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Integrated Analysis of a Jacket Platform Installation

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ABSTRACT

This study presents a comprehensive analysis for the safe installation of a Jacket Platform from on-shore to off-shore locations. The analysis utilizes numerical simulations with MOSES software, considering factors like barge trim angle and skid way friction coefficients. Results reveal that an initial trim angle of 3.25° meets safety requirements. Further examination shows a trim angle of 3.1° and friction coefficient of 0.06 achieves an acceptable tipping time of 1 minute and 9 seconds. However, increasing the friction coefficient to 0.065 prolongs the tipping time to 1 minute and 39 seconds with a 3.5° initial barge trim. This integrated analysis offers valuable insights to ensure safety during Jacket Platform installation, preventing potential accidents and financial losses.

1. Introduction

Under the 2010 Economic Transformation Program (ETP), the Malaysian government demonstrated its policy to increase the competitiveness of its domestic Oil Field Services & Equipment (OFSE) industry with the objective of transforming the country into a leading oil and gas services hub in Asia [1]. In fact, Malaysia relies heavily on the oil, gas, and energy sector, which contributes approximately 20% of the country's GDP [2]. This has led to a steady increase in the research, improvement, design, and fabrication of offshore oil and gas platforms. In Malaysian waters, steel jackets are the most common type of offshore platform that can support a conventional superstructure for drilling and production operations.

For the installation of Jacket Platforms from on-shore to off-shore locations, an integrated process analysis is conducted with the primary objective of preventing accidents that could endanger human life and result in significant financial losses. Numerical simulations using the MOSES software are employed, considering various parameters such as the trim angle of the barge and friction coefficients of the skid way [3]. The simulation results reveal important findings, and an initial trim

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angle of 3.25° results in an acceptable tipping time that complies with standard requirements. Further examination of the effect of the initial trim angle of the barge shows that a trim angle of 3.1° and a friction coefficient of 0.06 achieve an acceptable tipping time of 1 minute and 9 seconds [4]. Conversely, increasing the friction coefficient to 0.065 prolongs the tipping time to 1 minute and 39 seconds when associated with an initial barge trim of 3.5° [5]. Overall, this integrated analysis provides valuable insights for predicting the installation operation of Jacket Platforms and ensuring operational safety throughout the various processes involved.

An integrated process analysis aims to ensure safe Jacket Platform installation from on-shore to off-shore locations, preventing accidents and financial losses [6]. Utilizing numerical simulations with MOSES software, parameters like barge trim angle and friction coefficients are considered [7]. Results reveal that an initial trim angle of 3.25° yields an acceptable tipping time, complying with standards. Further analysis shows that a trim angle of 3.1° and friction coefficient of 0.06 achieve a tipping time of 1 minute and 9 seconds [8]. However, increasing the friction coefficient to 0.065 with an initial barge trim of 3.5° prolongs the tipping time to 1 minute and 39 seconds [9]. This integrated approach provides crucial insights for efficient and safe Jacket Platform installation. Jacket platforms are commonly used in shallow water regions worldwide [10,11]. Yet, their fabrication onshore and subsequent installation at the target location pose significant costs and irreversible processes. To minimize errors during installation, extensive simulations are performed, ensuring precision and reliability in the Jacket Platform deployment.

This paper presents a numerical simulation study using the MOSES software to analyze the launching process of a jacket platform. The installation process of a steel jacket platform typically consists of four phases: load-out, transportation, launching, and up-ending [12]. The focus of this investigation is on the launching and up-ending phases, where numerical simulations and parametric studies are conducted by varying the barge's trim angles and the skid way's friction coefficients. The objective is to identify the most suitable combination that ensures a safe and efficient installation process. By observing the tipping time and comparing it to standard requirements, valuable insights are gained to enhance overall performance and safety measures during the installation of the jacket platform. The findings from this study contribute to advancing offshore platform installation techniques and mitigating potential risks associated with the process.

