NEXT GENERATION CRANE VESSEL

The ‘Oleg Strashnov’ heavy lifting vessel for Seaway Heavy Lifting

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ABSTRACT

A monohull heavy lift vessel has always been a compromise between the required stability during a heavy lift of the maximum capacity, the motion characteristics of the vessel when performing routine lifts during preparation and execution of an installation job or when performing additional duties, such as pipelaying. Recent developments have also placed emphasis on transit speed, which is difficult to achieve with traditional monohull heavy lift vessel designs.

To address the compromises as described above an innovative concept has been developed which combines both stability for heavy lifts and good motion characteristics, as well as a high transit speed, in a monohull. The resulting vessel design has a maximum lifting capacity exceeding all other monohull heavy lift vessels in operation today. It features enhanced motional behavior when performing routine lifting operations and the future possibility of the addition of an S-lay or J-lay pipelay system has been integrated into the design. The vessel is capable of achieving a high transit speed, reducing mobilization time and enabling the vessel to work profitably in remote areas.

The vessel’s key feature is the dual-draught hull concept. This encompasses a hull design with a small waterline breadth for transit and general construction activities and a significantly larger waterline breadth when additional stability is required for heavy lift operations.

The small waterline breadth at transit/operational draught offers the following advantages over the traditional large beam heavy lift vessels:

- Improved motional behavior, thereby increasing workability;
- Significantly reduced resistance, enabling a relatively high transit speed of 14 knots without installing excessive propulsion power.

This paper focuses on the design features, both those unique to this vessel and the combination of several features into one vessel. It highlights the design process, which involved a successful blend of expertise in designing advanced offshore vessels and practical experience.

CRANE VESSEL DESIGN

“Crane vessels are always a compromise between stability and hydrodynamic performance”

“Crane vessels are a special breed. They require special design approaches within the international regulatory regime”

These have always been the constraints in which owners, vessel designers and regulatory authorities had to work with regard crane vessels. This is particularly true for the high capacity vessels with cranes of 2,500 [t] lifting capacity and above.

In being very specialized vessels, their appearance is often markedly different than those of other vessels and may include special types of units. Well known examples of such vessels are the semi-submersible units like Balder, Thialf and Saipem 7000 or the DB-101. Monohull examples of this capacity are few, the most well known being the DB-50, Saipem 3000 and “Stanislav Yudin”. All these units have been designed and built several decades ago and are still in successful operation. Recently a number of new units have been designed and are built or under construction. However, although these designs have been evolved with respect to their systems and general arrangement, most of these units are very much a compromise based on these considerations, except for one. The design of this vessel, the “Oleg Strashnov” for Seaway Heavy Lifting, is discussed in this paper.

A compromise between stability and hydrodynamic performance

The main dimensions of existing monohull vessels are governed by the required stability when performing heavy lifts. Particularly the required breadth is driven by stability. Therefore high length over breadth (L/B) ratio’s are often found with these vessels. These L/B ratios are resulting in either low transit speeds or high propulsion power requirements to reach higher transit speeds and unfavorable motional behavior.

A special breed requiring special design approaches for regulatory compliance

Crane vessels are highly specialized vessels. They differ from general cargo vessels, tankers, bulk carriers and passenger vessels in many ways. Yet most of the international regulations are developed to cope with these more common vessels. In the past specific requirements for crane vessels and barges were developed by amongst others Det Norske Veritas, American Bureau of Shipping, etc. but these are also found to have limitations.

DESIGN BRIEF FOR THE “OLEG STRASHNOV”

End of 2004 GustoMSC was approached by Seaway Heavy Lifting (SHL) to discuss their plans regarding fleet expansion. In February 2005 SHL awarded GustoMSC a study to assist in concept development based on their functional requirements culminating in the design of the “Oleg Strashnov”.

The main functional requirements laid down by the Owner were:

- A transit speed of minimum 14 knots, in order to serve geographically spread markets;
- A lifting capacity of 5000 metric tons with a clear lifting height of minimum 100 meters below the main hook;
- Capability to add S-lay pipelaying capability without impacting the heavy lift capability of the vessel;
- Comply with the latest and known future regulatory and environmental requirements.

KEY DESIGN SOLUTIONS AND PHILOSOPHIES

To meet the design challenges and the design brief a number of solutions and philosophies were applied to the design of the “Oleg Strashnov”. The design incorporates the latest developments in offshore vessel design in almost all aspects. This section discusses the key aspects of the design.

Dual draught hull

The main challenge in the design brief was the combination of lifting capacity, pipelay capability and design speed in one single hull. As previously discussed, this is the main design challenge for crane vessels.

Start of the design for the “Oleg Strashnov” was the development of various concepts to meet this design challenge (see also the discussion on the discussion on concept design in this paper). From a number of concepts the most favorable solution found was a dual draught hull.

