Offshore Platforms Sizing Optimization through Genetic Algorithms

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Abstract

The definition of the main dimensions of an offshore production platform is usually a complex problem due to the several variables that have influence over the behavior of the unit. Some of the main aspects related to the sizing of the platforms are the deck area, deck weight, subsea systems interface, stability issues and motions in waves. Recently, the demands of high oil volumes processing capacity are bringing large area and weight requirements, together with more stringent motion requirements due to the interface with the subsea equipment connections, frequently with steel catenary risers. The stability questions are also determinant in the definition of the platform geometry and dimensions. Construction and assembling of the platform also pose some additional questions due to the limit draft of shipyards. Deck mating operations are also constraints that affect the platform available ballast capacity. In order to tackle this kind of problem with a more general approach, advanced optimization techniques, based on genetic algorithm strategies have been proposed for the initial stage of the design process. A software has been used to assemble the sequence of design, enabling the designer to select what are the more important stages that must be checked and that can impact the platform main dimensions. From this sequence several generations of tentative designs have been produced aiming at the optimized combination of the input variables that results in the most adequate design. This procedure has been applied to a semisubmersible based deep water floating production system. The paper show the constraints, the objectives and the details of the genetic algorithm employed and also the resultant optimized design.

1. Introduction

Usually the process to select the main dimensions of a deep water floating production system can be an exhaustive trial and error exercise. This search can lead to several designs that can be either unfeasible or not fulfill the design criteria. The lack of a clear directive to explore the trends that lead to feasible designs, and moreover to select an optimal design, can bring the designer to the choice of an inadequate combination of dimensions. As the possible sets of combinations of main dimensions can amount to several thousands, a rational approach to guide the designer in this pursuit is deemed as necessary and very useful.

Bearing this scenario in mind, at Petrobras Research Center a couple of alternatives have been proposed to generate the main dimensions of floating production platforms in the early stages of an oil field development. The idea is to develop an organized searching process to end up with the platforms that meet the owner's requirements and at the same time have the least cost. The owner's requirements are mainly translated in terms of process plant equipment type and area and risers load capacity, the cost requisite can be expressed in terms of the estimated steel weight and the equipment size and type. In between those two aspects, several technical issues arise. As a floating production system, the stability restraints are very important and are a great contributor to the platform dimensions. Another point, related to the risers, is the motion behavior of the unit, particularly if the operation with steel catenary risers is envisaged. The building constraints can also be as important as the ones previously mentioned. Questions related to quay draft, channel draft can affect deeply the size of the main components of the hull.

The first procedure selected to move on from the trial and error process has been based on the generation of a great set of designs through the variation of the main dimensions through a range of adequate values and the combination of these variations. This brute force way, leads to several thousands designs. This approach can be automated, but the number of platforms is big and has to be analyzed in order to find the best alternatives.

After assessing the draw backs of this procedure, and using the references of the optimization algorithms based on analytical techniques, the genetic algorithms came up as a natural and interesting approach for this kind of problem. The genetic algorithms enables the search process to "learn" from the designs previously generated, making the search for the optimal configuration a more rational process. The combination of the genetic algorithms with the possibility to use ordinary tools and the resources to process the output data made the program ModeFrontier an interesting computational tool to proceed with the rational approach already mentioned.

2. Platform Geometry and Shape Generation

The basic shape of the floating production platform has been selected as a four-column semi-submersible, with rectangular or circular columns cross section. The pontoons have been chosen to be of rectangular cross section. The platform was supposed to have a deck box with two decks and with modules on top of the main deck, enabling the assembly of the different components in different locations. With this basic assumption, an automatic geometry shape generation sequence has been developed to create the file to MG program. This program is a geometry generator that uses CAD techniques and has a very simple and compact file. This step comprised the development of a code that reads the main dimensions and prepares the MG file. Currently the MG program has an script language that enables the user to write a file with the script language instead of a set of primitives of MG, like straight lines, splines or arcs. It should be noted that the procedure includes the generation of internal compartments, once damage stability or loading conditions definitions, like ballast amount and equilibrium, can be evaluated.

3. Weight and Area Definition

Another important item for a floating production platform is the weight estimate. In the conceptual phases of a field development or in the early stages of a defined project, the correct prediction of the lightship weight is fundamental. One of the first decisions in a platform design is the definition of the main dimensions, and those figures are promptly frozen, in order that the other disciplines can develop their work. If unexpected weight increases or miscalculations occur the platform dimensions have to be changed, bringing an undesirable impact over all other disciplines of the project, particularly the structural studies.

The weight estimates in this phase must be based on previous experience and on the required equipment to process the reservoir oil. This is dependent on the oil characteristics and the reservoir management options along the oilfield production life. Choices like oil and liquid processing volumes, number of separation trains, water or gas injection, CO2 or sulphate removal, power generation on board are key decisions to area definition and weight estimates.

After the process plant definitions it is necessary to propose a structural weight calculation procedure. This shall be obviously related to the volume or to the area or the structure and bring some connection with the depth or equipment weight, once we are dealing with supporting elements.

Another aspect that is important for floating production systems is the subsea systems interface with the platform. This requirement can define the minimum clearance between columns, once the risers are connected to the platform at pontoon level.

4. Main Performance Tests Analysis

The performance situations that have impact on the definition of the platform hull main dimensions should be defined before the analysis stage. The performance situations in this context mean the operational constraints that affect the platform dimensions. Obviously the operational condition is the principal performance situation that should be assessed, including stability and loading conditions definition, and motion behavior in waves. Regarding these situations the following characteristics are influenced by these situations: the water line area, ballast tanks volumes, inertia, pontoon to columns volume ratio, height of the center of gravity and so on. Another important case is the transit condition from the shipyard or from some temporary locations to production site. In spite of the operation condition be the more important situation where performance requirements must be met, there are other situations where performance requisites can impose limitations that will define some of the dimensions. These situations are related, for instance, to the construction phase, where draft limitations are of special concern. Hence the completed platform moored to shipyard quay to finalize the construction process is definitely an important performance situation. Another condition related to this phase is the possible deck mating operations in which the unit and its systems are faced with different requirements from its operational life. Other performance situations can be selected, like, for instance, docking the unit after completing some time of production.

