1. INTRODUCTION

In July 1995, a European Ship Owner approached Nigel Gee and Associates Ltd (NGA) with a request for a fast freight vessel capable of carrying 13,000 tonnes of cargo at 30 knots whilst using an installed power of only 30 MW. Since ships of this speed and deadweight had previously required 50 MW, the Ship Owner’s requirement seemed difficult if not impossible. Initial parametric studies by NGA indicated that a trimaran hull form could give powers close to the desired level. Further parametric studies and tank tests showed that a trimaran hull form modified to a long, narrow monohull stabilised by a total of four small sponsons produced a vessel of the required performance with an installed power of 33 MW which was regarded by the Owner as sufficiently close to his target to proceed further.

Further tank tests, self-propulsion tests and large model scale tests on a manoeuvring basin were carried out and positive results achieved. Further design work was undertaken to establish the weights and arrangements of the vessel, and a Classification Society approached to give a preliminary indication that Class approval would be possible. The proposed hull form is now referred to as “Pentamaran” and UK and world patents have been applied for. The Pentamaran project is currently at the stage of detailed shipbuilding quotations.

Since development of the first Pentamaran, the concept has now been extended to the design of a fast Car Ferry. A preliminary design study has been completed on a vessel capable of carrying 225 cars and 900 passengers at 40 knots. The resistance of the proposed vessel is sufficiently low that steel construction and medium speed diesels can be used. This vessel has also been tank tested and the preliminary design and specification produced.

The form of the Pentamaran hull is unusual and presents some challenging structural design problems. The vessel is in the form of a long, slender monohull, stabilised by discreet sponsons feeding in stabilising loads at fixed local points along the length of the hull. The normal Classification Society Rule approach to the design of such structures is not appropriate and, in the case of the Pentamaran vessels, a direct calculation approach has been
applied. Using this method, a finite element model of the whole structure is produced and then loads advised by the Classification Society are applied to this finite element model to optimise the structure and produce minimum scantlings. Classification Societies derive the loads using their own 3-D hydrodynamic loading programs which also predict the motions and these motions can be compared with motions measured on the tank tests to verify results from the program. The FE model and optimised scantlings are then used to produce accurate weight predictions for the vessels and refine initial estimates.

The paper describes the development of the Pentamaran concept and shows arrangements for both the Fast Freight vessel and the Car Ferry. Performance and motions data for both vessels are published.

2. INITIAL INVESTIGATIONS

The development of the Pentamaran concept started with a relatively large ship. European Container Ship Owner, Norasia Services SA of Fribourg, Switzerland, approached NGA with what they called their 30-30-30 Project (Figure 1). Norasia’s requirement was for a fast container ship capable of maintaining a service speed of 30 knots whilst carrying 13,000 tonnes of containerised cargo on fast feeder routes but using only 30 MW of installed power. They also wanted a vessel which could be built for US$30 million. NGA’s initial advice to Norasia was that these figures could certainly not be achieved with existing known ships and configurations, and would be very difficult to achieve even with a new and radical approach. However, it was agreed that an initial Parametric Study would be undertaken to determine what might be possible.

The broad outline of the Parametric Study undertaken by NGA is shown in Figure 2. Vessels with one, two and three main hull elements were investigated and the effects of adding bulbous appendages, lifting foils, and air cushions also studied. The requirement given to NGA was for a relatively large vessel implying Froude numbers in the region 0.3 to 0.4 depending upon the hull form adopted. At these Froude numbers, it would not be expected that a catamaran hull would show any benefit and the Study showed that the twin hulled variant had the highest drag of all those hull forms studied. This was due to the much higher wetted surface area working at a relatively low Froude number. Similarly, the trimaran form with displacement equally shared between three hulls also showed high drag. As would be expected, monohulls showed the lowest drag and it was evident that relatively high length/beam ratios showed significant benefits in reducing resistance. At this stage in the investigations, the Study was concerned only with achieving minimum drag and power. The Study showed that for the mass, volume and speed required, a monohull vessel with a length/beam ratio of approximately 10:1 would give the lowest resistance and, therefore, installed power. Such a vessel would, however, be profoundly unstable when loaded with containers. An investigation into the effects of stabilising the
monohull with trimaran outriggers showed that if very low displacement, slender, outrigger sponsons were used then the total drag of the vessel would be very little more than that for the unstable monohull. The Froude number of the main hull of this vessel was approximately 0.32 and at this Froude number the vessel total resistance was very sensitive to midship area coefficient, prismatic coefficient, and the use of bulbous bow and stern appendages. Optimisation of these features produced a vessel which could operate at 30 knots when using little more power than the target figure specified by Norasia. As would be expected at this Froude number, the use of foils or air cushions had a negative effect on total vessel powering.