This hull combines a small waterline during transit and operations not requiring a large stability, such as small(er) lifts or pipelaying with a large waterline during heavy lifts when a large stability is required. To provide the small and large waterline in one hull the vessel was designed with two draughts:

- Transit draught: Small draught / small waterline;
- Lifting draught: Deep draught / large waterline.

The small waterline at transit draught reduces the resistance by both reducing the wetted area of the hull (drag resistance) and allowing for a smoother fairing of the hull reducing pressure on the hull. The reduced resistance allows for a high(er) transit speed with lower propulsion power. Motional behavior at the small waterline is improved as the vessel’s natural periods are increased, thereby moving away from the commonly found wave periods. This is most significant in swell governed areas.

The large waterline at lifting draught provides stability during heavy lifts. The large waterline is obtained by adding sponsons to the hull. This design has the added advantage that, by locating the sponsons as far aft as possible, additional buoyancy is provided aft and the

Longitudinal Center of Buoyancy (LCB) of the vessel is moved aft when at lifting draught. As the Longitudinal Center of Gravity (LCG) of the vessel during a heavy lift is located aft as well, additional buoyancy in the aft ship is favorable for both ballast capacity and longitudinal strength as less trim is to be compensated. The resulting hull designed for the “Oleg Strashnov” is shown in Figure 1 below.

Figure 1 Dual draught hull for "Oleg Strashnov"

The transverse cross-section of a dual draught has to be carefully designed. Other than a conventional monohull vessel the proportions between draught and breadth is very critical as is shown in Figure 2 below. In transit, sufficient distance between the sponsons and the waterline is to be maintained to reduce wave-sponson interaction whilst also maintaining propeller emergence. However, in lifting draught sufficient immersion of the sponsons is required to avoid emergence of the sponsons whilst providing sufficient freeboard.

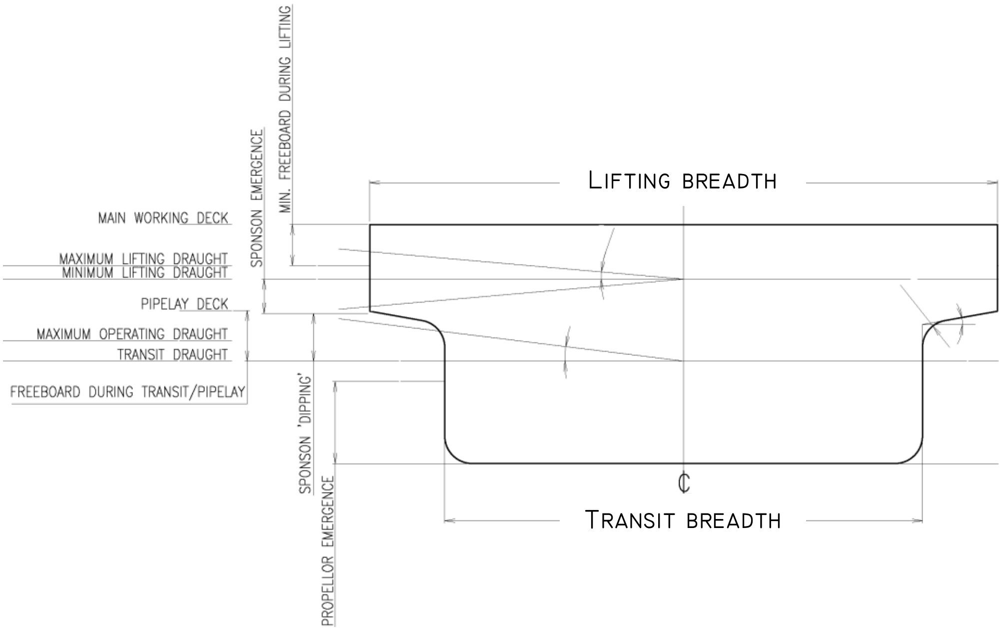


Figure 2 Transverse cross-section dual draught hull

Heavy lift capabilities and characteristics

The main purpose of a crane vessel is to perform heavy lifts and offshore construction work. The main tool here is of course the main crane. The crane design was based on the experience of the Owner with the operation of the “Stanislav Yudin” crane and was developed in close cooperation between Owner and crane Designer, who has also been responsible for the design of the “Stanislav Yudin” crane.

The crane is capable of performing lifts of up to 5,000 [t] at an outreach of 32 [m] in fully revolving mode. This capacity is available while allowing for sideleads of up to 2º. When allowing for sideleads of up to 3º, a maximum capacity of 4,500 [t] is available. The main hook further features a clear height to the maindeck of the vessel of maximum 100 [m]. This combination of clearances and allowable sideleads make the crane, apart from being one of the highest capacity cranes available, also suitable for large and odd-sized loads.

In addition to the main hook, two auxiliary hooks of 800 and 200 [t] capacity and a whip hoist of 110 [t] are available. The 800 [t] auxiliary hoist is specifically designed to work in combination with the main hoist for the purpose of upending jackets.

