Optimal Design Based on Finite Element Analysis for Elevating Platform

Wu Xiaoqiang¹, Hao Ruican²

1. Inner Mongolia University for the Nationalities College of Mechanical Engineering College,
Tongliao 028000, China

2. Beijing Polytechnic, Beijing, 10000

¹wangzai8402@163.com; ²haoruican@163.com

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Abstract: Hydraulic elevating platform has the features of big load capacity, easy maintenance, stable and reliable operation. The kind of hydraulic elevating platform is many, and they can be used in a variety of different working conditions. The stable and load capacity of the elevating platform are the most important in the working process. In this paper, according to the requirements of the user, a variety of methods are used in hydraulic lift platform design. Analysis is conducted through the finite element analysis software to analyze the any kind of structure, and determine the optimal structure. First of all, the three-dimensional model is established according to the lift platform design requirements, then, the three-dimensional model of elevating platform are simplified as the many alternatives, at last, through the finite element analysis of various schemes of elevating platform to making statics analysis, the optimal structure design scheme is given.

Introduction

In 2800 BC, a lifting device driven by human appeared —elevator. In the mid-17th century, French scientists proposed the static pressure transmission principle to guide the application of hydraulic drive technology, and the the hydraulic transmission theory and technology has been developed rapidly. Under the background, the world's first hydraulic lifting platform was successfully developed in 1845^[1], which means lifting platform step into a new era. In recent years, the prosperity of the oil industry to make the oil products replace water as a transmission medium, and the application of hydraulic transmission technology in the lifting platform had been more and more widely ^[2]. The requirements of the lifting platform in different working environment are also different, in order to determine the best design well adapted to the work environment, the design should be optimized in the design process. Traditional design methods has clear thinking and is strongly theoretical, but the calculation process is very complex, calculation amount is intensive, design cycle is longer, and it can only achieve partial simplification of the calculation, the detailed and accurate analysis of the overall structure doesn't work ^[3-4]. In addition, if the amount of calculation conditions become more, traditional design methods can't cope with the analysis of complex structures

and the heavy computation, so many kinds of assumptions and simplifications are made which leads to great difference between the calculation results and actual results ^[5].

In recent years, with the rapid development of computer technology, it has been widely applied in the field of design. Due to the continuous development and in-depth of new design theory, a lot of new modern design methods came out, including finite element method, optimization design, dynamic simulation design, reliability design and process technology design methods and so on^[6]. These design methods are applied in various areas of product design, which significantly shorten the design cycle, improve design efficiency, and reduce the workload of the designer. Currently, the finite element method is most widely applied in structural design^[7], the application in mechanical engineering are mainly in the following aspects: (1) static analysis; (2) modal analysis; (3) the harmonic response analysis and instant dynamics analysis; (4) thermal stress analysis; (5) contact analysis; (6) buckling analysis ^[6].

A three-dimensional model of the lifting platform is established based on the design of the lifting platform requirements. The static analysis of a variety of lifting platform program is carried out in finite element analysis software Abaqus after the simplification of the three-dimensional model, maximum integrated deformation and maximum stress in different programs are obtained for analysis of different indicators and to choose the optimum structure.

Structure design of lifting platform

Design requirements of lifting platform

Lifting platform role: transport the goods from warehouse to the upper deck in the operating condition; the platform is at the highest position to play the role of a shelter as hatch cover in the no-operating condition.

The overall design requirements:

- (1) Size of the lifting platform: 8m*1.5m
- (2) Lifting height of platform: 3.6m
- (3) Maximum: 0.15m/s
- (4) Maximum load of platform: 4t+6t (rated load of the platform is 4t , it needs to compact the seals when it is at the highest position, there is approximately 6t pressure)
- (5) Platform rise and drop smoothly, the height difference between both sides in the longitudinal direction is no more than 20mm during the rise and drop process; when the platform rises to the highest position, height difference around the sealing portion of platform can not exceed 5mm in order to ensure a reliable seal between the platform and the upper deck. In addition, when the platform rises to the highest position, the gap between the around of platform and the hatch of upper deck is no more than 10mm, shown in Figure 1;
- (6) The requirement of guide position: the guide can only be placed at a single side of the 8m longitudinal direction, the other three sides is not permitted, shown in Figure 2;
- (7) When the platform rises to the upper locking position, the long-term seals is required.
- (8) Platform and guide mechanism should have sufficient strength to ensure no deformation, and it is required to be able to resist or adapt the error from the deformation of hull when the ship operates a period of time.

(9) A reliable security measures of the lifting platform are required to ensure that platform can reliably stop and avoid rapid drop because of the hydraulic cylinder leakage or scission .

Figure1 The location of the platform and deck

Figure 2 Install location of lead rail

Three-dimension model of lifting platform

Mechanism is designed as figure 3 according to the requirements of lifting platform, moving platform 4 reciprocates linearly along the guide 3 under the effect of hydraulic cylinder 1, when the hydraulic cylinder piston rod stretches, the sleeve roller chain 2 drive moving platform 4 move.