5. Floating Production System Scenario and Performance Tests

The floating production system scenario selected to test the proposed procedure was the following:

Semi submersible production platform;
Processing capacity of 200.000 bbls of liquid and 180.000 bbls of oil;
Deep water location 1800 m water depth;
Steel catenary risers;
Hull and Deck Box separated assembling with deck mating operation;
11 production wells + 2 reserves
7 water injection wells + 2 reserves
2 oil export lines
2 gas export lines
Square ring configuration

From these main definitions the following performance tests in the Operating, Transit and Quay Conditions were derived:

Operating Condition

- Motions in SCR Fatigue Waves
- Motions in Extreme Waves
- Initial stability requirements in the operational condition
- Ballast volume usage and distribution in the operational condition
- Equilibrium in parallel draft at Operating Draft

Transit Condition

- Initial Stability
- Ballast volume usage and distribution in the transit condition
- Equilibrium in parallel draft at Transit Draft

Quay Condition

- Initial Stability
- Ballast volume usage and distribution in the transit condition
- Equilibrium in parallel draft at Quay Draft
- Quay Condition Draft must be smaller than the available shipyard quay draft

In order to verify these performance tests one needs to model the platform geometry, including the internal compartments, calculate the weights and respective centers of gravity, inertia and assemble the required files to start the computer programs that calculate the data. The initial stability and loading condition evaluations have been carried out using the SSTAB program and the motion calculations were executed with WAMIT. It should be mentioned that the model of the platform and the preparion of files to run these programs must be made through automated batch runs without interference of the user.

6. Application Set-up

This item discusses the application set up for the scenario described above.

6.1. Geometrical Model

In order to generate automatically the geometrical model a FORTRAN computer program was written to produce as output the file with the primitive geometry entities of the program MG. The input data are the following:

Table 1 Input Variables and Symbol

Variable	Symbol	Variable	Symbol
Transversal Pontoon Breadth	**dt**	Pontoons Distance	**dt**
Pontoon Height	**s1**	Free Board	**FB**
Hull Longitudinal Total Length	**Lt**	Draft	**T**
Hull Transversal Total Length	**Ll**	Longitudinal Pontoon Extension	**ll**
Longitudinal Deck Length	**Lcx**	Transversal Pontoon Extension	**lt**
Transversal Deck Length	**Lcy**	Deck Double Bottom Height	**Hdb**
Deck Height	**Hc**	Number of Process Plant Modules	**Nmod**
Longitudinal Column Length	**c1**	Process Plant Modules Height	**Hm**
Transversal Column Length	**c2**	Airgap	**AG**

Columns Distance	**lc**	Spider Deck Height	**Hsd**
Pontoon Tunnel Length	**Ltunn**	Pontoon Tunnel Breadth	**Btunn**
Pontoon Tunnel Height	**Htunn**	Shaft Length	**Lshaft**
Frame Space	**q**	Web Space	**Qweb**
Heading related to North	**Head**	Longitudinal Pontoon Breadth	**Bl**

