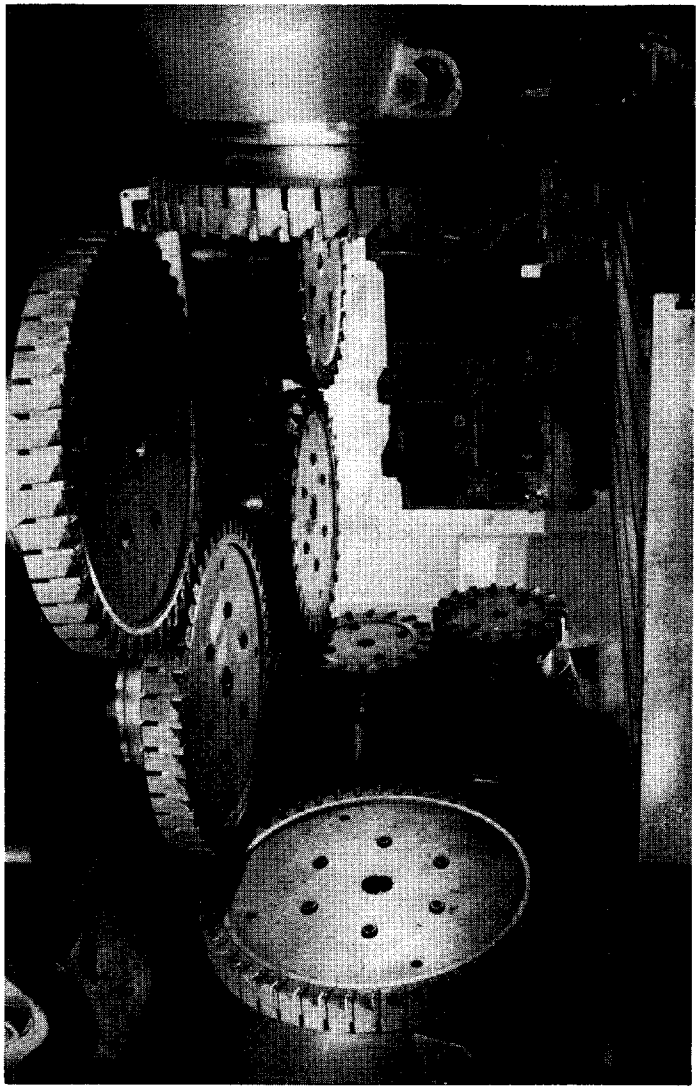


Multiple set-up of carbide face mills on large planing mill

NORTON ABRASIVES

CHAPTER III

Sharpening Carbide Multi-Tooth Cutters

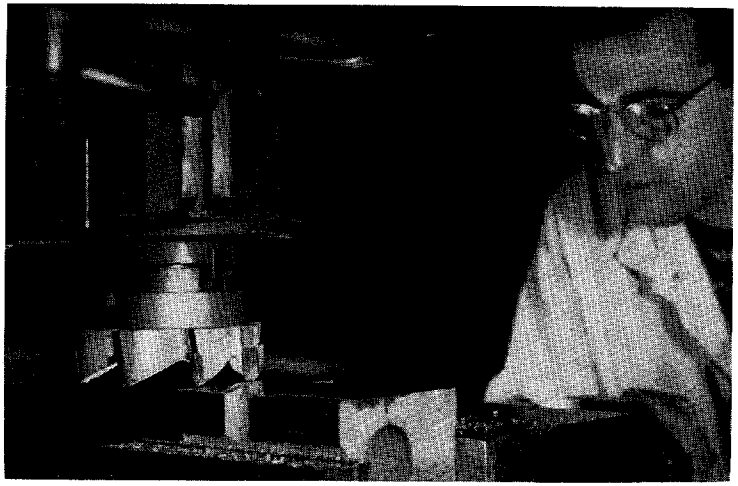
From the standpoint of grinding procedure, carbide face mills and straddle (half side) mills may be divided into two types, namely, (1) those with either brazed-in teeth or inserted blades which are ground on conventional cutter grinders and (2) those of the multiple fly-cutter type having removable blades which can be ground either offhand on an ordinary carbide tool grinder or in a jig on a surface grinder, or on a cutter grinder, if available.

1. In the case of solid or brazed-in types of cutters, it is considered good practice not to grind into the body of the cutter. This can be avoided by having the carbide tips project from $\frac{1}{32}$" to $\frac{1}{16}$" beyond the cutter body in the original braze. Ample wheel clearance should be provided in the cutter body for the periphery, side and face of the tooth.

