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Formation and Control of Drilling Burrs*

Wang Guicheng** Zhang Chunye

(School of Machinery Engineering, Jiangsu University of Science and Technology, Zhenjiang 212013, China)

Abstract: In this paper, a new forming model of the feed-direction burr for drilling process is presented. The feed-direction burr formation is experimented and studied. The related theories are analyzed, and the influential factors of the feed-direction burrs are pointed out. Furthermore, a certain number of new measures to prevent and decrease the burr in drilling process are advanced.

Key words: feed-direction burr, drilling, deburring technology, precision machining

The cutting burrs are often formed on the side, corner, edge and ends of a workpiece in the precision machining, FMS and the automatic metal cutting processes. It seriously affects the accuracy of measure and shape of the workpiece. Using life of the workpiece is greatly shortened and machining productivity is reduced and so on. In recent years, engineers and scholars of machinery engineering in some countries began to study the forming principle of cutting burrs and deburring technology. And a certain number of new positive results are achieved[1-4]. It promoted the development of mechanical technology greatly.

There are two kinds of the cutting burr produced in drilling operation based on the burr classification system of the cutting motion and cutting edge of tool[5-7], they are (in feed direction) entrance burr (I-F) and feed-direction burr (O-F). The feeddirection burr is comparatively large in size and deburring work is of difficulty. It often becomes an obstacle of the following machining operation. But so far academic papers of forming principle and deburring technology of the feed-direction burr in drilling process are not many. In the paper the type of forming mechanism and main influencing factors of the burr are experimented and studied, and related theories are analyzed. The theoretical and predictive bases are made in order to decrease and control feed-direction burr in drilling.

1 A Forming Model of the Feed-Direction Burr in Drilling

In the drilling process, if the material of the workpiece to be cut is even, plain twist drill is not partial, the geometry parameters of the relative point on the major cutting edge of drill is all the same and accuracy of the workpiece to be located is with great precision, a forming model of the feed-direction burr is shown in Fig.1. From Fig.1, the diameter of the drill is d_0 (mm), drilling feed is f ($\mathrm{mm \cdot r^{-1}}$) and drill included angle is 2φ. The end material of the workpiece to be out in feed direction is crushed out of shape by the function of the axial thrust force F_x. Supposing warp amount of a certain point contacted with tool major cutting edge on the workpiece is δ_x, then:

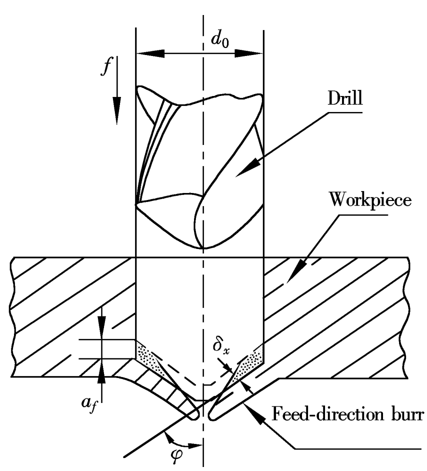

Fig.1 The forming model of the feed-direction burr in drilling

a) When $\delta_x = 0$, drilling process continues;

b) In the range of $0 < \delta_x < a_{cx}$ (underformed chip thickness of a certain point on the major cutting edge of drill), cross-sectional area of the uncut chip reduces with the increase of δ_x and it gradually concentrates the

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** Born in 1955, male, professor.

intersection of the major cutting edge and minor cutting edge of the drill. Drilling operation can be continuous although axial thrust force F_x increases on the end of the workpiece at the same time;

c) When $\delta_x > a_{cx}$, feed-direction burr is formed because the part material of the workpiece end is pressed and pushed under the action of F_x.

The main factors affecting burr formation in drilling include the workpiece material, the shape of the workpiece end, cutting parameters and cutting geometry of the drill, etc. In order to obtain a clear understanding of the forming process of burr in drilling, the experimental study and theoretical analysis are carried out as follows.

2 Experiment Condition and Measure Means

In the experiment, the drilling machine used is up right drilling machine Z5140. The universal twist drill made in H.S.S. is selected, drill diameter is 20?mm, and emulsions are used as cutting fluids. Workpiece material: H68, 20#, 45# and HT15-33 plate, the thickness of the plate is 15 – 20?mm. And H68 is selected as standard material for the test. The mechanical property of the workpiece material and drilling condition for experiment is shown in Tab.1 and Tab.2. The surface of the workpiece end is roughly ground before the test.

The burr height H in the test is measured by dial gauge (accuracy of the measurement is 0.01?mm) and burr root thickness B is measured by tool microscope (accuracy of the measurement is 0.01?mm). The forms of the feed-direction burr in drilling are classified on the basis of the experimental observation.

