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Comparative Study of CNC Controllers used in CNC Milling Machine

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ABSTRACT : *The quality of finished work piece depends on the relative positions between the work pieces, cutting tool, machining process parameters. It can be achieved if a CNC machine tool possesses sufficient strength to withstand the cutting forces, stiffness against deformation and capability of CNC controller. CNC controller is the heart of the CNC machine which controls most of the functions of CNC machine. Accurate and Perfect machining in minimum time is the requirement of manufacturing industries and along with other hardware and machining process parameters, CNC control system also playing vital and an important role. Hence, in this work an attempt is being made to investigate and analyse the comparison of the CNC milling controllers with same set of parameters. This project gives the detailed comparison of the three major CNC controllers used by industries on the basis of important parameter.*

Keywords - *Fanuc, Heidenhain, Machining Time, MRR, Sinumerik,*

I. INTRODUCTION

Controller is a combination CNC computer software, and hardware. Today the CNC are soft wired system that makes its flexibility for the different operations. Software control all the programming and function of the CNC machine. and the Computer is a basically responsible to generate signal i.e. supplied to the controller with the help of communication device or serial port for example the signal generated by the computer are 5V DC supplied to the controller and it communicate by the communication (DB25) or the serial port (DB9) and by this way it communicate with the controller hardware. It interprets a language such as G code into the signals. Computer system is generally operated on system of step and direct format of command signal. Some higher end machine used proprietary analogue or digital signals but after it is usually a variation of the step and direction format. In this system the two type of the command send to each driver-(1) Step signal (2) Direction signal. The communication signal in the form of the wave that is square in the shape and it is known as Transistor-to-Transistor Logic signal (TTL signal). This signal is a series of small pulses ranging from 0V to 5V that is represents 0 and 1 in a binary computer language. This signal is a form of the Pulse Width Modulated signal (PWM signal) where the duration of the pulse is varied to indicate information. The time duration of the pulse determines the binary code, either 0 or 1 as communicated by the computer and interpreted by the motor driver. Every motor have some specific step plus time for both 0 and 1 and have different microsecond.

(1) CNC CONTROLLER COMPONENTS

The CNC controller component responsible for the positioning the signals i.e. created by the computer and it work together with NC software for precise motor control. These all together makes the total control system. There are three basic component of CNC controller. (1) Power supply unit (2) Circuitry protection system unit (3) Motor driver unit

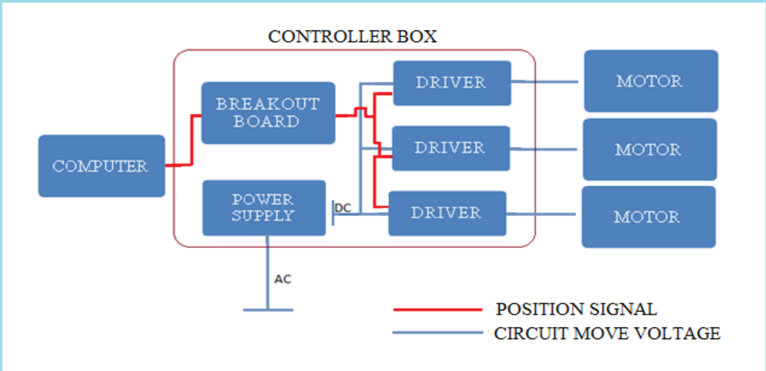

Fig.1**:** Block diagram of controller

(1.1) Power supply unit

Power supply unit is the one of the basic and important part of the CNC system.CNC machine have a low voltage communication line by which computer directs to the machine. This line is responsible to communicate the system and the machine. Power source is providing the power for moving, cutting and other machine related operation.

(1.2) Circulatory protection system unit

The circulatory protection system consist a breakout board that used to isolates signals. It provides the circuitry protection and distribution inside the controller box. It takes signal from the computer and distributes to desired drivers. It is also allow to limit switches that feed information back to the computer. Fuses are also part of the circulatory protection system. Fuses could save the equipment in case of electrical spikes, shorts, or faulty wiring. A low voltage communication signal passes from the computer through the break down board unchanged to the motor drivers. This isolated the computer from the circuit but also allows the signals to carry to the motor drivers.

