Experimental Analysis of Passive Damping Technique on Conventional Radial Drilling Machine Tool Bed using Composite Materials

Krishna Mohana Rao. G, and Vijay Mohan. S

***Abstract*—** Machine tool structures Drilling machines are subjected to regular unwanted vibrations or chatter. It results in degraded quality on the machined parts, shorter tool life, and unpleasant noise, hence are to be necessarily damped out. The unwanted vibrations must be arrested in order to ensure higher accuracy along with productivity. In the present work, the chatter vibrations on a slotted table Radial Drilling machine have been damped out using composite structure as a substitute for the base of the work piece. The signal and RMS amplitude, frequency and time period of vibrations are recorded for different number of layers. Moreover, experiments are also conducted without any composite material below the mild steel specimen. 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. Moreover, the optimum number of composites is also experimentally determined.

***Keywords*—** Radial Drilling Machine, Vibration Damping, Composite Layers, Frequency, Amplitude

I. Introduction

DAMPING mechanisms in composite materials differ entirely from those in conventional metals and alloys. Damping in machine tools basically is derived from two sources--material damping and interfacial slip damping. Material damping is the damping inherent in the materials of which the machine is constructed. The magnitude of material damping is small comparing to the total damping in machine tools. A typical damping ratio value for material damping in machine tools is **0.003**. It accounts for approximately **10%** of the total damping. The interfacial damping results from the contacting surfaces at bolted joints and sliding joints. This type of damping accounts for approximately **90%** of the total damping.

II. Literature Review

Lazan[1] conducted comprehensive studies into the general nature of material damping and presented damping results data for almost 2000 materials and test conditions. Rahman et al. [2] have made attempts to review and summarize the key developments in the area of non-conventional materials for machine tool structures over the last decades. Suh et al. [3] have used composites for the massive slides for CNC milling machine in machining moulds and dies because presence of these massive slides do not allow rapid acceleration and deceleration during the frequent starts/stops encountered in machining moulds and dies. Haranath et al. [4] have done attempts experimentally to establish that improvement can be attained by applied damping treatment using viscoelastic layers. Bert [5] and Nashif et al.[6] had done survey on the damping capacity of fiber reinforced composites and found out that composite materials generally exhibit higher damping than structural metallic materials. Chandra et al. [7] has done research on damping in fiber-reinforced composite materials. Gibson et al.[8] and Sun et al.[9] assumed viscoelasticity to describe the behavior of material damping of composites. Morison [10] analyzed the prediction of material damping of laminated composites and Kinra[11] Studied the influence of ply-angle on damping and modulus of elasticity of a metal-matrix composite. Gibson et al [12] used the modal vibration response measurements to characterize, quickly and accurately the mechanical properties of fiber-reinforced composite materials and structures. Koo KN et al. [13] studied the effects of transverse shear deformation on the modal loss factors as well as the natural frequencies of composite laminated plates by using the finite element method based on the shear deformable plate theory. Singh s. p et al. [14] analyzed damped free vibrations of composite shells using a first order shear deformation theory in which one assumes a uniform distribution of the transverse shear across the thickness, compensated with a correction factor. Ding Jiangmin et.al [15] proposed application of composite concrete bed for CNC machine tool which is composed of epoxy concrete structure faces and steel fiber cement concrete core in order to satisfy the requirements like high stiffness and high damping has been experimentally conducted.

III. Experimental Details

As shown in figure 1, the specimens of 210 x 210 x 6 size are prepared for Glass Fiber Epoxy and Glass Fiber Polyester. Size of the mild steel plate is taken as 210 x 210 x 10mm.

Krishna Mohana Rao. G is a Professor of Mechanical Engineering, JNT University Hyderabad, AP, India (corresponding author's phone: 919866123121; fax: 914023057787 ; e-mail: kmrgurram @jntuh.ac.in).

Vijay Mohan. S, was with the Department of Mechanical Engineering, JNTUH College of Engineering, Hyderabad, AP, India

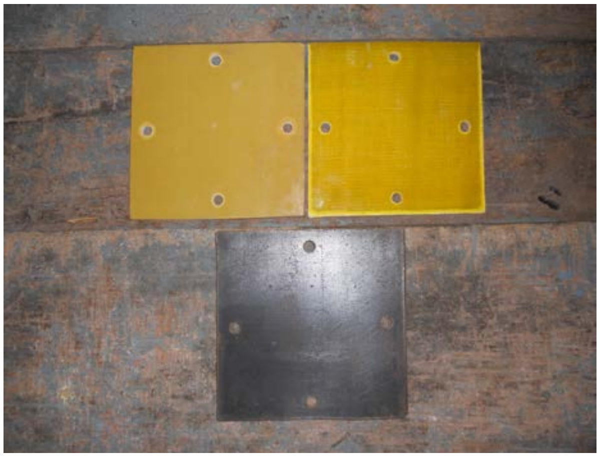

Fig. 1 Composite Layers

Drilling operation is carried out using a 12mm drill bit to a depth of 3mm with while increasing the number of composite plates from one to five. A contact type magnetic base vibration pickup connected to a digital phosphor storage oscilloscope of Tektronix 1000 series is used to pick up amplitude, time period, RMS amplitude and frequency. Finally Mild steel plate alone is machined with no layer under it. Figure 2 shows the experimental set up.

