

SECTION 3, CHAPTER 3

LATHE TOOLS - CUTTING FLUIDS - CUTTING SPEED AND FEED

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LATHE TOOLS

Introduction

1. Lathe tools are cutting tools because their purpose is to remove metal, or "stock" as it is known, from the work. A good knowledge of the tools to be used and the ability to prepare a tool for a particular job is very necessary if a lathe operator is to produce good results.

2. Lathe tools are named according to the work they are designed to do, viz, **roughing, finishing, parting, boring and screw cutting**. They vary in shape according to the work and the metal being machined; thus there are many different shapes for normal operations and special shapes are made as required. Information regarding the main types of lathe tools is given on the fly-out page.

3. Experience still plays an important part in machining because metals vary widely in regard to the ease with which they may be machined and the class of finish that can be obtained; also, although much research has been done on the basic principles of cutting

metal, it is still not possible to cover all aspects with hard and fast rules. The metal is removed by shearing or is torn, rather than cut, in the form of a continuous chip which at times may break into a number of chips.

Tool Materials

4. Cutting tools must possess a number of properties such as the ability to retain a cutting edge at high temperatures, resistance to shock and abrasion and so on, and various materials are used for their manufacture depending upon the particular usage.

5. **High-Carbon Steel.** Steels with 0.8-1.4 per cent carbon are ideal for low cutting speeds and for intricate form tools which do not require grinding or are difficult to grind after hardening. High-carbon steel tools give a good surface finish, retain their cutting edge under normal conditions, are easy to temper and are cheap to produce.

6. **High-Speed Steel.** This is basically a straight carbon steel with the addition of various alloying elements such as tungsten, chromium, molybdenum, vanadium and so on.

(A.L. 20, June 65)

The addition of 14 to 18 per cent tungsten makes a very hard tool which retains its hardness over a much wider range of temperature than high-carbon steel. It can be operated at higher speeds than high-carbon steel without any appreciable loss of hardness which has led to its being quite widely used.

7. Stellite. This is an alloy of cobalt, chromium, tungsten and sometimes carbon. It is used in the form of tips where it is brazed or welded to the steel shank and does not require any heat treatment. It is inherently hard and has a cutting performance between those of high-speed steel and the cemented carbides.

8. Cemented Carbides. Tungsten carbide is the main constituent of this type of material and it is mixed with cobalt and processed to form the material which is brazed onto mild or medium carbon steel shanks to produce cutting tools which are very widely used in industry. The high cutting speeds which can be employed result in greatly reduced production times, and these tools also have a longer life than the previously mentioned types, provided that the correct grade of tip for a specific job and material is used. The grades may be classified broadly into two main groups:—

(a) **Straight Tungsten Carbide.** Most suitable for machining non-ductile materials such as cast iron, non-ferrous alloys and so on, which are not prone to adhesion between the chip and the tool face.

(b) **Tungsten and Titanium Carbide Mixtures.** Used for cutting all grades of steel.

Note The tool face is often provided with a chip-breaking groove (Fig. 1). This breaks up the turnings and aids removal of the swarf which can be a problem when the metal is being cut at such high speeds.

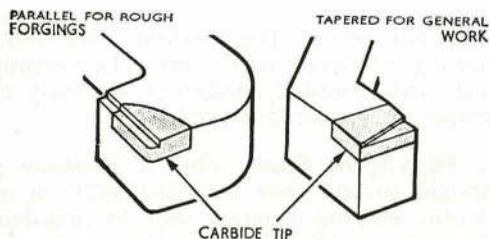


Fig. 1. CHIP BREAKERS

9. Diamond. The diamond is a natural cutting stone and is extremely hard. Diamond tipped tools are mostly used for turning operations on non-ferrous materials as their use on steel has not been very successful. These tools give a high surface finish and actually their use is almost limited to finishing because the depth of cut of these tools is relatively small. They are capable of very high cutting speeds and the speed used for a diamond tipped tool should always be as high as is possible. They are very widely used for the mass production of such components as aluminium alloy pistons.

