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Adaptive Control based Condition Monitoring of CNC Machine

S. Balamurugan[1], R.Vasanthakumar[2], R.Sudarshan[3], P. Sridhar[4]
[1, 2]*Assistant Professor, Department of Mechanical Engineering, K S R Institute For Engineering and Technology, Tiruchengode*
[3, 4]*UG Students. Department of Mechanical Engineering, K S R Institute For Engineering and Technology, Tiruchengode*

Abstract: ***An adaptive control constraint system has been developed for computer numerical control (CNC) turning based on the feedback control and adaptive control/self-tuning control. In an adaptive controlled system, the signals from the online measurement have to be processed and fed back to the machine tool controller to adjust the cutting parameters so that the machining can be stopped once a certain threshold is crossed. The main focus of the present work is to develop a reliable adaptive control system, and the objective of the control system is to control the cutting parameters and maintain the displacement and tool flank wear under constraint valves for a particular workpiece and tool combination as per ISO standard. Using Matlab Simulink, the digital adaption of the cutting parameters for experiment has confirmed the efficiency of the adaptively controlled condition monitoring system, which is reflected in different machining processes at varying machining conditions. This work describes the state of the art of the adaptive control constraint (ACC) machining systems for turning. AISI4140 steel of 150 BHN hardness is used as the workpiece material, and carbide inserts are used as cutting tool material throughout the experiment. With the developed approach, it is possible to predict the tool condition pretty accurately, if the feed and surface roughness are measured at identical conditions. As part of the present research work, the relationship between displacement due to vibration, cutting force, flank wear, and surface roughness has been examined.***

Keywords: displacement condition monitoring, surface roughness, Adaptive control, , model based control system and flank wear.

I. INTRODUCTION

Condition monitoring is becoming popular in industry because of its efficient role in detecting potential failures. The use of condition monitoring techniques will generally improve plant production availability and reduce downtime cost. A reliable adaptive control system can prevent downtime of the machine or avoid unwanted conditions such as chatter vibration, excessive tool wear by allowing the opti- mum utilization of the tool life. In metal cutting, as a result of the cutting motion, the surface of workpiece will be influ- enced by cutting parameters, cutting force, vibrations, etc. But the effects of vibrations have been paid less attention. Prasad et al.[1, 2] presented an investigation for a tool condition monitoring system, which consists of a fast Fourier transform preprocessor for generating features from online acousto-optic emission (AOE) signals to develop database for appropriate decisions. A fast fourier transform (FFT) can decompose AOE signals into different frequency bands in the time domain. This method has also been widely used in the field of metal cutting, detect process changes like displacement due to vibration, tool wear, etc.

The drawback of modern computer numerical control (CNC) systems is that the machining parameters, such as feed rate, speed, and depth of cut, are programmed off- line[3]. As a result, many CNC systems are inefficient to run under the operating conditions that are far from op- timal one. To ensure the quality of machining products, reduce the machining costs and increase the machining effi- ciency, it is necessary to adjust the machining parameters in real time to satisfy the optimal machining condition at any given time as per modern condition monitoring strategy[4]. The control of CNC machining processes is presently receiving significant attention due to potential economic benefits associated with automated machining. Control techniques that have been developed for machining traditionally re- quire some form of parameter adaptation. The solution to this problem is adaptive control. An adaptive control system was introduced to the cutting process by Stute and Goetz[5]. The most frequently used systems are model reference adaptive control (MRAC) and self turning regulations (STR).

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Tomizuka et al.[6] presented investigation on an adaptive model reference adaptive controller approach. These controllers were simulated, evaluated and physically implemented. For effective automization where the process takes place without the interference of the human, continuous monitoring of the machining is necessary. Most frequently, it is materialized by measuring the cutting forces because they contain more information about the process and the tool condition[7]. In spite of initial difficulties in the development, a trend towards equipping the CNC machine with modern adaptive systems can be noticed[8, 9]. The most commonly used adaptive control (AC) systems are adoptive control constraint (ACC) and the constraints implemented in ACC systems are the cutting force, displacement due to vibration, spindle deflection, current, and cutting torque. The operating parameters are usually the feed rate, depth of cut, and spindle speed. Therefore, we would implement on-line adaptive control in conjunction with off-line optimization. In our AC system, the feed rate and depth of cut are adjusted on-line in order to maintain a constant displacement and cutting force in spite of variations in cutting conditions.

As part of the present work, a simulation model for test- ing the stability and harmonizing the parameters of the adaptive system has been developed. After simulations, the system is fully ready and harmonized for the use in real CNC machining processes, particularly milling and turning.