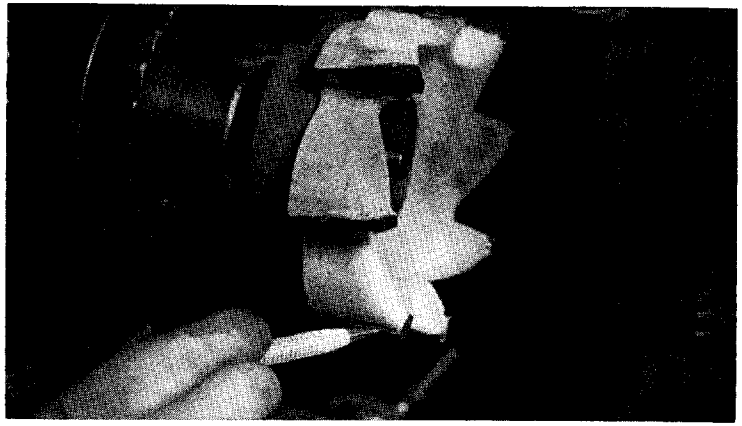
When the carbide tip is ground down to such an extent that the grinding wheel interferes with the body, the tip should be set out again or, if too small, replaced. With the use of a simple fixture to position the tooth in the cutter body and a suitably designed induction heating coil for brazing, this resetting operation should not take more than a few minutes per tooth.

2. Diamond wheels (resinoid or vitrified bonded) should be used exclusively for machine grinding the carbide teeth or blades:

(a) Use a 100 grit, type D1A1 (D1T) straight wheel for circle grinding a newly brazed cutter.



A sharp and accurately ground cutter is important in obtaining a smooth surface on the work



These newly brazed-in carbide tips project beyond the cutter body about 1/16″ on the periphery, cutting face, and tooth face

(b) Use a 100 grit, type D11V9 (D11B) flaring cup wheel (resinoid bonded) on conventional cutter grinders for rough backing off and for general rough grinding where more than 0.002″ of stock has to be removed.

(c) Use a 150 or 180 grit flaring cup wheel for finish grinding the various relief lands and tooth face of large face mills; 220 grit for other cutters.

(d) To facilitate the changing of roughing and finishing wheels on the cutter grinder, leave the wheel on its adapter or collet and remove both as a unit. This makes it unnecessary to indicate the periphery for truth each time the wheel is remounted on the machine.

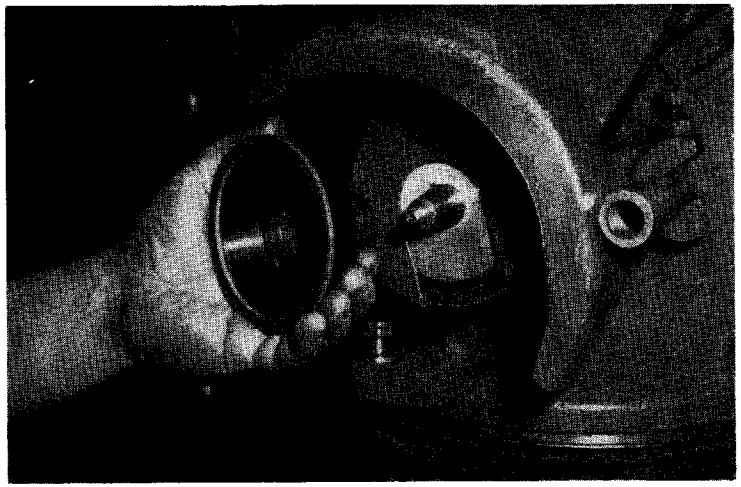
(e) If it is desired to compromise on one diamond wheel for both rough and finish grinding, use a 150 grit wheel. It must be expected that this wheel will neither cut as fast as a 100 grit wheel nor produce the finish of a 220 grit wheel.

(f) On the type of cutter grinder mounting 10″ diameter straight diamond wheels, use the same grit sizes as recommended above for cup wheels.

3. Operate the diamond wheels at the same speeds as ordinary vitrified wheels, namely, 5000 to 6000 surface feet per minute.

4. In roughing with a 100 grit diamond wheel, remove no more than 0.0005″* per pass; in finishing with a 150 or 220 grit

*The diamond particles in a 100 grit wheel measure about 0.006″ in diameter, and are imbedded in the resinoid bonding material at least three-fourths of this amount, leaving only about 0.0015″ of "cutting edge" projecting. Accordingly, the depth of cut for roughing should not exceed 0.0005″ if allowance is made for some wear of the diamond particles. Fast stock removal is nevertheless possible by combining the 0.0005″ infeed with fast table travel.

