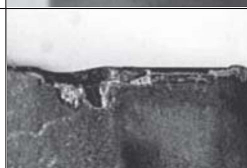
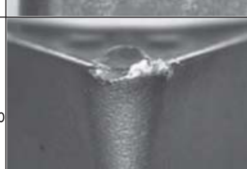
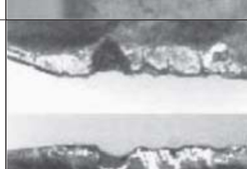
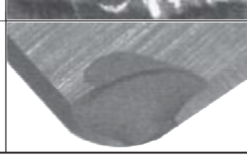
可转位铣削刀具 Reversiable Milling Cutting Tools

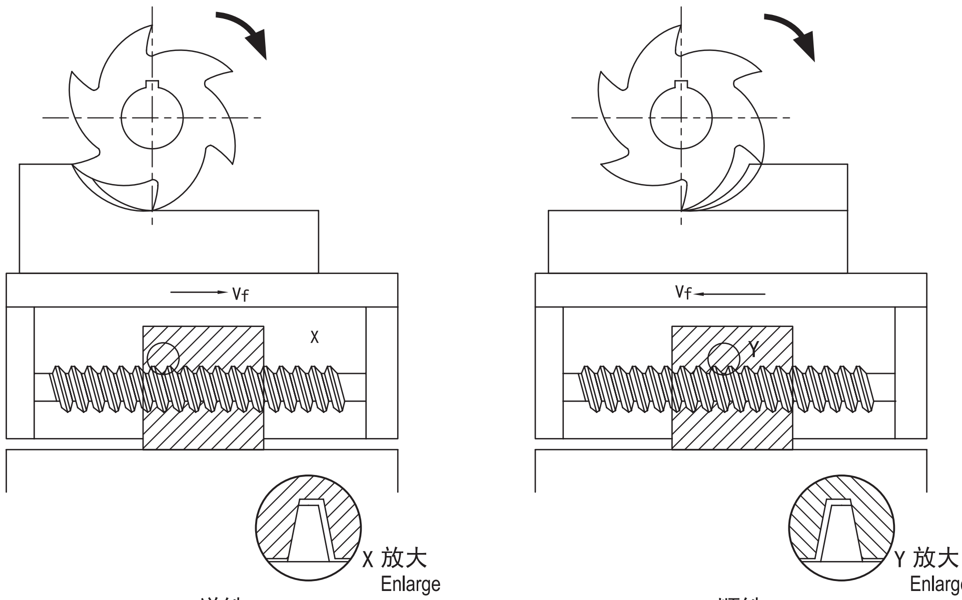
铣削加工常见问题及解决方案 Common problems and solutions for milling

