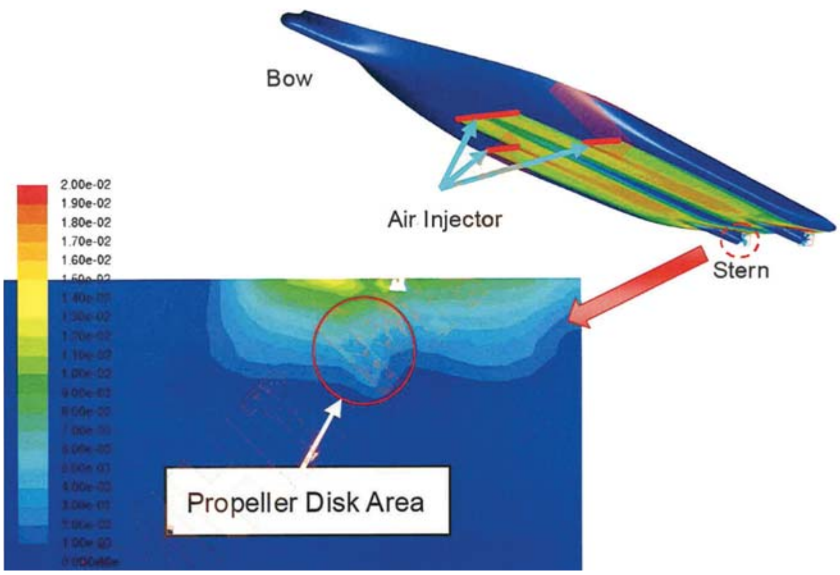
The results so far are impressive, says ClassNK's Executive Vice President Yasushi Nakamura. "A 13% reduction, even given the calm conditions of a sea trial is a major breakthrough, and the system has proven effective in regular operations, as well."

MHI is now targeting other vessel types for the application of MALS, but adapting the technology has its own challenges.

"One major obstacle is that it is not possible to adjust the size of the bubbles to the scale of standard ship models and so it is not possible to estimate the fuel efficiency benefits during model basin testing. As a result, estimating the effectiveness of the systems required complex calculations that require a high level of technical expertise."

"Moreover, the requirements of each ship type and operating conditions differ and the requirements in terms of air blower and pressure required will also differ. However we plan to develop MALS systems suitable for each type of ship." explains MHI's Shuji Mizokami.

Air bubble behaviour around ship hull : (Picture MHI)



Item	Unit	Module carrier	Bulk carrier	Container ship	Passenger ship
Length, L	m	153	230	350	240
Speed, Vs	kt	13.0	14.0	24.0	17.0
Flow rate, Qs	m^3/min	80 -120	150 - 250	200 - 550	100 - 200
Pressure, P	kPa	65	155	170	100
Item	kW	130 - 200	500 - 840	680 - 1900	230 - 460

Table 1 MALS design conditions and blower specifications

Effectively the air flow required for air lubrication increases or decreases in proportion to the air thickness covering the ship bottom (which is considered to be uniform) and ship speed.

"Along with an increase of the air thickness, the amount of reduced friction resistance increases, but electric power consumption for the blower also increases. Therefore it is necessary to determine the air flow in consideration of the trade-off between the amount of reduced friction resistance and the electric power consumption of the blower in order to obtain the most efficient energy-saving effect," according to MHI.

Commercially available blowers are not suitable for use on the MALS system and the development of a blower system or a series of blowers has been necessary to meet the needs of MALS. In particular the turbo blowers offer a higher efficiency which is needed for MALS.

In addition the air bubble outlets for slow speed vessels, with flat bottoms differ from faster ships such as ferries and containerships which have slender hulls. Flat bottomed vessels are equipped with a single bubble outlet placed near the bow of the vessel, whereas slender hulled ships are fitted with three separate bubble outlets, one placed near the bow and two more around one third of the length of the ship further back.

Results from the 162m long *Yamatai* and *Yamato* showed substantial improvements in the vessel's fuel consumption; the tests showed a 20% reduction in main engine power, but with the extra energy necessary to power the air blowers some 7% of this saving was lost, giving a net energy saving of 13%, according to the sea trial tests. The module carriers have flat bottoms and are very well suited to the MALS which sends out a stream of bubbles which covers the entire bottom of the vessel, but does not interfere with the flow of water into the propeller, through hundreds of holes in the hull.

The amount of bubbles and air pressure is controlled through the blower power and through a series of valves. The blower is located at the front end of the vessel and the bubbles flow along the length of the hull.

Actual air bubble flow was monitored on the module carriers using a remotely operated vehicle (ROV) towed beneath the vessel.

Having the opportunity to study the flow of bubbles on an operational vessel has given MHI an insight into the modifications that might be needed to transfer this technology to other ship types, the first attempt of which was completed on the ferry *Naminoue* in the middle of 2012.