II. CONFIGURATION OF ACC SYSTEMS FOR CONDITION MONITORING

Fig. 1 presents the configuration of an adaptive control constraint system designed for monitoring the cutting tool condition in the present work. It consists of a machine con- troller, the CNC machine, and a sensing device to measure the output process variables. The present work uses the experimental data presented in [1] for condition monitoring cutting tool in CNC turning by evaluating the proposed adaptive control constraint system. Experimental data are initially fed to the machine controller, and the constraints for every output process variable has been defined as per ISO standard. Digital adaptation of cutter parameters is programmed in such a way that value of output process variables will be compared with initially fed values in the machine controller. At this stage, it generates new input parameters (if needed) so as to improve the life of the cutting tool.

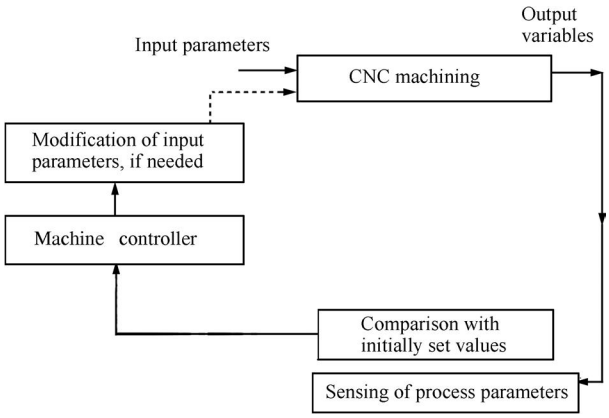

Fig. 1 proposed adaptive control constraint system

A. Sequence of steps for on-line optimization of the CNC turning process

In the present work, the cutting speed is kept constant throughout the experimental analysis. The sequence of steps for on-line optimization of the milling process is presented below.

1) The recommended cutting conditions are determined by ISO standards, which are basic elements of the simulated model.
2) Cutting conditions have been optimized according to the recommendations of ISO 10816 and ISO 3865 standards.
3) The pre-programmed feed rates determined by the offline algorithm are sent to CNC controller of the machine.
4) The measured displacement, tool wear and surface roughness values are sent to adaptive control scheme.
5) The adaptive control scheme adjusts the optimal feedrates and sends it back to the machine.
6) Steps 1) to 3) are repeated until the termination of the machining.

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B. Tool rejection criteria

In this work, cutting tool condition has been evaluated based on both ISO 10816 and ISO 3685. Based on the ISO 3685 standard, three conditions of the tool are considered: sharp tool (0 mm of the flank wear), semi-dull tool (0.3 mm of tool flank wear), and dull tool (0.6 mm of tool flank wear) in both face turning and face milling. The tool flank wear is measured with an optical projector. Similarly, as per ISO 10 816 for vibration severity standards, displacements in the rotating object (workpiece) up to 20 μm do not have any effect on tool flank wear. Tool flank wear is found to be effected by the measured displacements in the range between 20 μm and 60 μm. A displacement value beyond 60 μm is not acceptable as per standard.

III. METHODOLOGY FOR EVALUATION OF CONDITION MONITORING SYSTEM WITH ADAPTIVECONTROL

The objective of the proposed control system presented in Fig. 2 is to regulate the turning process operation parameters such as feed rate, spindle speed, depth of cut to achieve the required values of the surface finish, flank wear and displacement.

IV. CONTROL SYSTEM SIMULATOR FOR DYNAMICAL ADJUSTING OF CUTTING PARAMETERS IN TURNING

The simulation diagram of the proposed system is pre- sented in Fig. 3. The simulation diagram comprises of the simulator of CNC controls, simulator of the feed and main servo-drive, simulator of cutting, reference block and the models determining the mutual relations between the in- fluencing cutting values. When designing an adaptive control constraint system for condition monitoring as per ISO 10810, the following methodology has been adopted: 1) Its displacement values cross 20 microns, then immediately reduce the input parameters, either feed rate or depth of cut to smaller values so as to reduce the displacement. The subsequent values of flank wear and surface roughness will be reduced while the cutting speed is kept constant. 2) If displacement value crosses 20 microns, then immediately reduce input parameters, either cutting speed or depth of cut to smaller values so as to reduce the displacement. Hence, the values of flank wear and surface roughness will be decreased at a constant feed rate. 3) If the value of displacement crosses 20 microns, then immediately reduce input parameters, either feed rate or cutting speed to smaller values so as to reduce the displacement. It is observed that the values of flank wear, and surface roughness decreases while constant depth of cut is maintained.

