TractorPlus Performance Results

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SYNOPSIS: An innovative re-configuration to an existing Voith Water Tractor by Foss Maritime met the customer-driven need for a higher bollard pull tug to handle large new-build container ships in Tacoma, Washington State, USA. This paper describes the process Foss followed to develop the solution: installation of a single azimuthing stern drive thruster in an existing, highly successful Voith Tractor Tug. The *TractorPlus* project became a remarkable success and Foss shares the development story, as well as the results of testing and operations.

INTRODUCTION

Large new-build container ships coupled with the utilization of existing waterways at the Port of Tacoma, WA, and a new mandate by Puget Sound Pilots, called for an innovative upgrade to existing VSP Tractor Tugs within the Foss Maritime Company's fleet to gain improved thrust and manoeuvrability. This paper describes the need; presents the Foss solution; reviews the engineering, construction and training; and presents the results of vessel testing and operations over a period of the past 12 months of service.

Enhancing existing vessels within a fleet can improve performance, extend vessel life and allow new demands to be met. It is hoped that the experience shared through this paper will provide the industry with insights into an alternative to new construction. The transfer of knowledge is an important element of this paper. We firmly subscribe to this sharing of information with the goal of contributing to the safety, growth and overall effectiveness of our industry.

CUSTOMER-DRIVEN NEED

The primary need driving the development of this tug modification was the introduction of the new Evergreen *Hatsu* E-Class containerships to the Port of Tacoma in Washington State, USA. The port has developed a new container facility and turning basin for these 8,000 TEU containerships; however the waterway is relatively restricted, narrow, long and subject to high cross-winds.

Figure 1
Blair Waterway and New Turning Basin

The Glosten Associates of Seattle conducted a navigation study for the Puget Sound Pilots and Evergreen Shipping. The study calculated the loads on the containership, evaluated tug operational constraints, and determined required tug power for moderate and extreme weather conditions. The report recommended minimum tug forces, and indicated that two tugs should be adequate to control the Evergreen E-Class containerships through the Blair waterway and into their berth at the Port of Tacoma. Providing a 99% operability in beam winds up to 20 knots requires one tug capable of 46 tonnes working with a second 42 tonne tug. Tugs of higher horsepower could be used to allow operations in higher beam wind speeds, approaching 100% operability; however, the Pilots were comfortable with 99% and issued requirements to local tug companies calling for a 45.5 tonne bollard pull tug.

MEETING THE NEED WITH A VESSEL RE-CONFIGURATION

In 2001 Foss had completed a detailed overall assessment of the physical condition, economic and market life of their vessel fleet. They identified vessels within their fleet that were candidates for life extensions, performance upgrades and, in some cases, complete reconfigurations and/or replacements to meet or exceed the projected needs of the marketplace. Now with this new opportunity, Foss was well positioned to meet the need to effectively handle the new Evergreen ships with some early concept work already completed.

Foss Maritime had already determined that their existing Voith Schneider Tractor Tugs, built in the early 1980s, were ideal for ship docking but lacked adequate bollard thrust for the new generation of larger container ships calling on some ports where there are tight navigational limits. The Voith Tractor is considered worldwide to be a highly manoeuvrable ship assist tug. The existing 3000 HP ***Wedell Foss*** class tug was well-suited for ship assist at the time it was built, but ship size has increased remarkably over the past 25 years. Now more thrust is required while retaining manoeuvrability for the critical constraints within some port locations.

Several different options were considered:

- Taking out the existing machinery and installing new, larger engines and VSP units.
- Revising the skeg configuration with the addition of tunnel thrusters.
- Installing two ASD units aft, port and starboard.
- Removing the VSP units and replacing them with larger Z-drives.
- Adding a conventional shaft / propeller aft.
- Adding a VSP unit aft.
- Re-deploying the vessels, and replacing them.

Having rejected other options as too costly or not practicable, a Foss Design Team, including Marine Operations personnel and The Glosten Associates Naval Architects, was assembled to study the addition to the boat of some type of single, centreline aft propulsor.

Foss presented this idea to Kooren Shipbuilding, creator of Rotor® tug. Although Kooren had never considered the combining of VSP and single-screw ASD technologies, they felt this concept would work, and work well. Their experience and direct participation in the concept design were critical to meeting the intended performance requirements.