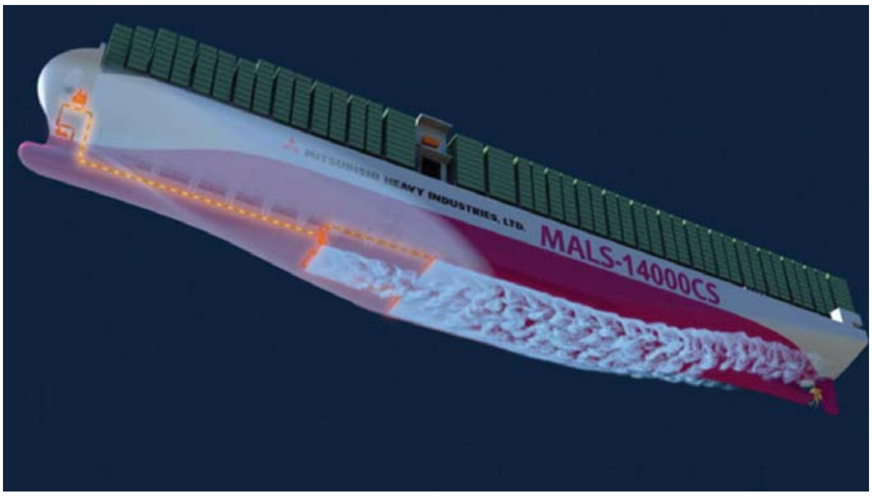
The application of MALS to the ferry *Naminoue* has sprung a surprise explains Mizokami: "The use of the bubble system actually reduced the amount of vibration noise on the vessel. This was a completely unexpected, but a very valuable benefit."

In the case of the module carriers regulating the amount of bubbles necessary to reduce friction was a comparatively simple task, but with the more slender lines of a ferry the reduction in fuel consumption has been more limited. Initial results from the project last year revealed the system had a achieved as much as 5% savings on the vessel.

While efficiency gains on *Naminoue* were lower than on the module carriers, MHI says it has learnt a lot from the installation of MALS onto the ferry. MHI says it is confident that modifications to the system will achieve positive results on other vessel types as well. "We believe that this technology can be applied to PCTCs, bulk carriers, ferries, cruise and passenger vessels, as well as container ships." says Mizokami.

With the success of the *Yamatai* and *Yamato*, and the adaptation of the MALS to the *Naminoue* now complete and further installations already planned for bulk carriers and PCTCs for delivery over the next few years; MHI may have its work cut out, but ship by ship it is proving the detractors of air lubrication systems wrong.

An example of an installation study of MALS on a mega container ship : (Picture MHI)



Sail like a fish

Hull resistance comprises 70% of the total resistance that a vessel encounters when it moves through the water. Less hull friction will inevitably reduce the amount of power a vessel requires to sail, thereby improving fuel efficiency and reducing emissions

Solutions to emissions that pollute the atmosphere are often developments of technology that has been improved over a period of time and through a number of incarnations.

So a solution to a problem that was provided by nature to protect nature is sensible and practical. At Nippon Paint Marine, the company studied the skin of Tuna to find a solution that would see the reduction in resistance that is a significant improvement on previous coatings according to the company.

A Tuna's body is covered by viscous mucus membrane which helps reduce friction and allow the fish to swim at high speed through the water" explained Yasushi Nakamura, Vice President of ClassNK. The A-LF-Sea coating mimics the skin of a tuna fish by making water stick to the microscopic indentations in the coating that make the hull extremely slippery.

PCC carrier with A-LF-Sea applied (Picture Nippon Paint Marine)

Nakamura told the Naval Architect that "the Low Friction paint of Nippon Paint Marine offers 4% fuel savings, but the Advanced Low Friction saves an additional 4% (8% in total) in fuel consumption".

ClassNK says the advanced low friction coating (A-LF-SEA) uses copper silyl acrylate for anti-fouling and an advanced hydro-gel that has so-called "water trapping" properties that is the key to the reduction of frictional resistance of the vessel.

"Hydro-gel is a raw material which creates a pseudo hydration surface on the coating film surface. General hydro-gels are not adopted for anti-fouling coatings due to the large degree of swelling after absorbing water. The Special hydro-gel selected for A-LF-Sea has a high hydration effect on the coating film surface but swells very little after absorbing water," explains Nippon Paint Marine Executive Officer Naoki Yamamori

According to Nippon Paint Marine, the effect of the hydro-gel offers a 15% reduction in the frictional resistance of the flat plate, which translates to as much as a 10% overall reduction in hull resistance which itself will translate to significant annual fuel savings.