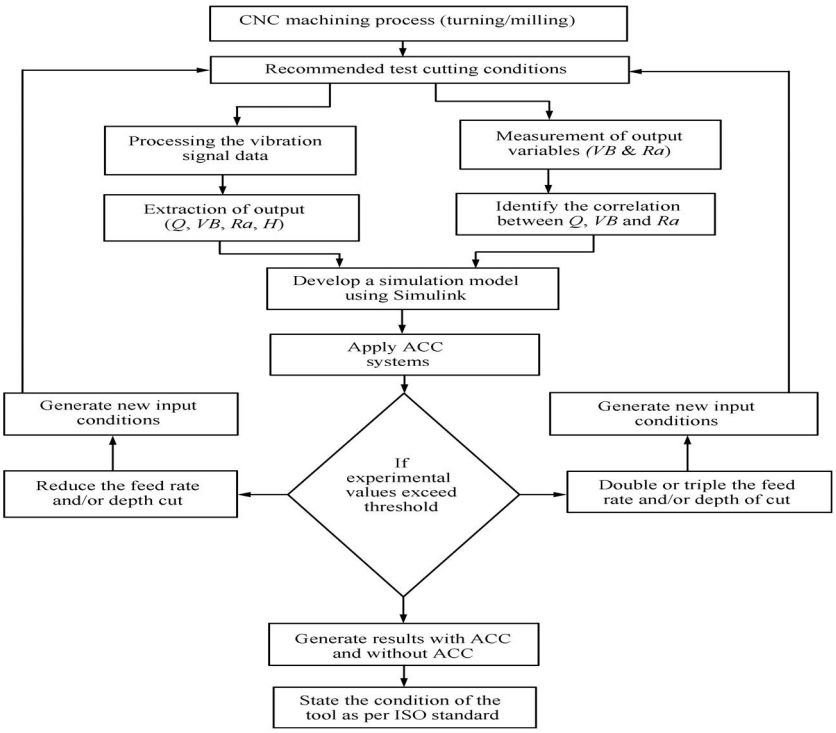

Fig. 2 Methodology of condition monitoring with ACC system

In every case, the correlation is identified between dis-placement values (ISO 10816) and flank wear values (ISO 3685) so as to judge the condition of the cutting tool. In ma- chining of parts, surface quality is one of the most specified customer requirements. The major indication of surface quality on machined parts is surface roughness. Because of the elevated temperature in the cutting zone, the tool tip temperature increases. This softens the tool material which in turn causes increased tool wear (*V B*) and the surface roughness. The variation in the hardness of material, feed rate and depth cut are the other parameters affecting surface finish and tool wear. Machined surfaces with surface roughness (*Ra*) values above 6.3 μm are treated as highly rough surfaces. In metal cutting operation, surface roughness parameters (*Ra*) and corresponding flank wear (*V B*) can be derived from experimental data by using the following relations. The relationships among parameters have been derived from the following relations for tool flank wear in terms of displacement, surface roughness, and all the other machining parameters. These relations have been derived from modified form of Taylor's tool life equation.

$$Ra = CRa \times H^{a} \times f^{y} \times \gamma^{n} \times d^{p} \times v^{x} \times t^{z} \quad (1)$$

$$VB = C_{\alpha} \times H_{d}^{\ x} \times \gamma_{n} \times v^{y} \times f^{\ } \times L_{mm} \quad (2)$$

where *v* is cutting speed (m/min), *t* is machining time (min), *L* is the length of the cut (mm), and *n, x, y, a, b, p, z* are exponents. When the simulation model of the feed servo- drive (shown in Fig. 4) and the model of main spindle rotation (presented in Fig. 5) are replaced by the real machine tool. A harmonized system for dynamic adjustment of cut- ting conditions ready for immediate use is obtained. The system with regulation of the displacement assures the required tool flank wear and surface roughness. The simulation models of the machine dynamics are on the basis of the technical specifications of the TC-CNC 250C machine.

A. Model Based Turning Process Control

A model based control system is a regulator that canmodify its behavior in response to change in the dynamics of the process and the disturbances. If the displacement due to vibration is maintained constant during the machining process, then the surface finish and flank wear will also remain stable. In the previous research work[1], the resultantdisplacement is obtained using a laser Doppler vibrometer which provides displacement measured on-line using Pulse Labshop software. These measured displacement signals are used in the model controller to regulate the displacement due to vibration. The main objective of this research is to develop adaptive model based control system, which can solve such difficult machining control problems. The objective of the proposed control system is to regulate the turning process operation parameters such as the feed rate, and depth of cut, and to maintain the displacement and flank wear under the constraint values.

