Experimental Investigation on Mechanical Properties of Reinforced Composites

Nageshwar Anant, Sanjay Jain

Abstract—This paper investigates how to implementation and testing of an active controlled palletised work holding system for milling operations and how to targets a work holding system for the control of unwanted vibration. As a resulting degraded quality on the machined parts, shorter tool life, and unpleasant noise, hence is to be necessarily damped out. As results unwanted vibrations& noise must be arrested in order to ensure higher accuracy along with productivity. A arises vibrations on a slotted table Horizontal Milling Machine have been damped out using composite structure as a substitute for the base of the job piece. Experiment wise investigations of the Polyvinylchloride(PVC) plates are fixed on to the slotted table below the workpiece specimen milling operation is carried out and the vibration signal is recorded on the screen of the digital phosphorus storage oscilloscope *and* surface roughness of machined plate was found from the Talysurf are recorded. The experiment is repeated for different sets of PVC plates, it is observed that the vibration amplitude decreases with increase in number of layers of sheets of composites and then increases with increase in number of plates.

Index Terms— Drilling Machine, Frequency, Milling Machine, Oscilloscope, Reinforced Composite Materials (PVC).

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1 INTRODUCTION

In order to damp out the vibration and noise of machines and structures, surface damping treatments have been widely used because they are easy to implement to various structures and have good damping capacity for wide frequency and temperature ranges. Milling machines are basically classified as vertical or horizontal. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type. Most milling machines have self-contained electric drive motors, coolant systems, variable spindle speeds, and power-operated table feeds. Vertical milling machine also can function like a drill press because the spindle is perpendicular to the table and can be lowered into the work piece, and horizontal milling machine spindle is parallel to the workpiece surface. Therefore, the tendency for chatter vibration to occur is peculiar to the given geometrical structure of each kind of milling machine. Studies on the vibration and damping in milling operation have been done for many years. Chatter stability lobes of high speed milling with consideration of speed-varying spindle dynamics. [1]. Analysis of the stability limits in self-excited chatter vibration requires the transfer function of the mechanical structure and loss of machining stability is caused by the work-piece [2],[3]. Cutting conditions affect dynamic cutting factor and a time domain method was proposed to identify the dynamic cutting factors through the vibration signals of the milling process. [4]. Ultrasonic vibrating system dynamic reactions full simulation of the vibrating system has been achieved by adding a coupling element. [5]. A property of glass/polyester composites was aimed via matrix modification technique and vibrating system dynamic reactions full simulation of the vibrating system has been achieved by adding a coupling element. [6]-[7]. Reduction of self-excited vibrations with dynamic properties of the machine tool-machining system use of vibration eliminators. [8]. A synthesis of damping analysis of laminate materials, laminates with interleaved viscoelastic layers and sandwich materials [9]. Active controlled palletised workholding system for milling operations for approach to controlling vibration in a machining system [10]. Chatter is defined as a form of relative structural self excited vibrations between the cutter and workpiece incurred at the cutting zone [11]. Improve the damping capacity of the column of a precision mirror surface grinding machine tool a hybrid column was manufactured by adhesively bonding glass fiber reinforced epoxy composite plates to a cast iron column [12]. When the tooth frequency was equal to the natural frequency of the system an optimizing method using a passive vibration damper for chatter vibration has also been proposed [13].

The peripheral milling is the operation performed by a milling cutter to produce a machined surface parallel to the axis of the cutter. According to the relative movement between the tool and the work the peripheral milling is classified under two headings: Down milling and Up milling.

