Technical Meeting — 9 February 2023

Tom Charter, Damen Shipyards Representative for Australia, New Zealand & South Pacific, and Sale & Purchase Manager with Australian Independent Shipbrokers/Asiaworld Shipping Services, gave a presentation on *Electric-drive Technology for Tugs—The Future is Now*, to a joint meeting with the IMarEST in the Harricks Auditorium at Engineers Australia's new premises at 44 Market St in the Sydney CBD and streamed live on 9 February. The presentation was attended by 24 with an additional 125 online.

Introduction

Tom began his presentation with some brief details of Damen's operation, which involves a team of 12 000 people over 36 shipyards across 5 continents.

Damen's operations
(Image courtesy Damen)

This project actually began back in 2014 with the delivery of the Damen ASD 2411 diesel tug *Hauraki* to the Ports of Aukland Limited (POAL), who were already investigating future options. In 2016 POAL stated that their goal was to be emissions neutral by 2025, and emissions free by 2040.

In 2018 a feasibility study on full-electric operation of tugs was completed, and in 2019 the concept design came to fruition. Construction commenced in 2020, and the first vessel, *Sparky*, was delivered in 2022. The vessel was awarded the ITS (International Tug and Salvage) Boat of the Year 2022, and *Time* magazine's Best Invention—Transportation 2022.

Sparky

Sparky is the first Damen RSD-E 2513 tug. The vessel has a length of 24.73 m, and a draft of 6 m, with two azimuthing thrusters with 3 m diameter propellers giving a bollard pull of 70 t, the same as the ASD 2411 diesel tug *Hauraki*.

The vessel is powered by eight battery racks holding 2240 batteries, totalling 2784 kWh of power. This is anticipated to save about 465 t of CO_2 in diesel emissions annually.

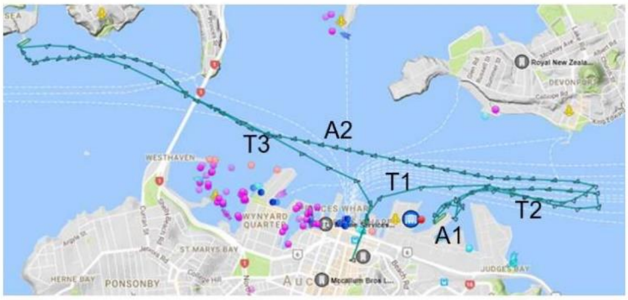
Sparky
(Photo from workboat365 website)

Considerations

Redundancy would be needed for delivery and docking voyages and for fire-fighting operations. Electrification is already present in the port and so there is readily-available and affordable renewable power.

The operational profile of a typical harbour tug shows less than 2% of full load, with significant periods at idle and low load.

A detailed operational analysis was conducted on the existing operation of *Hauraki*. This entailed a profile with two towing jobs right after each other. The first job was relatively nearby the home base, and the second job was further away.

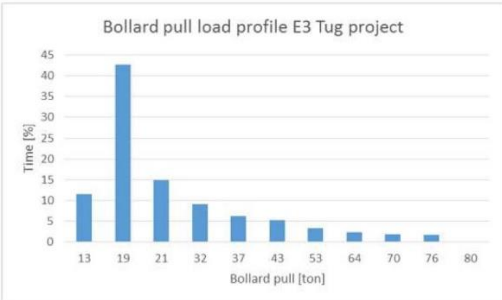


Operation	Average speed [kts]	Duration [min]
T1 - Transit 1	9.1*	11
A1 - Assist 1	-	38
T2 - Transit 2	4.1	37
A2 - Assist 2	-	94
T3 - Transit 3	8.1	18

Hauraki jobs profile
(Image courtesy Damen)

The tale and figure below show the typical profile for a tug during an assisting operation. The profile is based on the research in the E3 tug project and is used for the A1 and A2 operations. The E3 tug profile is used for the calculation because the load profile cannot be derived from the AIS data.

Bollard pull modes				
Mode [-]	BP [ton]	Time [% assist]	Time job 1 [minutes]	Time job 2 [minutes]
1	13	11.5	4	11
2	19	42.7	16	40
3	21	14.9	6	14
4	32	9.1	3	9
5	37	6.2	2	6
6	43	5.3	2	5
7	53	3.4	1	3
8	64	2.4	1	2
9	70	1.9	1	2
10	76	1.7	1	2
11	80	0.1	0	1
		Total:	38	94



Typical operational profile
(Image courtesy Damen)

Available Technologies

The technologies available include after-treatment for diesel fuels, bioFuels and eFuels which will give reductions in CO_2 emissions, but zero emissions really require electric propulsion or hydrogen/fuel cells.

