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Super-C ferry design problems surface

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Noise and fuel consumption problems with BC Ferries' new German-built 'Super-C' ferries appear to stem from basic design decisions, particularly with respect to propellers and hull form.

A technical paper authored by senior members of the design team, Stefan Krüger of the Hamburg University of Technology, and Heike Billerbeck and Tobias Haack of shipbuilders Flensburger Schiffbau Gesellschaft outlines a design process that utilized a combination of model testing and computer methods to create the world's largest double-ended passenger ferries.

While Flensburger has considerable experience with Ro-Ro (Roll-on, Roll-off) ships, they have all been single-ended designs; their website lists no previous experience with double-ended ferries. According to the design team: 'Some of the design requirements put forward by BCF had been very hard to fulfill in the final concept. Most challenging was the demand for extremely low fuel consumption, low wake wash, and very good steering performance that had to be combined with the requirement for a diesel electric power plant. Furthermore, the operational profile of the vessel required a very short acceleration time of the vessel from zero up to full design speed, which is quite high with 21 knots.'

The specifications included:

- 370 vehicles, 1500 day passengers on 2 car decks,
- Dimensions and deck strake compatible with all mainland terminals,
- 21 knot service speed, 20 knots without one prime mover, 18 knots without two prime movers (prime movers are diesel engines; Super-C ferries have four),
- Double-ended configuration based on C- Class experience,
- Diesel electric propulsion,
- High lift rudders for optimum docking performance,
- Fast acceleration to service speed, and
- Significant turning rate >90 Deg/minute.

BC Ferries' specifications were based on the actual performance of the existing C-Class double-ended ferries, which were designed and built in BC between 1976 and 1981, and which are still giving satisfactory service.

The first of these, the *Queen of Coquitlam*, cost $20 million to construct in 1976. The three Super C's were built under a $334 million design/build contract with Flensburger, with a total budget, including import duty, of $542 million. (Of course, one must allow for thirty years of inflation.)

'These requirements lead to an unconventional propulsion concept with bow and stern CPP–Propellers (Controllable Pitch) which are operated in constant rpm mode where the bow propeller feathers with the trailing edge (propeller blades are like airplane wings; this means that the propeller blades are turned around so the trailing edge is forward). This propulsion concept is embedded into a completely new hull form that was developed on the basis of numerical flow simulations,' continued the designers.

The original C-class vessels were equipped with two controllable pitch propellers (each somewhat smaller than on the new vessels) and rudders at each end, and displaced about 6500 tonnes and were 457ft long. They were, when they were built, the world's largest double-ended ferries, but later lost their title to Washington State Ferries' Jumbo MkII design, which are 460ft long. The Super-C's are 524ft long, and displace a little over 10,000 tonnes; close in size to the BC-built Spirits, which are 549ft long and displace 11,600 tonnes.

But the new vessels have nearly the same carrying capacity —vehicles and passengers—as the original C-class vessels, so direct comparisons are valid.

Fuel Consumption Higher

BC Ferries' officials have claimed that the Super-C's are 30% more fuel efficient than the original C-class, but so far experience has not borne that out. In fact, running on Route 2 (Nanaimo–Horseshoe Bay), the *Coastal Renaissance* averaged 8,416 litres per round trip, but the *Queen of Oak Bay* averaged 6,491 litres per round trip (figures from BC Ferries' own fuel consumption records).

It is not surprising that BCF has chosen to substitute the older vessel for the newer one on this run for four days of the week. And use the *Coastal Celebration*, on the Swartz Bay–

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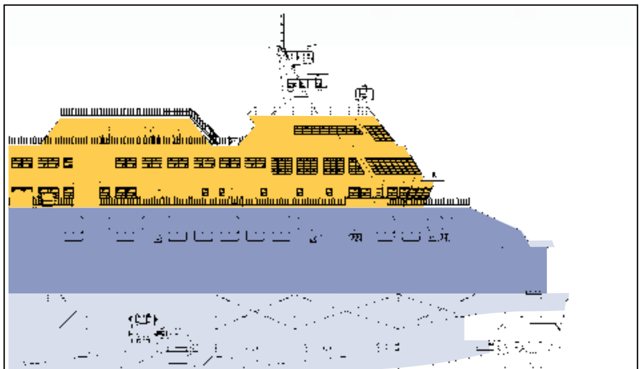
Tsawwassen route, only on weekends.

Noise and Erosion at the Terminals

It wasn't long after the *Coastal Renaissance* started running out of Nanaimo that local residents complained of the noise when the vessel was in the terminal, even to the point where some complained that the vibration was causing structural damage to residences. A 'carpet of foam' was reported from Horseshoe Bay when the vessel was loading and unloading there. And some erosion underneath a berth (leading to collapse of some of the concrete infrastructure) at Tsawwassen apparently occurred after the *Coastal Inspiration*, on the Duke Point run, had been docking there for some time.

