Damage Assessment of Structural Depression Caused by Ship Collision

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Abstract: In this paper, the nonlinear numerical dynamic simulation of an offshore jacket platform structure impacted by a large tonnage pipe laying crane vessel is carried out. The nonlinear spring is used to simulate the sunken characteristics of the damaged components. The damage of the components under different collision contact time is calculated and analyzed. Compared with the detection results of the actual structural damage, the inversion calculation and analysis of the collision between the ship and the platform at different speed are carried out, and the different collision contact time and the maximum impact force are obtained The stress and displacement time history curve of the main joints of the jacket platform structure can determine the damage degree of the structural members and joints of the jacket platform after the impact, which provides a theoretical basis for putting forward a reasonable and feasible repair and reinforcement plan.

1. Introduction

Steel jacket platform structure is widely used in offshore oil and gas development. They work in the complex marine environment, in addition to the normal working load, but also by the sea wind, waves, currents and sea ice and other environmental loads. At the same time, due to the occurrence of unexpected accidents, such as the collision between the ship and the offshore platform structure, the weight of the upper structure of the platform and so on. Collision often makes the whole platform structural components bend and sink, reduces the bearing capacity, affects the safety of the components, and sometimes greatly reduces the strength of the whole platform structure. On the other hand, due to the difficulty of repairing the damaged components at sea and the high cost, the reasonable and feasible repair and reinforcement plan should be based on the accurate assessment of the impact of the damage on the whole platform structure [1]. Therefore, how to correctly analyze and evaluate the damage of offshore jacket platform structure caused by collision and its impact on the strength, bearing capacity and fatigue life of the platform structure has become an important research topic in offshore engineering. Generally, in the study of the collision between the offshore jacket platform structure and the ship, the dynamic problem of the collision is transformed into the quasi-static problem, and the static strength analysis and calculation of the platform structure and components are carried out, which is feasible in the initial stage of the study of the collision problem, and is helpful to understand the collision mechanism and the residual strength of the damaged components. However, the collision process is a dynamic process, involving many complex and uncertain static and dynamic factors, such as the collision mode between the ship and the offshore platform structure, the contact time of the collision, the pile soil platform structure interaction, and the role of the marine environment load. In this paper, based on the damage detection results of the x-diagonal brace of a jacket platform structure in the South China Sea after being impacted by a large tonnage crane laying vessel during the jacket installation stage, the interaction of pile soil platform structure is considered, and the nonlinear spring is used to simulate the local depression damage of the damaged components, and the stress and displacement time history curve of the platform structure components and pipe joints are inversely analyzed and calculated The damage degree of jacket platform structure is evaluated and analyzed.

2. Mechanical Model of Collision System

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2.1. Impact Mechanics

For the collision between the ship and jacket structure, it is assumed that the collision time is much less than the ship's motion period, and the ship and the platform structure move together after the collision[2]. Before establishing the mechanical model of the collision system, the following assumptions are made: the hull is a specific speed and mass rigid body without volume, that is, the response of the offshore jacket structure to the collision is mainly studied, and the deformation of the hull structure is ignored; the system obeys the laws of conservation of momentum and energy in the collision process; during the collision process, the hydrodynamic force acting on the hull is added by introducing additional mass In consideration of that,in lateral collision and K = 0.1 in bow or stern collision with platform, it is assumed that the material is ideal elastic-plastic. According to the law of conservation of momentum, it can be concluded that, the common velocity after collision isthe kinetic energy before collision is absorbed to a certain extent by the plastic deformation of the ship and platform structure, so the conservation of energy can be expressed as , where M2 is the platform structure Mass; V1 is the speed of the ship at the moment before collision; V2 is the speed of the platform at the moment before collision; V12 is the common speed of the ship and the platform after collision; ES is the energy absorbed by the ship; EP is the energy absorbed by the platform. Due to the lack of reliable data on the plastic deformation of the hull, the plastic deformation energy of the ship is usually ignored, so the energy absorbed by the platform structure under conservative conditions is. The energy absorbed by the platform structure mainly includes: the local plastic deformation of the pipe wall of the impacted circular pipe component; the elastic-plastic bending deformation energy of the platform component; the overall deformation and elastic vibration of the platform structure Kinetic energy.

