



REPORT

FAST RORO FERRY STATE OF THE ART STUDY FOR SEABRIDGE FERRIES

Deltamarin Ltd
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DELTAMARIN LTD
Purokatu 1
FIN-21200 RAISIO
Tel. +358-2-4336 300
Fax. +358-2-4380 378
Email: info@deltamarin.com

REPORT FOR PROJECT 5377

FAST RORO FERRY

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STATE OF THE ART STUDY

CLIENT: SEABRIDGE FERRIES

PREPARED BY: DELTAMARIN MAK, EP, JAH

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DELTAMARIN LTD

	Date:	Initials:
DESIGNED:	27.6.04	EP, MaK
CHECKED:	27.6.04	JAH, MaK
APPROVED:	27.6.04	MaK

DELTAMARIN LTD
Purokatu 1
FIN-21200 RAISIO
Tel. +358-2-4336 300
Fax. +358-2-4380 378
Email: info@deltamarin.com

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PART I STATE OF THE ART ANALYSIS

0. INTRODUCTION

A state of the art analysis and market study has been carried out covering fast ro-ro ferry ships, designs, experience and expected future development and related and required technology and reference vessels.

The first part describes the objectives of SeaBridge Ferries and the possible solutions/designs/configurations to reach these objectives.

On basis of the available references (built ships and designs), theoretical background, development of required different technologies and our own experience, we have drawn conclusions about possible solutions to reach the set of objectives.

Possible risks related to different designs and configurations are listed and ways how to approach, check and minimize these risks.

1. OBJECTIVES

Objective for this analysis is to define possible available and/or promising designs, configurations and technologies to be able to successfully design, contract, build and operate a ro-ro passenger ferry with the following main characteristics:

- Payload of the vessel 4500 tons (minimum)
- Ro-ro lane meters 2500-2800 meters
- Total deadweight about 6500 tons
- Operational service speed 40 knots plus
- Reasonable and comparable fuel consumption and another operating costs
- Unlimited ocean service capability (at least as design criteria)

Secondary design criteria being:

- Acceptable passenger comfort
- Acceptable emission control and possibility to upgrade with fore seen future requirements
- Acceptable reliability and availability to secure scheduled traffic
- Good harbour manoeuvring, approach and berthing capabilities
- Straight forward and good cargo handling and logistics (comparable to the speed)

Reasonable refers to typical figures/levels with any competitive transport methods.

Comparable refers to typical levels with known solutions.

Acceptable refers to typical industry regulations or standards.

There are two essential objectives: Speed combined with high payload.

This combination (40 knots plus and 4500 tons payload) is not yet available on the market as a built ship. There are also no well-proven and tested designs directly available on the market.

There is, however, considerable research and development recently carried out or ongoing related to the above objectives. There are also several designs and configurations available which give promising results concerning one or several of the above objectives.

The minimum objective is to reach 40+ knots with a cargo carrying capacity of 125 trailer units of 20 meters each, i.e. minimum 2100 lane meters requiring a minimum of 3,500 tonnes payload or about 5,000-5,500 tonnes deadweight with reasonable fuel cost.

2. ANALYSIS

This analysis is built up with a stepwise approach:

- First looking at the present market of fast vessels
- Selecting possible promising platforms for further development
- Looking on possible ways to approach this sea transport task
- Looking on possible techniques available for set objectives
- Defining risks involved in the possible solutions
- Conclusions

This analysis is based on the available market information, related business information, our own company knowledge and also taking into account typical development on the marine field (when predicting possible future development).

2.1 Present Market Situation

High speed ro-ro ferries can be subdivided into two basic categories:

- Fast full displacement ferries
- High speed ferries

Hybrid solutions have also been designed and tested in model scale, but not yet built. The main difference between these two classes are the cargo carrying capability (payload) and maximum possible operational speed in service.

Fast full displacement ferries typically have a deadweight (payload and consumables) between 2,000 and 10,000 tonnes, depending on the size of the vessel, and speed below Froude number (Fn) 0,40.