A summary of the results of the initial Parametric Study are shown in Figure 3 which indicated that an optimum stabilised monohull (trimaran configuration) with the vessel using an optimum bulbous bow could achieve 30 knots with an installed power of approximately 37 MW. A sketch arrangement of the vessel is shown in Figure 4.

3. TRIMARAN TANK TESTS

The Ship Owner was sufficiently encouraged by the results of the Parametric Study that it was decided to go ahead and test a tank model. The lines for the first towing tank model are shown in Figure 5 which shows a slender monohull with a length/beam ratio of 10 and having bulbous bow and stern appendages stabilised by a pair of relatively short, outrigger sponsons located near the stern. During the tank tests, the lateral and longitudinal position of the stabilising sponsons was varied to determine the optimum position of sponsons relative to main hull. It had been assumed, following the Parametric Study, that there would be the possibility of significant beneficial wave-cancelling interference between the main hull and the stabilising sponsons. For this reason, the tank test sponsons were designed to be short and relatively full in form in order to minimise wetted surface area. This would have the effect of reducing frictional resistance but increasing wave-making resistance. It was assumed that the wave-making resistance could, at least in part, be cancelled by beneficial wave interference between sponsons and main hull. In fact, the tank tests indicated that there was very little beneficial interference effects no matter what the position of the sponsons. The reason for this was that the resistance characteristics of the central monohull were such that there was very little wave-making resistance to be cancelled. In excess of 80% of the resistance of the main hull at 30 knots was viscous resistance with only 20% being due to wave-making effects. It was, therefore, clear that with the central hull being close to a “waveless” form, wave cancellation would not be a significant effect and a better approach would have been to use long, slender, stabilising sponsons. The tank test results are illustrated in Figure 6. Main hull resistance was very close to that predicted from the Parametric Study but sponson resistance was significantly higher at 14% of the total for the reasons stated above.
4. THE PENTAMARAN CONCEPT

As a result of these figures, the “short-fat” sponson design was abandoned in favour of longer, more slender, stabilising hulls. A brainstorming session with the Owner examined a number of other issues including damaged stability and problems associated with berthing a trimaran vessel having only relatively short sponsons on each side. As a direct result of this meeting, a revised design of vessel was proposed using two stabilising sponsons on each side. This design solved a significant damaged stability problem because one complete sponson could be lost and the vessel would still remain stable, something which could never be true for a simple trimaran. Secondly, the use of two discreet sponsons per side coupled with the freedom to select the relative positions of these two sponsons, longitudinally and vertically, enabled the Designers to define a desired statical stability curve and then achieve it through sponson sizing and spacing. Figure 7 shows the stabilising principle of the ship with two sponsons per side. The configuration of sponsons adopted is one having two shallow immersion sponsons near the stern of the vessel and two independent sponsons positioned further forward and having their keel lines clear and above the loaded waterline. As the vessel heels, one of the aft sponsons emerges from the water at quite a small heel angle. This would normally have the effect of immediately halving the slope of the stability righting lever curve. In the case of the vessel with two further sponsons forward, the sponsons are arranged such that one of the forward sponsons enters the water just before one of the aft sponsons leaves the water. In this way, the slope of the stability righting lever curve can be controlled as required by the Designer.

At this point, it was realised that this type of vessel had a number of novel features and worldwide patents were applied for. The vessel was designated “Pentamaran”.

A further advantage of the Pentamaran over the trimaran is the ease with which the ship may be berthed parallel to a quay.

