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Research on Process Parameters for Deep Hole Gun Drill of 34CrNiMo6 Steel

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ABSTRACT

During the gun drilling process of 34CrNiMo6 steel, the drilling temperature is high, the chip removal path is long, and the tool wear is severe. In response to the problems of poor surface quality and difficult control of processing quality in deep hole drilling of the difficult-to-machine material 34CrNiMo6 steel, an experimental study on the deep hole drilling of 34CrNiMo6 steel with machine-clamped gun drills was carried out. The influence mechanism of the spindle speed and feed rate of the machine tool on the processing quality was studied, and the torque and the axial force Fz in the Z direction were quantified by combining the DEFORM-3D simulation software, achieving the optimization of the drilling process. The experimental results show that when the spindle speed n = 1600 r/min and the feed rate f = 40 mm/min, the surface roughness and straightness of the deep hole are relatively good, the processing process is stable, and the chip removal effect is good.

KEYWORDS

Difficult-to-machine material; Gun drill; Deep hole; Finite element simulation

1 Introduction

Steel 34CrNiMo6 features high strength, good toughness, excellent hardenability and stability against overheating. It is a typical difficult-to-machine material. After quenching and tempering, it forms tempered sorbite with an average grain size of 20 μm and a hardness of around 45 HRC, presenting excellent comprehensive mechanical properties. Therefore, it is widely used in various fields such as aviation, aerospace, petroleum, and chemical industries [1-2].

Gun drilling is one of the main methods for deep hole machining. The process is carried out in a closed or semi-closed state with limited chip removal space, making it difficult to ensure the quality of the hole and improve the machining accuracy. The spindle speed and feed rate are key factors affecting the quality of deep hole machining [3-4]. Zhao Yanchao et al. [5-6] conducted single-factor experiments to study the influence of cutting speed, feed rate, and oil pressure on the straightness, roundness, parallelism of the hole, and hole diameter deviation. The results showed that as the cutting speed increased, the straightness error decreased, while the roundness and parallelism errors first decreased and then increased, and the hole diameter deviation increased. With the increase of the feed rate, the straightness showed a V-shaped fluctuation and increase, but the increase was not significant. The roundness error decreased, and the parallelism increased. In recent years, finite element simulation technology has been widely used in the field of cutting research and has partially replaced experiments. Finite element analysis has become an important basis for the deep hole machining process [7]. Li Weiguo et al [8]. used the DEFORM-3D finite element analysis software to study the influence of different cutting parameters on tool wear during deep hole drilling of 42CrMo alloy steel. The results showed that the tool wear was proportional to the cutting speed and feed rate, and the change in feed rate had a more significant impact on tool wear than the cutting speed. Guo Yichao et al [9]. studied the influence of different drilling parameters on the machining quality of GH4169 high-temperature nickel-based alloy. The ABAQUS simulation software was used to simulate the established model. The results showed that the cutting temperature increased with the increase of feed rate and spindle speed, and the influence of feed rate on cutting temperature was greater than that of spindle speed.

In summary, the machining parameters in the drilling process have a significant impact on the quality of deep holes. Therefore, this paper conducted deep hole gun drilling experiments on 34CrNiMo6 steel under different processing parameters, studied and analyzed the influence of different spindle speeds and feed rates on the quality of deep holes drilled in 34CrNiMo6 steel, and quantified the cutting force and torque using the DEFORM-3D simulation software to determine the optimal processing parameters for gun drilling 34CrNiMo6 steel.

2 Deep Hole Drilling Test

2.1 Workpiece and Tool

The test adopted Ø24 mm × 250 mm 34CrNiMo6 steel bar stock after modulation treatment. Its mechanical properties are shown in Table 1 [10]. The tempered sorbite microstructure obtained after quenching and tempering has excellent comprehensive mechanical properties.

Table1 Mechanical properties of 34CrNiMo6 steel

Tensile Strength	Yield Strength	elongation	Shrinkage rate
(σ_b/MPa)	(σ_s/MPa)	δ/%	ψ/%
⩾980	⩾835	⩾12	⩾55

2.2 Test Equipment

The experiment was conducted on the large-bed MA-8000H horizontal machining center, using the processing method of rotating the tool axis and feed. This enabled the processing of through holes in the bar stock. To investigate the influence of different spindle speeds and feed rates on the processing quality, 11 groups of drilling experiments were carried out with the same oil pressure of 5 MPa and a cutting depth of 250 mm. The processing parameters of the experiments are shown in Table 2.

