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Study on the Mechanism of Improving Surface Roughness of Gray Cast Iron Machining by Wiper Inserts

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Based on the high hardness, poor thermal conductivity, and easy detachment of graphite in cast iron materials. Traditional rough machining inserts cannot achieve good machining surface quality, while the use of precision machining inserts results in rapid tool wear due to excessively sharp rake angles, limiting feed rates and reducing machining efficiency. In order to solve these problems, this paper proposes a method of cutting cast iron with coarse and wiper insert mixed cutting tools, aiming to improve the surface quality of machining and enhance machining efficiency. By studying the mechanism and cutting experiments of the wiper inserts, it was found that it improved the surface quality of cast iron and analyzed the reasons for tool wear. By controlling the integrity of the precision machined surface of cast iron, the aim is to establish the basic theory and key technologies for the precise and efficient manufacturing of high hardness materials. Improve the surface quality of cast iron processing, extend tool life, and improve processing efficiency.

Keywords: Wiper, Surface Roughness, Geometry, Wear, Workpiece Material, Cast iron

1 Introduction

One of the main advantages of micromachining is the low surface roughness of machining, because the surface roughness of the workpiece material directly determines the quality and life of the product,the biggest factor affecting roughness is the cutting tool. Low roughness means that lower feeds are required, but lower feeds reduce productivity. The use of wiper inserts can solve the above contradictions partly. [1]

The use of wiper inserts to improve the roughness of the machined surface is one of the most commonly used methods for production machining. Especially difficult-to-machine materials processing surface roughness requirements are relatively high, in the high-speed cutting, obtaining good surface roughness and at the same time improving machining efficiency and cost savings is worth in-depth study. The edge of the wiper inserts can improve the roughness of the machined surface by squeezing or scraping the machined surface. The geometry, machining principle and wear of the sharpening edge are interrelated.

From the perspective of appearance, the biggest difference between the wiper insertand conventional cutting tools is the geometric angle.[2] Because the special shape ofthe wiper insert that the machined surface roughness value is reduced, resulting in animprovement in the surface quality of the material.[3,4]

When machining a workpiece with a conventional tool, it is natural to form a periodi-cally regular uneven surface on the workpiece because of the rotating and feeding motion of the tool. The geometric principle of the conventional insert of the milling cutter is shown in the Fig. 1. Machining with a feed of f_z[5], which inevitably increases the surface roughness value.

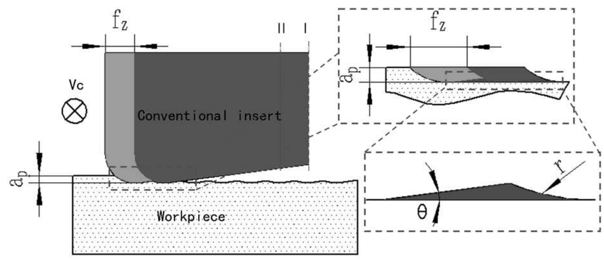

Fig. 1 *Geometric principle of the conventional insert of the milling cutter[5]*

Selection of wiper inserts can be used to improve the above problems, from the structural analysis,wiper inserts is the transition between the main cutting edge and the sub-cutting edge,in fact, it's the distance from the sub-cutting edge of the theoretical tip of a section of the deformation area as shown Fig. 2. It mainly plays a role in improving the impact resistance of the tool nose and reducing the surface roughness of the material. The b_s of the wiper insert is a length parallel to the feed direction.[6]

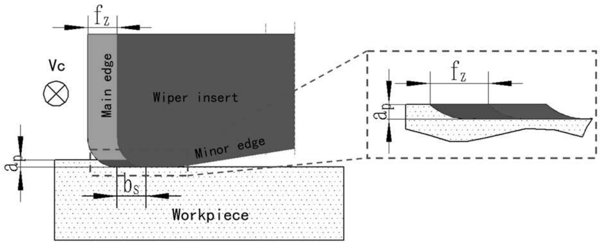

Fig. 2 *Geometric principle of the wiper insert of the milling cutter [5]*

The choice of wiper insert can effectively improve the surface quality,near the tip of a section of the sub-cutting edge b_s made vertical relationship with the center line of the tool, the section of the trimming edge plays a role in scraping. The use of a wiper insertcan effectively reduce the surface roughness value of the material. However, when the b_s value is too large it leads to excessive cutting force and thus vibration, instead the material roughness value starts to increase.[7,8]

The structure of the turning and milling cutter with wiper insert is slightly different,in the vicinity of the tip of the electric contact sub-cutting edge out to increase a radius,so that in the sub-cutting edge of the actual tip of the radius of the arc becomes larger, thus increasing the length of the polishing edge, reducing the machining of the surface roughness value as the equation (1). From equation, it can also be seen that the surface roughness value of using wiper insert is lower than that of traditional tools. The working principle is shown in the Fig. 3. [9,10]

$$R_a = \frac{f_n^2}{8r_\varepsilon} \tag{1}$$

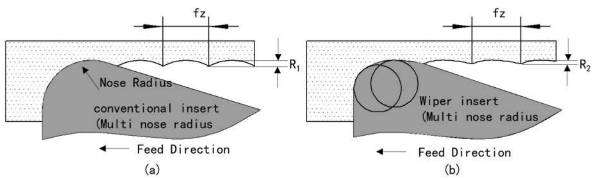

Fig. 3 *Geometrical difference between the conventional and the wiper turning inserts*

