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CHATTER MITIGATION IN BORING MACHINING PROCESS

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Abstract: Machining is a complex process in which many variable can detrimental the desired result. Technology is advancing demand is also increasing. Now a days the challenge of modern machining industries are mainly focused on the achievement of high quality dimensional accuracy of work piece ,surface finish ,high production rate ,less wear on the cutting tools and economy of the machining. For boring bar because of high length to diameter ratio deformation occurred as the overhang length increase and because of such self-excitation vibrations develop in the machining setup which limited the productivity, ultimately more machining time required and coarse surface finish is obtained. In this paper Finite element analysis of boring bar carried out in ANSYS .17 software 8 node solid 185 chosen for analysis at different overhang length for prediction of total deformation and von misses stress & optimum overhang length chosen for experimentation work and also analysis is done of hollow boring bar with different material particle in order to investigation of effects of material density on the deformation of the boring bar. This paper proposed particle damping method along with squeeze film of fluid in order to suppress the effect of chatter in boring operation. The experiments were performed using solid and modified boring tool. Boring experiments were planned by Taguchi method L9 orthogonal array. Three levels for spindle speed, feed rate, depth of cut and tool overhang were chosen as cutting variables. The obtained experimental data has been analyzed using signal to noise ratio. The main effects have been discussed and optimal cutting conditions have been determined. The overall work on this field is aim to investigate the optimal solution to give better results like good surface finish, machining time, excellent productivity etc.

Keywords: *Boring Tool, Tuned Mass Damper, Precision Turning, Chatter Taguchi Method*

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I INTRODUCTION

Boring is the process to enlarge and locate a previously made hole with the help of single point tool. As drill tends to wonder or drift hence when greater accuracy is required to, drilling is followed boring and reaming. Chatter is self-excited vibration caused by variation in chip thickness resulting from a time delay between current cut and preceding cut. Chatter vibration in machining limit the accuracy and productivity of boring processes. This lead to rapid tool wear and poor surface finish. In boring process, the long cantilever boring bar makes it vulnerable to chatter due to its low dynamic stiffness. Precision Internal turning machining op damping operation are now carried out almost exclusively using hard metal or diamond tipped cutting tools. Tool holder is available in variety of forms to suit the specific machining requirement. In boring operation self-excited vibration is occurred because of l/d ratio greater than 12. Boring is one of the machining operations, which is most widely used in industry. In the case whenever depth of the hole to be bored is more compared to diameter of hole, there is need of slender boring tool. For slender boring tools the ratio of length to diameter is higher due to which while machining tool may deflect. At the time of boring, forces are exerted at free end which finally results in vibration. As vibrations are always undesirable so it has adverse effects on surface finish and tool life. So to reduce vibrations there are various techniques which can be mainly categorized as active and passive damping. An active control system for boring bars using accelerometers on the tool for providing the controller with both reference and error signal. The signals are processed and sent eventually to the actuators located in the tool clamp, which compensates by providing dynamic forces to the boring bar.

Giovanni Totis and Macro Sortino [2] develop new probabilistic algorithm for a robust analysis of stability in internal turning is presented. In this approach, model parameters are considered as random variables, and robust analysis of stability is carried out in order to estimate system's probability of instability for a given boring bar geometry and material, tool geometry, work piece material and cutting parameters. M. Balajia, B.S.N. Murthyb, N. Mohan Raoc et al [3] performed experiment on drilling of AISI304 steel with carbide drill bits. Design of experiments was prepared according to Taguchi orthogonal array of L8 and experiments were performed with two levels of the cutting parameters.

Y. Alammari, M. Sanati, T. Freiheit S. S. Park et al [4] investigated the feasibility of shifting the natural frequency of boring bar based on semi-active fluid control. Mass at the end of a boring bar was modulated to tune its natural frequency by adjusting the level of fluid in a reservoir. This paper present particle damping is used to analyze behavior of boring tool under vibration. The results are collected in the form of vibration acceleration and surface roughness, comparison is made among boring tool without particle damping and tool with particle damping. Analysis results show that, particle damping reduces vibration and enhances the Surface finish.

II COMPUTATIONAL ANALYSIS

1). Computational Analysis

Boring Tool analysis is carried out in ANSYS software to determine the dynamic characteristics. The element 8 node solid 185 was chosen for analysis of boring tool holder geometry as shown in figure 1.