Deadweight is a big percentage of the displacement. Froude number is a non-dimensional coefficient defining the wave system [speed (m/s) divided by square root of the multiplication of waterline length (m) and gravity (m/s²)].

High-speed ferries do carry less deadweight and payload (deadweight is a smaller percentage of displacement), but operate at higher speeds, *i.e.* at a higher Froude number, above 0,45 to 0,50.

There are vessels built to the High Speed Code (HSC) (high speed vessels), Navy vessels and fast full displacement vessels (typical commercial displacement vessels), which all satisfy some of the above objectives and thus are possible platforms for further development. Different regulations however apply to these three categories.

High speed ferries are mostly catamarans and monohulls. A few other type of multihulls exist, but the common feature is that they are built to the HSC Code and are intended mainly for passenger traffic with some car/bus/truck capacity with a typical maximum sailing time of three hours (rule limit 4/8 hours or distance to point of refuge). Three hours sailing time is typically dictated by passenger comfort, vessel motions and accelerations in moderate and heavy seas. The biggest HSC Code built vessel as of now is the Stena HSS 1500, which can carry 1,500 passengers with a deadweight of 1,500 tonnes including capacity for cars and a few buses/trucks and able to reach a speed of 40 knots with gas turbines and waterjet propulsion.

Fast full displacement ferries are being built up to 30-32 knots service speed with high deadweight up to 10,000 tonnes, but typically being in the 5,000 – 6,500 tonne range. Their sizes vary from 110 meters up to 240 meters in length. They have diesel machinery with propeller propulsion, except the 1978 built Finnjet, which has gas turbines and propellers. Diesels were installed later for more efficient low speed operation.

The transAtlantic liner, SS United States, built in the 1950's had steam turbine machinery with four propellers and was able to reach 36 knots on trials. The passenger cruise vessel, Queen Mary II, was delivered in January 2004 and can reach 31 knots, using a combination of diesel and gas turbine electric machinery with four pods as propulsion, two of which are steering units.

Several projects of different topics and vessel types have been or are being carried out to reach operational speeds up to 40 knots and over and/ or to develop techniques to solve some of the related problems, some to mention:

- FastShip, new generation of fast container ship, service speed 37,6 to 40 knots, payload of minimum 10,000 tons, 250 mW in installed power with gas turbines and five waterjets;
- European High Speed Cargo Vessel (EHSCV) by IZAR and Rolls Royce, with a speed of 37 knots using two gas turbines with a total of 64 mW in installed power and two waterjets for propulsion and a capacity of 1,700 ro-ro lane meters;
- Virtual Ship and ROPAX 2000, a EU-funded project working among other things for a 40 knots ro-pax vessel with relatively high deadweight and at the moment based on gas turbine machinery with waterjet propulsion.
- EU-funded projects working on propulsion systems, efficiency and propulsion induced noise and vibration, such as project Leading Edge, Fastpod and similar
- Pentamaran with slender centre hull with two outriggers per side, using diesels and waterjet propulsion, the slender centre hull is designed to lower hull resistance at high speed with the outriggers providing adequate stability at different loading conditions
- Panamax cruise ship with three propellers, model tested up to 42 knots with several machinery options studied, including steam turbine, diesel-electric, combined gas turbines and diesels.
- New ferry developments carried out by shipyards, e.g. Aker Kvaerner yards, especially Masa Yards, together with Wärtsilä Diesel and ABB

All above designs have been widely model tested at different European model basins and preliminary designs have been prepared either by shipyards or by consultants/designers. Further development is required. None of the above vessel designs have yet been built either.

2.2 Platforms for Development

There are basically four ways to go ahead to develop a ro-pax ferry with the set objectives:

- Extrapolate fast full displacement ferry design
- Extrapolate high speed ferry design
- Hybrid solution
- Develop a prototype.

