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Strength Analysis and Calculation of JJ225/42-KC Type Oil Rig Derrick

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Abstract. Oil rig derrick is a large and complex metal frame with lots of bars and complex force. Moreover, the use of working condition is complex and harsh, so it is quite necessary to analyze strength and calculate oil rig derrick. In this paper, with the basic structure and force characteristic of JJ225/42-KC type oil derrick, the ANSYS finite element software is used to establish JJ225/42-KC type oil derrick structure finite element model. The strength and stability analysis of the maximum hook load working condition, the working wind load working condition and the maximum wind load working condition of three combined working conditions indicates that the overall structural design of JJ225/42-KC type oil derrick is reasonable with good both dynamic and static characteristics and the derrick meets the requirements of the strength. What is more, the derrick has a excellent overall stability. In the end, the strength of the lifting devices and the derrick leg pin of JJ225/42-KC type oil derrick are calculated and checked, showing that all meet the requirements of the strength.

Introduction

In the previous design of oil rig derrick, the designer uses traditional mechanical method and empirical formula to design this equipment. However, because of the complex working conditions of derrick, a lot of calculation was simplified inevitably, thus it could not fully reflect the overall results of the stress state and may cause redundancy of structural design. As the marketing becomes more and more competitive, a higher product is required and the designer is forced to adopt the method of modern design to improve the traditional design and calculation.

It can solve structural displacement and stress under static load, and also calculate the influence of fixed inertia loads on structure, as well as the influence which can be approximated by equivalent static force of time-varying loads (usually defined as equivalent static wind load and seismic load in many building codes) [1].

The introduction and parameter settings of derrick

JJ225/42-KC type oil derrick is a k-type drilling rig derrick which was developed by Equipment Engineering Company of Liao He Petroleum Exploration Bureau. It is a welded I-beam-based k-type cantilever mast, equipped with DZ225/6-kc box-type substructure, JC40-1 type drawworks and ZJ40/2250JD type rig.

This derrick was divided into two pieces, each piece consists of seven segments, the upper section is a whole welded structure, the remaining section is a door structure, and the door structure contains back crossbeam and oblique bar. The forced derrick legs made with the wide-flange

H-beam, this derrick has a good stability, a strong load-bearing capacity, a well open space for wellhead operation, as well as a better vision for driller. The main body and back beam are with pin connection, oblique bar and each section of derrick body are biconical pin connection.

The finite element analysis of derrick

The steel material properties and displacement constraints of derrick

The materials used for JJ225/42-KC type oil derrick are Q235 and 16Mn steel. As the drilling derrick is a three-dimensional bar structure, each bar not only bears the axial force, but also bears the additional bending moment. Therefore, using beam4 can better express the actual force of derrick in the overall analysis and calculations [2]. Four corner points at the bottom of derrick are the fixed node, which are used to limit their freedom in three directions.

The load analysis of derrick and the load applied

According to the field research and related literature, the load borne by derrick mainly include: constant load (the weight of derrick and its subsidiary structural), working load (dynamic and static hook load, the maximum casing weight, hook load of additional operations and incident handing), natural load (this paper only consider wind and earthquake load, the load of temperature is not taken into account) [3]. After the model and the analysis of load are completed, it can be loaded and calculated. Four combinations of loading conditions are calculated according to the principle of load distribution.

The strength analysis of derrick

The static strength requirement of derrick: if stress in any part of the structure has reached the calibrated yield strength σ_s, then the structures have been destroyed [4].It is critical state of carried structure when stress has reached the yield strength according to this requirement. API (American petroleum institute standard) consider that safety coefficient of static strength of derrick must be above 1.67 in order to meet the safety requirement. The maximum stress pattern of four kinds of combined working conditions (Fig 1) were showed.

