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Research on Design and Performance Improvement of Washing Machine Based on Structural Optimization

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Abstract: Introduction This paper investigates the structural optimization and performance enhancement of washing machines, focusing on the lightweight design of the outer drum flange structure and the rigidity enhancement of the box structure of the washing machine. The study adopted SolidWorks software for modeling and simulation analysis, and used finite element analysis to optimize the design of the outer drum flange structure and box structure of the washing machine. The performance of the different design alternatives was evaluated by simulating stress clouds, displacement clouds and fatigue analysis. It is shown that the optimized washing machine outer drum flange structure not only reduces the weight but also improves the structural strength, and the reliability of the design is verified by fatigue analysis. In addition, the optimization of the box structure improves the rigidity and overall performance. The study in this paper provides a valuable reference for the structural optimization of washing machines, and more efficient and environmentally friendly design solutions can be further explored in the future.

Keywords: Structural optimization, Lightweight design, Finite element analysis, Performance enhancement， Rigidity improvement.

1. Introduction

As people's living standards improve, consumers' expectations of washing machines are no longer limited to basic washing functions, but are increasingly concerned about their healthy washing functions, water-saving performance, and impact on the environment.

At present, domestic and foreign scholars have studied energy-saving washing machines in terms of drainage [1-2], washing methods and detergent types [3-4], and optimization of washing machine structure [5], etc. Parida, D [6] et al. studied the effect of temperature on the production of microfibers in washing machines by taking into account three temperatures ranging from high to low, and the results of the study showed that the higher the temperature, the more fibers were released. Sheraz, M [7] et al. developed a specialized microfiber capturing “barb filter” and showed that this filter can effectively capture and retain microfibers of different lengths and outperforms conventional control filters, and the study provides a promising solution to reduce the release of microfibers from laundry and textile industry wastewater. solution. Kim, S[8] et al. investigated ceramic membranes as a potential high-performance alternative to microplastic filters for domestic washing machines. The results of the study indicated the need for easy cleaning of mountable ceramic membranes before they can be widely used as filters in external washing machines in the long term. Cummins, AM[9] et al. evaluated the effects of vented and condensing tumble dryers on aquatic and airborne microfiber contamination and showed that vented tumble dryers were a significant contributor to aquatic microfiber contamination from lint filters, condensers and condensate. Masselter, T[10] et al. improved the microfiber filters for domestic washing machines and showed that there is great promise for integrating them into an easy to make and cost-effective filter concept.

Based on the above research, this paper carries out certain optimization of the washing machine for the problems of large drainage capacity and structural optimization. Aiming at the problem of large drainage capacity, this paper carries out a lightweight design of the outer drum flange structure of the washing machine, which reduces the weight of the flange structure and improves the strength of the flange at the same time. For the problem of structural optimization, this paper investigates the effect of different compression depths of the box on rigidity and stability through simulation analysis, and the results show that increasing the compression depth of the side of the box can significantly improve the rigidity and reduce the deformation. In addition, the drop simulation analysis shows that the optimized box structure has better impact resistance and durability.

2. Lightweight Design of Washing Machine Outer Drum Flange Structure

2.1. Modeling pre-processing

The pre-modeling process mainly includes the establishment of the geometric model of the outer drum flange structure, mesh delineation and the setting of related materials. The structural model of the outer drum wall flange of the washing machine was established in SW modeling software, and before the finite element analysis of the model, the meshing process was simplified in order to improve the speed of operation, and the simplified model was divided into meshes of the smallest 1.5 mm and the largest cell of 5.5 mm.

The corresponding material properties are given to the structural model of the outer drum wall flange of the washing machine, and 5052-0 aluminum alloy is selected, which has a modulus of elasticity of 7e4Mpa, Poisson's ratio of 0.33, density of 2680kg/m3, and a material yield strength of 90Mpa.