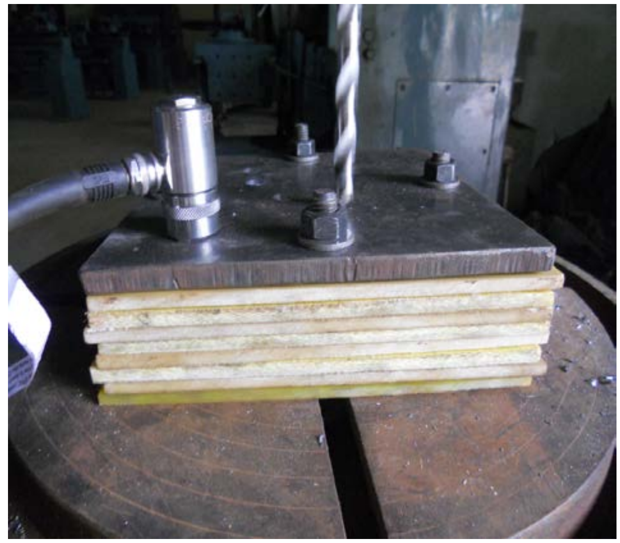

Fig. 2Experimental Set Up

IV. Results And Discussion

Table I gives the experimental values for glass fiber polyester plates. It is observed that when the number of layers are increased, the signal amplitude has decreased this shows presence of composite layers increased the counter vibration characteristics of the system. It is also observed that when number of layers are increased from 4 to 5 the amplitude of vibrations are increased abruptly, it represents after a certain limit it would have a negative effect with much of the progress.

TABLE I
EXPERIMENTAL FREQUENCY AND AMPLITUDE DATA RECORDED FOR GLASS FIBER POLYESTER PLATES.

SERIAL NO.	DEPTH OF CUT(mm)	NUMBER OF LAYERS	SIGNAL AMPLITUDE (mV)	FREQUENCY (KHZ)	TIME PERIOD (µs)	RMS AMPLITUDE (mV)
1	3	1	51.2	1.426	808.5	12.4
2	3	2	32.4	1.82	494.2	6.25
3	3	3	22.2	1.12	968.7	6.1
4	3	4	44.4	2.456	329	9.2
5	3	5	48.9	3.125	281.4	8.96

Table II gives the experimental values for glass fiber epoxy plates. It is observed that when the number of layers are increased, the signal amplitude has decreased this shows presence of composite layers increased the counter vibration characteristics of the system. It is also observed that when number of layers are increased from 3 to 5 the amplitude of vibrations are increased abruptly, it represents after a certain limit it would have a negative effect with much of the progress.

TABLE II
EXPERIMENTAL FREQUENCY AND AMPLITUDE DATA RECORDED FOR GLASS FIBER EPOXY PLATES

SERIAL NO.	DEPTH OF CUT(mm)	NUMBER OF LAYERS	SIGNAL AMPLITUDE (mV)	FREQUENCY (KHZ)	TIME PERIOD (μs)	RMS AMPLITUDE (mV)
1	3	1	32.5	1.283	868.6	5.46
2	3	2	28.8	1.93	447.7	7.61
3	3	3	51.1	1.79	537.5	9.04
4	3	4	56.2	1.52	542.1	13.04
5	3	5	63.2	2.37	416.9	15.8

Table III gives the experimental values for sand witch layers of composites considered. It is observed that when the number of layers are increased, the signal amplitude has decreased this shows presence of composite layers increased the counter vibration characteristics of the system. The corresponding values for mild steel plate are given in table IV.

It is also observed that when number of layers are increased from 8 to 10 the amplitude of vibrations are increased abruptly, it represents after a certain limit it would have a negative effect with much of the progress.

TABLE II
EXPERIMENTAL FREQUENCY AND AMPLITUDE DATA RECORDED FOR SANDWICH PLATES

SERIAL NO.	DEPTH OF CUT(mm)	NUMBER OF LAYERS	SIGNAL AMPLITUDE (mV)	FREQUENCY (KHZ)	TIME PERIOD (μs)	RMS AMPLITUDE (mV)
1	3	2	57.1	2.12	427.5	13.2
2	3	4	56.6	1.96	508.3	12.5
3	3	6	30.6	1.424	682.5	7.06
4	3	8	48.2	1.325	712.3	11.2
5	3	10	51.1	1.426	726.5	8.56

TABLE IV
EXPERIMENTAL FREQUENCY AND AMPLITUDE DATA RECORDED FOR MILD STEEL PLATE

SERIAL NO.	DEPTH OF CUT(mm)	NUMBER OF LAYERS	SIGNAL AMPLITUDE (mV)	FREQUENCY (KHZ)	TIME PERIOD (μs)	RMS AMPLITUDE (mV)
1	3	1	58.6	1.617	598.2	14.6

Hence optimum Number of plates is to be decided to profitably damp out the vibrations and it is represented in Table V.