(1.3) Motor system unit

The motor drivers receives the signals and then coordinates pulses of the desire current and voltage to elicit the movement in the drive motors. The motor drivers communicate position information from one way to the motor in the open loop system. And in another way its send and receives the position information in the close loop system

(2) STUDY IS FOCUSED ON CONTROLLERS

This research work mainly focused on the three controllers. (1) FANUC 21 M (2) SINUMERIC 840D (3) HEIDENHAIN TNC 426

(1.1) Features of FANUC 21 M

It's having 5 axes control. And have 4 control spindle and its can control 4 simultaneous controlled axes. This controller is specially design for the milling machining procedure. It's having the machining accuracy in the range of the 1 µm of the control. Both manually and through machine the input can be given to it. It's having facility of conditional and unconditional jump.ATC handle ability, pitch error compensation and zero offset compensation also in the FANUC 21 M. Mostly feature of the FANUC and SIMUNERIK are almost same.

(1.2) Features of SINUMERIK 840D

This controller has simultaneous axis control capacity with telediagnosis facility. And it is having the surface motion guidance system. Both manually and through machine software the input can be given to it. And It's having facility of conditional and unconditional jump. ATC handle ability, pitch error compensation and zero offset compensation also in the SINUMERIK 840D.this feature is same in the SINUMERIK series 840 and the FANUC 21 series.

(1.3) Features of HEIDENHAIN TNC 426

It's having the facility Shop-floor programmable contouring controls for milling, drilling and boring machines, and it have machine centers with up to five axes. It has the facility to change the angular position of the spindle under program control. It is able to handle more complex component as compare to other controller and Input & machining accuracy is very good. Linear movement is possible in up to the 4 axes simultaneously. It's having the facility to Returning to the contour after an interruption.

II. LITRETURE RIVIEW

Sungchul Jee et al. [1] this paper introduces a new cross-coupling controller with a rule-based fuzzy logic control. It is asserted that fuzzy logic controllers provide a better and accurate transient response (which is essential for better contour accuracy during transient motions) than the conventional controllers, such as PID controllers, and it cross coupling controllers perform better than axial controllers in trajectory tracking by machine tools. In this paper, a fuzzy logic controller and a cross-coupling controller are combined to reduce and control the contour errors. A simulation of the FLCCC was performed and it was implemented on a CNC milling machine, the simulation and the experimental results show improved contour accuracy over the conventional cross- coupling controller.

Ahmet Murat PINAR et al. [2] has suggested algorithm for minimizing the machining time of CNC part programming used in a vertical machining centre with the help of time calculator and CNC code editor .An algorithm was prepared and send from machine to CNC code editor with the cable (RS-232) i.e. used for minimizing the machining time of CNC part programs used in a vertical machining centre.. As resulted reanalyzing the new CNC program with the time calculation processor, the time save has been seen.

Sayyad naimuddin, et al. [3] developed an intelligent and very useful scheme to control the CNC machine under sudden breakdown condition. The work comprises to develop and program of a fuzzy controller for a closed loop speed control where the manipulated variable is the speed relation and, therefore, the slip value. The sudden power failure occurs at 0.5 second can be immediately recovered by the fuzzy controller at 1 second. The actual environment is immediately build up in the Makino A77 CNC machine which minimizes breakdown. This will help in minimizing the breakdown and controlled sudden breakdown, results in the enhancement of productivity.

MA Xiong- bo et al. [4] shown with the use of that method, the increasing of the degree of the reusability and openness leads to the decrement in the maintains cost and development time. 3-axis milling machine tool test-bed designed by means of the constructed software function module library and the system configuring method. The name of that machine is HIT-CNC that is along with the open architecture controller system. Control parameter like number of axis can be created by this control system. In this paper, after close scrutiny of the ways to realize the basic functions, a whole new structure of the controller is designed and a prototype is worked out on PC on the ground of OMAC (open modular architecture controller). The experimental results corroborate the gain of a satisfactory openness characterized by extendibility, modularity, portability, and scalability, reusability.

Mr. Sc. Afrim Gjelaj, et al. [5] discussed programming and simulation of work piece through CNC Mikron Milling machine, with using of the machine software as such HEIDENHAIN iTNC 530, MasterCAM. It's improved the productivity and machining time of the work piece.

