Layout optimization analysis of zero Point system under extreme conditions based on Workbench

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Abstract. In this article, Ansys workbench is used to perform mechanical simulation on the undetermined layout of the zero point system, and the difference between the layout and quantity of the different points of the connecting pins is analyzed, and the best layout is selected as the outer ring square (side length is 760). The inner circle is distributed in an equilateral triangle (side length is 250).

1. Introduction

In the aerospace industry, various light-weight, high-strength, large-scale thin-walled cylindrical parts are widely used. Before machining, the cylindrical parts are positioned and locked by special centering fixtures or general fixtures such as pressure plates. The positioning and clamping accuracy is low, the manual adjustment and clamping process are complicated, and the automation level is not high, which seriously affects the production and processing efficiency and quality of the cylindrical parts[1]. In addition, the size of the product changes greatly, requiring multiple dedicated fixtures. At the same time, in order to ensure the accuracy of product processing, the processing of large thin-walled structural parts requires repeated off-line inspection and reprocessing many times. Parts repositioning and clamping time will lead to a long time occupied by the machine, which greatly reduces the efficiency of machining. Therefore, how to improve the positioning and clamping accuracy and effectively shorten the replacement time is of great practical significance for promoting the automated processing of cylindrical parts[2].

The zero point positioning system is a positioning and locking device that uses a chuck to ensure that the workpiece is positioned and locked during the clamping process, reducing part clamping errors and reference conversion errors, realizing precise and rapid clamping of tooling, and effectively reducing re-finding Auxiliary time for positive zero[3,4]. Domestic scholars have studied the positioning and clamping technology based on the zero point system. Chen Sitao and others applied the zero point system to CNC machine tools, which reduced the machine tool's downtime by 60%-80%, and realized the continuous operation of the machine tool during the production cycle[5]. Zhang Xue et al. adopted a zero point system for the positioning and clamping of the rocket cone, which met the requirement that the deformation of the cone window processing area under the action of milling...
force and clamping force is less than 0.01 mm[6]. The number and arrangement of positioning pins in the zero point system have a very important influence on the stability and accuracy of the system. At present, there are few studies on the number and point-positioning of the positioning pins in the zero point system.

This article uses Ansys workbench to simulate the undetermined layout of the zero point system, and analyzes the difference between the layout and quantity of the connecting pins at different points. Finally, the best layout is selected to achieve the best solution for structural design, stability and positioning accuracy.

2. Scheme design of zero point system for cylindrical parts
The purpose is to process a series of cylindrical parts with a diameter between 280-1200mm and a maximum mass of about 80kg. The maximum resistance of the pin array during the processing of the overall structure is taken as the objective function, and the position and number of the zero point positioning pins are used as decision variables to establish an optimization model of the clamping point position and the number of clamping points using genetic algorithm to determine the optimal clamping Point position and the number of clamping points, a recursive optimization algorithm for the position of the clamping point and the number of clamping points of the overall structure is proposed. Through structural optimization design, mechanical analysis, economic factors and ease of assembly, the optimal layout of the zero point system is the outer square inner triangle and the outer triangle inner triangle.

3. Mechanical analysis of zero point system of cylindrical parts under extreme conditions
Combined with the structure of the zero point system, the weakest position is the bolt connecting the zero point system and the fixture plate. Therefore, this part is refined in the finite element analysis. In the load application, the force characteristics under extreme conditions (maximum cutting force 4200N is applied at the highest part of the workpiece) are considered, and the actual connection and assembly conditions are combined to construct a finite element analysis model. The finite element simulation results are as follows: (a.Y-direction deformation b.Equivalent stress change distribution c.Equivalent elastic strain distribution)

![Figure 1. Outer square inner triangle outer side length 800mm](image)

![Figure 2. Outer square inner triangle outer side length 760mm](image)
3.1. Locating pin check analysis

Based on the related theories of mechanical design and material mechanics, it is proposed to use the shear strain energy theory combined with the workbench simulation results to check the performance of the fixture plate and the zero point system assembly. The weakest part of the zero point system is the threaded connection, so it focuses on its performance check.

According to the theory of shear strain energy: when the bolt $\sigma_y = \sqrt{\sigma^2 + 3\tau^2}$ reaches the yield limit, failure occurs. Where $\sigma_y$ is the equivalent stress, $\sigma$ is the axial stress generated by the axial tension (when the bolt cap or nut is not in contact with the connected part, the axial tension is the axial tension, and only overcomes the friction force of the thread pair and the lift angle The generated torque; when the bolt cap or nut contacts the connected part, the axial tension is the pretightening force. In addition to the torque generated by the thread pair friction and the lift angle, it also needs to overcome the friction with the connected part, $\tau$ is the shear stress caused by the torque, calculated according to the thread theory: $\tau = 0.46\sigma$, at this time $\sigma = 0.78[\sigma_b]$ Take to get, and $[\sigma_b]$ is the allowable stress. From $\sigma = 0.78[\sigma_b]$, it can be concluded that when the tensile stress $\sigma$ reaches 0.78 times the allowable stress $[\sigma_b]$ caused by simple stretching, the outer thread groove bottom begins to yield. According to GB/T3098.1-2000, the bolt performance grade is 10.9, and the yield limit is 900 MPa. At this time: $\sigma$ is 702 MPa.

