CNC Lathe Cutter Saddle Body's Thermal Characteristics Analysis Based on ANSYS

Lu mo-wu[1, a], Wei shu-xian[2,b], Yin xing[3,c]

[1]professor of Shenyang aerospace university ; Shenyang China;110136.

[2]master of Shenyang aerospace university ; Shenyang China;110136.

[3]master of Shenyang aerospace university ; Shenyang China;110136.

[a]lumowu@163.com,[b]ytdxwsx@126.com,[c]1091362600@qq.com

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Abstract. Based on TZK6026 CNC lathe tool post that as the research object,using SolidWorks2010 software to build 3D entity modeling.And then through the proprietary software interface input the 3D modeling into ANSYS Workbench to Build finite element model of the cutter saddle.Then use the ANSYS Workbench to analysis its thermal characteristics , in order to get the temperature distribution and thermal deformation of the cutter saddle. Error compensation for subsequent structural improvements designed to provide a basis.

1 Foreword

Cutter saddle is an important part of the lathe, and its main role is to support and fixed knife.So it has the direct effect on cutting performance and efficiency of the machine.To a certain extent, the structure and performance of the lathe cutter saddle reflects the design and manufacturing standards of lathe. Cutter saddle not only must have good strength and rigidity to withstand the force of cutting, but also need to have good thermal properties in order to Reduce the thermal deformation, and ensure the accuracy and quality of cutting.So the Thermal Characteristics Analysis of CNC Lathe cutter saddle based on ANSYS come into people's vision.

2 Modeling Cutter Saddle Body

Using SolidWorks2010 software to solid TZK6026 CNC lathe cutter saddle model.modeling size must same as the true cutter saddle size during modeling process to ensure that research is closer to the true thermal performance cutter saddle. Solid modeling shown in FIG.1.

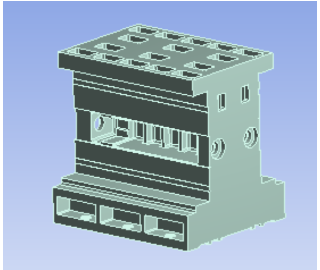

Fig.1. Model of cutter saddle body

And then through the proprietary software interface input the 3D modeling into ANSYS Workbench to Build finite element model of the cutter saddle. Before analysis, the cutter saddle structure is complicated, without prejudice to the premise of the thermal analysis, its structure should be simplified to some extent.The purpose is to improve the speed and quality of meshing.Such as removing some chamfer ,small steps, and so on non-bearing components of the cutter saddle, remove some of the body parts that are irrelevant to cutter saddle , such as cutter saddle pad.And put some of the cutter saddle's arc transition into a right angle.Selection of materials in ANSYS Workbench, tool steel material selection 45, the elastic modulus of 2.0×10^5 MPa, Poisson's ratio of 0.27 and a thermal conductivity of 46.8 $W\left(m^{2\,o}C\right)$, the thermal expansion coefficient of11.3×10^{-6}.When TZK6026 CNC lathe work, set the cutter saddle fast moving speed of 33 m / min, the working environment temperature set to 27 ℃.SOLID7 selection, and then use ANSYS Workbench software analysis the thermal modal of cutter saddle . the finite element meshing model shown in Figure 2.

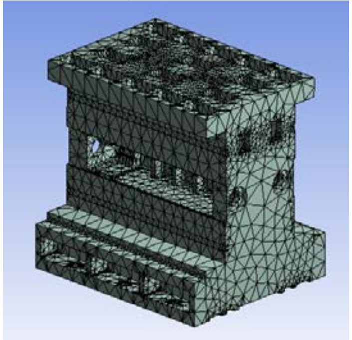

Fig.2. Element meshing model of cutter saddle body

3 Thermal Source Analysis of Cutter Saddle

The TZK6026 CNC lathe cutter saddle's heat mainly come from the moving friction between cutter saddle and the rail , bearing fever, cutter saddle motor heating, hereby bar fever.