QU Xin-he et al. [6] show the difference in between three-axis and the five-axis boring fixed loop program with the help of postprocessor. CATIA is used as design software and the characteristic is analysis over the SINUMERIK 840D system and C50 machine. Cycle E86 is used to analysis the result of the post processing algorithm. Result shows that the experimental variation of the three-axis and five-axis boring cycle program. Experimental results revels that five-axis boring closed loop program is more effective as compare to other.

D.Dimitrov et al. [7] had given comparison between 3-axis machining and 5-axis cutting machining with CAD/CAM system in various case study like Hermle C40U dynamic HSC milling centre was used with the CAM programming with the help of utilizing Delcam's Power mill, found that Using 5-axis machining the routing fixture could be machined in a single setup, with the help of this minimize processing and lead time. This study shows comparison of the 3axis and 5 axes machining with different parameters.

Kotaro Nagaokaa et al.[8] discussed a suitable compensator design for mechanical errors through case studies. The numerical simulation analysis indicate that an appropriate design of a dynamic model increase the motion accuracy of the tool center point.

Martin Eckstein, et al. [9] describes a new approach in real-time monitoring for drilling bolt holes in Inconel718. By extracting and processing controller data with non-linear algorithms. The Process related data origination from the NC of a SINUMERIC 840D Controllers.

Sergej N.Grigorieva, et al. [10] analyzed a method to simultaneously increase the accuracy and decrease the calculation time for complex tool path programming in multi-axis machining centers. The algorithms developed for the CAD/CAM software that allows for NC programming and machining on 5-axis centers employing any design model. That is improving the processing time in the complex job.

XU Xiao-minga et al [11] discussed an open CNC system based on PC and motion controller, Software and hardware of the system based on the idea of modularization construction. According to requirements of software, a kind of rings structure as the system management software development model is designed. A new algorithm has been developing that is able to control spline interpolation B-spline interpolation. The experimental result shows that the CNC system is effective. Two interpolation algorithms is developed based on motion controller interface, to cater the lack of which not supporting spline curve interpolation of motion controller, so as to enhance the functionality of numerical control system.

III. RESEARCH METHODOLOGY

In this research study Al 6061-T6 is taken as the material with the dimensions of 80×58×12 mm. EMCO 250 concept mill machine is used for the machining work and study of focus on the EMCO CONCEPT 250 CNC milling, because it’s having facility of interchangeable controller system. It’s having a facility of changing of three different-different controllers i.e. FANUC, SINUMERIK, and HEIDENHAIN. After selecting the proper geometry the part programming is design for the given geometry. Machining time is calculated with the help of the digital time watch. And for the measurement of the MRR the digital weight measuring machine is used.

Table-1: Properties of Al 6061- T6

Name of property	Value
Grade	T6
Ultimate Tensile strength	300 Mpa
Yield strength	241 Mpa
Young modulus	69 Gpa
Shear strength	207 Mpa
Thermal conductivity	167 W/m-k
Elongation	8%-10%
Specific heat capacity	0.896 j/g-˚C
Density	2.70 g/cm^2 or 2700 kg/m^3
Melting point	582 ˚C
Electrical resistivity	3.99 ohm-cm
Solidus temperature	582 ˚C
Liquidus temperature	652 ˚C