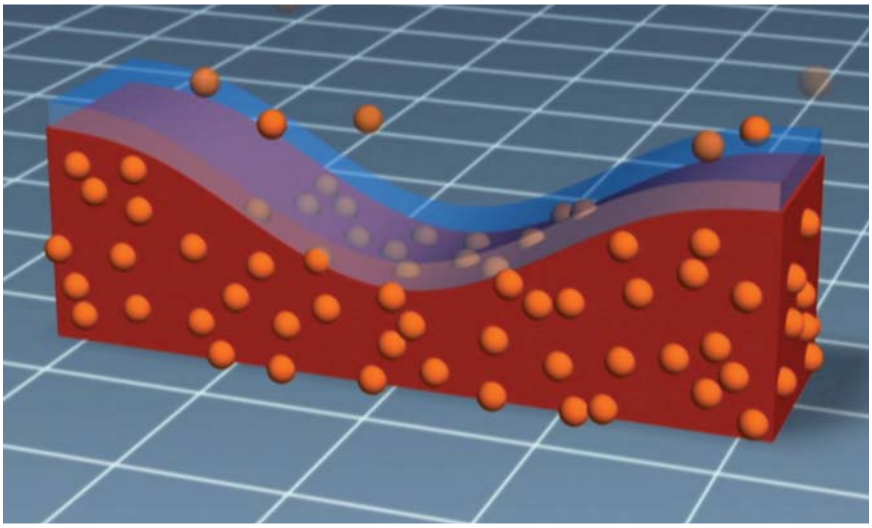
Under normal conditions with standard underwater coatings, frictional resistance is generated between the coating film, which is solid, and the liquid, sea water. "We speculated that the frictional resistance could be reduced drastically if the friction took place between liquid and liquid," says Yamamori.

In order to create the conditions for a coating to be effective, Nippon Paint Marine created what they call "a pseudo hydration surface" on the coating film surface by incorporating the hydro-gel, which has a high affinity to water, into the coating film. This reduced the frictional resistance.

"It is our understanding that the pseudo hydration surface does not keep water covering the entire coating film during the periods when the ship's sailing, but rather that water is held into the concave portions of the coating film. We named this the water trapping layer".

Naoki Yamamori, Executive Officer, Nippon Paint Marine

A-LF-Sea has improved water trapping characteristics (Picture Nippon Paint Marine)



Year	A/F Paint	n	Test period	AV.Speed (Annual)	FOC between fixed points		FOC reduction
						Speed Corrected	
				Knt	L	L	%
2010	SPC AF	24	2010.2-2011.1	12.41	242.0	242.0	Std.
2011	LF-Sea	19	2011.2-2012.1	12.51	235.2	231.5	-4.4%
2012	A-LF-Sea	19	2012.2-2013.1	12.49	226.7	223.8	-7.5%

Training ship test results

Applying A-LF-Sea to a vessel in drydock (Picture Nippon Paint Marine)

Having found a solution to the problem of reducing frictional resistance Nippon Paint Marine then had to address the issue of accurately measuring vessel hull resistance with and without the A-LF-Sea coating.

One of the greatest obstacles was selecting the correct hydro-gel and finding a method of accurately measuring the performance of the hydro-gel explains Yamamori. "Receiving advice from university professors, we developed a dedicated measuring device with which we could evaluate a large number of hydro-gels with a high precision in order to select most suitable hydro-gel for A-LF-Sea," he says.

In order to assess the efficacy of the coating the paint was applied to working vessels. "Thanks to the shipowners' positive cooperation, we were able to carry out the evaluation tests by applying A-LF-Sea to the entire underwater areas of several real ships. We very much appreciate their passionate support and proactive approach to using new technology, and jointly sharing risks," says Yamamori.

Nakamura says that the A-LF-Sea system was tested on a pure car and truck carrier, because the draught of such vessels varies very little, and the company found that the ship achieved 6-8% fuel savings.

There are no additional application costs for A-LF-Sea though the paint itself costs much higher than a standard low friction paint, but with HFO (Heavy Fuel Oil) prices at such high levels Nippon Paint Marine believes that owners will see a return on the cost of the coating in less than a year.

However, Yamamori is cautious: "It depends on the coating scheme, service life etc. In the case of a large container ship applied with a 60 month service life scheme, its initial investment can be recovered in about 2-3 months. In the case of a VLCC applied with a 60 month scheme, its initial investment can be recovered in about 6-7 months," he says.

"Nippon Paint Marine is confident enough in its coating to assure the performance of A-LF-Sea for five years based on the large track record of the first generation fuel saving AF coating, LF-Sea," says Yamamori.

Though in reality the paint's service life will depend on the thickness of the coating; "We recommend the necessary dry film thickness based on the service life requested by the customer. As A-LF-Sea has a long-term anti-fouling performance, we can recommend a 60 month scheme or up to 90 months depending on type of ship," says Yamamori.

First low friction paint developed by Nippon Paint Marine, LF-Sea, containing copper silyl acrylate was initially produced in 2008. Over 900 ships have adopted this patented technology which, Nippon Paint Marine confirmed saved up to 4% in fuel costs.

