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THE ADAPTIVE CONTROL SYSTEM USING TO HIGH SPEED MACHINES

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ABSTRACT

This paper has presented some solutions for improving dynamic performance of high speed machining by using adaptive control systems. The high speed machines (HSM) are widely used in manufacturing for them higher performance. HSM is applied to a large range of metallic and non-metallic materials, including the production of components with specific surface topography requirements and hard materials machining. The main problems for HSM are occurred high vibrations which can limit the machining process and workpiece quality. For preventing these inconveniences it's necessary to be used an adaptive control system which is monitoring the machining process, in special cutting forces and other dynamic cutting parameters of machines.

Keywords: adaptive control, controller, feederate.

1. INTRODUCTION

The applications of high speed machine are known a large application in machining hard materials and in automotive and aerospace industry. Since recently, metals up hardness 45HRC were considered too hard to cut at high speed, which due to the soft steel parts would be roughed and semifinised and after that to come back from hardening details and finished by an enable machine tool or handling. These operations are done at slow speed to avoid machine from crashing and breaking tools. To cutting hardened steels at high speed its necessary have a machine tool, control and tooling that are up to the task, combined with well program software that assured the stresses a tool undergoes at high speed. Potential benefits of high feed machining strategies of manufactures include: ability to achieve high metal removal rate in roughing with lighter duty, more affordable machines, more reliable processing with due to improve tool life, and using components machined nearer to net shape during cutting process.

Suddenly, high speed machining (HSM) is accomplished with small axial depths of cut to realize a good surface finished and avoided damages of cutter and workpiece. Feed rate optimization software can be obtained by a better efficiency with grater axial depths at high feed rates of HSM and protected cutter. The software can detects conditions where the chip load is greater and adjusting the feed rate at a good level, and that came back the machine to the higher feed rate when the chip load is permitted.

At using HSM is required integration intelligent electronics parts which can avoid perturbations during machining process, in special self-vibrations with direct effect about quality of process. Systems that is enable automatically adjusting, correcting or even optimizing cutting speed, feed rate, etc., with given constrains are known as adaptive control system. The sensors and sensing techniques had used in process control of machine tools depending on the monitoring object, which made as sensors are being divided into five main categories: surface texture sensors, surface integrity sensors, dimensional accuracy sensors, tool of condition sensors and chatter detection.

The process control strategies [4,5] include Adaptive Control with Optimization (ACO), Adaptive Control with Constrains (ACC) and Geometric Adaptive Control (GAC). In ACO systems, a performance index such as time or effort is minimized. ACC systems manipulate process parameters in real time to maintain a certain variable, such as force or power, at of constrain value typically in roughing operations. Finally GAC systems seek to maximize the quality of finishing operations in the face of structural deflexions and tool wear.

2. ADAPTIVE CONTROL SYSTEM

Adaptive control technology representing a real alternative to software optimization, by sensing cutting conditions and tuning feed rates in real time, being connected directly to a CNC machine tools. All of these mean more investment because all adaptive controls are setup individually installed after machines and controls for a correctly operating with any electro-mechanical system.

The tuning feed rates with adaptive controls is got by feedback they received from spindle drive motor that realized a constant load on spindle drive being similar with a rigid cutter which is taken a greater load.

An adaptive control model of milling process is fixed gain controllers for force control with best results if the geometry variation of cutting process is small [4,5]. For large changes in machining process is required using gain to tuning controller parameters in concordance with obtaining of force regulation. This model has presented the performance of two parameters adaptive control outlines through experimentation by using three axes OAC machining center. First parameter is a variable gain PI controller proposed by Stute [7], and second one proposed by Watanabe and Iwai [8], both of them didn't require an explicit process identification.

The PI controller with tuning gain item [4] is fit by using the past value of commanded feed drive velocity as inverse measure of cutting process gain (fig.1).