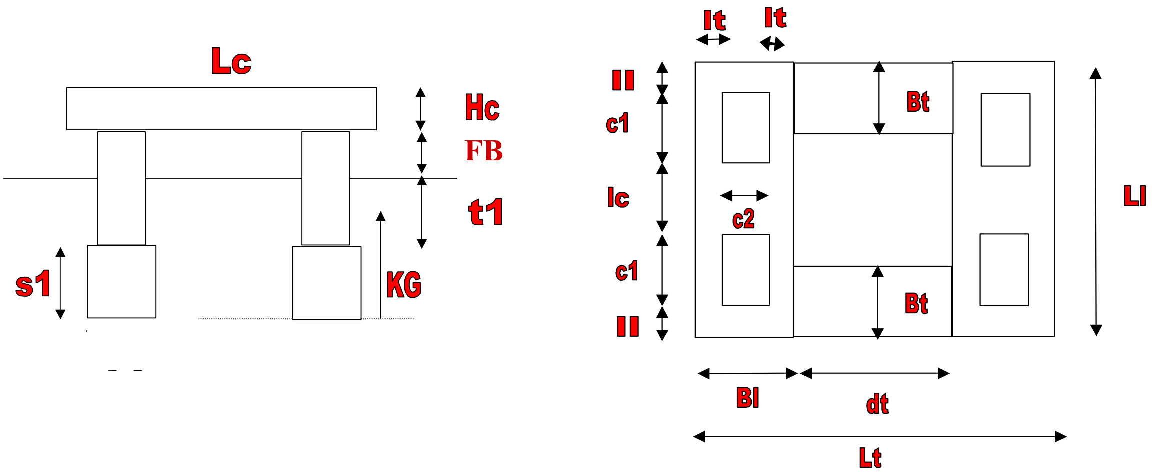


Figure 1 Platform Geometry Data

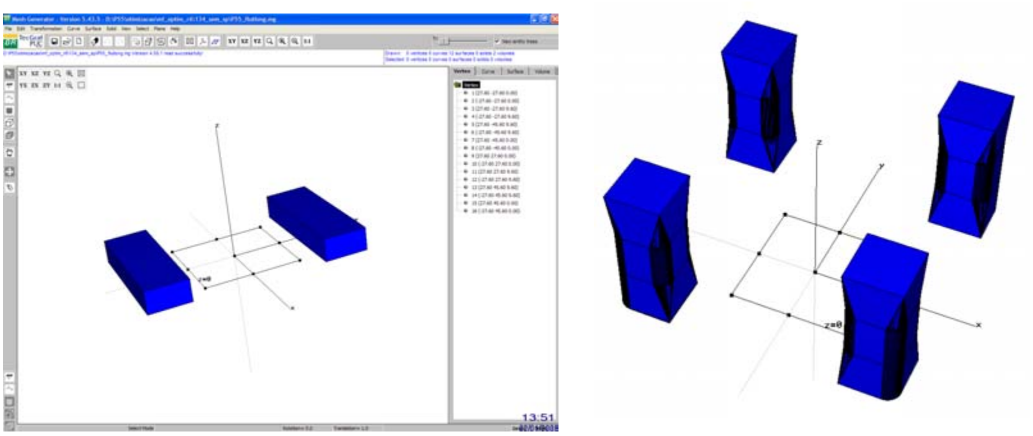


Figure 2 Platform Geometry Generation

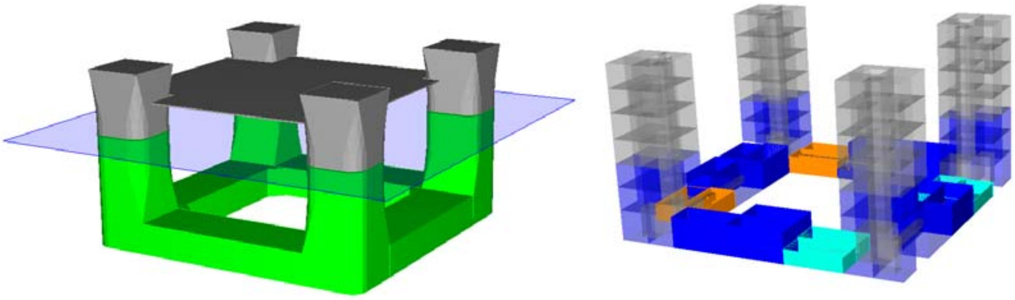


Figure 3 Platform Basic Geometry and Internal compartments

6.2. *Weight distribution*

The weights and CoG coordinates were given in two ways: The first one comprising fixed weights, defined in accordance with previous projects and equipment data. The second alternative comprises the calculation of the weight based on estimates of the relative weight by volume or by area, used for instance with the hull steel weight.

Table 2 Process plant Modules Weight and CoG Data

	PMOD(t)	XMOD(m)	TMOD(m)	XCMOD(m)	YCMOD(m)	ZCMOD(m)
MODULE_01	1480	26	75	45	0	60.3
MODULE_03A	1463	21	33	5.5	19	64.3
MODULE_03B	1575	21	33	5.5	-19	64.3
MODULE_04	1118	17	33	-35.5	19	64.3
MODULE_05	1163	20	33	-16	19	64.3
MODULE_06	1190	20	33	-16	-19	64.3
MODULE_07	956	12	46	-52	0	64.3
MODULE_09A	1150	12	23	24	11.5	64.3
MODULE_09B	1150	12	23	24	-11.5	64.3
MODULE_02	1625	17	33	-35.5	-19	64.3

6.3. *Subsea System Influence*

The sub sea system is formed of 34 lines connected to the platform, varying from steel catenary risers, flexible risers and umbilicals. Although these items are not strictly weight items, the forces applied by the lines must be accounted to attain the correct draft and ballast distribution. The production risers are connected

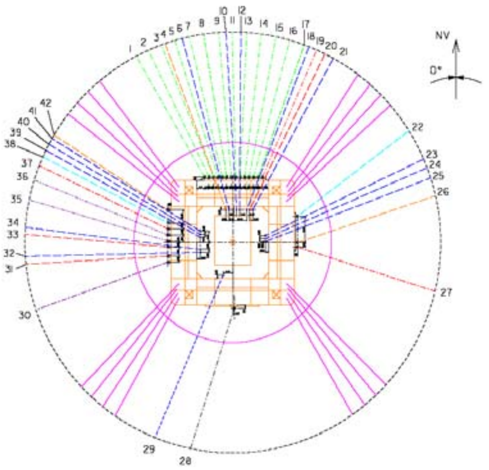


Figure 4 Subsea System Arrangement in Platform

Table 3 Subsea Vertical Loads

Label	Weight (tnf)	LCG (m)	TCG (m)	VCG (m)
Subtotal for Risers	4653.380	23.418	-3.117	9.600

6.4. Margins and Reserve Weights

In addition to the platform lightweight it is necessary to add some margins to take into account deviations during the construction phase. These deviations can be related to wrong estimates, changes of scope or unexpected situations. Another item included is related to future extensions during the platform operational life, this item is called reserve weight.

Table 4 Margins and Reserve Weights

Item	Weight (t)
Margin Hull	500
Margin Topsides	2000
Reserve	1000

6.5. Performance Tests

Three performance tests have been selected to define the platform dimensions:

Table 5 Performance Tests Description

	Operation Condition	Transit Condition	Quay Condition
Loading Cond. / Ballast	Parallel Draft Equilibrium / Volume of Ballast > 15% of the Displacement	Parallel Draft Equilibrium	Parallel Draft Equilibrium
Initial Stability	GM > 2.0 m	GM > 0.3 m	GM > 0.0 m
Hydrodynamic	SCR Fatigue Motions < Fixed Limits		

The motions of the platform in waves have been checked against limits imposed by the fatigue life of the SCRs. Therefore the sea states that have more contribution to the damage have been extracted and limits have been set for the vertical motion root mean square in the risers attachment areas.

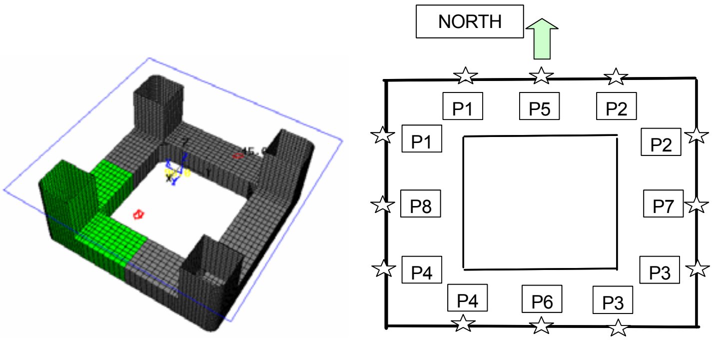
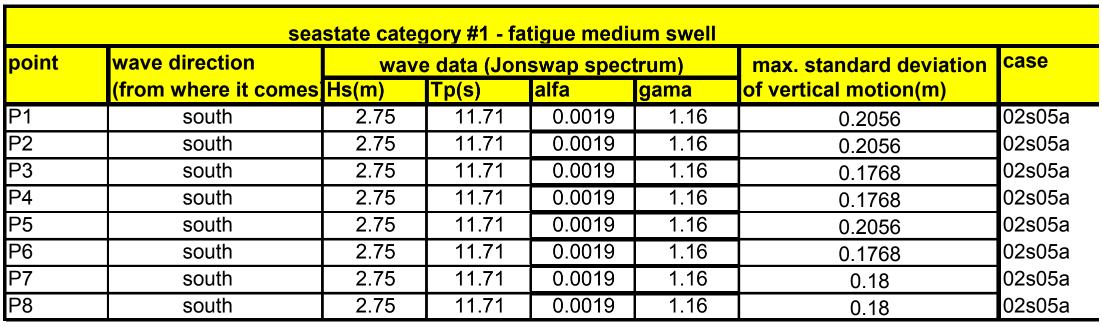