2. Theoretical Background

2.1 Jacket Launching Process

The launching process is crucial for moving the jacket from the barge to sea water. It occurs when the jacket slides towards the rocker arm at the barge's aft [13]. To avoid collisions in shallow water, the jacket is launched in deep water and then towed to the installation site. The whole process takes 1 to 2 minutes, ensuring an efficient and safe installation.

In the crucial launching of a jacket platform, engineers employ a 2D motion analysis in the vertical plane, creating an equation to accurately predict its movements. This analysis comprehensively evaluates the platform's dynamic behavior under varying environmental conditions and operational factors. Comprehending the motion response allows identifying risks, enabling precise strategies for a safe and efficient platform launch. The equation of motion in the time domain is expressed as

$$I\ddot{q} + C\dot{q} + Kq = s \quad (1)$$

The excitation force on the barge can be defined as

$$s = -A\ddot{q} - \int_o^t D\,(t-\tau)\,\dot{q}\,(\tau)d\tau \quad (2)$$
$$F_F = C_f F_N \quad (3)$$

The hydrodynamic force on the jacket is a summation of drag force and added mass, excluding hydrodynamic interactions in the launching analysis [14]. Thus, an equation of hydrodynamic force can be defined as

$$F_h = C_M pV\dot{U} - \frac{1}{2} C_D p\mathrm{A}|U|U \quad (4)$$

3. Simulation Condition

3.1 Principal Data of Barge

In this paper, we focus on the installation of a jacket using a Delmar barge. For this purpose, a specific Delmar barge with an overall length of 91.44 meters was carefully selected as the ideal vessel for the task. The Delmar barge model, essential for our numerical simulations, is conveniently available in the MOSES software library. To ensure a realistic representation, a model of a four-legged jacket platform was designed in SACS, adhering closely to the actual dimensions. To maintain consistency and precision throughout the process, all main dimensions of the jacket platform, including height, number of legs, and weight, were meticulously aligned with the reference specifications (refer to Figure 1). For a comprehensive overview, Table 1 and 2 provide detailed information about the main dimensions of the Delmar barge and the jacket model's parameters, respectively. Through these simulations and analyses, we aim to gain valuable insights into optimizing the installation procedures, ultimately ensuring a safe and efficient operation.

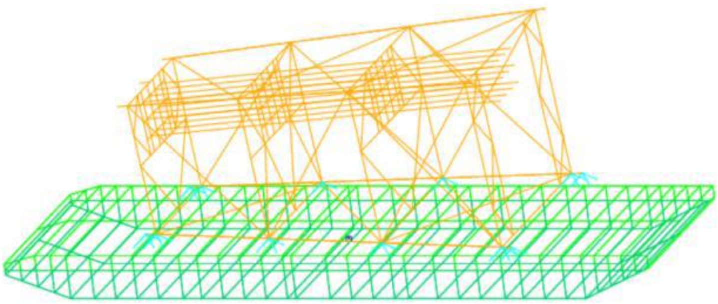


Fig. 1. Isometric view of jacket and barge

Table 1
Main dimensions of barge

Geometrical parameters	Full scale
Overall length (m)	91.44
Beam (m)	27.43
Depth (m)	6.10
Light ship weight (Tonne)	2557.81
Tilt beam length (m)	15.36

Table 2
Main dimensions of jacket

Geometrical parameters	Descriptions	Full scale
Length (Bottom) (m)		28.920
Width (Bottom) (m)		24.360
Length (Top) (m)		18.800
Width (Top) (m)		1840
Height (m)		53.60
Weight (Tonne)		2557.81
Lower layer legs (m)	Diameter	17.76
	Thickness	0.192
Medium layer legs (m)	Diameter	17.86
	Thickness	0.240
Upper layer legs (m)	Diameter	18.22
	Thickness	0.420
Connectors (m)	Diameter	11.84
	Thickness	0.192

3.2 Simulation Parameters

As per DNVGL-ST-N001 Marine Operations and Marine Warranty, the usual initial barge trim is set below 4° [15]. However, this study will simulate the launching process with initial barge trims ranging from 3° to 5°, at intervals of 0.5°, to investigate their effect on jacket motion response particularly tipping time and separating time. Additionally, the friction coefficient of the skid way, determined by the skid way's material, impacts the launching process duration. The analysis will be conducted with various friction coefficients based on the skid way's construction material. All data is sourced from Table 3 in the classification rules, DNV Load Transfer Operations.

