The Investigation of Standardized Routing Design of Project Logistics Based on the Process Screening Method

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Abstract In order to ensure the safety during the transportation of large-scale equipments and improve transportation method of large-scale equipments based on the experience, and analyze the influence of safety with the factors of human, technology and risk, and improve the predictive ability of risk and the safety coefficient of transportation, CAE technology is applied in large scale equipment transport logistics process in this research. By taking the rolling transportation of the shipping machine for instance, safety analysis and logistics scheme optimization is carried out, and an engineering project logistics standardization routing implementation plan based on the process of screening method is presented to improve the project logistics standard and the safety of the transportation.

Keywords Project logistics • Rolling transportation • Screening process • Shipping machine • Simulation analysis

1 Introduction

Along with the fast development of social economy and engineering technology, the number of large engineering increases rapidly. Because of the large size and great weight characteristics of the large-scale equipments, it is difficult to transport using the land transportation due to the capacity restriction of the road and bridge. Therefore, the Marine transportation mode is widely adopted.

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In order to improve the safety of transportation of large equipment during the maritime transport, the transportation projects of large equipment managements are discussed from the point of view of project logistics considering the combination of advanced management theory and system engineering idea.

Because the large equipment engineering logistics process is complicated, the process of screening method is adopted to optimize logistics solutions. Meanwhile, the advanced computer technology and virtual prototyping technology is used to simulate the key steps in the rolling process, so as to determine the optimal parameters of the cargo.

Taking rolling shipping process of a shipping machine in Marine transportation as an example, this paper proposes a method to optimize the key steps in engineering logistics management. The advanced CAE technical is adapted to analyze the key process in the transportation. Based on a parametric simplified model, the simulation of the attitude of the shipment machine and the load case of weather conditions such as wind are carried out to evaluate and optimize rolling plan.

2 Methodology

2.1 Organization and Implementation of Project Logistics Project

The key equipment is usually giant in major projects. The difficulty in the transportation process is increased significantly due to the high risk, strong limitation, disposable questions etc., because of its over length, super wide, over high and overweight. Researches in engineering logistics theory and practice in recent years provide solutions to the safety and the efficiency in transportations of large equipments [1–6].

2.2 Project Logistics and Its Simulation

Project logistics is an important part of modern logistics. It has obvious difference with traditional products logistics in supply chain characteristics, operation mode, management of the core content, decision-making methods and techniques as well as to the special equipment and technical requirements. It emphasizes the "project" characteristic, including the project implementation disposable, the overall relevance, the uncertainty of the process, the technological complexity, the risk of process, and the key role of solutions to achieve the overall objective of the project.

In order to reduce the risk of this complicated system engineering, the optimization of the simulation must be introduced to perform the analysis, observation and judgment. In this simulation, engineers can preset possible load case to