A special feature of the crane is the trolley hoist. This travelling hoist of 30 [t] capacity travels underneath the boom for base of the boom to beyond the main hoist. This feature, also available on the “Stanislav Yudin” crane adds a lot of versatility to the crane, from sling handling to man-riding and the ability to reach most parts of the maindeck without the need to use the boom hoist.

The load-radius chart of the different hoists is shown in Figure 3.

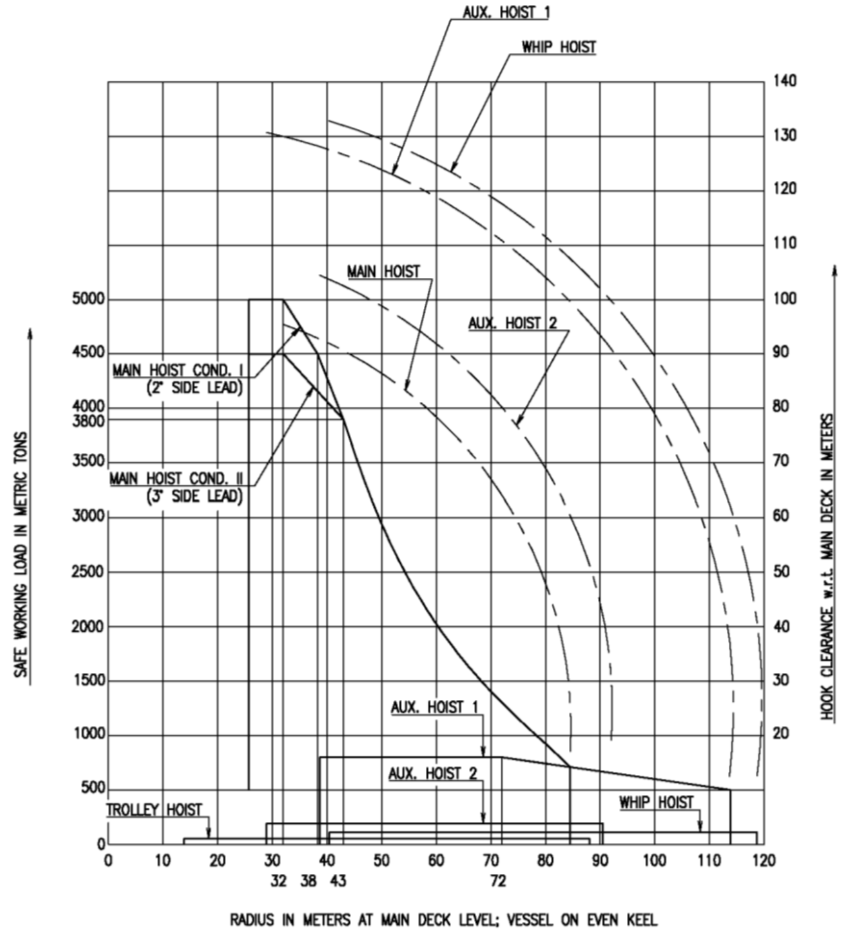


Figure 3 Load-radius chart of main crane

In addition to the main crane the vessel has been designed with a number of features which are designed to add to the efficiency in operations:

- Combination dynamic positioning system and 8-point position mooring system. The 8-point position mooring system, in addition to the class 3 DP system, allows for operations in shallow water and in very close proximity to other structures;
- Maindeck designed for 10 [t/m^2] and additional strongpoints on crossings of bulkheads and web frames. Also full strength welding of deck plating to stiffeners and web frames has been prescribed to also allow tensile forces to the maindeck plating;
- Cofferdam deck below the maindeck. This allows for welding to the maindeck in support of seafastening or construction activities (e.g. project equipment) without requiring precautionary measures to the spaces below deck or damaging the coating of the vessel's tanks;

- Maindeck largely unobstructed. Tank vents and access provisions are grouped in way of the poopdeck, boomrest and forecastle to provide as much free space on the main working deck as possible;
- Raised poopdeck housing mooring provisions, providing a clear working platform around the main crane tub.

Figure 4 Side and topview of "Oleg Strashnov"

Pipelay capabilities and characteristics

The vessel is designed to be capable of pipelaying operations. Although the combination of crane and pipelay vessels is quite common, addition of pipelay capabilities normally has a large impact on the operation of the vessel as a crane vessel, particularly when the capacity is later added.

Therefore the “Oleg Strashnov” has been designed including pipelay capability. As a reference a deepwater S-lay system available as in-house design from GustoMSC was taken. The aim was to minimize the impact on the operation as a crane vessel. This has been achieved by including the firing line in a tunnel below maindeck and a using a removable stinger and stinger handling system.