Down or climb milling: It is the process of removing metals by cutter which is rotated in the same direction of travel of the work piece. Up or conventional milling: It is the process of metal by cutter which is rotated against the direction of the travel of the work piece. Vibration reduction can be obtained by increasing the damping capacity and/or by increasing the stiffness. Damping of a structure can be attained by passive or active methods. In surface damping treatment rubbers have been widely used due to its chip and easy implementation, it is not appropriate for large and high stiffness structures, because of its low stiffness compared to metal. The most common damping materials available on the current market are polymer matrix and fiber reinforced composite materials have high potential for surface damping treatment, because they have both high damping capacity and high stiffness, which

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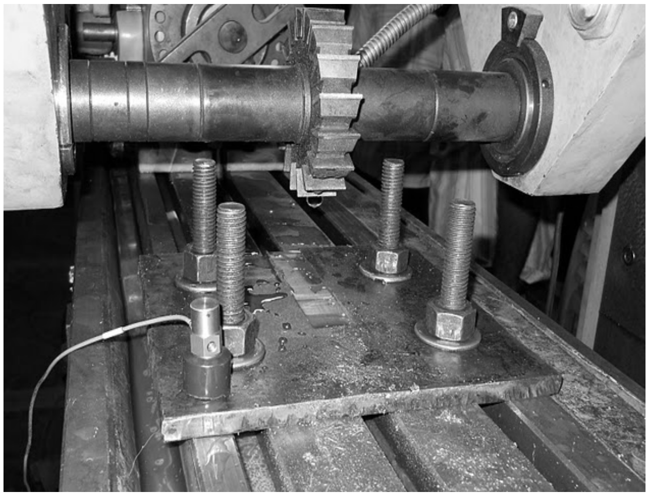
comes from the fact that the polymer matrix fiber reinforced composite materials are composed of high damping polymer resin and high stiffness fiber. Polymer matrix fiber reinforced composite materials have been widely used in spacecraft, aircraft, automobile structures and even machine elements such as robot structures due to their high specific stiffness and high specific strength as well as damping. In addition to these advantages, they are suitable for the optimal design of structures because their mechanical properties can be tailored by adjusting stacking sequences.

2 EXPERIMENTAL WORK

The purpose of the experimental investigation was to reducing the unwanted vibration occurring in a machining operation. Easy availability of reinforced composites materials made them ideal as the experimental workpieces for testing the tool milling performance. Milling experiments were conducted on the mild steel plate work specimen mounted on different multi-layered stacked sheets of Polyvinylchloride (PVC) during machining operations. This Experimental work is to be record vibration signals and analysis them to determine response characteristics of a work specimen mounted on varying multi-layered stacked sheets of PVC, during machining operations.

The experimental investigation of damping was performed for work specimen of mild steel and PVC plates is 210mm x 210mm x 5mm, this plates was drilled at four corners to fix it on the table of the milling machine. The comparison of vibration performance in the work specimen is between a mild steel was mounted on layer and multi layers sheets of Polyvinylchloride. The total four machining parameters are selected for the experimentation, and the machining parameter and their level are shown in Table1.



Figures 1. Mild steel plate bolted to slotted table of milling machine

First stage is no layered of sheet below to the work specimen, was tightly bolted to the slotted table of the milling machine. Experimental equipment a contact type magnetic base Accelerometer (or vibration pickup) attached to the top surface of the specimen was connected to Digital phosphor oscilloscope Tektronix 4000 series. The readings were taken.

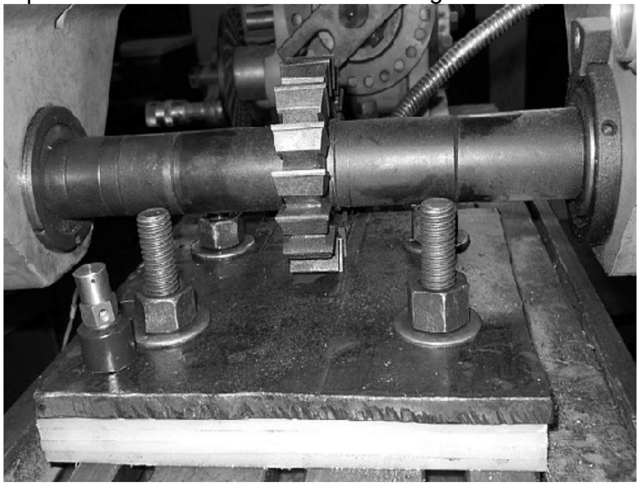


Figure 2. Milling machine with 5 layers of reinforced composites sheets bolted to slotted table