TABLE V
OPTIMUM NO. OF PLATES AND HEIGHT OF THE MACHINE BED

TYPE OF COMPOSITE	OPTIMUM NO.OF PLATES	HEIGHT OF THE MACHINE BED
Glass Fiber polyester	Three	18 mm
Glass Fiber Epoxy	Two	12mm
Sandwich Plates	Six	36 mm

V. CONCLUSIONS

1) 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.
2) Effective damping can be obtained only by proper fixation of the composites to the bed and the work piece. With improper nut and bolt joint there is a danger of additional slip vibrations between the plates. Hence a proper and intact joint is preferably necessary. On the contrary the optimum number of plates is decided and a single plate of optimum thickness is used as the bed material.
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) The results obtained are compared with respect to each other. Out of the two materials, signal amplitudes obtained are less for Glass fiber epoxy material. Therefore, it can be concluded that **Glass fiber epoxy** material can be used for machine tool structures to reduce the undesirable effects of vibrations.
5) The density of the matrix phase plays an important role in damping the vibrations. With same fiber phase, lower the matrix phase density more is the damping ability. Though both the thermo sets polyester and epoxy have same material properties like Young's modulus, Rigidity modulus and Poisson's ratio, epoxy has more damping ability than polyester because of its low density.

REFERENCES

[1] Lazan, B. J., "Damping of Materials and Members in Structural Mechanics". Pergamon Press, London (1968).
[2] Rahman, M., Mansur, A. and Karim, B. "Non-conventional material for machine tool structures".
[3] Suh, J.D., Lee, D.G. and Kegg, R. " Composite machine tool structures for high speed milling machines".
[4] Haranath, S., Ganesan, N. and Rao, BVA. "Dynamic analysis of machine tool structures with applied damping treatment".
[5] Bert, C.W., "Composite materials: A survey or the damping capacity of fiber reinforced composites in damping applications for vibration control".
[6] Nashif, A.D, Jones, D.I.G and Henderson, J.P. Vibration Damping, Wiley, New York, (1985).
[7] Chandra, R., Singh S.P, and Gupta.K Damping studies in fiber-reinforced composites—a review.
[8] Gibson, R.F., Chaturvedi, S.K. and Sun, C.T., "Complex moduli of aligned discontinuous fiber-reinforced polymer composites" and "Internal damping of short-fiber reinforced polymer matrix composites.
[9] Sun, C.T , Wu, J.K. and Gibson, R.F., "Prediction of material damping of laminated polymer matrix composites''.
[10] Morison W.D, "The prediction of material damping of laminated composites",
[11] Kinra, V.K., Wren G.G., Rawal S.P. and Misra. M.S. "On the influence of ply-angle on damping and modulus of elasticity of a metal-matrix composite.
[12] Gibson Ronald, F. "Modal vibration response measurements for characterization of composite materials and structures".
[13] Koo K.N, Lee.I. "Vibration and damping analysis of composite laminates using deformable finite element". AIAA J; 31 (4): 728-35,(1993).
[14] Singh S.P., Gupta K., "Damped free vibrations of layered composite cylindrical shells".
[15] DING JIANGMIN et.al [25] proposed "application of composite concrete bed for CNC machine tool bed".

G. Krishna Mohana Rao is a member of ASME, ISTE, IE(I). He was born at Machilipatnam, AP, India on 05.05.1970. He received his bachelors' degree in mechanical engineering from Nagarjuna University, AP, India in the year 1992. Later, he was awarded masters degree in mechanical engineering by the Indian Institute if Science, Bangalore, India in the year 1994. He received his doctoral degree in mechanical engineering from JNT University, Hyderabad, AP, India in the year 2007. He has been working for JNT University, AP, India since 1994. He is on the review board for many international journals. He has published 40 technical papers in international journals and conferences. He co-authored a book on engineering mechanics published by Pearson education. He visited countries including USA, UK, Egypt, UAE, China, Malaysia, Singapore, Hongkong, Thailand and Italy for presenting his papers in various international conferences. Presently, he is guiding 13 research students in the area of mechanical engineering.

Vijay Mohan. S, was a student of the department of Mechanical Engineering, JNTUH College of Engineering, Hyderabad, AP. India. He is interested in the area of advanced manufacturing systems.