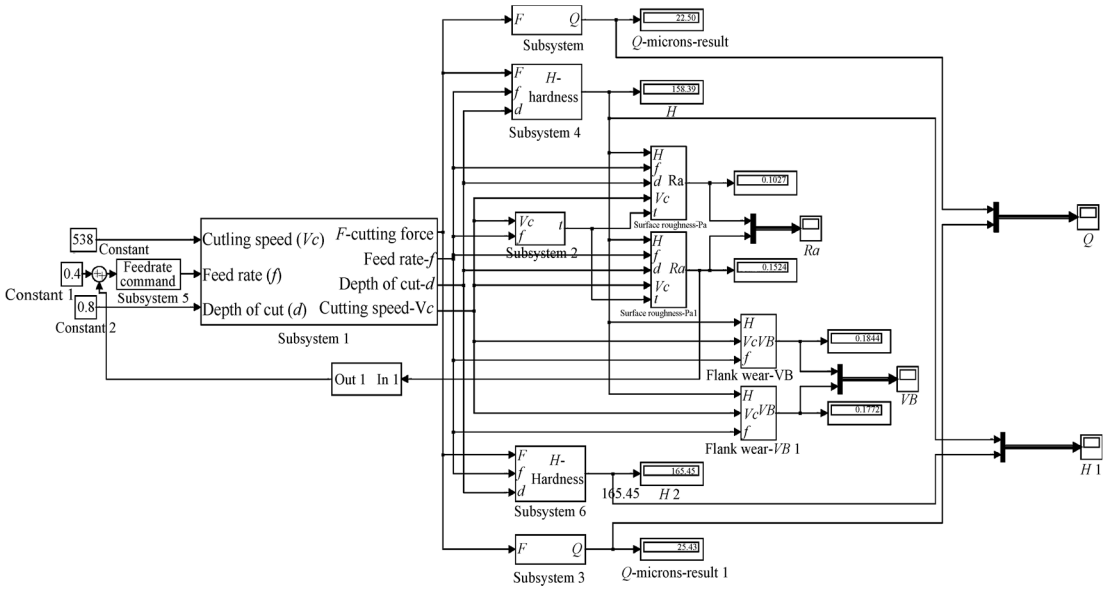

Fig. 3 Simulation diagram of the proposed system

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V. RESULTS AND DISCUSSIONS

A. Variation of Displacement with ACCand without ACC systems

The graph shows the displacement of the workpiece atthree different conditions with and without adaptive control. The displacement of the workpiece during machining process mainly depends on the sharpness of the cutting tool edge, depth of cut, and the feed rate. Displacement is highat the start of machining process, and it decreases with the decrease in sharpness of the cutting tool. This indicates worn out of the cutting tool. The same trend can be ob- served in Table 1. The graph shows the displacement of the workpiece during the machining process with and without adaptive control. The displacement of the workpiece without adaptive control is high. In machining, once input parameters such as cutting speed, feed rate and depth of cut are given to the system and the machine tool performs the machining operation based on the input parameters. But output results are not sent to the machine tool controller a feedback when the machining is done without adaptive control system. The displacement is low when machining with adaptive control, because the input parameters are monitored continuously and altered when the output parameter roughness, flank wear, and displacement values reach some constraint values. But the displacement is high at start of the machining process when machining with ACC also because of the high sharpness of the cutting tool. At the start of machine process, it reaches some peak value and it goes on with the machining process. The cutting tool sharpness affects mostthe workpiece displacement in machining with ACC.

B. Variation of Surface Roughness withACC and without ACC systems

The graph shows the surface roughness of the workpiece at three different conditions when machining with adaptive control and without adaptive control. The roughness of the workpiece is mainly affected by the feed rate, depth of cut, and the workpiece displacement. From the graph shown in Fig. 5, the surface roughness is high when ma- chining without adaptive control, because when machine is without ACC, the input parameters are not altered when the outputs reach some constraint values.

That implies once the input parameters are given to the system, the machining process takes place based on these inputs. The surface finish is good when machining with ACC system. This is because the continuous monitoring of input parameters fed to the system are based on the outputresults. The same trend is observed in Table 1.

Table 1 Experimentally calibrated displacements, hardness and flank wear with and without adaptive control turning