Tab.1 Mechanical property of the workpiece materials

Workpiece material	Mechanical property		
	Tensile strength $\sigma_b/(N \cdot mm^{-2})$	Specific elongation $\psi/\%$	Hardness /HB
HT15-33	200		170 – 190
20#	420	25	143
45#	650	16	210
H68	320	55	54

Tab.2 Drilling condition

Cutting speed $v/(m \cdot min^{-1})$	9.46, 20.4, 31.4
Feed $f/(mm \cdot r^{-1})$	0.056, 0.122, 0.224, 0.135
Drill included angle $2\varphi/(°)$	110, 118, 130
Helix angle $\beta/(°)$	20, 30, 40

3 Experiment Results and Discussions

3.1 forms and character of the feed-direction burr

From observation in the test, feed-direction burr in drilling can be classified into types Ⅰ, Ⅱ and Ⅲ burrs (See Fig.2). They have some special properties as follows:

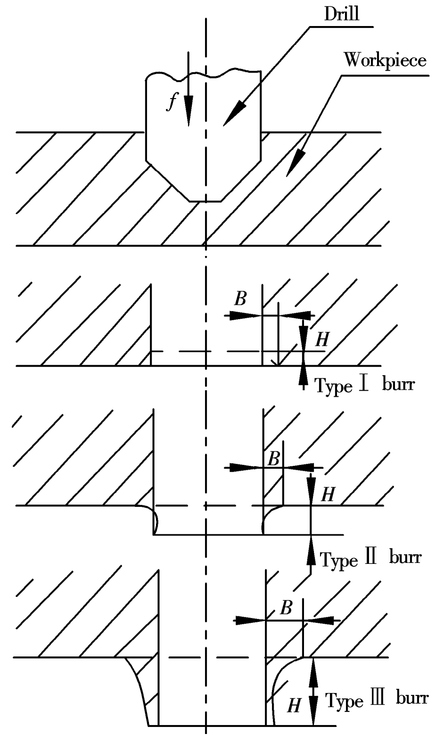

Fig.2 Forms of the feed-direction burr in drilling

Type Ⅰ burr: the end of workpiece is hollow and it's called cutting fracture. Burr height H and root thickness B are very small ($H < 0$, $B < 0$) in normal cases. Influence of type Ⅰ burr to accuracy and property of workpiece is not much, but it easily destroys forming accuracy of the fix case, assembly and travelling for machining etc.

Type Ⅱ burr: the burr height is $H < d/2$ and burr root thickness is $B > 0$. When the requirement of cutting accuracy of the workpiece is higher, type Ⅱ burr must be deburred, and the work time of the deburring is comparatively short.

Type Ⅲ burr: type Ⅲ burr in size is very large in the burrs produced for drilling, that is $H \approx d/2$, B is very big. The workpiece with type Ⅲ burr produced has to be deburred and the work time of the deburring is much. In most cases, it becomes one of the important factors to reduce machining productivity and increase cutting cost of the workpiece.

3.2 Effect of the cutting speed *v*

After cutting speed v is changed, feed-direction burr produced is shown in Fig.3. Fig.3 shows that the burr height H and root thickness B are reduced with the increase of cutting speed v, this is because that the temperature of the drilling area is increased and the material to be cut is softened with the increase of the cutting speed, then drilling force is reduced, the burr size is shorten.

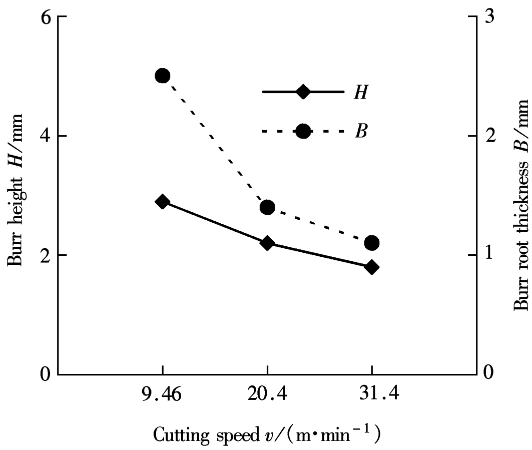

Fig.3 Effect of the cutting speed v on burr

3.3 Effect of the feed *f*

Fig.4 is a result experimented after feed f is changed. From Fig.4, it is known that burr size increases with the increase of the feed f. This is because that axial thrust force F_{ex} becomes large, the warp amount of the material to be cut on the workpiece end will be large with the increase of the feed.

