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Experimental Research on the Influence of Tool Material and Geometric Parameters on Cutting Surface Quality of Super Alloy

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Abstract

For nickel base superalloy GH4169 is investigated in the process of machining tool is easy to wear，cold-setting severe deformation, surface quality is difficult to guarantee and so on, using different carbide cutting tools and different tool geometry parameters, nickel-based superalloy GH4169 be turning experiments. The cutting tool material, cutting tool rake angle and corner radius of the influence law of super alloy surface roughness, different tool wear condition analysis. Results show that using K313, KC5510, SM1105 three kinds of cutting tool materials processing, the difference of obtained surface roughness is not big, but for the tool wear condition, the rake face and rear face wear of KC5510 is small. Integrated tool wear and workpiece machined surface quality, in the selection of the four tool materials, KC5510 is more suitable for processing GH4169; Single factor experiments found that with the gradual increase in rake angle and the corner radius, the surface roughness gradually decreases. Therefore, when GH4169 be turning, in order to reduce the surface roughness, grain refinement should be used, together with the PVD TiAlN coating carbide cutting tools, while a larger rake angle and corner radius are selected.

Keywords*: super alloy; tool material; tool geometric parameters; surface roughness*

1. Introduction

Superalloy with its superior thermal performance, thermal stability and thermal fatigue performance are widely used in manufacturing of aviation engines integral impeller, turbine disks, blades and various types of gas turbine. But the high temperature alloy machining is poor, mainly for cutting power, chilled severe deformation, high cutting temperature, tool easy to wear, where the tool is one of the main factors which impact machinability of high temperature alloy. Research tool material and tool geometry on cutting performance of high-temperature alloy, to meet the increasingly wide range of applications, has important practical applications.

For machining superalloy, the choice of tool materials with high-speed steel, carbide, ceramic, CBN, PCD, *etc.*, where a larger proportion of carbide cutting tools, in recent years, ceramic cutting tools, CBN tool material used in a proportion tended to increase. With the appearance of coated carbide tool materials (composites) and ceramic cutting tools, high temperature alloy machinability has been greatly improved; CBN second only to diamond in hardness, heat resistance be superior to diamond, often used in the manufacturing process of high-temperature alloys [1-3]. Scholars choose tool material as variable, comparative analysis coated and uncoated carbide tools when turning GH4169 variation of surface roughness[4]; In the cooling lubrication, using AI_2O_3+TiC and PCBN tool cutting GH4169, tool angle influence of surface roughness are researched[5]; Using different tools materials for finishing GH4169 test, study on variation of the machined surface quality [1]; Single factor test method to analyze the influence law of the rank angle and relief angle on the cutting process[6].

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Domestic grades of nickel-based superalloy GH4169 as research subjects (corresponding foreign grades InconeI718), experimental study for turning machining. In different tool material, tool geometry parameters to experiment their surface roughness variation. It will help to understand the difficult cutting materials machinability such as superalloy GH4169, in order to better guide the cutting of superalloy GH4169 .

2. Experimental Design

Tool Material: Carbide tool K313, YT 763; Coated carbide tools KC5510, SM 1105;
Experimental Machine: Lathe, model CA6140;
Experiment instrument: TR100 roughness measuring instrument;
Specifications of the workpiece: Φ155×60;
Experimental data acquisition: After a set of experiments, measure machined surface roughness, the workpiece is measured once with rotating 90°, and the averaged value of three times is recorded.

3. Experimental Study of Surface Roughness

3.1 Tool Material Impact on the Workpiece Surface Roughness

Test conditions: Rake angle γ =10°, relief angle α =3°, corner radius r_ε =0.4mm, cutting speed v_c=67m/min, feed rate f=0.15mm/r, back cutting depth a_p=0.4mm. Under the cutting conditions, study the impact law of tool material on the machined surface roughness, as shown in Figure 1.