Table 3
Simulations' parameters at different trim angles and frictional coefficients

Initial barge trim	Initial frictional coefficient (Cf)				
(deg)	0.050	0.055	0.060	0.065	0.070
3.0	√	O	O	O	O
3.5	√	√	√	√	√
4.0	√	O	O	O	O
4.5	√	O	O	O	O
5.0	√	O	O	O	O

3.3 Geometrical Modelling of a Jacket Platform

The Structural Analysis Computer System (SACS) software facilitated the creation of a detailed numerical simulation model for a 52.6-meter-tall jacket platform. Utilizing the SACS modeler tool, a 3D representation was generated, allowing precise specification of members and wall thicknesses. Figure 2 presents a solid view of the platform, visually depicting the SACS model. Later, a macro file transformed the model from SACS programming language to MOSES programming language, preparing it as a database for simulating the jacket installation process.

3.4 Setting-up a Numerical Simulation

MOSES offers diverse commands for simulating the jacket installation process, particularly during launching. These commands ensure the automatic offshore installation of the jacket platform within the MOSES system. Correct syntax arrangement is crucial for accurate analysis. The command file provides simulation instructions, while the data file supports the process with essential environmental conditions, model data, and barge initial conditions.

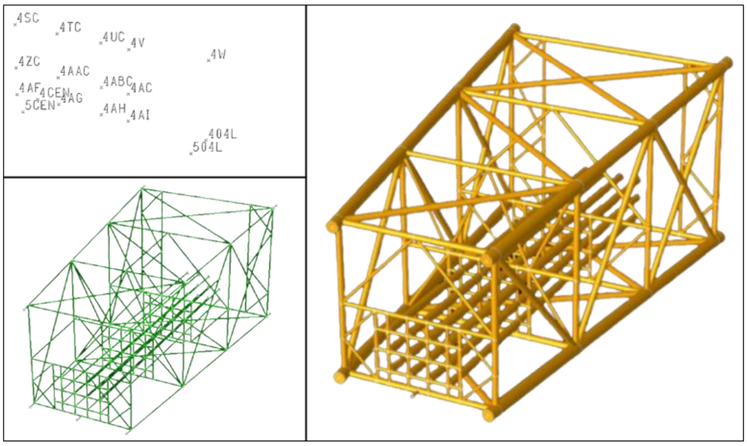
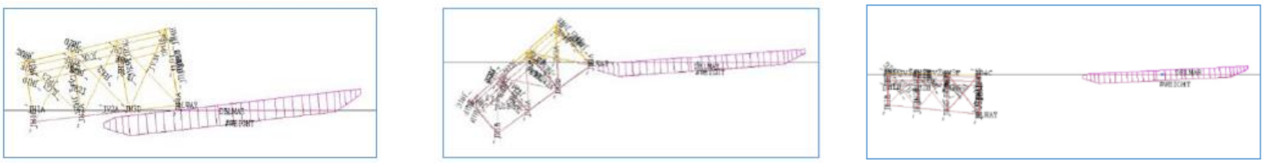


Fig. 2. Jacket model generation from SACS programming into MOSES language

4. Results and Discussion

In this study, we examine how the initial barge trim and friction coefficient influence the jacket's motion response, maximum barge trim, and rocker load during the launching analysis (refer to Figure 3). MOSES employs dedicated compartments for automatic ballasting, ensuring the desired mean draft and trim angle of the barge. Figure 4 depicts the positions of the jacket and compartments on the Delmar barge, along with the various stages of the launching process.



(a) Stage 1 (b) Stage 2 (c) Stage 3

Fig. 3. Launching process

4.1 Effect of Trim's Angle on Launching Process

The impact of different initial barge trim angles on the jacket launching process is investigated. Table 4 presents the effects on launching time, rocker loads, and maximum barge trim angle during the launch. The range of initial barge trim angles examined was from 3.0° to 5.0°. The research revealed that increasing the initial barge trim led to a significant 91.17% increase in tipping time during the launch. It is noted that higher initial barge trim angles can result in faster launching times [16], but recommended launching times should ideally be between 1 and 2 minutes [17].