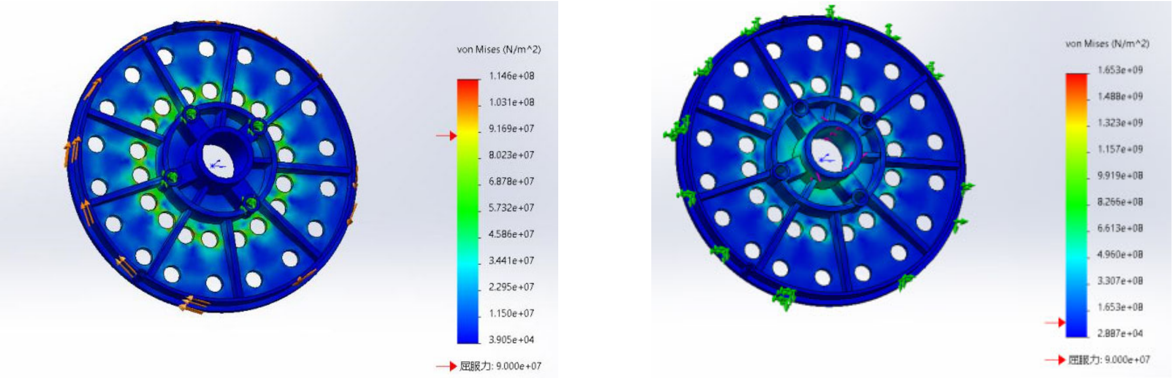
According to the operation of the washing machine and the outer cylinder flange force, analyze the two working conditions, add torque and bending moment at the outer ring and the bearing out respectively, and play a certain constraint on the bolt air and flange outer ring.

2.2. Boundary condition

When the washing machine is washing, under the influence of centrifugal force, the force on the clothes acts on the inner cylinder, which leads to the vibration of the inner drum, and the flange will accordingly bear some torque when the rotating shaft is rotating. Therefore, this question selects two different working conditions to analyze the actual operation of the washing machine and the flange force condition, this paper sets two working conditions, working condition one is to add the corresponding torque outside the flange to fix the four bolt holes. Working condition two is to fix the outer ring of the flange and add bearing torque.

2.3. Analysis of results

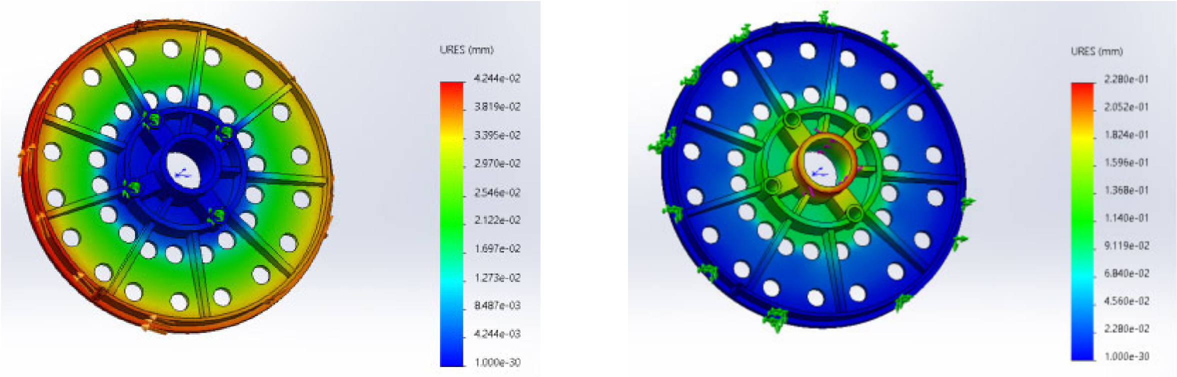
The stress cloud, displacement cloud and fatigue analysis are analyzed to obtain two working conditions, the stress cloud for the two conditions is shown in Fig. 1, the displacement cloud is shown in Fig. 2 and the fatigue analysis is shown in 3.