Angles

10. The shape of a tool depends upon the work to be done but in all cases, regardless of the shape, the tool must be ground so that it has cutting edges with suitable clearances (see fly-out page) and the direction of the cut must always be considered. The angles shown are:—

- (a) Side top rake.
- (b) Front top rake.
- (c) Composite rake.
- (d) Side clearance.
- (e) Front clearance.

11. The side top rake angle is usually between 6 and 15 degrees and, together with the side clearance angle, shapes the cutting edge to produce a shearing action as the tool moves sideways against the work. The side clearance angle also ensures that the vertical edge of the tool does not rub against the work. The softer the material, the smaller should be the side top rake angle.

12. The purpose of the front top rake angle is to present the cutting edge to the work so that it shears the material with an upward

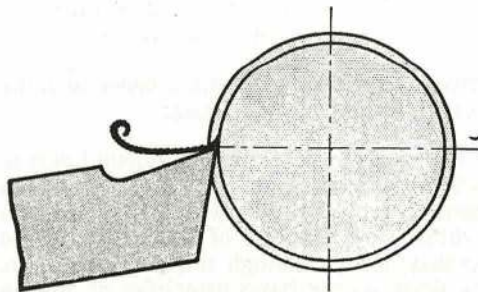


Fig. 2. UPWARD THRUST

rather than a forward thrust (Fig. 2). As a general rule the size of the angle is increased with increasing hardness of the work; using a tool having a front top rake angle which is too large when turning soft material will cause the tool to "dig in". This angle is not always ground on the tool as, in the case where a tool bit is used in a toolholder

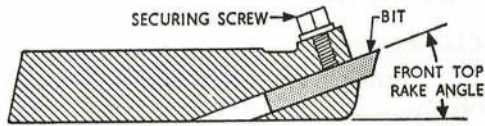


Fig. 3. TOOLHOLDER

(Fig. 3), the angle is provided in the slot for the bit.

13. The purpose of the front clearance angle is to prevent the work from rubbing against the tool. This angle should be made as small as possible because when the angle is too large the cutting edge of the tool wears very quickly. The composite rake angle (boring tool) ensures cutting efficiency.

14. It will be realized that the aforementioned angles are vital factors in the efficient operation of a lathe tool. It is important therefore for the tool to be located on the centre line of the work, otherwise the effect will be to increase or decrease these angles as shown in Fig. 4.