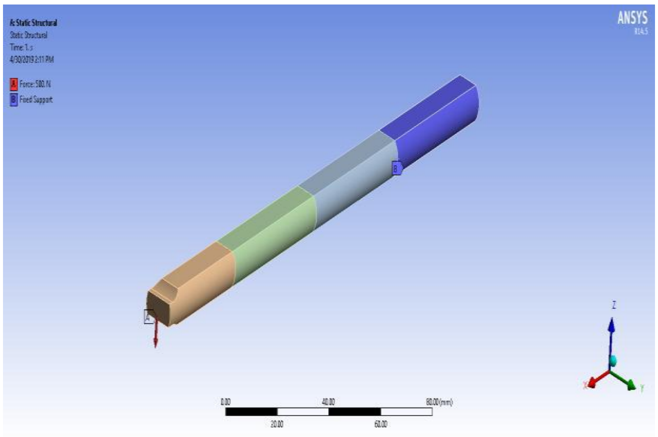

Fig.1 Geometry of boring tool

The entire tool holder is dividing into four sections 0mm, 45mm, 90mm, 135mm; Fig .2 shows deflection of boring bar at 0 mm overhang length.

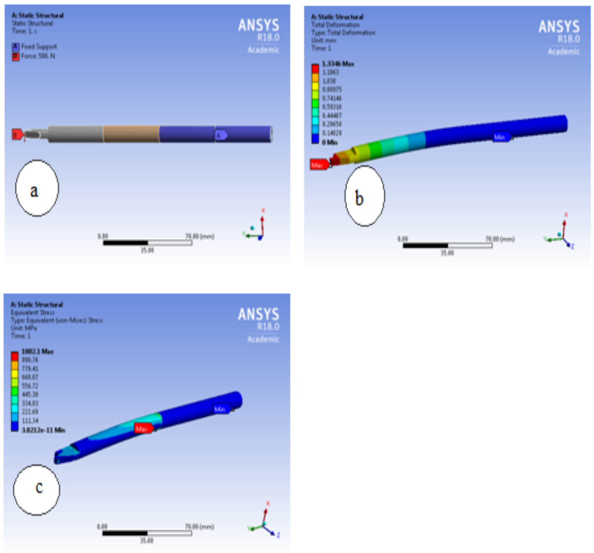

Fig 2 a) Boundary Conditions (90mm fix from one end) b) Total Deformation c) Von Misses Stress

The equivalent stresses i.e. Von Misses Stress observed in static structural analysis of tool holder is 561.13 MPa as shown in fig 2 b Fig 2 (c) The maximum total deformation is observed as 1.0054 mm.

Table 1

Effect of tool overhang length on deflection

Sr no	**Overhang length (mm)**	**Deflection (mm)**	**Von misses stress(MPa)**
1	0	0.0025868	47.231
2	45	0.091545	254.26
3	90	1.0054	561.13
4	135	3.7654	872.29

Table1 shows deflection for each overhang length of the boring bar similarly, modified boring tool analysis is carried out.

Table 2:
Material properties of stainless steel

Sr no	**Property**	**Value**
1	Elasticity	200 GPa
2	Poisson's ratio	0.3
3	Density	7850 kg/m3