The simulation results of all layout schemes show that the maximum stress value of the designed structure under working conditions is less than the tensile stress, indicating that the deformation of the zero point system under extreme working conditions is elastic deformation. Comparing and analyzing the equivalent stress changes of different distributed structures, it can be obtained that the greater the distance between the two zero point systems, the greater the equivalent stress. The overall deformation
in the force direction mainly occurs in the force-bearing area of the workpiece, and the average deformation is less than 0.006mm. The overall distribution law shows that the more the number of zero point systems, the smaller the average deformation.

Further analysis of the equivalent elastic strain law of the zero point system, the strain of the zero point system under load is less than 0.01 (repeat positioning accuracy); at the same time, the outer ring layout is square and its layout position is close to the edge of the workpiece. The strain is minimal. After the optimized layout of the outer four-point distribution structure, the maximum deformation is slightly larger than the strain value of the layout three structure, but the average strain is the minimum, and the optimized result is more instructive, mainly due to the fact that the two zero point system is in the experiment. When the distance is 400, the repeat positioning accuracy is less than 9μ, and the optimization result distributes more points with a distance of 400 to the system. In addition, the difference between the maximum equivalent strain value of the finite element analysis of layout a and b is only 0.00005mm, and the average strain is only 0.000017mm, which is negligible. Combined with the results of mechanical calculations, the overturning force of layout a and b systems is only 95N different (compare layouts 3 and 7), the shear force is the same, and the torsional force gap is only 10N. Comprehensive analysis shows that the result of layout b is better. In layout c and layout d, the distance between all outer ring points in layout d and their adjacent inner ring points is 400. Compared with the system strain, the strain value is decreasing. It is objectively reflected that when the system layout is more balanced and symmetrical, the strain value becomes smaller.

4. Program analysis

(1) From the perspective of structural design, in order to meet the requirements of multi-variety and multi-process flexible quick-change tooling, limited by the minimum workpiece size (diameter 280mm), combined with the theory of material mechanics, when the inner ring layout is a regular triangle, the system is relatively stable. And due to the relatively uniform stress and strain caused by processing and manufacturing, the three-point layout of the inner ring was first determined.

(2) From the stability analysis, because the product is a large thin-walled piece, in order to prevent the deformation of the fixture plate caused by manufacturing, gravity, stress release, etc., the fixture plate is relatively thick, and the weight of the largest workpiece is small, making the "workpiece" The "fixture zero point system" constitutes a system whose center of mass is close to the center of mass of the fixture plate, the more stable and reliable the overall system is. In addition, when the outer ring is a four-point square layout, the "dangling" area of the fixture plate is less than the "dangling" area when the equilateral triangle is distributed, and its shear, torsion, and overturning forces are also larger. Therefore, the adaptable workmanship The wider the situation, the better the stability.

(3) From the analysis of the positioning accuracy of the system, the repeat positioning accuracy is less than 9μ when the moment between two points is 400 (experimental basis). When the distance between two zero points is 400, the average deformation of the system is small and the positioning accuracy is relatively high. And the spacing of the outer ring layout has minimal effect on the deformation of the system; the overturning force is only 95N (compared to layout a and b), the shear force is the same, and the torsional force gap is only 10N. Therefore, choose the best layout in layout a and b.

5. Conclusion

Considering the structural design, economic cost, system stability and repeat positioning accuracy analysis, the inner ring layout is based on the three zero point systems distributed as equilateral triangles, and they are laid out on the edge of the smallest workpiece (the distance between the two zero point systems is 250mm). For the outer ring zero-point system layout, when the layout structure is a regular quadrilateral, its stability, repeat positioning accuracy and structural design are superior, and the economic cost is only one zero point system cost. In order to adapt to a wider range of application conditions, expand production capacity, and improve scale efficiency, the outer ring layout of a regular quadrilateral can achieve the core requirements of improving quality and efficiency, which is
of great significance to the development of the enterprise. Therefore, the final design is based on the optimization result of the genetic algorithm and the rounded design is the optimal result. The design is a regular quadrilateral on the outer ring (side length of 760), and a regular triangle distribution on the inner ring (side length of 250).

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