	A	B	C
	Low emissions	CO_2 reduction	Zero emission
Technology (short term < 4y)	Aftertreatment	BioFuels	E-propulsion
Technology (long term > 4y)	(Aftertreatment)	eFuels	H_2 / Fuel Cell
Driver	IMO regulations (NO_x/SO_x) EU (NO_x/SO_x/PM)	Paris Agreement 2015 IMO EU	Paris Agreement 2015 IMO EU

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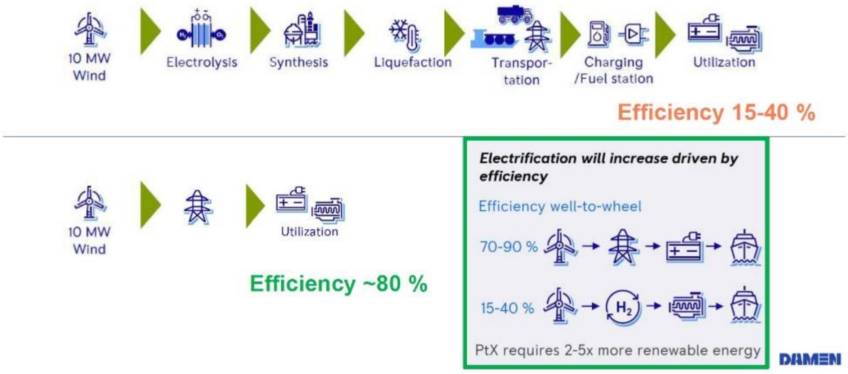
Available technologies
(Image courtesy Damen)

Economic Viability

The efficiency of a system to generate hydrogen, liquefy, transport and use it in a fuel cell for power is much lower than the efficiency of directly using electricity for power.

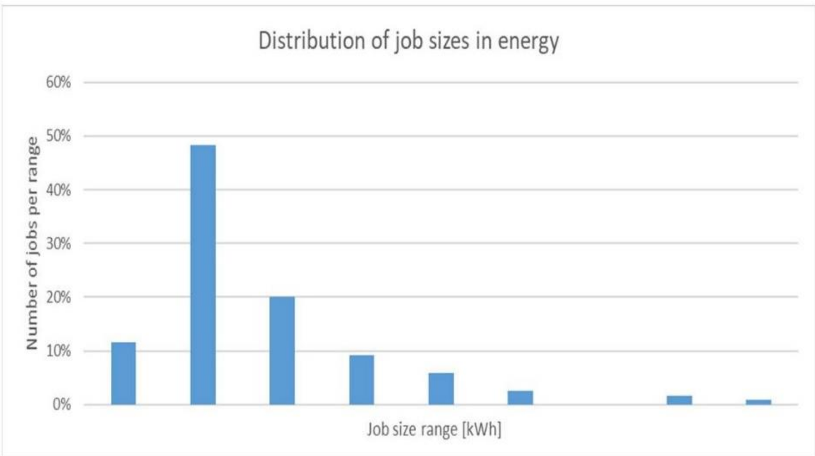


Economic viability
(Image courtesy Damen)

Electric System

Damen came into this project with the philosophy that they are a system integrator. They wanted a modular and scalable design which could be used world -wide, and with the lowest total cost of ownership.

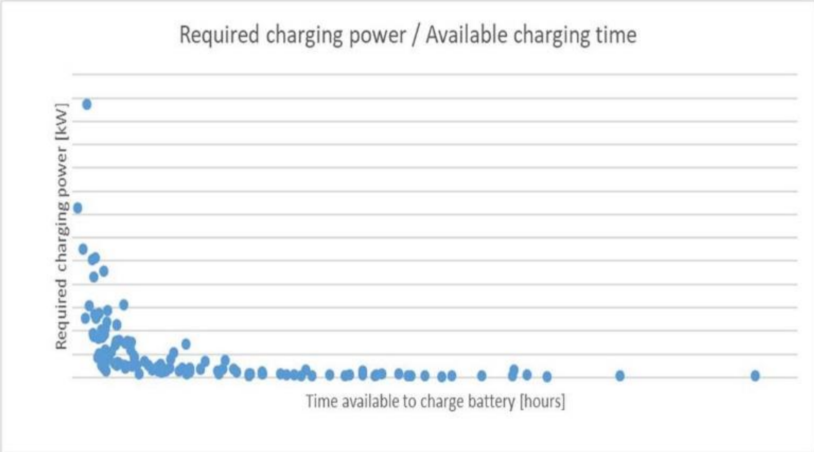
The energy storage capacity was adapted to meet the POAL operational requirements. These included up to four berthing/unberthing operations per charge with 50% battery capacity remaining, complete re-charge within two hours, and high autonomy operations on diesel generator sets for extended transit to maintenance facilities when required.



