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TOOL MONITORING IN DNC SYSTEMS UNDER QNX OPERATION SYSTEM

Summary. The paper presents tool condition monitoring system for machining center HP15M with CNC SINUMERIK 850M controller working in environment of DNC system, under real-time operating system QNX.

1. Introduction

Taking into consideration the large popularity of SINUMERIK 800 SIEMENS family of controllers and aiming to spread, as wide as possible, research results on the tool monitoring system (TMS), its version adapted to co-operate with SINUMERIK 850M controller in DNC control system of machining center has been developed.

2. Behaviors supervised by TMS

In the presented solution two basic operation modes are discerned, similarly as in [1], [2], i.e:

- threshold mode (also named alarm level mode) (Fig.1),
- pattern recognition mode (Fig.2).

Moreover, the TMS makes it possible to disclose abnormalities in automated machining cycles, such as:

- absence of tool in spindle or abnormal offsets values in the program,
- absence of work-piece on the table or overstepped tolerance in semi-manufactured product.

In the threshold mode, threshold values I_{pa} of main drive current intake are determined automatically on base of the relation:

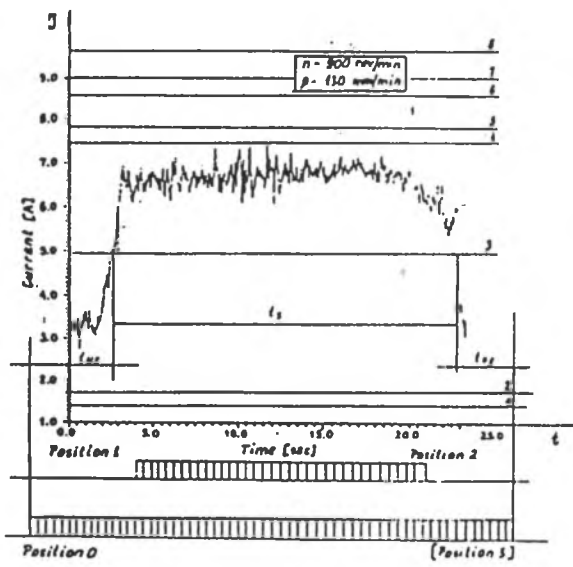


Fig.1. Illustration of the TMS-threshold mode

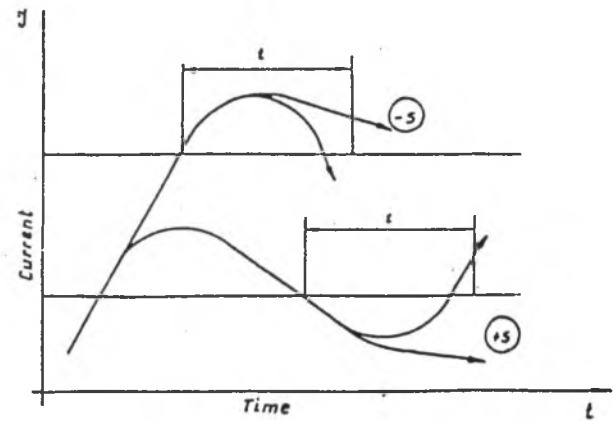


Fig.2. Interpretation of lower and upper limits crossing in pattern recognition mode

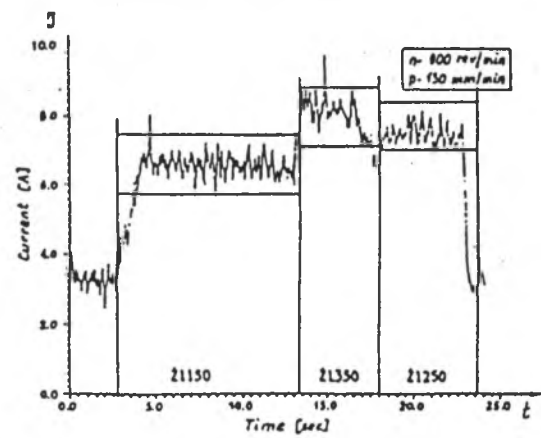


Fig.3. Illustration of change pattern recognition mode of the TMS

$$I_{pn} = I_o + (I_c - i_o) * a_{pn} \quad (1)$$

where:

- I_{pn} - treshold value of current for $n=1, 2, \dots, 8$,
- I_o - mean value of current intake at idle run (tare),
- I_c - mean value of current intake at drilling with sharp tool,
- a_{pn} - coefficient.