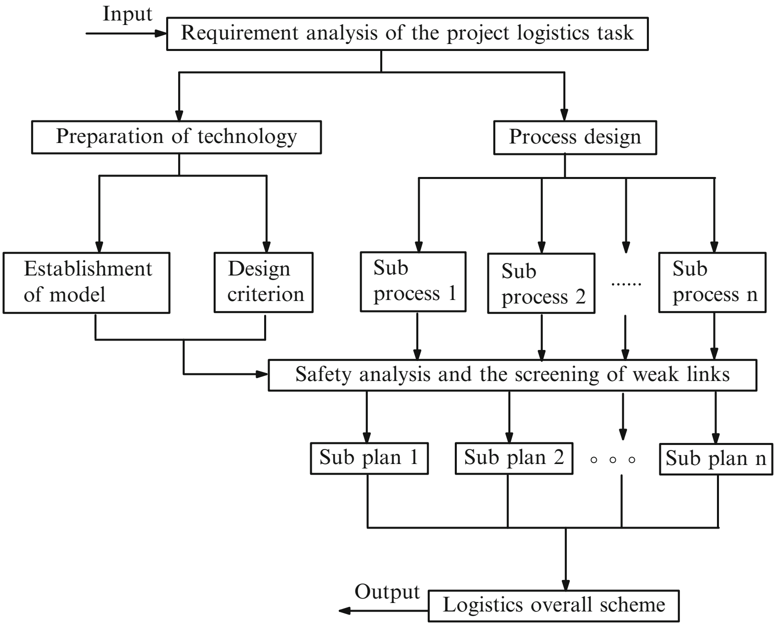

Fig. 1 The schematic diagram of the general scheme design in Logistics engineering

optimize and control the operation process, so as to achieve the improvement of the reliability, optimization of the scheme of key steps, cost savings, and improvement of efficiency.

2.3 Design of the Project Logistics Scheme Based on the Process of Screening Method

Most of the traditional engineering logistics is based on the engineering experience with the debugging method to determine logistics technology scheme, generating a great uncertainty in the logistics project and increasing the technical risk. In order to improve overall technical feasibility and effectiveness of the large equipment engineering logistics, process of screening method is introduced to comb each sub-processes in the process design. With this method, different process parameters which Influence the project logistics safety can be predicted. Based on this procedure, the key process parameters can be determined. At the same time, the potential safety hazard can also be evaluated. Furthermore, the related technical scheme will be optimized. In the thought of process design, with the help of advanced CAE technology, the implementation of safety analysis and the troubleshooting of the weak steps can be performed to determine the key process parameters (shown in Fig. 1).

3 Results

Taking the loading machine for instance, the overall scheme of the shipping machine logistics is carried out according to the above design idea of the project logistics. The shipping machine is arranged by transportation batch. There are four shipping machines in each batch; each machine is composed of a main engine and a caboose. The main engine is a four-bar mechanism with a telescopic rotary jib. The main engine includes portal-framed structure, long travel, jib structure and rotating frame. After production-manufacturing, the four shipping machines are transported to customer ports. Then the batch of shipping machines is transported in the way of complete machines by using a seaborne massive pontoon.

3.1 Demand Analysis of the Logistics Tasks of Shipping Machines

According to the characteristics of the equipment and terminal equipment allocation, the cabooses are transported by hoisting process. Meanwhile, the main engines are transported by rolling process. Considering the factors in the project progress, technical resource allocation and barge carrying capacity etc., the whole project is divided into three voyages. The first voyage will ship the four sets of cabooses, the second and the third voyage will ship two sets of main engines. In the organization and implementation process, the logistics project management organization, the preparation of transportation project progress plan (including batch schedule), the quality control of construction projects and the implementation of the project risk management must be established. Furthermore, CAE and virtual prototyping technology are used to simulate the key steps in the cargo loading and unloading process and the shipping process. The burst-interference caused by the variation of climate and hydrology must be calculated and then evaluated. Moreover, the troubleshooting and prediction of weak links in the shipping machine are as important as the formulation of contingency plans. Above all, every detail of the implementation must be monitored to ensure the safety of the project smoothly.

3.2 Technological Preparation Before the Simulation of Project Logistics

Because of the complexity of the structure of the Large Scale Equipment in Project Logistics, technical pre-simulation processing is necessary for the critical links in logistics. In the pre-simulation processing, the complex structure of the shipping machine is simplified according to the actual condition as much as possible. In the shipping machine rolling project, the simplification of the modeling parameters and the attitude control of the machine are a necessary preparation for the simulation and the formulation of the Rolling scheme.

3.2.1 The Digit Model of the Large Scale Equipment

Modeling of the finite element method for the large object is necessary before the simulation analysis of the logistics project. However, the shipping machine is a complex mechanical system with various components, structures of large scale and complex connection. Therefore, the simplification of the machine is necessary [7–12].

