Lock-based ship design

Getting creative with the haul

RICHARD A. MUELLER, *President/CEO, NETSCo., Inc.*
NICK HUNTER, *Naval Architect, NETSCo., Inc.*

For centuries, locks and canals have been critical components of our waterways, allowing us to efficiently move goods from port to port. In Part 1 of this column, we looked at the history and impact of lock-based design on ships and the design characteristics of vessels that are largely prescribed by lock dimensions. Designing a vessel that will traverse the Seaway or Soo Locks results in narrow, shallow vessels that make pursuits to carry volume-limited cargoes, like containers, very difficult.

The concept of volume-limited cargo versus weight-limited cargo comes from Bernoulli's principle of buoyancy that keeps the vessel afloat; a vessel must displace its weight in water to float. Therefore, if you want to carry more cargo, you only have two options: increase your vessel's size or decrease its weight.

In an environment like lock-based ship design, where the vessel's maximum size and volume is constrained, the cargo carrying capacity is also limited. This is where the concept of volume-limited cargo versus weight-limited cargo comes into play.

Cargo designation as weight or volume limited largely comes from its density. Generally, a bulk product like taconite or oil has a high density. The weight of the cargo will limit how much a vessel can carry. Alternatively, a vessel will run out of cargo volume when carrying a lighter density cargo like coal or limestone before it is limited by the weight of the product. This important distinction is easily seen in a ship's design when comparing, for example, the size of an oceangoing containership to a liquid product tanker.

Maximizing cargo

If you compare a containership and product tanker of similar dimensions, like those designed to transit a specific lock system, you will notice that the containership (carrying the volume-limited cargo) is wide and tall with a good portion of the cargo above the waterline. The containership grows vertically to add as much cargo carrying volume as possible.

The tanker (carrying the weight-limited cargo) may have similar waterline dimensions, but almost all of the cargo carrying volume is below the waterline. Adding volume vertically does not help the tanker to carry more cargo because it is weight-limited, so the tanker's hull form becomes more full and "boxy" to displace as much water as possible in the lock dimensions. Both vessels are designed to maximize the cargo they can carry through the lock.

The size limitations through the Seaway, however, are such that any economies of scale for containerships, or other dedicated volume-limited cargo ships, are limited, therefore, forcing more creativity in vessel design and operation.

Business acumen

Creativity is a key for successfully shipping volume-limited products on the Seaway. One clever method for moving lightweight product is to back-haul grain. After a foreign vessel has brought in steel or iron products into the system, the crew will load grain for export instead of returning with ballast. This practice has been commonplace for years, and it consistently makes up about a quarter of the overall Seaway tonnage traffic.

Other emerging products have also been embraced by shippers to diversify and augment their business models for low density cargoes. Project cargoes (windmill blades, fermenters, etc.)—too large and costly to move over land—have been increasingly more evident on the Seaway.

An increasing number of containers are moved on the Seaway every year, too. Despite a limited number of Great Lakes ports capable of handling containers, the traffic has nearly tripled in the last 20 years, and the world market continues to see an optimistic future for container movements.

Great Lakes cruising is also a well-documented industry that has seen substantial recent growth despite the volume-limited nature of its "cargo." While COVID-19 closures have hampered the cruise industry recently, there has been a steady growth in the number of cruises offered through the Great Lakes/Seaway system.

Aided by technology

In lock-based ship design, when so many design criteria are controlled or limited, shipowners, operators and designers find creative ways to continue using the infrastructure to their benefit. However, not only do the vessels and owners adapt to their environment but, in some cases on the Seaway, the environment adapts to the vessels. As more pressure is put on the Seaway and its management to find ways to keep the waterway cost competitive with truck and rail transportation, methods and tools that can cut locking time, maintenance costs and improve operating efficiencies become more important.

The St. Lawrence Seaway system has had a long history of being in the forefront of using cutting edge technology, often in unique and novel ways, to make the passage of ships happen as rapidly as possible, yet more safely.

One of the earliest "new" technologies to take hold in the system was the use of the Automatic Identification System (AIS). Beginning in 2002, the system was the first inland waterway in North America to see the value and use the technology.

Combined with more accurate GPS technology, the use of AIS allowed lock operators to have much more accurate knowledge of vessel positions, real time vessel speeds and courses, and the

Despite a limited number of Great Lakes ports capable of handling containers, the traffic has nearly tripled in the last 20 years, and the world market continues to see an optimistic future for container movements.

ability to plan accurate vessel transits, dramatically improving events like pilot scheduling and flag-state inspections. Shipowners like to keep their vessels moving and employing GPS and AIS allowed the system to dramatically streamline vessel traffic.

With the success of AIS, shipowners looked for other technologies to improve operations. One such area involved ice. Given the winter climate, ice formations in the locks have long been an issue. The ice formations had to be locked through, much like the ships, during the opening and closing periods when ice was heaviest.

With the Seawaymax vessels, the lock must be flushed of ice before these large vessels can enter the lock. Beginning in 2011, ice flushing systems that reduced the strain on the locks and water valves were installed, resulting in fewer delays and the ability to keep the locks ice-free throughout the season.

About the same time, in 2012 and 2013, draft information systems allowed vessel owners and system authorities to accurately assess a vessel's under keel clearance, making transits safer and reducing the risk to physical assets, in particular, the locks. In 2013 and beyond, systems at each lock allowed the vessel to spot itself, improving operations even more by eliminating the need to have shoreside personnel spot each vessel as it entered the lock. These technology improvements, largely invisible to the public, played a major role in the system's ability to operate more efficiently.

Such innovations have continued. Hands-Free Mooring for vessels in the locks has been in use in the Welland Canal locks since 2007 and is now deployed across the system. This is a significant safety and time improvement, for both the crew and shoreside personnel, who no longer need to handle wire ropes and operate high speed deck winches.

Lastly, but by no means least, ongoing projects to test and eventually deploy all season buoys and aids to navigation on both sides of the border will likely result in safer navigation and reduced operating costs as we find ways to permanently mark important buoy locations without putting them in and removing them each year.

As you can see, merging vessel design with the physical realities of lock and canal designs and employing the latest technologies are working together to maximize the efficiency and effectiveness of the system.

Today, we're seeing the benefits as we watch hi-tech newly designed Seawaymax vessels transit the system, maximizing their loads, optimizing their transits and operating with the optimal crew size; so that in total, system and shipowner, and eventual the consumers, benefit from those savings. Now that's what good design engineering is all about. ■