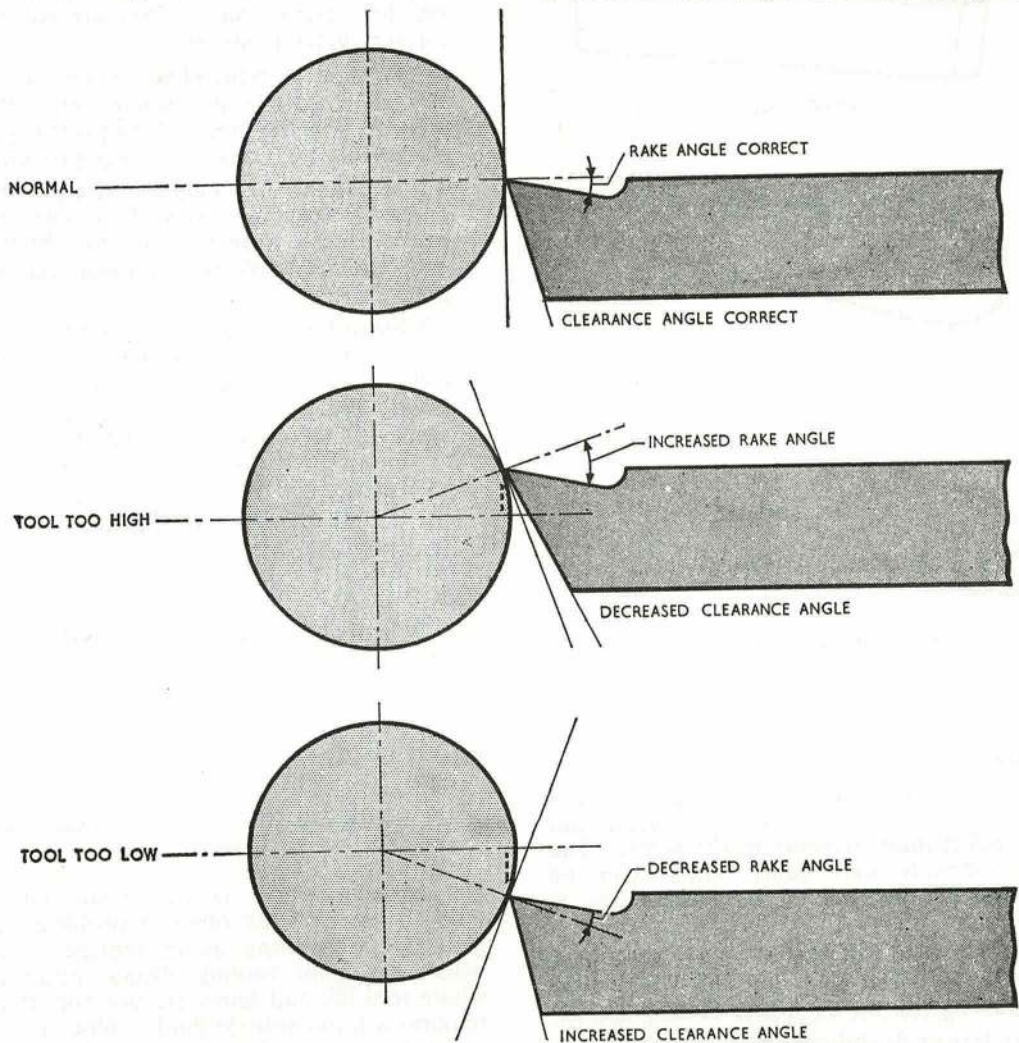


Fig. 4. EFFECT OF INCORRECT TOOL LOCATION

15. It will be found in practice that the angles of tipped tools are usually different from those previously quoted. The greatest divergence affects rake, particularly with carbide tools, where it has been found that the use of negative rake cutting overcomes the weakness of this material when cutting ductile steels.

Single-Point Tools

16. Single-point lathe tools (Fig. 5) may have a solid shank, comprise a holder and a tool bit, or consist of a small tool carried in a bar (boring).

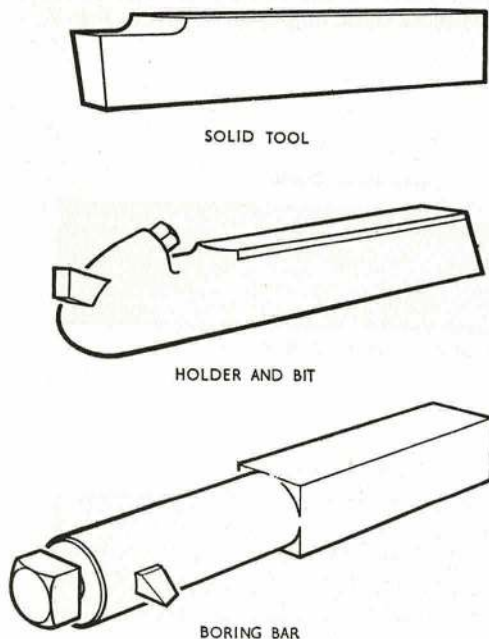


Fig. 5. SINGLE-POINT TOOLS

CUTTING FLUIDS

General

17. The use of a cutting fluid or lubricant will often aid the machining of certain metals and also effect improvements in the work. The improvements and gains which can be attained by the use of a lubricant are as follows:—

- (a) The fluid will cool and carry away heat from both the tool and the work, thus allowing the use of higher cutting speeds.
- (b) It provides lubrication between the chip and the top face of the tool where the rubbing action is severe. This lengthens

the life of the tool, gives a better surface finish, and decreases the power required.