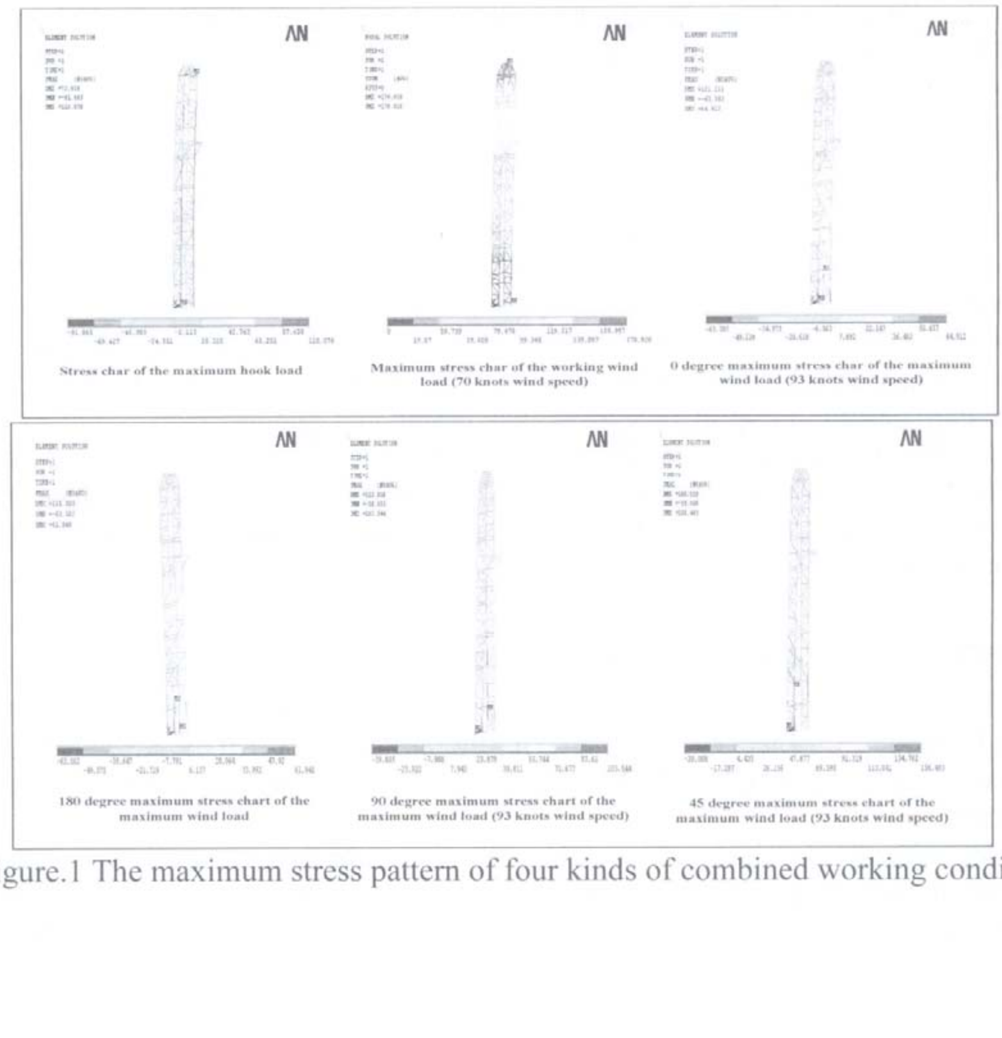

Figure.1 The maximum stress pattern of four kinds of combined working conditions

The result of analysis: the most likely to appear the maximum stress is the front leg of the lower section of derrick, the maximum stress is axial compressive stress which is 92.46MPa, and bending stress is 34MPa, the maximum UC value is less than the allowable minimum value 1.0 of the steel specification formula [5, 6], so it shows that the maximum hook load condition is safe. Crossbeam 6 and 100 may be the most dangerous part of the stress on the working wind load condition, two bars suffer a bending load, the maximum value of UC is less than 1, which illustrates that it is safe; under the maximum wind load condition, the most dangerous stress part may be the crossbeam 5 and 99, 10and 104, 6 and 100, etc. Two bars bear bending load and UC values are less than 1, so it indicates that all of them are safe.

The stability analysis of derrick [7, 8]

The integral or partial instability of derrick may appear in the huge hook axial load, so the instability load is an important parameter to evaluate the working performance of derrick. This paper uses the method of non-linear calculation in the finite element analysis, but to the physical material properties of derrick, the linear elasticity equations are still used. When to the specific calculation, this paper assume that the derrick bears the constant load without the wind load; the attic of derrick bears the 3/5 load of standpipes.