A Single Large Propeller at Each End

The Super-C's have a single large propeller and a single large rudder at each end, unlike all the other BC Ferries that cross the Strait of Georgia, which have twin screws and twin rudders. It is an accepted maxim in ship design that the larger the propeller, the more efficient it will be. To quote the designers: 'Based on the maximum draft of 5.75m, a propeller diameter as large as reasonably possible was selected, which resulted in a 5



Engineering drawing of one end of a Super C-Class. The propeller height and loaded waterline are shown.

metre propeller diameter.' (See drawing.)

So each four-bladed controllable pitch propeller is 16.4ft in diameter, operating at a constant speed of 130rpm, whether the ship is docked or moving. The speed and direction of the vessel is controlled by the direction of rotation of the propellers, and by the pitch, or angle of the blades.

The pitch varies from positive, when acting as the stern propeller driving the vessel forward, to negative, when acting as the forward propeller set, with blades trailing edge first, to minimize drag. When the vessel is stationary in a berth, the pitch of the forward propeller is set near zero, but both propellers continue to rotate at 130rpm.

Propellers Close to Surface

Drawings indicate that the lowest point of each propeller is in fact 5.75m below the loaded waterline, which means that the highest point is .75m below the loaded waterline. But, unloaded and in its berth, the draft of the ship is about 5.2m (see photo),

One of the rudders of the *Coastal Celebration*. The vessel is berthed, unloaded, and the propellers are stationary. Note the draft markings.

and so the tips of the rotating propellers are a mere 0.2m (8 inches) below the water's surface. And the speed of the propeller tips is 51.5 ft/revolution, or 76mph.

A propeller tip traveling at 76mph only 8 inches below the water's surface might very well create disturbance and noise from cavitation, described by the designers as 'air drawing'. (As the propeller tip travels at speed just under the water surface, it will cause waves, possibly breaking waves, which will enable air to be drawn down from the surface). This is not, of course, a problem when the vessel is fully loaded and at speed, because the propellers are amply covered, not only because of the load, but also by the bow and stern waves induced by the hull shape.

Test for cavitation were carried out on a scale model at the Hamburg Ship Model Basin: 'If the stern wave height and the dynamic sinkage at the A.P. (aft propeller) were taken into account, the dynamic immersion of the propeller was large enough to fully absorb all required power without any hint on air drawing ... During all tests, there was no indication of air drawing. To check for the influence of air drawing on the station keeping, additional bollard pull tests were performed. These tests showed that without stern wave, some slight air drawing could be noted.' (A bollard pull test means that the ship is held stationary but the propellers are run at full thrust.)

Tests at Maximum Draft

It seems probable that the scale model used assumed maximum draft (5.75m). However, the designers were aware that the vessel would spend part of its time unloaded and in a berth: '... the operational profile of BCF required a significant

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amount of time where both propellers were idling in harbor during loading/unloading, resulting in an off-design condition that had to be regarded for the propeller design with respect to erosive cavitation. This condition was considered a problem as the propellers were always operated in the constant rpm mode.'

BC Ferries have stated that when the ship is fully loaded, the disturbance resulting from the rotating propellers is reduced. A couple of weeks ago, to enable this theory to be tested, eighteen fully loaded gravel trucks were driven onto the deck of one of the ferries while it was tied up. BCF have not yet announced the result of this experiment.

Operating the Super-C's

There seems no doubt that 'driving' a Super-C is different from any other BC Ferry. To reduce wake, the hull shape has a wide, flat bottom, different from the V-shaped bottom of the original C-class vessels. There is no skeg (keel), leading to a different approach to steering. From the designers' report: 'Course keeping ability is a problem for this type of ship due to the unfavorable main dimensions (with respect to maneuvering) combined with the double-end ferry restrictions. There are only a few ways to influence the hull yawing moment due to the fact that both the fore and aft body are the same. Furthermore, the bow rudder is problematic because it decreases course stability drastically even if fixed at the neutral rudder angle.'

In fact, concern with this was so great that BCF required the designers to guarantee that the new vessels could be safely steered through Active Pass in adverse tide and weather conditions. (A number of years ago, the C-Class *Queen of Alberni* ran aground in Active Pass, resulting in damage to trucks and cars and the death of one racehorse.)

The designers met this challenge by setting up a model of Active Pass on a Danish nautical training simulator. The ship's characteristics used were drawn from the extensive mathematical models which, together with tank testing, had been developed during the design process.

Greater Weight = Heavier Fuel Consumption

The Super-C's are some 70% heavier than the original C-Class vessels. They have more decks and are more heavily built; possibly the structural need to absorb the energy emanating from two very large propellers constantly rotating and located at the very ends of the vessel may be a factor. But this weight, together with the need for new 'driving' techniques, may well be a major influence in higher fuel consumption.

BC Ferries President David Hahn has suggested that the fuel economy of the new ferries may well improve as crews become more experienced at operating them. This remark seems to have met with some scepticism among the crews, but time will tell. But the fact remains that the new vessels are bigger and heavier, but do the same job as the older ones, albeit with more amenities.

And whether fundamental design decisions—hull shape and propellers—were sound, remains to be seen. ✐

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