Optimization Design of CNC Lathe-bed based on ANSYS and MATLAB

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Abstract

Based on the joint call technology of ANSYS and MATLAB, this paper puts forward a method of NC Lathe-bed optimization design. The structural parameters of the guide rail and the middle support plate are taken as the design variables, the quality of the bed is the objective function, and the numerical control Lathe-bed is optimized by genetic algorithm.By optimizing the design of a Lathe-bed, the results show that the design optimization method can reduce the structure mass to the greatest extent while satisfying the constraints of strength and stiffness.

Keywords

CNC Lathe-bed; Optimization Design; Genetic Algorithm (GA).

1. Introduction

CNC lathe has the advantages of high processing accuracy, high production efficiency, occupies an important position in the modern manufacturing industry, the bed as the main component of the lathe, plays the role of supporting the spindle, tool rest and other key components. The optimization design of CNC Lathe-bed has become a research hotspot.

For CNC Lathe-bed, domestic and foreign scholars have carried out extensive research. Xiao-peng li [1] ANSYS software was used to simulate the structure of a machine bed in several different layout of reinforcement plates, and the optimal structure layout was determined. Huang Tingmei [2] CK6163c CNC Lathe-bed was optimized by using the progressive topology optimization method in ANSYS software, and the results show that the bed performance is greatly improved; Paredes [3] The optimization design of the bed was also proposed based on the simulation. Yildirim [4] On the basis of predecessors, scholars proposed that changing the thickness of the middle support plate can greatly improve the reliability of CNC lathe work. These methods all use the optimization of software to design, and do not realize the optimization design of the whole space. This paper presents a design method based on parametric modeling and optimization design function in ANSYS and MATLAB, and realizes optimization design of NC lathe in static analysis.

2. Model

CNC Lathe-bed is generally horizontal structure, the bed and the table guide surface are inclined to set (45° oblique bed), the internal design of the bed is hollow structure, there is a support plate in the middle, the plate thickness is roughly 20-25mm, the outer wall thickness of the bed is roughly 20-30mm, can withstand large cutting load. This paper studies the integral CNC lathe, and the bed and the base are connected as a whole by combination without welding, as shown in Figure 1. The parametric model of CNC Lathe-bed can be established by ANSYS APDL language, in which the structural parameters are the coordinate values of two guide rails of the workbench at the headstock of the bed and the coordinate values of the middle support plate at the guide rail. All the structures of the integral CNC bed are simulated by solid elements.

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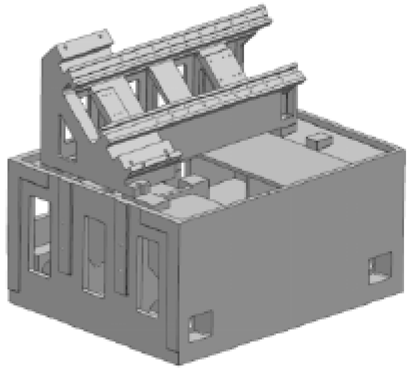

Fig 1. Parametric model of CNC Lathe-bed

Integral CNC lathe base size is fixed, the bed is generally fixed in the middle of the base, that is, do not need to consider the position of the bed in the base parameters.

2.1. Structure Parameters of CNC Lathe

The two guide rails are installed on the bed body at the spindle box and are symmetrical to the spindle box. The main view of the base is selected as the basic plane, and a position parameter is set, that is, the horizontal height Y between the front guide rail and the center line of the spindle box$_1$, the position parameters of front and rear guide rails at the spindle box are shown in Figure 2.

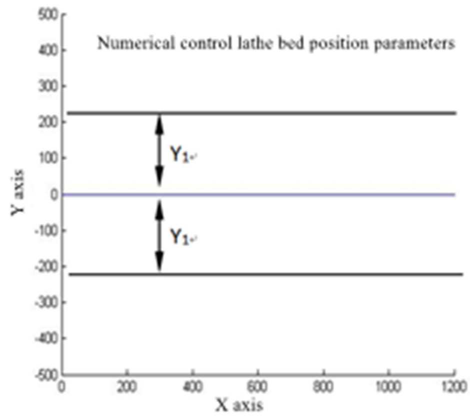

Fig 2. Front and rear spindle positions on the bed body at the spindle box

The middle support plate is installed in the hollow part of the CNC bed center, and is connected with two guide rails and the base. The coordinate position of the support plate can be determined by the guide rail. The position parameter X of the support plate on the guide rail can be determined by the guide X_1, X_2 As shown in Figure 3.

