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Topology optimization design of the suspension arm of a certain type of train battery system

Yaqin Luo, Yuerong Peng
Chengdu Technological University
School of Intelligent Manufacturing
Chengdu, China

***Abstract*—Aiming at the problem of excessive weight of a certain type of train battery system, a variable density topology optimization of the suspension arm structure of the BMS system is proposed. The solidworks software is used to establish its three-dimensional model, and the finite element analysis software ANSYS Workbench is used to carry out strength analysis and topology optimization of the suspension arm structure. Under the premise of considering the manufacturing and processing of parts, the model of the suspension arm structure after topology optimization is reconstructed, and the strength of the reconstructed suspension arm model is analyzed in ANSYS Workbench. By analyzing and comparing the reconstructed model with the original structure model, it is concluded that the weight of the reconstructed suspension arm after topology optimization is reduced from the original 13.65g to 5.76g, and the strength is changed from the original 17.141Mpa to 44.142Mpa. The analysis results show that the optimization completes the lightweight design of the suspension arm while ensuring the strength requirements.**

Keywords—Suspension arm;finite element analysis; topology optimization;lightweight design

I. INTRODUCTION

Due to the overall weight limitation of a certain type of train on-board battery system, all structural parts need to be considered for lightweight design. The suspension arm is one of the structural parts. Although the weight of a single component is relatively light, it is particularly important to carry out a lightweight design due to the large number of use in a single set of products. At present, the commonly used continuum topology optimization methods include increasing and decreasing thickness method, homogenization method, variable density method (SIMP+RAMP), progressive optimization method (ESO), independent continuous mapping method (ICM), level set method, etc. [1-2]. The basic idea of the variable density method is to define the relative density μ with a value range of [0,1], express the optimization target with the explicit function of the relative density μ, and then use the mathematical programming method or the optimization criterion method to solve [3]. This article takes a certain type of train-mounted battery system suspension arm as the research object, and uses the SIMP method [4] based on the variable density theory to carry out lightweight research on it.

II. TOPOLOGY OPTIMIZATION PROCESS

The variable density topology optimization process of the suspension arm is as follows:

(1) Define the design area;

(2) Establish correct boundary conditions;

(3) Set the relevant parameters of topology optimization according to actual needs;

(4) Calculate and analyze the determined parameters;

(5) Compare the updated design variables with the optimized parameters to determine whether they meet the requirements;

(6) Repeat steps 3 to 5 until the processing conditions are met;

(7) Model reconstruction of the topology optimized structure.

III. TOPOLOGY OPTIMIZATION OF THE SUSPENSION ARM

The material of the suspension arm is aluminum alloy, and its material properties are shown in Table 1. The suspension arm is placed vertically, the axis of the three holes is parallel to the horizontal plane, the three holes are non-designed areas, and the remaining areas are designed areas. Set the grid size to 0.5mm in ANSYS, add a fixed constraint to the large hole at the upper end of the suspension arm, and two small holes at the lower end to bear the tensile force. In addition, the suspension arm has to bear its own gravity. In the process of topology optimization, the design goal is to retain 40% of the mass of the suspension arm.

TABLE I. MATERIAL PROPERTIES OF THE BRACKET

Material name	**Elastic modulus /Gpa**	**Poisson's ratio**	**Density /kg/mm3**	**Allowable stress/Mpa**
Cast aluminum alloy	73	0.33	2800	215

The original structure and topology optimization cloud diagram of the suspension arm are shown in Figure 1 and Figure 2.