Concept layouts confirmed that an azimuthing thruster could actually be configured in the stern. There was room for a compact diesel engine and shafting, and there was aft fuel tankage that could be eliminated from the vessel to allow for the added machinery weight. Some primary engineering challenges remained to be addressed. These included:

- Skeg configuration and modification, to provide continued directional stability.
- Capability to meet US Coast Guard (USCG) Stability Criteria – with the new azimuthing thruster located directly below the towing staple.

- Prediction of final ahead and astern thrust, given that the new thruster would be operating in the wake field of the VSP units forward, or vice-versa.
- Noise control, given that the installed horsepower was to increase by 67%.

Earlier, while developing the Rotor® tug, Kooren and Schottel had invested significant effort in model testing at MARIN. The information that was garnered, coupled with Foss's own extensive VSP Tractor Tug model tests at MARIN, supported by conservative and encouraging performance predictions from The Glosten Associates, gave Foss the confidence to proceed with this new concept, now named *TractorPlus*.

Skeg Modification

The treatment of the aft centreline skeg, and how it interacted, or interfered with, the aft centreline thruster was a clear challenge. Kooren was adamant that the skeg area had to be eliminated to reduce wakefield interaction between it and the ASD while powering forward. Both Foss and Kooren thought that the functioning ASD, as a powered and controllable skeg, would offset the loss of fixed skeg area. The thruster nozzle was recognized as having an annular lifting surface; however, at the time it was not foreseen how well this would work out.

The simple most direct modification was to remove the skeg below the height that interfered with the new ASD, leaving an upper part to support the stern of the boat in dock and provide some skeg area for directional stability.

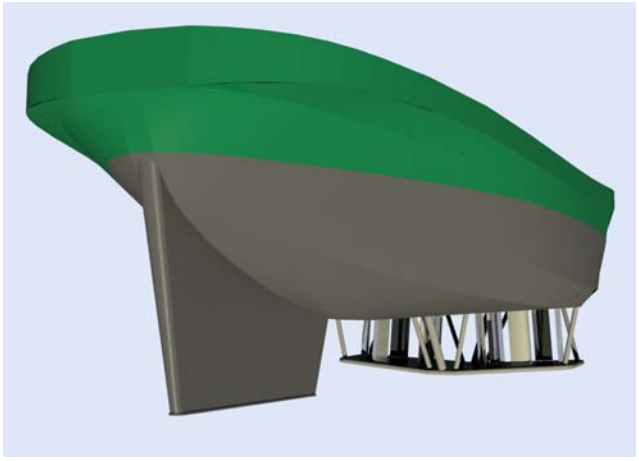

Figure 2
Underbody before Modification

Thrust Prediction

Based on previous full scale model testing of the VSP Tractor Tug and Rotor® tug design, Glosten applied first-principles engineering to develop total thrust predictions, given that each thruster operates in the wake field of other thrusters.

Astern thrust (thrusting aft to tow or push ahead or run ahead) was calculated with the new Z-drive in the wash of the VSPs, and was engineered for an advance speed greater than zero because the propeller will operate in the wash from the VSPs. Splaying the VSP thrust direction outboard (up to about 6 degrees) by adjusting the control settings was envisioned to address the wash problem, reducing the VSP thrust by less than 1% but increasing ASD thrust to more than compensate.

Ahead thrust (thrusting forward to push astern, or run astern) was calculated with the VSPs in the wash of the new Z-drive. Assuming that the VSP pitch can be increased and exceed the 80% bollard pull setting in this condition, we qualified that the VSP thrust deduction would be a smaller percentage.

It was the realization that the new ASD had to operate in the VSP wake field that led to the selection of a Controllable Pitch Propeller (CPP) unit with full feathering. As the design developed, the CPP propeller decision proved to be one of the primary elements of success.