Workpiece surface roughness obtained after cutting by the YT763 and K313 carbide cutting tools is analyzed, the surface roughness of carbide cutting tools YT763 obtained is 1.62μm, the surface roughness of carbide cutting tools for the K313 is 1.15μm, The results show that W-Co type hard alloy K313 is more suitable for processing superalloy GH4169 under the normal speed. Using K313, KC5510 and SM1105 to processing superalloy GH4169, the resulting surface roughness of coated tools KC5510 is 1.18μm, obtained surface roughness for SM1105 is 1.19μm, superior coated tools. Studies have shown that coating tool material impact on the finished surface roughness is not significant, through comparative analysis of the surface roughness, the preferred tool material is the KC5510 and K313.

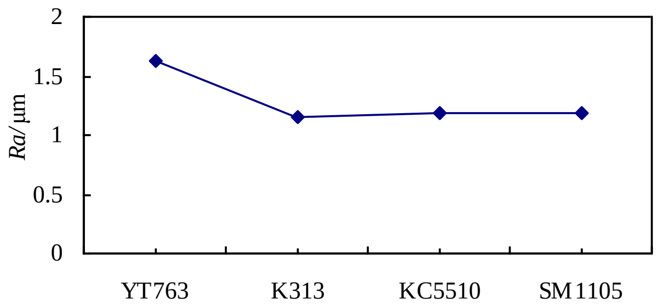
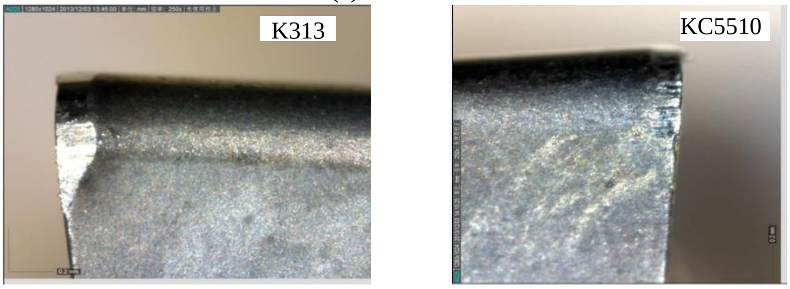


Figure 1. Effect of Tool Materials on Surface Roughness

3.2 Morphology Analysis of Tool Wear

In the process of cutting, will occur the extrusion and friction between rake face and chip, at the same time, also occur extrusion and friction effect between rear face and the workpiece, which resulting in the cutting temperature increases, speed up tool wear.Tool wear areas are mainly concentrated in the rake and rear face, temperature having a decisive impact for cutting tool wear form. Wear form of rake face is mainly crater and wear form of rear face is mainly wear band. Tool wear causes include mechanical wear, adhesive wear, diffusion wear, chemical wear, hot wear and other aspects. By contrast, the preferred tool material is the carbide cutting tools K313 and coated carbide tools KC5510, research K313 and KC5510 blade wear morphology analysis, then get the optimal tool material in this experimental conditions. Through electronic microscope after 25 times, the blade wear morphology is shown in Figure 2.

