Preface

During many years I had been joining engineering forces of major heavy lift contractors, busy in the offshore oil industry. As I was working contract, I had to change jobs so now and then, where I had the opportunity to learn from all these companies. There were many occasions to meet new fellow rigging designers. From seasoned colleagues I have learnt the trade, and later it was my turn to solve odd problems, and to help coach my new colleagues. In the many discussions in which I took part with fellow engineers, I often came across situations that I would describe as having a 'déjà vu' experience: like being on stage in the same play again, but then played by new actors. Again I could then hear engineers who were new with the industry, coming up with the very same questions and fighting the very same basic problems.

Due to these discussions I then felt the need for engineers who were new in this trade, to have a handbook on this discipline available. Even a book containing the bare basics that could give, let's say six answers out of every ten questions, would save lots of man-hours spent during all those eternal discussions, informal on-the-job training sessions and so much time lost on re-designs. This idea gave me a good reason why I eventually decided to set down everything I know and all I could find, together in a book and present it to the industry as a cost-saver.

Although much of the material has been derived from my personal experience, it would be practically impossible to cover this field of application without using many other sources. To compose the book, it was also the gathering of all relevant information and data that could be helpful when designing heavy lift rigging. This information includes: supplier's data sheets, engineering pamphlets, designer's standards, offshore rules and warranty surveyor's guidelines. The many heavy lift contractor's standard engineering procedures, and other publications were also consulted. As what is normal with so many handbooks: not everything mentioned here will be new to the reader.

For the reviews and critical readings contributing so much in the preparation of this book I thank many but especially: Mr. Jan-Peter Breedeveld, engineering manager at Seaway Heavy Lifting installation contractors, Han Commandeur, engineering manager at SBM-offshore crane designers, Anton van der Zalm, senior product & marketing manager at Van Beest, manufacturer of Green Pin Shackles.

Bocholt Belgium, April 2013 Willy Leefmans

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Abstract

1 Introduction
The book is meant to be a handbook for the engineer who is new in the field of rigging design for offshore heavy lifting. Basic information for calculating geometries, loads, eccentricities of loads, features of rigging elements and factors of safety are all made clear. This chapter includes a glossary of terms and abbreviations, that are common in the industry's jargon, references and standards are noted. In all examples, figures, diagrams and tables included in this book the SI-units (International System of Units) have been applied. Weights and loads are expressed in metric tons or KiloNewtons, linear dimensions in millimetres or meters, while stresses in component details will be expressed in Newtons per square millimetre (N/mm^2) or MegaPascal (MPa) which is synonym.

2 Heavy lifting at a glance
The first days of offshore oil industry go back to as early as the 1870's, when modest attempts were made to drill for crude oil just off the coast. It was not before the late nineteen forties however, when offshore heavy lifting operations, similar to what we know today, were initiated. Simply speaking, the process of creating offshore structures, such as platforms, could roughly be broken down into a number of major phases: initiative – studies – engineering – procurement – fabrication – testing – transportation – installation – hook-up – commissioning. Heavy lift operations being part of the installation work, are performed by heavy lift contractors, and the scope of the heavy lift work involves: engineering, equipment, supervision, workmanship, material, supplies and lift operations where a crane vessel and marine support are also necessary.

3 Rules, criteria and guidelines
There are many parties having their interests involving heavy lifting activities. These are: the client, being the owner or operator of the platform, the marine warranty surveyor, who is an independent third party that must ensure that "the terms of the marine insurance warranty clause are complied with". Other institutions involved set applicable rules and regulations, codes and standards. These institutions could be: Classification society, API, ISO standards, European standards, British standards, IMCA codes, IMO regulations, SOLAS, MARPOL, NMD rules and regulations. For all heavy lift projects it is recommended to develop a 'Design basis' or a 'Design brief' or both, in order to obtain a common basis of understanding for all parties involved during design, engineering and verification. The 'Design brief' should describe the basic input parameters, characteristic environmental conditions, characteristic loads and load effects, load combinations and load cases.

4 Crane vessel
Offshore heavy lifting is performed by means of a 'crane vessel', often called 'heavy lift vessel', 'crane barge' or 'derrick barge'. Most are self propelled units: monohulls and semi-subs. For lifting operations the crane vessel is kept stationary by means of its mooring system. Before performing the lifts, the crane vessel and the cargo barge will be moored in stand-off positions. After lifting-off the module from the barge the crane hook will be moved to the setting location. A common offshore heavy lift crane is an assembly that comprises a number of typical prominent components and parts: the crane

tub, crane platform, the winch house, the counter-weight, the A-frame, the boom and the hooks. The hook can be positioned by: slewing the whole crane, the boom may be lowered and raised and any hook may be lowered and raised.