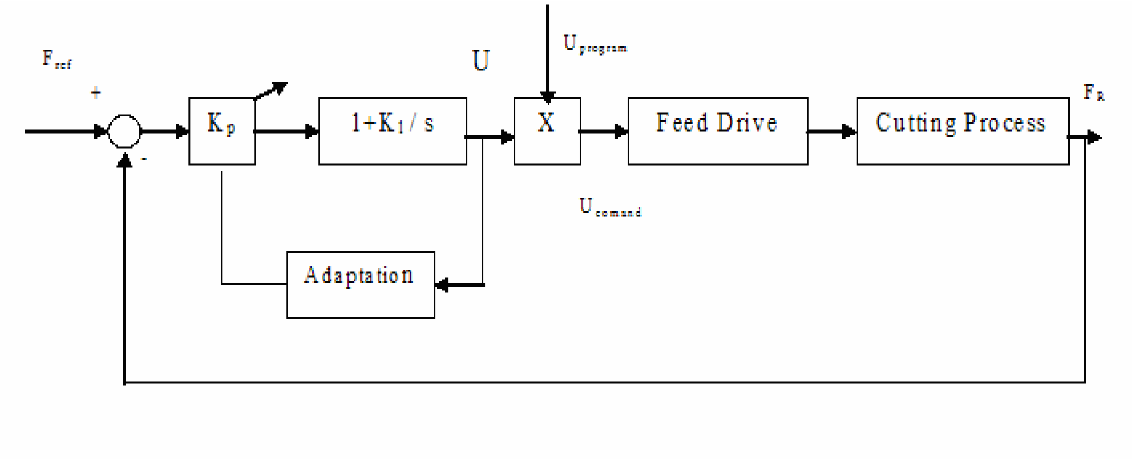

Figure 1. Tuning PI adaptive control with programmed federate.

The peak force is controlled instead of the principal force. This controller is similar to a PI controller, except that the gain-K_p is adjustable as:

$$K_p(k) = \frac{C_0 U(k-1)}{F_{ref}} \tag{1}$$

where: *U(k-1)*-is the delayed controller output feedrate percentage with values between 0 to 2. This percentage is multiplied by the program feedrate due to command feedrate that is get to the drive servos. The implementer digitally controller is done using for integration a trapezoidal approximation, obtaining the control equation:

$$u(k) = C_0 u(k-1)\left[1 - \frac{u(k-2)}{u(k-1)} + \left(\frac{u(k-2)}{u(k-1)}\right)\left(\frac{F(k-1)}{F_{ref}}\right) + K_1 T_s - (1 + K_I T_s)\frac{F(k)}{F_{ref}} + \frac{1}{C_0}\right] \tag{2}$$

The constant-C_0 and the integral gain item-K_1 are calculus from cutting tests asssured a stability with force control system. The gain increase reduces the force error and hence the controller output-*U(k)*.

The sampling interval-T_S are selected to be the same with delay tooth period of cutter-T assured a fast response. This stability assured by this controller isn't viable for nonlinear systems which required an expensive compute system to control the changes of milling process.

The second parameter of adaptive control proposed by Watanabe and Iwai [4] which used an adaptive peak force controller, where instead an indirect inverse measure of cutting process gain is computed past values ratio of mean drive velocity and peak cutting force going at obtaining commanded feed drive velocity (fig.2).

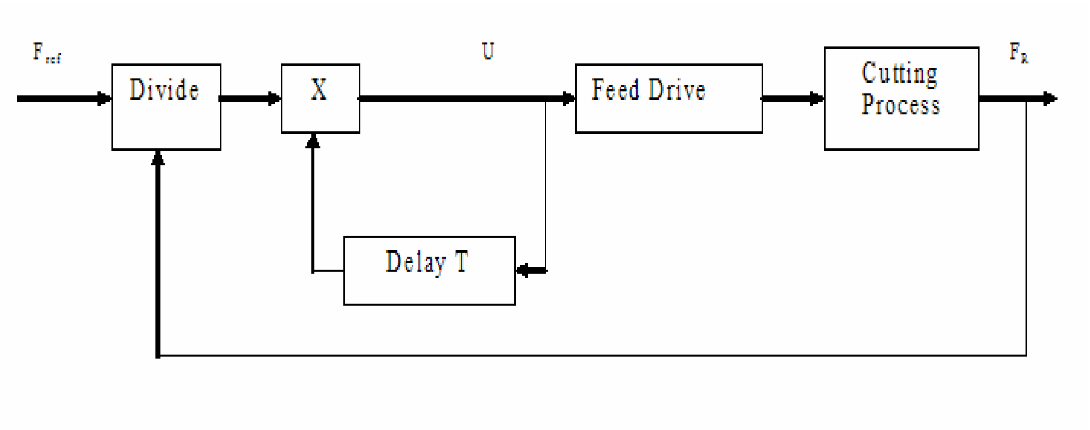

Figure 2. Divisional adaptive controller.