Fig. 2: EMCO CONCEPT MILL 250 machine tool

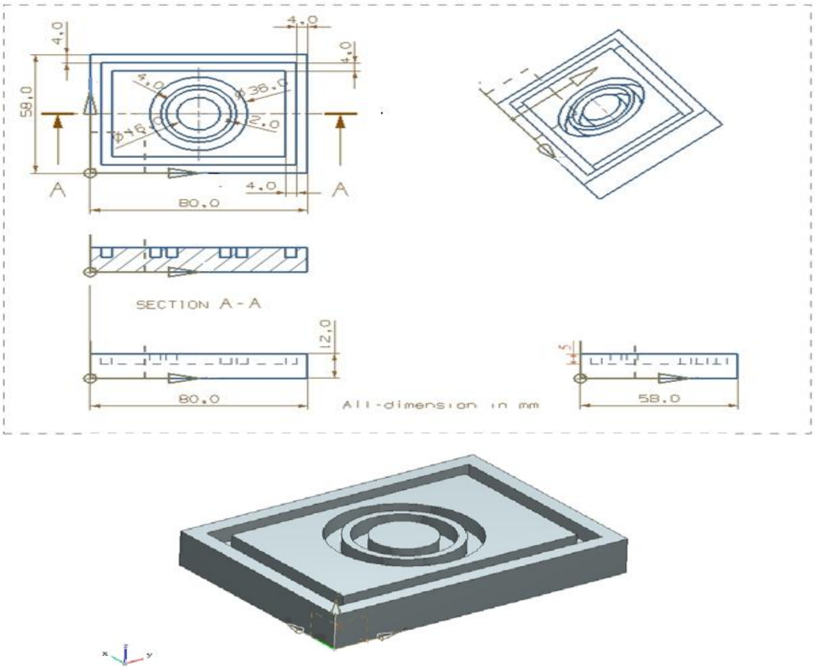

Fig. 3**:** Drawing of the work

(1) Material Removal Rate (MRR)

MRR is calculated using the volume loss from the work piece material as cubic millimeter per minute (mm^3/min). The weight loss i.e. difference between the weight of work piece before machining and the weight of the work piece after machining is measured by an electronic balance weight measuring machine with a least count of 0.001 gm. Depth of cut 0.5 mm is taken in ten steps.

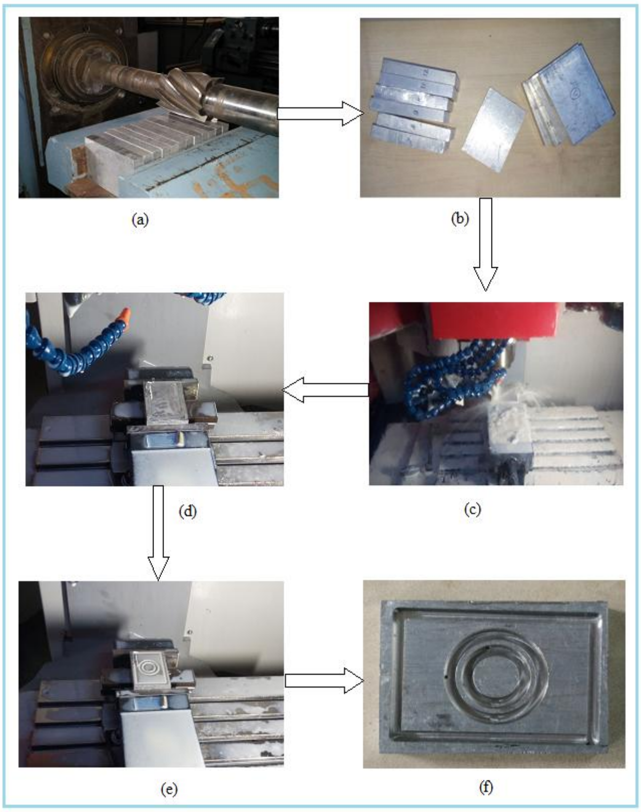

Fig.4: Pictorial representation of the preparation of the workpiece

(2) CONTROLLER PROGRAMMING

This part of the work includes the Part programming i.e. program made for the different CNC controllers. The program made for all three controllers are shown in the form of the picture and written. Programming are arrange in the order of the HEIDENHAIN 426 TNC, SINUMERIK 840D and FANUC 21 M respectively. In case of HEIDENHAIN controller we have select IZ-0.5(cutting depth in z direction) with REP 9/9. First its take 1 complete slot cutting than after it takes the 9 repetition of it so overall its 10. This is the feature of HEIDENHAIN controller. In case of FANUC and SINUMERIK, we have selected the direct 10 repetitions. We have select feed as 100 (mm/min) for the inserting of the tool into the material. Than we change it, according to the practical problem that is 450, 500, 550, and 600.we also change the corresponding spindle speed with respect to the feed that is 1500, 1600, 1850, and 2000. Manual Part program were developed for three controllers and executed.