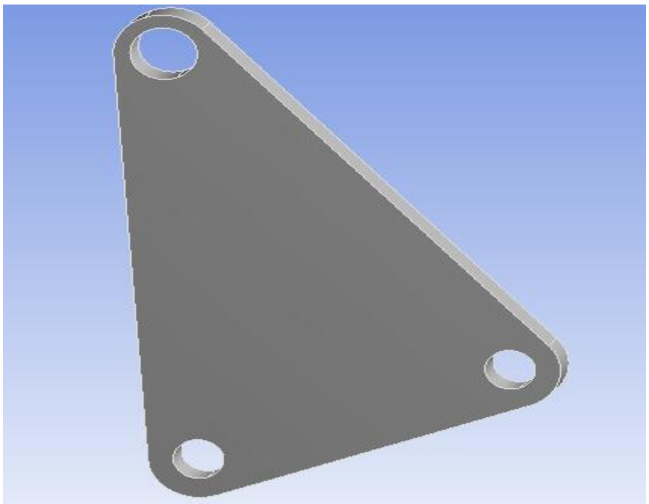

Fig. 1. *Original structure of suspension arm*

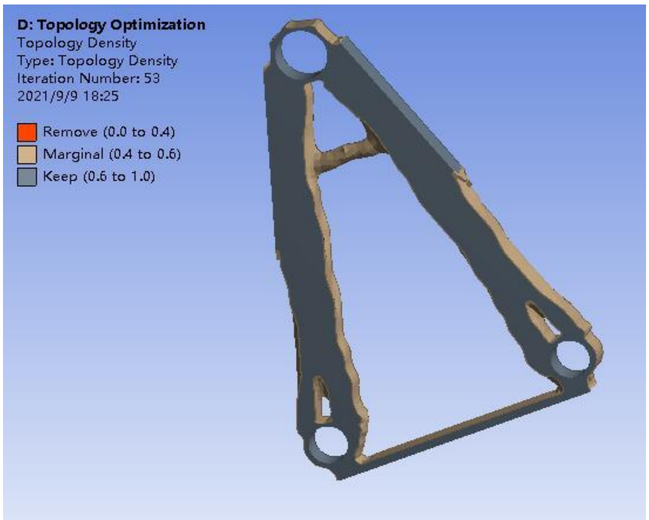

Fig. 2. *Topology optimization cloud diagram of suspension arm*

According to the topological structure of the suspension arm, combined with the cost of the structure in actual manufacturing, the suspension arm structure is modeled and reconstructed. After reconstruction, the mass of the suspension arm decreased from 13.65g to 5.76g, as shown in Figure 3.

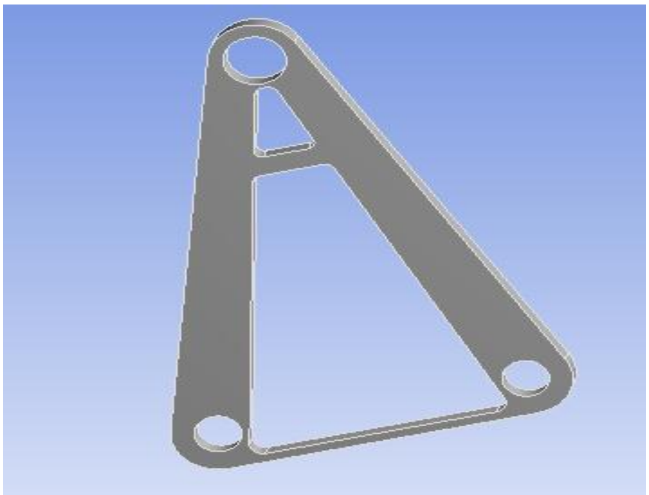

Fig. 3. *Reconstruction model of suspension arm*

Von Mises equivalent stress [5] is used for static analysis of the model before and after optimization, and the stress cloud diagram is shown in Figure 4 and Figure 5.