对策与检查要点 Main points of solution and inspection / 故障内容 Fault content			刀具材料选择 Selection of tool material		切削条件 Cutting condition					刀具形状 Tool shape								机床装夹 Machine clamping system		
			硬度更高的材料 Material with higher hardness	韧性好的材料 Material with perfect toughness	切削速度 Cutting speed	进给 Feed rate	切深 Cutting depth	改变铣刀直径与宽度 Change the diameter and width of milling tools	切削液 Cutting liquid	前角 Rake angle	主偏角 Approach angle	切削刃强度 Strength of cutting edge	齿数 Number of teeth	增大容屑空间 Increase the width of chip pocket	检查副切削刃几何形状 Examine the geometry shape of Minor cutting edge	检查端面跳动 Check the run-out of end face	提高刀具刚性 Improve the rigidity of tool	工件刀柄装夹 Clamping system of workpiece	刀柄悬伸 Overhang of tool	动力、机床间隙 Power, gap
刀尖的损伤 Fracture of tool nose	后刀面磨损大 Severe abrasion of clearance face	切削条件不合适 Improper cutting condition			↓				✓											
		切削刃几何形状不合适 Improper geometry shape of cutting edge	✓							↑		↑								
	前刀面磨损大 Severe abrasion of rake face	切削条件不合适 Improper cutting condition			↓	↓	↓		✓											
		切削刃几何形状不合适 Improper geometry shape of cutting edge	✓							↑	↑	↑								
	切削刃破损 Fracture of cutting edge	切削条件不合适 Improper cutting condition				↑	↑													
		切削刃几何形状不合适 Improper geometry shape of cutting edge		✓							↑	↑			✓	✓	✓	✓	✓	✓
	热冲击破损 Thermal cracking	切削条件不合适 Improper cutting condition			↑	↑	↑		✓											
		切削刃几何形状不合适 Improper geometry shape of cutting edge								↓		↑								
	积屑瘤粘结 Build-up edge	切削条件不合适 Improper cutting condition			↓	↓			✓											
		切削刃几何形状不合适 Improper geometry shape of cutting edge								↓		↑								
加工精度 Machining precision	表面粗糙度大 Coarse surface	刀具磨损铣刀振摆大 Abrasion of tool Great vibration of milling tool	✓		↓	↑	↑		✓			↑			调整修光刃 Wiper	✓				
	产生毛刺 Causing burr	切削条件不合适 Improper cutting condition			↑	↑	↑	✓												
		切削刃几何形状不合适 Improper geometry shape of cutting edge								↓	↓	↑			✓					
	产生塌边 Side collapse	切削条件不合适 Improper cutting condition				↑	↑													
		切削刃几何形状不合适 Improper geometry shape of cutting edge								↓	↑	↑	↓		✓		✓			
	平面度.平行度恶化 Worse planeness and parallelism	切削刃几何形状不合适 Improper geometry shape of cutting edge				↑	↑			↓	↓		↑		✓	✓	✓	✓	✓	
其他 Others	振动大 Great vibration	切削条件工艺不合适 Cutting condition Improper technology			↑	↑	↑	✓		↓	↓	↑					✓	✓	✓	✓
	切屑缠绕堵塞 Chippings are twisting and jamming	切削条件不合适 Improper cutting condition			↓	↓		✓	✓				↑							
		切削刃几何形状不合适 Improper geometry shape of cutting edge								↓			↑	✓						