5 Other vessels

Most common for offshore operations is the transportation by an offshore cargo barge of the fabricated objects such as jackets, decks and other modules, from the fabricator's yard to the erection site in the offshore oil field. An anchor handling vessel (AHV) is part of the marine spread for offshore construction work. The AHV is required for assisting with the mooring of the crane vessel at sea. An alternative for using offshore crane vessels is the application of the floating sheerlegs. The floating sheerlegs is a barge having a sheerlegs structure at one end fitted out and arranged for lifting. Maybe not as frequent as we see crane vessels, we might meet the floating sheerlegs at the building site. In respect to the crane vessels the floating sheerlegs have their specific advantages and disadvantages that may vary from project to project.

6 Oil platforms

In general a petroleum well contains three products in separate layers: natural gas in the top layer, petroleum (crude oil) and water at the bottom. Upon confirmation of sufficient petroleum or gas reserves the recovery process is set in motion, and production platforms are designed, fabricated and installed. Platform sizes will vary, depending on the local water depth and the anticipated number of wells to be drilled, expected volume and type of products to be recovered. Platforms vary for their use: from very large production and drilling units, accommodation platforms, to small satellites. A fixed platform is defined as a platform extending above the water surface and supported in the seabed by means of piling, running through a jacket. A jacket is a completely braced welded tubular space frame, extending from an elevation at or near the seabed to a level well above the water surface.

7 Installation process

Platform installation includes engineering, planning, equipment, supervision, workmanship, material, supplies, crane vessels and marine support necessary to install all modules associated with the platform. Well in advance to the installation of the jacket a diver's survey is made on behalf of the heavy lift contractor to inspect the sea bottom in way of the jacket's target position. In general jackets are transported from the fabrication yard to the construction site offshore on deck of a cargo barge: the lighter weight class where the jacket can be lifted-off from the cargo barge by means of the crane hook, and the heavy weight jackets that weigh beyond the crane lift capacity of the crane vessel that is to be assigned for the installation operations in question will be launched off a launch barge. The launched jacket will then be up-ended by the main hook of the crane vessel.

8 Some basics

The load spread of the module weight over its lift points is proportional to the position of the module's COG in plan. The rigging designer is to verify the integrity of the lift points, where the module structure just adjacent to the lift point details should also be checked. Actually the decimal positions should more or less represent the accuracy that is relevant for its purpose of the figure in question. Due to the fabrication process of rolled steel plate the average minimum yield as found during tests the thicker plates show a slightly lower figure. Lamellar tearing is a type of defect that may occur in rolled steel plating below a welded joint at points of high stress concentration. The stress in question is tensile stress applied perpendicular to the plating surface. Welding symbols used in the figures are according to American Welding Society.

9 Lifting and safety

Offshore heavy lifting must be performed within a defined and recognised level of safety. The structural integrity of the rigging must also have an acceptable level of safety. The rigging designer should not only be alert on safety matters, but he or she should, more than anyone else, be able to understand every detail of the subject. The classification for the various levels of risk can easily be made clear by using the risk assessment matrix. The level of consequences, sometimes called 'the class of severity', for a failure during offshore heavy lifting, has been established and recognised as being 'severe' or 'fatal'. One practical and useful method, commonly applied in the analyses for heavy lift riggings is called 'the partial coefficient method'. This method works with many individual factors, being coefficients, to adjust in detail, coping for all possible unfavourable anomalies.

10 Weight and weight factors

Terms used for various conditions of the weight definition. Budget weight being the not-to-exceed dry weight of the module. Dry weight being the weight of the module, as fabricated and ready for shipment without any weight allowances nor rigging weights, nor installation aids added. (Fabricator's 'dry weight'). Dry weight (for installation) is the dry weight plus the installation aids like bumpers, guides, rigging platforms, special braces, etc. Dry hook load is the sum of the module dry weight (for installation) plus the weight of the rigging. Design weight is equal to the dry weight (for installation) as factored for weight growth due to inaccuracies and contingencies. Static hook load is the design weight of the module plus the weight of the rigging. Lift weight is the design weight factored for dynamic loading (DAF). Dynamic hook load is the lift weight of the module plus the static weight of the rigging.