(1) Heat conduction

The calculation and generate of Thermodynamic coupling model are mainly rely on the convection coefficient of the main source different heat generation rate and heat transfer components and heat generating boundary conditions of the key components.Calculated on the loading cutter saddle and get its steady-state temperature field and thermal deformation displacement.When the internal body exists temperature gradient , heat will transferred from the hot part of the low hot part of the body.In addition, when the body of different temperatures contact with each other, the heat will be transferring from hot part of the low hot part of the body,Even the circumstances of there's no matter transferred.Such a way that the heat transfer is generally referred to as thermal conductivity or thermal short.The root cause of the thermal conduction is due to the disorder thermal motion of matter microscopic particles . Solving the temperature field is obtained primarily a function of temperature.

$$\partial[(Kx\partial T)/\partial X]/\partial X+\partial[(Ky\partial T)/\partial Y]/\partial Y+\partial[(Kz\partial T)/\partial Z]/\partial Z=q$$

In formula p —Per unit time and per unit volume heat rate

With the change of the time, the matrix of the thermal conductivity is:

$$[K_t]=\begin{bmatrix}K_x & 0 & 0\\ 0 & K_y & 0\\ 0 & 0 & K_z\end{bmatrix}$$

(2) calculate the heat of friction between the rail and the turret

When CNC lathes is working at high speed , the cutter saddle is moving in accordance with the program command.cutter saddle do X, Z directions sport along the rail.the heat generate from friction during sport between Turret and rail.

$$Q_f = f_2 p_g g_n v / J \qquad (1)$$

In formula f_2 —Coefficient of friction

p_g —Working load

g_n —Acceleration of gravity

v —Sliding speed

J —Mechanical equivalent of heat, $J = 4.2\,j/cal$

(3) Calculate the heat generation of bearing

Seeing from PALMGREN that the bearing heat generation:

$$Q_b = M\omega \tag{2}$$

In formula ω—Bearing circle speed

M —Bearing friction torque

M is Composed in two parts that are friction torque which was generated by the lubricating oil viscosity and friction torque which was generated by the loads.

$$M = 0.45 f_0 (vn)^{2/3} d_m^3 + f_1 (F_s / C_s)^{1/3} F_\beta d_m \tag{3}$$

In formula n—Spindle speed

f_1—Load factor

f_0—Lubrication factor

v—Kinematic viscosity

F_s—Static load bearing

C_s—Static load rating of bearing

F_β—Calculation of bearing load

Bearing heat generation rate

$$q_b = Q_b / V_b \tag{4}$$

In formula V_b—Nuts volume

(4) Calculation of Ball screw nut’s heat generation

The main source of the ball screw are coming from the friction torque M_{pre} caused by Preload and the friction torque M_{fa} caused by external loads.

Namely

$$M_{pre} = F_p l (1 - \eta_g^2) / 2\pi\eta_g^2 \tag{5}$$

$$M_{fa} = 10^{-3} F_a l / 2\pi\eta_g \tag{6}$$

In formula F_p—Preload

F_a—Friction

l—Lead

η_g—The efficiency of the ball screw nut

The ball screw nut heat

$$Q_n = 0.12\pi n M_z \tag{7}$$

$$M_z = M_{pre} + M_{fa} \tag{8}$$

The ball screw nut heat rate

$$q_n = Q_n / V_n \tag{9}$$

(5) Determine the thermal boundary conditions

According the condition of turret heat flux Strength boundary to define the condition of cutter saddle thermal boundary.Unit time through unit area , the relationship of heat flow and temperature gradient is:

$$\partial T / \partial n = q(x, y, z, t) / - kn$$

The main defined parameters of cutter saddle’s components boundary conditions.

The friction heat between cutter saddle and rail/W : 12478

Bearing heat/W : 478.6

Motor heat/W : 957

Screw friction heat/W : 453

Screw and air convection heat transfer coefficient $W(m^2\,{}^{o}C)^{-1}$: 69.4

Bearings and air convection heat transfer coefficient $W(m^2\,{}^{o}C)^{-1}$: 58.3

4 Thermal Characteristics Analysis of Cutter Saddle Body

(1) The thermal analysis of cutter saddle

Based on the above conditions,Using the ANSYS Workbench software do thermal analysis of cutter saddle in order to obtain the temperature field distribution of the cutter saddle.As can be seen from the temperature profile,when cutter saddle in working condition, the upper half of the cutter and cutter saddle temperature are lower, close to the surrounding environment temperature.The main high temperature area is at the contact area that between bottom and the rail cutter saddle.The figure shows that the maximum temperature in the region is 43.734 ℃. As shown in Figure 3.The main reason is due to that the knife fast-moving with rail sliding friction generated a lot of heat when the lathe at working.Temperature of the cutter saddle on an uneven distribution, will lead turret produce different degrees of thermal expansion.Making the cutter saddle structure will produce micro-deformation, thereby affecting the precision of the CNC lathe cutter saddle.