问题与对策 Questions and solutions

代表性的问题 The problem of representation		现象 Phenomenon	原因 Reason	对策 Countermeasure
刃口磨损 Blade wear		精加工的表面粗糙度和尺寸精度下降 reduction of surface roughness and size for finishing	切削速度过高 刀具使用寿命结束 High cutting speed results in the end of the cutter working life	降低切削速度 改用耐磨损性更佳的材质 Lower cutting speed Use material with better wear-resistance
一次边界磨损 A boundary wear		产生毛刺 切削阻力增加 Burrs Cutting resistance increased	进刀量过大和切削速度过高 The amount of feed is too large and the cutting speed is too high	提高锋利度 降低切削速度 改用抗热性更好的材质 Improve the edge sharpness Lower cutting speed Use material with better thermal shock resistance
凹坑磨损 Crater wear		切屑控制恶化 精加工表面恶化（起毛） Chip control deterioration Finishing surface deterioration(Terry)	切削速度过高 Cutting speed is too high	降低切削速度 使用更高切削速度的刀片如瓷金刀片和三氧化二铝涂层刀片 Lower cutting speed Use higher cutting speed insert, such as cermet inserts and Al_2O_3 coating speed
塑性变形 Plastic deformation		工件尺寸变化 先端崩损 Workpiece size change Blade damage	切削负荷过高 刀具材质错误配对 Cutting load is too high Cutter material mismatch	改用硬度更高的材质 降低进刀量和切深 Use high hardness material Reduce the amount of feed and cutting depth
磨损崩损 Wear damage		精加工表面急速恶化 工件尺寸超差 The rapid deterioration of processing surface,Workpiece size tolerance	切削速度过高 The cutting speed is too high	降低预设的刀具寿命 改用耐磨损性更佳的材质 Reduce the preset tool life The use of abrasion resistance and better material
表面粗糙 Surface roughness		切削阻力增加 表面粗糙恶化 Cutting resistance increased Surface deterioration	进刀量过大 切削时的振刀 刀片韧性不足 The amount of feed is too large Cutting vibration knife Blade low toughness.	降低进刀量和切深 改用刚性更高的刀把 改用韧性更大的材质 Reduce the amount of feed and cutting depth Use higher rigidity tool holder Use better toughness material
粘刀与刃口积屑瘤导致崩刃 Sticking to the knife and built-up edge cause chipping		精加工表面恶化 切削阻力增加 Finishing surface deterioration Cutting resistance increased	切削速度过低 The cutting speed is too low	增加切削速度 提高锋利度（前角，倒角） Increasing the cutting speed Enhance the sharpness (rake angle, chamfer)
机械性磨损 Mechanical abrasion		突发性崩损 刀具寿命不稳定 Accidental damage Tool life instability	进刀量和切深过大 切削时的振刀 The amount of feed and depth of cut is too large Inserts vibration during cutting	改用韧性更大的材质 加大倒角 加大刀尖圆弧半径 R 改用刚性更高的刀把 Use better toughness material Increase chamfer Increas the radius of the cutter tip Use higher rigidity tool holder
热龟裂性崩损 Thermal cracking damage		由热循环而崩损 多出现于断续切削和铣削 Damaged by thermal cycle Occurring in intermittent cutting and milling	进刀量过大和切削速度过高 The amount of feed is too large and the cutting speed is too high	降低进刀量 降低切削速度 改用干式加工 Reduce the amount of feed Reduce the cutting speed Use dry-machining
崩缺 Chipping		多出现于高硬度材料切削加工 多出现于有振刀的切削加工 Appearing in high hardness material machining Appearing in machining with inserts vibration	刀片韧性不足 刀把的刚性不足 Blade with low toughness Tool holder with less ringidity	改用硬度更高的材质(TiC系陶瓷→CBN) 改用刚性更高的刀把，变更刀尖式样 Use higher hardness material (TiC ceramics and CBN) Use higher rigidity tool holder, change the blade tip.

技术资料 Technical information
顺铣和逆铣的差别和选择 Difference and selection between down milling and up milling



顺铣：铣刀与工件接触部分的旋转方向与切削进给方向相同的铣削方式。

逆铣：铣刀与工件接触部分的旋转方向与切削进给方向相反的铣削方式。

Climb milling (also called down milling): the feed direction of workpiece is the same as that of the milling rotation at the connecting position.
Conventional milling (also called up milling): the feed direction of workpiece is opposite to the milling rotation at the connecting position.

顺铣时，切削刃主要受到的是压应力，逆铣时，切削刃受到的是拉应力。硬质合金材料抗压强度比抗拉强度大得多；顺铣时，切屑由厚变薄，刀刃与工件间相互挤压，刀齿与加工表面相对滑行时摩擦小，可减小刀齿磨损、减少加工表面硬化、减小表面粗糙度Ra值。逆铣时，切屑由薄变厚，刀片切入时产生强烈的摩擦，较顺铣产生更多的热量和使加工表面硬化。

逆铣时，由于铣刀作用在工件的水平切削力方向与工件进给方向相反，所以工作台丝杆与螺母的一个侧面紧密贴合。而顺铣切削时铣削力的方向与进给方向一致，当刀刃对工件的水平面作用力大到一定程度时工作台会发生窜动，从而将间隙留在后侧，随着丝杆的继续转动，间隙又恢复到前侧。在这一瞬间工作台停止运动;当下次水平切削分力又大到一定程度时，工作台会再次窜动。工作台的这种周期性窜动，将严重影响加工质量和损坏刀具。

使用立铣刀顺铣时，刀齿每次都是由工件表面开始切削，所以不宜用来加工有硬皮的工件。

铣削薄壁零件或精度较高的方肩铣采用逆铣。

In down milling, the major force of cutting edge is compressive stress; in up milling, cutting edge bears the tensile stress. The compressive strength of cemented carbide material is larger than its tensile strength. In down milling, chip becomes thin from thick gradually , cutting edge and workpiece press each other. The friction between edge and workpiece is small, thus can reduce the abrasion of edge , the hardening of workpiece surface and the surface roughness (Ra). In up milling, chip becomes thick from thin gradually. When insert cutting into the workpiece, it generates strong friction and more heat than down milling, and make workpiece surface harden.