The deepwater pipelay system has been designed for the following pipe ranges:

Table 1 Pipelay system capabilities

Target waterdepth	Pipe spec.		(Weight) coating		Unit weight pipe incl. coating	
	OD	WT	Thickness	Density	Dry	Submerged
[m]	[mm] (inch)	[mm] (inch)	[mm]	[kg/m^3]	[kg/m]	[kg/m]
2000	323.9 (12.75)	38.1 (1.50)	-	-	269	184
1372	609.6 (24)	30.5 (1.20)	-	-	437	137
130	914.4 (36)	20.6 (0.81)	127.0	3040	1721	620
76	1219.2 (48)	31.8 (1.25)	152.4	3040	2930	1058

The system features a 400 [t] tensioning and abandonment and recovery system, combined with a 90 [m] long deepwater stinger capable of radii between 73 and 365 [m]. The vessel can accommodate X welding stations (for single joints) and/or a double jointing installation (on maindeck forward of boomrest). An artist impression of the deepwater stinger and stinger handling system is shown in Figure 5 below.

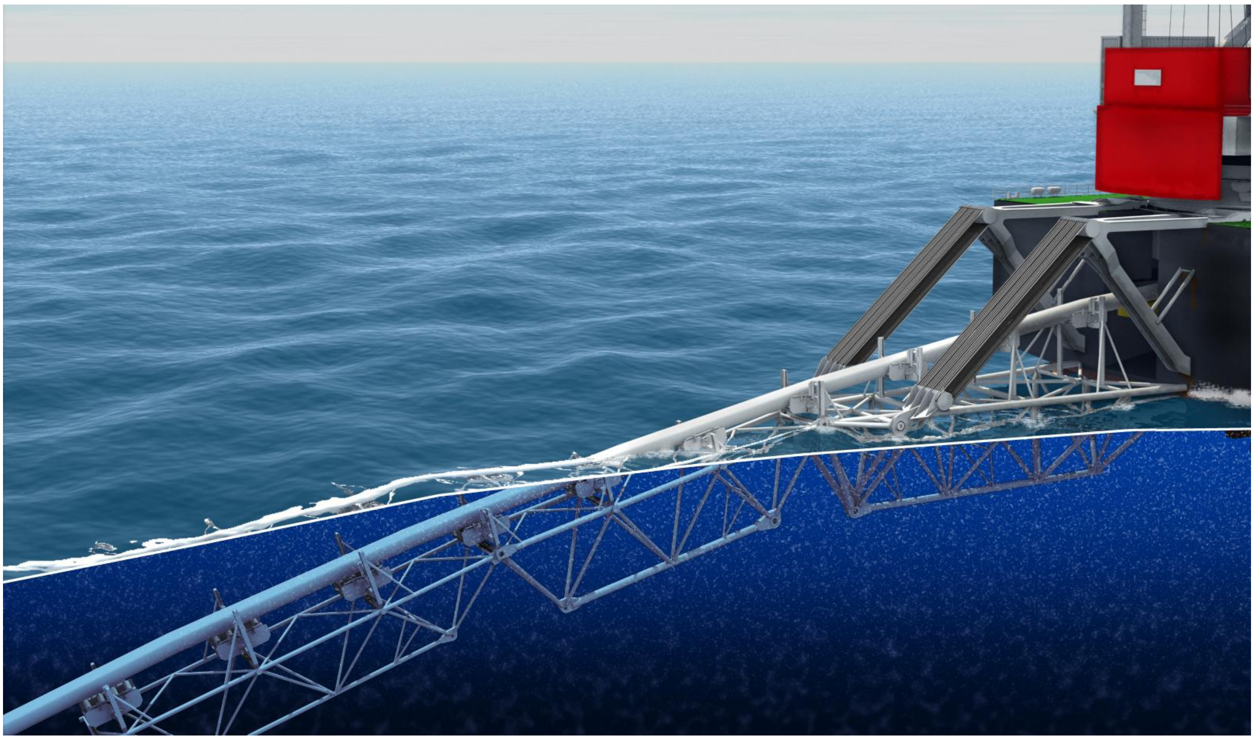


Figure 5 Artist impression of deepwater stinger and stinger handling system

Dynamic positioning and redundancy concept

Dynamic positioning today is a common requirement for a crane vessel. For heavy lift operations, which are commonly in close proximity to other structures, the highest class of redundancy may be required. The highest redundancy is commonly referred to as DP class 3[1]. This requires the power generation system to be designed such that the vessel can keep station after any single failure, including fire or flooding of a compartment. This effectively necessitates at least two separated engine rooms, switchboard rooms and propulsion equipment rooms. Moreover, to reduce the possibility of a black-out these operations are to be carried out with separated power distribution systems (open bus-bars).

For pipelay operations and operations in stand-off position[2] DP class 2 are generally sufficient. The redundancy requirement is reduced with respect to DP class 3 in that fire or

[1] The "Oleg Strashnov" is designed according to DNV class DYNPOS-AUTRO, equivalent to DP class 3.