IV. RESULTS

On the basis of experimental work, performance measure i.e. MRR and machining time are calculated and presented in following table-1 shows the experimental values of machining time**.** Based on the manual programming & operation, measured reading in the form of the minute: second: millisecond. **[**(00:00:00) = (m: s: µs)]

Table-2: Machining Time

S.NO.	Machining parameters	Geometry	Time on HIEDIENHAIN 426 TNC	Time on SINUMERIK 840D	Time on FANUC 21 M
1	F=450 SS=1500 DOC=5	RS	5:47:55	5:47:79	5:49:77
		CR 1	2:06:37	2:07:19	2:08:17
		CR 2	2:55:05	2:55:58	2:58:15
2	F=500 SS=1650 DOC=5	RS	5:15:77	5:16:85	5:18:07
		CR 1	1:58:10	1:59:07	2:00:84
		CR 2	2:42:26	2:42:93	2:44:48
3	F=550 SS=1800 DOC=5	RS	4:53:25	4:54:99	4:56:02
		CR 1	1:50:53	1:50:59	1:52:53
		CR 2	2:31:76	2:31:92	2:32:50
4	F=600 SS=2000 DOC=5	RS	4:28:01	4:29:27	4:30:41
		CR 1	1:44:30	1:45:98	1:46:54
		CR 2	2:19:68	2:20:03	2:21:84

(1) EFFECT ON MATERIAL REMOVAL RATE (MRR)

On the basis of experimental results of MRR calculated according to measured values are given in table-2 on the basis of the experiment the result shows that MRR controller wise.

Table-3: MRR Data Controller wise

S No.	Controller	Feed (mm/ min)	Spindle speed (rpm)	Workpiece weight (Gram : milligram)		Diff.	MRR (mm^3/min)
				Before machining	After machining		
1	HEIDENHAIN 426 TNC	450	1500	144.68	122.89	21.79	746.137
2		500	1650	145.62	124.67	20.95	780.97
3		550	1800	144.96	123.07	21.89	868.459
4		600	2000	147.69	126.17	20.83	904.041
5		450	1500	143.92	122.85	21.07	719.726

S No.	Controller	Feed (mm/ min)	Spindle speed (rpm)	Workpiece weight (Gram : milligram)		Diff.	MRR (mm^3/min)
				Before machining	After machining		
6	SINUMERIK 840D	500	1650	146.03	125.10	21.58	776.540
7		550	1800	145.05	123.79	21.26	848.545
8		600	2000	145.07	124.84	20.23	872.459
9	FANUC 21 M	450	1500	146.85	125.77	21.08	713.963
10		500	1650	144.81	124.50	20.31	747.966
11		550	1800	143.20	122.36	20.84	825.448
12		600	2000	145.33	125.21	20.12	861.844

On the basis of experimental results of MRR data is represented according to experiment set no. shown in table-3 on the basis of the experiment the result shows that MRR controller wise.

Table-4: MRR Data experiment set no. wise

Exp. Set No.	Controller	Feed (mm/ min)	Spindle speed (rpm)	Workpiece weight (Gram : milligram)		Diff.	MRR (mm^3/min)
				Before machining	After machining		
1	HEIDENHAIN 426 TNC	450	1500	144.68	122.89	21.79	746.137
	SINUMERIK 840D	450	1500	143.92	122.85	21.07	719.726
	FANUC 21 M	450	1500	146.85	125.77	21.08	713.963
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	SINUMERIK 840D	500	1650	146.03	125.10	21.58	776.540
	FANUC 21 M	500	1650	144.81	124.50	20.31	747.966
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	SINUMERIK 840D	550	1800	145.05	123.79	21.26	848.545
	FANUC 21 M	550	1800	143.20	122.36	20.84	825.448
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	SINUMERIK 840D	600	2000	145.07	124.84	20.23	872.459
	FANUC 21 M	600	2000	145.33	125.21	20.12	861.844

(2) COMPARISON OF MRR (mm^3/min)

Comparison of MRR is shown in figure-5 as per experimental values. After analysis of the experimental results we can see the FANUC 21 M have lowest MRR while the HEIDENHAIN have highest MRR.