In up milling, because horizontal direction of cutting force that milling cutter conducting on workpiece is opposite to the feed direction of workpiece, therefore the lead screw of work table joints closely with one side of screw nut. In down milling,the direction of cutting force is same as the feed direction. When edge's radial force on workpiece is big enough to some extend , the work table will bounce left and right, thus make the gap fall behind. The gap will return to front side along with the continuing rotation of lead screw. At this moment the work table stops motion, however it will bounce left and right again when the radial cutting force is big enough to some extend again. The periodical bounce of work table will cause poor surface quality of workpiece and tool breakage.

When use end mills for down milling, every time the edges begin the cutting at workpiece surface, therefore end mills are not suitable for machining the workpiece with hardened surface.

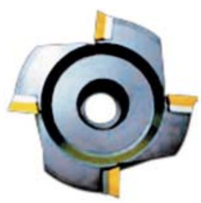
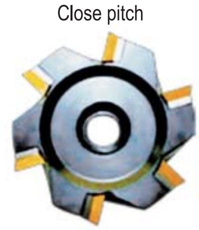
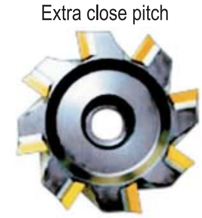
Up milling is recommended for milling the thin-wall components or square milling with the demand of high precision.

技术资料 Technical information

刀具齿距的选择 Pitch selection

铣削刀具齿距是刀刃上某点和下一刀刃相同点之间的距离。铣削刀具分疏齿、密齿、超密齿。

Pitch is the distance between one point on one cutting edge and the same point on the next edge. Milling cutters are mainly classified into coarse, close and extra close pitches,

操作稳定性 Stability of operation		
L （低）(Low)	M （中）(Medium)	H （高）(High)
疏 齿 Coarse pitch  不等齿距设计 Differential pitch	密 齿 Close pitch 	超密齿 Extra close pitch 
实际铣削面积等于铣削面积时，加工系统 稳定，机床主电机功率足够时，选择疏齿 刀具，可得到高的生产效率。 When the milling width is equal to diameter of cutter, the machining system is stable and main power of machine is sufficient,selecting coarse pitch can achieve high productive efficiency.	一般用途铣削和多种混合生产。 General milling function and multiple mixed productions	实际切削面积远小于铣削面积时，以最多的刀刃来参与切削，可获得高的生产率。 When the milling width is less than diameter of cutter, cutting by maximum edges can achieve high productive efficiency.

选择主偏角 Selection of approach angle

铣削刀具的主偏角是由刀片与刀体形成的，主偏角影响切削厚度、切削力和刀具寿命。在给定的进给率下，减小主偏角，则切削厚度会减小，可使切削刃在更大的切削范围内与工件接触。

较小的主偏角可使刀片更为平稳地步入或退出刀具表面，这有助与减少径向力、保护刀刃，并减少破损机率。但会增大轴向力，故不适应加工薄板类零件。

The approach angle is composed by insert and tool body, Chip thickness, cutting forces and tool-life are affected especially by the approach thickness and spreads the cutting area between cutting edge and workpiece for a given feed rate.