Cutting speed (N)	Feed rate (f)	Depth of cut (d)	Hardness (BHN)	Displacement with ACC (μm)	Displacement (μm)	Flank wear with ACC (mm)	Flank wear (mm)	Surface Roughness with ACC Ra	SurfaceRoughness Ra	Machining time (min)
538	0.08	0.5	152.5	12	14	0.08	0.09	0.07	0.09	8.22
538	0.08	0.8	153.5	14	15	0.10	0.102	0.07	0.09	12.22
538	0.08	1.5	155.5	16	18	0.12	0.123	0.08	0.09	16.22
538	0.4	0.5	157	18	18	0.14	0.145	0.09	0.12	20.22
538	0.4	0.8	158.5	20	21	0.17	0.18	0.10	0.13	24.22
538	0.4	1.5	160	26	28	0.19	0.2	0.12	0.13	28.22
538	0.8	0.5	161.5	28	28	0.2	0.22	0.15	0.18	32.22
538	0.8	0.8	164	30	31	0.24	0.25	0.22	0.26	36.22
538	0.8	1.5	167	32	32	0.26	0.29	0.38	0.39	40.22
836	0.08	0.5	153.5	16	18	0.15	0.16	1.14	1.16	4.10
836	0.08	0.8	153	20	21	0.15	0.16	1.40	1.42	6.05
836	0.08	1.5	155	22	22	0.17	0.19	1.52	1.53	8.11
836	0.4	0.5	157	24	25	0.21	0.23	1.66	1.69	10.04
836	0.4	0.8	158.5	32	25	0.26	0.28	1.87	1.89	11.58
836	0.4	1.5	160	40	45	0.31	0.34	2.18	2.19	13.33

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836	0.8	0.5	162	50	58	0.32	0.34	2.70	2.15	15.48
836	0.8	0.8	164	60	64	0.32	0.34	3.75	3.76	17.33
836	0.8	1.5	169	72	74	0.33	0.36	6.87	6.88	19.28
1 135	0.8	0.5	155	12	14	0.21	0.22	2.62	2.66	1.5
1 135	0.8	0.8	158	16	18	0.24	0.26	2.80	2.84	2.25
1 135	0.8	1.5	159	22	23	0.26	0.29	3.02	3.06	3.03
1 135	0.4	0.5	162	26	29	0.36	0.38	3.32	3.34	3.78
1 135	0.4	0.8	164	38	29	0.39	0.41	3.75	3.79	4.58
1 135	0.4	1.5	165	48	51	0.41	0.42	4.35	4.36	5.45
1 135	0.8	0.5	168	60	64	0.43	0.45	5.35	5.36	6.13
1 135	0.8	0.8	170	72	76	0.46	0.47	7.49	7.50	6.9
1 135	0.8	1.5	173	84	88	0.49	0.52	12.69	12.70	7.66

C. Variation of workpiece flank wear withACC and without ACC systems

The input parameters of feed rate, depth of cut, and the hardness of the material have great influence on the cutting tool wear. From Fig. 6, it is observed that the flank wearis 0 at the start of machining process and it increases withthe machining time.

It is observed that the tool wear is increasing with the increase in the cutting speed. The tool wear is low when machining with ACC. Because machining with ACC involves on-line changes of input parameters like feed, depthof cut, and cutting speed when the output values reach constraint values. The tool wear is high when machining without ACC. The reason behind this is input parametersare not altered even if the values of output reach constraintvalues.

VI. CONCLUSIONS

The control of machining processes is presently receiving significant attention due to its potential economic benefits associated with automated machining processes. Control techniques that have been developed for machining traditionally require some form of parameter adaptation. The solution to this problem is adaptive control. An adaptive control system is introduced to the cutting process. The research work presents the model based system of dynamic adjusting of cutting parameters. By dynamic adaptation of feeding and spindle speed, the system controls the surface roughness and the cutting forces on the workpiece in turn- ing. The correlation between the surface roughness and the cutting forces is determined. By dynamic adaptation of feed rate and spindle speed has been done. Roughness and the cutting forces on the work piece in turning and the cutting fc