However, the larger the ship the greater the frictional resistance of the flat plate on the vessel and that means that low friction paint can make a greater impact on reducing the fuel expenditure for a vessel.

A-LF-Sea is a further development of this technology that can effectively double the fuel saving potential for owners. "About 8% fuel-saving effect has been analysed and confirmed on a training ship from Kobe University. This confirmed the results of fuel-saving effect which have been achieved on the PCCs" says Yamamori.

THS and EGS, a marriage made in Heaven

Meeting stringent new IMO rules concerning NOx and SOx emissions as well as particulates and CO_2 is proving a tough nut to crack. However, Mitsui Engineering & Shipbuilding and ClassNK believe they have a number of technological fixes that improve the performance of marine diesels, says Takashi Kuwada

Improving the efficiency of marine diesels is becoming increasingly difficult as the gains available become ever smaller as each new development is added.

Innovative design offers a premium to engine suppliers who must produce units that can meet the most stringent of the new regulations, IMO's Tier III reductions. Mitsui Engineering & Shipbuilding (MES) believes it has managed to squeeze more efficiencies from its marine diesels by marrying two technologies, the Turbo Hydraulic System (THS) with its Exhaust Gas Separation (EGS) technology.

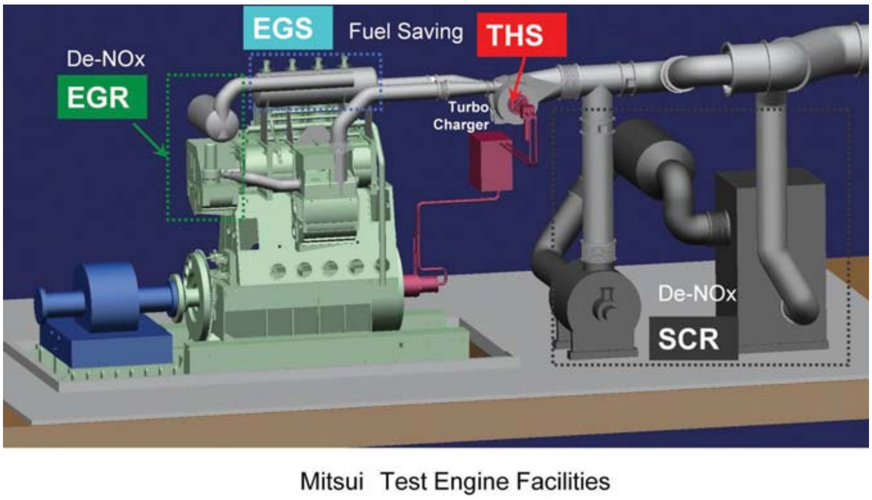
One technology complements the other improving the overall performance of the marine diesel. According to MES the THS uses hot exhaust gas directed from the engine to the turbocharger to drive a hydraulic pump that in turn drives a hydraulic motor attached to the crankshaft of the engine. Indirectly, the excess energy from the exhaust gas is captured and redirected to add efficiency to the main drive.

According to MES and ClassNK the system can recover up to 4% in engine power depending on the engine load. Details of performance tests show that the THS reduced fuel consumption by 2.5% at 75% loading, nearly 3% at 85% engine load and a little over 4% when the diesel was operating at 100% load.

"Verification tests have confirmed that by combining THS and EGS systems a 4-5% reduction of CO_2 emissions is possible," says Kuwada.

Confirmation of the test results has been achieved through the installation of the THS onto a handymax bulk carrier in 2012. Results showed that the vessel achieved the expected fuel savings.

A hydraulic system was chosen over an electric version because the hydraulic system is more compact and it is, therefore, less costly to buy and install. The small size of the THS means that the system can be installed even in restricted spaces on smaller vessels.



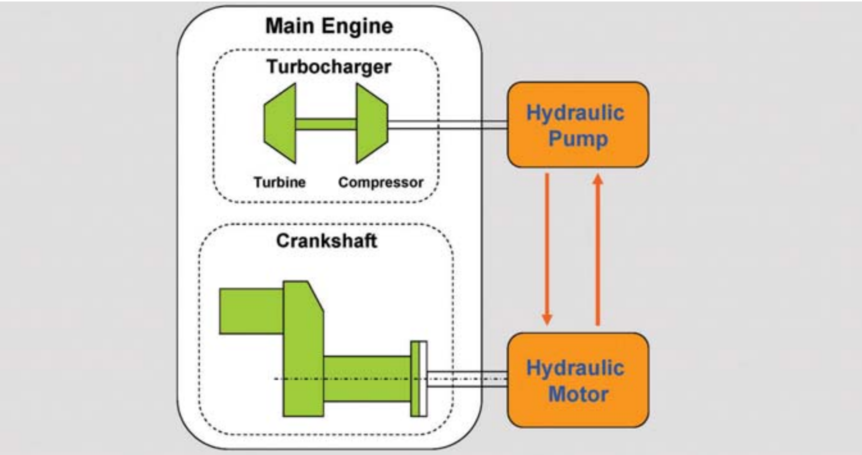
Development of fuel saving technology that complies with IMO NOx Tier III regulations

"With THS, we are converting the residual energy found in exhaust gas which was previously wasted into hydraulic energy driving a hydraulic crankshaft motor to assist engine revolutions. As a result, we can reduce the amount of fuel needed for engine operation," Kuwada explains.