1. *Principle of the simplification*
   Considering the objectivity of the simulation analysis is the overall performance of the machine in the process of cargo on board, it is reasonable that some details of the structures can be ignored or equivalent simplified. There are two kinds of details to be processed: the first one is the simplification of the structural details. Process chamfering, tank, holes of process without affection to the structure strength can be ignored in the modeling. In addition, Screw fastening is treated as rigid connection, and Welding connection is considered as idealized uniform. However, details which will affect the structure strength must not be ignored. The second one is the processing of accessory structures, such as the operator cabin, the electrical control room and the driving mechanism of the Rotating frame. Details like that can be treated as mass elements.
2. *Elements selected in modeling*
   The selection of elements must follow the next three principles: the first one is to ensure sufficient calculation accuracy to meet the requirements of analysis, the second one is to apply loads easily, and the third one is to get convenient intuitive view of the structure in analysis. In the FEM, the beam element is selected to model the slender or medium short beam structure, because it is convenient to control the type, direction and offset of the distributed force. The shell element is selected in the modeling to extract the modal. In addition, the link element is used to simulate the slings and the hydraulic shafts because of its incapacity of the bending moment and torque. Finally, the lumped mass is modeled by using mass element.
3. *Connection processing*
   There are 6 degrees of freedom at each node of shell and beam element. In addition, the two types of elements can share nodes with each other when modeling. Therefore, force and deformation can be transferred through the shared nodes. Multi-point constraints (MPC) must be introduced into the connection points when modeling the connection between beam and shell to avoid the stress distortion [13]. For connection type of Pin hole connection, only the rotational degree of freedom is released at the pin shaft center, the other 5 degree are coupled.

4. *Overall modeling of the machine*
   Before the overall modeling, pre-modeling and pre-analysis are performed by using beam element. After that, models of each part are established. The determination of the dimension and the parameters should be considered during the modeling process that is convenient to adjust and modify.

3.2.2 Design Principles of Rolling Attitude

Because the center of gravity of shipping machines is high, the position of the shipping machine and the distribution of the self-weight will be affected by the rolling attitude. In the plan making of the rolling process, it's considered that the machine must be adjusted to a reasonable attitude to keep the stability of the shipping machine. In this attitude, the center of the gravity should be at a lower position, the load distribution of each part should be uniform, and the demand to the space and the equipment should be much lower.

3.3 Design of Rolling Process of Shipping Machine

According to the loading machine characteristics and transport requirements, the adjustable ballast water semi-submersible barge is used in the cargo transportation. The process can be divided into four sub-steps as follows:

1. *Alignment of rails*
   According to the requirement of the rolling technique, the barge is parked closed to the wharf into a T-shaped position. The attitude of the barge is adjusted to ensure the alignment between the barge cargo rail and shore rolling rail. All the links should be ready for shipment such as laying the rolling approach bridge, tightening the Lashing rope and so on.
2. *Modification of load with traction step by step*
   After checking for the personnel and the equipment, and adjusting the alignment between the deck surface and the terminal level, hoist traction can be started on board. When the first row wheels approaches the barge through the rails, the ship stern begins to sink because of the gravity of the shipping machine. As a result, the barge trims. Then, the ballast water adjustment system begins to adjust the load. During the process of adjustment of load, the adjustment progress can't usually keep up with lighter trim speed because of the tide. When the barge orbit plane height difference becomes more than 50 mm, the traction must be stopped, and the shipping machine should be constrained using temporary fixed facilities, waiting for the ballast water condition to make the orbit plane on both sides back to the level state. In this way, shipping machine will be loaded onto the rolling ship step by step. The same method is also used when discharging the shipping machine step by step.