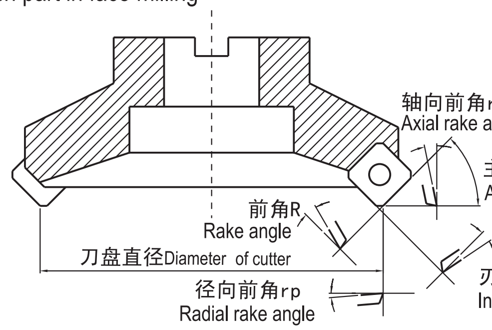
A smaller approach angle also guarantee that it is stable entrying into or exiting workpiece,to protect the cutting edge and extend tool life.However this will increase higher axial cutting forces on the workpiece, thus is not suitable for machining thin workpiece such as thin plate.

主偏角 Approach angle	每齿进给量 Feed rate per tooth	实际最大切削厚度 Real maximum cutting depth
90°	f_z	$h_{ex}=f_z\times \sin kr$
75°	f_z	$h_{ex}=0.96\times f_z$
60°	f_z	$h_{ex}=0.86\times f_z$
45°	f_z	$h_{ex}=0.707\times f_z$
圆刀片 Round insert	f_z	$h_{ex}=\frac{\sqrt{iC^2\times(iC-2a_p)^2}}{iC}\times f_z$

技术资料 Technical information

铣削刀具各部分的作用 Function of each part in face milling

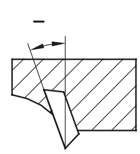
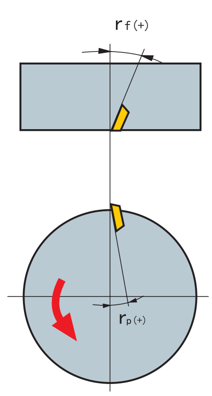
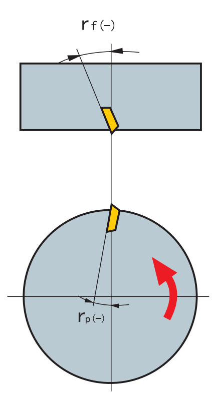
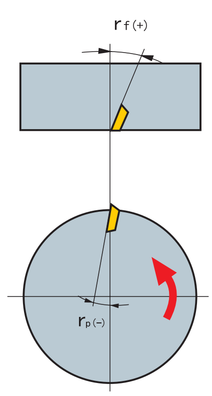
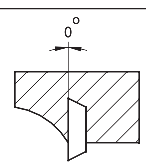
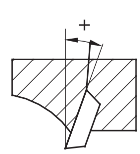
平面铣刀主要角度
Main angles of face mills



平面铣刀主要角度标注 Main angles of face mills

名称 Designation	作用 Function	效果 Effect		
轴向前角 r_f Axial rake angle rf	决定排屑方向 Determining the chip direction	角度为负：排屑性能好 negative angle, excellent capability of chip removal		
径向前角 r_p Radial rake angle rp	决定切削轻快与否 Determining whether the cutting is light and fast or not	角度为正：切削性能好 Positive angle, good cutting performance		
主偏角 Kr Approach angle Kr	决定切屑厚度 Determining the chip direction thickness	Kr↑，切屑厚度↑；Kr↓， 切屑厚度↓； Kr↑, chip thickness↑; Kr↓, chip thickness↓		
前角 R Rake angle R	决定切削轻快与否 Determining whether the cutting is light and fast or not	切削性能差, 切削刃强度高 Poor cutting performance, high strength of high strength of cutting edge	（—） ←0→ （+）	切削性能好,切削刃强度低 Good cutting performance, cutting edge
刃倾角 λs Inclined angle of cutting edge	决定排屑方向 Determining the chip direction	排屑性能差, 切削刃强度高 Poor cutting performance, high strength of high strength of cutting edge	（—） ←0→ （+）	排屑性能好,切削刃强度低 Good cutting performance, low strength of cutting edge

不同前角的组合特征 Characteristics of different rake angles combined

			双正前角 Double positivec	双负前角 Double negative	一正一负前角 One positive, one negative
负型前角 Negative rake angle					
零度前角 0° rake angle					
正型前角 Positive rake angle					
轴向前角 r_f Axial rake angle rf			+	—	+
径向前角 r_p Radial rake angle rp			+	—	—
适合加工材料 Applicable material machined	P		√		√
	M		√		√
	K			√	√
	N		√		
	S		√		√