To assist the THS and make certain that it achieves the full potential savings that the system is capable of MES has designed an EGS unit that separates hot exhaust gases from cooler gas. Essentially the EGS uses fresh scavenging air to push exhaust gases out of the cylinder. Hot gas is directed through a valve to the THS but the cooler exhaust is directed to a cool gas receiver unit.

Kuwada says: "With EGS, we are able to capture and use higher temperature, and therefore higher energy, exhaust gas than was previously possible. By feeding this high energy gas into the devices that use exhaust gas power such as THS and

Takashi Kuwada says ClassNK is a strong believer in this technology



Concept of the THS; Hydraulic pump: Take out excess energy of exhaust gas from the Turbocharger Hydraulic motor: Assists rotation of crank shaft with recovered hydraulic power

gas boilers, we can further increase their effectiveness. As a result, EGS improves the total efficiency of the engine or combined engine efficiency."

The exhaust gas separation system is an MES design and is built around the main outlet valve system; hot exhaust gas is sent to the high temperature receiver through the main outlet valve before the piston reaches top dead centre. When the piston goes beyond top dead centre a sub-valve opens and cooler air is directed to the cool air receiver.

MES says that the effect of the EGS working in tandem with the THS is to improve the overall performance of the engine, and the higher the load the more significant the fuel savings are.

At an engine load of 75% the THS working alone reduces fuel consumption by 2.5%, but this increases to 3% with the EGS. The systems show similar gains at 85% load, 2.9% and 3.6% respectively and at 100% loading the THS alone saves 4% in fuel consumption, but this is elevated to 5% with the EGS.

While THS is ready for market however, Kuwada explains that EGS will require a bit longer to achieve practical application. "We are strong believers in this technology, and our tests confirm that EGS has a great potential for use on marine diesel engines. While there are a still a few issues that need to be addressed, with these results in hand we can begin the work to bring this technology to the market.

Marine diesels are becoming more efficient and technology such as THS and EGS along with SCR's (Selective Catalytic Converters) can reduce fuel consumption decreasing emissions and the amount of the greenhouse gas CO_2 that is produced. The attachments for the engines may prove significant for ships that are already operational.

"Our goal was to find a way to separate high and low temperature exhaust gas into two separate channels without reducing efficiency, while also maintaining a traditional exhaust piping structure. Optimising the shape of the passageways was a major challenge, but essential to achieving the results," Kuwada explains.

Kuwada admits, however, that retrofitting the THS and EGS to existing vessels could prove challenging. "The engine rooms of many modern vessels have been so optimised, in terms of space, that retrofitting any type of engine attachment presents challenge. We can't say that retrofitting this system is 'easy', it's technically feasible to retrofit the THS/EGS system during a standard docking, and we're looking at ways that the THS/EGS system can retrofit on existing vessels."

In using the same materials that would ordinarily be found on standard diesel engines any retrofit would not be complicated by other issues than space. In newbuildings the opportunity exists to design the vessel with the THS and EGS already fitted.

However, for newbuildings there could be an alternative as new high pressure gas injection engines could provide a single solution. LNG power can reduce CO2 emissions by 20-25%, and either eliminate or substantially decrease the pollution that occurs from burning marine diesel, either HFO or distillate.

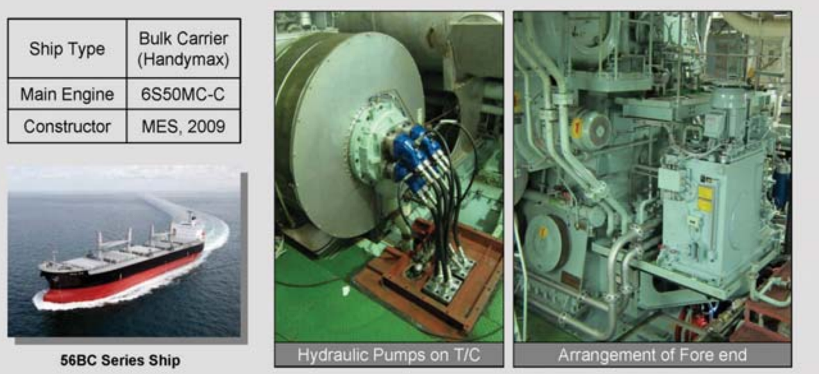
Full scale demonstrations of the MEGI engines built by MES have shown that the latest natural gas fuelled engines can switch seamlessly between marine diesel and gas and may prove to be an alternative to HFO or distillate fuel in the future. And, says Kuwada, "THS and EGS can achieve the same benefits on an LNG fuelled engine as they do on standard heavy diesel engines".