And the second stage in multi layers of Polyvinylchloride plates below to the work specimen was tightly bolted to slotted table of the milling machine. By interposing 5 layers of Polyvinylchloride sheets each of 5mm thickness below the mild steel specimen and fixing with the help of bolts to the slotted table. The machining of the surface was accomplished with constant depth of cut of 0.01mm and feed rate of 16 mm / min. The response signals were observed on the screen of the oscilloscope. After careful examination the amplitude, time period, and frequency was noted and the signal spectrum was stored in the computer memory

TABLE 1

MACHINING PARAMETER AND THEIR LEVEL

Control Parameter					
Parameter	Sym-bol	Level			Unit
		1	2	3	
Feed	F	16.0	20.5	25.0	mm / min
Speed	S	180	230	280	RPM
Depth of cut	d	0.01	0.02	0.03	mm
No. of plate	no.	1	3	5	

Then the number of layers was reduced t and observation was made. In this way the experiment was repeated in decreasing the number of layers each time by 3 layers. The experiment was conducted for 1, 3 and 5 layers respectively.

3 RESULT AND DISCUSSION

The influences of the cutting parameters (F, S, d and no.) on the response variables selected have been assessed for secondary bed materials by conducting experiments as outlined in section of experimentation. A Minitab generated design was used with three levels of each of the four design factors. The process variables along with their values on different levels lettings are listed as follows for secondary bed material materials. The number of experiment was 27 for different parameters set of secondary bed material. The results are put into the Minitab software for further analysis following the steps outlined in same section. The second-order model was derived in obtaining the empirical relationship between the two response parameters [amplitude of vibration (Amp) surface roughness parameters (Ra)] and the machining variables (F, S, d and no.).

TABLE 2

Experimental Result for Secondary Bed Material Polyvinylchloride (PVC)

Run no	PtType	Blocks	Feed (F)	Speed (S)	Depth of cut (d)	No. of plate (no)	Amplitude (Amp)	Roughness (Ra)
1	2	1	16.0	180	0.02	3	14.647	0.80
2	2	1	25.0	180	0.02	3	13.559	1.20
3	2	1	16.0	280	0.02	3	15.930	2.00
4	2	1	25.0	280	0.02	3	14.300	1.60
5	2	1	20.5	230	0.01	1	15.400	1.40
6	2	1	20.5	230	0.03	1	16.090	1.72
7	2	1	20.5	230	0.01	5	7.228	1.70
8	2	1	20.5	230	0.03	5	12.136	1.95
9	2	1	16.0	230	0.02	1	14.100	1.69
10	2	1	25.0	230	0.02	1	14.000	1.50
11	2	1	16.0	230	0.02	5	10.803	1.50
12	2	1	25.0	230	0.02	5	7.236	1.81
13	2	1	20.5	180	0.01	3	14.610	1.80
14	2	1	20.5	280	0.01	3	13.512	2.00
15	2	1	20.5	180	0.03	3	14.610	1.89
16	2	1	20.5	280	0.03	3	22.500	2.00
17	2	1	16.0	230	0.01	3	13.460	1.60
18	2	1	25.0	230	0.01	3	14.870	1.20
19	2	1	16.0	230	0.03	3	22.800	1.80
20	2	1	25.0	230	0.03	3	15.000	1.90
21	2	1	20.5	180	0.02	1	11.000	1.80
22	2	1	20.5	280	0.02	1	16.400	1.80
23	2	1	20.5	180	0.02	5	8.427	1.00
24	2	1	20.5	280	0.02	5	7.337	1.60
25	0	1	20.5	230	0.02	3	10.200	1.70
26	0	1	20.5	230	0.02	3	11.600	1.20
27	0	1	20.5	230	0.02	3	10.569	0.80