Table2 Gun drill drilling test process parameter table

group indication	Spindle speed (r/min)	Feed rate (mm/min)	group indication	Spindle speed (r/min)	Feed rate(mm/min)
1	1200	25	7	800	40
2	1200	30	8	1000	40
3	1200	35	9	1400	40
4	1200	40	10	1600	40
5	1200	45	11	1800	40
6	1200	50			

3 DEFORM-3D Deep Hole Machining Simulation

3.1 Establishment of the Drilling Model

In the simulation software, the tool material model is defined as a rigid body, and its deformation is ignored to enhance the calculation efficiency; the material model of the workpiece to be processed is defined as a plastic body, and its stress, strain, and temperature parameters are obtained. Using the yield stress expression of the Johnson-Cook constitutive model as shown in Equation 1 [11], the characteristics such as plastic strain, strain rate strengthening, and temperature softening of the material can be effectively reflected.

$$\sigma = \left(A + B\varepsilon^n\right)\left[1 + Cln\left(1 + \frac{\dot{\varepsilon}}{\dot{\varepsilon}_0}\right)\right]\left[1 - \left(\frac{T - T_r}{T_m - T_r}\right)^m\right] \tag{1}$$

In the formula, σ represents the flow stress, ε denotes the strain, is the strain rate, is the reference strain rate, T is the cutting temperature, is the ambient temperature, and is the material melting temperature. A, B, C, m, and n are material constants, which are the yield stress, hardening modulus, strain rate sensitivity coefficient, temperature softening coefficient, and strain hardening coefficient respectively. The Johnson-Cook constitutive parameters of the workpiece are shown in Table 3[10].

Table 3 The JC material constant of 34CrNiMo6 steel

A (MPa)	*B* (MPa)	C	m	n	T_r (℃)	T_m (℃)
792	510	0.014	1.03	0.26	20	1530

4 Analysis of Simulation Results

4.1 The Influence of Feed Rate on Drilling Force in Deep Hole Machining

Under the same rotational speed of 1200 r/min, the influence of different feed rates on torque and Z-direction axial force Fz was compared. The feed rates were 25, 30, 35, 40, 45, and 50 mm/min respectively. The changes in simulated torque and Z-direction axial force Fz are shown in Figures 1 and 2. From the figures, it can be seen that the changes in torque and Z-direction axial force Fz can be roughly divided into two stages. The first stage is from 0 to 0.04 s, during which torque and Z-direction axial force Fz increase significantly from 0. The second stage is after 0.04 s, during which torque and Z-direction axial force Fz change slowly and fluctuate around a certain value. During this stage, chips are formed, and the chips flow out along the rake face. Their work is less than elastic deformation, resulting in a slight decrease in torque and Z-direction axial force Fz.

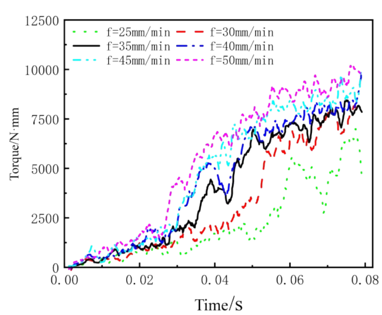

Figure 1 The influence of different feed rates on torque

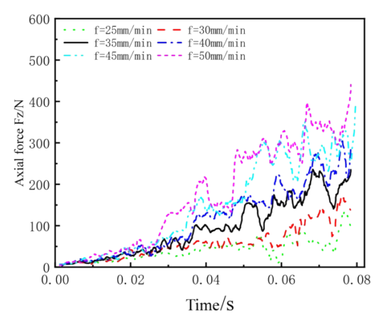

Figure 2 The influence of different feed rates on axial force

4.2 The Influence of Spindle Speed on Drilling Force in Deep Hole Machining

Under the same feed rate of 40 mm/min, the influence of different spindle speeds on torque and Z-direction axial force Fz was compared. When the spindle speeds were 800, 1000, 1200, 1400, 1600, and 1800 r/min, the torque and Z-direction axial force Fz are shown in Figures 3 and 4 respectively. From the figures, it can be seen that the changes in torque and Z-direction axial force Fz can be roughly divided into two stages, and the variation process is consistent with the effect of feed rate on the drilling force in deep hole processing as mentioned above.

