Topology Optimization for Important Components of Sausage Packaging Vision Detection Equipment

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This article introduces the OptiStruct iterative algorithm, and the corresponding sensitivity analysis. Combined with the practical application of engineering, important support structures are used for topology optimization design by HyperWorks. The results show that in the case of meeting production requirement, the volumes of structures are reduced significantly, material distribution is more reasonable, lightweight design of component is achieved, theory reference is provided to improve and optimize device structure.

Key words: Topology Optimization; OptiStruct; Sensitivity Analysis; HyperWorks

1. Overview

Continuum structure main beam, shell and plate, its topology optimization design is one of the new direction in the field of structure optimization design, The topology optimization of continuum structure is mainly divided into two aspects of research: Mainly study abroad in the global stiffness topology optimization problem under the restriction of volume, and domestic research on the local stress intensity under the restriction of topology optimization problem [1-2].

Based on the research and development of ham sausage packaging visual inspection equipment as the object, Application of OptiStruct iterative algorithm and the corresponding sensitivity analysis, Finally in the HyperWorks topological optimization, and the finite element analysis have been carried out to verify the results of optimized, to illustrate the feasibility of the optimization results.
2. Optimization Algorithm of Calculating the Continuum Structure

2.1. OptiStruct iterative algorithm

OptiStruct local approximation method is adopted to solve the optimization problem. Local approximation algorithm to solve the optimization problem steps are as follows:

1) The finite element method analysis corresponding physical problems. 2) Convergence of judgment. 3) Design sensitivity analysis. 4) The sensitivity information are used to get the approximate model, and solve the approximate optimization problem. 5) The first step in return.

In the structure optimization design and calculation, the design variables, the sensitivity analysis of the structural response is from simple design changes to the most important part in the process of mathematical optimization. Design variable update model was optimized by using approximate method, the approximate model using sensitivity information. OptiStruct approximation model established by using three methods: the optimization criterion method, dual method and the feasible direction method. The latter two are based on convex linear design space [3-4].

2.2. Sensitivity analysis

Design is the structural response sensitivity to the design variables of the partial derivative of structural response [5-6].

For the finite element equations:

\[ KU = P \]  \hspace{1cm} (1)

\( K \) is the stiffness matrix; \( U \) is unit node displacement vector; Node load vector \( P \) is unit.

On both sides of the design variables \( X \) partial derivative:

\[ \frac{\partial K}{\partial X} U + K \frac{\partial U}{\partial X} = \frac{\partial P}{\partial X} \]  \hspace{1cm} (2)

then

\[ \frac{\partial U}{\partial X} = K^{-1} \left( \frac{\partial P}{\partial X} - \frac{\partial K}{\partial X} U \right) \]  \hspace{1cm} (3)

In general, the structural response can be described as a function of the displacement vector \( U \)

\[ g = Q^T U \]  \hspace{1cm} (4)
So the sensitivity of structural response is

\[ \frac{\partial g}{\partial X} = \frac{\partial Q^T}{\partial X} U + Q^T \frac{\partial U}{\partial X} \tag{5} \]

With fewer constraints for the design and design variables, many optimization problems, can use another method, to calculate the sensitivity can be introduced with variable E.

\[ KE = Q \tag{6} \]

then

\[ \frac{\partial g}{\partial X} = \frac{\partial Q^T}{\partial X} U + E^T \left( \frac{\partial P}{\partial X} - \frac{\partial K}{\partial X} U \right) \tag{7} \]

3. Topology Optimization for important components

3.1. Brush roll support optimization analysis

Adjustable brush roller device is mainly for centrifugal wheel exports of ordered sausages output, through the brush roller brush off cascading sausage, im only allowed a sequence output. Brush roller supports mainly realize the brush roller and adjust the structure of the connection. Adjustable brush roller device as shown in Figure 1. Brush roller supports 3d model as shown in Figure 2.

![Figure 1. Brush roll installation drawing.](image1)

![Figure 2. Brush roller supports.](image2)

The finite element model parts as shown in Figure 3. In Figure 3, the red in the middle of the part in order to optimize the area, as a result of the middle rung on the need to install the brush roll, so the hole is local is defined as the design area, in the process of optimization, the reserved hole structure. Green as a design area, that is, in the process of optimization, the regional structure does not change.

Optimal parameter Settings are as follows: definition response (flexibility in response to the Compliance, volume fraction Volume frac response), define the
objective function (the minimum Compliance $\text{min}$), define the constraints (upper limit of volume fraction upper bound = 0.6). Finally submit tasks for topology optimization analysis. Topology optimization result is acquired after 15 iterations, topology optimization analysis results as shown in figure 4.

![Figure 3. Brush roller finite element model.](image1) ![Figure 4. Finite element model of the optimized.](image2)

By the topology optimization analysis results indicate: after 15 iteration, part convergence topology optimization, structure total flexibility value decreased from 103.6 to 103.6, than the original decreases by 13.9%; The volume of the design area reduced to 60%.

3.2. **Brush roll support optimization analysis**

![Figure 5. Figure inclined brush roller device.](image3) ![Figure 6. Oblique brush roller supports.](image4)

Inclined brush roller device switch main realization to the movement of the wheel to the stipulations in the location of the sausage to weed out the function, and can realize the brush roll up and down position adjustment, so as to realize effective for different specifications of sausages. Oblique brush roller supports the main implementation of the whole inclined brush roller device is fixed and the supporting function of adjusting device. Brush roll device as shown in Figure 5. Brush roll support a 3 d model as shown in Figure 6

According to the structure characteristics of inclined brush roller supports, shell element can be used to optimize a component analysis, through the finite element software functions, the extraction of surface for oblique brush roller supports 2 d geometry model, according to the needs of the optimization analysis, the geometric model of oblique brush roller for region segmentation. Figure 7 is inclined to brush roller supports extraction model diagram.
Figure 8 is inclined to brush roller support a finite element model. According to the structure characteristics of inclined brush roller supports and the loading situation, define the upper part is divided into design area, namely the red part of figure 8, three of the round hole and the surrounding area is defined as the design area, main is to accord with the actual parts installation, and convenient to load the model. Figure 8 in the green part is the design area.

Brush roll support to optimize the parameter Settings are as follows: define the response (flexibility in response to the Compliance, volume fraction volume frac response), define the objective function (the minimum Compliance min), define the constraints (upper limit of volume fraction upper bound = 0.7, the stress constraint stress constrain = 60 mpa). Finally submit tasks for topology optimization analysis. After 24 iterations for topology optimization as a result, the topology optimization analysis results as shown in Figure 9. By the topology optimization analysis results indicate: after 24 iteration, part convergence topology optimization, structure total flexibility value decreased from 699 to 466, than the original decreases by 33.3%; The volume of the design area reduced to 70%. Optimized analysis and design, reduce the weight of the brush roll support items, increase the stiffness of the parts.
4. Conclusion

Around the topology optimization of continuum structure basic theory and application research on the main line, relying on the HyperWorks software established the process of solving the structural topology optimization. On the research and development of equipment of the important support for the topology optimization, the simulation results show that the topology optimization is reduced in volume after parts, satisfied the intensity of the work environment and the rigidity requirement of optimization results.

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References