5. PENTAMARAN TANK TESTS

Figure 8 shows the calculated total installed power for the various forms of sponson design investigated, clearly illustrating the potential of the Pentamaran design to have the lowest resistance and, therefore, lowest required power level. Calculations were based on tank test results for the central monohull, as tested, with certain improvements and direct calculations of slender, shallow sponson drag. Predictions indicated that a total installed power of 36 MW for operation at 30 knots should be possible. To confirm the predictions, a new tank model was constructed and this is illustrated in Figure 9. Results showed that the Pentamaran configuration could achieve 30 knots with an installed power of 36 MW using a single, controllable pitch propeller or as low as 33 MW using a single, contra-rotating propeller, as shown in Figure 10. A tabulation of these results, showing how the installed power
levels were calculated from the measured tank test drags, is shown in Figure 11. The final Pentamaran powering then was within 10% of Norasia’s original requirement and it was agreed to proceed with further development work.

A larger scale model was constructed for work on a manoeuvring basin. This model was used to measure motions at a series of headings to regular and irregular waves and also, to measure forces and moments in the connection between the sponsons and the main hull.

Figure 12 is a tabulation of average ship motions and accelerations measured during these tests. In all cases, data was gathered on each heading equivalent to 30 minutes full scale ship time. Motions and accelerations figures are still being analysed but, in general, the figures achieved for the Pentamaran container ship are at least as good as those for comparable monohull ships and, in most cases, offering lower motions and accelerations values.

Work continues on the Pentamaran ship project with the object of producing a design in sufficient detail to enable firm, fixed shipbuilding quotations to be obtained. This work includes the creation of a global finite element model and production of sufficient drawings to obtain preliminary Classification Society approval.

6. THE PENTAMARAN CAR FERRY

The excellent results achieved from the Pentamaran form in an application to a large, high speed, moderate Froude number vessel encouraged NGA to look at other possible applications for this concept. In particular, the car ferry market with its soaring demand for new, high speed tonnage suggested a possible application. A preliminary investigation showed that powering levels at higher Froude numbers (0.5-0.6) for a Pentamaran vessel with an appropriate design of main hull would also show resistance and motions advantages over monohulls and catamarans. It was decided to look at the market pointers for high speed car ferries to determine the market requirements in terms of size and speed for the period between 1996 and 2001. An extensive market survey looked at the history of the high speed car ferry deliveries over the previous five years and then looked forward to probable market demand over the next five years. The market predictions took account of known operators’ fleet expansion plans and also, looked at new operators switching from conventional tonnage to high speed vessels where appropriate. The results of the market survey are shown in Figure 13, indicating a strong and continuing market for 30 or more high speed car ferries delivered per year, with a peak market requirement by 2001 for relatively large vessels capable of carrying 200-250 cars and 800-1,000 passengers at speeds of around 40 knots. The study was unable to detect a strong bias towards either catamarans or monohulls. It was clear that the market was primarily sensitive to cost, with fuel economy, ride quality, and
other factors dependent on hull form being important but secondary considerations. The 1996 competitive sales price for a vessel of this specification was between US$50 million and US$60 million.

This market is currently entirely serviced by catamarans and monohulls and their derivatives. Figure 14 indicates approximate size, power and cost of catamaran and monohull vessels to satisfy this specification with comparative preliminary estimates and targets for a new Pentamaran vessel. As a result of these deliberations, an initial Parametric Study was undertaken (Figure 15) and a summary of the results are shown in Figure 16. The Pentamaran vessel had a length of just under 128 metres with an extremely slender central hull with a length/beam ratio of approximately 16 appropriate with the Froude number under consideration. Powering levels were very much lower than for competitive monohulls and catamarans of this size and displacement. All the vessels (catamaran, monohull and Pentamaran) were compared on the basis of construction entirely from aluminium alloy and powering by multiple high speed diesel engines driving waterjets. The 20%-30% power advantage of the Pentamaran vessel persuaded Norasia and NGA that further development and tank testing would be worthwhile.