3. *Drifts away from the wharf*
   When the last row wheels are driving onto the rails on the barge from the rails on the wharf, the shipping machine should stop racing ahead. After that, the ballast water adjustment system began to adjust the load to make the ship bow slightly dipping. At this time, the ship bow is slightly dipped to avoid the big trim of the barge. Finally, the shipping machine should be pulled onto the barge carefully to the designate location.
4. *Jacking into the designate position*
   In order to keep the stability of the shipping machines during the transportation, the machines should be constrained on the fixed rails. After rolling the shipping machine into the designated location, the wheels should be lifted up using the jack, and then rotated 90° prior to laying on the fixed rails.

3.4 Safety Analysis of the Rolling Process and the Screening of Weak Links

The standardization routing design is the premise of risk estimates in the project logistics. The potential risk should be estimated in each step to ensure the safety of the whole project, shown in Fig. 2. In the rolling process, according to the four steps in Fig. 2, the analysis is focused on the traction and lifting process.

3.4.1 Choice of the Rotating Frame Attitude

A rotating frame can make a rotation of 360° around its rotation center. Two limit attitudes of parallel to the X axis (A status) and Z axis (B status) are chosen to calculate the center of gravity of the shipping machine and the stress situation of support columns. Considering the boundary conditions and the gravity, the contour plot of the stress distribution of the support columns can be presented after solution. Under A status, the stress filed of the support columns on both sides is seriously inhomogeneous. The center of gravity is almost in the middle plane parallel to the rails under B status. Furthermore, the stress distribution is uniform in the support columns under B status. Therefore, the B status is chosen in the transportation.

3.4.2 Choice of the Attitude of the Boom System

Different attitudes of the boom system is simulated with its angle from $-6°$ to $+20°$ step by step to calculate the maximum deformation, the stress field of each part and the position of the gravity center of the main engine. In each step, the gravity is applied on the model in the static solution to get the contour plot of stresses and deformations of the complete machine. It is found that the deformations and

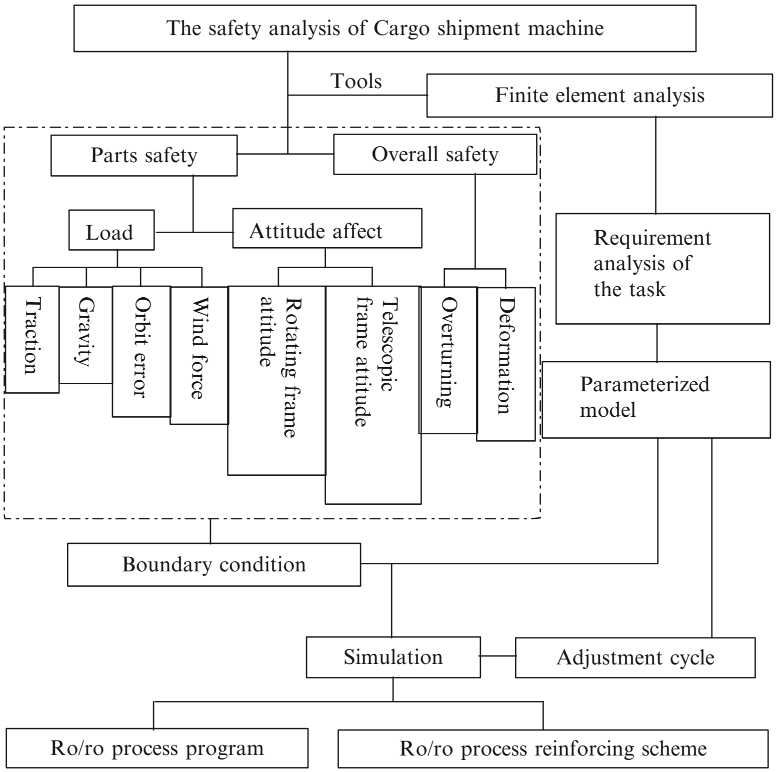

Fig. 2 The diagram of the Rolling safety analysis

stresses of parts decrease with the angle increasing. At the same time, the height of the gravity center increase rapidly with the angle of the boom system. Considering the above factors, the optimal angle of the boom system is $+7°$.