[2] Operations not taking place in close proximity of other structures

flooding of a compartment need not be taken into account. Also a significant difference is that these operations may be carried out with all switchboards connected (closed bus-bars).

Apart from redundancy requirements heavy lift operations are distinguished from the other operations in that they are carried out in favorable weather conditions and of short duration. This reduces the required power for station keeping purposes. Contrary, pipelay operations are commonly carried out in more severe weather conditions and of prolonged duration thus requiring more power. Additionally a horizontal pipe tension component may act on the vessel resulting in additional forces on the vessel which need to be counteracted.

Application of DP class 3 can have a significant impact on installed power and the required number of thrusters, i.e. the ‘equipment count’. Effectively, DP class 3 results in two separated station keeping systems, each of which requires sufficient capacity to enable position and heading control. Each of these systems should therefore have enough power generating capacity and thrusters. A vessel suitable for DP class 3 can perform DP class 2 operations without changes as DP class 3 is a higher redundancy. However, a higher performance can be reached with the same system in DP class 2 when the power distribution systems are connected (closed bus-bars), which is allowed under DP class 2.

The equipment count is commonly governed by the amount of thrusters required for station keeping in DP class 3. To reduce the equipment count any failure should result in the loss of a minimum amount of thrusters, as the DP capability is essentially determined by the amount of effective thrust that can be generated after a failure. Ideally, only one thruster should be lost in the event of a failure. For DP class 3 systems this could be achieved by providing a completely separate system for each thruster but this leads to impracticable numbers of systems and lay-outs. Alternatively, loss of more thrusters can be accepted by adding more thrusters. This however leads to an increased capital expenditure (CAPEX) and maintenance costs (operational expenditure, OPEX).

To reduce both the installed power and the equipment count for the “Oleg Strashnov” a sophisticated power distribution system has been designed. The system is designed to offer maximum flexibility whilst providing a robust and redundant system. The key to this design is integration of DP class 2 and 3 operations and dual feed to critical thrusters.

To reduce the power generation requirements the power distribution system is designed that it can operate as two separate systems (DP class 3) or as one integrated system (DP class 2). In DP class 2 mode this allows better load sharing between generators after failure of a single generator. In addition, it allows for greater flexibility in the operation of the system when less power and redundancy is required (i.e. in transit conditions).

To reduce the equipment count a number of thrusters are provided with a dual feed. This allows the thruster to be fed from either power distribution system. In case of failure on one of the systems, the thruster switches from one system to the other. To prevent loss of position or heading directly after failure this arrangement has however to be carefully designed to be accepted by the classification society. For the “Oleg Strashnov” this system has been designed in close cooperation between the Designer, Owner, Supplier and Class.

The resulting set-up of the key one-line diagram is shown below.