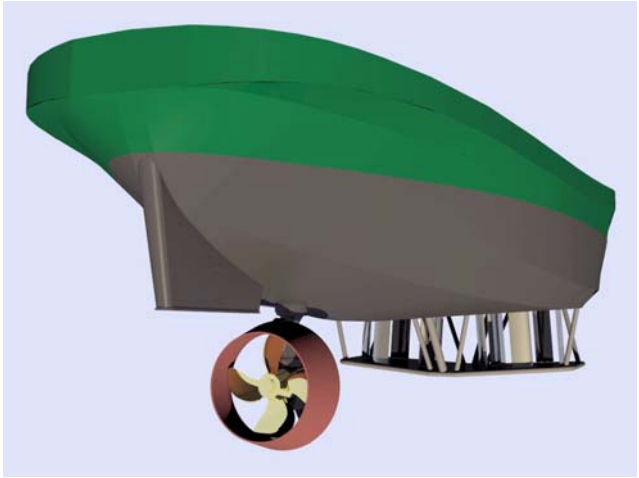

Figure 3
Underbody after Modification

Stability

Because the new thruster was to be positioned directly under the aft staple, USCG tow-line pull criteria became significant. With three thrusters of two different types and different longitudinal locations, the different tow line pull criteria, the Voith Tractor criterion and the ASD criterion were applied simultaneously to evaluate the worst case condition.

Vessel heeling moments were calculated for each of the propulsion units, and then superimposed to arrive at a total heeling moment. The calculation for the total heeling moment exceeded the maximum allowed by the combined criteria. To meet the criteria, analysis was performed that led to USCG / American Bureau of Shipping approval to limit pitch with azimuth angle, reducing athwartship thrust. Given that the primary

need was to have forward and stern thrust, this reduction of athwartship thrust, while not desirable, was considered to be operationally acceptable.

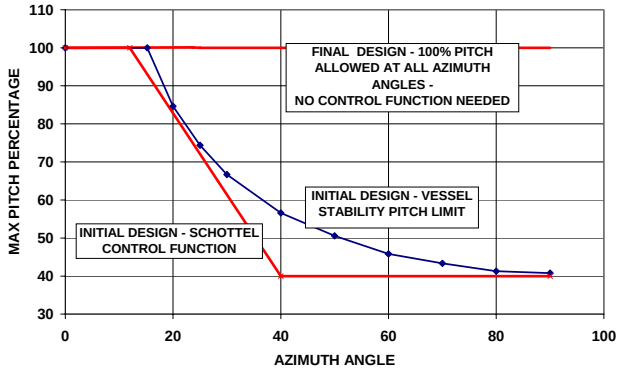

Figure 4
Pitch Control Function to Limit Athwartship Thrust

Fortunately, the final inclining of the modified vessel indicated a vertical centre of gravity (KG) lower than estimated, thanks to a conservative initial shipyard inclining in 1982 and a good Foss weight control program. *This reduction in actual KG was enough to enable the vessel to exert full thrust athwartships and still meet the USCG tow-line pull stability criteria.*

Noise Control

Foss Maritime has a long history of addressing noise control on their fleet of tugboats. The same had to be true for this tug modification.

Foss recognized that installed horsepower was going from 3000 to 4700 BHP in the same 29 metre hull, and particular attention needed to be paid to noise control. Pre-modification noise measurements were taken, predictions were made of the post-modification conditions and the following noise control efforts were worked into the project:

- Soft mounting of the new engine to its foundation to reduce structure-borne noise.
- New high-grade silencers for the existing main engines as well as the new stern drive engine.
- New resilient mounting of the entire exhaust systems for each of the three main engines.
- New sound-tight door, separating the galley from the machinery casing.

CONSTRUCTION

Detailed engineering was carried out in conjunction with Foss Shipyard personnel to fabricate and outfit the new engine and thruster foundations in modules outside the vessel, and then to hoist them into place from underneath the hull in drydock.

Construction was relatively straightforward as the vessel's machinery arrangement was well suited to the modification. A large aft rope locker / stores space was converted to the new thruster room, and conveniently the fuel oil tankage was eliminated to provide both space and weight allowances for the thruster. Net fuel capacity was still more than adequate to support harbour work.

An existing generator was relocated to make space for the new Cummins drive engine, and the new shaft line was run under an existing hydraulic skid, avoiding significant rework. Power is transmitted from the new engine to the ASD unit through a torsional coupling and CENTA carbon fibre shaft. A line shaft bearing was used at the watertight bulkhead between the engine room and new ASD compartment. Three CENTALINK line shaft couplings were used to accommodate the movement of the soft mounted main engine.