3.4.3 The Influence of Wind Load on the Safety of Rolling and Structure

The wind load is one of the most negative factors which will affect the balance of the shipping machines in the rolling process. The wind acting on the large scale equipment and other structures in engineering will form load because of its pressure. This approximate constant load will make the shipping machine capsize [14]. The ability against overturning of the shipping machine is defined as the stability of the shipping machine in the rolling process. In this process, when the algebraic addition of the stabilizing moments is greater than that of the overturning moments, the structure can be considered as stable. For the shipping machine, the stabilizing moment M_S, is generated by its gravity, while the overturning moment M_K, is generated by other loads such as wind load, dynamic load and vibration load, which is the force to rotate the shipping machine about a defined axis. The condition for the stability is $M_S > M_K$. However, in the actual working conditions, a margin for safety should be considered. Therefore, the factor of safety against overturning is introduced as $\gamma = M_S/M_K$ to ensure the safety of the shipping machine. From the relationship between the wind velocity and the factor against overturning, it is found that the factor against overturning decreases obviously with the increasing of wind. According to the Chinese standards used in engineering, the factor against overturning should be $\gamma > 4.0$. Most parts of the Shipping machine are flexible connections. Especially the boom system which is connected with other parts with hinge has a great wind area. As a result, the wind load will cause great influence on the structure. When the wind-force exceeds 8, the structure will has super linear increase with the increase of wind-force. The material of the shipping machine is Q345B steel whose yield strength is 345 MPa. When the safety factor is set to 1.5, the allowable stress is 230 MPa. According to the analysis results, the stress of the structure will approach to the allowable stress when the wind-force exceeds 10. In the actual case, considering the interference to the barge caused by shaking of waves, safety of rolling equipment, the security factors of the structure and ease of construction for workers, rolling process should be performed under the condition of no more than seven wind-force.

In summary, in the above case, the shipping machine is stable against overturning. Meanwhile, the impact of the wind on the structure security is within the safe range, and be of enough sufficient safety margin.

3.4.4 Safety Analysis of the Boom Maintenance Frame in the Rolling Process

The boom maintenance frame is installed bellow the fixed arm, its function is to adjust and maintain the boom frame system when necessary, and deliver the personnel and the equipments. In the rolling process, the boom maintenance frame is pulled forward with the main engine.

According to the static analysis results of the whole machine, the stress in the front section of the swing frame is greater under the effect of the gravity of the fixed arm and the telescopic arm. When designing the rolling plan, the fixed arm is constrained on the maintenance frame so that part of the gravity of the boom frame is shared to maintenance frame. Therefore, the influence of the boom frame gravity on the swing frame and the rotating frame column is reduced. Meanwhile, stability against overturning is also enhanced in the Z direction. In the simulation of the stress distribution of maintenance frame, parts with the maximum stresses are supporting position where the maintenance frame and the fixed arm are connected. The maximum stress is not only less than the allowable stress of the maintenance frame, but also has a sufficient safety margin. It is indicated that the maintenance frame structure is safe. In the rolling process, the attitude of the maintenance frame may present the following two cases.

First, the front wheels are driven onto the barge along the rails; at the same time, the rear wheels are still driving ashore. There is an altitude difference of the orbital plane between the shore side and the barge. From the analysis of the evolution of the maximum stress in the maintenance frame following the altitude difference, it is presented that the stress of the maintenance frame increases with the height difference., the maximum stress which is in the diagonal brace beam is in the middle of the connection frame when the altitude difference reaches 60 mm. The maximum stress approaches to the allowable stress as the altitude difference reaches 70 mm. As a result, the altitude difference must be strictly kept less than 70 mm.