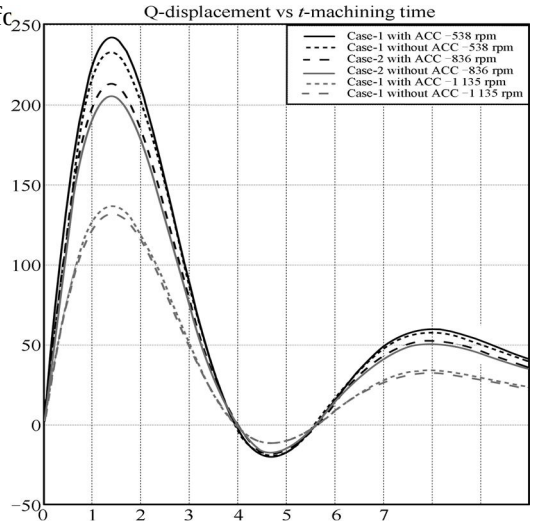


Fig. 4 Displacement variation with ACC and without ACCsystems

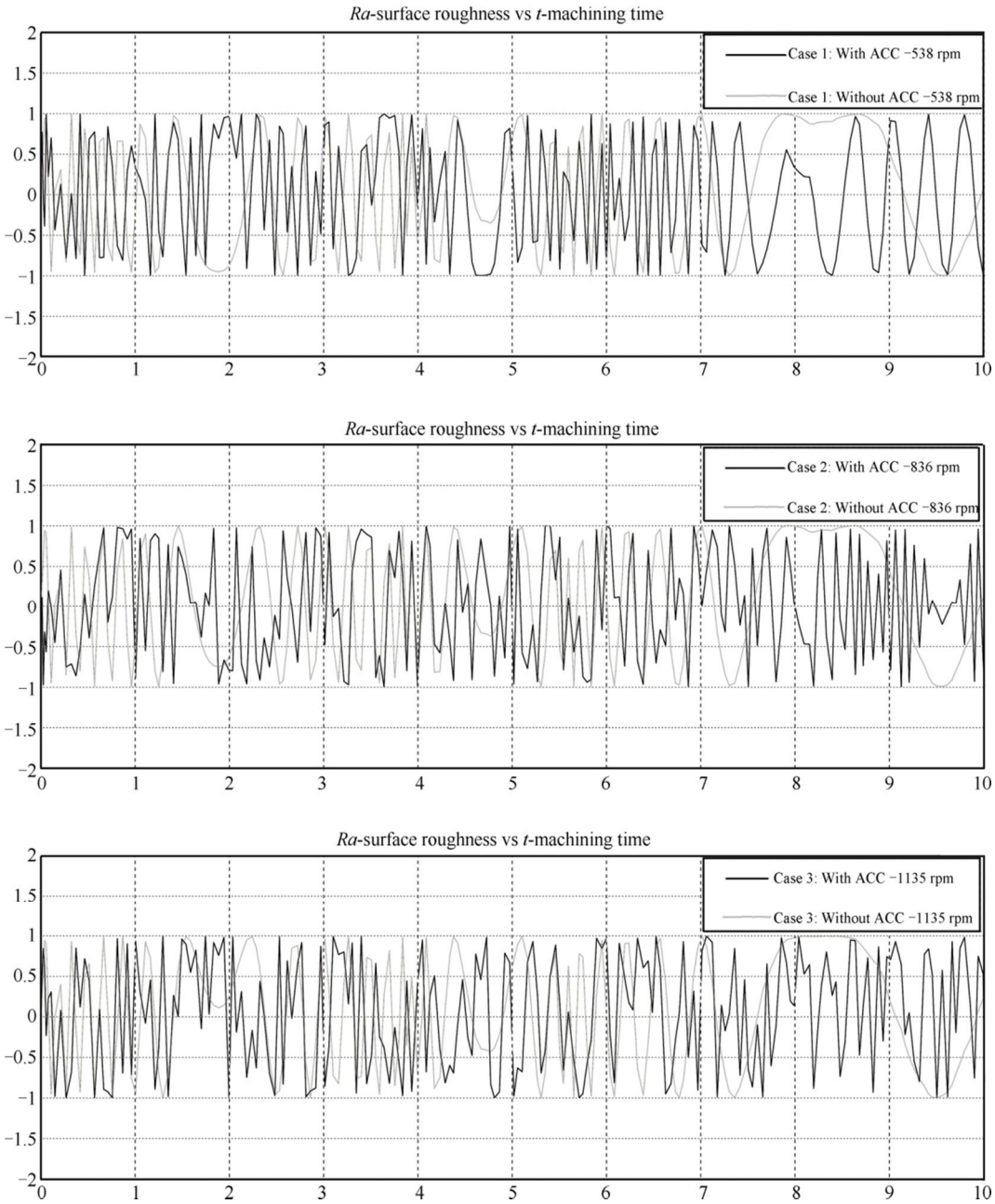


Fig. 5 surface roughness variation with ACC and without ACC systems

By simulations, the adequacy and stability of the control system are confirmed. It has been proved that the surface roughness which is an important indicator of the process quality can be successfully controlled by cutting parameters. Quality of surface is assured by monitoring the cutting speed, feed rate and depth of cut with the help of adaptive control systems. On the basis of results of numerous simulations, the described system of control has been decided to realize experimentally. The system has been conceived for the turning operation, although it can be modified for all process of machining by cutting. From the results, it is observed that a high degree of correlation is found between displacement of the workpiece and the tool wear at all machining condition in different machining processes. An effective adaptive control constraint system has been developed and evaluated in CNC turning. The results also suggest that the proposed methodology has been justified at all test conditions.