For MES the main issues performance and consistency and improving the technology to the point where it is commercially viable.

"Ensuring reliability and effectiveness is always the number one priority. For this technology in particular, there have been many similar systems in the past, but the slim return on investment has meant they have not been very popular. So with THS we worked very hard to create a system that is cheap enough to earn wide acceptance the market, while also focusing on maintaining a small form factor and ensuring durability," concludes Kuwada.

Service experience; The THS was approved by ClassNK and Installed to a vessel in service in 2012.

Ship Type	Bulk Carrier (Handymax)
Main Engine	6S50MC-C
Constructor	MES, 2009



Playing the generation game

Fuel can be saved through resource efficiencies offered by combining a generator with a turbocharger. Keiichi Shiraishi Manager, Turbocharger Designing Section, MHI and Ayako Hashimoto, Researcher, Maritime Technology Group, MTI explain

Hybrid technology has allowed NYK, Monohakobi Technology Institute (MTI), Japan Marine United (JMU) and Mitsubishi Heavy Industries (MHI) to create an energy generating device that uses the excess energy generated from the turbocharger.

Husbanding precious resources is an important element of ensuring that ships operate more efficiently.

Often overlooked when considering the power requirements for cargo vessels is the ship's requirements for auxiliary power. However, power needs for the crew accommodation, cargo handling and other supplementary power requirement can mean that vessels burn significant levels of fuel simply to stand still.

In some cases the auxiliary power demand can be very high; for example the need for energy to power reefer containers on a large container ship could be considerable as are the energy requirements for large cruise ships and passenger and freight ferries.

However, even mainline commercial vessels like bulk carriers expend significant amounts of fuel on auxiliary power. With this demand in mind any supplement to the auxiliary power through alternative means can offer owners significant fuel savings and further decrease emissions from a vessel.

While at first sight the Hybrid Turbocharger (HTC) appears to offer only limited savings, high bunker prices combined with low charter rates mean that even a few percent savings on fuel consumption can provide major benefits to shipowners, especially when the technology makes use of energy that has already been generated and that would otherwise be lost.

Turbochargers use the kinetic energy from exhaust gases to increase the pressure on gas in the injection phase of an engine. The increase in pressure means that more air is sucked into the cylinder and that means that the fuel is burnt more efficiently.

Subsequently the hot exhaust gas is expelled when the outlet valve is opened and hot gases pass from the engine through the exhaust system. Turbochargers use this ejection of gas to turn a turbine that compresses the air before it is pushed into the cylinder prior to combustion.

Keiichi Shiraishi of MHI says the HTC applies to any kind of ship

Ayako Hashimoto says CO_2 emission reductions were respectable

Mitsubishi Heavy Industries (MHI) has designed a generator that sits on the HTC and utilises the spinning kinetic energy generated by the exhaust gas and converts that energy into electricity that can be used on the ship's grid.

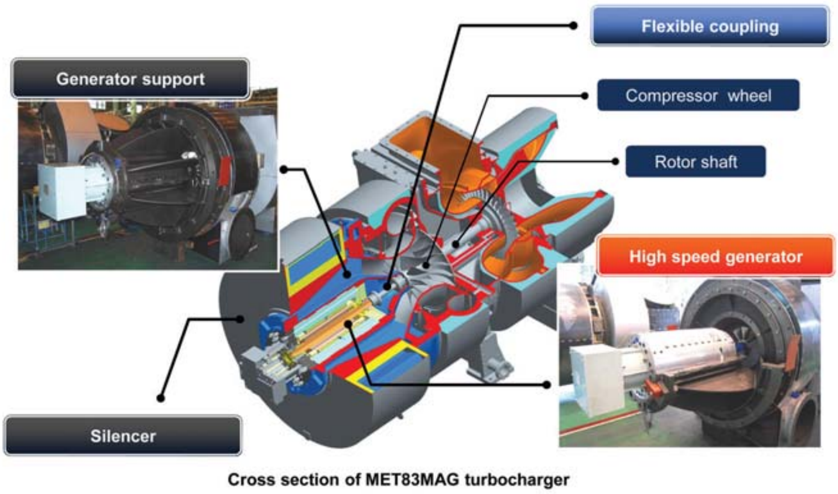
This is not a new idea says Keiichi Shiraishi, Manager, Turbocharger Designing Section Mitsubishi Heavy Industries (MHI). He explained "MHI greatly respect MAN Diesel who developed an HTC for their turbocharger in 1979. At MHI, we originally started development of an HTC for air to fuel ratio control of gas engines in 2008, and we searched exhaustively for a supplier of this kind of high speed generator. We were very happy to find an excellent development partner in Calnetix Technologies Ltd."