Figure 5 Motion Analysis Typical Model and Riser Connection Points Evaluated

Table 6 Maximum Vertical Relative Motions Swell



seastate category #1 - fatigue medium swell							
point	wave direction (from where it comes	wave data (Jonswap spectrum)				max. standard deviation of vertical motion(m)	case
		Hs(m)	Tp(s)	alfa	gama		
P1	south	2.75	11.71	0.0019	1.16	0.2056	02s05a
P2	south	2.75	11.71	0.0019	1.16	0.2056	02s05a
P3	south	2.75	11.71	0.0019	1.16	0.1768	02s05a
P4	south	2.75	11.71	0.0019	1.16	0.1768	02s05a
P5	south	2.75	11.71	0.0019	1.16	0.2056	02s05a
P6	south	2.75	11.71	0.0019	1.16	0.1768	02s05a
P7	south	2.75	11.71	0.0019	1.16	0.18	02s05a
P8	south	2.75	11.71	0.0019	1.16	0.18	02s05a

Table 7 Maximum Vertical Relative Motions Operational

seastate category #2 - maximum operational motion							
point	wave direction (from where it comes	wave data (Jonswap spectrum)				max. standard deviation of vertical motion(m)	loading case
		Hs(m)	Tp(s)	alfa	gama		
P1	south	3.75	12.08	0.00309	1.08	0.2816	02s07a
P2	southwest	4.25	11.7	0.0048	1.42	0.3784	03sw08a
P3	southwest	4.25	11.7	0.0048	1.42	0.284	03sw08a
P4	southwest	4.25	11.7	0.0048	1.42	0.3256	03sw08a
P5	southwest	4.25	11.7	0.0048	1.42	0.3128	03sw08a
P6	southwest	4.25	11.7	0.0048	1.42	0.2856	03sw08a
P7	southwest	4.25	11.7	0.0048	1.42	0.3184	03sw08a
P8	southwest	4.25	11.7	0.0048	1.42	0.2848	03sw08a

Table 8 Maximum Vertical Relative Motions Fatigue

seastate category #3 - fatigue medium sea							
point	wave direction (from where it comes	wave data (Jonswap spectrum)				max. standard deviation of vertical motion(m)	loading case
		Hs(m)	Tp(s)	alfa	gama		
P1	southeast	2.25	8.85	0.00434	1.26	0.138	02se04b
P2	northeast	2.75	7.86	0.00905	1.88	0.099	01ne05b
P3	southeast	2.25	8.85	0.00434	1.26	0.121	02se04b
P4	northeast	2.75	7.86	0.00905	1.88	0.106	01ne05b
P5	southeast	2.25	8.85	0.00434	1.26	0.095	02se04b
P6	northeast	2.75	7.86	0.00905	1.88	0.067	01ne05b
P7	southeast	2.25	8.85	0.00434	1.26	0.085	02se04b
P8	southeast	2.25	8.85	0.00434	1.26	0.098	02se04b

7. Optimization procedure

After the set up of the complete model, including geometry, weight items, subsea system and mooring lines, and the analysis required, in this case, initial stability, loading conditions assembly and motion analysis, it is possible to select the optimization strategy.

The tool used to carry out the optimization process was the program ModeFrontier from ESTECO. This program enables the user to set up the sequence of analysis and it verifies if the tentative design satisfies the constraints. The program also select the input variables based on a range defined by the user. In this work the NSGA-II scheduler has been used. This scheduler is based on NSGA-II - Non-dominated Sorting Genetic Algorithm II of prof. K. Deb et al. (2000, KanGAL Report No. 200001).

Its main features are:

1) Allows both continuous ("real-coded") and discrete ("binary-coded") variables.
2) Allows user defined discretization (base).

3) The constraint handling method does not make use of penalty parameters.

4) Implements elitism for multiobjective search.

5) Diversity and spread of solutions is guaranteed without use of sharing parameters.

6) Allows concurrent evaluation of the n independent individuals.

The n (number of individuals per generation) entries in the DOE (Design of Experiment) table are used as the problem's initial population. In this case the DOE table has 10 designs.

The basic idea of the genetic algorithm is to develop a number of generations with a fixed number of members. Each member is a possible design, that is assessed against the input constraints and also against the output constraints.

The figure below presents an overview of the analysis sequence set up in the program ModeFrontier:

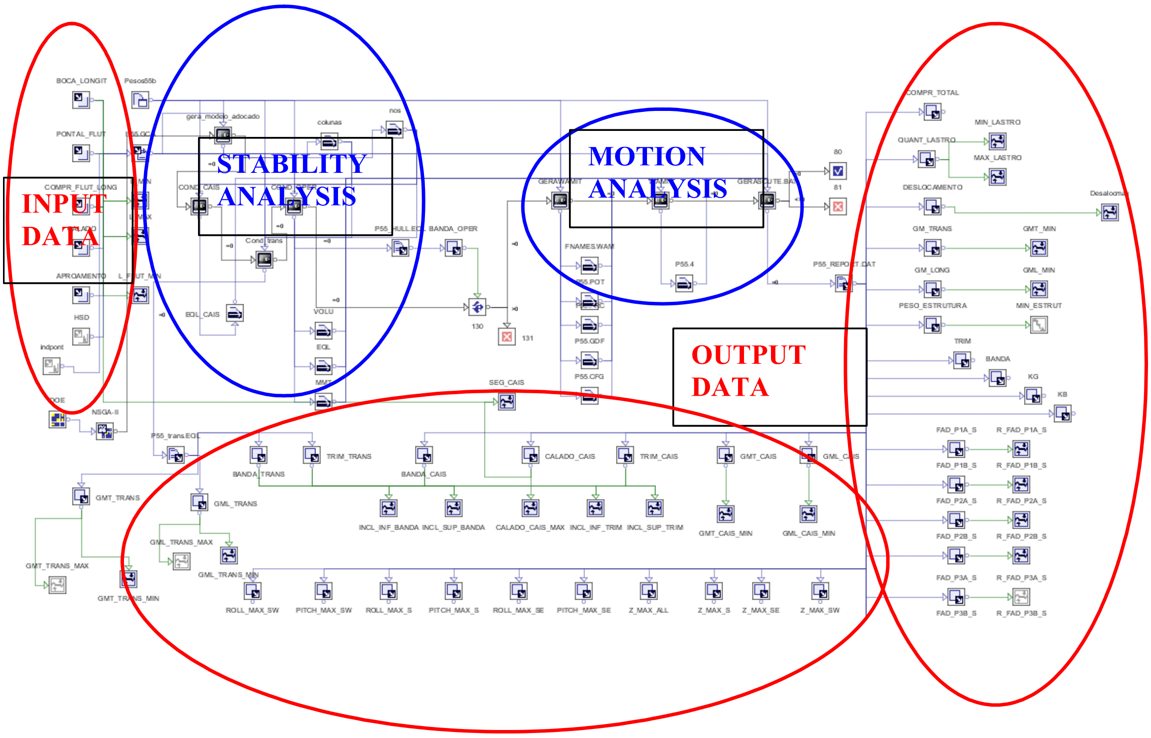


Figure 6 Design Sequence Assembled in ModeFrontier program

7.1. Input and Output Data

If one looks closer to the input data area, the variables and files that belong to this part are the following:

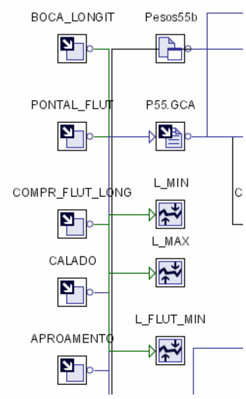


Figure 7 Input Variables to be Optimized – Extracted from ModeFrontier Program

Table 9 Selected Input Data for Optimization Process

Name	Type	Description	Lower Bound	Upper Bound	Base	Step
LONGIT_BREADTH (m)	Variable	Longit Pontoon and Column Breadth	9.6	27	30	0.6
PONTOON_DEPTH (m)	Variable	Pontoon Height	6	21	26	0.6
PONTOON_LONG_LENGTH (m)	Variable	Length of Transv and Longit Pontoons between columns	52.8	72	9	2.4
DRAFT (m)	Variable	Draft	25	40	76	0.2
HEADING (degrees)	Variable	Platform Heading related to North	0	40	17	2.5

These variables are the ones that the optimization procedure will vary in accordance with the algorithm selected. It could be observed that the variables are discrete ones, once the lengths of the platform are based on frame spacings. The program ModeFrontier automatically writes the new values in the files below. The user specify the correct position in the file and the other input data are kept constant.

Table 10 Input Data Files

PESOS55B	FILE	Weight Data file
P55.GCA	FILE	Geometry Data File

Several variables are included in the output data, like displacement, motion and initial stability information. Any file that contains the relevant information for the analysis can be used to extract the required figures.

7.2. Constraints

The constraints used in this problem are presented below. Basically the constraints are related to construction, equilibrium with parallel draft, stability and motion aspects. These problems translate into total platform length, ballast amount, maximum displacement, GM, heel and trim, maximum quay draft and freeboard and motion responses in fatigue sea states restrictions.

The maximum length is related to shipyard available docking extensions to build, assemble and finalize the platform. Also the maximum quay draft is connected to the shipyard dock and channel to leave the shipyard available depths. This variable had a great impact in the design, in spite of being a temporary condition. This problem arises from the relative lack of buoyancy of the large semisubmersibles.

The maximum and minimum heel and trim in transit and in quay conditions are indications that the platform has a loading condition with parallel draft, meaning that there is enough ballast volume to balance the condition. The GM verification is a measure of the initial stability required. This parameter is also intended to give a margin for the more detailed calculations of stability in intact, damage and flooded cases. The limits in the RMS (Root Mean Square) of the vertical motions are concerned with the increase in the fatigue life of the SCRs.

Table 11 Constraints Data

Variable Name	Description	Type	Limit	Tolerance
L_MIN (m)	Minimum Total Length	Greater	70	2
L_MAX (m)	Maximum Total Length	Lesser	95	2
L_PONTOON_MIN (m)	Minimum Pontoon Length	Greater	52.7	0
MIN_BALLAST (%)	Minimum Amount of Ballast	Greater	0.18	0.02
MAX_BALLAST (%)	Maximum Amount of Ballast	Lesser	0.32	0.02
DISPL max (t)	Maximum Displacement	Lesser	84500	0
GMT_MIN (m)	Minimum GMt in Operating Condition	Greater	1.9	0
GML_MIN (m)	Minimum Gml in Operating Condition	Greater	1.9	0

GMT_TRANS_MIN(m)	Minimum GMt in Transit Condition	Greater	0.3	0
GML_TRANS_MIN(m)	Maximum GMl in Transit Condition	Greater	0.3	0
GMT_QUAY_MIN(m)	Minimum GMt in Quay Condition	Greater	1	0
GML_QUAY_MIN(m)	Maximum GMl in Quay Condition	Greater	1	0
INCL_INF_TRIM	Minimum Trim in the Quay and Transit Cond	Greater	-1	0.05
INCL_SUP_TRIM	Maximum Trim in the Quay and Transit Cond	Lesser	1	0.05
INCL_SUP_HEEL	Maximum Heel in the Quay and Transit Cond	Lesser	1	0.05
INCL_INF_HEEL	Minimum Trim in the Quay and Transit Cond	Greater	-1	0.05
DRAFT_QUAY_MAX (m)	Maximum Quay Draft	Lesser	11	0.5
SEG_QUAY (m)	Minimum Freeboard in Quay Condition	Greater	0.5	0.05
R_FAD_P1A_S (m)	Max RMS Vert Motion P1A Sea 2.75 m 11.71 s-	Lesser	0.23	0
R_FAD_P1B_S(m)	Max RMS Vert Motion P1B Sea 2.75 m 11.71 s-	Lesser	0.23	0
R_FAD_P2B_S(m)	Max RMS Vert Motion P2A Sea 2.75 m 11.71 s-	Lesser	0.23	0
R_FAD_P2A_S(m)	Max RMS Vert Motion P2B Sea 2.75 m 11.71 s-	Lesser	0.23	0
R_FAD_P1A_S1(m)	Max RMS Vert Motion P1A Sea 3.75 m 12.08 s-	Lesser	0.321	0
R_FAD_P1B_S1(m)	Max RMS Vert Motion P1B Sea 3.75 m 12.08 s-	Lesser	0.321	0
R_FAD_P2A_SW(m)	Max RMS Vert Motion P2A Sea 4.25 m 11.70 s			

7.3. Objectives

Objectives are the response parameters, i.e. the quantities that the designer wish to be maximized or minimized. As an example of MAX we could cite: efficiency, performance, etc. In the case of MIN, cost, weight, etc. Although ModeFrontier enables the use of multi-objective optimization, meaning that two objectives can be chosen, in this case only one objective was selected. The minimization of the vertical motion RMS in points P1A and P3 with the south and southwest sea states was used. This criteria has been set after some tests with the algorithm, that involved also the usage of all points and the multi-objective option, using the minimization of steel weight as the other objective. The selection of only these two points proved to bring good results to the other points as well, somewhat simplifying the process.

