The Optimal Design of Swing Arm for Loader

Kaige Yang[1, a], Xiaohe Zhao[1, b], Wei Ni[1, c], Gaohua Cao[1, d], Xiaosong Huang[1, e]

[1]Shandong University of Science and Technology, Qingdao 266590, China.

[a]2541090225@qq.com, [b]zxh9301@sina.com, [c]393022806@qq.com, [d]465407872@qq.com, [e]1129715585@qq.com

Abstract

The swing arm is one of the important components for loader, and it's structure will affect the life, efficiency, and fuel consumption. For example the swing arm in wheeled loading by Caterpillar, the force analysis is performed on each hinge point of the swing arm, and a parameter model of the swing arm is established. The UG10.0 software is used to design the weight of the swing arm under different working conditions. The structure of swing arm has been greatly improved.

Keywords

The swing arm, The force analysis, A parameter model.

1. Introduction

The loader can efficiently carry out loading, shoveling and traction operations, and it is one of the most rapidly developing mechanical products in large-scale industries. Its application is very extensive, and it can be applied to mines, ports, municipal construction and other aspects, and brings great convenience to people. With the increase in people's demand and the enhancement of loading capacity, large-scale loaders have become more and more a trend of development, and have also become major areas for competition of large companies[1].

In recent years, the loader has continued to increase in size and miniaturization, focusing on improving efficiency and reducing costs. In the industrial field, the competition in the modern industry is becoming more and more cruel. Many companies continue to innovate in scientific research, continuously absorb advanced technologies, and exert great efforts on talents. Structural optimization design is a key development direction in the field of large-scale mechanical engineering, achieving lightweight design. For example the swing arm in wheeled loading by Caterpillar, the force analysis is performed on each hinge point of the swing arm, and a parameter model of the swing arm is established. The UG10.0 software is used to design the weight of the swing arm under different working conditions. The structure of swing arm has been greatly improved.

2. The Method of Structure Optimization Design

People usually divide the structural optimization according to the degree of difficulty of design variables: topology optimization, size optimization, shape optimization, layout optimization and type optimization. Among them, topology optimization saves materials and can be widely applied to various engineering fields. It is considered as one of the most challenging areas. The basic idea is to translate the optimal topology problem sought into finding the optimal material distribution within a given design area. At present, the ICM method is the main aspect of research in the field of structural optimization[2].

The ICM method was proposed by Yan Yunkang in 1998.The basic idea is: Let t_i in the range of [0,1] be the presence and absence of the i-th cell. The goal is to optimize the structure with the goal of minimizing the quality of the structure. By introducing a filter function, a one-to-one correspondence between discrete design variables and continuous design variables is established to establish a complete truss structure. The optimization model is:

$$\begin{cases} find t_i (i = 1,2,\dots,n) \\ \min \quad W = \sum_{i=1}^{n} t_i^{\alpha} W_i^{\beta} \\ s.t. \quad \sigma_{ij} \le t_i^{\alpha} \sigma_i (j = 1,2,\dots,p) \\ 0 \le t_i \le 1 \end{cases}$$

Among: n-the total of units; σ_i - the stress of the i-th cell; W_i^{β} - the inherent quality of i; p- the total of rating conditions; α,β- constant.

Identify the cell properties parameters using the following formula:

$$w_i = f(t_i) w_i^0, \quad [\sigma_i] = f(t_i) \sigma_i^0, \quad k_i = f(t_i) k_i^0$$

Among: w_i -unit quality; $[\sigma_i]$ -unit allowable stress; k_i -unit stiffness; k_i^0 -elemental intrinsic stiffness.

3. The Process of Structural Optimization Design

Structural optimization design is a comprehensive design method that provides a safe and reliable method for large-scale institutional design. To ensure that mechanical parts are under normal working conditions, reduce engineering costs and shorten product development cycles[3]. The specific optimization process can be divided into: establishing an optimization model, stress analysis, establishing a model, statics simulation analysis and determining the optimization result.

3.1 Establish an Optimization Model

The establishment of the optimization model is the most important part in the structural optimization design. Based on the selection of models, it must be based on a large number of experimental phenomena and scientific theoretical basis, select a representative, there is ample room for optimization. Figure 1 shows the Cat 980H wheel loader. The wheel loader is selected as the research object and a series of structural optimization designs are developed.