(a) Stress maps for Case 1

(b) Stress map for Case 2

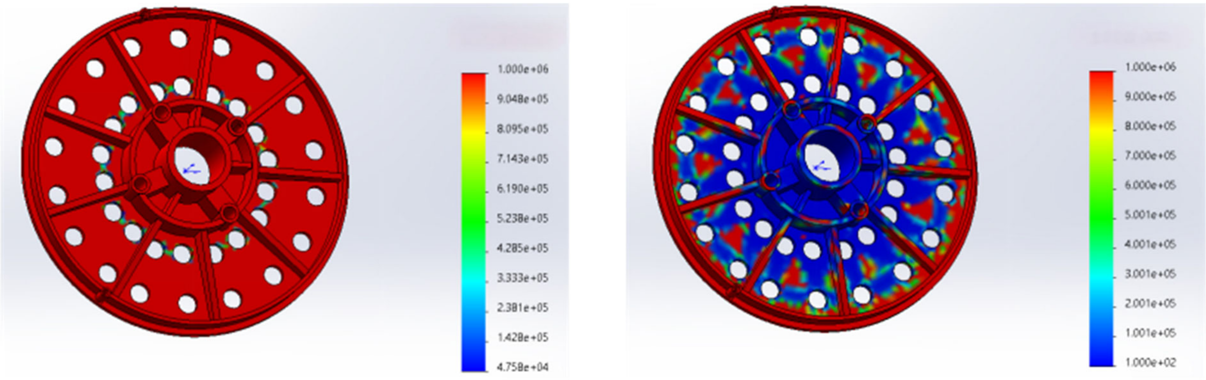
Figure 1. Stress cloud analysis for two working conditions



(a) Displacement map for Case 1

(b) Displacement maps for Case 2

Figure 2. Displacement cloud analysis for two working conditions



(a) Fatigue analysis for Case 1

(b) Fatigue analysis for Case 2

Figure 3. Fatigue analysis for two working conditions

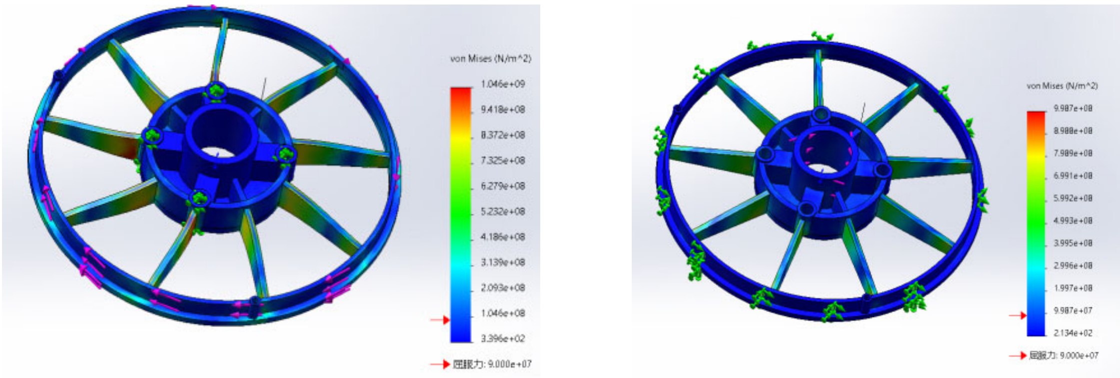
According to the static strength analysis, it can be seen from Fig. 1, Fig. 2 and Fig. 3 that the maximum stress in Case 1 is 114.6Mpa, and the maximum displacement is 0.04244mm; while in Case 2 the maximum stress is 1653Mpa, and the maximum displacement is 0.2280mm, which indicates that both Case 1 and Case 2 have greater mechanical strength. After fatigue analysis, it can be seen that the damage occurs after 100,000 times of operation in Case I, while the damage occurs after 2,504,000 times of operation. In summary, the structure of the outer drum flange of the washing machine can be designed for lightweighting.

2.4. Lightweight design

Based on the manufacturing and assembly requirements, the finite element model of the outer drum flange of a washing machine was partitioned into regions to separate the design and non-design regions, where the main surface of the flange was defined as the design region, while the rest of it was considered as the non-design region. The design constraints are based on the maximum displacement of the model, while the optimization objective is to achieve the minimization of the model volume. In order to guarantee the fabrication feasibility of the optimized structure, fabrication constraints including minimum size limits, symmetry requirements and demolding directions are set.