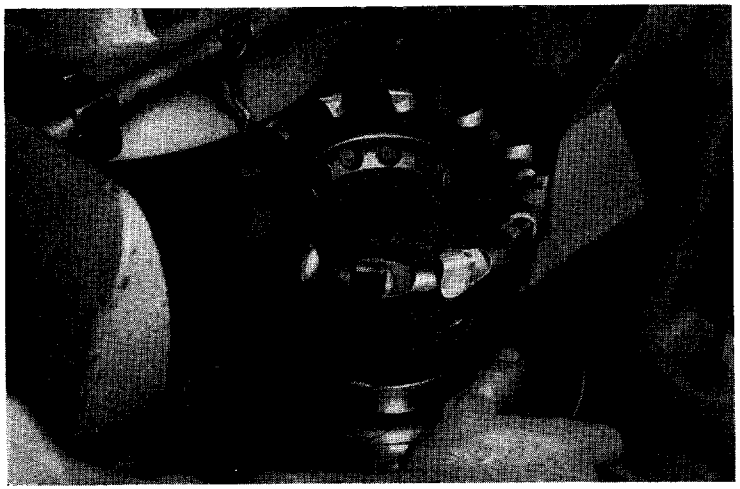


Leaving the diamond wheel on its own mount facilitates changing of wheels

diamond wheel, reduce the depth of cut to 0.0003" per pass and then let the cut sound out (spark out), to obtain the best possible finish. If heavier cuts are taken with normal table traverse, the wheel will not cut as freely, with consequent overheating and possible cracking of the carbide as well as rapid wear of the diamond wheel.

5. Use a relatively fast table travel—about 50" per minute —in roughing. Reduce the table travel to less than one-half this amount in finishing.

6. The grinding may be done with the wheel running either onto or off the cutting edge, provided the grinding is done carefully and the above recommended depths of cut per pass are not exceeded. While the general opinion has been that the grinding wheel must always run onto the cutting edge to avoid chipping the carbide tip, it is not always convenient to

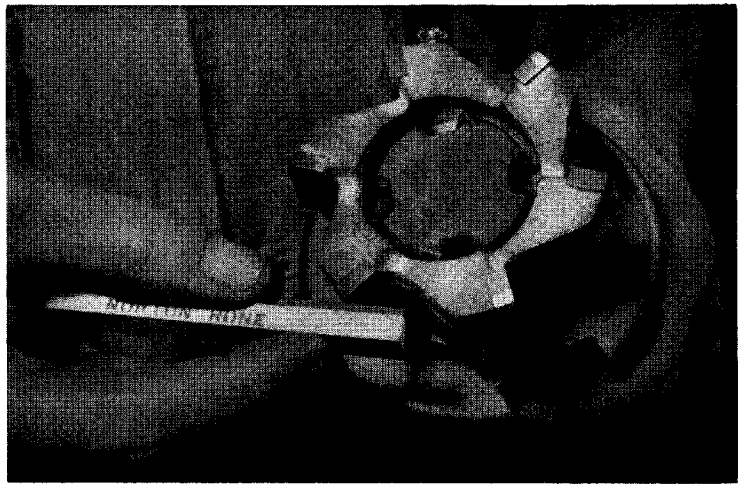


Sharpening a carbide inserted blade face mill on a special cutter grinder equipped with a type D1A1 (D1T), 150 grit diamond wheel

grind in this manner. Furthermore, recent tests have indicated that actually there is no measurable difference in surface finish and practically no difference in tool life or performance, when the grinding is done carefully.

7. When grinding the various relief angles and face on conventional tool and cutter grinders, use a cup shaped diamond wheel with a rim no wider than ⅛" in order to insure a free and cool cutting action.

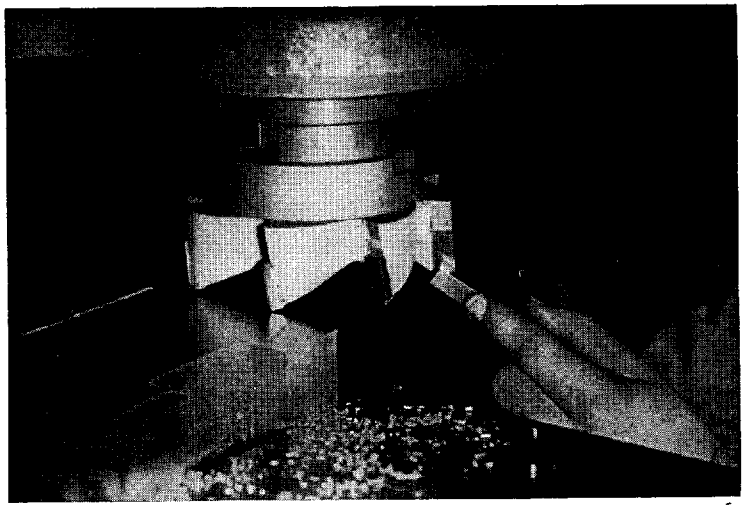
8. Diamond wheels should be used with a coolant, if at all possible. A stream or mist coolant is better than a felt wick. The most satisfactory all-round coolant, from the standpoint of keeping the wheel clean and the work cool, as well as producing a good finish, is a thin solution of soluble oil and water (about 80 to 1). Plain water with a rust inhibitor may also be used.