7.4. Summary of the optimization process

The process can be summarized as follows:

1. Define 5 input variables
2. Generate the hull, internal compartments, lightweight and variables loads
3. Evaluate Quay Condition Equilibrium and Initial Stability
4. Evaluate Transit Condition Equilibrium and Initial Stability
5. Evaluate Operating Condition Equilibrium and Initial Stability

6. Evaluate Extreme Motions and Fatigue Motions
7. Extract Output Data
8. Return to the Beginning

8. Results and Discussion

The number of generations has been set to 500, with 10 designs in each generation. The initial generation has been provided based on preliminary tests, although Modefrontier has random generation possibilities. The initial set is showed below:

Table 12 Initial Set of Designs – 1st Generation

DESIGN	LONGIT_ BREADTH (m)	PONTOON_ HEIGHT (m)	PONTOON_LONG_ LENGTH (m)	DRAFT (m)	HEADING (deg)
0	18.6	9.6	55.2	32	0
1	18.6	9.6	57.6	32	0
2	18.6	9.6	60	32	0
3	18	9.6	60	32	0
4	18.6	9.6	55.2	32	10
5	18.6	9.6	57.6	32	10
6	18.6	9.6	60	32	10
7	18	9.6	60	32	10
8	11.4	19.2	55.2	26.8	10
9	20.4	11.4	64.8	34.4	10

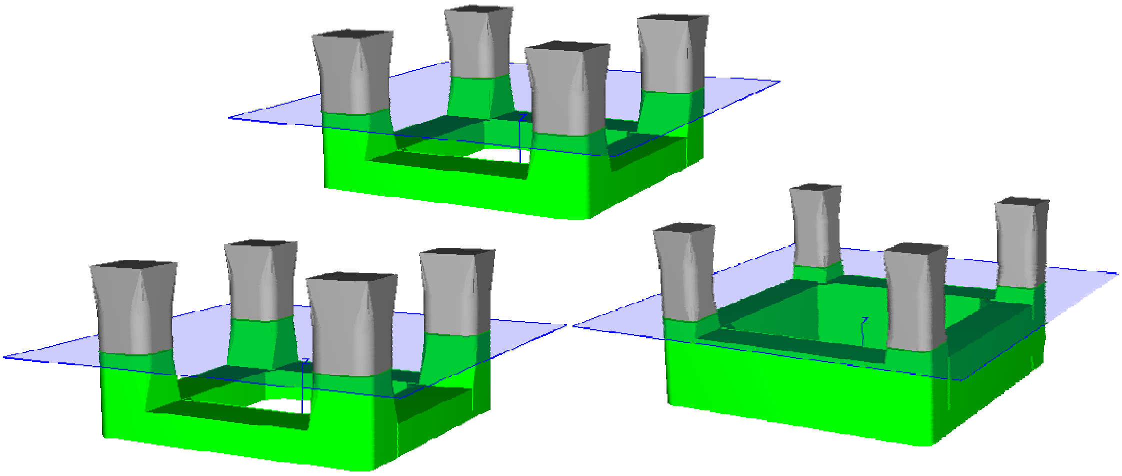


Figure 8 Designs proposed for the First Generation

5046 designs have been generated in this particular application. From these designs, 672 were different ones, i.e., with unique combinations of the input variables, 35 feasible, 563 unfeasible and 74 failed in the equilibrium determination of either Quay or Transit conditions.