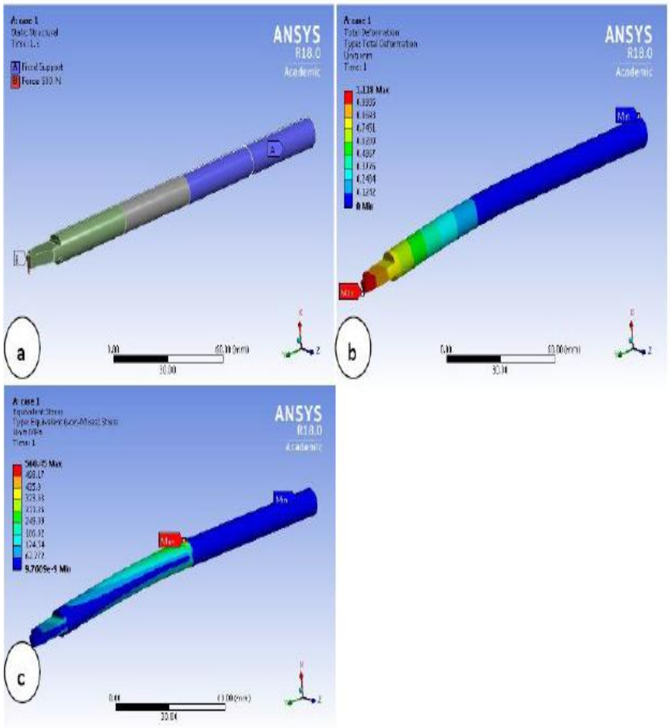

Fig 3 a) Boundary Conditions (90mm Fix from One End) B) Total Deformation C) Von Mises Stress

From fig 3 b maximum total deformation is observed as 1.11mm.The equivalent stress i.e. Von Mises Stress observed in static structural analysis of tool holder Figures is 560.45 MPa as shown in fig 3 c. This stress is beyond elastic limit of material**.**

Table 3

Effect of tool overhang length on deflection

Sr no	**Overhang length (mm)**	**Deflection (mm)**	**Von mises stress(MPa)**
1	0	0.00698	422.47
2	45	3.05	299.78
3	90	1.11	560.45
4	135	3..05	746.12

III. EXPERIMENTAL ANALYSIS USING FFT ANALYZER

The experiment was conducted with solid boring bar having 12 mm diameter and 180 mm length on cnc lathe machine having l/d ratio greater than 12 the principle of boring operation as shown in figure 4. The hollow work piece is fitted in 3 jaw chuck which rotated with spindle of cnc machine and the boring bar is fixed in the tool post. The 9 trial

Fig .4 Experimental set up for boring operation

The accelerometer is placed on tool post as shown in figure 7 to sense displacement acceleration, frequency etc.

1). FFT analyzer

Fig 7 (a) shows Fast Fourier Transform (FFT) Analyzer FFT analyzer is an electronic device that converts the input signal with time or an independent variable into frequency spectrum and display in Graphical form .such analyzer receive analog voltage signal from amplitude through the filler for computations. One channel FFT analyzer was used with accelerometer. Acceleration and frequency graph were recorded. Accelerometer was placed on the tool post in order to sense vibration from machining set up. The specifications are as follows 4. Gx series microlog specification

Fig .4(a) FFT analyzer (b) Accelerometer

1)Input sources • Acceleration, velocity, and displacement from hand-held or installed vibration sensors or monitoring systems • AC / DC sensors • Pressure sensors • Temperature sensors. 2) Preprocessing • Enveloper (demodulator): With four selectable input filters for enhanced bearing and gear mesh fault detection • Filter selection:5 Hz to 100 Hz, 50 Hz to 1 kHz, 500 Hz to 10 kHz, 5 kHz to 40 kHz 3)Input parameters: Tachometer: TTL / analogue programmable to ±25 V, RPM range 1 to 99 999, Tachometer power supply output +5 V at 100 mA •

Input over-voltage protection: AC ±50 V peak, DC ±50 V sustained • Dynamic range: >90 dB (24 bit ADC sigma-delta) 4)Input connectors: CH1: Six pin Fischer, CH1, CH2, CH3,CH2: Six pin Fischer, CH2, CH3,USB host / CHR / headphone: USB keyboard, CHR, headphones, USB Device / power / trigger: Seven pin Fischer trigger in, trigger tachometer power supply, USB COMMS, charger • Input signal range: ±25 V maximum 5)Data processing and storage • Microprocessor: Marvell 806 MHz PXA320 • Internal storage: 128 MB (capable of storing approximately 4 000 spectra) • SD card: SD memory card up to 16 GB.

2. Sensor (Accelerometer):

Deltatron accelerometer combines high sensitivity, low and small physical dimensions making them ideally suited for model analysis. Easily fitted to different test objects using a selection of mounting clips. It measures the rate of change of velocity per time period. Fig 5(b) shows accelerometer

3). Boring bar

Boring bar supports the cutter for boring operations on work Pieces having large diameters. The boring bar as shown in fig 8(a) serves to transmit the power from the boring machine spindle to the cutter as well as to hold rigidly during the boring operation.