(c) A good flow of lubricant will flush away the swarf and chips and keep the cutting point clear.

(d) The lubricant will give some measure of protection from rust or corrosion to both the newly machined surface of the work and the machine.

Classification

18. Cutting fluids are classified broadly as follows:—

(a) **Soluble Oil Solutions.** These are used primarily as coolants, their lubricating property being small. They are basically oil and water mixtures.

(b) **Straight or Neat Oils.** These may be animal, vegetable or mineral oils either alone or compounded. They possess good lubricating but limited cooling properties.

(c) **Sulphurized or Compounded Oils.** Oils under (b) compounded with sulphur, zinc oxide or other agents. Used as lubricants and coolants. Possess pressure-resisting properties.

(d) **Fixed Oils.** With or without diluents or solvents. They comprise lard oil, sperm and whale oil, linseed oil, and so on. These fluids possess the property of "wetting" the metal with a highly adhesive oil film and are used for high-speed work.

(e) **Air Blast.** This has limited cooling effects and is used mainly for disposal of the swarf and chips.

Use

19. When considering which cutting fluid to use for a particular operation, the following requirements must be known:—

- (a) Cooling effects only.
- (b) Cooling and lubrication effects.
- (c) Lubrication mainly.
- (d) Reduction of adhesion between chip and tool.

20. Deciding which is the most suitable fluid to use is, quite often, a problem. In general, high cutting speeds require a fluid which has good cooling effects; roughing, where tool life and finish are not important, requires a water soluble fluid. When taking a finishing cut, where cooling, finish and tool life are important, it may be found that a sulphurized oil is the most efficient. Soft

and ductile metals usually require reduction of metallic adhesion. Cutting is probably most efficient when the temperatures of both the fluid and the work are low, the chip and the tool bright, with the chip coming off smoothly. A fluid which is widely used is known as "suds" or "slurry"; this is a white solution produced by mixing a soluble oil with water.

21. The cutting fluids recommended for use when turning the following metals are:—

- (a) **Aluminium.** May be cut dry but kerosine improves the surface finish.
- (b) **Brass.** Cut dry.
- (c) **Cast Iron.** Cut dry; an air blast may be used for removal of swarf if necessary.
- (d) **Copper.** Use kerosine or lard/kerosine mixture.
- (e) **Mild Steel.** Use a soluble oil—suds.

Application

22. The method of application of the cutting fluid will depend upon the particular work which is being done. Heavy and continuous cutting requires a pump system in which the fluid contained in a drain sump is pumped to a feed which discharges over the tool and work, the rate of flow being adjustable to suit the job in hand; deep drilling or boring operations require a more copious supply of fluid in order to clear the bore of swarf. For less arduous working conditions a small gravity feed tank, fitted with a tap to regulate the drip feed, is often used. When working conditions are light the fluids can be applied by hand with the aid of a brush.

CUTTING SPEED AND FEED

Definitions

23. The term **cutting speed** as applied to the machining of metals in a lathe is defined as the circumferential speed of the work relative to the cutting tool or the distance which a point on the circumference of the work will travel in one minute—usually expressed in feet per minute. **Feed** indicates the amount of longitudinal movement of the tool on the work and is defined as the rate at which the cutting tool is advanced; it may be expressed as a fraction of an inch per revolution of the work e.g. 1/16 in. per revolution (Fig. 6) or, as the number of turns the work makes

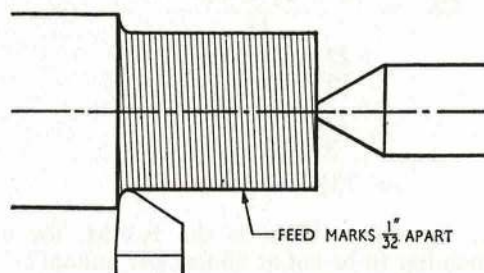


Fig. 6. FEED

whilst the tool travels one inch e.g. 32 feeds or cuts per inch.