If cutter is used on steel, honing the cutting edges lightly at a 45° angle to the tooth face retards breakdown of cutting edges

At cutting speeds above 300 feet per minute, carbide tools sometimes have a tendency to develop fine thermal cracks or checks in the crater and on the flank approximately perpendicular to the cutting edge. These will lead to ultimate tool failure by chipping. It is very important, therefore, that all of the damaged portion of the tip be removed in the regrinding operation. A five to ten power magnifying glass is recommended for examining the carbide tip before grinding and at intervals during the grinding operation.

13. After grinding, it may be desirable to hone the cutting edges lightly with a 320 grit Crystolon stone (37C320-NV) or 400 grit diamond hand hone at a 45° angle to the face of the tooth to leave about a .003" wide land. Hand honing the cutting edge increases the tool life of cutters employed on steel because scale and heavy chips are apt to cause an extremely



Honing the top face and relief lands while the cutter is on the machine prolongs its life between regrinds

sharp edge to flake off. Carbide cutters for machining cast iron, aluminum and other nonferrous metals should not be honed in this manner. On these materials a keen cutting edge will stand up longer and give a superior finish.

14. Check the cutter for runout after grinding. For best results, this permissible runout should be kept within the following amounts:

Cutter Diameter	*Roughing Cuts*		*Finishing Cuts*	
	Cutting Face	*Periphery and Chamfer*	*Cutting Face*	*Periphery and Chamfer*
Up to 12"	.001"	.002"	.0005"	.0015"
12" to 16"	.0015"	.003"	.00075"	.002"
Over 16"	.002"	.004"	.001"	.0025"

In addition, carefully check the cutter for clearance and body interference. This is especially important for small diameter cutters.

15. The cutter grinding machine should be in first-class operating condition. The spindles should be free of end-play and runout and the table and cross slide should move freely.

16. After a cutter has been ground, it should be stored in a strong wooden box with the inside measurements large enough so that the cutter can be removed easily with the hands instead of having to turn the box upside down and dump the cutter out.

17. The cutter should be plainly stamped with its serial number, radial and axial rake angles and grade of carbide. This information will serve both to identify the cutter and to instruct the grinder hand in the rake angle settings.

18. While the cutter is in use, periodic honing of the clearance lands and face of the tip with a 400 grit diamond vitrified hone will prolong the life of the cutter between regrinds. Any small notches appearing on the cutting edge (easily detected by the fingernail test) and also any accumulated built-up edge can be removed with a diamond hand hone.

Steps in Resharpening a Dulled Face Mill

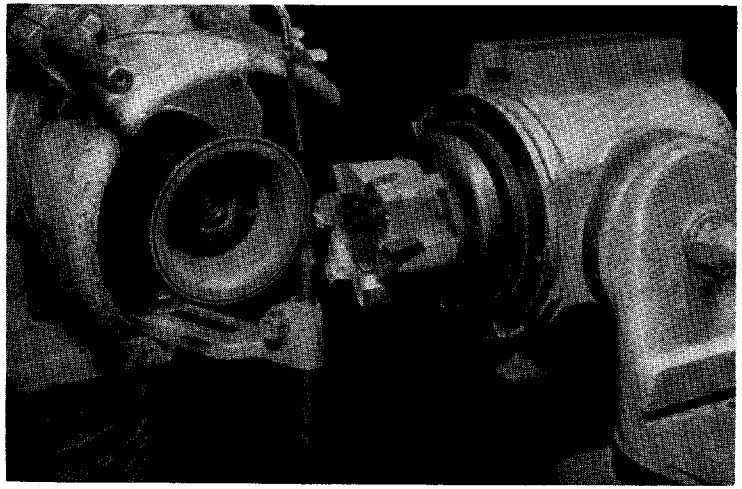
Carbide milling cutters should be reground before the cutting edges have broken down completely. On face mills employed on steel and cast iron, when an average flank wear (or wear on the land below the cutting edge) of about .030" has occurred, the cutter should be considered dull and ready for regrinding. When machining aluminum and brass, as soon as the cutter shows about .005" wear on the cutting edge, it should be reground.

Inspect the carbide teeth with a magnifying glass and estimate the amount of wear on the cutting edge to determine how much will have to be ground off the face, O.D. and chamfer.