Second, all the trolleys of the shipping machines are driven onto the barge, while the wheels of the maintenance frame are still ashore. Because the maintenance frame is a statically indeterminate structure, the wheels of the maintenance frame will be apart from the orbital plane and hanging in the air. At the moment, all the gravity of the maintenance will be imposed on the connection frame. In the contour plot of the stress, the part with maximum stress is still the diagonal brace beam which is in the middle of the connection frame. Furthermore, the maximum stress approaches the allowable stress. The simulation has shown that this plan cannot ensure the safety of the main engine. As a result, the rolling plan should be improved.

According to the simulation results, the improvement of the plans can be presented as follows. For the first plan, a group of pins which is used to connect the connection frame and the main engine can be released, so a rigid body rotational degree of freedom is released to decrease the deformation caused by the altitude difference. However, this plan will decrease the stiffness of the connection between the maintenance frame and the main engine. For the second plan, the wheels of the maintenance frame are removed before the rolling process. In this case, the bottom of the maintenance frame is free. This plan can avoid the deformation caused by the altitude difference because the maintenance frame just imposed by its gravity. In the simulations of the improved plans, the second plan makes the stress distribution more uniform. The maximum stress position of the maintenance frame is still in the diagonal brace beam in the middle. But the value of the maximum stress is much smaller than the allowable stress. It is indicated that the maintenance frame has the ability to afford its gravity. Therefore, the improved second plan is adopted in the rolling process.

3.4.5 Jacking Safety Analysis

The shipping machine should be constrained on the barge to increase the stability in transportation. When the complete machine of the shipping machine is pulled onto the barge, the machines should be jacking and rotated with the help of jacks prior to constrain.

Before constraining, the trolley is lifted to a certain height from the orbital plane. After being rotated 90°, the trolley is placed into the perpendicular fixed rails.

In order to ensure the stability and the safety of the parts such as the support column, the jacked height should be limited in a safe value, otherwise some parts of the machine may be destroyed.

When jacking the trolleys one by one, it is equivalent to the constraint with one degree of freedom, which is applied in the jacking point of the model. The relationship between the stress distribution and the jacking height can be obtained with the help of the simulation. According to the stress field from simulation, the maximum stress of the shipping machine occurs at the connection point between the corner of the gantry frame close to the jacking point and the support column. The relationship between the jacking height and structure stress shows that the maximum stress increases linearly with the jacking height. When the jacking height exceeds 80 mm, the maximum stress of the gantry frame approaches the allowable stress. Thus, the allowable height of jacking is limited to 60 to ensure the safety of the shipping machine.

3.4.6 Evaluation and Analysis of the Reinforce Plan in the Rolling Process

Based on the modal analysis of the complete machine, the mode of vibration can be use to research the vibration details of the complete machine when the machine is perturbed by the other loads in the rolling process. The weakest link in the rolling process can be found out with this method of evaluation which can supply the basis to the reinforce plan of the whole machine. In fact, the low order modes of vibration take main effect in rolling process. Therefore, the Blook Lanczos method is selected to extract the first 20 modes of vibration [15]. The modal analysis indicates that the frequencies of low order modes of the shipping machine are obviously greater than the frequencies of load variation in the pulling cables, as well as the frequency of the impact frequency caused by the trolley wheels through the rail joints. That is to say that there is not resonance in the rolling process. However, the impact frequency caused by the trolley wheels through the rail joints is very close to the low order frequencies. The combined effect caused by the multi loads will still induce small vibration on the lower stiffness of the boom frame system and the rotating frame. Thus, in order to ensure the safety in the rolling process, the weak parts need to be reinforced.

According to the simulation, the boom structure is a weak link. The fixed arm forepart can be connected with the gantry frame through associated constructions to limit the vibration. Meanwhile, the associated constructions can also be set between the rocking frame forepart and the rotating frame column as well as the rocking frame weight and the rotary rack tail weight to increase the stiffness of the structure. The cable between the rocking frame and the fixed arm is a slender rod which is easy to vibrate. Its stiffness can be enhanced by using a wire rope tied in the middle.