In the solution for CNC SINUMERIK 850M controller, possibility of taring the monitoring system has been introduced, thus enabling it to make allowances for idle run current intake changes due to machine tool thermic stabilization or due to network voltage fluctuations.

When giving different values to the treshold coefficient a_{pn} adequate treshold values with their assigned functions are obtained.

- Treshold 1 - detection of tool and workpiece contact,
- Treshold 2 - coolant turned on/off,
- Treshold 3,4,5 - disclosing wear of cutting edge,
- Treshold 6,7 - standing by,
- Treshold 8 - state of break-down due to machine moving parts collision.

In the presented solution, tool breakage is detected by way of testing current intake signal sudden drop, with three criteria being simultaneously fulfilled:

- signal exceeds upper treshold I_{ug} ,
- signal falls under lower treshold I_{ul} , below the idle run current value,
- signal fall time t_f is shorter than a pre-set value.

Signal treshold values in the treshold mode at through-drilling in function of cutting time are shown in Fig.1. In the pattern recognition mode upper and lower signal of admissible change tolerance are determined:

$$I_{jmin} = (1 - a_T) * I_{sj}$$

$$I_{jmax} = (1 + a_T) * I_{sj}$$

where:

- I_{sj} - mean signal value in the measuring point indexed "j",
- a_T - coefficient.

In that operation mode, when growing signal exceeds the upper limit, spindle rotation speed gets diminished by determined percentage of programmed value (S); when decreasing signal falls under the lower limit, spindle rotation speed gets increased (Fig.2). An example of using that operation mode is shown on Fig.3 against background of current intake signal changes arising at drilling a pile of grey cast iron plates with variable hardness.

3. TMS programming in CNC SINUMERIK controller version

Several M functions are used in TMS programming for CNC SINUMERIK 850M controller.

They are:

M73 - monitoring in treshold operating mode.

Co-ordinates of characteristic Z-axis points are introduced into registers R120, R121, R122, R123, i.e.:

R120 - co-ordinate Z_0 before tool entry into work-piece,

R121 - co-ordinate Z_1 after tool entry into work-piece,

R122 - co-ordinate Z_2 before tool passing through work-piece,

R123 - co-ordinate Z_3 after tool passing through work-piece;

M74 - monitoring in pattern recognition mode.

Co-ordinates of characteristic Z-axis points are introduced into registers from R130 to R145:

R130 - co-ordinate Z_0 before tool entry into work-piece,

R131 to R_n - co-ordinates of points selected on drilling depth (Z_j for $j=1, 2, \dots, n$),

R_{n+1} - co-ordinates Z_{n+1} after tool passing through work-piece;

M63 - current value measurement in treshold mode (learning).

Measurement is effected in segment defined by the co-ordinate values stored in registers (R121, R122);

M64 - current value measurement in pattern recognition mode.

Measurement is effected in segment defined by pairs of the co-ordinate values stored in registers (R131, R132), (R132, R133), ..., (R $_n-1$, R $_n$);

M78 - taring, i.e. idle run current value measurement.

CO-ordinates beginning and ending tare interval are introduced into two registers (R120, R121);

M60 - permission to investigate base treshold.

Those functions are compulsory only in the block where they occur. More than one function M may occur in one block, e.g. M60, M78, M63. Taring function M78 may accompany in a block one of the functions M63, M64, M73, M74. It may be programmed in another block as well, e.g. during positioning. Taring need not occur in every monitored block but it should be done after tool change, after spindle rotating speed change and as working time goes on, so as to compensate temperature influenced resistance of motion or network voltage fluctuations.

4. Monitoring operation applied to HP15M machining center

The monitor communicates with operator by means of four windows, i.e. main window, form editor window, behavior monitoring window, and interactive parameter correction window.