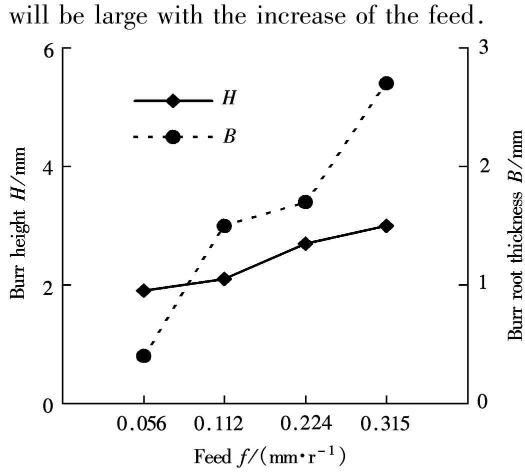

Fig.4 Effect of the feed on burr

3.4 Effect of the drill included angle 2*φ*

After drill included angle 2φ is changed, feed-direction burr produced is shown in Fig.5 in order to know the effect of drill-included angle. From Fig.5, it is known that burr, size increases fast with the drill-included angle. This is because that underformed chip is increased and width of the uncut chip is reduced, F_x and M are reduced and axial thrust force F_x is increased along with the increase of drill included angle 2φ.

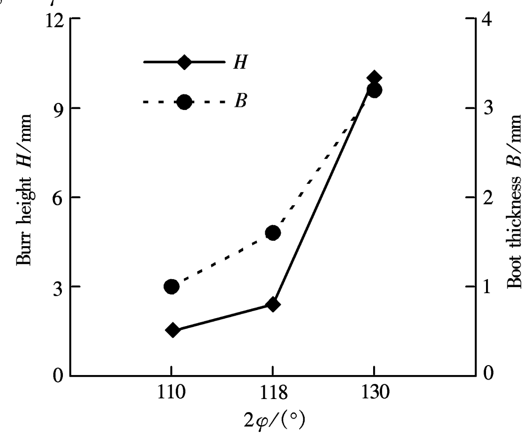

Fig.5 Effect of the drill included angle

3.5 Effect of the helix angle *β*

Fig.6 is a result tested after helix angle β is changed. Burr size reduces with the increase of the helix angle. This is because that the larger the working orthogonal rake angle of the drill is, the larger the helix angle is, and the chip will flow easily, F_x and M will reduce with the increase of the helix angle β.

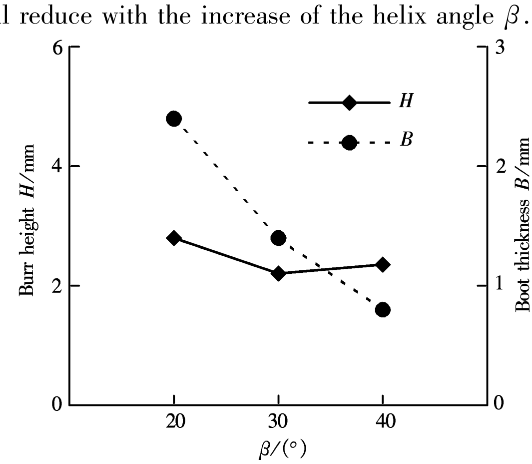

Fig.6 Effect of helix angle of the drill

3.6 Effect of the workpiece materials

In the standard drilling condition, the size of the feed-direction burr for workpiece materials H68, $20^{\#}$, $45^{\#}$ and HT15-33 is shown in Fig.7. It shows that the size of the burr is changed with the difference of the material to be cut. Type Ⅰ burr is formed in drilling HT15-33 and type Ⅱ burr is formed in cutting $20^{\#}$, $45^{\#}$ and H68. This is because of the difference of the mechanical property of the workpiece material (they are tensile strength and specific elongation). That is, the larger the burr sizes are, the bigger the specific elongation of the material is and so on.

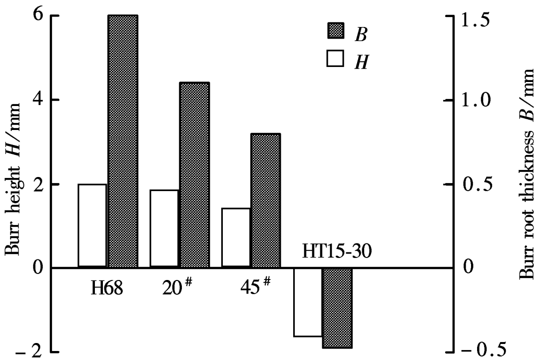

Fig.7 Effect of workpiece material

4 The Measures to Restrain and Decrease Burrs

4.1 Overlap of the workpiece

In the drilling process, the support strength of the material on the exit of the drill is one of the important factors to effect burr size. The overlap method of the workpiece is selected in order to increase strength of the end of the workpiece (in Fig.8). The change of burr size after overlap of the workpiece is shown in Tab.3. We can see that the burr size formed in cutting workpiece (1) and (2) is much smaller than that in cutting workpiece (3).