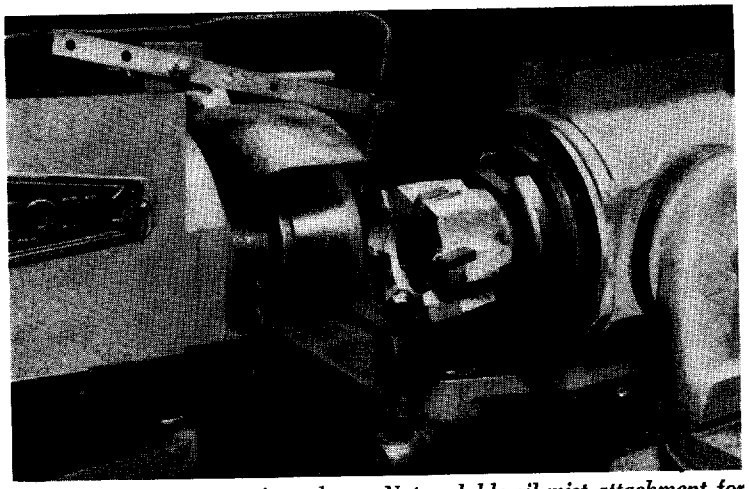
On a Cutter and Tool Grinder

1. If the carbide teeth are chipped at the cutting edges, a 100 grit diamond wheel should be used for rough grinding all the teeth around the cutter (backing off), removing about .0005" per pass, until the damaged portion has been ground off. The complete marking of this diamond wheel in the popular type D11V9 (D11B) flaring cup shape is SD100-R100B6$\frac{1}{16}$ or SD100-R75B6$\frac{1}{16}$.

If the cutting edges show simply normal dulling, use a 220 grit diamond wheel for resharpening (complete marking: SD220-R100B6$\frac{1}{16}$ or SD220-R75B6$\frac{1}{16}$). First, grind the primary relief angle on the O.D. or peripheral cutting edges. The



Regrinding the primary relief angle on periphery of carbide face mill



Backing off the face cutting edges. Note soluble oil mist attachment for keeping work cool and diamond wheel lubricated

tooth rest finger is set on the tooth to be ground. If very light cuts are taken, no more than a few ten thousandths inch per pass, this operation can be done without injury to the carbide, with the wheel rotating *off* the cutting edge considered the safer method.

The relief angle on the peripheral cutting edges varies with the material to the machine, such as 5° for steel, 7° for cast iron and 10° for aluminum.

Grind all the teeth successively after each increment of wheel infeed rather than each tooth completely. This allows the carbide tip to cool between each pass round the cutter.

If, after grinding the primary relief, the land has become excessively wide, the secondary relief angle (also called the clearance angle) should be reground to restore the land to its proper width. For face mills 3″ to 8″ in diameter, this land is usually held between $\frac{1}{32}$″ and $\frac{3}{64}$″ wide.

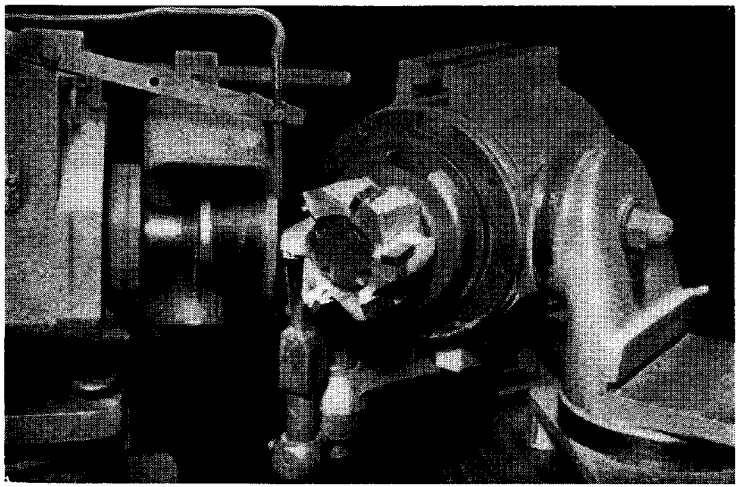
Use the 100 grit diamond wheel previously referred to for rapidly grinding the secondary relief angle behind the land.

2. Next, grind the primary relief on the face cutting edges. The face relief land is held to about ⅛″ width by regrinding the secondary relief angle or clearance angle about 2° (by swiveling the work head).

This secondary relief angle is necessary only if the face cutting edges are perfectly flat or concaved less than 1°. If they are concaved more than 1°, a secondary relief angle is not required.

3. Regrind the relief angle on the chamfer or corner, following the same procedure as for the periphery and face. The land on the chamfer should blend into the lands on the periphery and the face.