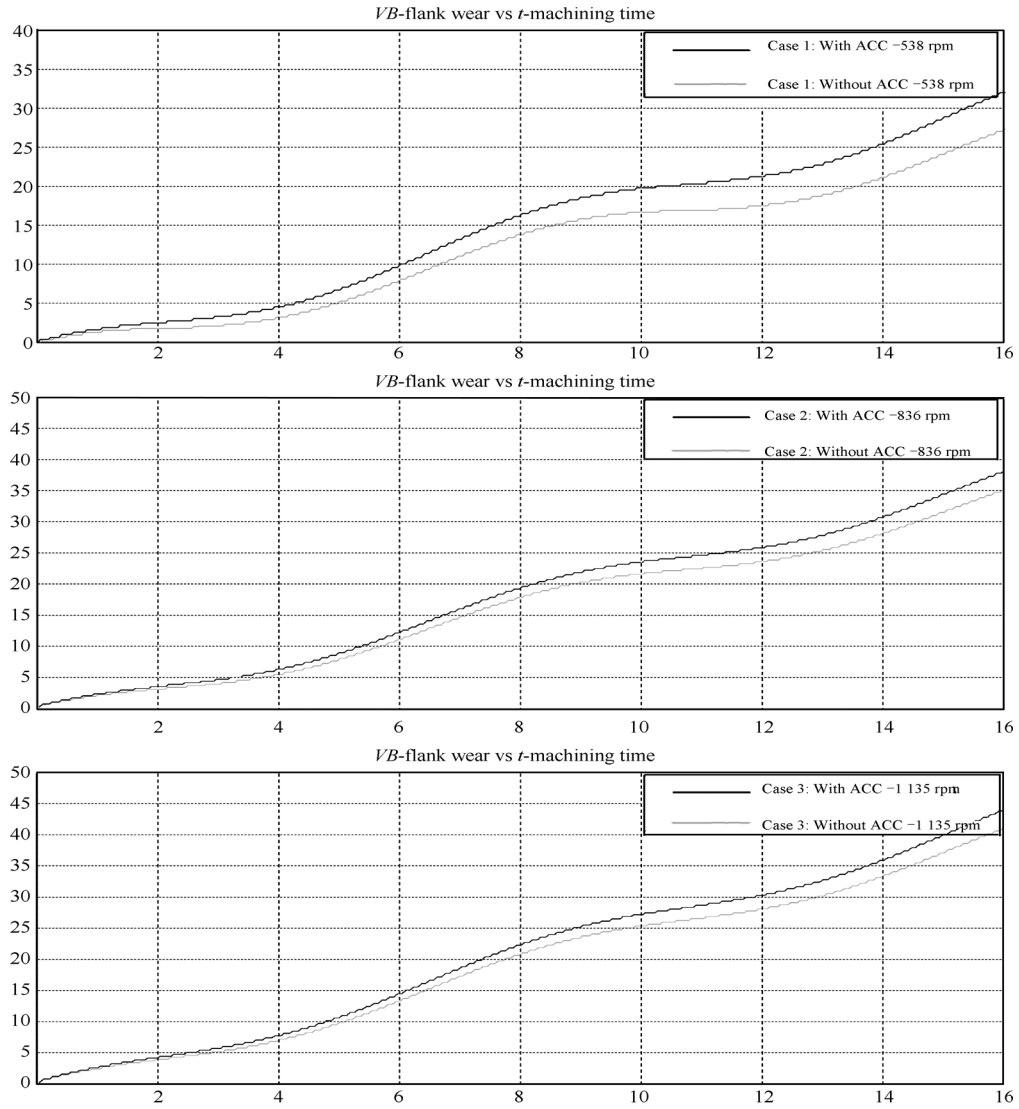


Fig. 6 Variation of work piece flank wear with ACC and without ACC systems

REFERENCES

[1] B. S. Prasad, M. M. M. Sracar, B. Satish Ben. Development of a system for monitoring tool condition using acousto op- tic emission signal in face turning – an experimental ap- proach. The International Journal of Advanced Manufac- turing Technology, vol. 51, no. 1–4, pp. 57–67, 2010.

[2] B. S. Prasad, M. M. M. Sracar, B. Satish Ben. Real-time tool condition monitoring of face milling using acousto-optic emission – an experimental approach. International Jour- nal of Computer Application in Technology, vol. 41, no. 3–4, pp. 317–325, 2011. cesses. Journal of Achievements in Materials and Manufac- turing Engineering, vol. 17, no. 1–2, pp. 237–240, 2006.

[3] F. Cus, U. Zuperl, E. Kiker, M. Mifelner. Adaptive con- troller design for feed rate maximization of machining pro-

[4] U. Zuperl, F. Cus, E. Mifelner. Fuzzy control strategy for an adaptive force control in end-milling. Journal of Materials Processing Technology, vol. 164–165, pp. 1472–1478, 2005.