In a US/Japan cooperation effort designers set to work to develop the original idea set out by MAN more than 30 years ago. "Calnetix have developed advanced technology in high speed generators, but had no experience with marine equipment. As a result the HTC size, bearings and oil seals were carefully designed back and forth between Calnetix and MHI to integrate into the turbocharger and to enable the use of main engine system oil," explained Shiraishi.

Calnetix worked on the PMG magnetic design and thermal design and the converter basics while also collaborating with MHI on the housing and rotor dynamics. MHI was responsible for the PMG bearings, seals and mounting shells and the turbocharger structural design.

The work on the development of the HTC was jointly carried out with engine builder Hitachi Zosen which looked at NOx control and waste gate control as well as wiring and engine/turbocharger matching.

This work and the eventual testing of the MHI HTC were carried out with the support of the Japanese government, which invested in the technology as part of its program to reduce maritime emissions, and ClassNK,



Construction of a hybrid turbocharger

	Max. output [kW]	Notice
MET42MAG 42MBG	250	Proto type
MET53MAG 53MBG	300	
MET60MAG 60MBG	370	
MET66MAG 66MBG	470	
MET71MAG 71MBG	550	
MET83MAG 83MBG	750	Completed !

MET-MAG, MBG expexted output

which supported the development as part of its Joint R&D for Industry program.

Once the design had been settled the HTC had to be tested and so the HTC was fitted to a Capesize bulk carrier operated by NYK. For the installation, Universal Shipbuilding (now JMU) designed the engine room layout, power management systems, inverters and cooling systems as well as working with MHI and Hitachi on wiring and Calnetix on the start/stop system and signal interface.

MTI's Ayako Hashimoto says that the service experience gained from this trial vessel showed that CO_2 emissions reductions were 1.8 – 3.0 %; a respectable amount for a new technology of this type. Hashimoto concedes that, "In the case of a newly built vessel the payback time would be anywhere from 7– 15 years, but it very much depends on the kind of vessel, sailing route, and operating conditions under which the ship is operating."

However, Hashimoto also explains that, "Ships operating continuously at high load conditions can gain a very large benefit, and we are continuing to carry out design improvement to achieve lower cost and higher efficiency for future models."

The advantage for ships like the Capesize bulk carrier, says ClassNK Executive Vice President Yasushi Nakamura, is that "once the engine is operating at roughly a 70% load, the hybrid turbocharger can provide all the ship's auxiliary power needs, meaning diesel generators can be shut off during standard operations."

The relatively compact size of the HTC means that it can be retrofitted to ships already operating as well as applied to a variety of newbuildings. Nakamura says that as MHI has already taken orders for HTC's that will be fitted to three different engines, "The possibility is there to retrofit these systems onto a variety of vessels," says Nakamura.

Shiraishi further explains: "The HTC can be applied to any kind of ship with a diesel engine. The exhaust gas power turbine generating system is similar to a waste heat recovery system that uses main engine exhaust gas. It is already very common for power turbines to be combined with a steam turbine to drive an alternator. However, steam turbines require a large boiler and, therefore, for ships that cannot have a large boiler and steam turbine skid due to the limited space within the engine room, an HTC can be the best solution to recover waste heat from the exhaust gas before turbocharging."

Retrofitting of an HTC is possible to most ships. However, Shiraishi cautions that the following issues must be addressed and could pose some challenges;

1 Space to mount power electronics cabinets.
2 Installation of an additional switchboard for HTC.
3 Modification of the turbocharger including rotor.
4 NOx measurement on board for a renewed NOx certificate.

"Furthermore, the application of the HTC for an engine with two or more turbochargers requires power electronics for each turbocharger. This may require a larger space in the engine room, and at this moment the power control of each HTC is not established yet. In this sense, an engine with one HTC is preferable, and accordingly main engine power should be 20MW or lower."

Even so Shiraishi points out that the five MET83MAG, MBG have been delivered from MHI, and the first HTC MET83MAG has already been running for around 27 months without any problem. With a further one MET83MBG and six MET66MAG on order, MHI's HTC technology is already finding a place in the industry, one that can be expected to expand as the leading Japanese company further refines and improves the technology.

Expanding Efficiency

Saving energy can improve margins and reduce pollution, says ClassNK, but it requires accurate data and analysis to achieve these gains. With new technology, those benefits could be realised on a global scale across the maritime industry

Vessel operations have come under severe scrutiny in the twenty first century as the onus has shifted from speed to clean shipping. Fuel savings and a reduction in pollution can be realised through reducing resistance, more efficient engines and renewable energy add-ons such as generators.