Prior to tank testing, another brain-storming session between Designers and Ship Owner was organised with the objective of finalising the most market-friendly vessel configuration that the tank tests would model. It was quite clear that the market wanted low purchase and operating costs, high reliability and, if possible, compatibility of new tonnage with existing fleets. It also seemed clear that, in recent years, the vehicle ferry operating market had accepted that purchase and total operating costs for fast car ferries could and should be less than those for conventional tonnage, due to lower purchase costs for a similar work capacity and much lower crewing costs, offsetting increases in fuel consumption. Notwithstanding this acceptance, many operators were still very cautious about investing in fast car ferry tonnage, mainly because of worries about the long term durability and maintainability of large, aluminium structures, and the lack of familiarity with the repair and maintenance of high speed diesels or gas turbine prime movers. In an ideal world, the fast vehicle ferry operators would like a 40 knot vessel constructed of a familiar material and propelled by the medium speed diesels used on most of their existing craft. Norasia/NGA/CETEC decided that it should be possible to satisfy all of these requirements by trading off the power advantage of the aluminium Pentamaran by designing the vessel for steel construction and the use of medium speed diesels. Initial estimates suggested a displacement increase up to 2,500 tonnes fully loaded and a best power estimate at 40 knots of 32 MW. If this could be substantiated, the Pentamaran would still have a power level as good as the best existing fast car ferry at 40 knots, but offer steel construction, medium speed diesel propulsion, and very much reduced purchase and operating costs in a vessel with superior seakeeping.
The tank test results confirmed the theoretical predictions, and powering and motions results are shown in Figures 17 and 18. Figures 17 confirms the powering of the Pentamaran as 32 MW at 40 knots and 27.2 MW at 37.3 knots (85% of power for 40 knots). Figure 18 shows a summary of the motions and accelerations data acquired to date. This is limited to data gathered in head seas on the towing tank. RMS pitch and RMS CG vertical accelerations are shown over the high speed range.

7. STRUCTURAL DEVELOPMENT

7.1 Basic philosophy

The overall approach to both the structural design of the Pentamaran container ship and car ferry vessels has been one of optimised weight using a first principle analysis methodology. This has to be accomplished under the umbrella of the relevant international regulatory requirements whilst recognising current shipyard building technologies, the need to control building costs, and the need to obtain Classification Approval.

7.2 Pentamaran Container Ship Structural Development

7.2.1 Global and Local Loads

The Pentamaran configuration of the vessel, with its narrow centre hull, takes the vessel outside of the empirically based Classification Rules, which have been developed around vessels generally having a block coefficient greater than 0.60. Consequently, the global loads have to be investigated using an appropriate computational hydrodynamic analysis, based on the vessel’s predicted motions in the selected operational envelope. Several programs exist for such analysis using a strip theory approach and which can cater, if necessary, for non-linearities in the hull shape. It is important to validate as far as is possible the results of computational analysis with the data obtained from the tank tests of the model. Furthermore, it is important to ensure that the selected Classification Society has validated the software used to establish the global loads computationally. Close liaison, therefore, is maintained with the Classification Society in order to ensure that the estimated global and local environmental loads, ie those caused by ship movement and wave slamming, are acceptable.

Preliminary design of the structure has been undertaken using global loads estimated from empirically based algorithms, assuming a quasi-static condition.

Particular attention has been paid to the effect of the sponsons which induce additional torsional forces into the hull. The structure is also investigated for container hold flooding and inertial effects from the containers due to ship motions.
7.2.2 Choice of Materials

The size of the Pentamaran container vessel leads to the selection of steel as the principal building material for the main hull and sponsons. Although aluminium alloy could be used, the resulting hull flexibility would be a major concern and the associated build cost would be unacceptably high. Aluminium however, is a suitable material for deckhouse construction, leading to a reduced weight over steel, even though greater weight of insulation will be required in some areas.

The steel selected is 355 N/mm² yield for all longitudinal material and 235 N/mm² yield for all transverse material, except in localised areas of high stress concentration where the higher strength steel has been used. The 355 N/mm² yield steel is now commercially available throughout the world for both plate and sections and shipyards have no difficulties in working in this higher strength steel. It would be structurally efficient to use a much higher strength steel, say up to 700 N/mm², where the structure is governed by strength alone, but this could incur some production difficulties and rolled sections are not readily available.