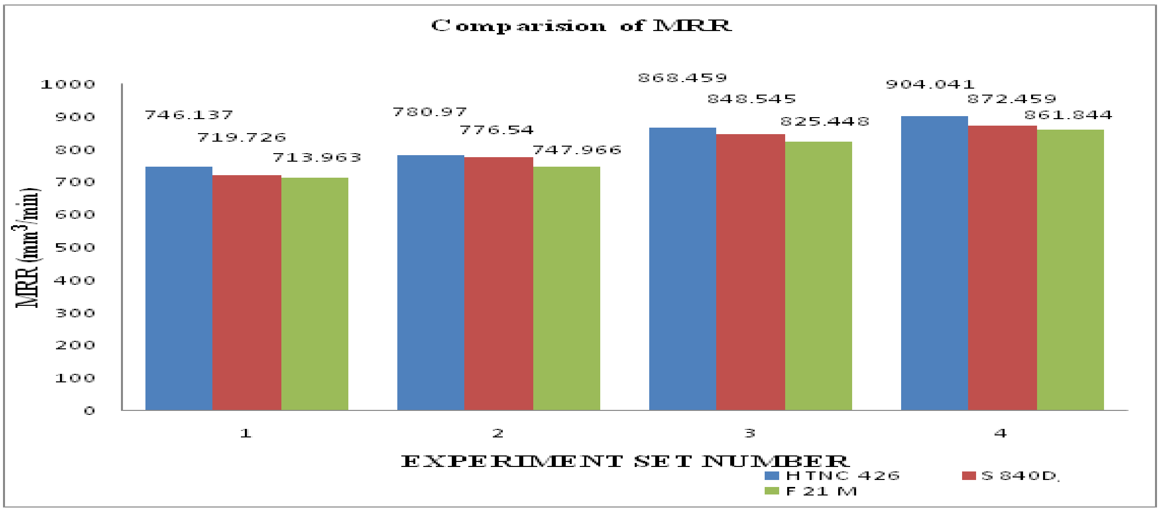

Fig.5: Comparison of MRR

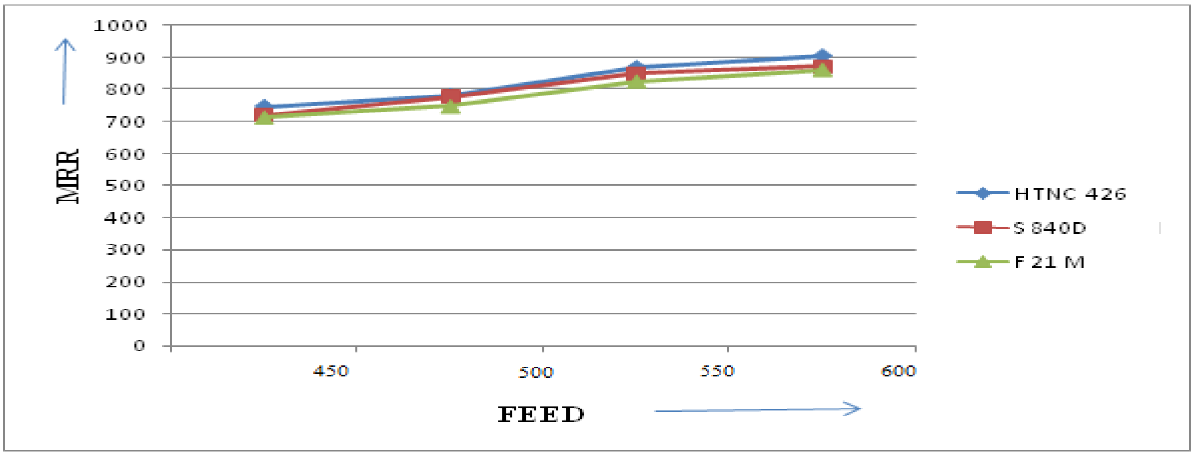

Fig.6**:** MRR and Feed variation with controller

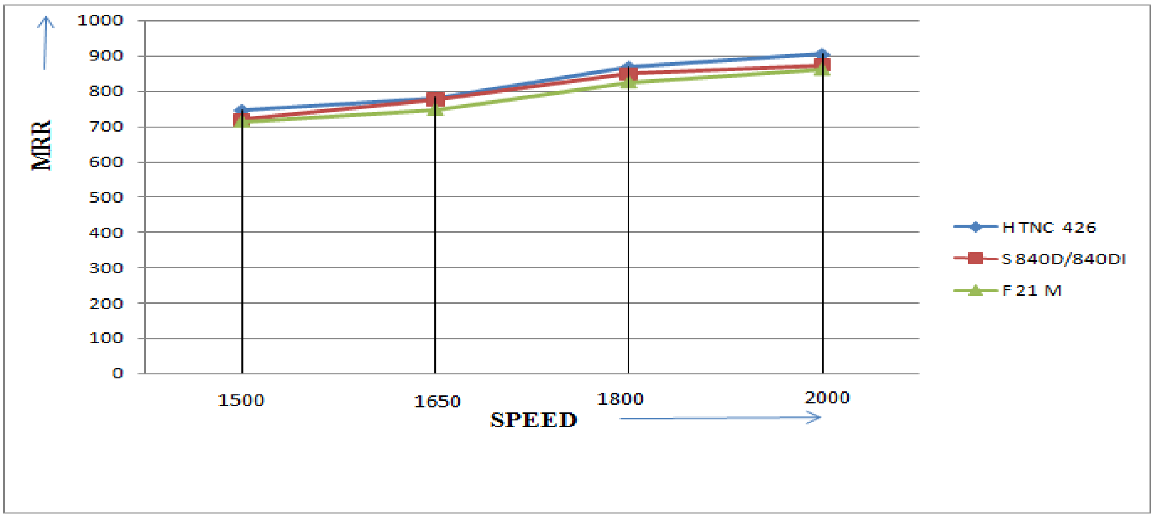

Fig.7**:** MRR and Speed variation with controllers

As shown in Fig 6 and Fig 7 between the MRR and feed, and MRR and speed respectively, that shows the variation of MRR for the particular speed and feed. Results are clearly shows that for a given geometry and given material the value of MRR is high for the HEIDENHAIN TNC 426 controller. But variation is clearly shows that FANUC 21 M has the lowest value among selected controllers.

(3) CONTROLLER PROCESSING TIME

CNC controller's processing time calculation is done on the basis of time study pattern. On the basis of the experimental work some important results have been obtained. On the basis of the experimental investigation the main finding is that for a same geometry, same set of parameters related to the machining and respective manual part programme the controller processing time is different in all three controllers considered for this study. Controller machining processing time is more for FANUC 21M and SINUMERIK 840D as compared to the HEIDENHAIN TNC 426. Overall controller processing time is less for the HEIDENHAIN TNC 426 as compare to SINUMERIK 840D and FANUC 21 M. The experimental program data input time is high in case of FANUC 21 M as comparison to the other two. It is also noted that referencing time is more for the H TNC 426 as compared to the other two controllers except program execution time all other time can varies to person to person. It depends upon skills of the machine operator.

