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Paper: DESIGN & CONSTRUCTION OF A 100 VEHICLE FERRY

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INTRODUCTION

The British Columbia Ferry Corporation was incorporated in 1960 as an independent agency under the control of the B.C. Provincial Government.

B.C. Ferries operates a total of 39 steel ferries, 17 of which operate on "open water" mainland routes and 22 of which operate on short distance routes to various islands on the protected waters of the B.C. coast.

Over the last four decades, the volume of traffic has steadily increased. Consequently, the original vessels are now too small to accommodate current and future demand.

In January of 1995, B.C. Ferries issued a "Request for Proposal" for the design of a "fairly spartan and cost efficient" 100 vehicle Century Class commuter ferry.

The Century Class ferry is intended for use on a number of short distance ferry routes serviced by B.C. Ferries. These routes are one to five miles in distance and predominantly commuter-oriented with heavy early morning and late afternoon rush hour traffic patterns. This ferry was also to be capable of operation on longer routes.

After a tendering process which included preliminary design submissions and a presentation to B.C. Ferries' management and operator committee, McLaren & Sons, Naval Architects, a division of Allied Shipbuilders Ltd., was awarded the design contract.

Subsequent to completing the vessel design Allied Shipbuilders participated in a public bidding process and, on a low bid basis, was awarded the construction contract.

The design and construction of this significant vessel provided Allied the opportunity to conceive and execute a variety of ideas which we felt would both simplify construction and provide a vessel of superior performance and longevity.

HULL FORM DEVELOPMENT

B.C. Ferries operates eight ferries of 50 to 85 vehicle capacity, each fitted with four 360º steerable drives. These vessels have two basic hull forms; barge-like or double-ended "conventional" form of relatively shallow draft and high beam.

It was the designer's original intent to utilize a similar "conventional" hull form for the Century Class ferry. This was not to be the case.

McLaren & Sons, Naval Architects, engaged the services of Josip Gruzling, P.Eng., of Nautican Research & Development Ltd. to undertake resistance and powering predictions for the new Century Class ferry. While comparing the performance of similar four 360º steerable drive ferries of the Owner's fleet, it became apparent that these types of vessels had a speed performance significantly lower than similar ferries driven by conventional shafts and propellers. The Owner's speed/power requirements of 14½ knots at 4500 HP seemed unlikely to be met for a four 360º steerable drive ferry of the size of the new Century Class ferry, based on these comparisons.

Further analysis of the resistance and powering data indicated that the bare hull resistance of the group of steerable drive ferries were similar to the bare hull resistance of the conventionally propelled ferries.

Josip Gruzling concluded that the location of the four 360º steerable right angle drives and the flow direction in the vicinity of these drives was responsible for the performance loss. It was evident that a different hull form had to be developed to accommodate the four 360º steerable drives to achieve the Owner's speed/power requirements.

In addition, the User Committee raised the issue that the new Century Class ferry was required to have very little lateral resistance to permit the vessel to hold herself in a cross current, without being swept downstream; a very real requirement of the Campbell River/Quathiaski Cove route.

So great was the concern of the need for the new vessel to exhibit good sideways performance that B.C. Ferries arranged to bring a vessel of similar size and power to the proposed Century Class ferry route to undertake a sea trial.

The "*Queen of Capilano*", a 314 ft., 4800 HP, four 360º steerable drive ferry, was moved to the Campbell River/Quathiaski Cove route. The ferry operators and designers were given a first-hand

opportunity to witness her performance during moderate conditions. The "*Queen of Capilano*" was trialed when sideways to the current during her transit across this route and proved unsatisfactory. The results of this trial, together with the speed/power requirements, caused the designers to completely re-evaluate the hull of the Century Class ferry.

Consultation with the User Committee indicated the current vessel on the route, the "*Powell River Queen*", a 3600 HP, four 360º steerable drive ferry, has been successful.

A review of the "*Powell River Queen*", originally designed by McLaren & Sons in 1963, revealed that the hull presented little lateral resistance, had a large bilge radius and virtually no skeg.