The use of the higher strength steels, even at 355 N/mm², leads to the need for greater attention to detail to avoid through-life fatigue-induced failures.

7.2.3 Mathematical Modelling

In order that the structure can be fully analysed leading to an optimised weight, the complete vessel is modelled mathematically for solution by finite element analysis. Modelling is undertaken by using the NISA II DISPLAY III software with the hydrodynamic pressures applied to the hull surfaces.

The model is run for the global wave-induced bending moments and torsional moments appropriately added to the still water bending moments. Generally, three loading configurations are taken - ballast, full load departure, and full load arrival.

Sub-models are created for areas of high stress concentration and for the Pentamaran container vessel, this is the connection in way of the deck to the engine room, and the bulkheads to the hull. Various other sub-models are used to verify the midship section structure, bulkheads, and the sponson to the hull connections.

Having finalised the vessel scantlings, the model is then used for further structural optimisation and vibrational analysis.
7.3 Pentamaran Car Ferry Structural Development

7.3.1 Structural format

Although the car ferry follows the Pentamaran principle, it differs from the container ship in so much as the vessel is a great deal smaller and significantly faster. This leads to a greater drive for minimum weight. However, all the other facts remain the same as the Pentamaran container ship - it is a novel design which has to follow the same basic philosophy of structural design by a first principle analysis methodology. The smaller size and greater speed places more emphasis on local loads although the effect of global loads will still determine the midship structure.

A transversely stiffened structure is utilised with longitudinal shell stiffening. High strength steel (355 N/mm² yield) is used for the hull up to the passenger deck and welded aluminium alloy for the superstructure. The selection of steel for the hull provides for a greater flexibility in build area and permits the use of a conventional shipyard as opposed to a specialist fast vessel builder. It also reduces the weight of thermal insulation required in the car deck area.

Extensive use will be made of aluminium alloy extrusions for the upper structure which reduces the amount of welding, decreases weight and provides for a greater control of distortion during fabrication.

Deck panels of laser welded thin steel sandwich plates are being considered for the car decks, which provide for a lighter structure than conventionally stiffened flat steel plates.

7.3.2 Structural Design

An interactive process is used to develop the structure and it is one which commences at the conceptual stage of the vessel. This permits the structural designer to ensure that the structure developed has adequate load paths and structural continuity whilst satisfying the needs of the vessel itself - the hydrodynamic shape of the vessel and the ability to carry the given payload. This leads to three important phases in the overall structural development:

(i) Initial structural weight estimation
(ii) Preliminary scantlings
(iii) Structural design by first principle analysis

Initial structural weight has to be based on experience gained from previous or similar structures, using either an estimation of weight of surface area or by structural density. Practical margins must be included to allow for the first order nature of the estimation, changes in vessel format, changes in the overall parameters, etc.
Although the final design is undertaken by first principle analysis methodology, the use of empirically based algorithms, as found in any of the relevant Classification Rules, is a good starting point for the estimation of preliminary scantlings. This also has the benefit of being able to explore the minimum thickness criteria often laid down in such Rules for say steel plating, decks, etc and the minimum criteria of the structure as laid down in IACS requirements, such as the midship section modulus. The emphasis though is placed on seeking the minimum weight of all elements of the structure, whilst ensuring a practical level of robustness, and within the restraints of economical building practices. The preliminary scantlings provide a more detailed structural weight estimation which is used to complete the detailed loading criteria.

The first principle analysis methodology is based on global loads developed by computational analysis in conjunction with local loads arising from environmental effects, such as wave slamming, and those arising from the payload and heavy items of machinery.

An overall mathematical model is constructed of the vessel and analysed for the various load cases considered against agreed acceptance criteria. Figure 19 shows part of the overall model developed by the NISA II DISPLAY III software and Figure 20 shows the typical midship section of the structure.

The model is used to optimise the preliminary scantlings in conjunction with detailed calculations covering those areas of the structure governed by local loads - decks, hull shell plating subjected to slam pressures, engine seats, etc.