Window consists of two or three subwindows in which the adequate monitor task is effected (e.g. form editor) or which contains HELP for operator to realize his task.

Operator attends TMS when using menu. Selection of an option from menu results in either going over to another window or effecting a function within the same window. Going over to the behavior monitoring window occurs with the moment of starting machining program and reversion to the former window - after switching over CNC to manual work mode.

Behavior monitoring window is shown on Fig.4. Thee window gets open when the program receives from CNC SINUMERIK 850M signal of starting machining program. The window remains open up to program realization completion or to stop of its course.

Interactive parameter correction window is shown on Fig.5; it serves to interactive modification of signal set of monitoring parameters. Window is accessible:

- from the form editor during manual work of CNC SINUMERIK 850M controller,
- from the behavior monitoring window, i.e. when the machining program is carried out.

Operator may stop program realization, correct coefficient values against background of spindle main drive current intake signal and then resume the program realization. In the course of editing operator has to his disposal several key buttons which are displayed in the subwindow HELP.

5. TMS exploitation in DNC environment

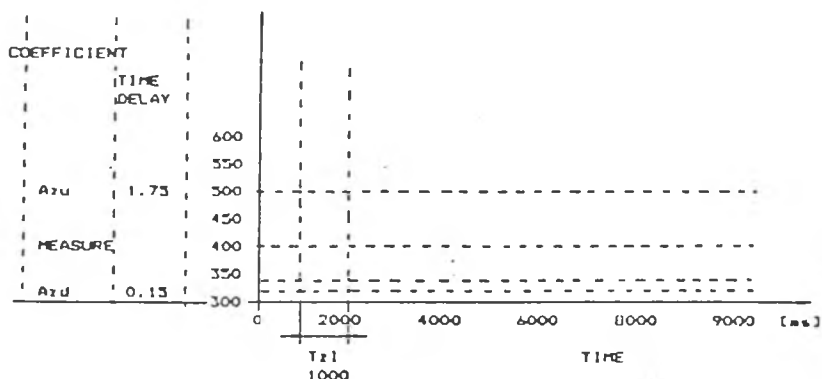
To exploit effectively the monitor in its version intended for CNC SINUMERIK 850M controller several conditions must be fulfilled. Large files of coefficients values corrected in machining process must be stored, as they are valuable information obtained from machining process. Considering the storage of those data is not possible in CNC machine controller, there is a need of creating for TMS an environment making possible efficient management of necessary data files. Therefore works at TMS have been joined with works at DNC control whose structure is shown on Fig.6.

In CAD/CAM computer under operating system DOS, system AutoCAD and interactive part programming system KSPF have been installed. Machining program (POT) may be written on base of geometric data imported from AutoCAD over DXF format or by means of interactive part programming system in KSP language. Taking advantage of KSPF system properties technologist prepares also programs of TMS functions which are introduced into machining program (POT) by part programming system.

DNC system software is installed in DNC computer. That software assures communications between DNC computer and CNC SINUMERIK 850M controllers in machining center and between DNC computer and TMS monitors too. Co-operations of CNC SINUMERIK 850M controller, TMS monitor and DNC computer is under realtime network operating system QNX of the company QNX Software Systems Ltd. Machining program (POT) transmission from DNC computer to

INDICATOR		# BLOCK	- 1000						
		# MACROPROGRAM	- 100						
		# TOOL	- 12						
MONITORING MODE: M63 - MEASURE IN TRESHOLD									
POSITION Z: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16									
BEHAVIOUR MONITORING									
BEHAVIOUR	POSITIONING	COOLANT	WEAR	BREAKAGE	CORRECTION	SIGNAL OVER	SIGNAL BELOW		
REAL VALUE OF PARAMETER	Ab Tb	Ac Tc	Azu	Azg Azd Tzj	Avk Tvk	Acw Tow	Acn Tcn		
	0.0 0000	0.0 0000	0.0	0.0 0.0 0000	0.0 0000	0.0 0000	0.0 0000		
MONITORING	YES	NO	YES	NO	YES	NO	YES		
ALARM									
F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
STOP		EDITOR		CONT					

