Chapter 4
Problem Definition

Machinability can be defined as "the relative ease with which a metal can be machined by an appropriate cutting tool" (16). There are a number of critera typically used to assess machinability in a given operation, including:

Tool life. A long tool life is desirable;

Surface finish. The workpiece finish must satisfy the design specification;

Dimensional stability. Workpart dimensional tolerance must be achieved;

Cutting force, power consumption, and temperatures. Good machinability implies low forces, power, and temperatures in the operation;

Economic criteria, such as minimum cost, maximum profit rate, or maximum production rate; and, so on.

To obtain these desirable performance criteria, the machining operation must be carried out using the appropriate machine, cutting tool, cutting speed, feed rate, and depth of cut. The machining is specified on the route sheet for the part by the process planner. The selection of the cutting tool must be based on such factors as: type of operation (turning, milling, etc.); whether a roughing or finishing operation is used; work material type; and, the experience of the individual who selects the tool. Specification of cutting tool includes a definition of both geometry and tool material.

Finally, after the machine tool and cutting tool have been selected, success in the operation depends on the proper choise of cutting conditions (cutting speed, feed rate, and depth of cut). Depth of cut is usually predetermined by the workpiece geometry and operation sequence. Therefore, the problem reduces to one of determining the proper cutting speed and feed rate combination.

The tool life depends, of course, on the conditions under which the tool is used. By changing the cutting conditions, it is possible to alter the life of a given tool. Changing these conditions, however, change the tool life which also changes the time it takes to perform a machining operation. For example, decreasing the cutting speed of the tool normally increases the tool life but at the same time increases the time needed to machine a given part. By establishing the cost of the tool and the cost of machining time, it is then possible to economically optimize the cutting situation. The cost computations of the machining operations are based on the traditional concept in machining economics, where the machining cost per workpiece is composed of elements as given in the Eq.4.1:

$$MCPW = MR*(TTFT+WCT)+(MR*TCT+TC)/N \qquad (4.1)$$

where MCPW = Machining cost per workpiece (baht/piece);

MR = Machining operation rate (baht/min);

TTFT = Total tool feed time (min/workpiece);

WCT = Work changing time (min/worpiece);

TCT = Tool changing time (min/cutting edge);

TC = Tool cost per cutting edge (baht/cutting edge);

and, N = Number of workpieces per cutting edge (workpiece/ cutting edge).

In particular, total tool feed time consists of before cut tool carried time, before cut tool feed time,actual machining time, after cut tool feed time, and after cut tool carried time. However, before and after cut tool carried time are constant times which depend on the machining operation. In NC turning machines, the programmers usually use the fastest capacity. Therefore, the total tool feed time considered is reduced to the actual machining time, the before cut tool feed time, and the after cut tool feed time, which depend on the cutting conditions (cutting speed and feed rate) given in the Eq.4.2:

$$TTFT = 3.142*D*(L+L_1) / 1000*F*V \qquad (4.2)$$

where D = Workpiece diameter (mm);

L = Workpiece length (mm);

L_1 = Before and after cut length (mm);

F = Feed rate (mm/rev); and,

V = Cutting speed (m/min).

For the number of workpieces per cutting edge, it is usually true that one cutting edge will last longer than a single workpiece. Therefore, the number of workpieces per cutting edge will have a value greater than 1. There are two alternative methods to determine the number of workpieces per cutting edge:

1. Exact method: Count the number of workpieces until tool change or tool failure.

2. Approximate method: Number of workpieces per cutting edge can be approximated by means of the fraction of the tool

used per workpiece.

After the number of workpieces per cutting edge is determined, the tool life can be calculated by the Eq. 4.3:

$$TL = N*MT \tag{4.3}$$

where TL = Tool life (min);

MT = Actual machining time (min/workpiece);

and, MT = 3.142*D*L/1000*F*V. (4.4)

$$MT = 3.142*D*L/1000*F*V. \tag{4.4}$$

The cutting conditions optimization procedure uses an index of performance to guide the search. The machining cost of the Eq.4.1 can be applied as the index of performance. Cutting speed and feed rate are the independent variables of interest in the machining process. The index of performance can be viewed as a response surface with the cutting speed and feed rate as the coordinate axes. The procedure is based on "Evolution Operation; EVOP", and to find quickly optimum cutting condition suggests the procedure of the "Optimum Gradient Method".

Research objectives:

1. To study, experiment, and determine flank wear of a cutting tool.

2. To study, calculate, and determine tool life of a cutting tool.

3. To study, experiment, and determine optimum cutting conditions of carbide and coated cutting tools using evolution by the optimum gradient method.

4. To compare the machining cost of the optimum cutting conditions between carbide and coated cutting tools.

Scope of research

1. Type of machining operation

Process type: NC turning machine

Cutting type: rough cut

2. Tool material types

carbide cutting tool: TNMG 160404-R/LC

coated cutting tool: TNMG 160404-27

3. Workpiece material type : steel AISI 1045

4. Operation parameters : cutting speed and feed rate

5. Job specifications

Workpiece length: 170 mm

Before and after cut length: 5 mm

Workpiece diameter: 50 mm

Tool changing time: 40 s or 0.67 min

Work changing time: 15 s or 0.25 min

6. Cost factors

Machining operation rate: 10.5 baht/min

Insert price of carbide tool: 133 baht/piece

Insert price of coated tool: 171 baht/piece

Total cutting edges on insert tool: 6 cutting edges/piece

7. Wear level at tool failure

Wear level of carbide tool : 0.375 mm

Wear level of coated tool : 0.350 mm

These wear levels were tested in laboratory (5).

8. Cutting conditions

Depth of cut: 2 mm

Starting condition

Cutting speed: 160 m/min

Feed rate: 0.2 mm/rev

9. Gradient specifications

Different cutting speed: 10 m/min

Different feed rate: 0.04 mm/rev

Step move: 1

10. Stopping criteria

The search will be continued until the optimum is reached. At the optimum cutting conditions, the gradients have approximated about zero or machining cost per workpiece has the least value of the test points.