The "*Queen of Capilano*" on the other hand had a full length keel with hard edges which protruded about one foot below the bottom.

A sea trial of the "*Powell River Queen*" traveling at full power sideways indicated she could attain a speed of about 4 knots.

In response to these two challenges, a unique new hull form was developed which would provide:

- suitable displacement and stability characteristics for a roll on / roll off vehicle ferry which is expected to accommodate all manner of road legal vehicles from private vehicles to loaded semi-trailers;
- low resistance for economy;
- low sideways resistance to permit operation and stopping in a side current;
- directional stability during transit; and
- high maneuverability.

Additional characteristics McLaren & Sons imposed upon the hull form design included:

- The hull in way of the drives to be flat permitting all four right angle drives to be identical and the shaft lines horizontal, a desirable feature for construction. This would also permit one spare drive unit to fit at any position on the ship.

- Hull geometry to be of developable geometry to maximum extent possible to permit building with minimal compound curvature of plating.

- Hull geometry had to suit machinery space access from the outboard superstructure to suit the concept general arrangement.

- Hull geometry had to dictate a logical level of double bottom, preferably in one plane for ease of construction.

McLaren & Sons, working with Josip Gruzling, developed a unique new hull form which addressed all the parameters (see Figure No. 7).

Hull form geometry was a shallow draft, flat bottom with round bilges and cylindrically developed bottom and side shell. The flat of bottom rose to a flat in way of the four right angle drives to permit all the right angle drive seatings to be identical.

The hull in way of the drives was shaped to align the water flow into the propellers. The propellers are situated relatively close to centreline. Both of these features were to permit the propellers to operate more efficiently.

To meet the sideways performance criteria, the hull was formed with a large bilge radius and flat bottom. The hull was kept smooth and a fairing fitted on each side of the bottom of the keel at the ends of the vessel to reduce lateral resistance.

To ensure each drive unit could operate at maximum efficiency when they are turned athwartship in the same direction, and to minimize the wash of one propeller from being directed into the opposite propeller, a simple deflector skeg below the keel line was incorporated in way of each pair of drives. This deflector skeg would help divert the wash of the upstream drive unit below the propeller of the downstream unit.

A concern regarding directional stability arose due to the flat bottom and the absence of a skeg. We felt this concern would be addressed by the slender aspect ratio of the waterlines, fine bow entry and stern exit and the use of four propulsion nozzles, which would act as control surfaces enhanced by the momentum of water through the nozzles.

Other features of the hull include:

- Straight line camber on the main vehicle deck outboard, with a 15 ft. wide flat section at centre.
- A "reverse" straight line sheer on the main deck such that the hull is deeper at midship than at the vessel ends. The full depth is required at midships to

accommodate longitudinal strength requirements. The depth is reduced at the vessel ends to suit the existing ferry terminals.

In June 1995, the Vienna Model Test Basin was commissioned to construct a large scale (1:14.7) model and conduct model testing to confirm the hull form would achieve the desired results. The model test results met or exceeded objectives.

Test results indicated:

- The hull could attain 14.5 knots using only 3700 HP.
- The hull could attain 4.2 knots sideways at a power of 6500 HP.
- No cavitation at the drive units due to air ingestion in a seaway.
- Good directional stability.
- Very good alignment of flow into the four right angle drive nozzles.
- The deflector skeg for athwartship thrusting was effective.
- Very low wake characteristics.

PERFORMANCE

An extensive series of sea trials were conducted on the "*Skeena Queen*" prior to delivery of the vessel to B.C. Ferries.

Trials instrumentation included strain gauges fitted to all four propulsion shafts, computer integrated course plotting and data logging of all trials data.

(i) Wake Characteristics

Although no measurements were taken, the "*Skeena Queen*" displayed very low wake characteristics.

Observation of the wake is that it does not appear to increase with increases of speed over the range of 10 to 17 knots.

After nearly one year in service, there has been no "big wave" complaints from shoreside residents or marine traffic. The "*Skeena Queen*" is able to run at full speed in locations where all other ferries must reduce speed to minimize wake.