Furthermore, an initial barge trim in the range of 3.0° to 5.0° results in a gradual decrease in the weight of the jacket exerted on the rocker arms, leading to a decrease in the total rocker load from

80% to 72%. A higher initial barge trim angle corresponds to a higher maximum barge trim during the launch. This increase in barge trim is attributed to the jacket sliding faster, generating greater momentum, and causing the barge to sink at the stern to counterbalance the load. However, this higher barge trim compromises the stability of the barge, which could lead to a more dangerous and unpredictable launching process, especially when dealing with a high friction coefficient. The reduced transfer of load to the rocker arms is attributed to the faster sliding of the jacket, which may lead to higher collision forces between the jacket and the sea water surface, potentially causing damage to the jacket's structure.

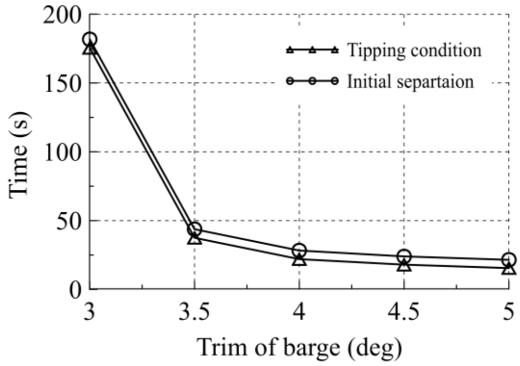


Fig. 4. Time for tipping and initial condition at various trim's angle

Table 4
Launching process results with different trim's angle of barge

Trim of Barge (deg)	3.0	3.5	4.0	4.5	5.0
	Tipping condition				
Time (sec)	175.50	37.50	22.00	18.00	15.50
Length of leg on deck (m)	28.03	28.35	29.23	27.92	21.50
Port rocker load (T)	486.85	471.20	463.67	443.90	439.88
Starboard rocker load (T)	487.05	470.69	462.77	442.29	437.98
Total rocker load (T)	974.00	941.99	926.53	886.19	877.86
Percent of jacket weight (%)	80.00	78.00	76.00	73.00	72.00
Jacket trim angle (deg)	6.08	6.81	7.27	8.21	8.61
Barge trim angle (deg)	5.92	6.62	7.17	7.84	8.29
	Initial separation condition				
Time (sec)	181.72	43.75	28.25	24.00	21.50
Length of leg on deck (m)	1.26	0.69	1.31	0.85	1.13
Port rocker load (T)	56.80	44.66	48.78	43.36	44.06
Starboard rocker load (T)	48.47	36.53	40.04	35.83	36.63
Total rocker load (T)	105.28	81.29	88.82	79.29	80.69
Percent of jacket weight (%)	8.00	6.00	7.00	6.00	6.00
Jacket trim angle (deg)	37.41	36.62	36.70	35.21	34.60
Barge trim angle (deg)	4.18	5.13	6.20	7.07	8.00
	Fully separation condition				
Jacket displacement (T)	43.75	28.25	24.00	1288.64	1288.64
Jacket trim angle (deg)	47.47	48.77	45.83	46.68	44.78
Jacket CG long, velocity (m/sec)	6.13	5.95	5.82	5.66	5.67
Jacket CG vert. velocity (m/sec)	-1.80	-1.98	-1.77	-1.89	-1.75
Barge trim angle (deg)	6.20	7.03	7.77	8.46	9.10
Barge CG long velocity (m/sec)	-1.23	-1.23	-1.25	-1.27	-1.28
Barge keel submergence (m)	8.06	8.64	9.13	9.53	9.86

4.2 Effect of Frictional Coefficient of Skidway on Launching Process

The friction coefficient (C_f) significantly affects the jacket's motion response during launching, particularly the tipping and separating times (refer to Figure 5). An increase in Cf from 0.050 to 0.070 results in a 644.19% increase in tipping time and a 13.04% increase in separating time. A smaller Cf leads to a shorter sliding duration along the skidway, while higher C_f causes longer launching times. The recommended C_f for optimal performance is 0.065, resulting in a launching time of 1 minute and 46 seconds with a constant initial barge trim of 3.0 degrees.