Speed

24. Although a given cutting speed for a certain metal using a particular type of tool does not vary, it is still necessary to revolve the work at varying speeds in order to obtain this given cutting speed for different diameters of work. Also, the cutting speeds of different metals vary considerably and provision is made on the lathe so that the required speeds can be obtained. The aim is to use the highest rate of speed and feed consistent with safety, maximum tool life, accuracy and type of finish required.

25. The term **cutting speed** must not be confused with **machine speed** which is the spindle speed in revolutions per minute. As a general rule the harder the material being machined the lower will be the cutting speed, but experience and the tool manufacturer's recommendations will give the required guidance in actual practice.

Formula

26. The cutting speed or the revolutions per minute, dependent on what facts are known, can be found by use of the following formula:

$$CS = \frac{\pi \times D \times R}{12} \text{ ft./min.}$$

Where CS = cutting speed

$$\pi = 3\frac{1}{2}$$

D = diameter of work in inches

R = revolutions per minute

27. **Example.** A piece of mild steel bar of 3½ inches diameter revolves at 80 r.p.m.; what is the cutting speed?

(A.L. 20, June 65)

$$\begin{aligned}
 CS &= \frac{3\frac{1}{2} \times 3\frac{1}{2} \times 80}{12} \\
 &= \frac{22 \times 7 \times 80}{12 \times 7 \times 2} \\
 &= \frac{220}{3} \\
 &= 73\frac{1}{3} \text{ feet per minute.}
 \end{aligned}$$

28. **Example.** What is the R.P.M. for a 2 inch bar to be cut at 80 feet per minute?

$$\begin{aligned}
 R &= \frac{12 \times CS}{\pi \times D} \\
 &= \frac{12 \times 80}{\frac{22}{7} \times 2} \\
 &= \frac{12 \times 80 \times 7}{44} \\
 &= 153 \text{ R.P.M. approx.}
 \end{aligned}$$

Spindle Speeds

29. Although other methods such as the coned pulley and belt drives have been used, the majority of lathes are now equipped with a headstock containing a range of gears designed to provide the required speeds in accordance with the range of work which the machine will be required to handle.

Factors

30. The factors which affect the speed at which work may be turned are as follows:—

- (a) The material being machined. A lower speed is required for hard and strong metals than for those which are soft and ductile.
- (b) The rigidity and condition of the lathe; the rigidity of the tool and the work.
- (c) The material of which the tool is made. Much higher speeds can be employed when using special cutting alloy or high-speed tools than when carbon steel tools are used.
- (d) The depth of cut and the feed. A higher speed can be employed for a light finishing cut with a fine feed than for a heavy roughing cut.

Feed

31. It has been stated previously that the feed of the tool is the distance the tool moves along for each revolution of the work. The feed used for a turning operation is chosen after due consideration of several factors.

32. A high limiting factor for feed is the power available on the machine and, of course, the condition of the machine. The product of the speed, feed and depth of cut gives the amount of metal that is being removed and hence the power needed.

33. Another factor is the smoothness of the finish that is required. A coarse feed produces wider and deeper machining marks and consequently the finish is inferior to that produced by the use of a fine feed. The shape of the tool must also be taken into consideration because a blunt-nosed tool gives a better finish than a pointed tool for the same feed.

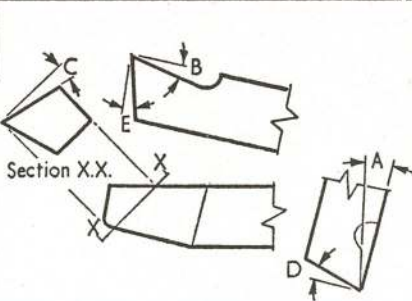
34. Generally speaking, roughing cuts are taken with the maximum depth of cut and feed possible in order to reduce the work-piece to within the limits of size allowed for the finishing operation; thus, the amount of metal left for removal is small and finishing is done at a high speed.