4. Round over the primary relief intersections of the



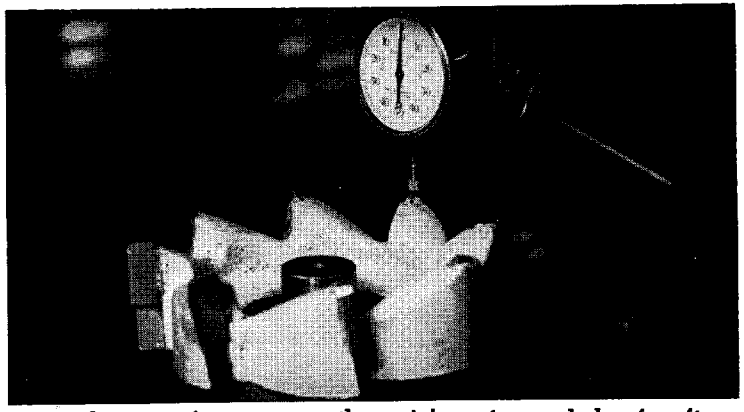
Grinding the primary relief on the chamfer

chamfer with the periphery and the face of the tooth to about a .010″ radius, using a 320 grit Crystolon stone (37C320-NV) or 400 grit diamond vitrified hand hone (D400-V$\frac{1}{16}$). Finally, if the cutter is to be employed on steel, hone the entire cutting edge lightly with the same Crystolon stone or diamond hone at about 45° to the cutting edge to leave a "white line" or land about .003″ wide. A few light strokes of the hone will suffice to produce this land which serves to strengthen the edge against chipping and to prolong the tool life.

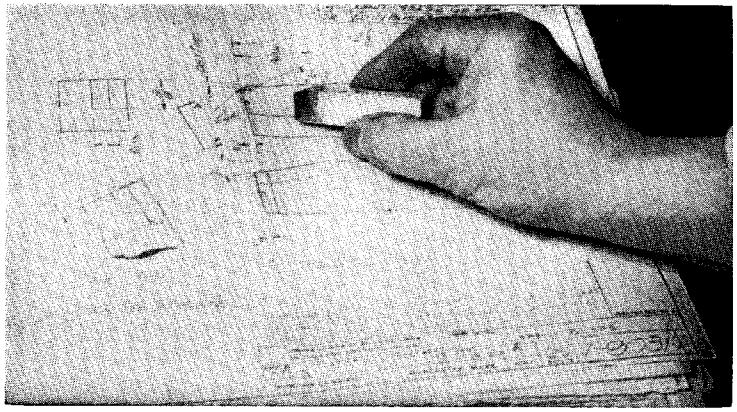
5. Test the cutter for runout on the periphery, corner and face, using a 1/10,000″ indicator. At the same time, make certain that no part of the cutter body projects beyond the cutting edges.

Steps in Sharpening a Multiple Fly-Cutter Type of Face Mill

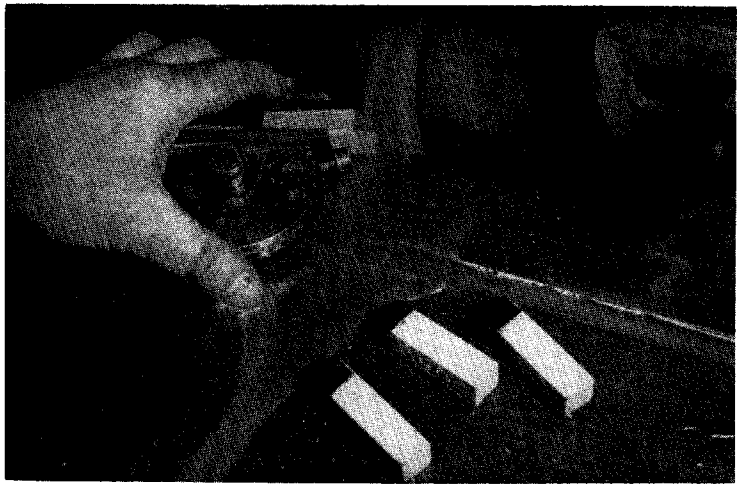
When the blades show an average of about .030″ flank wear, remove them from the cutter body and grind them off-



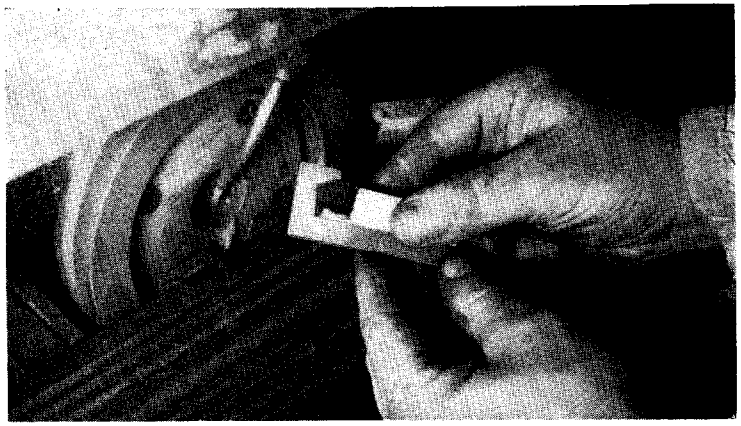
Test the cutter for runout on the periphery, face and chamfer after grinding