11 COG position

For heavy lifting the position of the module's centre of gravity (COG) is as important as the weight figure. The weight figure will dominate the overall loading figures, while the COG position in plan will effect the geometry of the rigging as well as the load distribution over the lift points. Of most modules the COG position will show to have offsets as measured in the X- and Y-directions from the lift points centre, the reference point. Tilt is defined as the inclined attitude from horizontal of the module after lift-off, where the module is free from lateral restraints and at rest. Tilt, or 'out-of-levelness', is caused by the hook position in the rigging, where its X and Y-coordinates differ from those of the module's COG. This difference is called 'the hook's eccentricity', 'the eccentricity of the hook' or 'the eccentricity of the lift'.
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12 Load and load factors

During the lift the assumed 'lift weight' of the module will be carried by a number of rigging legs running from the crane hook to the lift points on the module. Starting with the lift weight, there are a few load factors that are used for defining the load in the individual rigging legs. These factors can be summarized in: Factor for the number of lift points – Factor for COG position – Factor for uneven load spread (skew load factor) – Other load factors (if applicable) – Factor for angular displacement of the leg. In line with the same philosophy behind the weight growth uncertainties, a certain space may be defined, showing up to where the COG may be expected to possibly move, in case of the weight growth that was counted for.

13 Resistance and resistance factors

To assess the design load for the individual rigging leg its base load must be multiplied by the proper load factors. The initial strength of the rigging component will be factored for the known conditions of service causing a certain decrease of the strength, to achieve the design structural strength of the component. The applied reducing factors for the actual conditions of service, could well be for an uneven load spread, a bend efficiency of rope components, etc. Rigging components such as slings, grommets and also the interfaces such as crane hooks and padeyes have their limitations for their strength, because of the circumstances of service. These circumstances sometimes require de-rating for the structural strength.

14 Rigging components

Rigging components are individual parts that can be used to compose a rigging leg that is part of the rigging arrangement. Essential features of steel wire rope components are their flexible structure and relative elastic behaviour under tension. Slings are basically steel wire ropes with a spliced eye in each end. There are two types of steel wire ropes for fabricating heavy lift slings. Slings fabricated out of small rope sizes may be fabricated out of 'standard steel wire ropes', while the heavier sling sizes are fabricated out of the so called 'cable laid ropes' or 'hand laid ropes'. A grommet is a construction of steel wire ropes, arranged into a stranded construction, cabled together and spliced so that there is no end. Shackles show to be the least complex of all rigging components. In principle the sister plates assembly is applied to replace a regular shackle in a rigging configuration.

15 Lift points

Lift points are special designed structural details of the module to which the legs of the rigging will be attached for lifting. Since the lift point form an integral part of the module, the design for the lift points is made by the module designers and the fabricator of the module will approve the design, fabricate and install the lift points on the module. There are three typical lift point structures applied to modules and spreader components: padeyes, padears and trunnions. The padeye is the most commonly used type of these three lift point types, and some 80% or more of all lifts have padeyes at their lift points. The crane hook station in the rigging, being one of the results of the rigging design, will determine the rigging legs orientations, and so the proper orientation of the lift points.

16 Spreader components

Spreader beams and spreader frames are separate steel structures, applied as components in rigging arrangements. What spreader components have in common is their rigidity, giving them the ability to sustain compressive loads, being their main task. Spreader components are applied in some situations where their purpose is to avoid horizontal load vectors applied to the lifted object. The beam comprises a middle body to which beam terminals are welded at both ends. Most effective for the middle body is found to be a tubular section when considering the required mechanical properties of the section, to its specific weight and the type of loadings applied to it during the lift. The spreader frame is a flat rectangular steel structure comprising two tubular sections arranged as diagonal bracings, plus four tubular sections forming the perimeter of the rectangle.

17 The rigging arrangement

Designing a rigging is mainly assembling rigging components, where the choices eventually made, have been proven to be acceptable, by making the necessary computations. The design is complete when the rigging design report is made, showing the load and stress analyses, the material take-off. 'Proper fit', by using new slings, and 'best fit' arrangements, with used slings, are discussed. An arrangement may comprise 2, 3, 4 or even more rigging legs, while it may even incorporate one or more spreader beams or a spreader frame. The rigging design procedure includes some 24 major steps: from assessment of the dry weight up to setting down the material take-off. Leg compositions can be many: from a simple sling running as one part up to a loop forming a leg of four standing parts.