A new stack was designed, following the same trademark Foss design but expanded to accommodate the third engine exhaust piping and to maximize 360 degree visibility on the horizontal plane. See Figure 7.

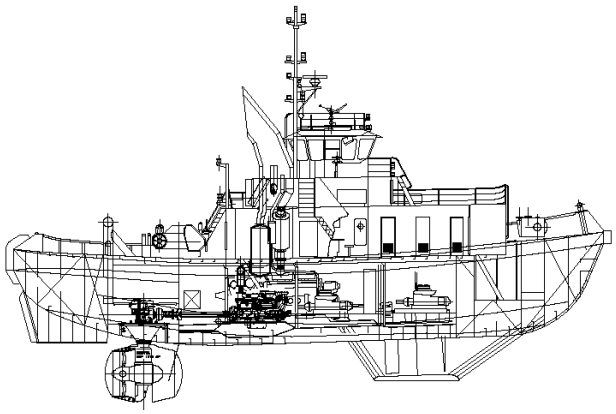

Figure 5
Inboard Profile

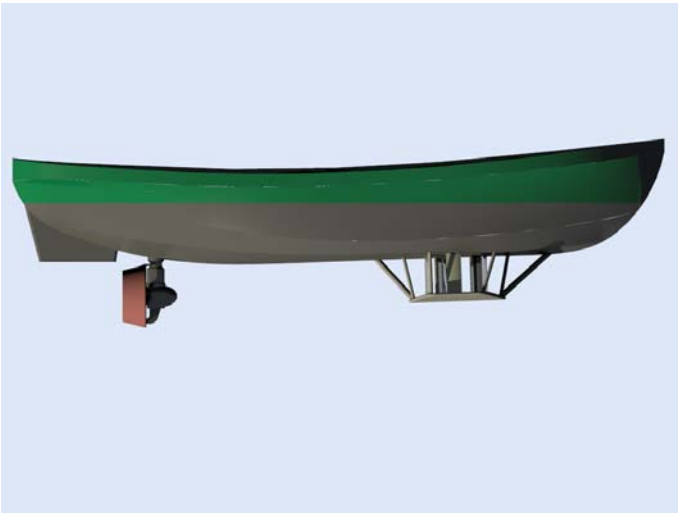

Figure 6
Outboard Profile

Figure 7
New Foss Stack – Expanded Profile with Integrated 3rd Engine Exhaust

Figure 8
New ASD Unit Installation

The resulting product out of the shipyard was a well-integrated vessel, in many respects with the appearance of having been originally designed and built in this configuration.

Figure 9
New ASD Unit
(with skeg support fixture shown on the left)

The layout of the wheelhouse was an important part of the overall design process. As the command and control centre for the vessel, it was essential to maintain the simple, direct interface between operator and tug. The main engine, propulsion unit and winch controls were located to facilitate single operator ease of command. Fortunately, Foss deck officers had the opportunity to train on the Kooren Rotor® tugs in Europe, and incorporated that experience into the final wheelhouse configuration that resulted in a natural user-friendly environment to operate the boat through all its shiphandling activities. See Figure 10.

Figure 10
Wheelhouse Configuration

VESSEL TESTING AND PERSONNEL TRAINING

Full-scale vessel tests were conducted on the waters of Puget Sound. Normal ahead, astern and rotation manoeuvres were conducted. Greatly improved side-stepping was tested and operational stability of the vessel confirmed.

Bollard pull tests were conducted at Everett, Washington, under the guidance of the American Bureau of Shipping. The bollard pull performance exceeded predictions with results presented in Figure 11. Bollard pull ahead reached 52 tonnes and astern reached 40 tonnes.

Ongoing personnel training continues as we fully understand and apply the capabilities of *TractorPlus*. The following observations have been made so far:

- It is advantageous to have the skippers first be accomplished Voith Tug handlers. The boat is still primarily a Voith Tractor, enhanced by the new ASD.
- The traditional Voith combined controls (wheel and levers) are manipulated by one hand, and the ASD joystick is manipulated by the other. Pilothouse arrangements facilitate this control, which is coming naturally to the operators.