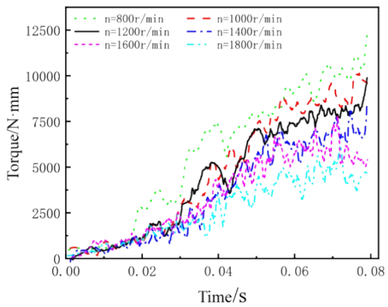

Figure 3 The influence of different spindle speeds on torque

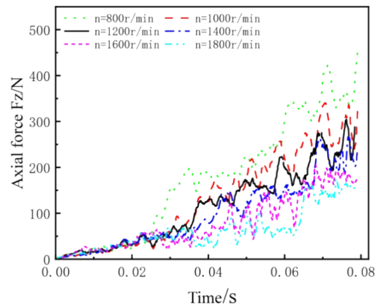

Figure 4 The influence of different spindle speeds on axial force

5 Analysis of Test Results

5.1 The Influence of Processing Parameters on the Quality of Deep Holes

Using a surface roughness measuring instrument, the surface roughness of the deep holes in the bar material was measured. The surface roughness of the deep holes corresponding to different feed rates is shown in Figure 5, and the straightness of the deep holes corresponding to different feed rates is shown in Figure 6.

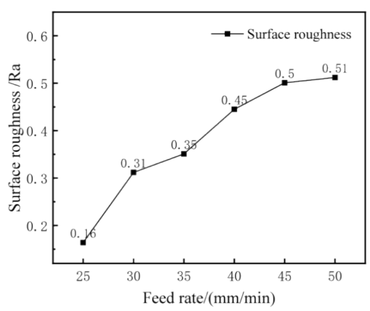

Figure 5 The influence of feed rate on surface roughness

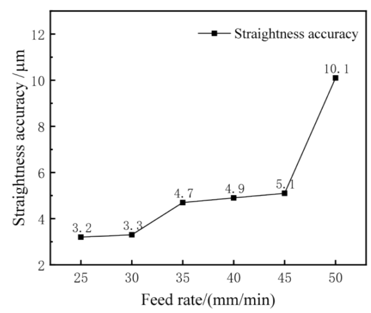

Figure 6 The influence of feed rate on straightness

As can be seen from the figure, with the increase of feed rate, the surface roughness and straightness of the deep hole show an upward trend. When the feed rate f is 25 mm/min, the surface roughness and straightness are the best, with a surface roughness of Ra = 0.164 μm and a minimum straightness of u = 3.2 μm. A smaller feed rate makes the cutting process more stable, reduces the friction between the tool and the workpiece, lowers the cutting temperature, and slows down the tool wear rate. Therefore, the drilling path is more stable and the processing quality is better. When the feed rate increases, the chip becomes thicker, it is difficult to discharge the chip, and it is prone to scratch the already processed surface, resulting in deterioration of the surface roughness. At the same time, the local part of the workpiece expands unevenly due to heat, causing the processing path to shift, and the straightness of the deep hole increases. Considering the influence of processing quality, processing efficiency and tool wear, it is advisable to choose a feed rate of 40 mm/min.

The size of the spindle speed determines the speed of cutting. The cutting speed directly affects the quality of deep hole processing. The surface roughness of the deep hole corresponding to different spindle speeds is shown in Figure 7, and the straightness of the deep hole corresponding to different spindle speeds is shown in Figure 8.