Sampling the cutting force every millisecond over the entire control-sampling interval and founding the largest force is get the peak value-F_R. Velocity of command feed drive is given by:

$$U(k) = \frac{F_{ref}U(k-1)}{F_R(k)} \qquad (3)$$

The controller sampling interval-T_s is set equal to T. This reduce problems caused by interrupted cutting by the cutter flutes and the resulting force variation, which due to cutter runout are handled by finding the peak resultant force over one tool revolution.

A real steep in development of open architecture controller [6] has been realized by its implementation at a high speed milling machine with a Mazac CNC. This implementation at CNC machine has assured by a PC-based open architecture controller, which including: adaptive force control during milling process, strong control of high speed milling machine, multi-axis contouring control and linear motor control (fig.3).

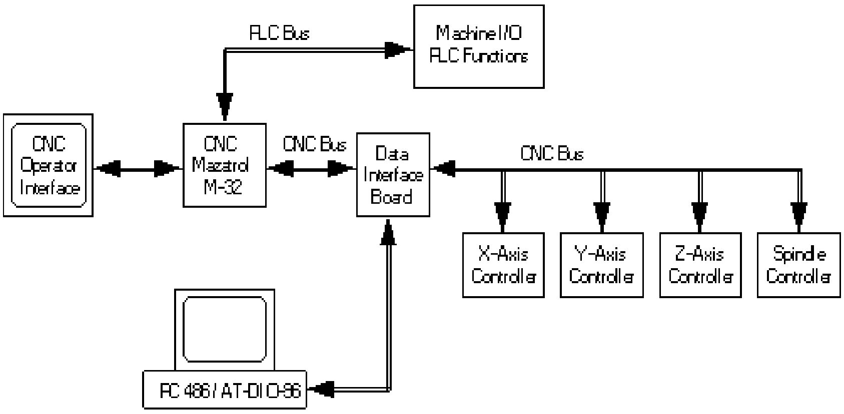

Figure 3. Open architecture controller at HSM with Mazac CNC.

In present, it's a tendency of change the control concepts of Proportional-Integral-Derivative (PID) with Model Free Adaptive (MFA) control for high speeds, in special for nonlinear process [2].

MFA controllers had solved some problems as: single input-single output (SISO) MFA replaced PID controllers by elimination of controller manual tuning; control nonlinear process and reached control conditions in minim time; multiple inputs-multiple outputs (MIMO) MFA for control multivariable process.

For example, MFA controller used in a single loop (fig.4) has proposed to get an output-u(t) to force the variable process-*y(t)* attended given trajectory of its setpoint-*r(t)* under variation of setpoint, disturbances and dynamic process, minimize the error-*e(t)* of system.

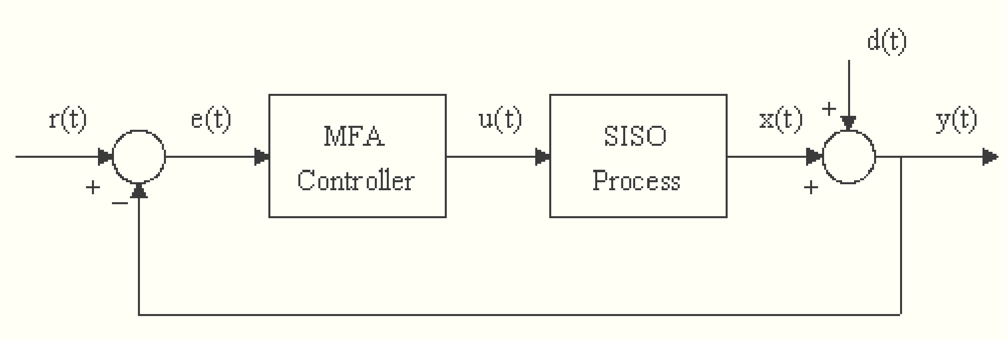

Figure 4. Single-loop MFA controls system.

MFA controller is an intelligent controller, which due to neural network based MFA controller is remembered a portion of data process assured information for dynamic process.

3. CONCLUSIONS

This paper has presented certain solution used for improving dynamic machining process of HSM by using active control technique. The active control has changed dynamics of machine tools as chatter instabilities occurred at much high depths of cut by controlling cutting forces and feederates with using controllers. These controllers are enabled to estimate cutting process parameters and altering cutting force by commanded a new spindle speed or feerate reference to reduce chatter.

The force control technology is widely used in HSM became a real impact about economic machining process and tools by improving productivity and quality parts.

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