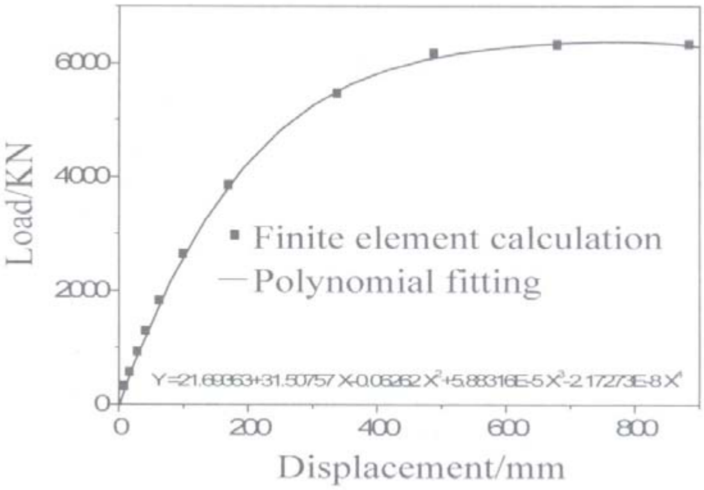

Figure.2 The nonlinear destabilizing curve of JJ225/42-KC derrick

Nonlinear destabilizing curve of large deformation of the derrick (Fig 2) was showed, the abscissa is the maximum integrated displacement of derrick, and the ordinate is the vertical load which the derrick to bear. It can be seen from the curve, with the vertical load increasing, the maximum integrated displacement becomes longer, when the load is greater than 6300 KN, the smaller load will cause very large integrated displacement. At this point, the derrick will cause overall instability. With the influence of instability load on the JJ225/42-KC derrick, by fitting the equation and then derivation can calculate the maximum axial load of the derrick, namely instability load and the load is 6370KN. According to the design specification of the JJ225/42-KC derrick, the maximum hook load of derrick is 2550KN, equivalent approximately the top load which is 2722.5 KN. As a result, the overall instability of safety coefficient of the derrick is 2.31, which indicates that JJ225/42-KC derrick have sufficient capacity to lift and instability to resist when the derrick without wind load.

Strength calculation and check of derrick lift devices and leg pins

This derrick is a single vertical lifting structure, but the seventh segment is not to be raised, so the lifting system bears the maximum force when the operator starts to raise the sixth segment. The square shaft is used to support the derrick when it is lifted, as a result, when to the sixth segment, the shaft bears the maximum force. Pins which used for connecting plate are used to fix both sides of the dead line. Derrick leg pin is used to connect the four feet of bottom of the derrick to the four base structure, all three materials are 35CrMo and modulation processing, the allowable stress

[σ]=324Mpa, the stress values of the two dangerous cross-section of square shaft are 146.1Mpa and 165.59Mpa, and the Pins for connecting plate and the leg pins of derrick are 256Mpa and 240.73Mpa respectively, all of them are less than the allowable stress 324Mpa, the result illustrates that all above meet the requirements of the strength. Connected tripod is used to lift derrick and the material is 16Mn, the allowable stress and shear stress is [σ]=204Mpa and [τ]=136Mpa respectively, the upper wire rope of tripod is the dangerous cross-section after calculating, the stress is 55Mpa less than the allowable stress 204Mpa; the lower handing cap subject to shear force, which is 15Mpa less than the allowable shear stress of 136Mpa, the result show that the connected tripod is safe. Wire rope is also used to lift the derrick, these two kinds of wire rope could meet the requirement of derrick lifting after checking.

Summary

(1) The result of model analysis JJ225/42-KC derrick shows that the derrick has a good dynamic and static characteristic in the vertical (longitudinal) and horizontal (lateral) direction.

(2) JJ225/42-KC derrick meets the strength requirement under the working condition of maximum hook load, the non-working state of maximum wind load (namely working condition of equipment preservation), as well as the same weather condition.

(3) When the JJ225/42-KC derrick bears the maximum axial ultimate load, it will cause the overall longitudinal instability, the load of instability is 6370KN.at that time.

(4) The result shows that the lifting devices and the leg pin of JJ225/42-KC type meet the requirements of the strength after calculating and checking the strength of them.

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References

[1] Liu Tao, Yang Fengpeng, in: *Proficient in ANSYS*, Tsinghua University publising, Beijing (2002), in press.

[2] ANSYS Inc. ANSYS Elements Reference. 11th ed. SAS: IP Inc, 2001.

[3] Chang Yulian, Liu Yuquan, in: *The design calculation of rig derrick and substructure,* Petroleum Industry publishing, Beijing (1996), in Press

[4] People's Republic of China national standard. steel structure design specification, GBJ17-88. China Planning Publishing, Beijing (1989).

[5] API Spec 4F. Specification for drilling and well servicing structures (1995).

[6] The U.S. steel specification manual. Allowable Stress Design, Ninth Edition (1995), p.7～8.

[7] Zou Longqing, Fu Haifeng, Ren Guoyou: Study of JJ160/41-K type derrick finite element analysis and carrying capacity. Journal. Oil Field Equipment, 6 (2004), p. 33～35.

[8] Hou Yifu. *Design guidelines for drilling and well servicing structures*, Petroleum Industry Publishing, Beijing (2005), in press.

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