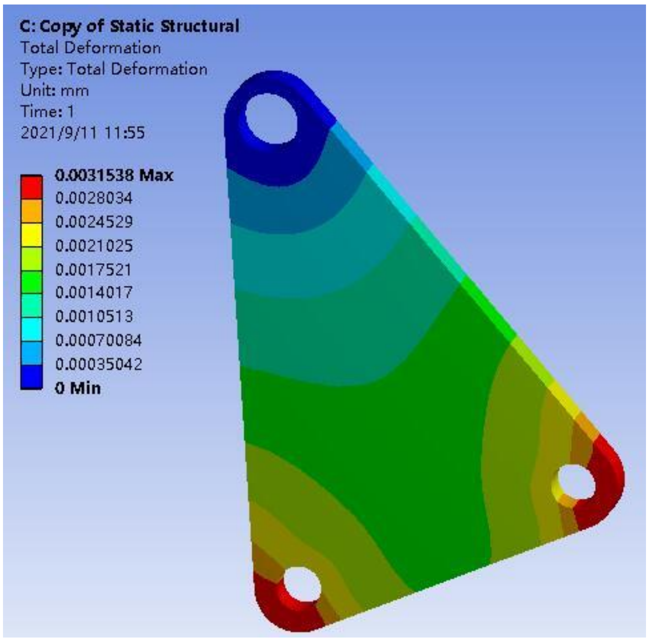

Fig. 4. *Stress cloud diagram before suspension arm optimization*

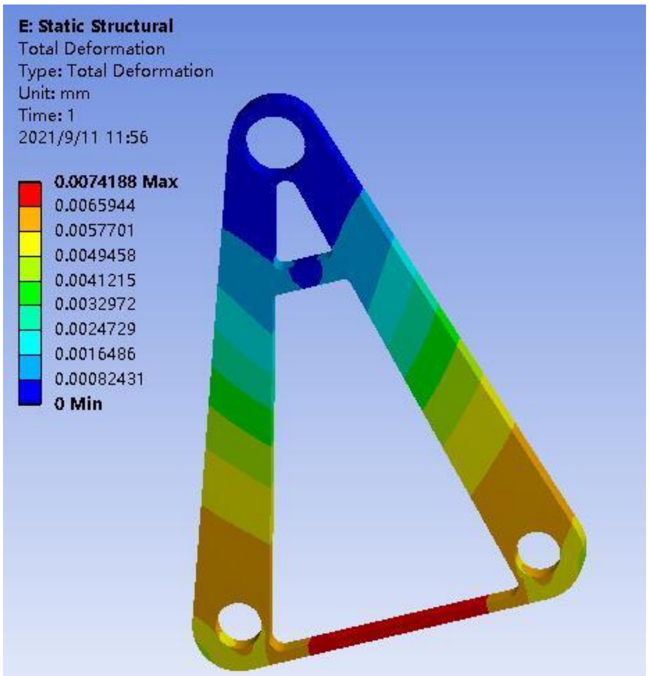

Fig. 5. *Stress cloud diagram after suspension arm optimization*

It can be seen from the figure that the maximum stress before and after optimization is concentrated at the two small holes at the lower end of the suspension arm, and the stress value is increased from the original 17.141Mpa to 44.142Mpa. The actual stress value of the structure is much smaller than the yield limit of the material, so the optimized performance of the suspension arm fully meets the requirements of use.