V. CONCLUSION

Overall the research study reveals that the different–different CNC controllers have the different features. This research study conclude that for the given geometry, the result are better for the HEIDENHAIN 426 TNC and SINUMERIK 840D milling controller as compare to the FANUC 21M for the given geometry or job some more important result are concluded during this work. Different Controllers are having different capabilities, so we need to identify the right controller for right job that can minimize the machining time and ultimately optimize the associated parameters. Average processing time for the HEIDENHAIN TNC 426 is minimum as compared to other two controllers. In some observations, the results of SINUMERIK 840D are very near to the HEIDENHAIN TNC 426. MRR is found dependent on the controller features. During this work MRR is found high for the H TNC 426, than compared low for the S 840D and lowest for the F 21 M.

REFERENCES

Journal Papers:

[1] *Sungchul Jee, KSME International Journal, Vol. 12, No. 5, pp. 800~810, 1998*

[2] *Admit Murat PINAR, Abdulkadir GULL "Time Minimization of CNC Part Programs in a Vertical Machining Center in Terms of Tool Path and Cutting Parameter Criteria" in Turkish J. Eng. Env. Sci. 29 (2005), 75 – 88*

[3] *Sayyad Naimuddin, S. B. Warkad, Dr. G. M. Dhole, Mohammad Nasiruddin Journal of Theoretical and Applied Information Technology, 2005 JATIT www.jatit.org*

[4] *MA Xiong-bo, HAN Zhen- yu, WANG Yong-zhang, Fu Hong-ya Chinese Journal of Aeronautics 20 (2007) 272-281*

