Optimization and Analysis of Grinding Head Components Based on MGK-4080 CNC Grinding Machine

Liu Yan¹*, Zhou Gui-sheng ², Lu Guang-hua ¹³, Shen Yao-qi ¹, Yang Di-pei ¹

¹ Taizhou Institute of Science and Technology of NUST, Taizhou Jiangsu 225300
² NARI Technology Co., Ltd. Nanjing Jiangsu 211106
³ Taizhou Continental Zhizi Intelligent Technology Co., Ltd., Taizhou Jiangsu 225300

*Corresponding author’s e-mail: 93867120@qq.com

Abstract: The research of CNC grinding machine system has become an important frontier topic in the field of machinery industry. In this paper, the design and optimization analysis of the grinding head components of MGK-4080 CNC grinding machine are carried out. Therefore, the research of this subject has high scientific research value and economic value, which is of great significance to the development of the subsequent grinding machine parts system of CNC grinding machine.

1. Preface
With the rapid development of science and technology and the increasing demands of equipment processing precision, research on precision machining technology is extremely urgent. Grinding technology is more and more widely used as a precision and ultra-precision technology. Therefore, the development of grinding technology not only improves the proportion of grinding technology in processing methods, but also further promotes the development of grinding machines and their processes. In order to meet the needs of reality and strengthen the promotion and use of grinding equipment, this topic is based on MGK-4080 CNC grinding machine shown in Figure 1. Some measurements were made on the grinding machine of this series and a new grinding machine was developed based on this, which had high working precision and geometric accuracy. And the processing performance is stable, the feed sensitivity and accuracy are high, and the degree of automation of grinding is high.

Figure 1: Overall view of a CNC grinding machine based on MGK-4080
2. Design of grinding head parts based on MGK-4080 CNC grinding machine
In the grinding head component, the grinding head component of the machine tool is a common surface grinding head, and the rotation motion of the main shaft in the spindle system of the grinding head is driven by a servo motor, and is directly connected to the main shaft by using a flexible coupling. Thereby driving the spindle to operate at the set speed.

3. Finite element analysis based on key components of MGK-4080 CNC grinding machine
In order to ensure the machining accuracy of the workpiece, the necessary structural static analysis of the grinding machine must be carried out to improve the overall stiffness of the new CNC grinding machine based on MGK-4080[3,4].

3.1 Finite element analysis based on MGK-4080 CNC grinding machine grinding head
The force analysis based on the grinding head of MGK-4080 CNC grinding machine is shown in Figure 2. $F_y$ should be the grinding force in the normal component force $F_n$, stress situation, $F_x$ should be the tangential force of the grinding force $F_t$, stress situation, $M_t$ should be the reaction torque of the torque generated by the main grinding force of the grinding head to the entire grinding head component.

![Figure 2: Force analysis based on the grinding head of MGK-4080 CNC grinding machine](image)

3.1.1 Load calculation and constraint analysis based on the grinding head of the MGK-4080 CNC grinding machine:
(1) Calculation of the load based on the grinding head of the MGK-4080 CNC grinding machine: The formula for calculating the grinding force can be:

$$ F_x = F_t = 350, \quad 1 \text{ N} \quad F_y = F_n = 910, \quad 3 \text{ N} $$

$$ M_t = F_t \times R = 350. \quad 3 \text{ N} \times 0.2 = 70 \text{ N} \cdot \text{m} $$

When the grinding head reciprocates move up and down, the four head sliders move the grinding head components and the constraint area of each slider is: $162 \times 140 \text{mm}^2 = 0.02268 \text{m}^2$.

The total constrained area of the four sliders is: $S = 4 \times 0.02268 \text{m}^2 = 0.09072 \text{m}^2$.

(2) Calculation of the bearing area of the grinding head based on MGK-4080 CNC grinding machine:
The normal grinding force component of CNC grinding machine $F_n$ and tangential grinding force component $F_t$ are transmitted to the main shaft through the flange plate of the grinding wheel. The radius of the cylindrical shape is calculated as: $R = 26 \text{ mm}$, the height value of the truncated cone $L = 80 \text{ mm}$, therefore, the total area of the load force applied to the slider is:

$$ S' = 3.14 \times 26 \times 26 \times 0.5 \times 80 = 0.08 \text{m}^2 $$

(3) Constraint analysis based on the grinding head load of MGK-4080 CNC grinding machine:
The grinding head component of the grinding machine is fixed on the grinding machine’s column by 4 sliders, and only has one degree of freedom of movement in the Y direction.

