Float Off Operation of a Semi-Submersible Barge with Unsymmetrical Floater Arrangement *1

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When a large size offshore structure such as Spar transported by a semi-submersible barge floats off, floaters located at the corners of the barge sometimes become obstacles for the operation. Especially, when the float off site is open sea, the probability of contact damage between the floaters and the transported structure will be high. This paper discusses possibility of reduction of the number of floaters to shorten float off duration so that the contact damage can be avoided. It is concluded that float off operation of Spar can be carried out with a semi-submersible barge with three floaters located unsymmetrically from the view point of stability, loads on the barge and ballasting operation.

Keywords : *Semi-Submerisible Barge,Stability,Floater,Float off*

1. Introduction

For transportation of a large size offshore structure such as Spar, it is usual to apply dry tow operation using semi-submersible barge. The structure loaded onto the barge by skid out or float on operation near the construction yard is transported to the designated area and discharged from the barge by float off operation.

Normally the semi-submersible barge has floaters at her corners for stability at submerging condition. These floaters, however, sometimes become obstacles for float off or float on operations. Especially, in the case of floating Spar off, careful operation should be required because of its long discharging off time. Moreover the off loading site at open sea often encounters adverse weather and sea conditions. Damage to the transportation cargo due to contact with floaters should be avoided.

In this paper, authors discuss about the possibility of reducing the number of floaters of a semi-submersible barge in order to avoid contact between the transportation cargo and the floaters of semi-submersible barge. That is, the feasibility to reduce one or two floaters which are normally located at the corner of the deck is studied. At this time, adverse effect may be expected on the stability during submerging operations. The purpose of this paper is to clarify these issues which have seldom been discussed.

2. Calculation Condition

The principal dimensions of semi-submersible barge and Spar are as follows.

(a)Barge-F2

Semi-submersible, with two floaters at port/fore and starboard/aft.

$L \times B \times D = 170.00m \times 50.00m \times 12.00m$ (Pontoon)

$L \times B \times D = 22.00m \times 9.00m \times 14.00m$ (Each floater, the top level is 12.00m above pontoon deck.)

(b)Barge-F3

Semi-submersible, with three floaters at port/fore and port and starboard/aft

$L \times B \times D = 170.00m \times 50.00m \times 12.00m$ (Pontoon)

$L \times B \times D = 22.00m \times 9.00m \times 14.00m$ (Each floater, the top level is 12.00m above pontoon deck.)

(c)Spar

Cylindrical type

Length: $229.00m$

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Diameter : 41.00m
Weight : 35,000tf

Outline configuration of Barge-F2, F3 and Spar are shown in Fig.1 and 2.

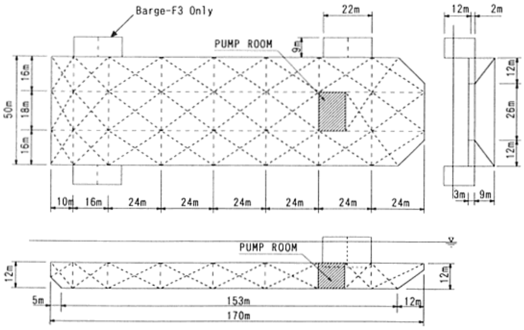

Fig. 1 Barge-F2 and F3.

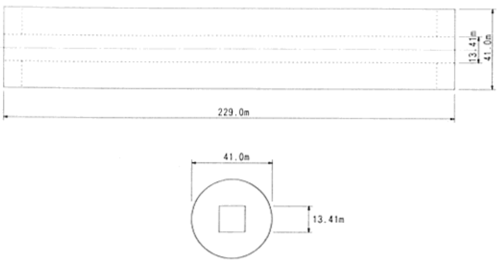

Fig. 2 Spar.

3. Float off Operation

Two types of float off are considered to reduce the length of operation time as shown in Fig.3. One is to use Barge-F2 and the other is to use Barge-F3.

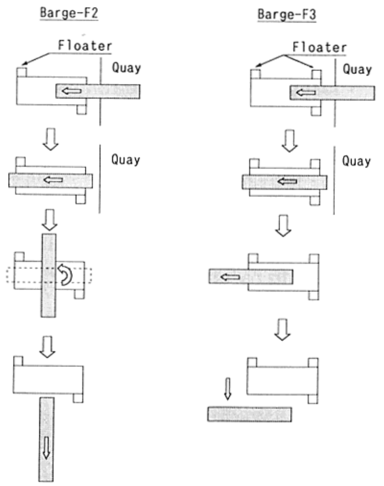

Fig. 3 Float off procedure.