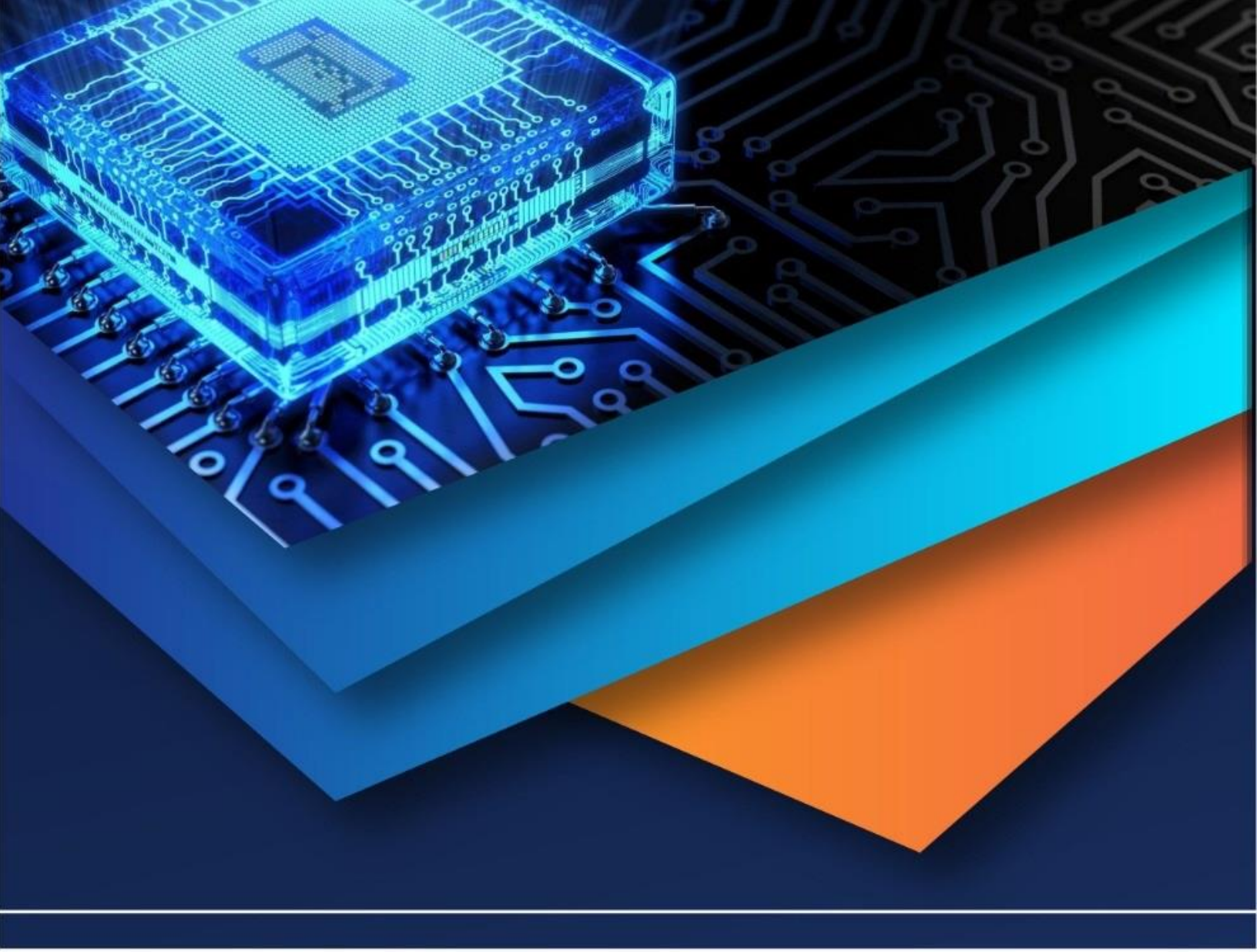
[5] G. Stute, F. R. Goetz. Adaptive control system for vari- able gain in ACC systems. In Proceedings of the 16th In- ternational Machine Tool Design and Research Conference, Manchester, England, pp. 117–121, 1975.

[6] M. Tomizuka, J. H. Oh, D. A. Dornfeld. Model reference adaptive control of the milling process. In Proceedings of the Symposium on Manufacturing on Manufacturing Pro- cess and Robotic Systems, New York, USA, pp. 55–63, 1983.

[7] S. J. Huang, C. C. Lin. A self-organizing fuzzy logic con- troller for a coordinate machine. The International Jour- nal of Advanced Manufacturing Technology, vol. 19, no. 10, pp. 736–742, 2002.

[8] X. Chen, T. Limchimchol. Monitoring grinding wheel redress-life using support vector machines. International Journal of Automation and Computing, vol. 3, no. 1, pp. 56– 62, 2006.

[9] Y. Zhang, X. L. Bai, X. Xu, Y. X. Liu. STEP-NC based high-level machining simulations integrated with CAD/CAPP/CAM. International Journal of Automation and Computing, vol. 9, no. 5, pp. 506–517, 2012.



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