3.1.2 Static analysis results based on the grinding head of the MGK-4080 CNC grinding machine: The division of the static analysis grid based on the grinding head of the MGK-4080 CNC grinding...
machine is shown in Figure 3:

Figure 3: Division of static analysis grid based on MGK-4080 CNC grinding machine grinding head

The static analysis results based on the MGK-4080 CNC grinding machine grinding head are shown in (a), (b), (c) and (d) of Figure 4:

![Static Analysis Diagrams](image)

(a) Comprehensive static analysis deformation diagram of the grinding head
(b) X-direction static analysis deformation diagram of the grinding head
(c) Y-direction static analysis deformation diagram of the grinding head
(d) Z-direction static analysis deformation diagram of the grinding head

Figure 4: Static analysis results based on the grinding head of MGK-4080 CNC grinding machine

The maximum deformation of the grinder based on MGK-4080 CNC grinding machine is shown in Table 1:

| Direction of deformation | Deformation (μm) | Uniformity |
|--------------------------|------------------|------------|
| Comprehensive maximum deformation | 1.304 | - |
| X-direction maximum deformation | 0.726 | - |
| Y-direction maximum deformation | 0.156 | - |
| Z-direction maximum deformation | 0.124 | - |

Table 1 is based on the maximum deformation of the grinding head of the MGK-4080 CNC grinding machine.

It can be seen from the maximum deformation of Table 1 that when the grinding head component is subjected to the force in the X-axis and the Y-axis, the deformation magnitudes are 2.4μm and 0.92 μm, respectively, and the comprehensive deformation magnitude is 2.81μm. The deformation amount is small, which fully meets the design requirements of the machine tool.
3.2 Finite element analysis based on MGK-4080 CNC grinding machine bench

The force area and force analysis of the workbench of the new CNC grinding machine based on MGK-4080 is shown in Figure 5: The combined effect of $M_1$, and $F_x$ produces $F_y$, simultaneously the direction of the force $F_y$ is negative along the Y axis. $M_1$ represents the force exerted by main grinding force of the tool on the workbench during operation. There is a t-slot on the workbench of the machine tool, in order to reduce the calculation interference, the size of the t-slot area should be removed when calculating the force area.

\[
\begin{align*}
F_x & = M_1 \\
F_y & = F_t 	imes (\text{Grinding Wheel Radius})R = 350.3N \times 0.2m = 70N \cdot M
\end{align*}
\]

Figure 5: Force analysis of the workbench based on the new CNC grinding machine of MGK-4080

3.2.1 Load calculation and constraint analysis based on MGK-4080 CNC grinding machine workbench: (1) Load calculation based on MGK-4080 CNC grinding machine workbench

The formula for calculating the grinding force can be:

\[
\begin{align*}
F_t &= 910.3N \\
F_t &= 350.1N \\
F_x &= F_t = 350.1n \\
F_y &= 600 \times 9.8N + 910.8N = 6790.8N \\
M_1 &= F_x \times (\text{Grinding Wheel Radius})R = 350.3N \times 0.2m = 70N \cdot M
\end{align*}
\]

(2) Based on the calculation of the load bearing area of the MGK-4080 CNC grinding machine workbench:

Calculating the corresponding pressure based on the area of the applied load:

The working area based on MGK-4080 CNC grinding machine is:

\[
S = 0.54 \times 0.8 = 0.432m^2 \\
F_y = F / S = 6790.8N / 0.432m^2 = 0.016MPa \text{ (uniformly distributed)}
\]

(3) Constraint analysis based on the load of the MGK-4080 CNC grinding machine workbench:

The static pressure rail is in contact with the workbench and the lathe bed based on the MGK-4080 CNC grinding machine. The geometry of the hydrostatic guide rail is: 800mm×132mm×4. The workbench is constrained by the rails with only one X-axis freedom of movement. The static analysis grid based on the MGK-4080 CNC grinding machine workbench is shown in Figure 6:

Figure 6: Division of static analysis grid based on MGK-4080 CNC grinding machine workbench

The statics static analysis results based on the MGK-4080 CNC grinding workbench are shown in (a), (b), (c) and (d) of Figure 7:

(a) Comprehensive static analysis of the grinding head deformation
(b) X-direction static analysis of the grinding head
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(c) Y-direction static analysis of the grinding head deformation diagram
(d) Z-direction static analysis deformation diagram of the grinding head

Figure 7: Static analysis results based on the MGK-4080 CNC grinding machine workbench

The maximum deformation of the grinding head based on the MGK-4080 CNC machine is shown in Table 2:

Table 2 is based on the maximum deformation of the MGK-4080 CNC grinding machine workbench

| Direction of deformation | Deformation (μm) uniformity |
|--------------------------|-----------------------------|
| Comprehensive maximum deformation | 0.217 |
| X-direction maximum deformation | 0.0497 |
| Y-direction maximum deformation | 0.0554 |
| Z-direction maximum deformation | 0.0375 |

It can be seen from the maximum deformations in Table 2 that when the workbench is loaded with its X-axis and Y-axis alone under uniform conditions, the deformation magnitudes are 0.0497μm and 0.0554μm, respectively. The comprehensive value is 0.217μm, and the deformation value is small, which fully meets the design requirements of the machine tool.

4. Conclusion

This paper designs and optimizes the grinding head parts of MGK-4080 CNC grinding machine, which makes the grinding machine has high working precision and geometric precision. Therefore, this topic is of great significance to the development of the subsequent grinding machine parts system of CNC grinding machines.

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