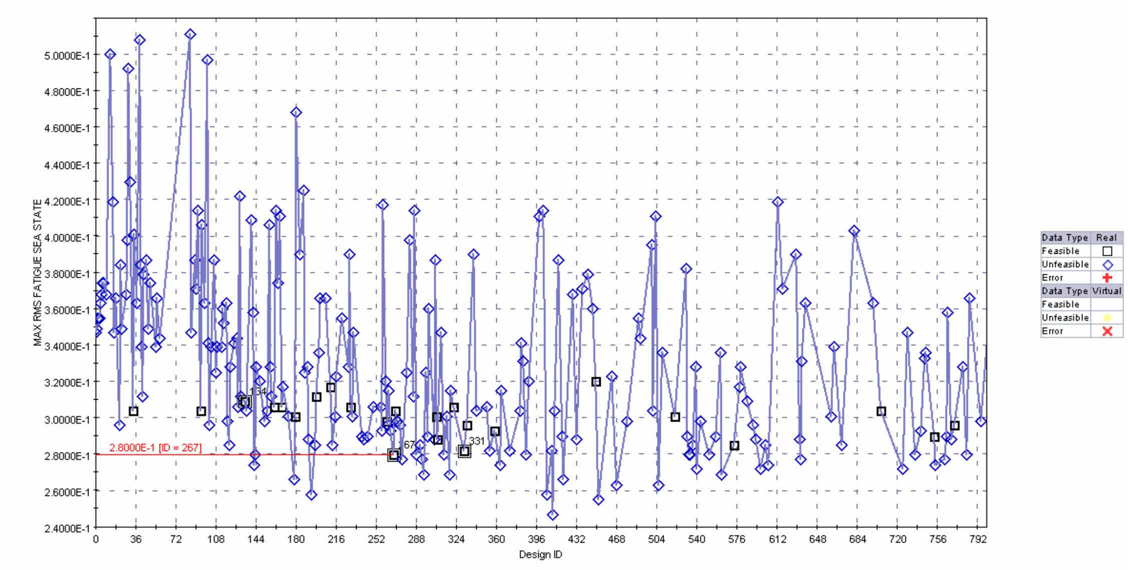


Figure 9 History Chart with the Objective Maximum RMS in Fatigue Sea States

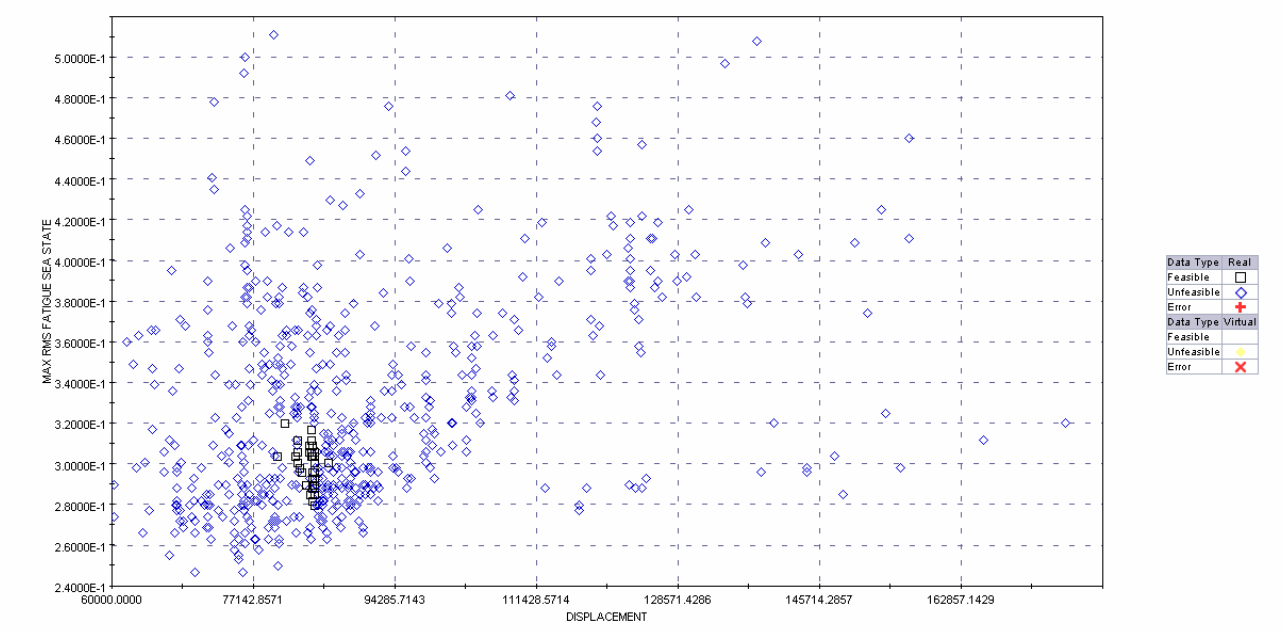


Figure 10 Scatter Chart with the Objective Maximum RMS in Fatigue Sea States x Displacement –With Feasible and Unfeasible Designs

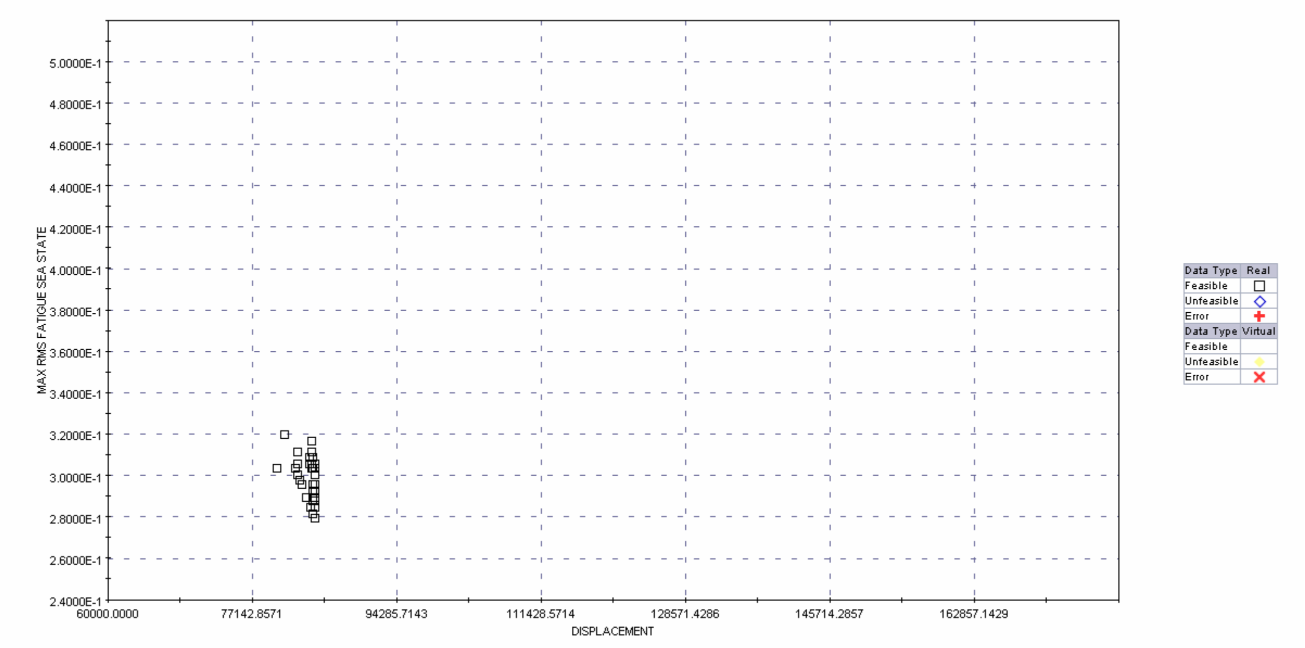


Figure 11 Scatter Chart with the Objective Maximum RMS in Fatigue Sea States x Displacement- Only Feasible Designs