3.1 Influence of Amplitude of Vibration (Amp)

During the process of machining, the effects of various machining parameters like Feed (F), Speed(S), Depth of cut (d) and no. of plate (no.) on Amp are shown in Figure 3. This figure indicates that Feed is first decreases the Amp up to optimum level then slightly increasing it. Speed is directly proportional to Amp, but depth of cut is first decreasing then increasing. The no. of plate is inversely proportional to the Amp.

A check on the normal probability plot of the shows that, the residuals fall on or near a straight line shown in figure4. This refers that the errors are distributed normally. Also residuals versus the predicted response plot reveal that there is no obvious pattern and unusual structure. This implies that the model proposed is adequate.

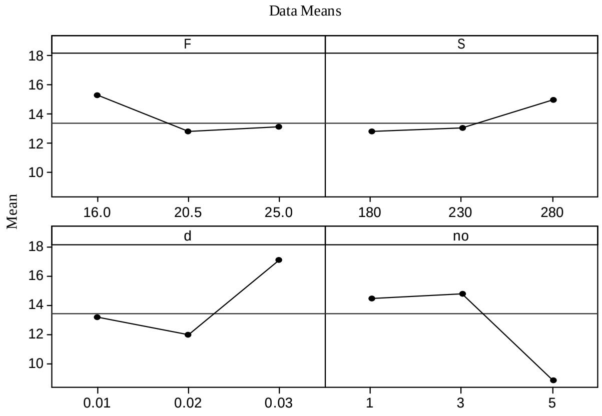


Figure 3. Main effect plot for Amp

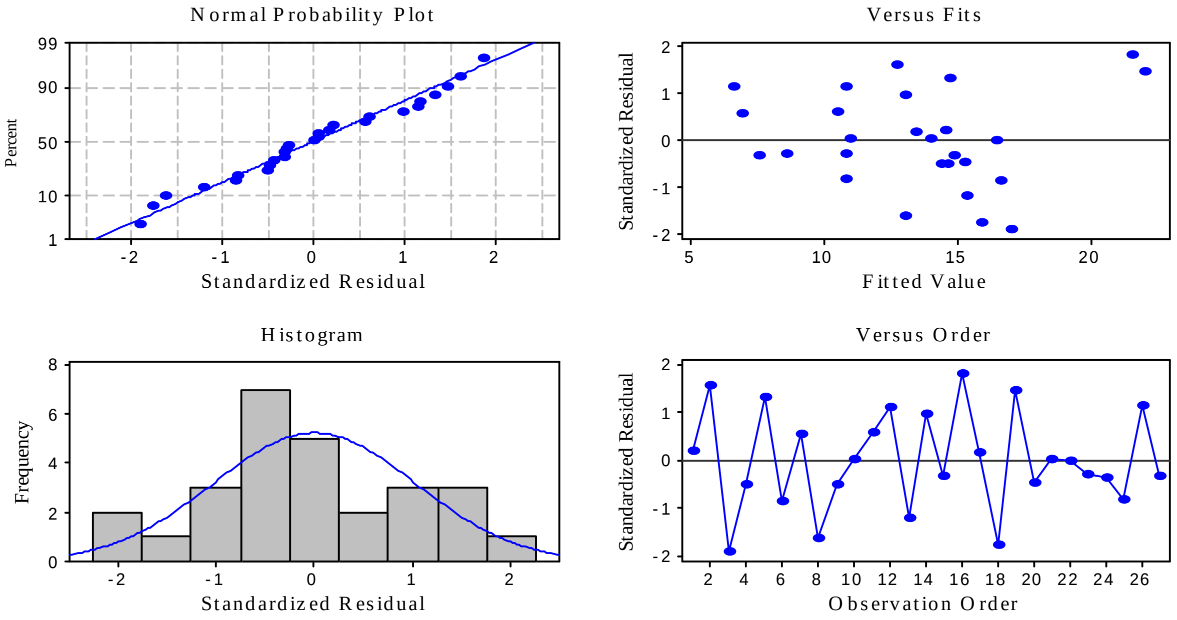


Figure 4. Residual Plots of Amp

The analysis of variances for the factors is shown in Table 3 which is clearly indicates that the all Linear, and square terms is most influencing factors for Amp and as well as the interaction F*d, S*d, S*no and d*no is significant that shown in P column in same table.

The parameter R2 describes the amount of variation observed in Amp is explained by the input factors. R2 = 96.87 % indicate that the model is able to predict the response with high accuracy. Adjusted R2 is a modified R2 that has been adjusted for the number of terms in the model. If unnecessary terms are included