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Experimental study on oilstone abrasive for superalloy deep-hole honing

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ABSTRACT

Superalloy has excellent high temperature strength, thermal stability and thermal fatigue resistance, it can withstand the complex stress and operate securely for long-term. This material is suitable to be applied in aeronautics, astronautics and petrochemical industry. However its high hardness and mechanical strength bring great difficulty in machining, which is particularly outstanding in deep hole honing. This article has analyzed the cutting performance and the machinability of 8 kinds of oilstones by deep-hole honing nickel-base superalloy inconel718, the experimental result shows: using medium hardness oilstone which contained 30% ceramic corundum as the abrasive, the honing efficiency and grinding ratio are both higher than other abrasives.

KEYWORDS

Superalloy;
Oilstone abrasive;
Deep-hole honing.

INTRODUCTION

Superalloy is also known as high-temperature alloy, heat resistant alloy, which has excellent high temperature strength, thermal stability and thermal fatigue resistance. At 600 ~ 1000 □ high temperature oxidation and corrosive gas conditions, it can withstand the complex stress and operate securely for long-term. Superalloy is not only the critical material of hot sections in aviation engines, but also the indispensable material in many fields (atomic energy, energy and power, transportation, petrochemical, metallurgy, etc).

While the superalloy has many advantages, but its machinability is extremely poor because of the oilstone adhesion and low grinding efficiency. In addition, the work hardening and abrasive wear easily occur in the superalloy processing, the grinding force and grinding heat of superalloy are much larger than other steel materials.

Honing is a multi-blade cutting efficient processing method, which can not only remove the larger process redundancy, but also improve the dimensional accuracy of workpiece and reduce the surface roughness, its application has become increasingly widespread. Since currently there are no mature process parameters of superalloy in deep hole honing process (reasonable honing stone, honing dosage and honing liquid). Therefore, aimed at the nickel-base superalloy inconel718 we conducted contrast test by using different honing oilstones, during the test by measuring the honing temperature, oilstone wear (grinding ratio) and the removal honing data of workpieces in the honing process of various oilstones, then we obtained the optimum parameter of superalloy honing oilstone.

Analysis on the cutting performance of deep-honing oilstone abrasives

The honing oilstones generally used in the deep-

honing process mainly include corundum oilstone and silicon carbide oilstone. Corundum honing oilstone has a good self-sharpening, higher tenacity and grinding efficiency. However, abrasives often crumble in the honing process and the wear pattern of abrasives consists mainly grain breaking and fast abrasion before involving in cutting. The corundum abrasives are generally suitable for honing the higher hardness workpiece and the metal materials with higher toughness and tensile strength. For honing oilstone made from silicon carbide abrasives, this abrasive hardness is higher than corundum abrasives, while its toughness and self-sharpening is poorer than corundum abrasives. Moreover, in the honing process occurs the chemical reaction that $SiC+4Fe \rightarrow FeSi+Fe_3C$, which greatly reduces the hardness and strength of the silicon carbide. Therefore, silicon carbide abrasives are not suitable for honing steel parts, but it can grind cast iron (especially the cast iron with high content of Si and C), because of the cast iron has a large number of Fe_3C and $FeSi$, thus reduces the possibility of the chemical reaction between metal and silicon carbide.

The grinding characteristics of abrasives can't give full play when use a single abrasive honing different materials workpieces in actual production. Especially for some difficult-to-cut materials (such as titanium alloys, stainless steel, etc) the honing effect are very poor. Mixed abrasive oilstone is made of two or more kinds of abrasives (such as corundum and silicon carbide abrasive) according to a certain proportion. Theoretically, according to the grinding characteristics of workpieces and abrasives' different grinding characteristics, use a suitable mixed abrasive oilstone in the honing processing may be able to give full play to all kinds of abrasive grinding characteristics and achieve better honing effect and honing efficiency.

For the white corundum and single crystal corundum are mainly used to honing superalloy material. However, at the beginning of the honing, the abrasives will adhere to the workpiece, which makes abrasives lose cutting capacity and reduces the processing efficiency. Meanwhile, the surface of workpiece will occur more severe plastic deformation, the machining quality of the part surface is difficult to guarantee.