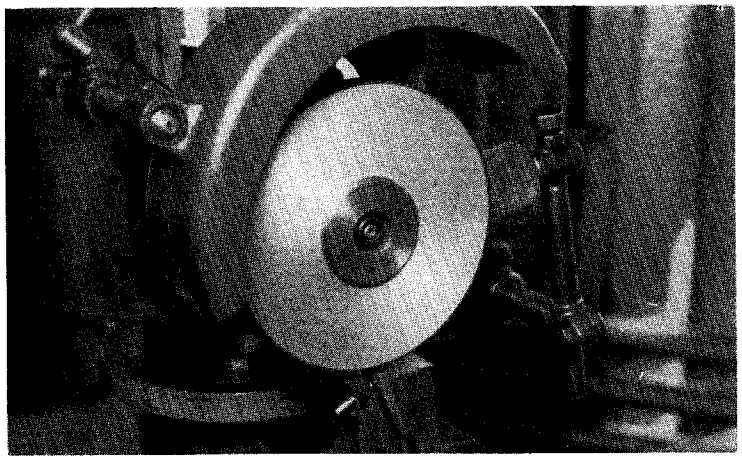
Before grinding the blades of a multiple fly cutter, check the tool angles from the drawing



Rough grinding the carbide-tipped cutter blades offhand on a 60 grit Crystolon wheel



Checking the peripheral cutting angle with a template after finish grinding the cutter blades offhand on a 220 grit vitrified bonded diamond wheel



Set-up on a universal tool and cutter grinder for regrinding solid carbide face mill blades. The special toolholder insures accurate and uniform rake and relief angles

hand on a standard carbide tool grinder. Rough grind the face and various cutting angles on either a 60 grit Crystolon wheel (39C60-I8VK) or 100 grit diamond vitrified bonded cup wheel (SD100-P50V$\frac{1}{16}$) and finish grind on a 220 grit diamond wheel (SD220-P50V$\frac{1}{16}$). These operations can be speeded by contouring the cutting edges of the blade to fit a template.

If the cutter is used for step-cutting, the reground blades can be set in the cutter body sufficiently close, as a rule, with a scale. Where the cutter is used for face-milling, the blades can be set even on the peripheral cutting edges and faces by cutting a swath in the work with a single blade and then setting the remaining blades to the machined surface while drawing up the clamping screws.

A recent design of carbide face mill incorporates the use of wedged-in, replaceable blades of solid carbide. This type of cutter, like the multiple fly-cutter, does not have to be ground in a cutter grinder. The blades are removed from the cutter body and ground individually to the proper angles on a small surface grinder (equipped with a magnetic chuck) while being held in an accurately machined jig incorporating all the cutting and relief angles. If the blade is chipped or cracked, it is first rough ground offhand on a standard carbide tool grinder with the table set at 25°.

For sharpening the blades on the surface grinder, a 220 grit straight type diamond wheel, either SD220-N100B$\frac{1}{8}$ resinoid bonded or SD220-L100V$\frac{1}{8}$ vitrified bonded, is recommended.

Advantages of Diamond Wheels for Cutter Grinding

The economy of using bonded diamond wheels, perhaps as much as any other single factor, may be said to be responsible

for the increasing use of carbide milling cutters. Despite their higher first cost, diamond wheels will actually give a lower cost per cutter ground than silicon carbide abrasive wheels because they not only cut much faster, but wear at only a fraction of the rate of silicon carbide wheels. Moreover, diamond wheels produce a keener, more durable cutting edge.

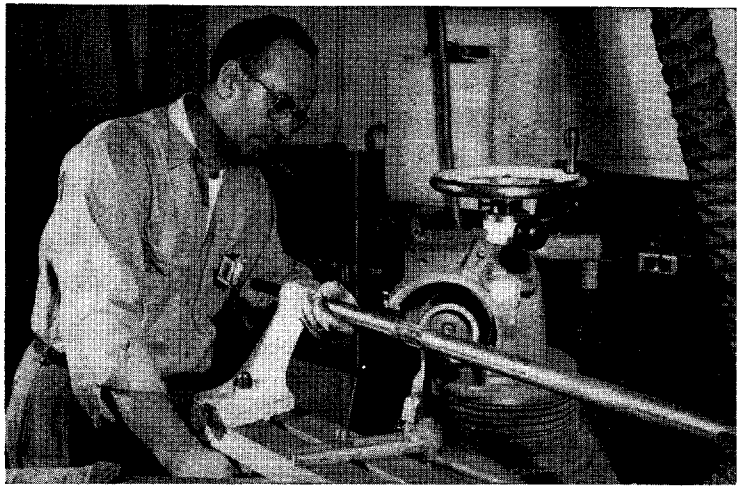
The difference in hardness between cemented carbide and the silicon carbide abrasive employed in wheels for grinding the material is so slight, relatively speaking, that the abrasive grains dull rapidly and the wheels must be of a very soft grade, such as H and I, in order to break down readily and thereby constantly present new, sharp cutting grains to the work. Otherwise the dulled grains would set up thermal stresses in the carbide, resulting in grinding checks or cracks.