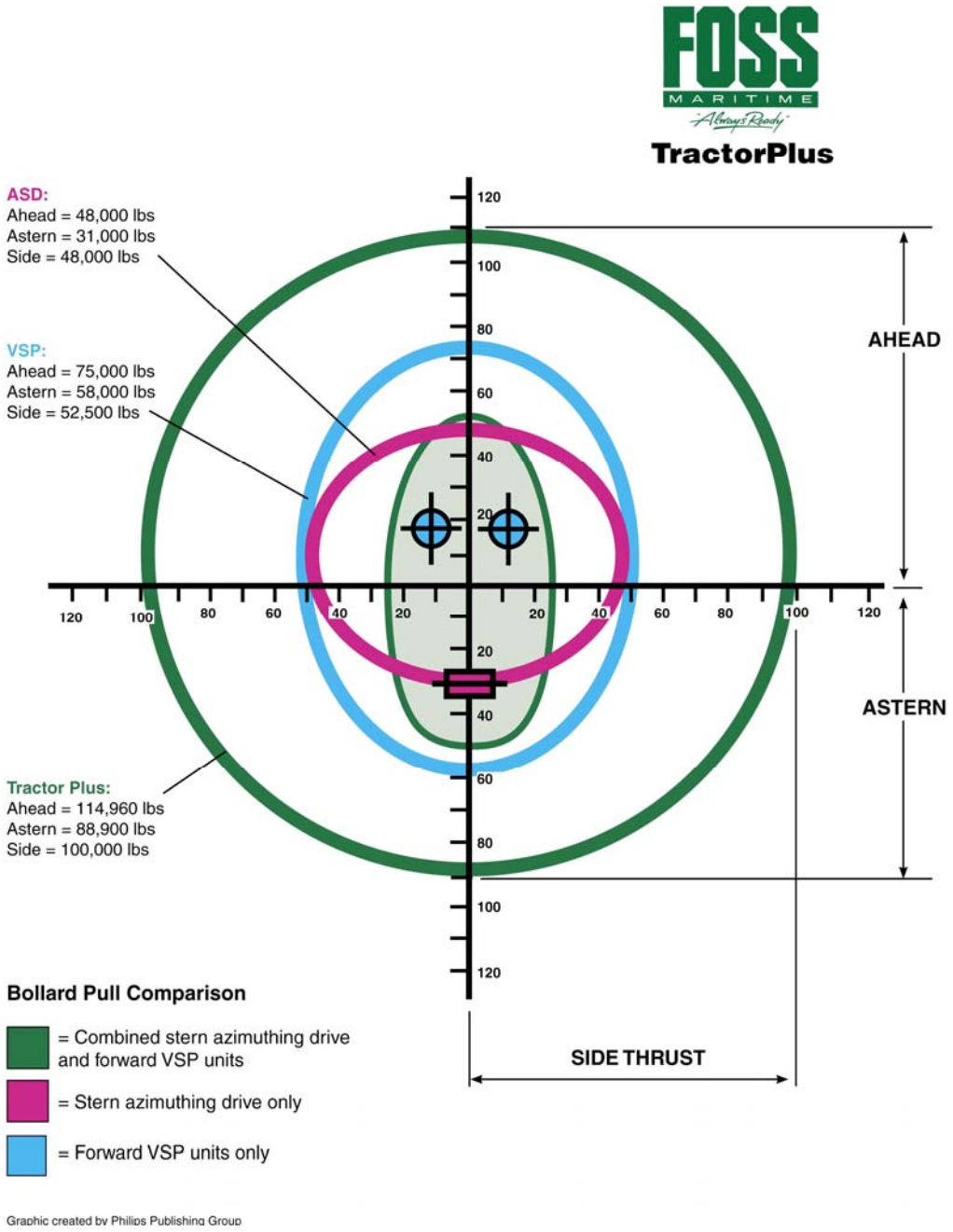

Figure 11
TractorPlus Bollard Pull Characteristics

TRACTORPLUS OPERATIONS

As originally built, the Foss Tractor Tugs were very good ship assist tugs. They were agile and quick. They had the ability to work any ship's chock with a single line and excelled in 'tight-lining' during underway situations. This is especially true for the trailing vessel and at higher speeds in the 'indirect' mode of operation.