In the former method, as soon as floating off, the Spar will be rotated by ninety degrees and shifted athwartships. This will bring the shortest float off time. In the latter one, just after floating off, the Spar is moved forward and then athwartships as soon as aft end of Spar passes aft floaters of semi-submersible barges. In this case the length of time for floating off will be one third of usual case, that is, semi-submersible barge with four floaters.

4. Stability Calculation

4.1 Barge with Two Floaters

In many cases, semi-submersible barge with loaded cargo can have better stability performances compared with that of barge alone. This is because the loaded cargo contributes stability improvement of barge plus cargo system. Then the stability performance of Barge-F2 alone is examined here as a severe condition.

Fig.4 shows the minimum height of metacenter above the base line of the barge (KM) about the axis passing through the center of floatation of both floaters. In Fig.4, KM for trimmed axis up to five degrees are shown. Mark X indicates height of center of gravity of the barge including ballast water above the base line (KG). Conditions of the Barge-F2 for each step are shown in Table 1. When mark X is below KM line, the barge has positive GM, that is stable. In Fig.4, as X of case 2 through case 6 are below KM of without trim, they are stable. But in case 7, KG exceeds KM's except that for trim of 5 degrees. This means the barge should be trimmed by 5 degrees between case 6 and 7. However during the barge goes from case 6 to case 7, she has to pass trim of 1 through 4 degrees which give unstable condition (After deck emergence at which displacement is about 10,100tf, the barge has enough stability).

Therefore, Barge-F2 cannot obtain sufficient stability performance at refloating condition of barge alone.

Table 1 Stability calculation of Barge-F2.

Case	Draft at Midship m	Disp. tf	Trim deg	KG m	GGo m	KGo m	Min.KM m	Min.GoM m
1	23.00	105,534	0.0	5.95	0.31	6.26	6.66	0.40
2	21.00	104,722	0.0	5.96	0.31	6.27	6.54	0.27
3	18.00	103,503	0.0	5.98	0.31	6.30	6.39	0.09
4	17.50	103,302	0.0	5.99	0.31	6.30	6.37	0.07
5	17.00	103,097	0.0	5.99	0.31	6.31	6.35	0.04
6	16.60	102,935	0.0	6.00	0.31	6.31	6.33	0.02
7-1	16.00	102,772	0.0	6.00	0.32	6.32	6.31	-0.01
7-2	16.00	102,772	5.0	6.00	0.32	6.32	9.93	3.61
8	15.00	101,892	5.0	6.03	0.32	6.35	11.92	5.57
9	14.40	101,017	5.0	6.07	0.32	6.39	11.98	5.59
10	14.00	100,249	5.0	6.00	0.54	6.54	11.99	5.45
11	12.60	100,231	2.0	6.02	0.54	6.55	12.32	5.77

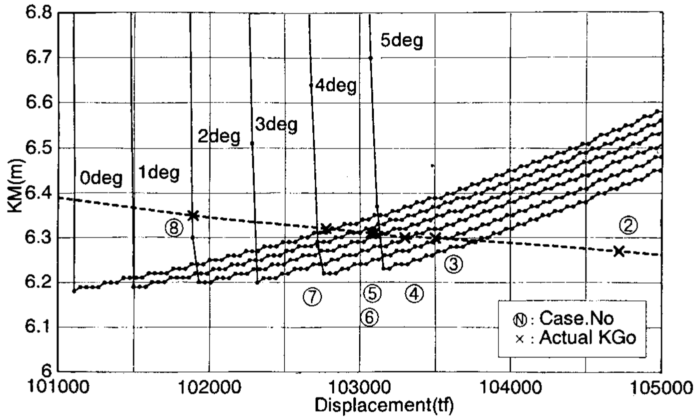

Fig. 4 Minimum KM of Barge-F2.

Table 2 Stability calculation of Barge-F3.