Fig 1. The Cat 980H wheel loader

3.2 Force Analysis

Force analysis process is an important part of the entire structure optimization design process, and its accuracy is related to the success or failure of the entire structure optimization process[4]. When carrying out stress analysis on the optimized structure, the simplification of the model is minimized, and the accuracy of the stressed member and each articulated position is ensured. When carrying out force analysis on the loader, it is first necessary to perform an overall stress analysis on its working device, and then analyze the various components of the working device based on the overall force analysis, and finally record the results of the force.

When the rear wheel left the ground, the previous wheel was the support point. Figure 2 shows the structure of the loader working device. The work quality of Machine G=49560kg, Calculate the main cutting plate force F.

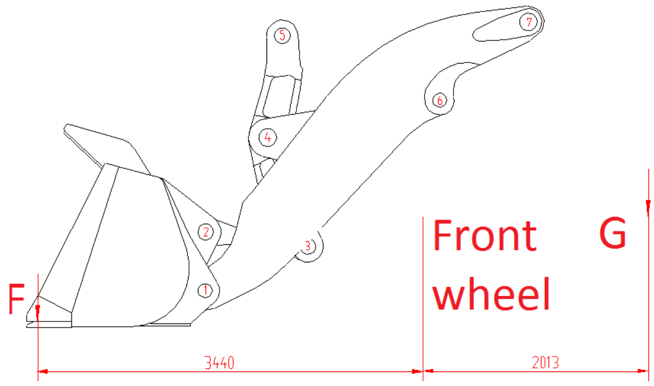

Fig 2. The structure of the loader working device

From $\sum M = 0$ to 3440×F=2013×G, so F=284110N.

As shown in Fig.3 , a bucket structure diagram is used to calculate the force F2 of the tie rod (hinge 2) and the force F1 of the lower hinge of the boom (hinge 1) according to F.

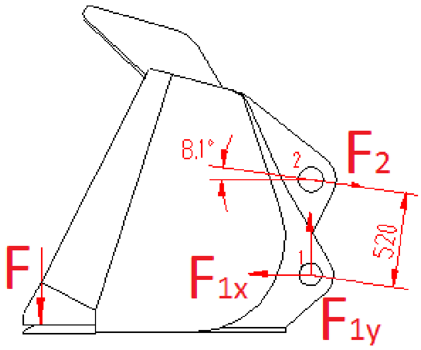

Fig 3. The bucket structure diagram

Take the lower arm hinge point (hinge point 1) as the fulcrum and calculate F2. From $\sum M = 0$ to 1495×F=520×F2 so F2=817104N.

According to bucket balance to calculate F1.

From $\begin{cases} \sum M_x = 0 \\ \sum M_y = 0 \end{cases}$ to $\begin{cases} F_{1x} = F_2 \times \cos 8.1° = 808952N \\ F_{1y} = F + F_2 \times \sin 8.1° = 399340N \end{cases}$

As shown in Fig.4 for rod structure, because the rod is a two rod, so F3=F2=817104N.

As shown in Fig. 5, it is a rocker arm structure. According to F3, the force of hinge point 4 and hinge point 5 is calculated.

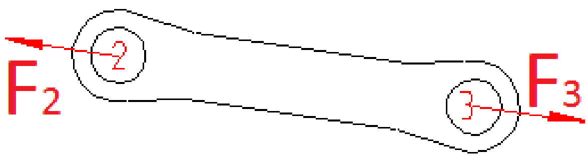

Fig 4. The rod structure

From $\sum M = 0$ to F3×913=910.3×F5 so F5=819528N. According to rocker arm balance to calculate F4.

From $\begin{cases} \sum M_x = 0 \\ \sum M_y = 0 \end{cases}$ to $\begin{cases} F_{4x} = F_3 \times \cos 8.1° + F_5 \times \cos 0.3° = 1628469N \\ F_{4y} = F_3 \times \sin 8.1° - F_5 \times \sin 0.3° = 110839N \end{cases}$

The structure of the swing arm is shown in Fig. 6. The force F6 of the hinge point of the swing arm (hinge point 6) is calculated by using the hinge point (hinge point 7) on the swing arm as a fulcrum. From the above analysis:

$F6\times1052.6+F4x\times1034+F4y\times2329=F1x\times2403+F1y\times2885.4$

So F6=1096510N.