As a matter of fact, it has been estimated that the proper grade of silicon carbide wheel, in order to avoid dulling and heat-checking the carbide, will wear fifty times more by volume than aluminum oxide wheels on high-speed steel. As a result, when grinding multi-tooth cutters with silicon carbide wheels, the wheels wear so rapidly that it is usually necessary to check each blade or tooth for size with an indicator.

Diamond wheels, on the other hand, will hold their size when grinding completely around a cutter, thereby insuring all the teeth being in the same plane. Furthermore, danger of checking and cracking the carbide tip is practically eliminated because of the exceptionally free and cool cutting action of diamond wheels.

Reamers

Reamers are essentially end-cutting tools and the accuracy of the cut taken by the end-cutting edges is limited by the accuracy of the body diameter. Experience has shown that the



Sharpening a carbide tipped line reamer by grinding the 45° chamfer, using a type D11V9 (D11B) diamond cup wheel

most generally satisfactory method of sharpening carbide tipped reamers is to simply grind the 45° chamfer with adequate but not excessive relief.

Occasionally the radial face of the blades will require touching up to remove any slightly rounded edge or built-up material. The relief angle at the cutting edge varies with the diameter of the tool. Recommended relief angles for reamers of various diameters are listed in the following table.

Reamer Diameter	*Relief Angle*	*Clearance Angle*
1/4" to 3/8"	20° to 15°	40° to 30°
3/8" to 5/8"	15° to 10°	30° to 20°
5/8" to 1"	10° to 8°	20° to 16°
1" to 1 1/2"	8° to 6°	16° to 12°
Over 1 1/2"	6°	12°

The width of the circular land on the periphery of the cutting blades is more dependent upon the abrasive nature of the material being reamed than on any other factor. The more abrasive the material, the more rapidly the cutting edges of the chamfer will dull. When these edges become dull, the reamer is not cutting to size but instead is being forced into the material the amount of the cut. If the land is too wide, the force required to drive the tool becomes excessive, particularly if the material being reamed is hard. In addition, excessive heat is generated. The generally accepted practice with respect to circular land widths is shown by the following table.

.005"–.010"	*.010"–.020"*	*.020" plus*
Aluminum bronze	Aluminum castings not heat treated	Heat treated aluminum
Low lead bronze	Free cutting steel	Babbitt
Copper	Free cutting brass	
Magnesium	Cast iron	
Steel—heat treated	Die castings	
Steel forgings	Bearing bronze	
Bakelite		
Hard rubber		

Where reamers are piloted through bushings, grind the body behind the carbide tips .0002" to .0004" under the cutting diameter and leave full circular lands on the tool body for bearing in the guide bushing.

In reaming some particularly tough materials like aluminum castings and aluminum bronze where a ribbon form of chip is desirable, the conventional 45° chamfer sharpening may not work satisfactorily. In such cases, a lead angle sharpening is recommended. This lead angle is generally 2° and the length of the lead angle, $\frac{3}{16}$" to $\frac{5}{16}$". The length of the 45° chamfer on the end of the tool should be held to about $\frac{1}{16}$".

For sharpening by grinding the chamfer or lead angle, use a 220 grit diamond resinoid bonded wheel, SD220-R100B6$\frac{1}{16}$ (or $\frac{1}{8}$) in a relatively thin straight (type D1A1 [D1T]) wheel, or SD220-R100B6$\frac{1}{16}$ in a type D11V9 (D11B) flaring cup wheel. This same type cup wheel may be used for regrinding the radial faces of the carbide tipped blades to remove any low or rounded front edges.

If the O.D. of the tool is damaged, expand it .0005" (assuming the reamer is of the expansion type) and lap it to size, using No. 4 diamond powder or No. 400 Norbide grain mixed with olive oil on a split lap made of bearing bronze. Remember to always run the tool backwards when lapping.

Maintaining sharp cutting edges by resharpening the chamfer (or lead angle) before the tool becomes extremely dull, greatly prolongs the tool life and prevents excessive wear on the diameter. Maximum tool life is further assured by taking care to remove a minimum of stock during resharpening.