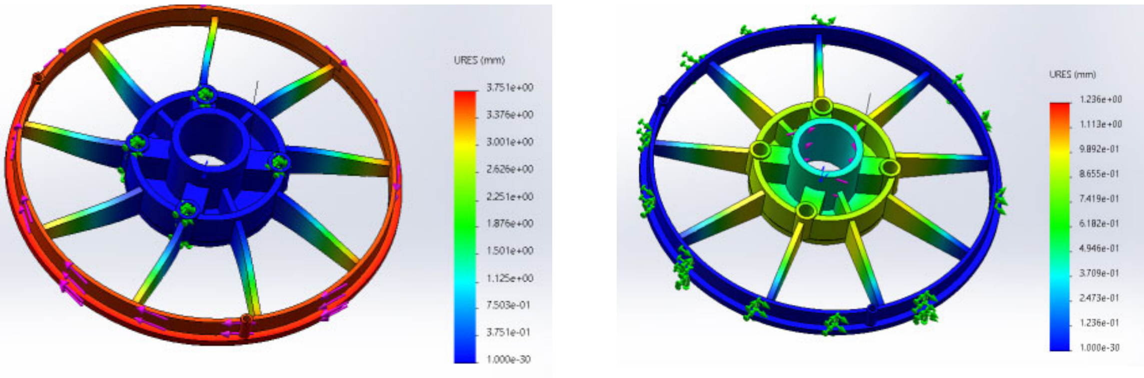
Based on the results of the topology optimization, the 3D model of the washing machine outer drum flange structure is redrawn, and the mass of the established new model is the original mass of the model is 616.773g, which is about 30% weight reduction compared with the original 801.8159g.

The division of the optimized mesh and the setting of the related materials as well as the boundary conditions are exactly the same as those before optimization, and the stress cloud, displacement cloud and fatigue analysis under two working conditions are reanalyzed and obtained, and the optimized stress cloud is shown in Fig. 4, the optimized displacement cloud is shown in Fig. 5, and the optimized fatigue analysis is shown in Fig. 6.



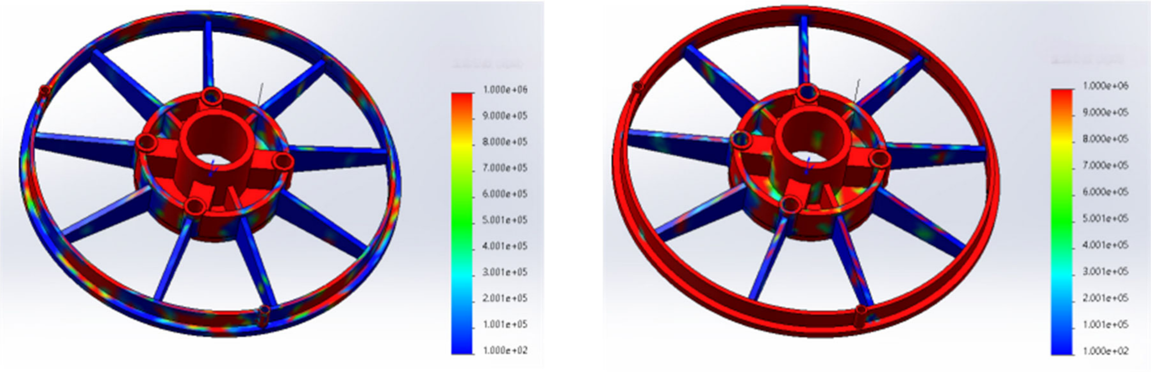
(a) Stress maps for Case 1 (b) Stress map for Case 2

Figure 4. Stress cloud analysis under two operating conditions after optimization



(a) Displacement maps for Case 1 (b) Displacement maps for Case 2

Figure 5. Displacement cloud analysis for two operating conditions after optimization