This interactive approach to structural design, backed up by a thorough first principle analysis approach, leads to a full understanding of the structure developed and an optimised structure which helps to reduce weight to a practical minimum. A close liaison with the selected Classification Society throughout the structural development, analysis and design, eases the path to Classification for a vessel well outside the bounds of the conventional.

8. **CONCLUSIONS**

Development work on both Pentamaran vessels is now well advanced with the pre-contract design work for both sizes being completed by the end of March 1997.

A General Arrangement of the container vessel is shown in Figure 21. This vessel is configured as an open top container vessel capable of carrying a mix of 40 ft and 20 ft containers and refrigerated containers. The vessel carries approximately 1,200 TEU equivalents at 30 knots with the specified power and is capable of a deep draft operation carrying 1,500 TEU at the same power at a speed of 29.5 knots. Higher speed container vessels capable of cruising up to 40 knots are currently under investigation.
A final measure of the validity of the Pentamaran concept is shown in Figure 22 which is a transport efficiency plot for the Pentamaran container vessel compared with other published fast freight vessel figures. A range of vessels having speeds of 27 knots up to 45 knots has been plotted and a line suggested which indicates a limit of achievement of prior fast freight vessel concepts. The clear advantage of the Pentamaran hull, in terms of transport efficiency, is indicated on the diagram with the Pentamaran having a transport efficiency approximately 50% better than that indicated by the “limit of existing concepts” line. Pentamaran performance figures have been substantiated by extensive tank tests and weight estimates confirmed by detailed structural analysis and modelling.

The Pentamaran car ferry is at a similar stage of development and Figures 23 and 24 show a General Arrangement of the proposed vessel. Figure 25 is a transport efficiency plot for high speed car ferries with two versions of the Pentamaran indicated. Very clear powering and transport efficiency advantages of the aluminium constructed, high speed, diesel powered Pentamaran are indicated and the highly competitive position of the steel hulled, medium speed diesel engined version also shown.

Detailed cost estimates indicate that the Pentamaran car ferry constructed in steel and powered by medium speed diesels driving waterjets for a speed of 40 knots could be built for a selling price of approximately US$45 million. This price has been compared on a cost efficiency basis with published prices for other high speed car ferries in Figure 26. It can be seen that not only is the Pentamaran highly cost competitive in its speed range but, indeed, is a vessel which can be produced at one of the lowest costs per tonne of any high speed car ferry of any speed over 30 knots. Series production may lower costs even further.

In summary, then, the developed Pentamaran concept offers the market a product which will meet market requirements for fast freight or car ferry applications at low cost using familiar, reliable, maintainable materials and equipment installations.
Fig 1: THE “30-30-30” PROJECT

- 30 KNOTS
- 13000 tonnes
- 30 MW
- $30 MILLION
Fig 3: INITIAL PARAMETRIC STUDY

Craft Speed (knots) vs. Craft Power (kW)

- Monohull
- Catamaran
- Symmetrical Trimaran
- Asymmetric Trimaran
- TRI with Bulbous Bow

NORASIA
TARGET
Fig 4: PRELIMINARY GENERAL ARRANGEMENT
Fig 5: TANK TEST LINES
Fig 6: TANK TEST RESULTS

- Monohull with Fwd & Aft Bulb
- Trimaran with Fwd & Aft Bulb

13.9% difference @ 30 knots
Fig 7: PENTAMARAN STABILISING CONCEPT

Progressive Heeling

- All Sponsens
- Upright - Zero Heel Angle
- Small Heel Angle
- Larger Heel Angles

- Forward Sponsens
Fig 8: EFFECT OF SPONSON DESIGN ON TOTAL INSTALLED POWER

- 2 Sponsons
- 4 Sponsons
- 4 Shallow Sponsons Two Lifted

Craft Speed (Knots)

Installed Power (MW)
Fig 9 : 3D-WIRE FRAME MODEL
Fig 10: TANK TEST RESULTS

Vessel Speed (knots)

Installed Power (MW)

- Vessel with Improvements - CRP System
- Vessel with Improvements - CPP System
Fig 11 : POWERING ESTIMATION FOLLOWING TANK TESTS

