Adaptive Control Machining Systems

- For a machining operation, the term 'adaptive control' denotes a control system that measures certain output process variables and uses these to control speed / feed.
- Some of the process variables that have been used in adaptive control machining systems include spindle deflection or force, torque, cutting temp, vibration amplitude.

Where to use adaptive control

- NC (both DNC & CNC) reduces the non-productive time in a machining operation. This time savings is acheived by reducing such elements as workpiece handling time, tool changes, etc.
- Although NC has a significant effect on downtime, it can do very less to reduce the in-process time. The in-process time can be reduced by the use of adaptive control.

- The NC guides the sequence of tool positions or the path of the tool during machining. The adaptive control determines the proper speeds / feeds during machining as a fun of variations in such factors as work-material hardness, width / depth of cut, air gaps in the part geometry & so on.

Situations where AC is beneficially applied:

(1) There are significant sources of variability in the job for which adaptive control can compensate. AC adapts feed / speed to these variable conditions.

(2) The typical jobs are ones involving steel, titanium, and high strength alloys.

(3) The cost of operating the m/c tool is high. The high operational cost results mainly from the high investment in equipment.

Sources of variability in machining

The greater the variability, the more suitable the process will be for using adaptive control.

(1) Variable geometry of cut in the form of changing depth/ width of cut :-

In these cases, feed rate is usually adjusted to compensate for the variability.
This type of variability is encountered in profile milling or contouring operations.

(2) Variable workpiece hardness and variable machinability :-

When hard spots or other areas of difficulty are encountered in the W/P, either speed or feed is reduced to avoid premature failure of the tool.

(3) Variable workpiece rigidity :-

If the workpiece deflects as a result of insufficient rigidity in the set up, the feed rate must be reduced to maintain accuracy in the process.

(4) Tool wear :-

It has been observed as the tool begins to dull, the cutting forces increase. The adaptive controller will respond to tool dulling by reducing the feed rate.

(5) Air gaps during cutting :-

- The W/P geometry may contain shaped sections where no machining needs to be performed.
- If the tool were to continue feeding through these air-gaps at the same rate, time would be lost. So feed rate is increased by 2 or 3 times, when air gaps are encountered.

Two types of adaptive control

(1) Adaptive control optimization (ACO)

(2) Adaptive Control Constraint (ACC)

Adaptive control optimization (ACO)

- In this form of AC, a performance index is specified for the system.
- This performance index (PI) is a measure of overall process performance such as prodⁿ rate or cost/vol of metal removed.
- The objective of Adaptive Controller is to optimize the performance index by manipulating speed/feed in the operation.
- Most ACO systems attemp to maximize the ratio of material removal rate to tool wear rate.

$$PI = \text{a fun}^n \text{ of } \frac{MRR}{TWR}$$

where, MRR → Material removal rate
TWR → Tool wear rate

- The trouble with 'PI' is TWR cannot be measured on-line with today's measurement technology. Hence, IP cannot be monitored during the process.
- Eventually, sensors will be developed to a level at

which the true process can be measured on-line.

- However, because of the sensor problems encountered in the design of ACO systems, nearly all adaptive control machining is of the 2nd type, adaptive control constraint systems.

Adaptive Control Constraint :- (ACC)

- The production AC Systems utilize constraint limits imposed on certain measured process variables.
- Accordingly, these are called adaptive control constraint (ACC) systems.
- The objective in these systems is to manipulate feed/speed so that these measured process variables are maintained at or below their constraint limit values.

Operation of an ACC System

- Adaptive Controller (AC) are attached to an NC m/c tool.

Because (1) NC m/c tools possess the required servomotors on the table axes to accept automatic control.

(2) The usual kinds of machining jobs for which NC is used possess the sources of variability that makes AC feasible.

- The adaptive control package consists of a combination of hardware & software components.