(a) Fatigue analysis for Case 1 (b) Fatigue analysis for Case 2

Figure 6. Fatigue analysis under two operating conditions after optimization

From the fatigue analysis of two working conditions after optimization in Fig. 6, it can be seen that the optimized structure of the outer drum flange of the washing machine has a maximum stress of 1046Mpa and a maximum displacement of 3.751mm under working condition 1, while the maximum stress of 998.7Mpa and the maximum displacement of

1.236mm in working condition 2, both of which are larger than the original model of the outer drum flange before optimization in the two working conditions, indicating that the strength of the structure after optimization has been improved somewhat. The strength of the structure after optimization has been improved, and the number of damages during operation has also been improved compared with that before optimization. Therefore, the optimized model achieves a lightweight structural design.

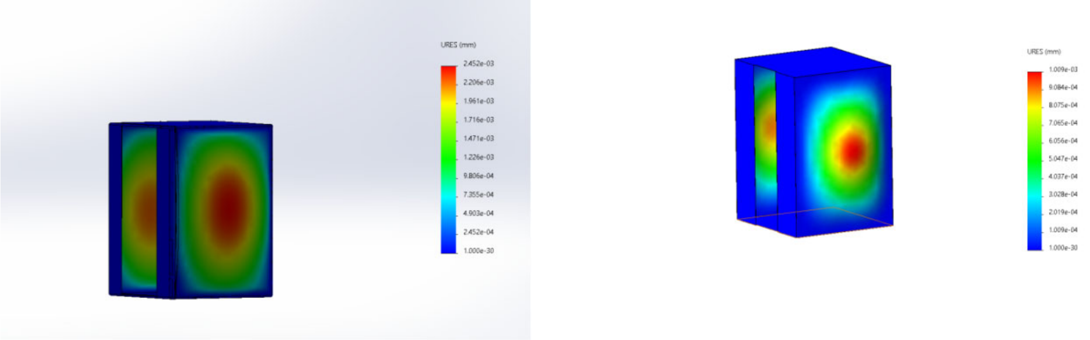
3. Simulation and Optimization Study of Washing Machine Cabinet Structure

3.1. Determination of loads and boundary conditions

When the washing machine dehydration, the center position of the side of the box body has the largest amplitude, which can best reflect the overall stiffness of the box body. The thickness of the box is 0.6mm, and there are two options of 2.0mm and 3.0mm compression depth on the side of the box. A pressure load of 0.02MPa is applied at the center position of the box, and the area of the action is 150mm×150mm in order to check the amount of deformation. And static analysis and fall simulation analysis and modal analysis.

3.2. Static analysis

The two different box structure schemes are analyzed statically, and the deformation distribution of the box is obtained as shown in Fig. 7. From Fig. 7, it can be seen that the deformation is maximum when the load is applied at the center of the box, and the deformation gradually decreases from the center.



(a) Pressing depth 2mm (b) Pressing depth 3mm

Figure 7. Box center deformation distribution

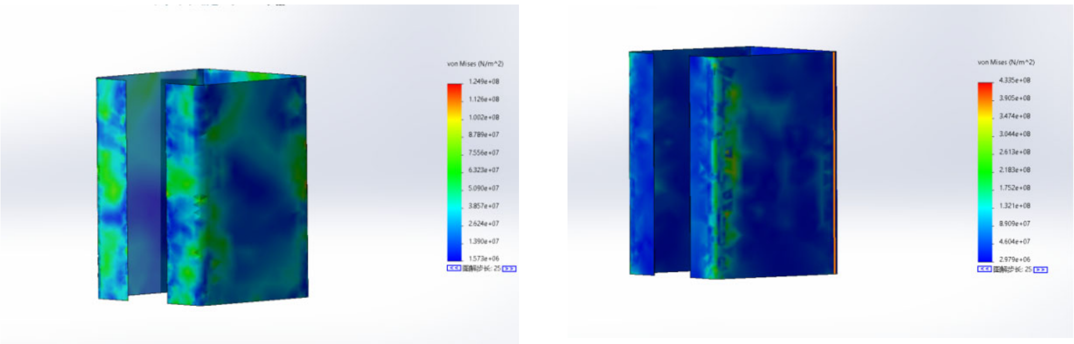
The results of the static analysis of the box are shown in Table 1, with the increase of the depth of compression molding, the lateral deformation of the box is gradually reduced, the deformation corresponding to the compression molding of 2.0 mm is 2.452 mm, and the compression molding is deepened to 3.0 mm, and the deformation is reduced by 1.009 mm, which is an improvement of 41.2%. The results show that increasing the depth of compression molding on the side of the box can significantly improve the rigidity of the box, and reduce the deformation of its side, and improve the overall stiffness.