Fig.5.(a) boring bar (b) surface roughness tester

4). Surface Roughness Tester

Fig 5 (b) shows Surface roughness tester is another measuring instrument by which we measure the surface finish of machining component. Initially the master piece was used to calibrate the surface roughness tester having value 1.52µm. it is used to measure RA value of nine different hollow work piece which is made up of aluminum as shown in fig . 6

5). Work piece

There are 9 work piece made up of aluminum used for experimentation is shown in figure below,

Fig.6 Work Piece

Table 4 shows the work piece specification below

Sr .no	Measuring factor	Dimension
1	Internal diameter	50 mm
2	Outer diameter	100 mm
3	Length	150 mm
4	Material	EN

6)Damping Particles:

To carry out experimental work spherical shaped particles of three different material steel ,copper, lead have been used as damper in order to see the effect of variation of different particles material of the output responses, which are shown as following, fig.7

Fig. 7 (a) Steel (b) Copper (c) Lead

As per experimental procedure, first trial is conducted as per taguchi array L9 without use of passive damping and responses measured in terms of vibrations and

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surface finish. Then before conducting second trial tool is modified by drilling hole along the shank length and then as per variation of various parameters values trial is conducted.

Table 5 Input Parameter

Sr no	Input parameters	Unit	Level		
1	Depth of cut	mm	0.25	0.5	0.75
2	Speed	RPM	1200	1500	1800
3	Feed rate	mm/minute	80	100	120

As we consider four parameter varying through three level so the taguchi test matrix for it as follows

Table.6

Test Matrix For L9 Orthogonal Array (Hollow Boring Bar Trial)

Run	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

According to above table first run can be predicted as follows: A1=Depth of cut = 0.25mm B1=Speed =1200RPM C1=Feed Rate = 80 mm/min D1=damping material =copper Similarly others can be calculated. As per following parameter we conducted test on cnc lathe machine with following input parameter listed as follows.

IV. RESULT AND DISCUSSION

Table 7:

Solid Boring Bar Trials without Particle Damping

Run	Depth of Cut (mm)	Spindle Speed (rpm)	Feed Rate (mm/min)	Vibration Level (m/s^2)	Surface Roughness (µm)
1	0.25	1200	80	1.770	5.960
2	0.25	1500	100	2.430	6.322
3	0.25	1800	120	2.120	4.164
4	0.50	1200	100	3.580	9.901
5	0.50	1500	120	0.881	7.402
6	0.50	1800	80	0.735	5.955
7	75.00	1200	120	1.410	6.554
8	75.00	1500	80	1.330	6.407
9	75.00	1800	100	1.650	5.550

Table 8

Hollow Boring Bar Trial with Particle Damping

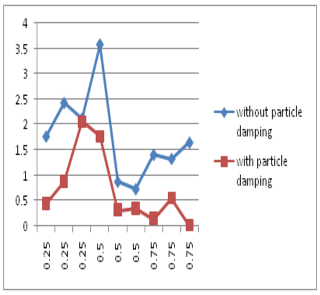
Sr .no	Depth of cut (mm)	Spindle speed (rpm)	Feed Rate (mm/min)	Damping Material	vibration level (m/s2)	Surfandce Roughness (µm)
1	0.25	1200	80	cu	0.4390	0.626
2	0.25	1500	100	Pb	0.8810	0.553
3	0.25	1800	120	St	2.0600	0.556
4	0.50	1200	100	St	1.7700	0.780
5	0.50	1500	120	Cu	0.3170	1.345
6	0.50	1800	80	Pb	0.3460	0.885
7	0.75	1200	120	Pb	0.1490	0.448
8	0.75	1500	80	St	0.5560	1.065
9	0.75	1800	100	Cu	0.0186	0.582

From table it's observed that vibration level is reduced to great extent due to combine damping effect of particle and film of lubricant and surface finish improved.