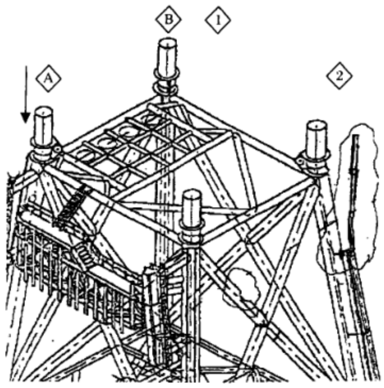

Figure 1 Collision damages of the platform

2.2. Local Deformation of Circular Pipe Wall under Impact Load

In order to study the overall response of the platform to the impact, it is necessary to study the deformation characteristics of the local hollow of the tubular members under the impact load. The shape and extent of the local deformation depends on the nature of the collision[3]. Due to the complexity of the collision problem, it is difficult to find a simple analytical model to analyze the local depression of the impacted circular tube. At present, there are two different models in this respect: the ring model and the depression model. The ring model assumes that there are four plastic hinges on the ring when the ring is in the middle of two rigid plates, and the p - relation is obtained by the method of maneuver. However, in general, under the action of transverse load, the local depression of the tube changes continuously with the length. Therefore, this paper uses the depression model to analyze the p - relationship. According to Bai Yong [4], the local linear elastic deformation of the tubular members subjected to the compressive load can be expressed by the following formula; E is the elastic deformation; E is the young's modulus; t is the wall thickness; D is the outer diameter of the tubular; LC is the axial characteristic length of the contact area, which is related to many factors, such as pipe diameter, pipe length and concave shape. In order to obtain the empirical formula of LC, Ueda [4] carried out the finite element analysis of linear plates and shells, and Smith carried out a series of depression experiments. According to their results, LC = 1.9d.

When the load p is greater than a critical value P0, the pipe wall will have permanent concave deformation. Through the rigid plastic analysis of the ring under the compression load with the length of LC, the critical load, where FY is the yield stress of the material. Through experimental research and theoretical analysis, API RP 2a-wsd code [5] puts forward the relationship between the permanent dent deformation and load Pd of the damaged tubular members.

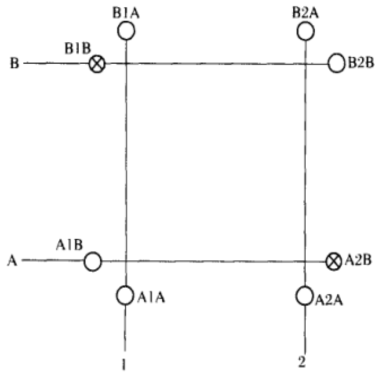

Figure 2 Layout of skirt piles

3. Dynamic Response Analysis of Platform Structure in Collision

The platform impacted by the ship is a steel platform with four legs and eight skirts piles. The designed water depth is 117.2 m, the penetration depth of piles is 91 m, and the diameter is 1829 M. During the installation of the jacket, it was impacted by a large tonnage crane laying vessel. The collision happened after the jacket was in place. At this time, all 8 skirt piles of the jacket have been inserted, among which B1B and A2B piles have been drilled, but the skirt pile sleeve and skirt pile have not been grouted. The collision occurred at the water surface. One component of the X diagonal brace between the legs of the jacket A2 and B2 was severely squeezed locally. The damaged area was 1.4m long along the longitudinal direction of the brace.[6] The starting point was 4m away from the top weld of the X diagonal brace node, the ending point was 5.4m away from the top weld of the X diagonal brace node, and the maximum radial extrusion depth was 0.150m. The riser on the B2 leg also severely damaged.

3.1. Pile Foundation Simulation

ANSYS finite element program is used to model and calculate the bearing capacity of single pile. The diameter of the single pile of the platform is 1829 m, and the length of the whole pile is 91 M. the unit is basically divided by 1.5 m. when dividing the unit, it is necessary to avoid the action range of a single spring beyond a certain layer of soil, and ensure the accuracy of the quasi Figure 4 jacket structure model of the platform. In this way, the pile is divided into n = 33 units along the length direction. When the pile bears the load, the action of each unit affected by the soil layer is simplified into three kinds of nonlinear springs - lateral spring (lateral bearing capacity of soil), vertical spring (surface friction of pile), torsion spring (surface friction force of pile). The action points of lateral spring and torsion spring are located in the center of the unit, and the action points of vertical spring are located At the bottom of the unit. The end bearing spring (the end bearing capacity of the pile) is also on the pile bottom unit, and the end bearing spring is compressive and non tensile . There are 30 lateral springs, 14 vertical springs, 15 torsion springs and 1 end bearing spring in the whole pile. The spring parameters are calculated from the p y curve data sheet, t Z curve data sheet and Q Z curve data sheet provided by the engineering address investigation report of the oilfield platform site [7]. The boundary conditions are applied to simulate the actual situation of the platform structure at the time of ship impact. The bearing capacity of the pile is not considered for the pile that has not been completed. For the pile that has been completed, the torsional nonlinear spring of the pile head is not considered because there is no grouting connection for the pile that has been completed.