The performance of wiper insert in processing workpieces with different material properties varies.[11,12] Especially in some difficult to process materials, such as high hardness materials, low hardness materials, high-strength materials, high-temperatureresistant materials, high plasticity materials, and low heat transfer rate materials. There are significant differences in the performance and mechanism of action of wiper insert.[13-15]

The cutting parameters have a significant impact on the wear of the wiper insert, with the cutting speed and feed rate having the greatest impact.[16–19] Through orthogonal cutting experiments of turning Ti6Al4V[20], wear length increases with feed rate,this is because a higher feed rate means a longer length of cut at the edge of the wiper insertper revolution. Especially for difficult to machine materials, the cutting force is very large, and the relationship between the geometric parameters of cutting tools, cutting parameters, and tool wear is particularly prominent.[21] At low tool wear, cutting speed has the least effect on wear length. At low cutting speeds, wear length is directly related to feed rate.[22]

2 Experimental procedure

2.1 Test equipment and materials

Due to the action mechanism of the wiper inserts, it leads to faster wear. In order to ensure the machining efficiency, this study fully consider the real manufacturing needs, choose the coarse and fine inserts mixed rotation form for the test. Respectively use one or two polishing edge inserts, due to the high hardness of gray cast iron, in order to avoid the impact of tool wear on the test results, each group of milling parameters are replaced with a new milling cutter. The machining site is shown in Fig. 4.

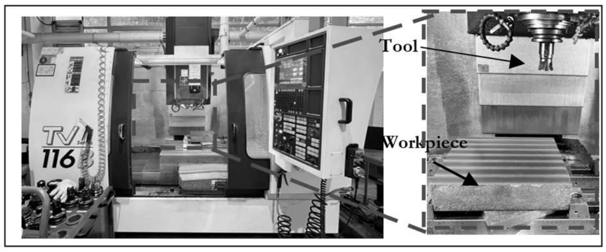

Fig. 4 *Processing site*

Workpiece material for gray cast iron HT250, pearlite more than 90%, phosphorus eutectic quantity less than 2%, hardness 190-230HB, 900 × 200 × 70mm. six sides flat, normalized, hardness 160-220HB. The machine is completed with Yongjin machining center TV116B vertical machining center.

Tool material coating nano TiAIN coating with fine grain cemented carbide matrix, with excellent wear resistance and chipping resistance. Suitable for semi-finishing to roughing milling of all types of cast iron at low to medium speeds in both wet and dry conditions. 12° front angle, R120 rounding of the dressing edge, length of the dressing edge 15.4mm, passivation value 0.008mm. wiper inserts protrudes axially and radially 0.05mm more than the roughing inserts.

2.2 Experiment method

In order to illustrate more clearly the effect of the dressing edge on the machined surface of cast iron, it is divided into two groups of experiments, the first group is selected to install 1 wiper insert and 14 roughing inserts, and the second group is selected to do cutting experiments with 2 wiper inserts and 14 roughing inserts respectively. The optimal cutting parameters were selected through several groups of cutting parameter experiments: the depth of cut was 0.5 mm, the cutting speed was 211.95 m.min^{-1}, and the feed f_z per tooth was selected as 0.247 mm.

3 Test results and Analysis

3.1 Surface roughness

The two groups of experimental roughness values Ra were 0.86 μm, 0.65 μm. it can be seen that the trimming edge has a good effect on the machining surface quality of cast iron. Roughing inserts and wiper inserts eating amount as shown Fig. 5, wiper inserts eating amount is very small, the free graphite tearing effect is very weak, ferrite, carburite and pearlite will not be easily broken from the free graphite and lead to surface pits, so the surface quality will also be improved, the alternating stresses borne by the wiper inserts will also be reduced, the cutting temperature and tool wear will also be reduced.[23]

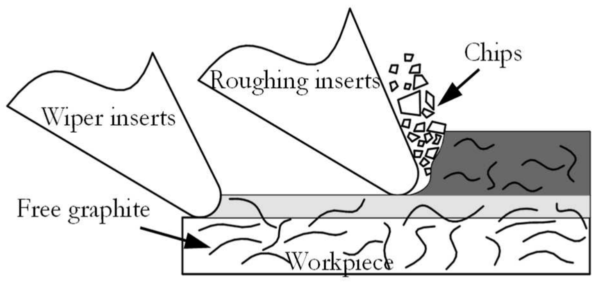

Fig. 5 *The principle of mixed processing of coarse and wiper inserts*

3.2 Tool wear

Ceramic coatings are hard and wear resistant, once the coating is worn, the tool substrate will be damaged quickly, so ceramic coatings play an important role in tool wear resistance. Cemented carbide coatings to TiAIN ceramic coatings, the coating has high hardness, wear resistance and resistance to high-temperature oxidation, but compared with the tool matrix WC-Co, TiC-Co, its toughness is low. Therefore, in the processing of high hardness materials, it is easy to shedding phenomenon, as shown in Fig. 6, coupled with the presence of flaky or needle-like graphite in the cast iron material, the workpiece material in the cutting process will appear along the graphite separation of the alternating stress, which further makes the coating force is not constant, resulting in rapid wear of the tool substrate, which in turn leads to the processing of the surface quality of the poor situation.