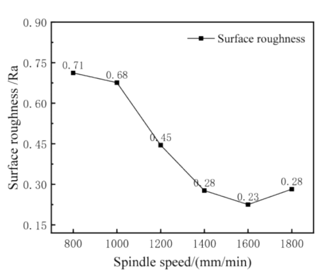

Figure 7 The influence of spindle speed on surface roughness

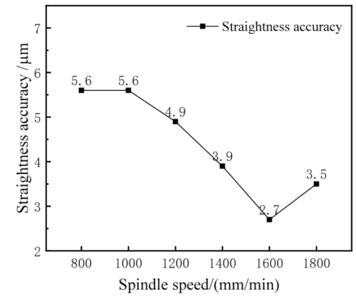

Figure 8 The influence of spindle speed on straightness

As can be seen from the figure, as the spindle speed increases, the surface roughness and straightness of the deep hole show a downward trend. When the spindle speed v = 1600 r/min, the surface roughness and straightness are the best, with a surface roughness of Ra = 0.225 μm and the minimum straightness of u = 2.7 μm. When the spindle speed is greater than or equal to 800 r/min, as the spindle speed increases, the heat generated during the cutting process increases, and the cutting edge is more likely to cut the material, reducing chipping and burrs, thereby reducing the roughness. At the same time, when the spindle speed increases, the material is not allowed to undergo sufficient plastic deformation before being removed, and the deformation of the chip is smaller, resulting in a reduction in cutting force and a weakening of the tool vibration, thereby reducing the straightness of the deep hole. After the spindle speed exceeds 1600 r/min, the generation rate of cutting heat exceeds the heat dissipation rate, and the high temperature will reduce the hardness of the workpiece material, increase its plasticity, and easily cause a sticking phenomenon of the tool. This leads to the tool constantly rubbing and squeezing against the workpiece material attached to it during the drilling process, leaving rough marks on the processing surface, increasing the surface roughness. An excessively high spindle speed will also intensify the vibration of the tool, making the eccentricity more obvious, and the eccentric tool will cause the center position of the hole to shift during the cutting process, resulting in an increase in the straightness of the deep hole. Considering the impact of processing quality, processing efficiency, and tool wear, it is advisable to select a spindle speed of 1600 r/min.

6 Conclusion

This paper conducts a drilling processing test on 34CrNiMo6 steel bar materials and combines the DEFORM-3D simulation software to quantify the torque and the Z-direction axial force Fz. It studies and analyzes the influence of different processing parameters on the surface roughness and straightness of deep holes, and the conclusions are as follows:

(1) As the feed rate increases, the surface roughness, straightness, torque and axial force in the Z-direction of the deep hole show an upward trend, resulting in a deterioration of processing quality.

(2) As the spindle speed increases, the surface roughness, straightness, torque and axial force in the Z-direction of the deep hole show a decreasing trend, leading to improved processing quality.

(3) Considering the influence of processing quality, processing efficiency and tool wear, the optimal processing parameters are: spindle speed n = 1600 r/min, feed rate f = 40 mm/min. At this point, the processing quality of the deep hole is relatively good, with surface roughness Ra = 0.225 μm and straightness u = 2.7 μm. The processing process is stable, without abnormal sounds, and the chips are discharged smoothly.

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References

[1] Pu Bowen, Liu Yuting, Wang Yanrong, et al. Effect of quenching and tempering on microstructure andhardness of 34CrNiMo6 steel forged connecting rods[J]. Metal Heat Treatment, 2024, 49(05): 173-178.

[2] Gou Chunmei, Dong Jing, Cui Dandan. High temperature rheological behavior and thermal processing diagram for 34CrNiMo6 steel[J]. Forging Technology, 2023, 48(02): 233-240.

[3] Zhang Xiaodong, Han Ce. Research Review of Deep Hole Machining Technology for Complex Shell Part[J]. Aerospace Manufacturing Technology, 2017, (15): 50-57.

[4] Biermann D, Bleicher F, Heisel U, et al. Deep hole drilling[J]. CIRP Annals, 2018, 67(2): 673-694.

[5] Zhao Yanchao, Wu Meiping, Wang Quanlong, et al. Study on the Influence of Gun-drill Processing Parameters of Gun Drillon the Hole Machining Quality of the Oil Injector Body[J]. Mechanical Design and Research, 2017, 33(05): 123-126 + 133.

[6] Zhao Yanchao, Wu Meiping, Wang Quanlong, et al. Optimization of processing parameters for the deep hole straightness of injector[J]. Journal of Engineering Design, 2018, 25(03): 302-308 + 314.

[7] Guo H, Yang W, Liu L, et al. Simulation Analysis of RuT450 Drilling Force Based on LS-DYNA Gun Drilling[J]. Key Engineering Materials, 2018, 764: 271-278.

[8] Li Weiguo, Shen Xingquan, Yu Shaohua, et al. Deep Hole Drilling of 42CrMo Alloy Steel Based on Gun Drill[J]. Tool Technology, 2019, Volume 53, Issue 01: 95-98.

[9] Guo Yichao, Dong Zhen, Zhang Zhibing, et al. Simulation of GH4169 High Temperature Nickel-based Superalloy Gun Drilling[J]. Tool Technology, 2023, Volume 57, Issue 03: 76-79.

[10] Liang Ru, Pang Siqin, Cheng Guanhua, et al. Finite Element Simulation of 34CrNiMo6 Steel After Dual Shot Peening[J]. Aerospace Manufacturing Technology, 2017, (10): 99-103 + 108.

[11] Sirigiri V K R, Gudiga V Y, Gattu U S, et al. A review on Johnson Cook material model[J]. Materials Today: Proceedings, 2022, 62: 3450-3456.