3.2. Analysis of Overall Modeling and Calculation of Platform Structure

In the installation stage, the jacket platform structure is impacted by a large tonnage pipe laying crane, so it is necessary to evaluate and analyze the damaged components and pipe joints. The overall model of the structure is constructed according to the design drawings, and the jacket members are simulated by pipe units. Every 2m is divided into one unit, and the damaged members are divided into one unit according to 0.4m. The calculation model has 2052 units and 1881 nodes in total. The impacted X-brace is 914mm 19 mm and the material yield stress is 345mpa. Because the impact time occurs in the installation stage of the jacket, the superstructure of the platform has not been hoisted, so the total mass of the jacket structure of the platform is 1889 T, the mass of the ship is Ms = 42000 T, and the mass of the jacket structure is far less than that of the ship. The additional mass coefficient of the ship is taken as 0.4, and the deformation of the hull structure is ignored in the calculation. According to the formula, the force displacement curve of nonlinear spring is established, which is used to simulate the collision between platform structure and ship[8]. Assuming that the ship impacts the platform laterally at the velocity of v 1, according to the principle of momentum conservation, the common velocity V 12 of the ship and the platform structure can be determined after the collision. When the velocity of the platform structure is greater than V 12 under the impact force, the ship and the platform structure separate from each other. Assuming that there is no second collision between the ship and the platform structure, and the collision process between the ship and the platform structure is simplified as an isosceles triangle impulse load, the maximum impact force of the platform structure under different collision contact time can be obtained by impulse theorem. It can be used to analyze the transient dynamic response of jacket structure under ship impact load.

4. Conclusion

In this paper, the collision process between the deep-water jacket platform structure and the large tonnage lifting pipe laying vessel in the construction and installation stage is analyzed by numerical simulation[9]. In the process of analysis, nonlinear spring is used to simulate the concave characteristics of damaged components, and the hydrodynamic effect, pile soil platform interaction and other factors are considered.

References

[1] Parunov, Joško; Rudan, Smiljko; Gledić,. (2018). Finite element study of residual ultimate strength of a double hull oil tanker with simplified collision damage and subjected to bi-axial bending. Ships and Offshore Structures.

[2] Deng Y, Xue Y, Shui Y, et al. (2017). Shallow hydrocarbon migration and accumulation theory and discovery of giant oilfield group in Bohai Sea.

[3] Chao Liang, Xinong Xie, Hua Wang,. (2019). Effects of igneous bodies on modification of modern slope morphology: Insights from the continental slope offshore Dongsha Islands, South China Sea.

[4] Anjli, Singh L. (2018). Effect of culture filtrates of some seedborne fungi on seed germination and root shoot growth of Carica papaya (L).

[5] Zhao X, Xiugang P U, Zhou L, et al. (2017). Reconstruction of Paleogene sedimentary system and reservoir evaluation in Qikou Sag,Bohai Bay Basin,China, vol. 44, no. 5, pp. 565-578.

[6] Zastrozhnov D, Gernigon L, Gogin I, et al. (2018). Cretaceous-Paleocene evolution and crustal structure of the northern Vøring Margin (offshore Mid-Norway): results from integrated geological and geophysical study.

[7] Giuseppe Palladino, Paolo Giannandrea, Agata Siniscalchi,. (2017). Quaternary tectonostratigraphic evolution of the Vlora Basin, south - western Albania. Geological Journal, vol.

53, no. 5, pp. 1698-1715.

[8] Bölcskei K, Kriszta G, Sághy É, et al. (2018). Behavioural alterations and morphological changes are attenuated by the lack of TRPA1 receptors in the cuprizone-induced demyelination model in mice, vol. 320, pp. 1.

[9] Hashemi S A G, Edalatnoor B, Edalatnoor B, et al. (2017). A comparison of body image concern in candidates for rhinoplasty and therapeutic surgery, vol. 9, no. 9, pp. 5363-5368.