Case	Draft at Midship m	Disp. tf	Trim deg	KG m	GGo m	KGo m	Min.KM m	Min.GoM m
1	19.98	106,335	0.0	5.92	0.46	6.38	11.07	4.69
2	19.00	105,735	0.0	5.91	0.54	6.46	11.02	4.56
3	17.00	104,519	0.0	5.92	0.55	6.47	10.94	4.47
4	15.00	103,302	0.0	5.91	0.54	6.45	10.88	4.43
5	13.00	102,080	0.0	5.88	0.58	6.46	10.84	4.38
6	12.10	101,472	0.0	5.86	0.58	6.44	10.83	4.39
7	11.00	92,298	0.0	5.79	0.77	6.55	30.30	23.75
8	9.00	74,560	0.0	5.51	1.16	6.67	28.02	21.35

4.2 Barge with Three Floaters

First, Barge-F3 alone case is examined. As shown in Table 2, all steps have positive GM (Min.GoM>0) and are in stable condition without trim. For Barge-F2, the minimum KM occurs about the axis passing the center of floatation of both floaters. In case of Barge-F3, the minimum KM is obtained by iterative calculation for several heeling axis.

Next, stability performance of Barge-F3 with Spar during float off operation is discussed. The center of Spar is located 10.0m aft of midship of the barge to improve stability performance during awash deck condition of the barge with trim by the stern.The loading condition is illustrated in Fig.5. The Spar is positioned on the skid way.

The center of gravity of Spar is assumed to be at the center, 1/2 of full length.The clearance between Spar and the deck of barge is 1.0m at the minimum.

The results are summarized in Table 3 and Fig.6. Each case at submerging operation is illustrated in Fig.7.

In Fig.6, the displacement and trim at which aft end of Spar starts floating are shown as Spar float off line. Of course, the displacement and trim should be within this limitation. Loads on the skid are examined in the following section. From the above results, followings can be derived.

(1)Metacentric heights (GoM) are positive in all cases keeping the barge trimmed by the stern. The maximum trim is 3.2 degrees. Those fulfill the requirement of ABS in its MODU rule that metacentric heights should be positive during transient condition from one mode to another.[1)] The minimum GoM is 0.06m at Case 10 which corresponds to the condition that the deck of barge has just submerged completely. If greater GoM is required, additional longitudinal bulkheads may be introduced to reduce free water effect (GGo) of 0.51m.

(2)The size of floaters of 22m x 9m x 14m seems to be the minimum. The minimum freeboard of the floater is 3.85m.

5. Load on the Skids during Floating off

During float off operation, the loads on the skid installed on semi-submersible barges will be changed due to draft and trim. Especially, a great concentrated load may occur at the moment of just floating off. In this section, the loads on skids during floating off are examined.

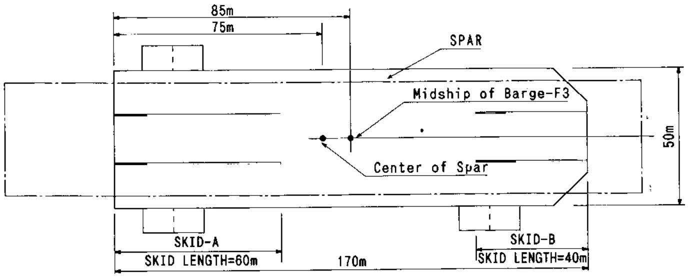

Fig. 5 Loading condition.

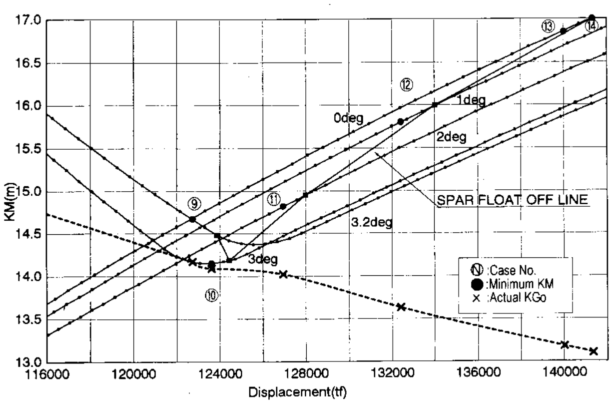

Fig. 6 Minimum KM of Barge-F3 with spar.