35. The use of negative rake tools and tungsten carbide tips has not only allowed the use of higher cutting speeds but has also resulted in good surface finishes, depths of cut and rates of feed which are much in advance of previous attainments. Such machining methods obviously require more power than was previously used and also demand absolute rigidity of both tool and machine.

36. It is not practicable in notes of this type to quote values for feeds because they vary with the material being machined and with the various types of lathes. In some cases it is advisable in practice to use a fine feed to start with, i.e. finer than would seem to be required, and then work up to coarser feeds; similarly with cutting speeds. Taking trial cuts at finer feeds and lower cutting speeds should be tried and these should be increased gradually until the optimum conditions are found.

Tool Life

37. The problem of cutting speed and feed is also bound up with length of tool life. The use of high cutting speeds and rates of feed will tend to hasten the destruction of the cutting tool edge with the consequent need for grinding.

		A SIDE TOP RAKE ANGLE	STR	ROUGHING			KNIFE			FINISHING			PARTING			BORING			SCREW CUTTING			CUTTING SPEEDS USING H.S.S. TOOLS	
B FRONT TOP RAKE ANGLE	FTR																					If Stellite, Tungsten Carbide or similar tools are used, these speeds can be considerably increased.	
C COMPOSITE RAKE ANGLE	CR																						
D SIDE CLEARANCE ANGLE	SC																						
E FRONT CLEARANCE ANGLE	FC																						
MATERIAL		D.T.D.	BRITISH STANDARDS		STR	FC	SC	STR	FC	SC	FTR	STR	FC	FTR	FC	SC	CR	FC	STR	STR	∅FC	SC	FEET PER MINUTE
* CHROMIUM NICKEL Non-corrodible steel			S.110; S.80		12	5	5	12	5	5	10	0	5	10	5	5	5	5	5	10	5	2	50-70
* HIGH CHROMIUM Non-corrodible steel			S.61; S.62		12	5	5	10	5	5	10	0	5	10	5	5	5	5	5	10	5	2	66-80
* NICKEL CHROMIUM STEEL			S.11; S.82; S.95		12	5	5	10	5	5	10	0	5	10	5	5	5	5	5	10	5	2	45-60
* NICKEL STEEL			S.15; S.67; S.69		8	5	5	8	5	5	8	0	5	8	5	5	5	5	5	8	5	2	40-55
CARBON TOOL STEEL			UK/AID/71/1		12	5	5	12	5	5	10	0	5	10	5	5	5	5	5	10	5	2	50-70
■ NIMONIC					12	5	5	10	5	5	10	5	5	8	5	5	5	5	5	5	5	2	30-45
* MANGANESE STEEL					8	5	5	8	5	5	8	0	5	8	5	5	5	5	5	8	5	2	40-55
HARD STEEL (55 Ton and over)		261	S.2; S.94		12	5	5	10	5	5	10	0	5	10	5	5	5	5	5	10	5	2	45-60
MEDIUM HARD STEEL (40-55 Ton)					12	5	5	12	5	5	10	0	5	10	5	5	5	5	5	10	5	2	50-70
SOFT STEEL (40 Ton and under)			S.1; S.6; S.14; S.93 15/1948; BS 970		15	5	5	15	5	5	15	0	5	10	5	5	8	5	8	10	5	2	70-110
⊕ HARD CAST IRON					6	5	5	6	5	5	6	5	5	4	5	5	4	5	4	4	5	2	40-50
⊕ SOFT CAST IRON					6	5	5	6	5	5	6	5	5	4	5	5	4	5	4	4	5	2	55-65
PHOSPHOR BRONZE			B.8; BSS; 369		6	5	5	6	5	5	6	5	5	4	5	5	4	5	4	4	5	2	50-100
HARD GUN-METAL					6	5	5	6	5	5	6	5	5	4	5	5	4	5	4	4	5	2	50-70
∅ COPPER			BS 24		15	10	10	15	10	10	15	5	10	12	10	5	15	5	5	10	5	2	70-100
⊕ BRASS			BSS 249, 250 & 251		0	8	8	0	8	8	0	0	8	0	8	5	0	5	0	0	5	2	Up to 250
⊙ ALUMINIUM					20	10	8	20	10	8	20	0	10	15	10	5	12	10	5	10	5	2	250-350
⊙ ALUMINIUM ALLOYS		423	L.1; L.44		20	10	8	20	10	8	20	0	10	15	10	5	12	10	5	10	5	2	200-300
†⊕ MAGNESIUM ALLOYS					25	10	8	25	10	8	25	0	10	15	10	5	12	10	5	10	5	2	850-950
⊕ EBONITE					15	10	10	10	10	10	10	0	10	5	10	5	5	10	10	10	5	2	100-300