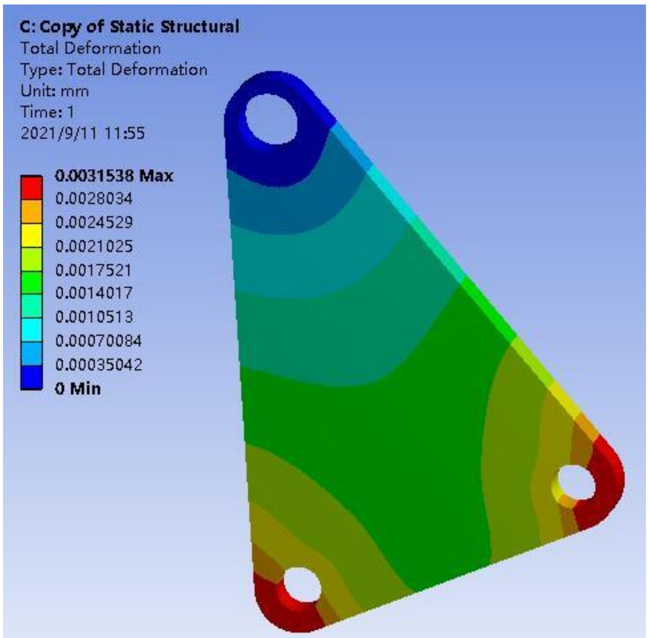

Fig. 6. *Displacement cloud diagram before suspension arm optimization*

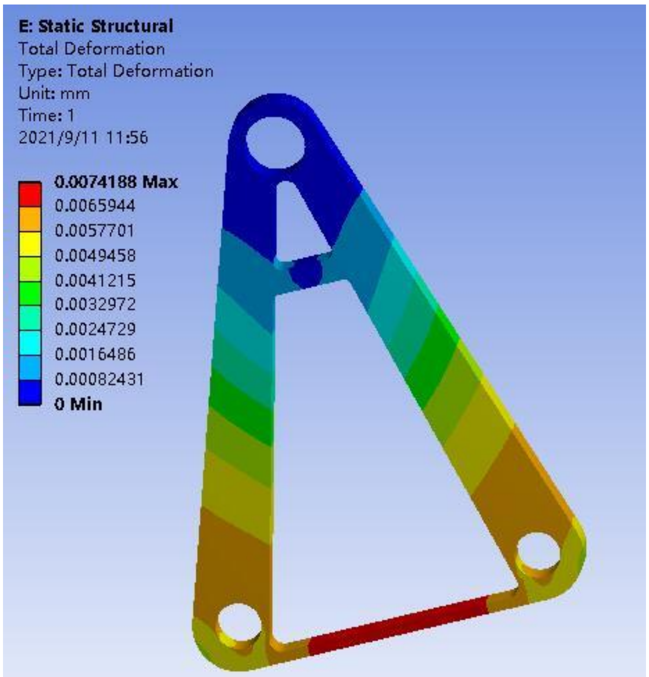

Fig. 7. *Displacement cloud diagram after suspension arm optimization*

By comparing the displacement cloud diagrams 6 and 7 of the optimized front and rear suspension arms, it can be seen that: after optimization, the deformation at the bottom two-hole connecting rod is the largest, and the maximum deformation is increased from 3.15×10^{-3}mm to 7.42×10^{-3}mm. The relevant data table before and after the suspension arm optimization is shown in Table 2.

TABLE II. OPTIMIZE THE PERFORMANCE OF THE FRONT AND REAR SUSPENSION ARMS

Name	**Weight/g**	**Maximum stress/Mpa**	**Maximum deformation /mm**
Before optimization	13.65	17.141	3.15×10^{-3}
After optimization	5.76	44.142	7.42×10^{-3}
Optimization rate	42%	/	/

IV. CONCLUSION

In this paper, the suspension arm structure of a certain type of train battery system is used as the research object, and its strength analysis and lightweight design are carried out using ANSYS Workbench. By analyzing and comparing the original structure and the optimized structure, it is concluded that the weight of the optimized suspension arm is reduced from the original 13.65g to 5.76g, and the stress is changed from the original 17.141Mpa to 44.142Mpa. The actual stress is still far less than the allowable stress of the material. The strength of the structure meets the requirements of use. The analysis results show that the optimized design completes the lightweight design of the suspension arm while ensuring the strength requirements.

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REFERENCES

[1] Wang M Y, Wang X, Guo D. A level set method for structural topology optimization[J]. Computer methods in applied mechanics and engineering.2003.192(1-2): 227-246.

[2] Zhuang C G, Xiong Z H, Ding H. Structural Topology Optimization Based on Level Set Method and von Mises Stress[J].China Mechanical Engineering.2006.(15): 1589-1595.

[3] Mlejnek H P, Schirrmacher R.An Engineer's Approach to Optimal Material Distribution and Shape Finding[J]. Computer Methods in Applied Mechanics & Engineering.1993.106（1-2）:1-26.

[4] Rietz A.Sufficiency of a Finite Exponent in SIMP Methods[J].Structural & Multidisciplinary Optimization.2001.21（2）:159-163.

[5] Liu Hongwen. Mechanics of Materials[M]. Beijing: Higher Education Press,2017.