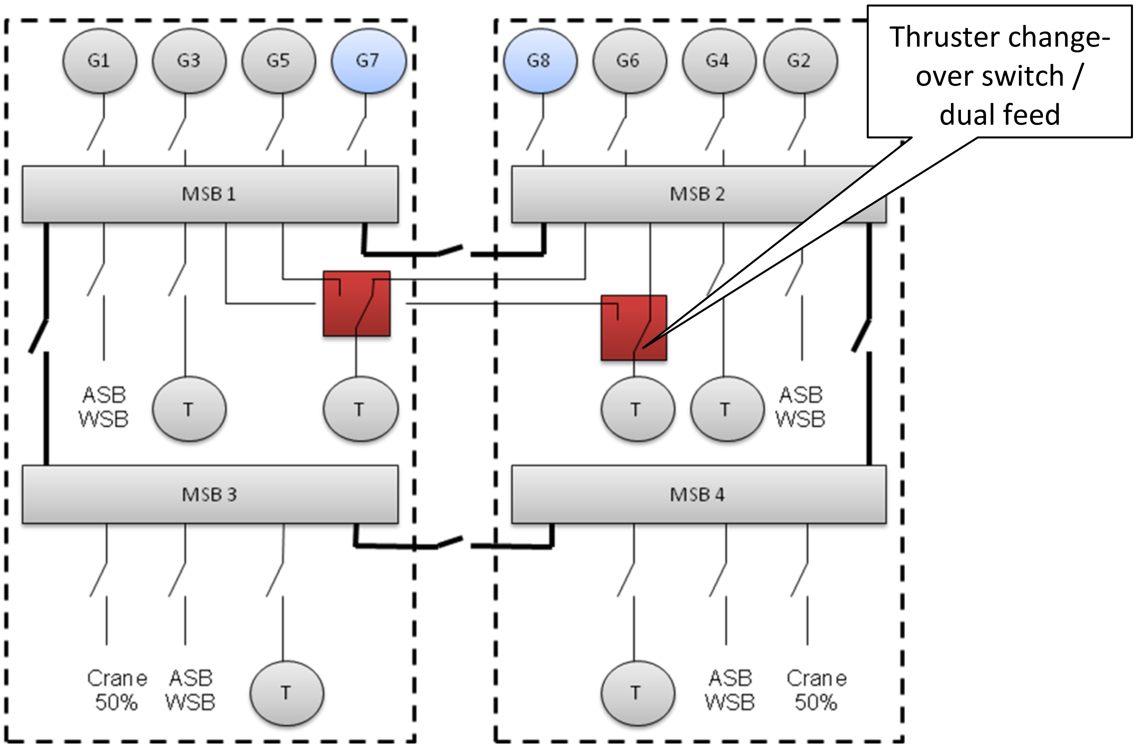


Figure 6 Key one-line

DESIGN OF THE “OLEG STRASHNOV”

Concept design

The design of what has become the “Oleg Strashnov” started end 2004 with a concept generation and evaluation phase which was also used to refine the requirements based on both Owner’s and Designer’s experience and insights. Several concepts were derived to meet the design brief for the vessel. The concepts ranged from a conventional single hull with large propulsion units and motion suppressing systems to concepts involving modular buoyancy modules and multi-hull solutions. To support the decision making process an interactive matrix was set-up to explore the various concepts in different scenarios. This matrix ranked pro’s and con’s for the various options against the refined requirements for the vessel, which were weighed with respect to their importance for different scenarios.

The concept which ranked most favorably in the majority of the scenarios was the dual-draught concept. The dual-draught concept offered the advantage over the other concepts that the performance is relying on the hull shape of the vessel and is thus not dependent on active systems. This approach saves both on capital expenditure (equipment and power generation capacity to be installed) and operational expenditure (less fuel consumption).

Modeltesting

As the dual draught concept was based on an innovative but as yet untested hull concept model tests were carried out with three main objectives:

- Investigate wave-sponson interaction;
- Investigate sea-keeping behavior;
- Verify the results of the numerical calculations.

Of particular interest were seakeeping and sponson-wave interaction phenomena. In the conceptual design phase analysis had been done by means of large amplitude diffraction analysis in time domain. Linear theory diffraction analysis allows the hull and the forces acting upon it to be calculated up to the waterline of the vessel area. Large amplitude analysis takes into account the instanteous interaction between the waves and the hull and therefore allows to take into account the interaction with hull parts above the waterline as well. This allowed to investigate the possible occurrence of wave-sponson interaction with respect to motions, but is not capable to quantify slamming due to this interaction nor does it allow the inclusion of the effect of forward speed. As no analysis tools outside the experimental phase are available for these analyses the modeltesting program was set-up.

Before start of the model-testing program the hull form was further optimized for transit speed with the aid of CFD analysis with the RAPID code. This resulted in a further optimized hull with a very good pressure distribution over the hull as is shown in Figure 7 below. Additional speed-power calculations were also carried out to further confirm the conceptual design.

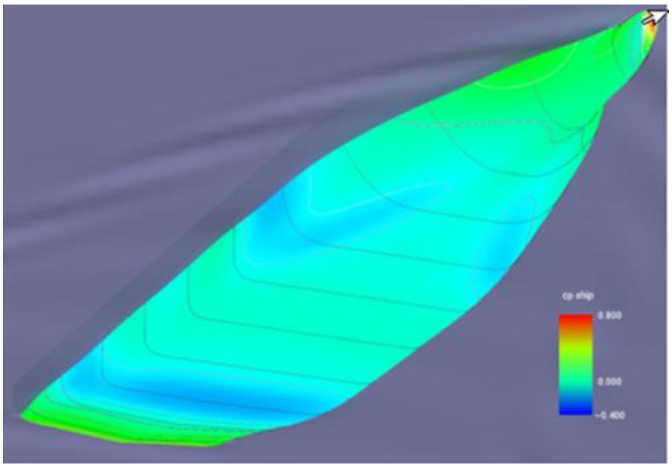


Figure 7 Pressure distribution over hull in RAPID

The model testing program lasted for about two weeks and involved sea-keeping, motion and resistance tests. The results of the tests were found to be in agreement with the numerical analyses as earlier carried out. The sea-keeping tests showed that there was no or very limited wave-sponson interaction due to the aftward location of the sponsons as is also shown in Figure 9.

The wave-sponson interaction tests were carried out in beam seas at the high end of the vessel operational envelope as shown in Figure 8 below. The test results showed some wave-sponson interaction in the form of local slamming but no significant influence on the overall behavior of the vessel. It was decided that the local slamming would be handled by designing the vessel structure on the sponson underside to be strengthened to resist the slamming.