Table 1. Static analysis results of the box

Depth of box press molding	2.0mm	3.0mm
Static analysis deformation	2.452mm	1.009mm

3.3. Drop Simulation Analysis

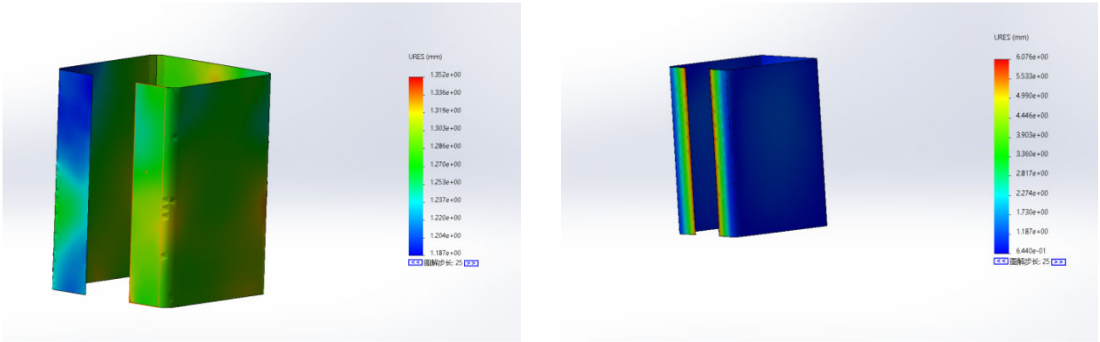
For the two different box structures, the decay analysis and fall simulation analysis were carried out, and the equivalent plastic strain distribution cloud diagrams of the two different box structures were obtained as shown in Figures 8 and 9.



(a) Decay strain diagram for a box thickness of 0.7 and a compression pattern of 2 mm

(b) Decay displacement diagram for a box thickness of 0.7 and a compression pattern of 3 mm

Figure 8. Decay strain



(a) Decay strain diagram for a box thickness of 0.7 and a compression pattern of 2 mm

(b) Decay displacement diagram for a box thickness of 0.7 and a compression pattern of 3 mm

Figure 9. Drop simulation analysis

From Fig. 8 and Fig. 9, it can be seen that the edge of the box presents curved deformation, and the location of the maximum equivalent plastic strain occurs on the side of the box.

The drop simulation comparison is shown in Table 2.

Table 2. Drop Simulation Comparison

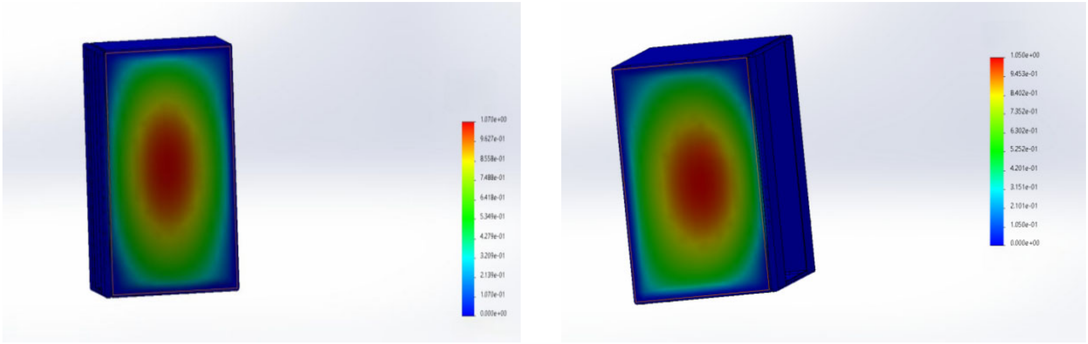
Box structure program	Scenario A	Option B
	Case thickness 0.7, compression molding 2mm	Box thickness 0.7, compression molding 3mm
Static analysis deformation	0.0712	0.0644