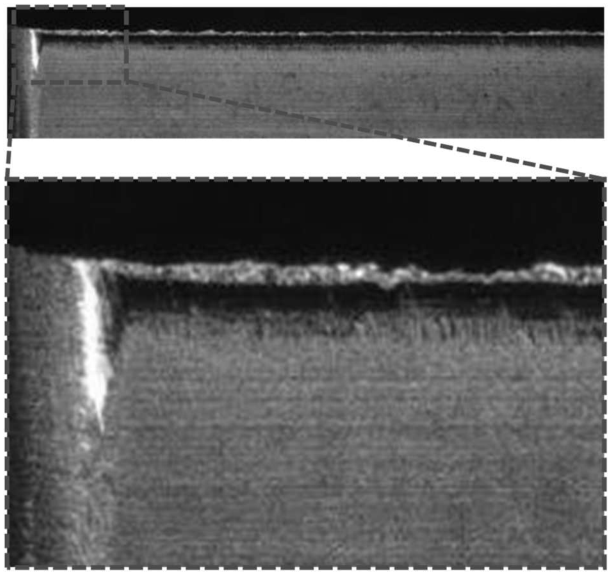

Fig. 6 *Photo of tool wear*

Loss of tool coating leads to rapid wear of the tool substrate, which in turn reduces the quality of the cast iron surface. When cutting cast iron, the free graphite separates the ferrite, which makes it difficult to transfer the cutting heat efficiently, leading to an increase in the temperature of the cutting chips. The high temperature conditions make the Co, C, W and other elements in the cemented carbide will diffuse into the chip and be taken away, and at the same time, the Fe in the chip will also diffuse into the cemented carbide, resulting in a reduction in the surface hardness and strength of the cutter surface, increased brittleness, and increased wear. As shown in Fig.7 tool matrix diffusion wear phenomenon.

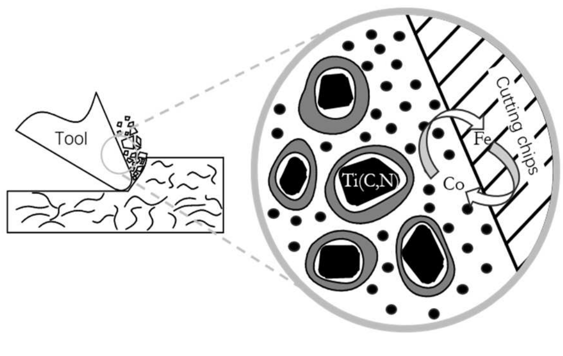

Fig. 7 *Schematic diagram of tool substrate diffusion wear*

The use of cutting fluids plays a key role in mitigating this diffusive wear. Cutting fluids not only reduce the driving force for elemental diffusion by lowering the cutting temperature, but also reduce the potential for diffusion reactions by forming a lubricating film between the tool and the workpiece, reducing direct contact. In addition, the additives in the cutting fluid can react chemically with the tool and workpiece surfaces to form a protective film that further prevents element diffusion. However, the selection and use of cutting fluids also need to consider the sensitivity of cemented carbide to sudden heat. Due to the poor thermal vibration resistance of cemented carbide, the insert itself is highly susceptible to cracking when suddenly warmed up or cooled down. Therefore, when selecting cutting fluid, the tool should be heated as evenly as possible to avoid excessive thermal stress. At the same time, the cutting fluid's cooling performance, lubricating properties and chemical stability also need to be considered to ensure that in slowing down the diffusion of wear and tear at the same time, will not have other adverse effects on the tool.

4 Conclusions

The unique processing characteristics of wiper inserts have a significant impact on improving the surface quality of materials. This article summarizes and elaborates on the geometric structure of wiper inserts, the processing performance of cast iron, and tool wear. The mechanism by which wiper inserts reduce surface material roughness values indicates:

- From a geometrical point of view, a wiper insert has the advantage over conventional insert to squeeze and polish the machined surface, resulting in a smooth surface. During milling, the greater the number of finishing edges, the lower the surface roughness value.
- The wiper inserts are in continuous contact with the cast iron surface, which accelerates wear. In the case of wiper inserts, the increase in strength and the rate of wear are dialectical. When machining high hardness materials such as cast iron, the wear rate of the wiper insert is higher than that of conventional tools. Moreover, cutting cast iron results in diffuse wear of iron and cobalt. Wear can be slowed down by using cutting fluids.

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