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Fitting and Machining
Trade Theory Book 2
MEM05F&MB2/1

FEEDBACK
We value your opinion and welcome suggestions on how we could improve this resource manual. Keep in mind that the manual is intended to help students learn and is not a text book. Send your comments and suggestions to:
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PREFACE

This book has been written as a reference book and training manual for students studying Fitting and Machining in the Certificate III Engineering-Mechanical Trade in the MEM05 Metal and Engineering Industry Training Package.

Its use however is no way restricted to just this course, the information contained in the book will be a valuable resource for other courses dealing with these topics.

This book is a modernisation of the Fitting and Machining Trade Course, Trade Technology, Book 2 text book last printed in the 1970s by the Department of Technical and Further Education, New South Wales.

This edition has put the topics into sections rather than chapters. This has enabled page and figure numbering in sections which allows revisions and additions to be completed more efficiently.

The contents of this book will cover the following Units of Competency from the MEM05 Training Package:

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Much time and effort has been invested in the production of this resource. It would not have been possible without the input and support from many different people and sections within TAFENSW.

Not least of which are the Fitting and Machining staff from around NSW who have provided photographs, assisted with proof reading and editing.

The Nepean Arts & Design Centre for their assistance with the design of the front cover. The staff at the Manufacturing, Engineering, Construction and Transport Curriculum Centre and other TAFENSW staff for their encouragement and kind assistance in making this project a reality.
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NOTE: Students are requested to refer to Section 5, Book One, before proceeding with this section.

The action of any cutting tool is that of wedging the material apart after the cutting edge enters the work, rather than actually shearing it with the sharp edge of the tool.

Figure 1-1 Cutting angle comparison

The difference in cutting wood or steel is largely a matter of the angle of the cutting tool used. In fig. 1-1 as a matter of comparison, is shown the cutting angle of a pocket knife suitable for cutting wood, and the angle on the point of a cold chisel used for chipping metal.

Although a finer grade of steel is usually used for the blade of knife than for a cold chisel, the latter may be used to cut steel without damaging the cutting edge, whereas the edge of the knife would be ruined if it were used on the steel. The reason for this is obviously the difference in the angle of the cutting edge.

Conversely, a cold chisel is not suitable for cutting wood. Although the cutting edge would not be damaged, too much power would be required to force the chisel through the material, and the resulting cut would be rough.

It will be seen, therefore, that when machining any material, the angle of the cutting edge must suit the texture and hardness of the work.

THE CUTTING ACTION

The action of a tool when cutting metal is illustrated in fig. 1-2, for simplicity, a tool is shown taking a straight cut. The action is similar on a circular cut, such as that on a lathe. The size of the sections formed is, of course, exaggerated in order to illustrate the cutting action.

At “A”, fig. 1-2 the tool is just entering the cut, and is compressing the metal ahead of the point, and as this force increases, the angle of the tool causes the metal ahead of it to fracture in small wedge shaped sections. This action is continued at “B”, where it will be seen that the outer ends of the chip sections are compressed more than where the actual cut is taking place, thus causing the chip sections to adhere together and begin to curl.

At “C” the tool has advanced still further, and the chip is forming into a curl.

Figure 1-2 Cutting action

If the material being cut is steel, the chip which is formed should be continuous throughout the length of the cut, and, if closely observed, the part of the chip which contacts the point of the tool will be shiny, while the other side of the chip will be dull and deformed.

The cutting of metal, in reality, consists of building up of forces with the edge of the tool until a small wedge is forced loose. The force then drops and begins building up again for the next section. The action is therefore a series of intermittent forces, hundreds of which may occur in a period of one second.

This intermittent rise and fall of the forces produces a very light vibration, which in itself, is not harmful to the tool.

However, if this vibration happens to synchronize with that of any natural vibration of a part of the machine such as the spindle, the tool, or the work, a heavy vibration called “chatter” will result. Such a vibration results in chatter marks which spoil the finished appearance of the cut.

Chatter is usually eliminated either by reducing the speed of the spindle, or raising the height of the tool to the work.