1 hydraulic cylinder , 2 sleeve roller chain , 3 guide ,
4 moving platform , 5 roller

Figure 3 Structure model of elevating platform

Static analysis

Analysis model

Simplify the model of the lifting platform, the hydraulic cylinder and the sleeve roller chain are simplified as fixed constraints to the chain pin, intercept one section of the guide. In order to choose the right moving platform structure, static analysis of these five kinds of structures shown in figure 4 is carried out to make comparison. These five kinds of programs are driven by two hydraulic cylinders, option 1 to option 4 all have two rails, option 5 has five rails to increase the constraints of moving platform . Structural parameters of these programs are shown in Table 1.

Figure 4(1) Project 1

Figure 4(2) Project 2

Figure 4(3) Project 3

Figure 4(4) Project 4

Figure 4(5) Project 5

Figure 4 Simplify model of elevating platform

Table 1 Structure parameters of any kinds of project

Program	Square steel	Steel plate	I-steel	Thickness of roller support plate	Chain
1	80×80×5	8000×1500×10	160×80×16	10	TG317(20A)
2	200×100×5	8000×1500×10	160×80×16	10	TG317(20A)
3	200×100×5	8000×1500×10	160×80×16	10	TG317(20A)
4	300×200×5	8000×1500×10	160×80×16	20	TG317(20A)
5	300×200×5	8000×1500×10	160×80×16	20	TG317(20A)

Material properties

The material properties of these parts in analysis model are shown in Table 2

Table 2 Property of material

Name	Elastic Modulus (Mpa)	Poisson ratio	Mass density (t/mm ³)	Parts
45	209000	0.269	7.89	roller、roller shaft、chain pin
Q235	212000	0.288	7.86	others

Constrains and loads

In the static analysis of lifting platform, the constrains and loads of these four programs are the same. Constrains: the guide's plane bonded to the wall is fixed, chain pin is fixed; loads: 4t surface load is added on the platform surface, 6t surface load is added on the around of the platform, gravity of the device.

The constrains and loads are shown in figure 5.

Figure 5 Constraint and loading

Analysis result

According to the previous constrains and loads, the results of these four programs are shown in figure 6 to figure 10, values are shown in Table 3.

Figure 6(1) integrated deformation contour

Figure 6(2) stress contour

Figure 6 Calculating result of project 1

Figure 7(1) integrated deformation contour

Figure 7(2) stress contour

Figure 7 Calculating result of project 2

Figure 8(1) integrated deformation contour

Figure 8(2) stress contour

Figure 8 Calculating result of project 3

Figure 9(1) integrated deformation contour

Figure 9(2) stress contour

Figure 9 Calculating result of project 4

Figure 10(1) integrated deformation contour

Figure 10(2) stress contour

Figure 10 Calculating result of project 5

Table 3 Static load analysis result

program	Maximum integrated deformation /mm	Maximum deformation position	Maximum stress /Mpa	Maximum stress position
1	12	The corners of the platform far away from the track	1134	Chain pin
2	6.47	The corners of the platform far away from the track	978	Chain pin
3	6.35	The corners of the platform far away from the track	958	Chain pin
4	1.98	The corners of the platform far away from the track	637	Chain pin
5	0.82	The corners of the platform far away from the track	956	Chain pin

Conclusion

From the above analysis results, increasing the steel cross-sectional area, and the number of guide can effectively reduce the amount of deformation, and increasing the number of guide is in favor of the smoothly running of equipment. The stress at chain pin is relatively high, it needs to be strengthened. Thus, program 4 is more appropriate than others by comparison of the analysis results and costs. Overall structure of the program 4 is shown in Figure 11. The main structural parameters of program 4 are shown in Figure 12 and Table 4, the weight of the moving parts are shown in Table 5, Table 5 shows that the weight of moving parts drive by hydraulic cylinder is about 3.86t

Figure 11 Project 4

L1:length of steel plate L2:total length of platform L3:central distance of two platform guides:

L4:central distance of sided platform guide L5:central distance of upper and lower rollers

L6:height of moving platform L7:total height of the device L8:distance of square steel

L9:distance of square steel L10:width of steel plate L11:width of platform

L12: total width of the device

1 supporting square steel 2 sealing square steel 3 steel plate

Figure 12 Structure of platform

Table 4 Structure parameter of platform

parameters	L1/mm	L2/mm	L3/mm	L4/mm	L5/mm	L6/mm
value	8000	8300	4000	600	800	1225
parameters	L7/mm	L8/mm	L9/mm	L10/mm	L11/mm	L12/mm
value	4200	1700	1800	1500	1800	2036

Table 5 Weight parameter of shift parts

number	name	specification	material	amount	unit	weight
1	supporting square steel	$300 \times 200 \times 5$	Q235	$8m \times 4 + 0.45m \times 18 + 0.615m \times 13 + 1.715m \times 6 = 56.67m$	38.5kg/m	2182kg
2	sealing square steel	$200 \times 150 \times 5$	Q235	$1.5m \times 2 + 8m \times 2 = 19m$	38.5kg/m	731.5kg
3	steel plate	thickness 10mm	Q235	$8m \times 1.5m = 12m^2$	$78.6kg/m^2$	943.2kg
total weight: 3856.7kg=3.86t						

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