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<th>Full Load Displacement</th>
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**DRAG SUMMARY**

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<td>1751.0 kN</td>
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<td>Central Hull and Sponsons and Appendages</td>
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<td>(inc Full Scale Roughness &amp; Aero)</td>
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<td>Hull Efficiency</td>
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<td>Transmission Efficiency</td>
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<td>Overall Propulsive Efficiency</td>
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<tr>
<td>Power @ 30 knots</td>
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<td>Overload Power</td>
<td>37233 kW</td>
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<td>(26500 tonnes @ 30 knots)</td>
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### Fig 12

**PENTAMARAN CONTAINERSHIP MOTIONS & ACCELERATIONS**

**RMS Values.**

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<th>C.G Accel.</th>
<th>Fwd Perp Accel.</th>
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Fig 13

HIGH SPEED CAR FERRIES - PEAK MARKET REQUIREMENT 2001

- 800 - 1000 Passengers
- 200 - 250 Cars
- 40 Knots
- Hull Form Offering Best Solution For Cost, Fuel Economy & Ride Comfort
- Fast Turn Around Time
- 1996 Competitive Sales Price - US$ 50 - 60m
**Fig 14**

HIGH SPEED CAR FERRIES - PEAK MARKET REQUIREMENT 2001

**REQUIREMENT:**
900 Passengers, 225 Cars, 40 knots.

**SOLUTIONS:**

<table>
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<tr>
<th>1. CATAMARAN</th>
<th>LENGTH</th>
<th>POWER</th>
<th>COST</th>
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<td></td>
<td>95 -100 M</td>
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<tr>
<th>3. PENTAMARAN</th>
<th>LENGTH</th>
<th>POWER</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Approx Target</td>
<td>30 MW</td>
<td>US$ 40</td>
</tr>
</tbody>
</table>
Fig 15. PENTAMARAN CAR FERRY
PARAMETRIC STUDY
(Aluminium Alloy Construction - H.S Diesel Propulsion.

Monohull: Highest Drag
Catamaran: High Drag
SES: Lowest Drag but not favoured by market
Pentamaran: Low Drag

Lift Devices
Hydrofoils: Possibility of further reducing drag

Most Suitable Option
PENTAMARAN DIMENSIONS FROM PARAMETRIC STUDY

- **LWL** = 128m
- **BWL (main hull)** = 8.0m
- **BOA** = 28.0m (Chosen Maximum)
- **DISPLACEMENT** = 18000 Tonnes
- **POWER** = 24 MW
- **SPEED (Full Load)** = 40 knots
Fig 17

PENTAMARAN CAR FERRY - INSTALLED POWER Vs SPEED

Ship Speed (knots)

Installed Power Requirement (MW)
Fig 19 : PENTAMARAN CAR FERRY MIDSHIP SECTION
Fig 20: MIDSHIP STRUCTURE ANALYSIS - LONGITUDINAL BENDING
MAXIMUM HOGGING CASE

AXIAL STRESS (Szz) CONTOURS
Fig 21: PENTAMARAN CONTAINER SHIP
GENERAL ARRANGEMENT
Fig 22: COMPARISON OF PENTAMARAN WITH OTHER HIGH SPEED CARGO SHIPS
Fig 23: PENTAMARAN CAR FERRY - GENERAL ARRANGEMENT
Fig 25: HIGH SPEED CAR FERRIES
TRANSPORT EFFICIENCY vs VESSEL SPEED

Efficiency: Payload x Speed / Power (kg.knot/kW)

- Catamarans (Solid if Craft in Service)
- Monohulls (Solid if Craft in Service)

PENTAMARAN (ALUMINIUM & MS DIESEL)
PENTAMARAN (STEEL & MS DIESEL)
Fig 26: HIGH SPEED CAR FERRIES
COST EFFICIENCY vs VESSEL SPEED

- Catamarans
- Monohulls

Vessel Speed (knots) vs Price US$ / (Speed x Payload)

PENTAMARAN CAR FERRY
(Steel & M.S Diesels)
PRELIMINARY SKETCH OF PROPOSED VESSEL FORM