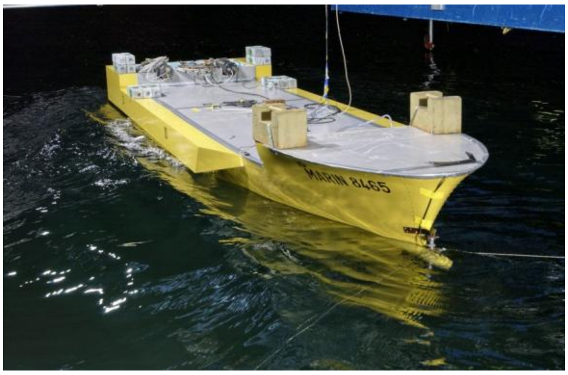


Figure 8 Wave sponson interaction beam seas Hs = 4.5 [m] Tp = 8.5 [s]

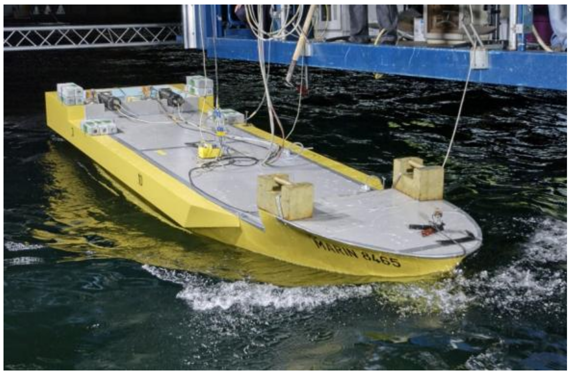


Figure 9 Sea keeping tests Hs = 10 [m] Tp = 16 [s]

The model testing program was carried out in September 2005 and confirmed the feasibility and advantages of the dual draught concept and it was decided to proceed with the basic design without alterations to the conceptual design.

<u>Basic design</u>

The basic design commenced in October 2005 and continued on the basis of the model tested concept design. The basic design was executed to generate an engineering package for the purposes as below:

- Technical part of the Owner Invitation to Tender to candidate shipyards;
- Obtain Class approval before entering into a contract to reduce both technical and commercial risk during the project execution;
- Allow the Owner to further mature the design without (major) commercial consequences.

The two last purposes are especially important when designing highly specialized or innovative vessels.

Key aspect of crane vessel design is the integration of heavy lift operations in the vessel design. The ‘matching’ of vessel capabilities with crane capabilities is a delicate process which requires a thorough insight in the operation of a crane vessel and the design of the hull and systems of such vessels. Close cooperation between Owner and Designer to combine the operational and design knowledge therefore was critical in the design.

The basic design produced a comprehensive package of naval architectural, structural, marine systems and electrical documentation of the design. The majority of the package was class approved in the period of April 2006 to July 2006 and was successfully used in the tendering of the vessel build contract which resulted in a contract for delivery 1Q2010. During the tendering process extensive support was provided to transfer the design responsibility from Designer to Yard.

Naval architectural activities included arrangements, weight and stability calculation, motion and station keeping calculations etc. The structural activities included basic construction plans, detailed FEA analysis of the vessel’s hull and crane integration and scantling calculations. For marine systems diagrams for all systems were produced and for electrical single line diagrams and a detailed load list were established. In addition a detailed technical specification of the vessel was produced. Particular emphasis was laid on critical parts of the design, such as stability, ballast system design and the DP and redundancy concept.

A noteworthy part of the basic design is the slamming impact analysis on the sponson bottom. As discussed under model-testing limited slamming was observed during the model-testing. In early discussions with Class no readily available design method was yet established. It was then decided to use the results of the ComFLOW JIP[3], in which both the Designer and Class were participant, to establish the wave impact pressures and use that as a design basis for the sponson bottom. This approach proved successful and shows a good example of using JIP results in day-to-day engineering.

[3] The ComFLOW Joint Industry Project (JIP) was established to investigate the slamming impact on offshore structures and amongst others developed a calculation method for slamming loads. This JIP is now followed by the ComFLOW II JIP.

Approval process of novel concept and specialized vessel type

Regulatory approval, covering both classification and flag- and coastal state approvals are an important aspect of offshore vessel design. Due to the specialized nature of crane vessels the normal regulatory requirements with respect to e.g. stability have to be interpreted with respect to certain aspects of the design. In addition, the vessel incorporates a number of special features which required further investigation with respect to the regulatory approach.

The project therefore contacted Det Norske Veritas, the classification society of choice, early in the project to discuss the technical challenges and approval process approach. Early on it was established that the vessel was a novel concept and required extensive review and possible exemptions to international regulations.

The main methods to achieve the approval were risk based analysis and design for equivalent safety. Although long established in the offshore industry this approach is relatively new to the shipping industry which is, with respect to rules and regulations, the reference for crane vessel approval. Combined experience from Designer and Class with these processes enabled this approach and this was successfully applied to the design.

SUMMARY

The ‘Oleg Strashnov’ incorporates a number of innovative features which truly makes it a next generation crane vessel. It combines operational capability and flexibility with a high transit speed and is not subject to the compromises traditionally found in heavy lifting vessels.