Through above all, we use the ceramic corundum abrasive in the superalloy honing oilstone abrasives test study. The ceramic corundum abrasive is a sintered abrasive and made by sol-gel method and its crystal size is extraordinary small (only 10-500nm), only as a few hundredth size of the corundum abrasive crystal. A 46 # size abrasive contains one hundred million crystals. The ceramic corundum abrasive has the same chemical composition and hardness as white corundum. Because of its uniform small microcrystalline structure, high toughness and micro-crushing performance, the ceramic corundum abrasive has been widely used in difficult-to-cut material such as grinding tool steel, stainless steel, heat-resistant alloy steel, etc.

TEST AND ANALYSIS

Test conditions

Combine the experience about superalloy deep-honing process over the years with the previous analysis of the cutting performance of deep-honing oilstone abrasives, we chose mixed abrasive oilstones which contained different contents of single crystal corundum, white corundum, ceramic corundum as testing oilstone. With the same honing solution (0 # diesel oil), the type of oilstone abrasive not only directly affect the honing efficiency and processing quality but also the tool life of oilstone. This test assessed the grinding performance of superalloy honing oilstones though a contrast experimental study on grinding performance for four 8 kinds of oilstone abrasives, which are shown in TABLE 1.

TABLE1: oilstones used in the test

number	type	main components	hardness
1#	QL120SA1K-01	single crystal corundum 100%	K
2#	QL120SA1M	single crystal corundum 100%	M
3#	QL120GAL	ceramic corundum 30%	L
4#	QL120GAN	ceramic corundum 30%	M
5#	QL120SA1M-04	single crystal corundum 50%	M
6#	QL120SA1K-04	single crystal corundum 50%	K
7#	QL120A1M	white corundum 100%	M
8#	QL120A1K2	white corundum 100%	K

Test procedures

Make the honing tests for the superalloy inconel718 under the same conditions. During the test by measuring various data such as oilstone temperature in the hon-

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ing process, the oilstone wear extent (grinding ratio) and the workpiece removal amount, to evaluate the efficiency of superalloy honing oilstones.

The specific test procedures are as follows:

Step1, use the single crystal corundum contented 100%, hardness (K/M), text, measure data.

Step2, use the single crystal corundum contented 50%, hardness (K/M), text, measure data.

Step3, use the ceramic corundum contented 30%, hardness (L/M), text, measure data.

Step4, use the white corundum contented 100%, hardness (L/M), text, measure data.

RESULTS AND ANALYSIS

The experimental data record as shown in TABLE 2.

The test results from Figure 1 and 2 show:

(1) The grinding ratio of ceramic corundum oilstone is the highest, the second is white corundum, the third is single crystal corundum (100%), and single crystal corundum (50%) is the lowest.

(2) According to the oilstone hardness comparison, the oilstone with smaller whole hardness are more efficient in the superalloy honing processing, in which the honing efficiency of single crystal corundum (100%) hardness M, ceramic corundum (30%) hardness M, single crystal corundum (50%) hardness M, white corundum hardness M are higher than the similar harder oilstone.

(3) According to the comparison of grinding temperatures, the grinding temperature of white corundum is the highest, the second is single crystal corundum, ceramic corundum is the lowest, which shows that the honing grinding force of ceramic corundum is the smallest.

(4) As shown in Figure 3, under the same honing conditions, the bonding of 4 # ceramic corundum oilstone is the least, the second is 5 # single crystal corundum oilstone (50%), 8 # white corundum oilstone is the biggest. This is the main reason why ceramic corundum oilstone has a higher grinding

TABLE 2 : The result of the honing test for four oilstones

Oilstones		Hardness	The honing workpiece temperature (℃)		The workpiece removal amount,(mm^3)	The oilstone wear extent(mm^3)	The grinding ratio	Phenomenon
			Inside	Outside				
Single crystal corundum 100%	1#	K	75	60	3897.18	2448	1.59	Clean 4 times
	2#	M	55	43	6130.58	3936	1.56	Clean 4 times
Ceramic corundum 30%	3#	L	56	50	5580.58	3024	1.85	Clean 4 times, oilstone is unbreakable, easy to splice and block
	4#	M	58	51	8403.75	4848	1.73	Clean 4 times, oilstone has small broken, easy to splice and block
Single crystal corundum 50%	5#	M	56	47	5035.23	3936	1.28	Clean 4 times, oilstone has small broken,
	6#	K	65	53	6145.6	4032	1.52	Clean 4 times, oilstone easy to break, uneasy to splice and block
White corundum 100%	7#	M	67	58	4450.02	2496	1.78	Clean 4 times, oilstone has small broken,
	8#	K	69	61	3890.36	2256	1.72	Clean 4 times, easy to splice and block

ratio and honing efficiency.