To extrapolate a fast full displacement ferry, there are two main problems: minimize hull resistance to reach acceptable/reasonable fuel consumption and use high loaded propellers for higher speeds than built until today. To improve propeller situation it might be required to use extensive, high draft for the vessel i.e. to have space for large propellers.

To extrapolate high speed code ferry we need to find fuel efficient, light weight machinery and especially to reach payload far above reached until today. A much bigger vessel with better fuel efficiency than built up till today should be extrapolated using light materials and machinery not yet applied on the market.

To develop a hybrid solution into a high payload ro-pax ferry requires even bigger steps than with HSC vessels. There are mainly two known concepts: Surface Effect Ship (SES) and Air Supported Vessel (ASV), both concepts still being at conceptual and testing level even at the smallest scale.

To develop a prototype may include several risks, such as finding efficient machinery, rules missing, no built references, structure and weight might be a question mark and so on.

2.3 Possible Techniques Available

Machinery

The well known, mostly applied machinery configuration in ro-pax vessels is diesel machinery with medium speed engines either direct coupled via gear box to propellers or diesel electric with electric propulsion motors coupled directly or via gear box to propellers. The first one being the most common whereas the second one being mostly applied in passenger cruise vessels. This is forming the basis for machinery efficiency and fuel consumption levels and is comparable to land transport. Diesel engines consume about 175 g/kWh burning heavy fuel of the size engines required for this size of vessel.

Gas turbines are mostly used in high speed code vessels due to high power/weight ratio. However the specific fuel consumption is high, 235g/kWh at high engine load and they burn marine gas oil, being 60 to 70 USD per ton higher in price. At low engine load specific fuel

consumption is between 280 and 330g/kWh further limiting the use of gas turbines in an acceptable reasonably fuel efficient ro-pax vessel. Some of the most recent passenger cruise vessels do have either combined gas turbine and diesel electric or gas turbine and steam turbine electric machinery. This is mainly for environmental reasons or for other power consumption than propulsion (hotel load) and to receive more passenger space and carrying capacity in limited dimensions.

At the moment the most promising machinery with acceptable and reasonable fuel consumption is diesel machinery burning heavy fuel oil. Installation for emission gas control should be taken into account.

Propulsion

All displacement type ro-ro passenger ferries have propellers as their propulsors. There are a few ferries built with pod propulsors. The biggest problem to use propeller propulsion for the required high speed is to install all the required power on the limited propeller diameter due to limited draft of the vessel. For example the TransAtlantic passenger liner mentioned above had a draft of 11 meters and a centre propeller of 8 meters with a maximum power of 84 MW.

The maximum propeller loading in commercial vessels is about 1700-1800 kW/propeller disc m². In a ro-pax ferry with a draft of 7,5 meters we could install a propeller of maximum 6 meters in diameter and have a maximum installed power of about 50 MW. Three such propellers would give us a total installed propulsion power of about 150 MW. Is this enough to reach the intended speed with the required payload? And is it possible to design hull form to have three such propellers installed? Passenger comfort is also of importance. These are the main challenges.

Navy vessels have even higher propeller installed power per disc area, but they are not used for continuous operation and do not have to fulfil any comfort requirements. Efficiency can still be high and acceptable at the propeller loading of 1800 kW/disc m², e.g. in the Trans Atlantic passenger liner/cruise vessel was heavily tested and propeller performance good/excellent. Typical highly skewed CP propellers were used and cavitation performance was acceptable.

Waterjets are typically used in high speed ferries. They are more suitable for higher speeds than propellers and their efficiency is relatively good. Propellers do have higher efficiency at same vessel

speed. Waterjets are already operating for speeds at 40 knots and well above. They do require specific location in the aft ship hull and thus hull form, limiting especially the design in the aft part of the vessel for high displacement.