The friction coefficient significantly affects the jacket's motion response during launching, particularly the tipping and separating times (refer to Table 5). As C_f increases, the tipping time and separating time also increase. A smaller Cf results in a shorter sliding duration along the skidway. Moreover, higher C_f leads to longer launching times. The recommended Cf for optimal performance is provided. Additionally, C_f has a clear effect on the maximum barge trim. As C_f increases, the maximum barge trim rises. This is attributed to the increased sliding speed of the jacket, resulting in a larger momentum exerted on the barge, causing it to sink at the stern and reducing stability. However, while C_f significantly affects tipping and separating times and maximum barge trim, it appears to have little influence on the total rocker load of the barge at a constant initial barge trim. The loads exerted on the rocker arms remain relatively equal across the range of varied friction coefficients.

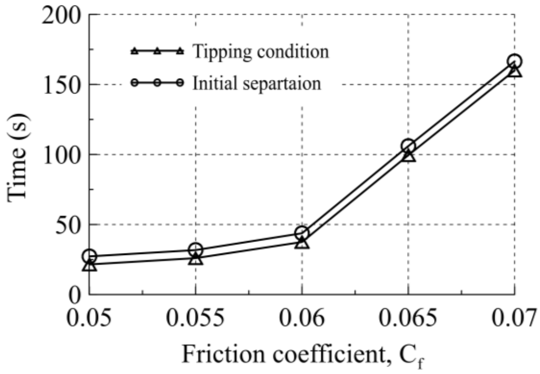


Fig. 5. Time for tipping and initial condition at various friction coefficients

Table 5
Launching process results with different friction coefficients

Friction coefficient, C_f	0.050	0.055	0.060	0.065	0.070
	Tipping condition				
Time (sec)	21.50	26.00	37.50	99.50	160.00
Length of leg on deck (m)	27.71	27.36	28.35	28.73	27.95
Port rocker loat (T)	468.39	463.87	471.20	472.60	465.98
Starboard rocker load (T)	467.68	463.17	470.69	472.00	464.57
Total rocker load (T)	936.07	927.14	941.99	944.70	930.65
Percent of jacket weight (%)	77.00	76.00	78.00	78.00	77.00
Jacket trim angle (deg)	6.76	6.95	6.81	6.82	7.13
Barge trim angle (deg)	6.49	6.60	6.62	6.69	6.85
	Initial separation condition				
Time (sec)	27.25	31.75	43.75	106.00	166.50
Length of leg on deck (m)	1.13	1.37	0.69	0.78	0.33
Port rocker load (T)	52.29	52.89	44.66	43.66	0.00
Starboard rocker load (T)	43.36	43.96	36.53	36.43	48.17

Total rocker load (T)	95.74	96.85	81.29	80.09	48.17
Percent of jacket weight (%)	7.00	8.00	6.00	6.00	3.00
Jacket trim angle (deg)	35.53	35.94	36.62	37.15	37.38
Barge trim angle (deg)	5.22	5.24	5.13	5.12	5.06
	Fully separation condition				
Jacket displacement (T)	1288.74	1288.44	1288.64	1288.44	1289.64
Jacket trim angle (deg)	45.47	45.61	48.77	49.36	51.07
Jacket CG long, velocity (m/sec)	6.11	6.03	5.95	5.87	5.81
Jacket CG vert. velocity (m/sec)	-1.95	-1.89	-1.98	-1.90	-2.19
Barge trim angle (deg)	6.88	6.96	7.03	7.11	7.19
Barge CG long velocity (m/sec)	-1.25	-1.24	-1.23	-1.22	-1.21
Barge keel submergence (m)	8.51	8.58	8.64	8.72	8.79