Speed or the lack of it has proved to be the greatest fuel saver and the feeling is that there are few major savings that can still be made. Thus finding a technology that can save you millions has become the Holy Grail for many maritime engineers.

One of the key areas for improvement is vessel operations, an area which ClassNK executive Vice President Yasushi Nakamura says is ripe for a revolution.

"There is still a real lack of consensus on the efficiency of vessels in actual operations," says Mr Nakamura. "Newbuilding contracts include performance requirements based on sea trials, but these are carried out in calm weather with little wind and flat sea conditions. As we all know, however, the environment ships operate in is very different from sea trial conditions".

This is why ClassNK turned to Finland's NAPA, one of the maritime industries leading software houses to jointly develop ClassNK-NAPA GREEN. The key feature of the system is a new Dynamic Performance Model (DPM) which continuously records and analyses operational and weather data from the ship to give owners an understanding of their vessel's actual efficiency.

Juha Heikinheimo, President of NAPA Group says that the system offers a tremendous opportunity for shipowners: "Matched with sound management systems, we think owners can conceivably save up to 30% in fuel costs using tools like speed optimization and advanced voyage planning which are included in the ClassNK-NAPA GREEN system".

"But even if they only achieve half of that, a 15% savings would equal 750,000 - 1.5 million tonnes reduced annually by one organisation alone. The financial impact of that saving would help to keep companies profitable, employees in work and also free up capital for investment across the industry."

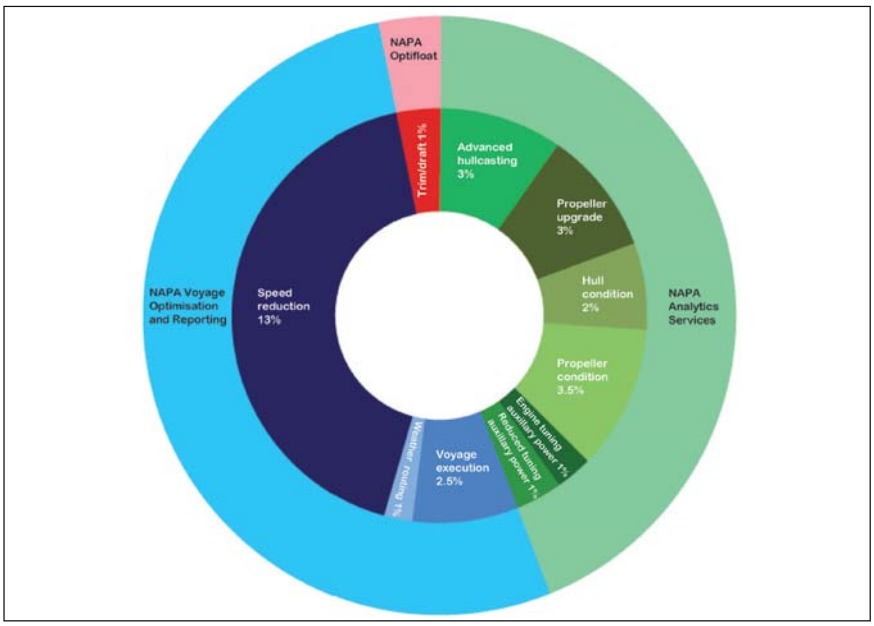
A further advantage is that DPM will be able to analyse the differences in ship performance between similar vessels, where one may have an add-on, such as a Mewis Duct, and the other vessel does not, offering data on the efficiency of the Mewis Duct. This would give owners a clear understanding of the benefits of new green technology on their actual vessels in a variety of operating conditions.

The system is already in use by Taiwan's Wan Hai Lines, Finland's Bore and others, but Mr Nakamura says that is only the beginning: "Beyond just helping owners today, this system can also be used by shipyards to better understand how their designs perform under voyage conditions. By feeding back operational data collated by ClassNK-NAPA GREEN, designers will be able to create a new wave of new vessel designs that can offer realistic and practical operational efficiencies for vessel owners.

ClassNK-NAPA GREEN functions

- dynamic/adaptive trim optimisation
- voyage planning and weather routing
- speed optimisation for just-on-time arrival
- schedule optimisation
- cargo and stowage planning for minimal deadweight
- workload reductions with electronic logbooks
- propulsion resistance management
- monitoring for increased awareness
- automatic distribution of data between ship and shore, and
- performance analysis
- while never compromising safety

Savings potential from ClassNK - NAPA Green




As maritime needs grow,
ClassNK has solutions.
As the world's economy grows and changes, the maritime industry is faced with ever greater challenges. With roughly 20% of the world's merchant fleet under class, we understand the requirements for the future of safe shipping, and we're working to develop new tools and technologies to meet the changing needs of the maritime industry. Learn more about our efforts to advance maritime safety and protect the marine environment at www.classnk.or.jp
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