The typical hardware components are :-

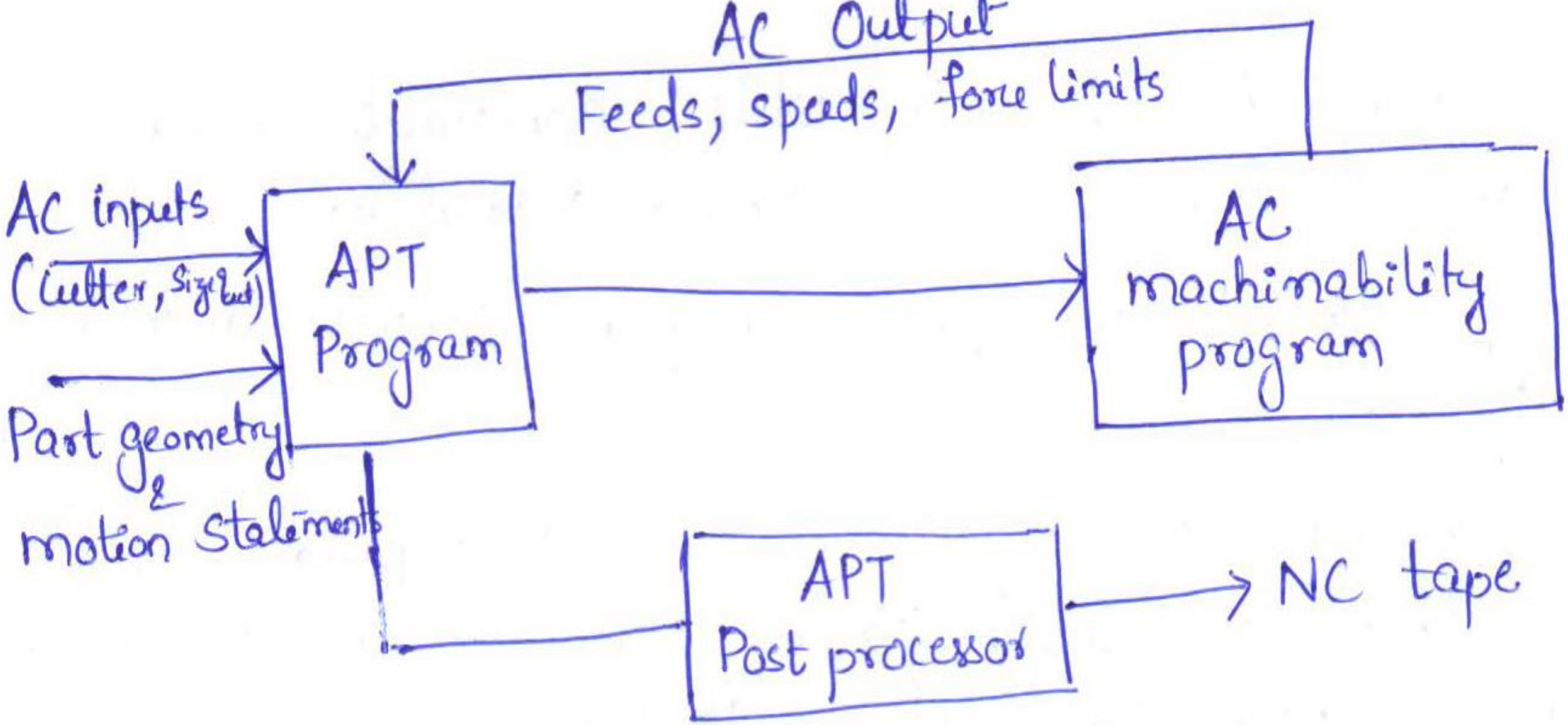
(1) Sensors mounted on the spindle to measure cutter deflection (force).

(2) Sensors to measure spindle motor current. This is used to provide an indication of power consumption.

(3) Control unit & display panel to operate the sys

(4) Interface hardware to connect the AC System to the existing NC or CNC control unit.

- The Software in the AC package Consists of a machinability program which can be called as an APT MACRO statement.



Relationship of AC Software to APT program

- The inputs to the APT program are :- cutter size & geometry, work material hardness, size of cut and m/c tool characteristics.

- From calculations based on these parameters, the outputs from the program are feed rates, spindle speeds & cutter force limits for each section of the cut.

- The objective in these computations is to determine cutting conditions which will maximize metal removal rates. The NC part programmer have to specify feeds & speeds for the machining job.

- With adaptive control, these conditions are computed by the machinability program based on the input data supplied by the part programmer.

- In machining, the AC system operates at the force value calculated for the particular cutter & m/c tool spindle.

- Maximum production rates are obtained by running the m/c at the highest feed rate consistent with this force level.

- Since force is dependent on factors such as depth of cut, width of cut, the end result of the control action is to maximize metal removal rates within the limitations imposed by existing cutting conditions.

Benefits of Adaptive Control machining

(1) Increased production rates:-

Productivity improvement was the motivating force behind the development of adpative control machining. On-line adjustments to allow for variations in work geometry, material and tool wear provide the m/c with the capability to

-increased production rates
-increased tool life and tool protections
-greater part protections
-less operator intervention
-easier part programming
-reduced break downs

Problems with AC systems-
It is true that AC sys may not be suitable for all situations. Some problems are as-
-complexity of sys
-sys stability
-cost
-sensor problem
-definition of index of performance etc.