Scheme B relative to Scheme A, the box thickness degree are 1.5mm, while the compression type are 2mm and 3mm, respectively, the equivalent plastic strain is reduced by 0.9%, and the area that produces plastic strain is significantly reduced, the improvement effect is obvious. The static analysis deformation of scheme B is smaller than that of scheme A, which indicates that the deformation of scheme B under force is smaller, implying that scheme B is better in terms of structural stability or rigidity.

3.4. Modal analysis

Modal analysis of different box structure scheme to obtain the first-order and second-order intrinsic frequency, box modal vibration pattern as shown in Figure 10 and Figure 11, the vibration pattern embodied in the box side of the center of the vibration, and the actual vibration test box side of the center of the amplitude of the largest coincides with.

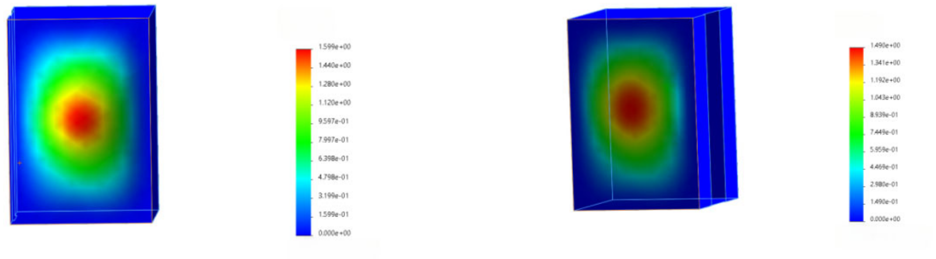
From Fig. 10 and Fig. 11, comparing the structural scheme of each box compression molding depth, the corresponding first-order intrinsic frequency and second-order intrinsic frequency are not much different; however, with the increase of the compression molding depth, the first-order intrinsic frequency and second-order intrinsic frequency are obviously increased; the first-order intrinsic frequency corresponding to the compression molding of 2 mm is 14.2 Hz, and the deepening of compression molding to 3 mm improves the first-order intrinsic frequency by 18.6 Hz. The results show that deepening the box compression molding depth can significantly improve the box modal state. The results show that the deepening of the side compression molding depth can obviously improve the box modal and increase the first-order intrinsic frequency.



(a) Inherent frequency of 14.2 Hz

(b) Inherent frequency of 14.3 Hz

Figure 10. Box thickness 0.7, pressing depth 2mm



(a) Inherent frequency of 18.6 Hz (b) Inherent frequency of 18.9 Hz

Figure 11. Box thickness 0.7, pressing depth 3mm

4. Conclusions

In this paper, the flange structure of the washing machine outer drum and the structure of the drying duct blade of the washing machine are optimized and simulated using SolidWorks software by establishing the relevant model molds, simulating the stress and displacement clouds of the flange structure of the washing machine outer drum, as well as performing the corresponding fatigue analysis of the flange structure of the washing machine outer drum, and according to the results of the flange structure of the drum, the design of the outer drum flange structure for lightweighting is carried out. In addition, a simulation and optimization study of the washing machine box structure was conducted to improve the overall performance and durability.

The results show that the optimized washing machine outer drum flange structure enhances the structural strength while reducing the weight, and the reliability of the design is verified by fatigue analysis. Meanwhile, the washing machine box structure is optimized through simulation to improve its rigidity and overall performance.

In this paper, the optimized design of the washing machine outer drum flange and box structure not only successfully reduces the weight, but also improves the strength and durability of the structure. The optimized structure has a more stable performance in actual operation and has a longer service life. The study provides an effective optimization idea for the design of washing machines, and more environmentally friendly and efficient design solutions can be explored in the future.

Acknowledgments

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