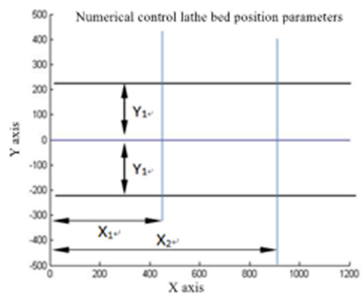

Fig 3. Position of support plate at guide rail

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2.2. Material Attribute Setting of CNC Lathe

The two guide rails are installed on the bed body at the spindle box and are symmetrical to the spindle box. The main view of the base is selected as the basic plane, and a position parameter is set, that is, the horizontal height Y between the front guide rail and the center line of the spindle box$_1$, the position parameters of front and rear guide rails at the spindle box are shown in Figure 2. in the design of CNC Lathe-bed, the properties of materials are determined. Because gray cast iron has good casting property, wear resistance, shock absorption, general CNC lathes use HT250 gray cast iron material. Material properties are shown in Table 1 below.

Table 1. Material properties of CNC lathes

performance parameters	HT250
Young's modulus E (Mpa)	1.2E+05
Poisson's ratio of mu	0.26
Density ρ (t/mm^2)	7.15E-09
Tensile strength X_t(MPa)	800
Compressive strength X_c(MPa)	250
Shear strength S (MPa)	298

3. Genetic Algorithm for Quality Optimization Design

3.1. Genetic Algorithm

Professor J. Holland of the United States first proposed genetic algorithm (GA), its basic idea is to search the optimal solution by simulating the natural evolution process. In the calculation process of genetic algorithm, we need to consider: coding mode, genetic algorithm, fitness function.

(1) Fitness function

Fitness function must be introduced before optimization design of nc Lathe-bed using genetic algorithm. Here, the fitness function is m= a-g /G0. A is A fixed positive number to ensure that M is never less than 0. In this paper, 100 is chosen. G is the structural mass of CNC Lathe-bed, the unit is kg; G0 is a fixed mass, 100 kilograms.

(2) Encoding mode

Binary encoding is usually adopted in genetic algorithm, but if there are discrete variables in optimization problem, the encoding length of binary is related to the discrete values that can be selected, so there will be a problem that cannot correspond with the number of discrete values one by one.

In this paper, the integer encoding strategy is adopted to reduce the intermediate process of converting binary to decimal, and the number of design variables corresponds to the encoding length. at the structural level, the optional area 12 of the abscissa of the critical control point is divided equally, that is, [0, 1, ⋯ 12] represents the number of the area where the key wing SPAR position is located.

3.2. Optimization Model

The objective of the integrated optimization design is to meet the strength and stiffness of the CNC lathe, and the structure weight is the lightest. The optimization model can be established as follows:

$$\min\ m(X)$$
$$\text{s.t.}\quad \sigma(X) < \sigma(t)$$
$$X = (X_1, X_2, Y_1)$$
$$S_1(\boldsymbol{X}) - S_{1\max} < 0$$
$$S_2(\boldsymbol{X}) - S_{2\max} < 0$$
$$X_{1\min} \leqq X_1 \leqq X_{1\max}$$
$$X_{2\min} \leqq X_2 \leqq X_{2\max}$$
$$Y_{1\min} \leqq Y_1 \leqq Y_{1\max}$$

Where, σ represents the tensile stress of the material, σ(t) represents the maximum tensile strength of the material;S_1 And S_2 respectively represent the bending stiffness and torsional stiffness of CNC bed;$S_{1\max}$ And $S_{2\max}$ are allowable flexural stiffness and allowable torsional stiffness. X represents the structural parameters of CNC Lathe-bed;X_1 And X_2 Respectively represent the position of the left support plate and the right support plate at the guide rail, $X_{1\min}$ And $X_{2\min}$That's the minimum, $X_{1\max}$ And $X_{2\max}$ Represents the maximum value that can be taken; Y_1 Represents the position of the guide rail on the bed at the headstock, $Y_{1\min}$ And $Y_{1\max}$ Represents the minimum and maximum values that can be taken.

4. Optimization Example

4.1. Problem Description

This section takes the bed of a CNC lathe as the optimization object, adopts the structure of two support plates and two guide rails, the size of the CNC lathe base is 1155mm×910mm×1040mm, the size of the bed supporting the spindle box is 1100mm×410mm×260mm, and the weight of the whole bed is 1105kg. The initial positions of the left and right support surfaces and the upper and lower guide rails are {X_1= 387 mm X_2=775mm, Y_1=1180mm}, the finite element model is shown in Figure 4.

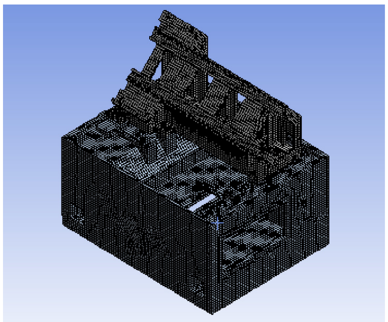


Fig 4. Finite element model of NC lathe

4.2. Structural Optimization Design

The force of CNC Lathe-bed under static state is analyzed and optimized.