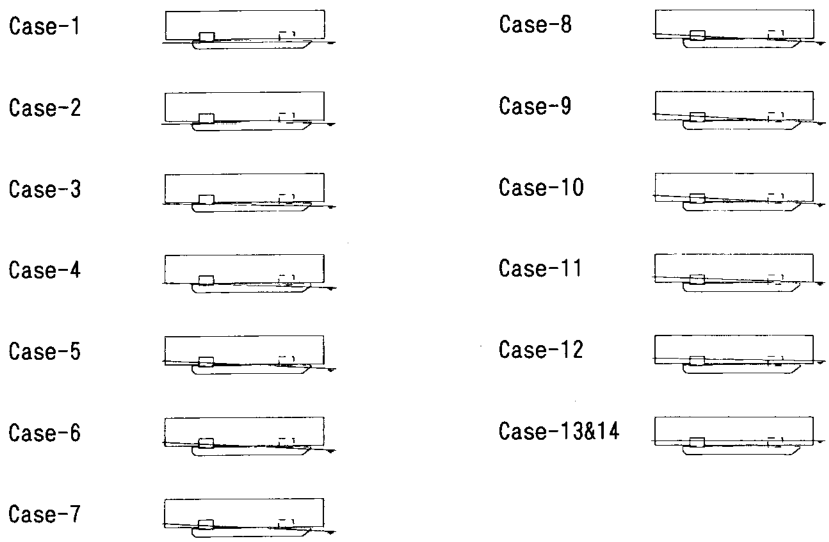

Fig. 7 Submerging operation.

Table 3 Stability calculation of Barge-F3 with spar.

Case	Draft at Midship (m)	Disp. (tf)	Trim (deg)	KG (m)	GGo (m)	KGo (m)	Min.KM (m)	Min.GoM (m)
1	9.00	74,564	0.0	18.39	1.08	19.47	28.02	8.55
2	9.30	77,130	0.0	17.99	1.29	19.28	27.39	8.11
3	9.90	82,912	1.0	17.00	1.20	18.20	30.34	12.14
4	10.66	89,058	2.0	16.32	1.22	17.54	23.29	5.75
5	11.90	97,473	3.0	15.33	1.12	16.45	18.77	2.32
6	12.30	100,274	3.2	15.16	1.09	16.25	18.21	1.96
7	13.00	104,889	3.2	14.97	0.96	15.93	17.94	2.01
8	14.00	111,325	3.2	14.41	0.72	15.13	16.90	1.77
9	15.90	122,731	3.2	13.65	0.52	14.17	14.67	0.50
10	16.20	123,624	3.0	13.58	0.51	14.09	14.15	0.06
11	17.40	126,951	2.0	13.29	0.73	14.02	14.82	0.80
12	18.56	132,423	1.0	12.98	0.65	13.63	15.80	2.17
13	19.81	140,012	0.0	12.79	0.39	13.18	16.85	3.67
14	19.98	141,335	0.0	12.75	0.35	13.10	17.00	3.90

5.1 Calculation Method

Load on the skids can be calculated as follows. Meanwhile, the study is based on a condition that the loads are assumed to be distributed homogeneously on each part of Skid A and B as shown in Fig. 8 by means of hydraulic jack system.

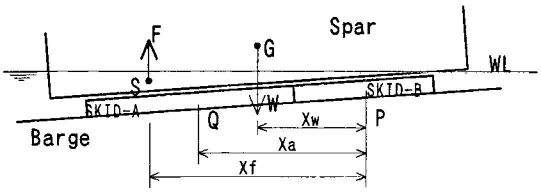

Fig. 8 Loads on skid way.

$$W \cdot X_W = R_a \cdot X_a + F \cdot X_f \quad (1)$$

Then,

$$R_a = (W \cdot X_W - F \cdot X_f)/X_a \quad (2)$$

$$R_b = W - F - R_a \quad (3)$$

Where,

R_a : equally distributed load on skid A
R_b : equally distributed load on skid B
P : center of skid B
Q : center of skid A
G : center of gravity of Spar
S : center of buoyancy of Spar
F : buoyancy of Spar
W : weight of Spar
X_W : distance between P and G
X_a : distance between P and Q
X_f : distance between P and S

5.2 Calculation Results

The calculation results of the loads on skid ways during submersing operation are summarized in Fig.9, where vertical axis and horizontal axis indicate loads on skids and barge midship draft respectively. From Fig.9, the followings can be found.

(1) Maximum load is 1,960kN/m on skid way B at the draft of about 16m at which the stability performance is critical.

(2) Both loads of skid A and B become zero at the moment of floating off. This means no one point contact occurs.