Third alternative is pod propulsor, being fixed or rotatable thrusters with an electric propulsion motor built in to the pod. They have mostly been applied in passenger cruise vessels for high passenger comfort and manoeuvrability reasons. They have been applied in a few ferries and most recently above 30 knots. Their efficiency is as per propellers or higher, overall propulsion efficiency.

Both propellers and waterjets offer possible solutions for propulsion as well as pod propulsors for the intended ro-pax ferry.

Hull form

Development of hull shapes of all different above listed vessel types has taken remarkable steps during the last ten-fifteen years. Vessels built today have 10 to 15 % better fuel efficiency than similar vessels built ten years ago simply due to better developed hull form characteristics and shapes. New features have been applied, such as surface piercing bulbous bows, trim wedges and then completely new hull form configurations, such as multihulls,

Full displacement vessels have received characteristics typical for high-speed vessels, i.e. utilising dynamic lift effects. Semi planning hull forms have been developed as well as multihull configurations, trimarans and pentamarans being typical examples.

Most promising hull forms are obviously full displacement high speed ferry hull forms combined with successful combination of characteristics from semiplanning hulls, or multihull configurations ensuring adequate displacement to reach required payload, or navy type of hull forms (frigates and fast patrol vessels), or combination of above.

The issue for a typical fast full displacement monohull is to minimize the resistance to reach an acceptable level of propeller loading and fuel efficiency. Characteristics of hull forms creating hydrodynamic lift could be an alternative, already applied to some extent in present fast full displacement ferries, e.g. trim wedges and similar. Navy type of hull forms with deep V-type bow, round bilge and pram type aftship have been applied e.g. in the FastShip and EHSCV projects.

Multihull configurations are typically designed to reach high speed with relatively low resistance and propulsion power, but they do lack displacement to carry high payloads.

Pentamaran multihull configuration is a combination of slender 'conventional' vessel and outriggers. Model test results so far have been promising.

Structure and materials

Ferries are built of normal shipbuilding steel and aluminium is used only in very limited extent mainly to improve stability. High tensile steel is used for weight saving purposes. All fast full displacement ferries are built with above principle material definition.

High speed code ferries are either built of aluminium or of light construction steel (HSC construction principles, i.e. limiting speed with wave height).

It is foreseen that vessels with unlimited service areas need to be constructed of steel and according to normal ship classification rules. It is not foreseen that other materials or construction principles could become an alternative within the next 15 to 20 years.

Speed and wave height, seakeeping, is of great importance for the hull form and dimensioning principles and loads for the hull structure. There is still rather limited amount of data available of operation at high speeds in high seas. The QEII is the only modern vessel with North Atlantic operational experience at relatively high speeds in severe weather.

Normal high tensile steel is considered to be the only alternative at this moment in the hull and superstructure, with some aluminium or similar applied in the upper parts of the superstructure.

Where as in other areas, such as piping and interior outfitting alternative materials are already being applied instead of normal shipbuilding practises and alternative design principles (IMO alternative rule) do support this.

2.4 Risks

The following describes the main risks encountered with the different platforms in developing them to fulfil the set SeaBridge objectives.

Fast full displacement vessels are capable to reach high speeds up to 36 knots today with adequate payload and the machinery is well supported by the volume and displacement of the vessel. Fuel efficiency is reasonable.

The main tasks are to develop the hull form to carry the payload with reasonable fuel efficiency. Two main risks are encountered:

- Can reasonable fuel efficiency be reached with the intended payload
- Can the required propulsion power be installed in given number of propulsors, propeller diameter and limited (harbour) draft.

Development of hull form characteristics and propulsion arrangement is required in model scale, with propellers, pods or their combination.

Risks are considered reasonable and no hidden risks are foreseen. The challenge is to have a good pram type hull form in the aft ship for three main propulsion units, propellers recommended, combined with large propellers and limited draft.

HSC ferries are mainly built of aluminium or with light steel structure and aluminium superstructure to reduce the weight. The main problem is the requirement for low lightweight in order to reach the high speed supporting relatively low payload.

