# Chapter 1
# Introduction

With large amounts of capital being tied up in the metal cutting equipment, more attention has been focused on the economics of operating such equipment. Presently, most of the methods used in finding the most economical metal cutting conditions, disregard the development of Adaptive Control (AC).

In the machine tool control systems, AC is mainly divided into two classes: Adaptive Control Constraint (ACC) and Adaptive Control Optimization (ACO). ACC control systems involve cutting conditions that are always subject to limits provided by the machine tool, tool and/or workpiece. ACO systems are another type of control systems. With these systems, cutting conditions are determined by using a performance index based on production economy.

The need for today's complex manufacturing systems and wage structure requires the use of machine tools operated by means of an adaptively controlled system. Adaptive control provides a continuous monitoring of performance and adjusts the system variables in order to approach the optimum conditions for chosen performance objectives. There are basically three functions which determine an adaptively controlled system shown in Fig. 1.1:

1. Identification;
2. Calculation and decision; and,
3. Modification.

The identification measures the actual state of the process performance without taking its quality into consideration. In the second function, the received information is the basis for the calculation comparing the actual state of preformance with a desired one. The decisions can be directed toward minimum or maximum process conditions or any required values between these extreme points. The modification function is the corrective action needed to adaptively control the process. The identification function which measures the actual performance relies mainly on sensing devices to monitor some of the process variables such as the cutting forces, power consumption, tool defection, tool wear, and so on.

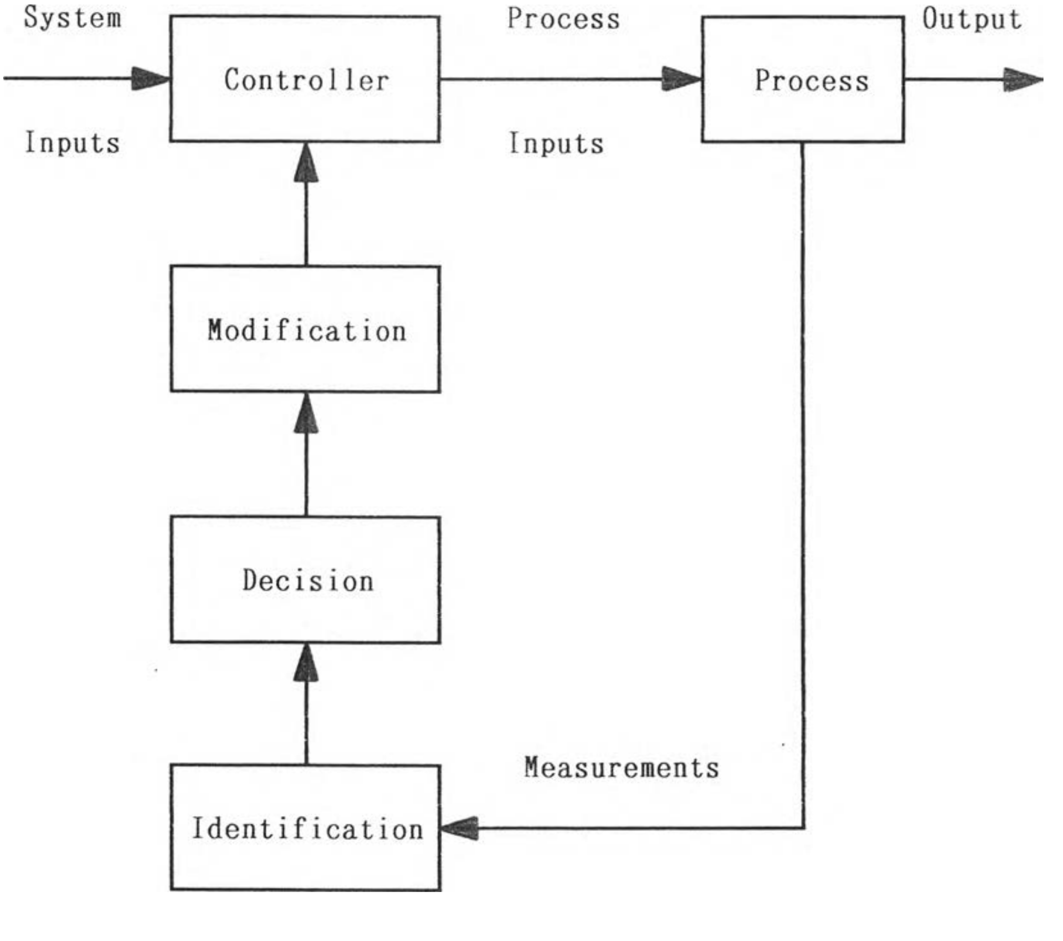


Fig. 1.1 Structure of adaptive control (1)

Adaptive control units, which have been marketed, are mainly based on ACC systems. To develop ACO systems, there exists two difficulties, control strategy and sensor technology. These problems have never been satisfactorily solved.

In an ACO system developed by Centner and Idelsohn (1), it was necessary to detect the tool wear rate. Takeyama, Sekiguchi, and Takada (2) developed a system which selected the optimum cutting conditions by in-process measurement of cutting forces.

The optimum cutting conditions can be determined by means of a performance index such as machining cost or production rate, and Taylor's tool life equation (3) as in the following equation:

$$V F^{a} T^{n} = C \tag{1.1}$$

where V = cutting speed (m/min);

F = feed rate (mm/rev);

T = tool life (min);

a = exponent of feed rate;

n = exponent of tool life; and,

C = constant in tool life equation.

Namely, if the parameters included in the equation 1.1 are known exactly, it is possible to select the optimum cutting conditions. These parameters, however, take different values for various combinations of tool and workpiece. Therefore, many measurements are necessary to determine these values.

Although abundant tool life data have been reported in various publications, such information is not always applicable for a particular job or specially for new work materials or tool materials. Therefore, the tool life equation has to be determined or estimated by some means for such specific cases. The usual practice to obtain a tool life relationship is to conduct an elaborate tool life test at a machinability laboratory under pre-designed test conditions and tool life criteria which is usually based upon either a predetermined flank wear limit or crater wear. These tool life tests are time consuming and expensive. Also there is no guarantee that these tool life data, under a laboratory test condition, can be readily applied to actual production operations with a machine tool in a workshop. As a matter of fact, unless the tool life data is reasonably well tested and adjusted for practical applications subject to various restrictions, it is a common experience to find many discrepancies when the laboratory tested tool life data is directly applied to shop production operations.

To improve the possible discrepancy of such laboratory tested tool life data, Hitomi (4) proposed a method called "Optimum Seeking Machining". His Method was used to estimate the tool life parameters with production data available from actual workshop operations.

Yonetsu, Inasaki, and Kijima (5) applied a recursive estimation method to estimate parameters included in Taylor's tool life equation and extended the control method to adaptive control by application of the variance perturbation method.

For a concept refining the techniques with a suitable computer program, the method called "Optimum Gradient Method" (6) is proposed. The advantage of the optimum gradient method is that in most problems it will be necessary to make exporation moves to find the gradient after every step move based on "Evolutionary

Operation Method". Since there is a time and cost associated with each exploratory, the optimum gradient method can be less time consuming and less expensive to operate in most search problems.