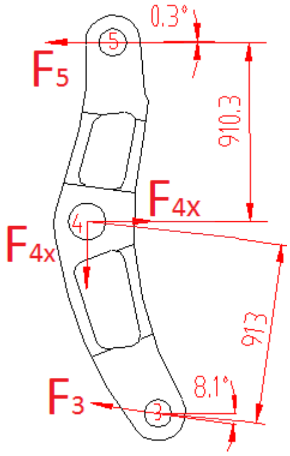

Fig 5. The rocker arm structure

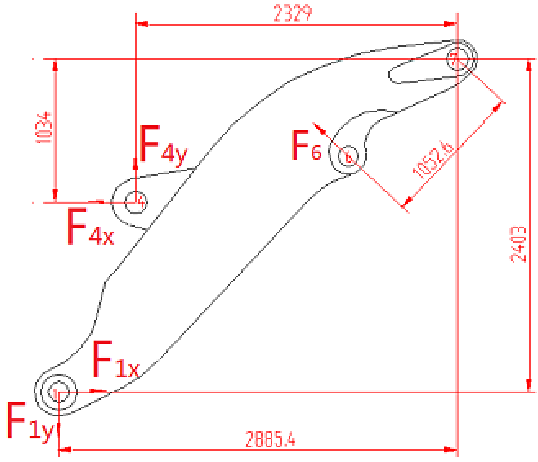

Fig 6. The swing arm

3.3 The Establishment of A Model

Establishing a model plays a role in the structural optimization design. On the one hand, an accurate model based on practical data is established, and on the other hand, the subsequent static simulation analysis and optimization analysis are paved. As shown in Fig. 7, it is a three-dimensional model of the swing arm. When the model is modeled, complex irregular solids and complex surfaces may exist. Must be based on the actual situation, can't arbitrarily simplify the model, resulting in the error of the follow-up statics simulation analysis.

Fig 7. The three-dimensional model of swing arm

3.4 Structural Simulation Analysis Results

Based on the results of force analysis of the model and its static simulation analysis is an important part of the structural optimization process. Statics simulation analysis mainly includes two parts: stress analysis and displacement analysis. The stress analysis is mainly to ensure the strength of the parts, while the displacement analysis is mainly to meet the stiffness of the parts.

Before the statics simulation analysis, the built model must be loaded into the UG10.0 finite element analysis software, and the structural optimization analysis of the structure is performed according to the force analysis results, and the optimization model is constrained to obtain the stress cloud map and displacement cloud map.

Based on the analysis results, the structure is optimized and improved, and a reasonable optimization model result is determined. If the continuous swing arm plate is designed to have a different thickness, the steel plate is preferably cast. Considering that this type of loader has a small production volume and high casting costs, the swing arm plate adopts a tunnel design. After many attempts have been made to dig holes and adjust the positions, the large and small holes are taken as examples. Their stress and displacement clouds are shown in Fig.8 to Fig.11. After analysis, none of them are suitable for selection as the final optimization of the swing arm model.