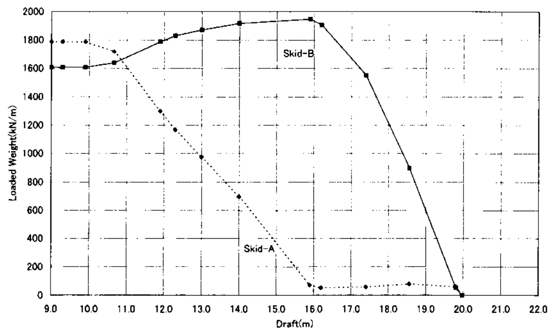

Fig. 9 Loaded weight on skid way.

6. Ballasting Sequence

Due to unsymmetrical arrangement of floaters, ballast arrangement will also be unsymmetrical. Ballasting operation, therefore, may be more complex than conventional one. In order to confirm this point, ballasting sequence calculation for each step of float off operation of Barge-F3 is carried out. The results are illustrated in Fig.10, where the bottom plane and vertical axis show the compartments of ballast tanks and

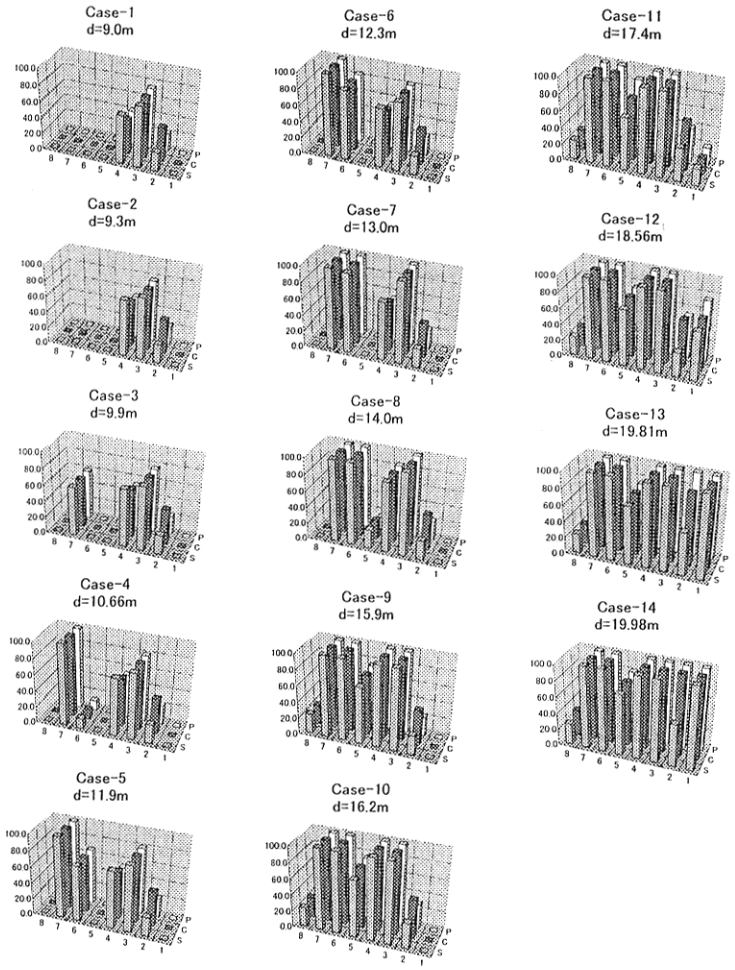

Fig. 10 Ballasting sequence.

the percentage of ballast volume respectively. This indicates that the number of ballasting tanks can be limited to six (No.2 and No.8) and only one pair of tanks (No.8 port and starboard tanks) will be ballasted unsymmetrically at the most critical stability conditon (case 9 - 10).

7. Conclusion

In order to shorten discharging time and reduce possibility to sustain damage at float off operation of Spar, semi-submersible barges with unsymmetrical floater arrangement are studied. Major conclusions are as follows.

(1) Semi-submersible barge with two floaters located diagonally cannot keep stable condition on the stability at submerging and refloating operation without Spar.

(2) Semi-submersible barge with three floaters is feasible from the view point of loads on skid ways, stability and ballasting operation.

In this paper, investigation was carried out basing on typical combination of barges, floaters and Spar in their shape, number, size etc. but the same procedure can be taken for other combinations.

References

1) American Bureau of Shipping: Rules for Building and Classing Mobile Offshore Drilling Units, Part3, Sec.3, Hull Construction and Equipment. 1997.