(a) Rake wear



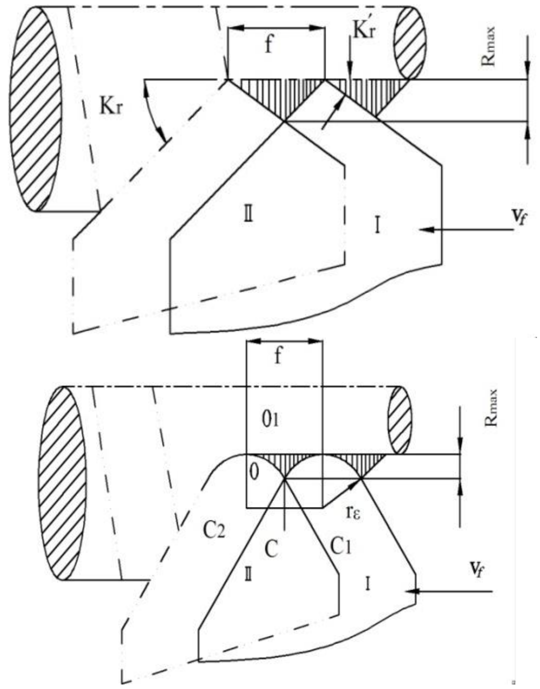
(b) Flank wear

Figure 2. Blade Wear Morphology

Under the experimental conditions, by single factor experiment, comparative analysis of the surface roughness, tool wear morphology, preferably suitable for machining superalloy GH4169 tool material is KC5510.

3.3 Effect of Tool Geometry Parameters on Surface Roughness

When seen the cutting edge as pure geometric lines, with respect to the machined surface of the workpiece movement formed by microscopic unevenness called the theory roughness. Theoretical roughness depends on the height of the residual area, Figure 3 (a) giving the cutting edge is the residual surface height in cusp state, Figure 3 (b) giving the cutting edge is the residual surface height in arc state. Surface roughness after processing is affected by many factors, accompanying the BUE growth and the instability of cutting mechanism itself can increase the surface roughness. Cutting edge and workpiece relative position changes will also increase the uneven of workpiece surface, at the same time, the wear of cutting edge will increase roughness of the workpiece surface. Roughness including the direction of feed and the cutting speed direction in two forms, in this paper, the author studies on roughness in the feed direction.



(a) $r_\varepsilon=0$ (b) $r_\varepsilon\neq0$

Figure 3. Residual Area Height

(1) When $r_\varepsilon=0$, the maximum height of the residual area *Rmax* is:

$$Rmax = \frac{f}{\cot\kappa_r + \cot\kappa_r'} \tag{1}$$

(2) When $r_\varepsilon\neq0$, it is:

$$Rmax = O_1O = O_1C - OC = r_\varepsilon - \sqrt{r_\varepsilon^2 - (\frac{f}{2})^2}$$

$$Rmax < r_\varepsilon$$

So

$$Rmax \approx f^2/8\, r_\varepsilon \tag{2}$$

By equation (1), (2) can be seen to reduce the theoretical roughness *Rmax*, it can be reduced by f、κ_r、κ_r', or increase r_ε to achieve.

3.3.1. The Influence of Tool Rake Angle on the Surface Roughness: Test conditions is corner radius r_ε =0.4mm, cutting speed cutting speed v_c=50m/min, feed rate f=0.15mm/r, the back cutting depth a_p=0.4mm. Under the cutting conditions, research the variation of the surface roughness when rake angle γ is 3°, 7°, 10°and 12°,the test required indexable inserts and holder is shown in Figure 4. Figure 5 is the graph of the surface roughness with the rake angle variation, which the surface roughness decreases with the rake angle increases.

When the rake angle increases, the chip deformation will reduce, the friction between the rake face and the chip is reduced, it can reduce BUE, scales thorns, chilled phenomenon, residual area height decrease gradually. While increasing the rake angle also makes tool edge more sharp, be able to meet the requirements of precision machining, reduces vibration in cutting process between the tool and the workpiece, the cutting process more stable. But the rake angle is too big, can weaken the strength of the cutting tool, reducing the volume of heat, to speed up the tool wear, the cutting tool under the condition of strength and life, in order to improve the surface quality of processed, optimizing the larger cutting tool rake angle.