SHARPNESS OF THE CUTTING EDGE

The cutting edge itself does not shear through the body of the metal when taking a cut, yet the smoothness of finish obtained on the work is directly dependent on the keenness of the edge. The reason for this is that as the chip is wedged off, a rough surface is left on the work, the sharp edge of the cutting tool shears off this roughness and leaves a smooth surface.
When taking roughing cuts, it is not necessary to have the edge of the tool sharp for; in any case, the edge will only remain sharp for a small part of the cut under these conditions, and then becomes rounded before breaking down altogether. However, if the top surface of the tool against which the chip bears is honed, less heat will be generated by friction, and slightly less power will be required to operate the machine.

When a fine finish is required, the tool cutting edge should be honed on a medium or fine grit oilstone. This is especially true when machining soft metals such as copper, aluminium, etc., as the cutting action and finish obtained on these metals is greatly affected by the keenness of the cutting edge.

**BASIC METAL CUTTING PROCESSES**

Building any machine consists of making each part of that machine to the required shape and size, by machining processes (e.g. turning, milling, grinding, etc.). These processes utilize suitable cutting tools to reduce the rough, uneven surfaces of castings, forgings, rolled metals, or other materials, to the required dimensions and degree of accuracy.

To properly carry out any machining process it is necessary to have an understanding of the tools, speeds, feeds, depth of cut, and cutting lubricants used. These factors determine the rate at which the surplus material can be removed.

Of the many machining processes used in the engineering trade, those with which the student will be concerned in the earlier stages of training are:

- Turning
- Planing
- Milling
- Drilling

Other processes such as grinding, broaching, hobbing, etc., will be dealt with later.

**COMPARISON OF DIFFERENT PROCESSES**

**Turning**

![Figure 1-3 Turning with a single point tool](image)

Figure 1-3 illustrates the single point tool as used in the process of turning. The following points may be noted:

1. The work rotates against the tool which is fixed, except for feed travel.
2. The tool cutting edge is subject to continual cutting action, and heat generation.
3. Cutting fluid may be applied copiously to the tool and work, if required.
4. There is unrestricted escape for the chips.
5. The work surface is exposed to the cooling action of the atmosphere throughout almost the whole cutting period.

Therefore metal may be removed at a comparatively fast rate, other conditions being favourable.

**Planing**

![Figure 1-4 Cutting with a planer tool](image)

Planing differs from turning, even though a single point tool, (fig. 1-4) is used when planing, the work has a reciprocating motion, that is, it moves forward and backward. The tool cuts on the forward stroke. On the return stroke the work returns to the new cutting position. No cut is taken, this allows for both tool and work to cool down.

The planing process is, therefore, performed under the following conditions:

1. Intermittent application of the tool to the work.
2. Cooling period between each cutting stroke.
3. An open field for escape of chips.
4. Unrestricted application of cutting fluid, if required.

This process lends itself to heavy cuts, and fairly high cutting speeds. Cutting is normally performed dry, cutting fluids being applied only when a bright, smooth finish is required on steel parts.
Milling

Figure 1-5 The milling process

Figure 1-5, illustrates the milling process. Note the following:

- The tool is a multi edged cylindrical type of cutter which revolves to bring each cutting edge into contact with the work.
- The work is advanced or "fed" towards the cutter.
- The majority of teeth, during the cutting process, are not in contact with the work, although the revolutions of the cutter are continuous, and the advance of the work towards the cutter is regular.
- Chip removal presents no problem, and the cutting fluid is easily applied to both cutter and work.

Metal may be removed at a fast rate by this process using coarse feeds, deep cuts, and moderate speeds.

Drilling

Figure 1-6 The drilling process

The drilling process is illustrated in figs. 1-6 and 1-7. It should be noted that:

1. The cutting tool (drill) revolves as it feeds into the work.
2. Drilling is a continuous operation, i.e., the cutting edges are in continuous contact with the work.
3. The cutting edges are buried in the work.
4. The cuttings or chips do not readily escape from the surface being cut.
5. Drilling a deep hole involves problems of cooling and lubricating the drill and work.
6. The drilling process is comparatively severe, and the selection of cutting speeds and feeds require careful consideration.