Tab.3 Experiment of overlap method of the workpiece

Workpiece number	H/mm	B/mm
Workpiece (1)	0.7	0.9
Workpiece (2)	0.7	0.9
Workpiece (3)	2.1	1.5

4.2 Selection of the drilling parameters

In the light of specific drilling condition and requirement, the high cutting speed v (See Fig.3) and the small feed f (See Fig.4) are first selected on the possible condition, therefore F_x and burr size are reduced, the cutting pronductivity is increased and the cutting quality is guaranteed.

4.3 Adjustment of the drill geometry

From Fig.5 and Fig.6, it is known that the burr size is reduced with the increase of the helix angle β or reduce of the drill included angle 2φ. So that the geometry of drill can be selected in the possible condition to effectively reduce and control the size or the shape of the feed-direction burr in drilling process.

4.4 Drill type improvement

The drill type improvement is shown in Fig.9, the test results are shown in Tab.4 using improved drill type. From Tab.4, we know that the burr root thickness B is reduced by 25% - 33% after using drill (a) or (b), but the burr height H is almost not changed. This is because that the cutting heat is given out fast, the wear amount of the drill reduces on the connection area of the drill major cutting edge and minor cutting edge, the length of the cutting edge increases, the specific cutting force for drill major cutting edge reduces, and axial thrust force F_z can be reduced after drill is improved. The angle of the range ε of the drill major cutting edge and minor cutting edge increases, the support strength of the end material of the workpiece is relatively raised.

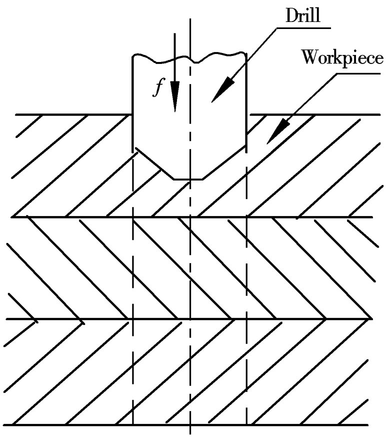

Fig.8 Overlap method of the workpiece

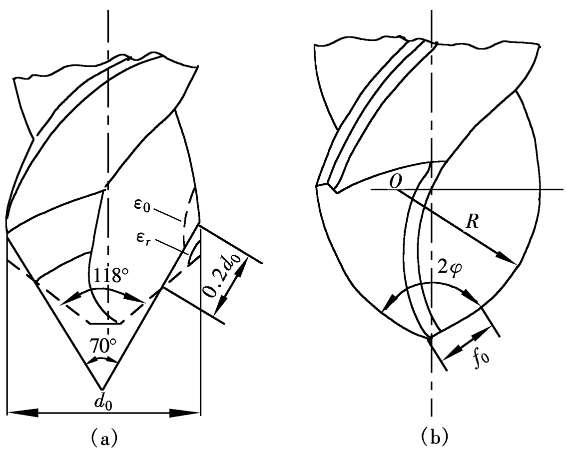

Fig.9 Drill type improvement

Tab.4 Experiment result of drill type improvement

Drill type	H/mm	B/mm
Drill (a)	2.0	1.2
Drill (b)	1.7	1.0
Universal drill	2.1	1.5

4.5 Strengthening method of the end material of the workpiece

The end material of the workpiece can be treated with strengthening method in order to reduce and control the burr in drilling (to increase fragility of the end material using hammer or spraying ball made in steel) or to reduce specific elongation of the material on the end material of the workpiece by painting chemical matters and so on.

5 Conclusions

1) In the drilling process, there are three types of the feed-direction burrs: type Ⅰ, Ⅱ and Ⅲ burrs.

2) The main factors to affect burr formation in drilling are workpiece material, drill geometry, drilling parameters and the shape of the end of the workpiece, etc.

3) We can take up the overlap method of the workpiece, selection method of drilling parameters, adjustment method of the drill geometry, method of the drill type improvement and strengthening method of the end material of workpiece to reduce and restrain feed-direction burrs in drilling process.

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钻削毛刺生成与控制的研究

王贵成　　张春晔

(江苏理工大学机械工程学院，镇江 212013)

摘　要　本研究以切削实验为基础,建立出钻削加工中毛刺形成的切削模型,并对其生成与变化进行了系统的实验研究与理论分析,揭示了钻削加工中毛刺形成与变化的基本规律,开发了若干抑制或减少毛刺的新技术、新工艺和新方法.

关键词　进给方向毛刺，钻削加工，去毛刺技术，精密加工

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