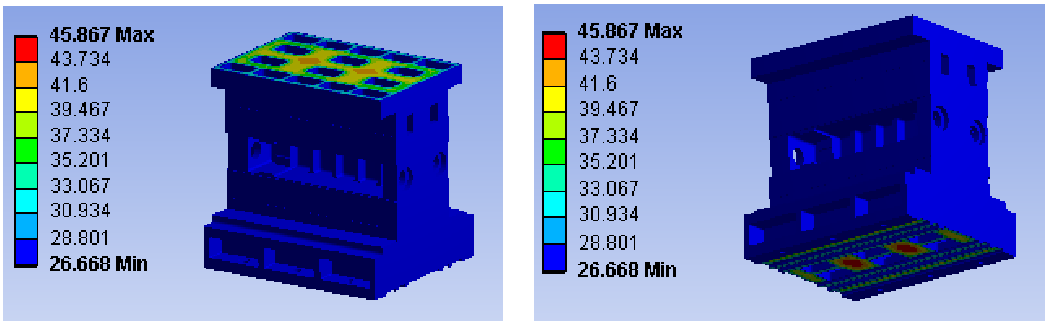

Fig. 3. Temperature contours

(2) cutter saddle body's Thermal Deformation Analysis

After cutter saddle's thermal analysis,using ANSYS Workbench software to translate the state thermal analysis model into a static force analysis model.Based on the actual working conditions of cutter saddle in CNC lathes, limiting its the degree of freedom of X , Y, Z direction where is the bolt node hole location that connect with machine unit.Through calculation analysis, got the thermal deformation figure of cutter saddle.As show in Figure 4 , the cutter saddle's Thermal deformation maximum position where is between tool turret and cutter saddle installed contact position away from the side of cutter saddle.The maximum amount of thermal deformation is 23.3 μm.Here a deformation that direct impact on tool clamping, will lead tool clamping is not tight, or cutting tool angle offset.Thus cause an imbalance in parts machining cutting force,and causing not easy to ensure the accuracy of the part.Since the bottom of the cutter saddle was fixed , due to its upper thermal deformation is more larger.And presenting on a decreasing trend from the lower.Due to the stiffness of the cutter saddle is larger, and the temperature of the rest position is closer , so the rest position of the thermal deformation is smaller.

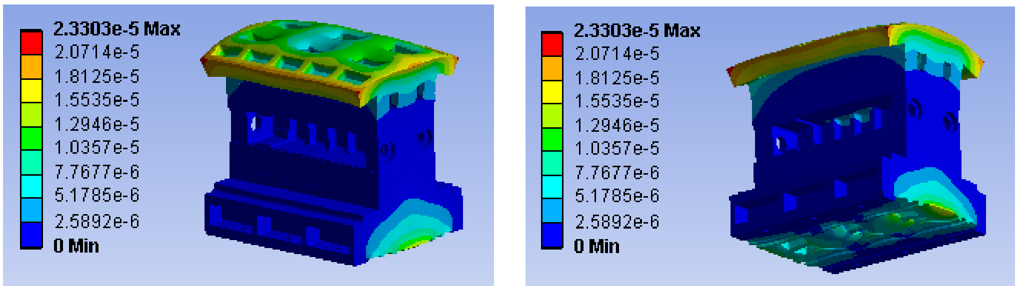

Fig. 4. Thermal deformation contours

5 Summary

This paper establishes the cutter saddle's solid model of TZK6026 lathe by SolidWorks2010 software,and carried out its thermal analysis by using the ANSYS Workbench / Thermal module. got conclusions as the following:

(1) By thermal deformation distribution of the cutter saddle can be obtained that the thermal deformation of cutter saddle's overall structure showed a decreasing trend from top to bottom.The maximum deformation amount is 23.3 μm.Occurred in where is between tool turret and cutter saddle installed contact position away from the side of cutter saddle. This distortion has a great impact on the TZK6026 CNC lathe Processing, will lead to machining accuracy is not easy to guarantee.

(2) When TZK6026 CNC lathe is moving in speed of 30m / min,the temperature of cutter saddle's overall structure is lower.Only the contact sliding friction position between bottom of the cutter saddle and the rail is at a high temperature.The maximum temperature is43.734 ℃.Consiste with the actual situation.

(3) Need to be installed temperature detector at the position of cutter saddle's maximum thermal deformation in the design of subsequent improvement.To compensate the processing errors that caused from Thermal deformation , in order to reduce the impact the machining accuracy.

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