技术资料 Technical information

通用公式 General formula

Vc： 切削速度（m/min） cutting speed(m/min)	Vf： 工作台进给量（进给速度）（mm/min） feed rate of worktable (feed speed)(mm/min)	Q： 金属去除率（cm³/min） metal removal rate(cm3/min)
Dc： 铣刀公称直径（mm） nominal diameter of milling tool(mm)	fz： 每齿进给量（mm/z） feed rate per tooth(mm/z)	fn： 每转进给量（mm/rev） feed rate per revolution (mm/rev)
n： 主轴转速（rev/min） spindle speed(rev/min)	π： 圆周率≈3.14 circumference ratio≈3.14	L： 实际走刀距离（mm） Real cutting distance(mm)
Zn： 刃数 number of teeth	Tc： 加工时间（min） machining time(min)	

● 切削速度 Cutting speed

$$V_c = \frac{\pi \times D_c \times n}{1000} \quad (m/min)$$

● 主轴转速 Spindle speed

$$n = \frac{1000 \times V_c}{\pi \times D_c} \quad (rev/min)$$

● 工作台进给量（进给速度）（mm/min）
Feed rate of worktable (feed speed)

$$V_f = f_z \times n \times z_n$$

● 每齿进给量 Feed rate per tooth

$$f_z = \frac{V_f}{n \times Z_n} \quad (mm/z)$$

● 每转进给量 Feed rate per revolution

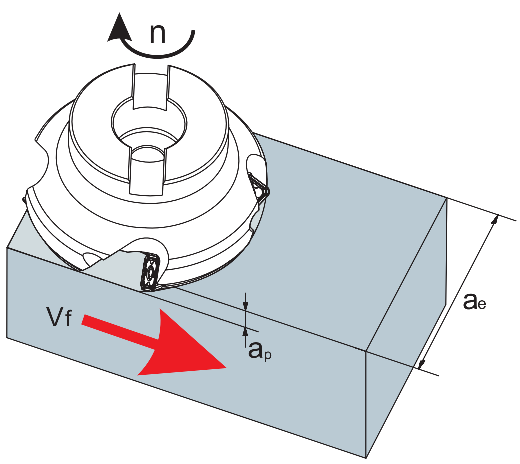
$$f_n = \frac{V_f}{n} \quad (mm/rev)$$

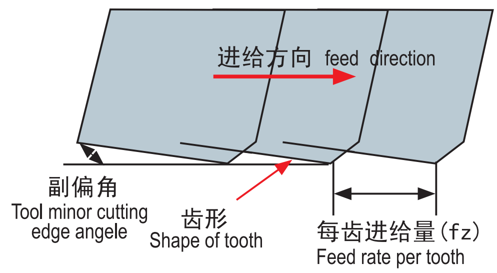
● 加工时间 Machining time

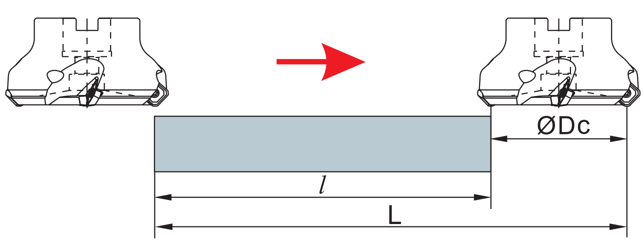
$$T_c = \frac{L}{V_f} \quad (min)$$

● 金属去除率 Metal removal rate

$$Q = \frac{a_p \times a_e \times V_f}{1000} \quad (cm^3/min)$$







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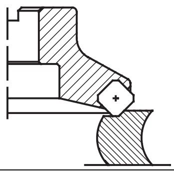
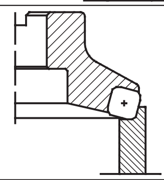
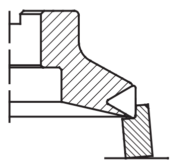
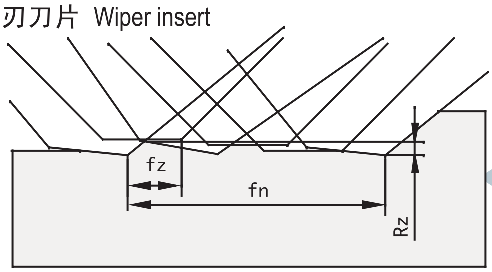
不同主偏角的切削性能 Cutting performances of different approach angles