What the boats lacked was simple bollard pull. And, when tight-lining under way, the towing vessel lost more power to the water as the VSPs had to steer the boat, which reduced the thrust ahead. With a standard Voith propulsion tractor, steering while running astern was generally accomplished by a "point and shoot" method. We would swing the bow to port or starboard causing the skeg to shear the stern in the desired direction. With the Schottel unit we simply direct the kort in the direction we desire to go and the rudder effect and the directional thrust moves the stern while the operator can leave the Voith units at a zero steering pitch, which maximizes speed and thrust.

With *TractorPlus* we have achieved a 53% increase in bollard thrust ahead. In the dynamic towing mode, power to the water has increased substantially enabling the vessels to be more effective. Figure 11 illustrates the improvement to bollard pull in the full 360 degree azimuth.

Side-stepping has improved to 5.5 kts for the vessels in the light condition. This is especially important for quick position recovery. It is also very useful for maintaining push-pull positions while maintaining a slack line.

Figure 12
***Wedell Foss* Stepping Sideways**

Increased control while handling barges is now assured as the third leg ASD can 'check' the barge more effectively than the VSPs alone.

The ASD has improved overall vessel manoeuvrability in tight operating environments.

The Voith Tractor has always been one of the most manoeuvrable ship assist vessels in the world. With the addition of the Schottel drive we have found many new and improved methods to assist ships in close quarters and narrow waterways. Response times to pilot orders have been improved. When working "open" sterns where the rudder and top quadrant of the propeller are exposed, we sometimes experienced a delay while manoeuvring to a position far enough forward to safely push on the ship. With the *TractorPlus* this delay is greatly reduced. Another inherent problem any ship assist tug encounters while retrieving their working line off the stern of a moving ship is the ship's crew dropping the line and the line finding its way to the tug's propulsion. The *TractorPlus* has the ability to "walk" sideways behind a moving ship (ninety degrees to the ships keel). This clears the propulsion units of any dropped working lines and lift messengers. The whole experience of ship assist has become smoother and more controlled than ever before.

With the ability to transverse sideways, barge movements have a greater degree of safety. Also we now can stop a moving barge quicker and hold a steady heading, whereas before the barge would have a tendency to swing off course while being slowed down.

On the down-side, we have found that the boats do not track well in free-running mode with the ASD secured. It is best to have the ASD active at all times. In the active mode, propulsion efficiency and overall manoeuvrability is improved, so from a practical point of view, having the third leg active is beneficial all around.

The addition of the Schottel unit has improved the ability to safely continue to assist a ship or finish a barge movement with the loss of one unit.

Greater safety is also achieved by having increased thrust and hence improved stationkeeping ability in heavy weather or strong currents. With 360 degrees of manoeuvrability these tugs can work with greater safety in many difficult conditions.

THE FOSS PHILOSOPHY

The development of the *TractorPlus* was carried-out under the Foss philosophy of continual improvement, innovation and collaboration, and within the guidelines of the safety management system.

Continual Improvement

As part of its quality and safety focus, Foss implemented an accredited, third party certified, safety management system over ten years ago – the first United States tug company to do so. The American Waterways Operators' Responsible Carrier Program (RCP) was chosen because it was specifically developed to address the unique needs of the tug and barge industry. Foss's RCP covers virtually every aspect of shoreside management and vessel operating

policies and procedures including: loss of electrical power, propulsion, steering or throttle control; tank barge operations; ship assist operations; navigation in restricted visibility; security rounds; non-entry into confined spaces; towing route and type of service; load line freeboard policy and voyage planning; maintenance; fuel transfer; safety; environmental policy; incident notification, response and investigation procedures; and on-board vessel and equipment inspection. In addition, human factors are addressed such as manning levels and standards, a work-hours statement of policy, and a training schedule.

Foss and its Marine Resources Group sister companies are currently using the detailed framework of RCP to attain voluntary Class certification under ISO standards and the International Safety Management (ISM) Code.

Also, as a result of legislation enacted in the United States and supported by our industry, the US Coast Guard is implementing a new safety management system inspection regimen for tugs and towboats. It will be an improvement from the "traditional" inspection approach because it includes management practices in addition to vessel design, certification and inspection criteria.