in the model, R2 can be artificially high, but adjusted R2 (=94.18 %.) may get smaller. The standard deviation of errors in the modeling, S= 0.9242. Comparing the p-value to a commonly used α-level = 0.05, it is found that if the p-value is less than or equal to α, it can be concluded that the effect is significant, otherwise it is not significant.

TABLE 3

Analysis of Variance for amp

Source	DF	Seq SS	Adj MS	F	P
Regression	12	369.918	30.8265	36.08	0.000
Linear	4	171.515	42.8787	50.19	0.000
F	1	13.600	13.6001	15.92	0.001
S	1	14.358	14.3577	16.81	0.001
D	1	48.224	48.2243	56.45	0.000
no	1	95.333	95.3329	111.59	0.000
Square	4	142.023	35.5058	41.56	0.000
F*F	1	14.032	25.7000	30.08	0.000
S*S	1	9.345	15.6142	18.28	0.001
d*d	1	104.591	70.4334	82.45	0.000
no*no	1	14.054	14.0545	16.45	0.001
Interaction	4	56.380	14.0950	16.50	0.000
F*d	1	21.206	21.2060	24.82	0.000
S*d	1	20.196	20.1960	23.64	0.000
S*no	1	10.530	10.5300	12.33	0.003
d*no	1	4.448	4.4479	5.21	0.039
Residual Error	14	11.960	0.8543		
Lack-of-Fit	12	10.907	0.9089	1.73	0.425
Pure Error	2	1.053	0.5265		
Total	26	381.878			

S = 0.924279 R-Sq = 96.87% R-Sq(adj) = 94.18%

3.2 Influence of Surface roughness (Ra)

The process of machining, the effects of same machining parameters as on Amp to Ra are shown in Figure 4. This figure indicates that Feed is first increases then slightly decreasing it inversely proportion to the Amp. Speed is first decreases and then gradually increases, but depth of cut is first increasing then decreasing. The no. of plate is inversely proportion to the Speed.