Table.9:

Comparison of output parameter

No of run	Without particle damping		With particle damping	
	Vibration level (m/s^2)	Surface Roughness (µm)	vibration level (m/s^2)	Surface Roughness (µm)
1	1.770	5.960	0.4390	0.626
2	2.430	6.322	0.8810	0.553
3	2.120	4.164	2.0600	0.556
4	3.580	9.901	1.7700	0.780
5	0.881	7.402	0.3170	1.345
6	0.735	5.955	0.3460	0.885
7	1.410	6.554	0.1490	0.448
8	1.330	6.407	0.5560	1.065
9	1.650	5.550	0.0186	0.582



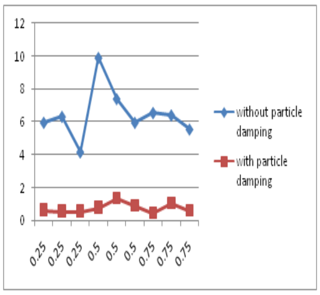
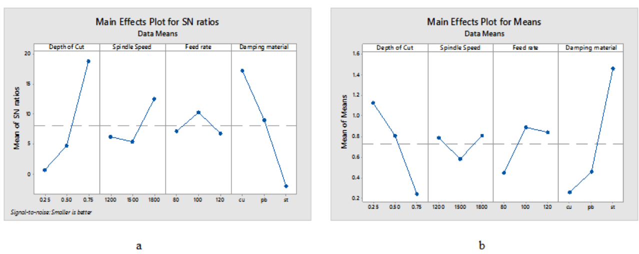
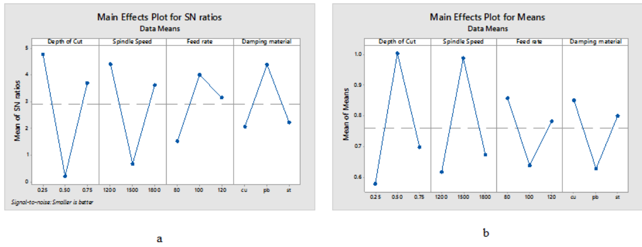


Fig 8 Comparison of Vibration Level Fig 9 Comparison of surface roughness (µm)



a) S/N ratio b) plot for means

Fig 10. Hollow Boring Bar with Particle Damping (Vibration level)



A) S/N ratios B) plot for means

Fig 11. Hollow Boring Bar with Particle Damping (Surface Roughness)

V CONCLUSION

Boring is internal turning operation carried out on predrilled whole work piece in order to enlarge the diameter of hole. In boring operations, a long overhang boring bar presents a critical challenge due to low dynamics stiffness. This often causes chatter, which leads to tool breakage and part failure. Moreover, maintaining the constant depth of cut and cutting speed is desirable in boring operations, in order to minimize sudden changes in inertia and cutting forces. In order to achieve high productivity in boring operations, the suppression of chatter is important. In this project, different filler materials namely copper lead and steel were used to examine static stiffness and damping characteristics. The conclusion of the report work are given below

1) Simulation work

Finite element analysis of boring bar is carried out in ANSYS software

- For solid boring bar it is observed that as the overhang length increases from 0 mm to 180 mm total deformation of boring bar is also increases from 0.002586 mm to3.7654 mm and von mises stresses from 47.231 MPa to 872.29 MPa. at 90 mm overhang the total deformation is 1.0054 mm and von mises stress is 561.13 MPa hence 90 mm. so overhang length is considered for experimentation
- For hollow boring bar the magnitude of total deformation increases from 0.010524 mm to3.5984 mm and von misses stress is increases from383.99 MPa to 1318.4 MPa as the overhang length increases from 0 to 180 mm

 For hollow boring bar with steel particle the total deformation and von mises stress is limited as compared to copper and lead particle. Also the total deformation of hollow boring bar with particle is improved as compared to hollow bar because of greater stiffness.

2) *Experimental Vibration Analysis*

From experimental result it is observed that resistance to self excitation vibration of hollow (modified) boring bar is greater than that of solid (conventional) boring bar.

 Vibration level reduces by about 61% due to use of passive damping and surface finish enhances by 88 %.

3) Optimization of Input Parameter for Reduction in Vibration Level & surface finish

From MINITAB 17 software The optimum combination of parameters obtained for vibration is

D=depth of cut = 0.75 mm. S=spindle speed = 1800 RPM. F=feed rate = 100 mm/min. Dm= Damping material = cu (copper)

 The optimum combination of parameters obtained for surface finish

D=depth of cut = 0.25 mm. S=spindle speed = 1200 RPM. F=feed rate = 100 mm/min. Dm= Damping material = Pb (lead)

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