[5] Sc. Afrim Gjelaj, Dr. sc. Avdyl Bunjaku, " Programming and simulation of work piece in cnc milling machine" in 14th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" in TMT 2010, Mediterranean Cruise, 11-18 September 2010

[6] QU Xin-he1, LU Yuan1, LI Zhen-hua, http://en.cnki.com.cn/Journal_en/B-B022-ZHJC- 2010-08.htm , 2010

[7] D.Dimitrov, M. Saxer "Productivity Improvement in Tooling Manufacture through High Speed 5 Axis Machining" in Procedia CIRP 1(2012)277 – 282, 5th CIRP Conference on High Performance Cutting 2012

[8] Kotaro Nagaokaa and Atsushi Matsubarab "Improving motion accuracy of tool center point using model-reference feed forward controller" in Procedia CIRP1 (2012) 605 – 608,5th CIRP Conference on High Performance Cutting 2012

[9] Martin Ecksteina, Ildiko Mankovab "Monitoring of Drilling Process for Highly Stressed Aero engine Components" Procedia CIRP1 (2012) 587 – 592 in 5th CIRP Conference on High Performance Cutting 2012

[10] Sergej N. Grigorieva, A.A. Kutinb, V.V.Pirogovc "Advanced method of NC programming for 5-axis machining" in Procedia CIRP1 (2012)102–107 5th CIRP Conference on High Performance Cutting

[11] XU Xiao-minga, LI Yia SUN Ji-honga WANG Shuo-guib, 2012 International Workshop on Information and Electronics Engineering (IWIEE), Procedia Engineering 29 (2012) 1845 – 1850

[12] Petr Vavruska, Engineering MECHANICS, Vol.19, 2012, No.4, p.219–229

[13] Abhishek Kumar Saroj, Dr. S.C Jayswal "Analysis of Different Parameters on Tool Path for Machining Sculptured Surfaces" International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 10, October – 2013 ISSN: 2278-0181

[14] S. Daneshmand, M. Mirabdolhosayni and C. Aghanajafi, "Sifting Through the Optimal Strategies of Time-Based Tools Path Machining in Software CAD-CAM" in Middle-East Journal of Scientific Research 13 (7): 844-849, 2013 ISSN 1990-9233

[15] Khairul Akmal Shamsuddin, A.R.Ab-Kadir, and Mohd Hairizal Osman "A Comparison of Milling Cutting Path Strategies for Thin- Walled Aluminum Alloys Fabrication" The International Journal Of Engineering And Science (IJES) Volume 2 Issue 3 Pages 01-08 2013 ISSN: 2319 – 1813 ISBN: 2319 – 180

[16] Rakesh Prajapati,Avadhoot Rajurkar,Vijaykumar Chaudhary "Tool Path Optimization of Contouring Operation and Machining Strategies for Turbo Machinery Blades" in (IJETT) - Volume4Issue5- May 2013

[17] Gustavo M .Minquiza, Vicente Borjaa, Marcelo Lopez-Parra, Alejandro C. Ramírez-Reivicha, Miguel A. Domínguezb, Alejandro 586, 6th CIRP International Conference on High Performance Cutting, HPC 2014,

[18] N .V. Malvade, S. R. Nipanikar Malvade et al, "optimization of cutting parameters of end milling on VMC using TAGUCHI method" Journal of Engineering Research and Studies ,E-ISSN0976-7916, Vol. V/ Issue II/April-June, 2014/14-17,J Engg. Res Studies /Vol. V/ Issue II/April-June, 2014/14-17

[19] S B Chikalthankar et al. "Investigation and optimization of various machining Parameters Affecting the Effectiveness of Turning: A Review" International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 3 Issue 5, May - 2014

[20] Christian C. Mbaocha, Lakpah Emmanuel A., Jonathan A. Emmanuel International Journal of Scientific and Research Publications, Volume 5, Issue 8, August 2015, 1 ISSN 2250-3153

[21] Pedro Ponce, Arturo Molina, Guillermo Tello, Luis Ibarra, Brian MacCleery and Miguel Ramirez, IFAC-Papers Online 48-3 (2015) 2203–2207