4 Discussion

The overall process and strengthening plan can be determined based on the four sub steps and the simulation of rolling process. The overall process is shown as follows: (1) the geometry of the Rotating frame structure is set to be symmetrical; (2) the optimal attitude of the boom frame system is + 7°; (3) the rolling process of the shipping machine must be implemented when the wind fore is below 7; (4) the trolley of the maintenance frame should be removed when the machine is moving forward; (5) the jacking height of the trolley must be limited no more than 60 mm in jacking and rotation; (6) the fixed arm forepart can be connected with the gantry frame through associated constructions to limit the vibration; the associated constructions can also be set between the rocking frame forepart and the rotating frame column as well as the rocking frame weight and the rotary rack tail weight to increase the stiffness of the structure; The stiffness of the cable between the Rocking frame and the fixed arm can be enhanced by using a wire rope tied in the middle.

5 Conclusion

In this paper, The Standardized routing design of Project logistics based on the Process screening method is reported to improve the Project logistics technology of large scale equipments. With the help of the Computer Aided Engineering (CAE), Risk prediction and optimization and the design of the plan in the project logistics are realized.

1. Design ideas of project logistics standardization routing process based on the Screening method is introduced which is an improvement compared to the traditional engineering design method of logistics solutions based on the engineering experience.
2. Advanced CAE simulation technology is employed to implement risk prediction, evaluation and optimization in the project of logistics technology scheme, which makes the overall design plan more scientific and improves the efficacy and safety.
3. The overall scheme design is comprehensive systematically elaborated taking the rolling process of shipping machine for instance. It will make a positive significance in the research and practice of transportation of large scale equipments.

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References

1. Lin Y (2007) Research on the operation system of project logistics. Master dissertation, Beijing Jiaotong University
2. Sun LN (2006) Safety analysis of large goods transport on the sea. Master dissertation, Dalian University of Technology
3. Ge SY (2009) Study of choice for heavy cargo barge and loading time. Logist Eng Manag 31(9):30–31
4. Xiao JY (2009) Research on RO/RO operation of heavy lifts by deck barge in free floating status. Navig China 32(2):49–53
5. Shen H, Kong X (2005) Mechanical analysis of securing scheme for a heavy vehicle onboard Ro-Ro ships. J Dalian Marit Univ 31(3):1–8
6. Lin HH (2004) Outline of stability and anti-overturing safety for ocean-going tug. Ship Eng 26(06):28–29
7. Liu R, Wu X, Zheng J (2005) The problem of geometry clean in constructing finite element model. Mach Des Manuf 9:145–147
8. Wang S (2008) Research on analysis method for complex mechanical system based on its simplified model. Master dissertation, Tianjin University
9. Zienkiewicz OC (2004) The birth of the finite element method and of computational mechanics. Int J Numer Methods Eng 60(Part1):283–288
10. Mujber TS, Szeesi T, Hashmi MSJ (2004) Virtual reality applications in manufacturing process simulation. J Mater Process Technol 155–156(Part 2):1834–1838
11. Yang RF, Cui ZQ (2003) Modeling technology study on the combined structure of heavy duty diesel. Chin Intern Combust Eng Eng 24(3):20–23
12. Maggi YI, Goncalves RM, Leon RT, Ribeiro LFL (2005) Parametric analysis of steel bolted end plate connections using finite element modeling. J Constr Steel Res 61(5):689–708
13. Zhou X, Dai ZJ, Liu HB (2010) Application of MPC in the finite element modeling and analysis. Heavy Truck 6:33–34
14. Ministry of Transport of the People's Republic of China, JT/T90-94 (1993) Specification of wind load for port crane. China Standards Press, Beijing
15. Liu XG, Lin B, Chen K (2010) Model analysis of milling machine. In: International conference on engineering design and optimization, Ning-bo, People's Republic of China, 28–30 Oct 2010, pp 671–673