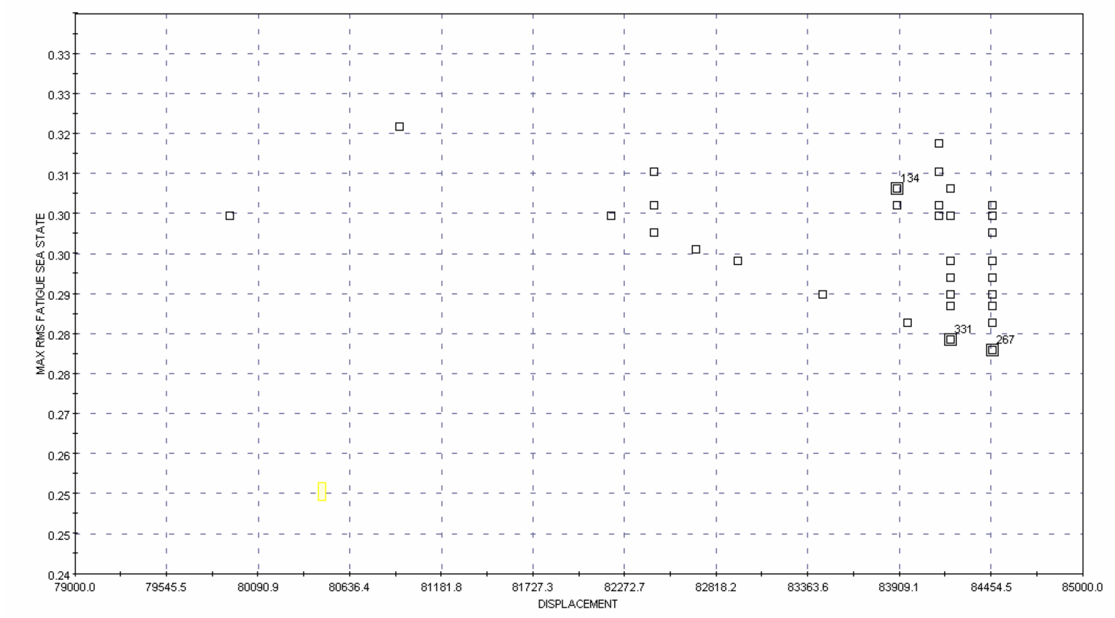


Figure 12 Scatter Chart with the Objective Maximum RMS in Fatigue Sea States x Displacement – Zoom in the Feasible Designs

The design selected as the best alternative for the scenario described above was design number 267, that attained the lowest vertical motion at the riser connection area. Table 13 show the input data of this design:

Table 13 Design 267

Input Variables	Value
LONGIT_BREADTH (m)	18
PONTOON_DEPTH (m)	9.6
PONTOON_LONG_LENGTH	52.8
DRAFT (m)	36.4
HEADING (degrees)	0

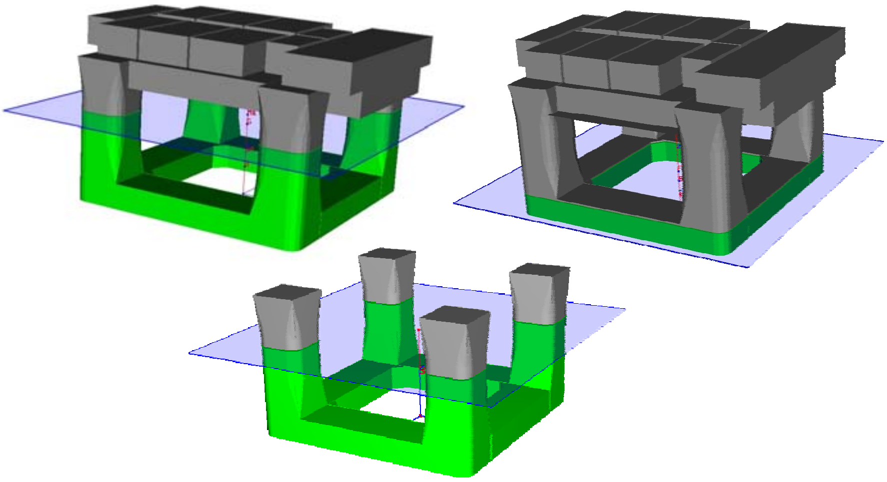


Figure 13 Design 267

Table 14 Design 267 Main Weight and Hydrostatic Properties

	Output Variables	Description	Value
1	GM_TRANS (m)	Oper GM Transv	2.52
2	TRIM (degree)	Oper Trim	0
3	HEEL (degree)	Oper Heel	0
4	GM_LONG (m)	Oper GM Longit	2.52
5	TOTAL_LENGTH (m)	Total Length	88.8
6	BALLAST_AMOUNT (%)	Ballast Amount	0.226
7	DISPLACEMENT (t)	Displacement	84458.77
8	KG (m)	Height of CoG	28.48
9	KB (m)	Buoyancy Height	12.08
10	STEEL_WEIGHT (t)	Steel Structure Weight	24698.81

Table 15 Design 267 Objective Fatigue sea State Motions

RMS Vertical Motion in Points P3A and P1A	Motion (m)
FAD_P3A_SW	0.242
FAD_P1A_S1	0.28

Table 16 Design 267 Operation, Transit and Quay Conditions Equilibrium and Stability data

Variable	Description	Value	Variable	Description	Value
DRAFT_QUAY(m)	Draft Quay	9.06	GML_TRANSIT(m)	GMt Transit	0.33
HEEL_QUAY(degree)	Heel Quay	0	GMT_TRANSIT(m)	GMl Transit	0.33
TRIM_QUAY(degree)	Trim Quay	0	HEEL_TRANSIT(degree)	Heel transit	0
HEEL_OPER(degree)	Oper Heel	0	TRIM_TRANSIT(degree)	Trim Transit	0
GMT_QUAY(m)	GMt Quay	62.3			
GML_QUAY(m)	GMl Quay	62.3			

9. Conclusions

Bearing in mind the complexity of the problem of the selection of the main dimensions of a deep water floating production system, with a potentially huge number of alternatives to be evaluated, the optimization process for the selection of the best option is a more rational approach;

The choice of the optimization technique, i.e., the search strategy, is very important. The robustness of the optimization algorithm, which is the ability to reach the absolute extreme of the objective function is fundamental. In this way the genetic algorithms may seen to fulfill this property.

The design sequence and the results post-processing tools have shown to be useful for the conceptual phases or initial cycles of the design of a deep water floating production system.

10. References

ModeFrontier Version 3.1.1. Documentation provided by ESTECO
WAMIT Manual
SSTAB Petrobras Stability program Manual