VESSEL DESCRIPTION

Principal dimensions and main particulars

- Length overall 183.0 m
- Length between perpendiculars 171.6 m
- Breadth moulded 37.8 / 47.0 m
- Depth at side 18.2 m
- Operational draught (pipe laying) 8.50 m
- Operational draught (crane lifting mode) 13.50 m

Classification

The vessel, including the crane is designed according to the rules and regulations of Det Norske Veritas to obtain the Class notation:
✠ 1A1 CRANE VESSEL CLEAN DK(+) HELDK-SH DYNPOS AUTRO E0 BIS

The vessel is designed in accordance with the requirements of Norwegian Maritime Directorate (NMD).

Machinery

Power generation:

- Main diesel generators 6 x 4,500 kW
- Emergency diesel generator 1 x 1,200 kW

Propulsion and DP

- Main propulsion azimuthing thrusters 2 x 5,000 kW
- Retractable azimuting thrusters 2 x 3,500 kW
- Tunnel thrusters 2 x 1,012 kW

Crane

Fully revolving offshore crane

- Mainhoist (slewing) 5,000 t @ 32 m
- Auxiliary hoist 1 800 t @ 72 m
- Auxiliary hoist 1 200 t @ 90 m
- Whiphoist 110 t @ 118 m
- Trolley hoist 30 t
  (travelling on underside of boom from base of boom beyond main hoist)

Pipe-lay system (future capability)

Capability to install an S-lay system with the following characteristics:

- Main firing line below maindeck leaving unobstructed maindeck
- Pipe diameter range 6" - 60"
- A & R system capacity 400 t
- Fixed type stinger with stinger adjustments system

Accommodation & Helideck

Accommodation unit 220 / 395 persons
Helideck Sikorsky S61N / S92

Tanks and storage capacities

- Fuel oil MDO 3,800 m3
- Fresh water 2,300 m3
- Ballast water 50,500 m^3

Design criteria

Maximum operating conditions lifting

- Significant wave height (H_s) 2.5 m
- Wave period (T_p) 3.5 – 14 s
- Wind speed I hour mean, (V_w) 17 m/s
- Current speed, (V_c) 1 m/s

Maximum operating conditions pipelaying

- Significant wave height (H_s) 4 m
- Wave period (T_p) 7.5 – 9.5 s
- Wind speed I hour mean, (V_w) 12.5 m/s
- Current speed, (V_c) 1 m/s

Maximum operating conditions standby *I* abandoning pipe

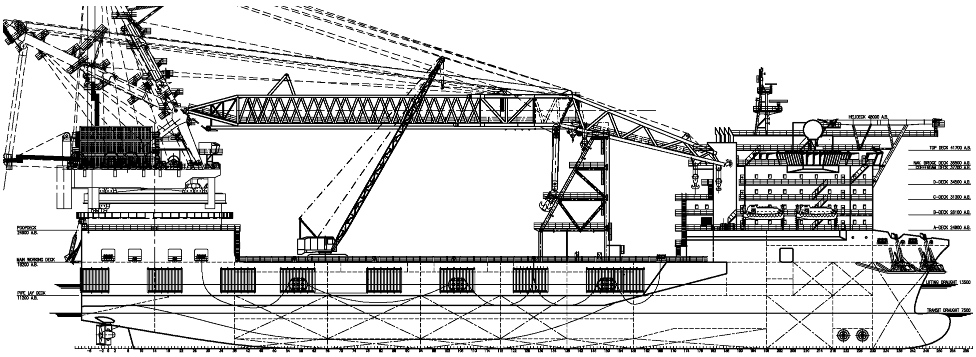
- Significant wave height (H_s) 6 m
- Wave period (T_p) 10 – 12 s
- Wind speed, I hour mean (V_w) 17 m/s
- Current speed (V_c) 1 m/s

Transit conditions

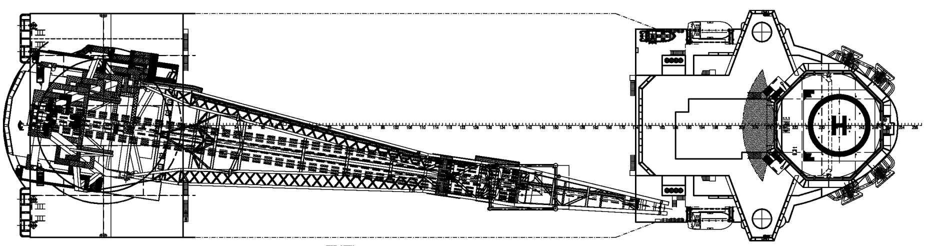
In transit condition, unrestricted worldwide service is ensured. The service speed is 14 knots.

Water depth

Pipe lay operations can be executed in maximum 2,500 meters water depth.



SIDE VIEW



TOP VIEW