Transfer of Knowledge

Foss, Glosten and Kooren are all committed to the process of transferring knowledge by sharing research, studies and study data because we believe it is the most productive way to contribute to improved vessel escort safety. The overall goal is to provide cost effective, reliable, safe and environmentally responsible service for customers.

As part of this commitment to accruing and transferring knowledge, Foss and Glosten have participated in numerous tanker escort and assist studies working with domestic and foreign customers, stakeholders and interest groups since the mid-1970s. These investigations have included ship and tug interaction studies, model basin tests, full-scale vessel trials, computer simulations and manoeuvring models for such diverse technical applications as Valdez Alaska, Puget Sound, Washington, San Francisco and Los Angeles/Long Beach, California, the Panama Canal Authority, Sullom Voe Terminals, the Louisiana Offshore Oil Port (LOOP), US Coast Guard Towing Safety Advisory Committee (TSAC) and the ASTM Escort Tug Working Group.

CONCLUSION

The Foss VSP Water Tractor Tugs were introduced to the marketplace in 1982. Conceived by the Foss Design Committee, the Foss Water Tractor utilizing the cycloidal propulsion system represented the state-of-the-art in ship handling, tanker escort and assist technology. Over the past 24 years, the unique design features of this class of vessel have been replicated many times over around the world.

Initially the vessels were built by Tacoma Boatbuilding Company to very high construction standards and maintained well by Foss personnel. *TractorPlus* was a logical performance enhancement and life extension effort to an existing platform.

The *TractorPlus* project resulted in many accomplishments, some of which are summarized as follows:

- Introduced an improved technology to the marketplace
- Reconfigured an existing platform with 3rd leg thruster
- Increased total power by 1700 HP
- Utilized low-emission Cummins KTA50 M-2 engine
- Retained and in some areas reduced overall vessel noise levels
- Retained lines of sight and ship contact angles
- Increased ahead bollard pull 53%
- Increased astern bollard pull 53%
- Increased side thrust 92%
- Increased VSP thrust by 4% with the installation of vortex fences on the blades
- Enhanced overall manoeuvrability
- Reduced pivot radius from 30.5 to 15.25 metres
- Increased side-step capability to 5+ knots
- Provided full CP capability with ASD and VSPs
- Provided free-wheel capability of ASD for fuel efficiency
- Introduced the concept of 'powered' skeg
- Retained indirect mode with lifting body effect of nozzle
- Added tension monitoring to hawser winch
- Added corrosion and marine growth protection to cooling circuit

As part of its Harbor Services fleet renewal program, Foss plans on performing *TractorPlus* upgrades to four additional tractor tugs (two 3000 HP and two 4000 HP Voith Tractor Tugs) over the next several years.

TractorPlus is the result of taking a very manoeuvrable vessel, the Voith Tractor Tug, and improving it even further in response to customer need. It is hoped that through this paper the reader will glean insights into one option available to introduce an innovative technological solution to improve performance and provide a significant life extension to a class of 25-year-old VSP Tractor Tugs.

Sometimes the challenges of meeting market-driven vessel performance standards can be rather daunting; however, complicated problems can be solved through a rigorous, thorough and systematic approach of research, engineering, construction, testing and training, and the extension of proven technologies to new concepts.

ACKNOWLEDGEMENTS

Don Hogue, Foss Director of Engineering, persevered in promoting his vision, passion and commitment to the development of this successful vessel. Without his ingenuity the *TractorPlus* would not have been realized.

The shipbuilders at Foss Shipyard contributed their ethic of high quality workmanship and efficiency to the success of the project.

Vendor Partners

The Glosten Associates.....Engineering
Cummins Northwest .....Main engine
Schottel, Inc. .....ASD unit
Harco Mfg. .....Exhaust silencers
Fisheries Supply .....Racor units
Markey Machinery .....Line tension monitoring
Marine Controls .....Alarm system
Peter Kalby Company.....Korfund exhaust mounts
Smith & Loveless.....Fast L – IX MSD System
Bill Blume.....Anti-fouling system
Centa.....Carbon fibre shafting