18 Special lifts

For lifting of partly or entirely submerged modules no general criteria are established. For the design of lift arrangements for this type of module a separate study has to be prepared, taking into consideration specific data such as weight, buoyancy and shape of the object plus the added mass and any special conditions which may arise during up-ending or lifting. Computations should clearly show what the maximum hook load would be for the whole lift operations. For every oil well will come the day when the production will be ended. The well will then be abandoned and legislations require removal of platforms, pipelines and other subsea structures that are no longer in use. Platform dismantling is also part of the offshore heavy lift scene.

19 Related matters

All planning for offshore installation work shall be based, where possible on the assumption that it may be necessary to interrupt or reverse the operations. In general, reversing the operations is impracticable for heavy lift operations. The planning for the operations shall be based on the use of well proven principles, methods, systems and equipment to ensure acceptable health and safety levels and prevent loss of human lives, and major economic losses. It is common practice that heavy lifts may only be performed after approval of relevant documents by authorities involved in the project. The discussion about installation aids is included, as in most cases it is the engineer designing the rigging who will be designing some or all of the installation aids for the module.

20 Worked examples

Five worked examples of rigging designs and a padeyes review are discussed. The presented examples have all been applied in real offshore lifts. In the first example a two-legged arrangement is discussed to lift and install a bridge. Example #2 shows a lift of a tripod. In example #3 two designs will be discussed for a simple rigging arrangement, comprising four rigging legs, to lift a box-shaped compressor module,

measuring about 30 m by 14 m and 9 m high. The first design is the 'proper fit' arrangement, using new slings and the Example #4 is a compressed rigging design report, showing the design of two separate four-legged rigging arrangements that are required for two sequential lifts of a jacket. Example #5 is a padeye review report. Example #6 presents a complex rigging arrangement to lift a deck, comprising twelve rigging legs and three spreader beams.

21 Data base example
The presented tables form a contractor's stock list of steel wire rope rigging components, as stored in their data base. These tables have been added to the book to present an example and to have a realistic 'data base' when working out the examples of Chapter 20. In a data base the listed slings and grommets may be sorted for their stock numbers, their diameters, their lengths, their work load limits, etc. It is up to the user of the data base what options to apply, to sort the data before listing of the stock table. The information that is missing in the tables is the indication whether the slings have right handed or left handed twist. When the engineer is to compose rigging legs comprising more than one sling in a string, the proper sling certificates need to be verified to make sure that slings connected have identical twist directions.
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The author

Name	Willy Leefmans
Address	Reppelerweg 64, 3950 Bocholt, Belgium
Telephone	landline 00 32 89 84 00 87
E-mail address:	willy@leefmans.nl
Date of birth	August 5, 1942
Nationality	Dutch

The author studied naval architecture at the HTS (Institute of Technology) in the town of Dordrecht, Holland. He started his career in Holland as a marine inspector(1968) and moved house to South-America in 1971 where he was in charge as a mechanical engineer in an aluminium smelting plant, with Alcoa.

In 1975 he moved house to Holland and started with Gusto Engineering, an offshore related engineering company in Schiedam. With Gusto he was designing mono-hull and semi-sub heavy lift vessels, pipelay vessels, jack-ups and other offshore structures. After 6 years with Gusto he then moved (1981) into the offshore installation world, by joining forces of Mc Dermott, an offshore installation contractor, then in Brussels, Belgium.

Mc Dermott closed their Belgian office in 1986 and he then started to work contract and could then join engineering forces of installation contractors in Holland (Seaway Heavy Lifting, Smit Maritime Contractors, Excalibur, Blue Water), in France (Bouygues Offshore, Stolt Offshore), in Azerbaijan (Saipem), and with offshore operator Agip KCO he was in: Malta, Milan Italy, Egersund Norway and Dubai UAE. Most of the work included transportation and installation of offshore structures.

He used his spare time spent during all those days in the many hotel rooms, down in those remote places, to set down the first pages of the book's manuscript. He retired and finished his last paid project with AgipKCO in the summer of 2008 and in December following he moved house to the village of Bocholt in Belgium, where he could spend more time in finishing the manuscript. He decided to publish the book himself and the copies of the first edition were ready in April of 2013.
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