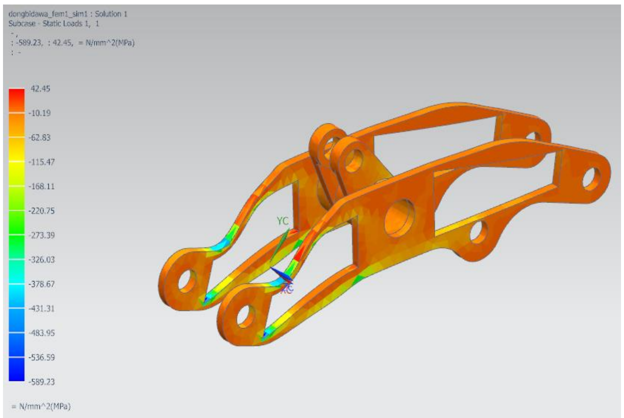

Fig 8. Big whole stress cloud

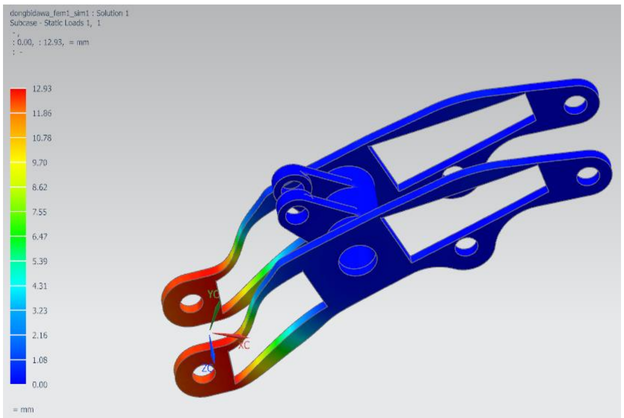

Fig 9. Big whole displacement cloud

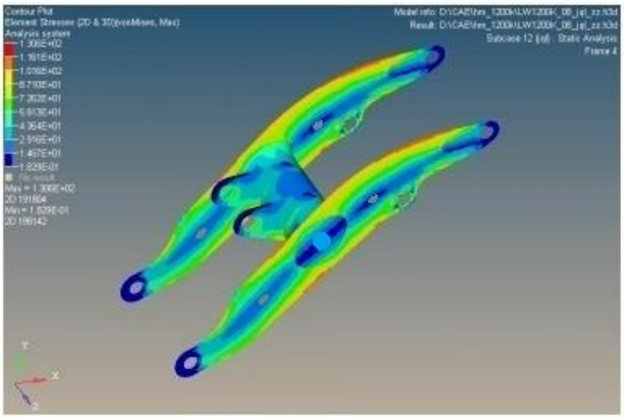

Fig 10. Small whole stress cloud

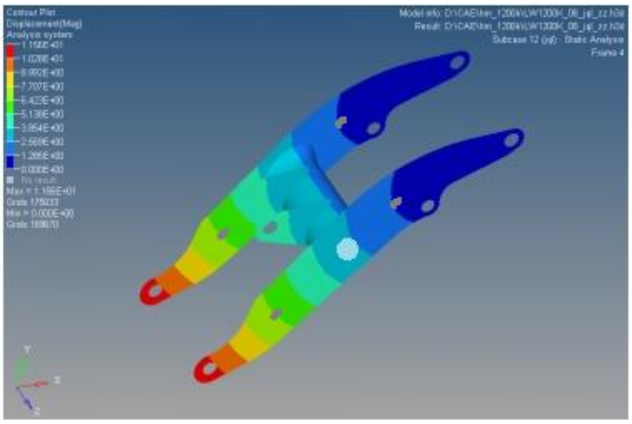

Fig 11. Small whole displacement cloud

Fig.12 shows the final swing arm optimization model. This model has a weight loss of 11% compared to the original model. Not only has the structure made significant progress, but it has also achieved light weight in quality and saved production costs. Work performance can meet people's daily work needs and achieve optimal goals.

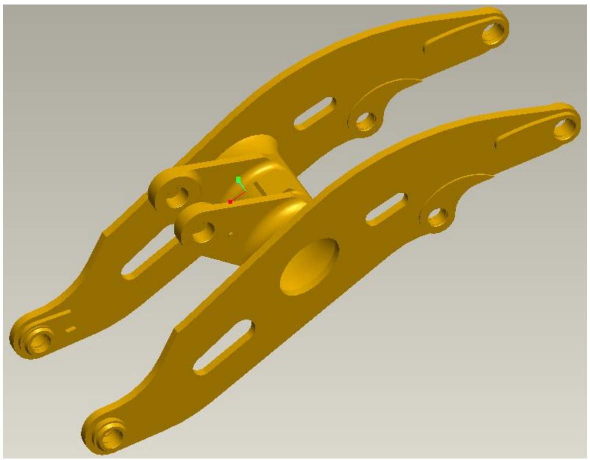

Fig 12. The final swing arm optimization model

4. Conclusion

In this paper, the wheeled loading manipulator arm produced by Caterpillar company is taken as an example. Using the combination of mechanics and finite element analysis, the force analysis is performed on each hinge point of the boom and a parameter model of the swing arm is established. Use UG1.0 software to design the swing arm lightweight to get the optimal engineering structure. The realization of lightweight handling of the loading manipulator structure has reduced the investment in production costs and improved the competitiveness, economic and social benefits of the company.

References

[1] Lily Dong, Yipping Zhao, Laquan Liang, Xuan Zhu, Guangdong Duane. Review on Theory and Approach of Mechanical Optimization Design [J], Vol. 38 (2010) No.15, p.114-119.

[2] Xin Cain, Hong Xuan Li, Jingle Wu, Jibe Zhu. Research Progress of Optimal Design for Engineering Structures [J], Vol. 39 (2011) No.3, p.269-276.

[3] Jing Li, Xiao yang Lu, Shying Chen. Advance In Study on Theory and Method of Optimized Design of Structure [J], Vol. 39 (2007) No.6, p.21-31.

[4] Shay Wang, Guoyu Liu, Shire Boa. The Status and Progress of Structural Optimization Design [J], Vol. 20 (1999) No.4, p.3-14.