4.3 Up-Ending Process After Side-Lift

The dynamics of up ending a jacket platform through the utilization of the sidelift method are vividly illustrated in Figure 6. During the initial descent phase, the hook load gradually decreases as the jacket submerges, carefully maintaining a horizontal orientation. This phase sees a subtle pitch angle change from 6.01° to 7.29°, accompanied by the center of gravity's movement along the z-axis from 13.01m to -12.57m, as meticulously detailed in Table 6. As the process progresses to the subsequent up-ending stage, a significant hook load shift is noted, ascending in tandem with the jacket's emergence from the water. This transformation triggers a distinct pitch angle change from 7.33° to an impressive 83.48°, showcasing the achievement of a near-vertical up-ending position. Concurrently, the center of gravity undergoes a calculated migration from -12.69m to -6.73m. The genesis of this shift is rooted in the intricate interplay of mass distribution adjustments, exerting a pivotal influence on the jacket platform's structural stability. These dynamics align with the insights highlighted by Amid and Allahyaribeik [18] and Omdehghiasi *et al.,* [19], casting light on the nuanced correlation between maneuvering, angles, and the underlying mechanics of structural integrity.

Initiating with the first flood stage, seawater infusion into jacket legs triggers a moderate adjustment in hook load and pitch angle, transitioning from 3380.50kN to 4358.50kN and 83.48° to 82.62°, accompanied by a notable elevation in the maximum FC from 1143.50kN to 1523.10kN, and a descent of the center of gravity from -7.08m to -7.57m. In the subsequent flood stage, hook load rises from 4528.70kN to 5439.00kN, along with a surge in maximum FC from 1543.14kN to 1536.01kN. The pitch angle shifts from 83.26° to 87.71°, signifying a calculated shift towards vertical alignment. The center of gravity follows this adjustment, moving from -7.88m to -8.39m. Concluding with the final lowering stage, gradual hook load reduction and subtle pitch angle change to 90.39° achieve a poised upright stance. Simultaneously, the center of gravity reaches -20.26m, with a slight 0.3° deviation from exact vertical alignment, testament to meticulous execution and structural precision.

Table 6
Results analysis for up-ending process after side-lift

Event	Pitch (deg)	Roll (deg)	Hook load (kN)	Max connector force (kN)	Ballast (T)	WPA (m^2)	C.O.G about x (m)	C.O.G about y (m)	C.O.G about z (m)
Lowering									
0	6.01	0.06	11676.63	4471.01	0.00	0	22.57	0.00	13.01
26	7.29	0.02	223.74	22.34	0.00	186	23.42	-0.03	-12.57
Up-ending stage									

27	7.33	0.00	0.00	0.00	0.00	190	23.42	-0.04	-12.69
64	83.48	0.10	3208.50	1085.32	0.00	22	0.54	0.1	-6.73
1st flood									
65	83.48	0.10	3380.50	1143.50	172.20	22	0.46	0.1	-7.08
74	82.62	0.10	4358.00	1523.10	1148.20	31	0.69	0.1	-7.57
2nd flood									
75	83.26	0.10	4528.70	1543.14	1319.50	25	0.34	0.09	-7.88
84	87.71	0.10	5439.00	1536.01	2235.50	20	-2.81	0.04	-8.39
Lowering stage									
85	88.14	0.10	5209.30	1501.72	2303.20	20	-3.2	0.03	-9.34
97	90.39	0.10	3187.00	1016.31	3106.40	20	-5.21	-0.03	-20.26