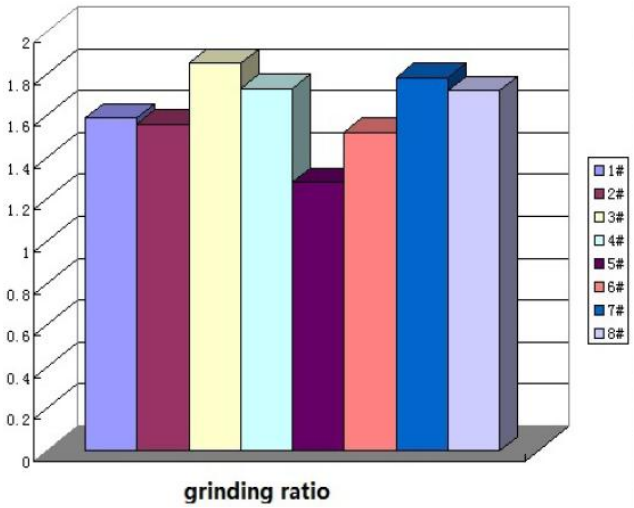

Figure 1 : The area chart of oilstone grinding ratio

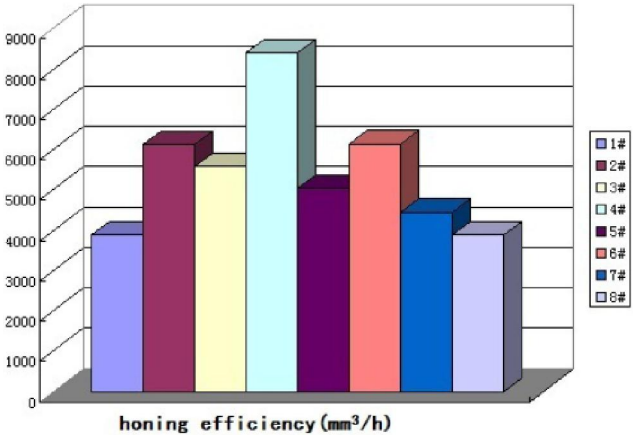

Figure 2 : The area chart of oilstone honing efficiency

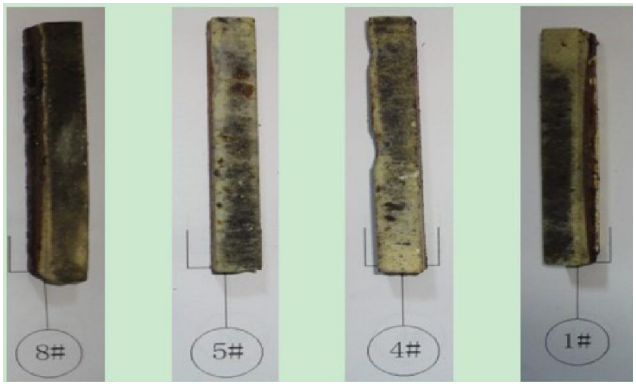

Figure 3 : The adhesion conditions of honing oilstone.

CONCLUSIONS

According to the above test results, we obtained that using ceramic corundum as the abrasive, the honing efficiency and grinding ratio are both higher than other abrasives. This is mainly because its specific microcrystalline structure, which makes possess strong self-sharpening and even wear features, moreover its micro crush reduces the speed of oilstone abrasives' macro crush. For the anti-bonding capacity of ceramic corundum is higher, so it puts off the effective time of the third stage at the three stage of honing (abrasive cutting off stage, abrasive broken cutting stage and abrasive adhesion blocking cutting stage), increases the effective working time of honing, Therefore, we suggest use the medium-hard ceramic corundum materials in superalloy honing process.

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