(ii) Speed/Power – Ahead

Actual shaft horsepower was calculated from the shaft speeds and torques measured at each shaft line during speed trials (see Figure No. 9). Performance showed a close correlation with the tank test data from the Vienna Model Basin. The "*Skeena Queen*" achieved 14.5 knots at approximately 3400 SHP and attained a maximum trial speed of 17.3 knots at 6000 SHP. The vessel is fitted with four modified type 19A (shortened chord) propulsion nozzles. Propellers are fixed four blade moderately skewed, 1900 mm diameter x 2275 mm pitch. The propellers were designed by Josip Gruzling, Nautican R&D and manufactured by Osborne Propellers Ltd., both of Vancouver, Canada.

(iii) Speed/Power – Sideways

All four drive units were positioned in the same direction athwartship and a speed trial conducted at various shaft speeds with the vessel traveling sideways. Shaft torques were measured and a speed power curve produced (see Figure No. 10). The vessel attained a sideways speed of 4 knots at approximately 5000 SHP which correlated very well with the tank test results.

(iv) Vessel Acceleration

As the inter-island route ferries spend a large proportion of their transit time maneuvering and coming to operating speed, a test of the acceleration performance of the "*Skeena Queen*" was conducted. From a stopped position in the water, full throttles were applied to all four main engines and the speed and time was recorded (see Figure No. 11).

The vessel attained a stabilized full speed of approximately 17.3 knots in 120 seconds. The operators felt this was very good performance.

(v) Emergency Stops

Emergency stop trials were conducted with the "*Skeena Queen*" traveling forward and the four 360º steerable drives turned 180º to thrust forward while throttle positions were maintained. At a top speed of 17.3 knots, the 110 m (360'), 2100 tonne vessel stopped in one and a half ship's lengths (see Figure No. 12).

IN SERVICE

After the "*Skeena Queen*" was delivered to B.C. Ferries on March 27, 1997, the vessel and new crews underwent a six week training period to familiarize themselves with their new vessel prior to entering service.

Although the "*Skeena Queen*" was originally destined for the Campbell River/ Quathiaski Cove route, she entered service on the Swartz Bay/Fulford Harbour (Saltspring Island) route where she has served ever since.

Feedback from the operators has been very favourable and includes:

- the operators like the high performance capabilities of the "*Skeena Queen*";
- the vessel provides very good visibility from the control positions;
- the stability characteristics of the hull permits very easy loading of vehicles. Any manner of vehicles including fully loaded trucks can generally be located anywhere on the vehicle deck without causing trim or list or requiring adjustment of the shoreside vehicle loading ramp.

CONCLUSION

The Century Class ferry has a unique hull shape which minimizes wave-making, enhances sideways performance, and enables reasonable transit speeds at relatively low power.

The Century Class ferry provides superior vehicle and passenger carrying capacity and performance at significantly lower construction, operating and maintenance costs as compared to similar sized minor route ferries.

The Century Class ferry, M.V. "*Skeena Queen*", has proven to be a very successful solution to B.C. Ferries' requirement for a "spartan and cost-efficient" ferry.

THE FUTURE

The fitting of 360º steerable drives in new vessels is now a common occurrence. The unique hull form developed for this project provides speed performance equal to conventional "solid shaft" ferries with the benefit of exceptional maneuverability.

360º steerable drives free the designer to utilize entirely new forms.

Figure No. 14 presents speed/power curves for the "*Skeena Queen*", both as built and as predicted, were the nozzles to be removed and the propellers optimized accordingly.

A 50 car ferry is considered which would be very similar to the "*Skeena Queen*", but smaller. A 470 car ferry is also proposed. This proposal is based on a vessel of overall size and displacement similar to that of the 550 ft. Spirit class vessels of the B.C. Ferries fleet.

The designers firmly believe that the use of a "high efficiency" nozzle design would be very appropriate on such a vessel. It is expected that a "high efficiency" nozzle will provide performance similar to an open propeller variant while providing for superior maneuverability and safety.