Distribution of job sizes in energy
(Chart courtesy Damen)

Charging Power

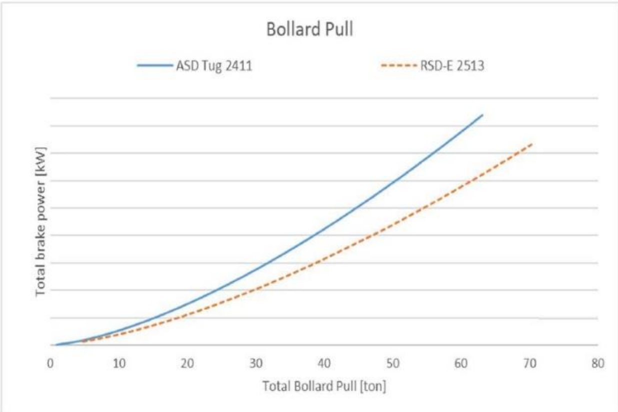
For the required charging power, they analysed the operational profile, subject to the requirement of complete charge within two hours. They could, of course, have back-up charging from the generator sets, but this was not factored in to the profile.



Required charging power
(Graph courtesy Damen)

Discharging Power

Sparky is able to achieve 70 t bollard pull and 12 kn free-running speed on batteries. On the diesel generator sets 40 t bollard pull is achieved. The vessel has been optimised for propulsion efficiency, and bollard pulls are achieved with less power output than a diesel-driven tug.



Power vs bollard pull
(Graph courtesy Damen)

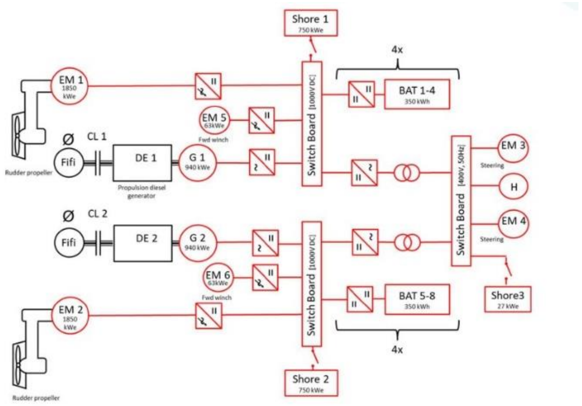
Battery System

The battery system is based on the Toshiba lithium titanium oxide (LTO) battery module with the Toshiba battery-management system (BMS) up to string level, including protection. Racking uses the Eschandia Marine System BMS. The expected lifetime is 30 000 cycles or 30 years. The system is classed by both DNV and BureauVeritas.

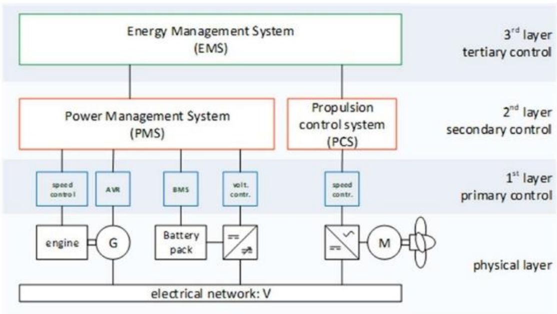
Generator Sets

Sparky is fitted with twin generator sets for back-up, range extension (for delivery and maintenance voyages) and fire fighting. Caterpillar C32 diesel engines which are IMO Tier 3 certified with Damen SCR systems driving Leroy Somer generators for 940 eKW each at 1800 rpm. There is also an optional fire-fighting pump.

Electric and Control Systems



Electric system schematic
(Drawing courtesy Damen)



Control system schematic
(Drawing courtesy Damen)

Operating Modes

Battery Mode

- Under way Full battery mode with zero emissions.
- Moored Vessel is at the quayside and being charged by the shore charging station.