Figure 1-7 Drilling stainless steel (Photo courtesy of Avesta Welding)

CHARACTERISTIC PROPERTIES OF TOOL MATERIALS

The materials from which cutting tools are made have certain essential characteristics:

- Resistance to wear
- Hardness
- Toughness
- Ability to conduct heat
- Capacity to retain cutting properties at high temperatures.

The degree to which the material possesses these qualities determines its suitability for doing a particular job.

CLASSIFICATION OF TOOL MATERIALS

To meet the normal requirements of workshop practice, tool steels and alloys have been developed, which may be classified in three main groups:

- Carbon Steels.
- High Speed Steels
- Cemented Carbides.

Applications

- **Carbon Steel Tools**
  The cutting qualities of carbon steels vary with their carbon content. A steel of high carbon content has a high factor of resistance to wear. The hardness is also increased, but this is offset by an increase in brittleness. Carbon steels do not retain their hardness at high temperatures. Therefore, cutting tools of carbon steel are suitable only for conditions of light duty, low temperature, and absence of shock.
High Speed Steel Tools
High speed steels hold their toughness and hardness at high temperature, and offer resistance to wear even at red heat. Such a high temperature is caused by the increased rate at which metal is removed in comparison to the rate of removal by carbon steel tools. Where high speed steel tools are employed and reach high temperatures, the tool dimensions will be a factor in the life of the tool. It should be of sufficient cross-sectional area and length as to conduct the heat generated during the cutting process away from the cutting edge. For heavy duty, high temperature, and conditions of shock, high speed steels are the most appropriate choice. The main high speed steel alloys are Tungsten, Cobalt, and Molybdenum.

Cemented Carbide Tools
Cemented carbides possess properties of hardness and wear resistance, greater than that of high speed steels. They are available as tips brazed on to a carbon steel shank, (fig. 1-8), or as throw away inserts clamped in suitable toolholders (fig. 1-9).

Considerably higher cutting speeds than those of high speed steels are used, resulting in an increase in the rate of production. The sharp cutting edge is also maintained for a much longer period. Carbide tipped tools will cut hard material, where high speed steel would fail.

Care must be taken in the application of carbide tips, owing to their brittleness and low transverse strength.

Carbide tipped tools function best under conditions of:
- Full tool support
- Rigidity
- Continuity of cut
- Constant load.

WHAT IS CEMENTED CARBIDE?
Cemented carbide is a product of a powder metallurgy process. In the process particles of hard material such as tungsten carbide, titanium carbide, tantalum carbide and niobium carbide are sintered together with cobalt. The carbides give the hardness and the cobalt gives the toughness.

The majority of cemented carbides used today are coated grades. These have a core of tough cemented carbide, and are coated with one or more thin coats of very hard material. A typical coated cemented carbide insert, has two coats - a layer of pure titanium carbide 6μm (0.006mm thick) and a layer of aluminium oxide 1μm (0.001 mm thick).

The cemented carbide inserts with a gold colour have a coating of titanium nitride. The coated grades of cemented carbide give you a tool that is tough and hard because they have a tough core and a hard coating. Coated grades of cemented carbide cannot be sharpened because the hard coat will be ground away, leaving the softer core.

SELECTING CEMENTED CARBIDE INSERTS
The majority of cemented carbide tools used in industry today are of the indexable or disposable insert type. The brazed on tip types are also available, but rarely used as they have two main disadvantages:
- they are not available in coated grades.
- it takes a lot longer to sharpen them than to simply change an insert.

So we will only look at the disposable insert type.

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CHOOSING THE RIGHT TYPE OF CEMENTED CARBIDE
To get the maximum life from a tool you must choose the right grade. The grade of cemented carbide you choose depends of two things:

1. The type of material you are cutting.
2. The working conditions under which you are using it.

There is an international code for the material type and working conditions ISO 1832, sometimes called the PMK code. This code allows you to select the correct grade of carbide for a given application. Manufacturers make their