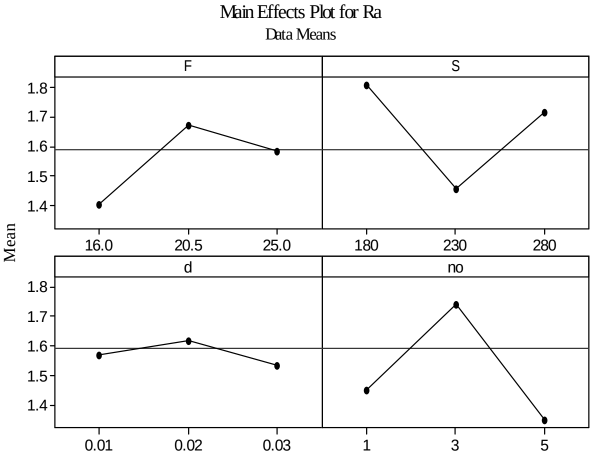


Figure 5. Main effect plot for Ra

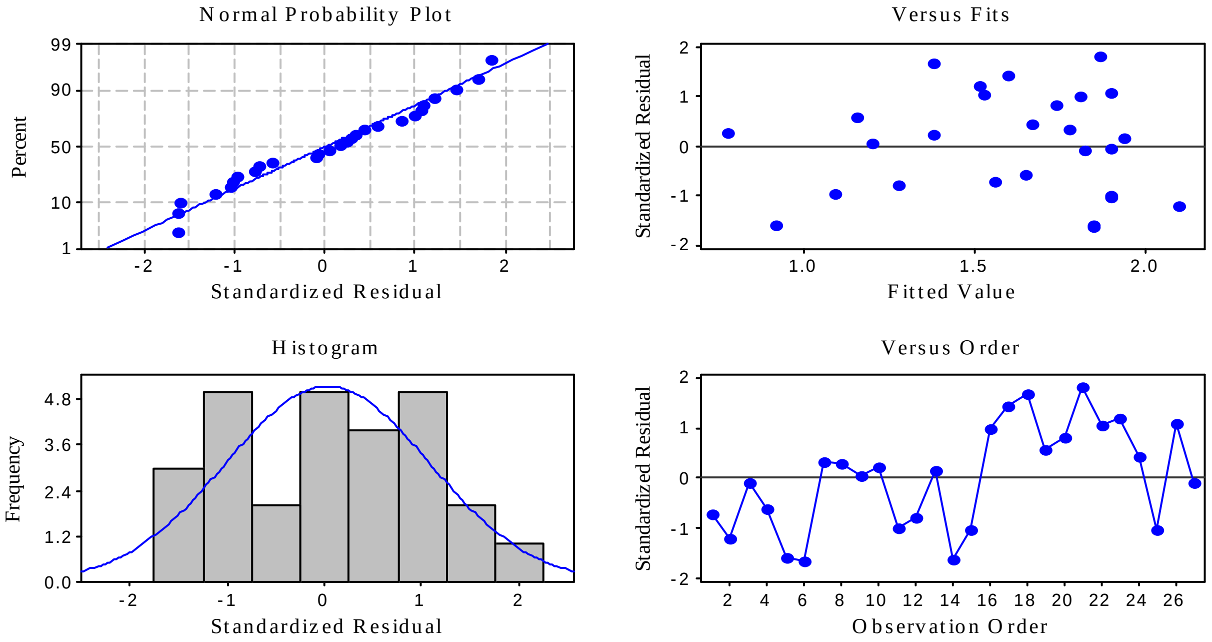


Figure 6. Residual Plots for Ra

The analysis of variances for the factors is shown in Table 4 which is clearly indicates that the all Linear, and square terms. The parameter R2 describes the amount of variation observed in Ra is explained by the input factors. R2 =94.15% indicate that the model is able to predict the response with high accuracy in surface roughness. Adjusted R2 is a modified R2 that has been adjusted for the number of terms in the model. If unnecessary terms are included in the model, R2 can be artificially high, but adjusted R2 = 86.13 %. may get smaller. The standard deviation of errors in the modeling, S= 0.115679. Comparing the p-value to a commonly used α-level = 0.05, it is found that if the p-value is less than or equal to α, it can be concluded that the effect is significant.