主偏角 Approach angle	示意图 Schematic diagram	说明 Instruction
45°		轴向分力最大。加工薄壁零件时，工件会发生扰曲，导致加工工件的精度下降；加工易破碎材料时，有利于防止工件边缘产生崩落。 Axial force is the largest. It will bend when machining thin-wall workpiece, and reduces the precision of workpiece. It is benefit to avoid fringe breakage of workpiece when machining cast iron
75°		主要的为径向切削分力，是平面铣削最常用的一种主偏角。 The main purpose is to resolve the radial cutting force, it is often used for general face milling.
90°		理论上轴向分力为零，适合于薄板件的铣削。 The axial force is zero in theory, suitable for milling thin plate workpiece.

修光刃刀片 Wiper insert

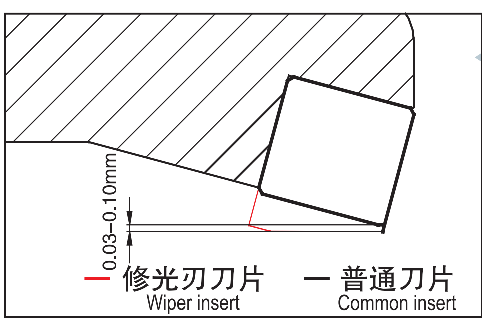


由于刀体和刀片存在制造误差，所以，刀具存在端刃的端面圆跳动和圆周刃的径向圆跳动，端刃的端面圆跳动将导致已加工表面粗糙度Ra值升高，使表面质量达不到要求。

It has axial and radial run out because of tools and inserts exist manufacturing tolerance. The axial runout lead to poor surface roughness.

解决办法
Solution

安装修光刃刀片
Aassembling wiper inserts

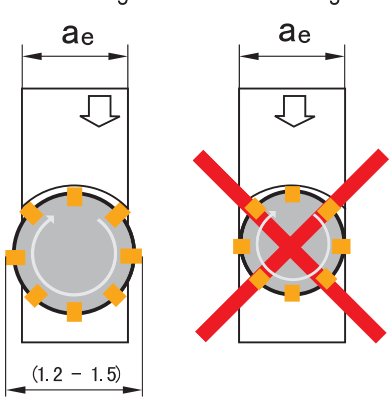


用法
usage

在端向上修光刃必须比其它刃高0.03-0.1mm，才起到修光作用。
一般来说一个刀盘装一片修光刃刀片即可，当刀盘直径比较大时或刀盘的每转进给量大于修光刃长度时，可装2-3片修光刃

The wiper insert must protrude below the other inserts by 0.03-0.10 mm at axial direction, only that the wiping function can take into effect. Generally speaking, a cutter can just assemble only one wiper insert. If the diameter of cutter is much bigger or cutter's feed rate per revolution is bigger than the length of wiper edge, 2 to 3 wiper inserts can be assembled.

面铣中切宽与刀具切削直径的选择
Selection of cutting width and tool cutting diameter in face milling



Dc ： 刀具切削直径 Tool cutting diameter
ae： 切削宽度 Cutting width

一般来说，切削宽度与刀具的切削直径与切宽的关系为：Dc=（1.2-1.5）ae.
在实际加工中尽量避免刀具中心与工件中心相重合

Generally speaking, the relation between cutting width and tool cutting diameter is Dc=(1.2—1.5) ae. In the machining practice, it need to avoid coincidence of tool center and workpiece center as much as possible.