Fig.4. Behaviour monitoring window of the TMS



HELP	
Up	ALT [1] ON/OFF BEHAVIOUR [1]
DOWN	CTRL[1] - PARAMETER CORRECTION OF BEHAVIOUR [1]
RIGHT	ENTER - NEXT PARAMETER OF BEHAVIOUR [1]
LEFT	BEHAVIOUR [1]: 1. POSITIONING 5. CORRECTION
GRAY +	2. COOLANT 6. SIGNAL OVER
GRAY -	3. WEAR 7. SIGNAL BELOW
	4. BREAKAGE

F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
ENTER	INITIAL STATE	REDRAWING							

Fig.5. Interactive parameter correction window

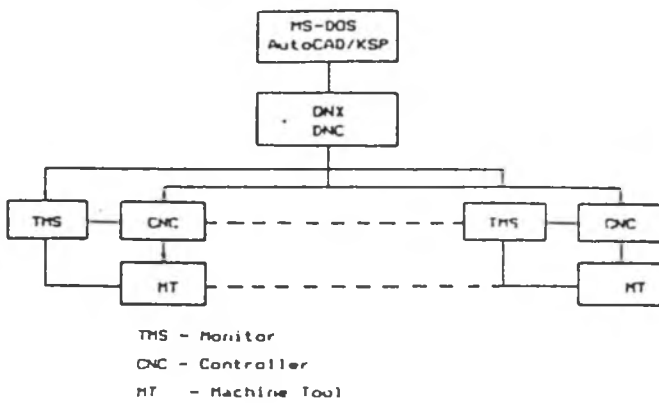


Fig.6. Basic configuration of DNC system

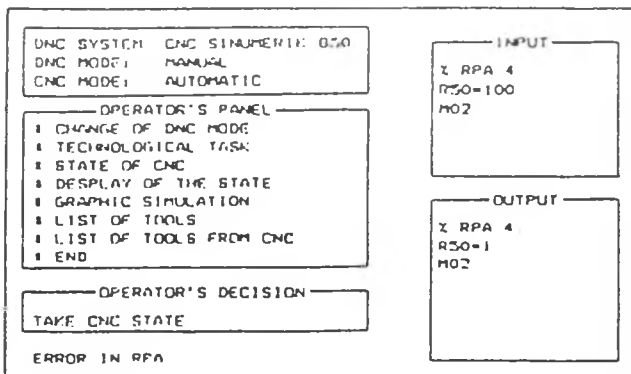


Fig.7. Main window of the DNC system

CNC SINUMERIK 850M controller goes together with transmission of threshold coefficient value files to TMS. Inversely, the experimentally verified threshold value file which accompanies machining program (POT) stored in CNC SINUMERIK 850M controller memory may be transmitted from TMS memory to DNC system storages after machining completion. Already that solution creates conditions of an effective TMS exploitation in automated manufacturing systems. After calling control program DNC_MAIN.EXE, main window of DNC system (Fig. 7) is displayed on computer monitor. On the right side of the main window, separated interactive subwindows to serve transmissions between DNC and CNC are shown. Messages from DNC are displayed in lower window and those from CNC controller in the upper one.

Upper left window shows current operating mode of CNC SINUMERIK controller and of DNC system. Operator makes mode option while choosing adequate item on the interactive window. Left lower window displays DNC system menu - all system options are listed. For some commands submenu is displayed and the operator has to make next choice. Lower left part of main window is assigned for message and signals of error sent from DNC system, whereas the upper part of the fields displays informations on DNC system activities at the moment.

6. Conclusions

The realized research has brought valuable experience in field of both algorithmic monitoring and co-operation between TMS and controller. Elaboration of DNC system has made it possible to create an effective management system of files containing coefficients for threshold mode and for pattern recognition mode, where the current signal changes represent tool wear. The present knowledge allows to realize TMS for supervision of an other machining task, since the implemented and verified strategies at drilling are also applied at other machining operations.

7. References

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