TABLE 4

ANALYSIS OF VARIANCE FOR RA

Source	DF	Seq SS	Adj MS	F	P
Regression	12	3.01372	0.251144	18.77	0.000
Linear	4	0.16028	0.040071	2.99	0.056
F	1	0.09901	0.099008	7.40	0.017
S	1	0.02521	0.025208	1.88	0.191
d	1	0.00403	0.004033	0.30	0.592
no	1	0.03203	0.032033	2.39	0.144
Square	4	1.58332	0.395829	29.58	0.000
F*F	1	0.21004	0.367500	27.46	0.000
S*S	1	0.51756	0.108300	8.09	0.013
d*d	1	0.00770	0.151875	11.35	0.005
no*no	1	0.84801	0.848008	63.37	0.000
Interaction	4	1.27012	0.317531	23.73	0.000
F*S	1	0.12602	0.126025	9.42	0.008
F*d	1	0.16000	0.160000	11.96	0.004
S*no	1	0.06250	0.062500	4.67	0.048
d*no	1	0.92160	0.921600	68.87	0.000
Residual Error	14	0.18734	0.013382		
Lack-of-Fit	12	0.16728	0.013940	1.39	0.493
Pure Error	2	0.02007	0.010033		
Total	26	3.20107			
S = 0.115679 R-Sq= 94.15% R-Sq(adj)= 89.13%					

4. CONCLUSIONS

This paper presents a frequently method for the simulation of workpiece surface through measured experimental vibration signals in horizontal milling and also analyzed the effects of cutting vibration on the surface generation. Our investigations demonstrate that, from the point of view that unwanted vibration on the workpiece and the tool life. The following conclusions are obtained:

1. Extensive experiments are carried out to determine vibration response of work specimen with specified machining parameter, i.e., depth of cut and feed rate.
2. Use of composite materials reduces the vibrations of the system as desired which is justified from the experimental observations. With increase in number of layers of composites at an optimum level the vibrations are decreased considerably.
3. Abrupt increase in vibration amplitude has also been observed with increase in number of layers of composites above an optimum limit interposed between the table and work piece.
4. For Polyvinylchloride with increase of number of layers amplitude first increased and then decreased.

REFERENCES

[1] Hongrui Cao, Chatter stability of milling with speed-varying dynamics of spindles, International Journal of Machine Tools & Manufacture Vol. 52, pp. 50–58, (2012)

[2] Norikazu Suzuki, Identification of transfer function by inverse analysis of self-excited chatter vibration in milling operations, Precision Engineering 5906, (2012)

[3] Marcin Hoffmann, Experimental investigation on using the piezoelectric and electromagnetic vibration absorbers in milling, Theoretical and Applied mechanics letters 2, 043007, (2012)

[4] C.Y. Huang, Effects of cutting conditions on dynamic cutting factor and process damping in milling, International Journal of Machine Tools & Manufacture Vol.51, pp. 320–330, (2011)

[5] C. Andersson, Experimental studies of cutting force variation in face milling, International Journal of Machine Tools & Manufacture Vol.51, pp. 67–76, (2011)

[6] S. Erden , Enhancement of the mechanical properties of glass/polyester composites via matrix modification glass/polyester composite siloxane matrix modification, Fibers and Polymers, vol. 11, no. 5, pp. 732-737, (2010)

[7] Kei-Lin KUO, Ultrasonic vibrating system design and tool analysis, Trans. Nonferrous Met. Sov. Chian 19, pp. 225-231, (2009)

[8] ArkadiuszParus, suppression of Self-Excited vibration in cutting process using piezoelectric and electromagnetic actuators, Advance in Manufacturing Science and Technology Vol. 33, No. 4, (2009)

[9] Jean-Marie Berthelot, Damping analysis of composite materials and structures, Composite Structures, Vol. 85, pp. 189–204, (2008)

[10] Amir Rashid, Active vibration control in palletised workholding system for milling, International Journal of Machine Tools & Manufacture, Vol.46, pp. 1626–1636, (2006)

[11] Y. Altintas, Modelling approaches and software for predicting the performance of milling operations at MAL—UBC, CIRP International Workshop on Modelling of Machining Operations, Sydney, Australia, pp. 60–74, (2000)

[12] Dai Gil Lee (1998), Damping improvement of machine tool columns with polymer matrix fiber composite material, Composite Structures, Vol. 43, pp. 155-163, (1998)

[13] K. J. Lin and K. E. Rouch, Optimal passive vibration control of cutting process stability in milling, J. Mater. Process. TechnoL 2g (1/2), pp. 285-294, (1991).