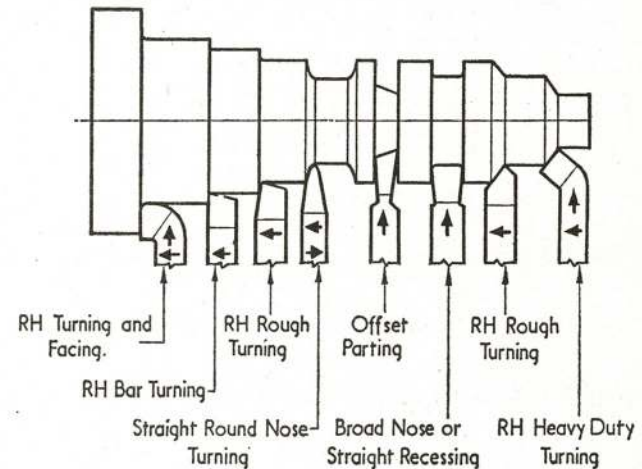
THIS CHART IS INTENDED FOR INITIAL GUIDANCE ONLY. TURNING EXPERIENCE WILL INDICATE ANY CHANGES NECESSITATED BY FACTORS SUCH AS THE CLASS AND TYPE OF TOOL, FINISH REQUIRED, WORK DIAMETER, CUT, SPEED AND LUBRICANT.

* THESE STEELS WILL WORK-HARDEN IF RUBBED BY THE TOOL. A BLUNT TOOL WILL WORK-HARDEN AND DRAG THE SURFACE AND LOWER THE CORROSION RESISTANCE OF THE MATERIAL.
THE MOUNTING OF BOTH TOOL AND WORK SHOULD BE AS RIGID AS POSSIBLE, ALL SLACK TO BE TAKEN UP ON THE MACHINE SLIDES.

∅ THESE ANGLES SHOULD BE ADJUSTED TO SUIT THE PITCH ANGLE.

● USE ROUGHING TOOL FORM.
■ FOR NIMONIC USE ULTRA CAPITAL PLUS ONE HIGH SPEED STEEL.
⊗ PRECISION GRINDING IS THE NORMAL FINISHING METHOD FOR THESE MATERIALS.
LATHE TOOLS PROVISIONED FOR THE RAF ARE LISTED IN AP 1086, SEC 3B
TURNING LUBRICANTS
⊕ TURN DRY
∅ USE KEROSENE OR MIXTURE OF LARD AND KEROSENE.
○ USE MIXTURE OF KEROSENE AND MINERAL SEAL OIL. FOR OTHER MATERIALS USE OIL, ZX-1.

TYPES OF LATHE TOOLS



† THERE IS A RISK OF FIRE WHEN MACHINING THESE MATERIALS; PRECAUTIONS ARE AS FOLLOWS:-

- (1) KEEP TOOL VERY SHARP.
- (2) CUT DRY.
- (3) USE STONE ON CUTTING EDGE.
- (4) DO NOT USE CHIPPED TOOL.
- (5) KEEP AREA CLEAN.
- (6) COLLECT TURNINGS FREQUENTLY AND STORE IN STEEL BINS WITH LIDS.



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