There is high risk considered in trying to develop a 40 knots plus ferry with high payload out of a typical high speed code ferry. The main risk is that the task is not considered feasible at all, with major issues in structure, materials, hull displacement and thus in payload. Another risk is also related to weight i.e. low weight requires gas turbines as machinery leading to high fuel consumption and fuel costs.

The present developments do not indicate that there would be any designs or even basic concepts available within the next five years, which could fulfil the set objectives.

Hybrid solutions are e.g. Surface Effect Ship (SES) or Air Supported Vessel (ASV). Air supported vessel concepts have been developed to overcome the problems with the curtains related to SES technology. Air is blown between side parts of the hull underneath the centre part for about 2/3 of the length of the hull and air is regulated by the flaps at the stern of the ship. However promising this concept may look at the moment, it is still a long way from being applied commercially. At this moment it is not possible to predict if it will be possible to design high payload ASV vessels that can carry sufficient payload on commercially viable costs.

Risks are considered as high to reach the set objectives within next five to ten years, main risks being in the final required engine power to give the required air support and actual payload gained.

Some prototype vessel concepts and configurations have been developed and tested during the last 3 to 7 years, best known examples being the FastShip and Pentamaran concepts. The EHSCV resembles FastShip. Fastship and EHSCV both use gas turbines and waterjets, whereas Pentamaran utilises diesel engines and waterjets.

Fastship and EHSCV concepts do not yet offer a platform with reasonable fuel efficiency. Utilising diesels in these concepts instead of gas turbines would be the easy solution, but due to additional

weight and high propulsion power demand the risk is considered high within short notice, less than five years time. The problem is the volume required by diesel machinery and the relatively high additional weight brought in by diesels.

Pentamaran configuration offers two benefits in comparison to FastShip: lower resistance allowing for diesel machinery and higher displacement and volume in the main hull to accommodate diesel engines.

The structural issues of a Pentamaran design are not yet studied with a prototype and regulations are do not yet fully support this type of multihull. Weight of the structure is a risk related to the dimensioning of the outriggers and especially their supports. Additional structure may lead to increased weight and thus higher required displacement and further to higher required propulsion power. Detail investigations are required for this size of Pentamaran.

3. CONCLUSIONS

On basis of our analysis in this part and the market study in part two of this report, our conclusions are:

- There are two potential candidates for development of a ro-ro ferry to meet the objectives of SeaBridge Ferries: fast full displacement type ferry and the Pentamaran.
- Fast full displacement ferry needs to be developed for the high operational speed concerning hull form and propulsion arrangement. Alternative approaches should be developed and analysed with theoretical methods and only after that model tests should be carried out. Criteria for the model test results should be defined before starting any testing. Final dimensions of the vessel require careful investigation. It is preferable to stay in the Froude number below 0,40 and in the length and beam of the vessel Panama Canal restriction should be carefully considered. Draft of the vessel should be maximised within the limitations of intended harbours.
- Full structural analysis should be carried out for the Pentamaran configuration including definition of design criteria and applicable loads together with detail weight analysis together with model tests with the final hull form and displacement. Sensitivity study is recommended to check the consequences of large variations in the final lightweight of the vessel. Hull form and structure of the vessel should not limit the operation of the vessel, but other limitations may apply i.e. passenger comfort.
- Diesel engines are recommended as main machinery. Booster engines might be considered if different operational speeds are considered, gas turbines might offer a best solution then.
- Propellers and/or waterjets and/or pods are recommended as propulsors. Combinations of the above might offer interesting solutions especially concerning overall efficiency. All possible and realistic combinations should be studied even for Pentamaran, which should be feasible for propeller propulsion as well.

- Typical shipbuilding steel is considered and recommended for structural purposes. Aluminium and other light materials should be used for weight saving purposes, but in secondary areas only.

Third party (experienced) reviews are recommended through out the development process, whichever solution is selected for further development. It is considered possible to reach the set objectives with a well-planned and organised development project.