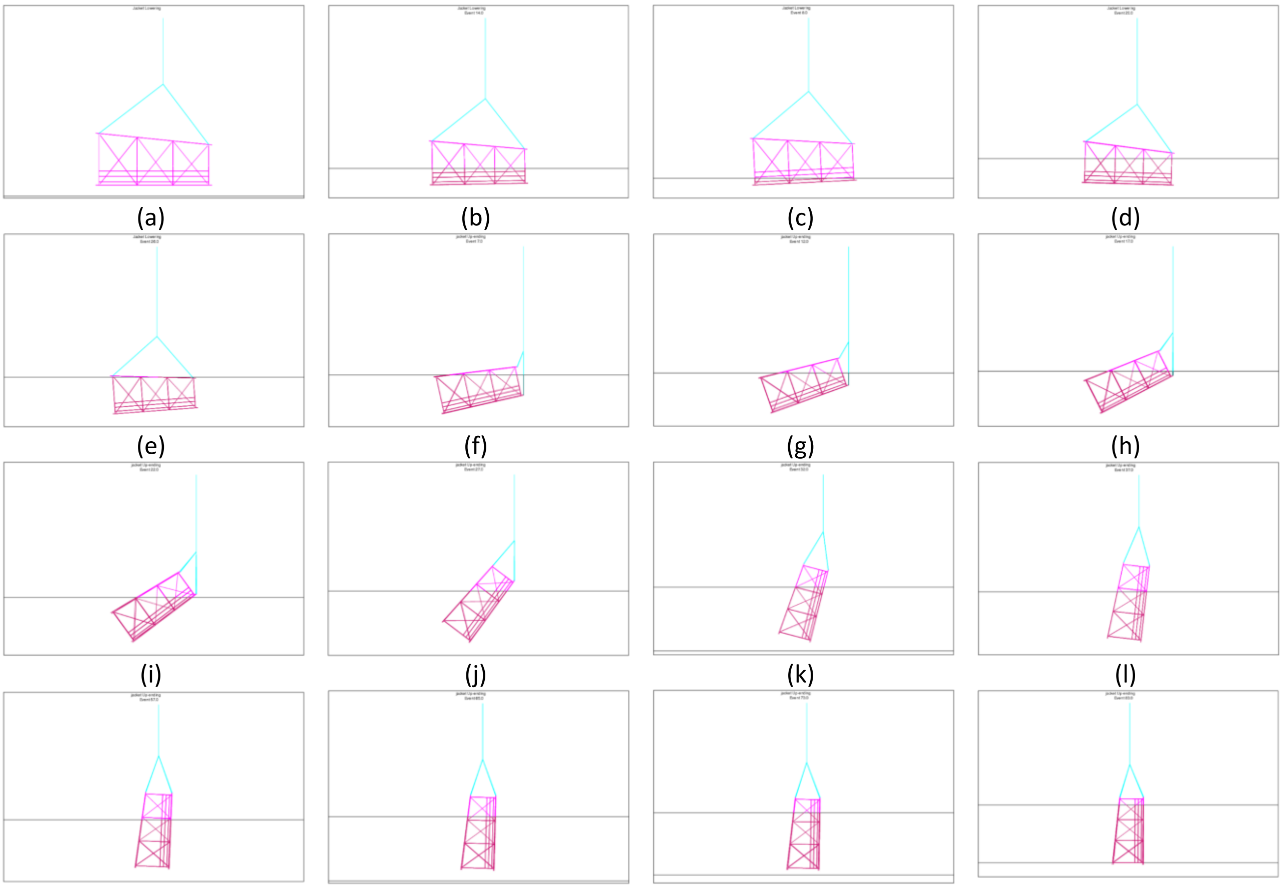

(a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l) (m) (n) (o) (p)

Fig. 6. Up-ending process after side-lift

5. Conclusions

The study investigated the impact of initial barge trim angle and friction coefficient on the jacket launching and up-ending processes. The results showed that:

i. An increase in the initial barge trim angle resulted in a significant rise in tipping time, maximum barge trim, and a decrease in rocker load.
ii. A higher friction coefficient led to longer launching times and higher maximum barge trim but had minimal impact on the rocker load.

iii. The recommended initial barge trim angle is 3.0 degrees, and the recommended friction coefficient is 0.065.
iv. The sidelift method's up-ending dynamics are illuminated. Initial descent maintains a slight pitch angle change (6.01° to 7.29°) and center of gravity movement (13.01m to -12.57m). Subsequent up-ending involves hook load ascent, significant pitch angle change (7.33° to 83.48°), and center of gravity migration (-12.69m to -6.73m), influenced by mass distribution adjustments crucial for stability.

This investigation offers valuable insights to enhance the safety and efficiency of jacket launching operations.

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