In the structural design, the position X of the support plate is considered$_1$And X_2, the position of the guide rail Y_1. for the CNC Lathe-bed, the optimization model is given as follows:

$$\min m (X_1, X_2, Y_1)$$
$$\text{s.t.} \quad \sigma(X) < \sigma(t)$$
$$320 \leqq X_1 \leqq 450$$
$$720 \leqq X_2 \leqq 850$$
$$1150 \leqq Y_1 \leqq 1208$$
$$S_1(X_1,X_2,Y_1) - S_{1\max} < 0$$
$$S_2(X_1,X_2,Y_1) - S_{2\max} < 0$$

In this paper, the maximum displacement of CNC lathe is used to express the bending strength S_1, the torsional stiffness S is represented by the displacement difference between the two ends of the guide rail which is 70% away from the supporting spindle box$_2$.

Matlab was used to build the initial population, and Ansys was called to complete the modeling and analysis process by running APDL language. The results were stored in the file, and Matlab read the data and made judgment. Matlab uses call statements to complete modeling and analysis of each generation population optimized by genetic algorithm.GA algorithm was used to evaluate the fitness of the population, and the best were eliminated slightly. The convergence structure was obtained by cyclic iteration, that is, the final optimization scheme.

Genetic algorithm (GA) was used to solve the optimization model, and the optimization iterative process was shown in Figure 5. when iterating to the 40th generation, the structure mass of CNC lathe converges to about 978.3kg. At this time, the maximum displacement is 0.02mm, which occurs at the guide rail end. The displacement difference on both sides of 70% of the guide rail direction is 0. 01mm.The optimization results of CNC Lathe-bed are shown in Table 4.

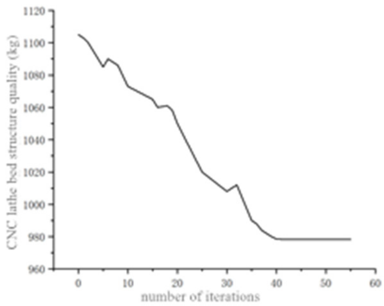


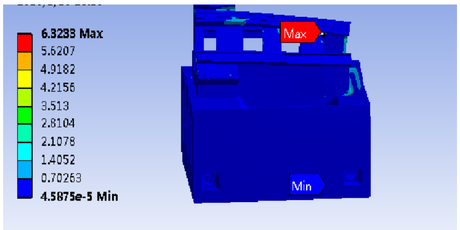
Fig 5. Optimization iteration process

Table 2. The optimization results

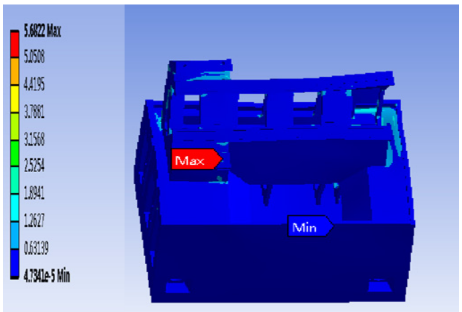
	design variables	optimization results
structure	Abscissa/mm	X_1= 380; X_2= 803;
level	ordinate/mm	Y_1= 1187;

4.3. Finite Element Verification

Figure 6 shows the comparison between the stress results of the initial scheme analyzed by ANSYS software and that of the scheme after integrated optimization design. as can be seen from the stress cloud diagram before optimization, after structural optimization design, the stress distribution of CNC bed is basically consistent with that before optimization, but the maximum stress decreases from 6.3233MPa to 5.6862MPa, a decrease of 10.1%. As can be seen from the structure quality structure diagram, after optimization design, The weight decreased from 1105kg to 978.3kg, and the weight reduction was about 11.5%, indicating that the optimization achieved the desired effect.



(a) before optimization



(b) after optimization

Fig 6. Equivalent stress cloud of CNC lathe before and after optimization

5. Conclusion

In this paper, an optimization design method is proposed for the structural optimization of CNC lathe, which takes the position of the guide rail and the support plate as the structural direction design parameters.The results show that the structural mass of the bed decreases from 1105kg to 978.3kg, with a decrease of about 10.1%, under the premise of satisfying the strength and stiffness.The maximum Von Mises stress decreased from 6.3233MPa to 5.6862MPa, decreasing by 10.1%.The optimization effect achieves the desired effect, and the proposed optimization design method can optimize the design of CNC Lathe-bed, which solves the problem that the optimization result of traditional software optimization design is not the optimal solution of the whole design space.

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