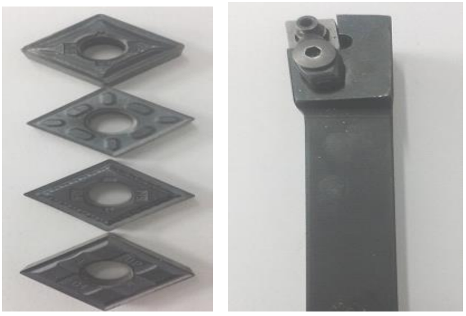


Figure 4. Different Rake Angle of the Blade and the Cutter Bar

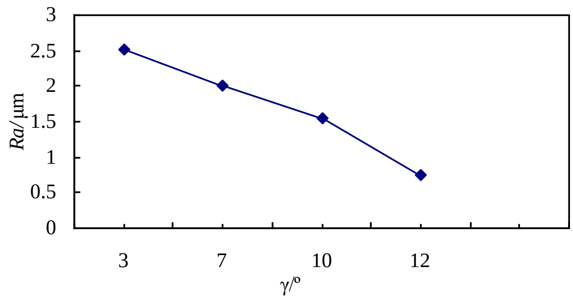


Figure 5. Influence of Rake Angle on Surface Roughness

3.3.2 The Influence of Corner Radiuson the Surface Roughness: Test conditions is rake angle γ =10°, relief angle α =3°, cutting speed v_c =50m/min, feed rate f =0.15mm/r, the back cutting depth a_p=0.4mm. Under the cutting conditions, research the change rule of surface roughness when corner radius r_ε is 0.2 mm, 0.4mm, 0.8mm, 1.2mm, test required indexable inserts and holder is shown in Figure 6. Figure 7 shows the graph of the surface roughness law with the variation of corner radius, the study found that the surface roughness decreases with the increase of the corner radius, accord with the theoretical basis of Figure 3 (a) and (b). With increasing corner radius, the contact tip and the workpiece length longer, in the feed process, the machined surface leaving less peak valley height, the height of the residual area decreases, leading to the machined surface roughness degrees lower. In order to improve the surface quality after machining, preferably a large corner radius.

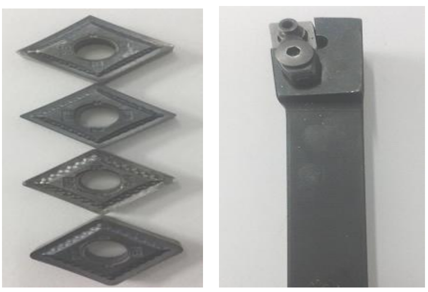


Figure 6. Different Corner Radius of the Blade

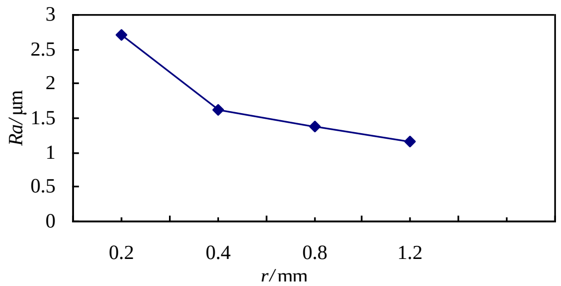


Figure 7. Influence of Tool Corner Radius on Surface Roughness

4. Conclusion

(1)Selected tool material are K313, YT726, KC5510, SM1105, single factor test. Under the same test conditions, surface roughness, tool wear morphology as an analysis standard, KC5510 is selected to suitable for machining superalloy GH4169.

(2)Cutting tool rake angle as a single variable, in the study of single factor experiment. Under the same experimental conditions to study the effects rake angle to the surface roughness. Rake angle are separately selected 3°, 7°, 10°, 12°. The study found that the surface roughness decreases with the cutting tool rake angle increasing gradually, in order to reduce the surface roughness of the workpiece after processing, optimizing the larger cutting tool rake angle.

(3)In single factor experiment of cutting tool corner radius. Under the same experimental conditions to study the effects corner radius to the surface roughness. Corner radius are separately selected 0.2mm, 0.4mm, 0.8mm, 1.2mm. The study found that the surface roughness gradually decreases as the cutting tool corner radius increases, in order to reduce the surface roughness of the workpiece after processing, optimizing the larger cutting tool corner radius.

Acknowledgments

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