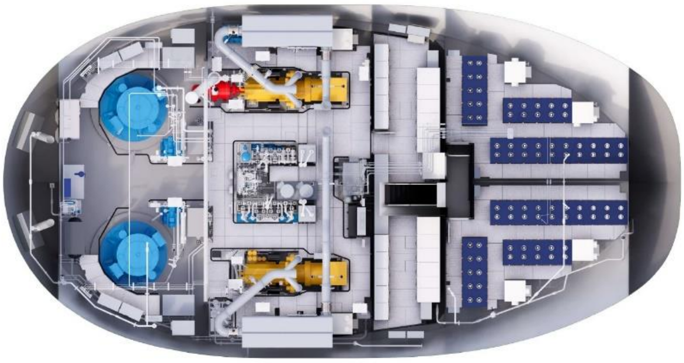
Genset Mode

- Under way Both C32 diesel engines are powering the generators for propulsion without battery power.
- Moored Both C32 diesel engines are powering the generators for charging without shore power.
- Fire fighting Both C32 diesel engines are powering the fire-fighting pump and the generators for propulsion simultaneously without battery power.

Hybrid Mode

- Under way Both C32 diesel engines are powering the generator for propulsion and/or battery charging. When necessary, batteries are supplying boost power. Maximum performance and autonomy of the vessel are available in this mode.
- Moored Vessel is at the quayside and both C32 diesel engines are powering the generator for fast charging the batteries together with the shore charging station. Completely charging the batteries within 1 h is possible in this mode.

General Arrangement



Arrangement below main deck
(Image courtesy Damen)

Battery room
(Photo courtesy Damen)

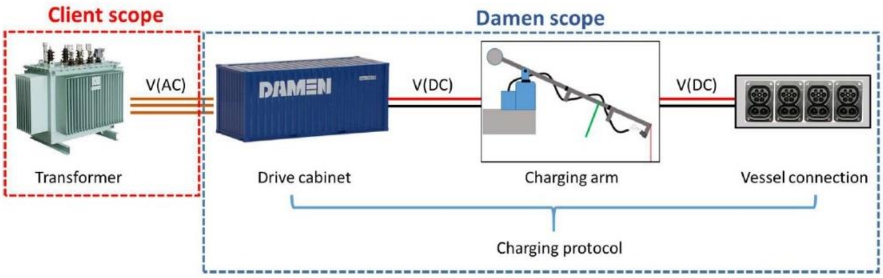
Switchboard room
(Photo courtesy Damen)

Engine room
(Photo courtesy Damen)

Rudder propeller room
(Photo courtesy Damen)

Charging Requirements

The time for the batteries to charge fully from shore power is 2 h at 1.5 MW. Connection and disconnection can be completed in 5 min.

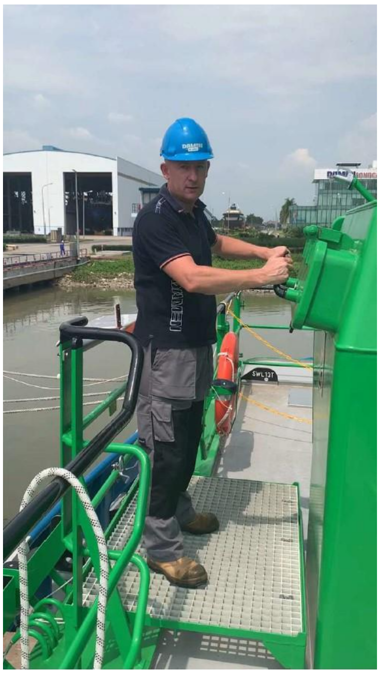


Shore power charging schematic
(Diagram courtesy Damen)

A charging arm of robust and simple design provides for tidal difference compensation and allows one-man operation from the quayside or on board the vessel.

Charging arm
(Photo courtesy Damen)

The charging cables are automotive High-power Charging (HPC) cables which are compact and lightweight, allow easy handling, and are an off-the-shelf product. The 1.5 MW charging power requires four 375 kW cables, and the shore-power connection terminal box is located on the starboard funnel.



Connection terminal box
(Photo courtesy Damen)

Conclusion

Damen's RSD-E 2513 tug *Sparky* provides zero emissions (and hence no future CO_2 tax), low electricity costs due to high efficiency, low maintenance costs, low financing costs, no fuel costs, and low total cost of ownership. The technology is available and the infrastructure is available. The future is now!

Questions

Question time was lengthy and elicited some further interesting points.
The presentation was recorded and is expected to be available soon on the RINA YouTube channel.
The vote of thanks was proposed, and the "thank you" bottle of wine presented, by Adrian Broadbent. The vote was carried with acclamation.

Tom Charter (R) and Adrian Broadbent
(Photo Phil Helmore)