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Investigation on Maximum Resonating Amplitudes Obtained upon Experimental Modal Testing of Solid (Without damping) boring bar and Hollow (Particle + Viscous damping) boring bar

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***Abstract*— Boring, also called internal turning, is used to increase the internal diameter of the hole. During most deep hole boring operations —4× length to diameter and greater—the enemy is chatter. It seems to show up sporadically, and the deeper the bore the worse it can be. Chatter results from vibration between the tool tip and workpiece interface. It is further increased by deep hole boring because as the length to diameter ratio of the boring bar increases. Thus, instead of smoothly lifting and breaking a chip, the tool tip vibrates, causing the chatter to appear on the workpiece surface. This is bad for jobs requiring tight dimensional accuracy. Here the resonating peaks and the mode shapes of the boring bar at these peaks have been found out. In this paper boring bars have been designed to exhibit chatter, and resonating peaks have been recognised, mode shapes at these peaks have been extracted.**

***Index Terms*—Hollow boring bar, mode shapes, normal modes, solid boring bar.**

I. Design of Boring Bars

Firstly the two boring bars, hollow and solid were designed for length to diameter ratio of 6, so that they exhibit chatter, the hollow and solid boring bar designs are shown in Figures 1 and 2 respectively.

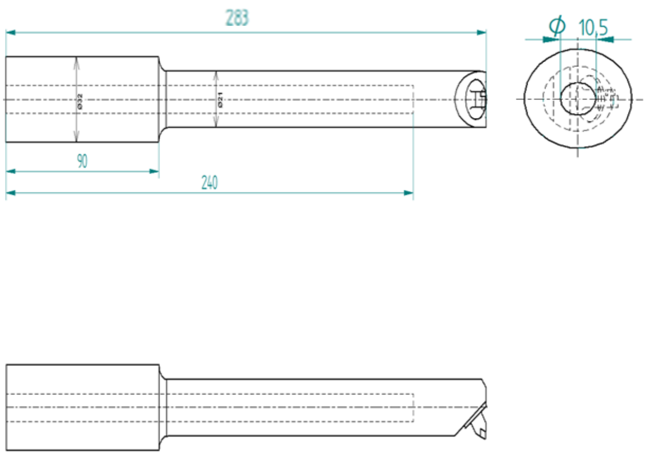

Fig1: Hollow boring bar design

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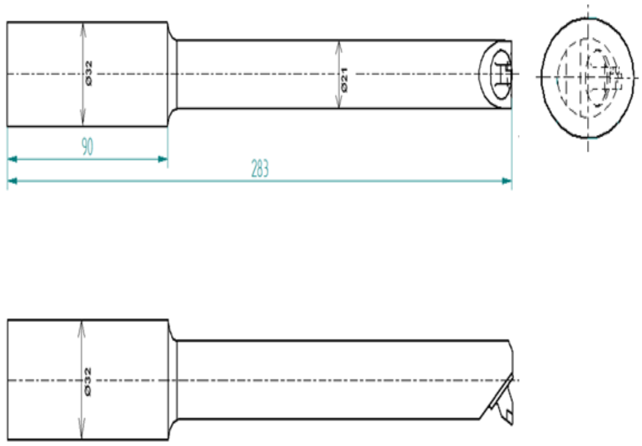


Fig. 2: Solid Boring Bar Design

II. Experimental Modal Testing

Experimental modal testing was carried out using FFT analyzer, a series of tests were conducted. Here the bar was excited manually by using modally tuned hammer (model 086c40) as shown in the Figure 3.

Fig 3: Mannual excitation of the bar using modally tuned exciation hammer

An I.C.P. accelerometer is mounted on the spindle housing using adhesive glue, this accelerometer measures the effect (of vibration) caused by the hammer impact. Both the signals are then amplified and sampled. The transfer function, which describes the dynamic characteristics of the spindle/tool-holder/tool-system is then computed and used to calculate the stable speeds for a certain work piece material and cutting conditions.

Tool tip is excited by striking the area exactly opposite to the tool tip with impact hammer. The vibrations at the tool tip are measured by the accelerometer mounted on the spindle. The FRF response is taken for the following cases by exciting:

- Only Hollow boring bar
- Hollow boring bar filled with 4mm steel balls.
- Hollow boring bar filled with 5mm steel balls.
- Hollow boring bar filled with 6mm steel balls.
- Hollow boring bar filled with a mixture of the different sized balls
- Hollow boring bar filled with oils of viscosities SAE-40, 15W-40 and 20W-40 together with 4mm, 5mm and 6mm balls.
- Solid boring bar

Specifications of the machine

- Model: VMC1000
- Axis traverse: X-600, Y-400, Z-600
- Table size: 400mm×800mm
- Spindle size: 70mm, BT40
- Spindle speed: 60 to 6000 RPM
- Automatic tool changer: 16 Tools
- CNC system: Siemens 810D

The working of FFT involves exciting the boring bar by means of the exciting hammer. Meanwhile the entire setup is connected to the computer via a hardware lock. Various parameters involved are assigned to the channels before taking results. When the tool holder is excited then the parameters FRF, coherence, spectrum channel-1 and spectrum channel-2, cross-phase, trigger channel-1, channel-2 are shown. Peak value is noted down and thus modal frequency is calculated.

The above procedure mentioned is repeated for boring bar with 4mm, 5mm, 6mm steel balls and oil of different viscosities. It is necessary to ensure that the boring bars are to be properly fitted into the machine tool holder (ISO-40, side-lock holder). The accuracy of excitation must be such that same amount of force and pressure must be applied for each excitation trial. More accurate the excitation, more accurate the results will be. Hence, resulting in a very good coherence.

The above mentioned procedure is repeated for the solid boring bar and the results are observed. Necessary calculations are made. The results obtained are compared with those obtained from previous trials and suitable conclusions are drawn.

III. Damping Calculations

Damping calculations are shown for hollow bar filled with 4mm balls in dry condition. Here, δ=Logarithmic decrement (Fig 4), ξ=Damping factor, ω_d=Damped natural frequency, ω_n=Natural frequency, $\xi_{(modal)}$=Modal damping.

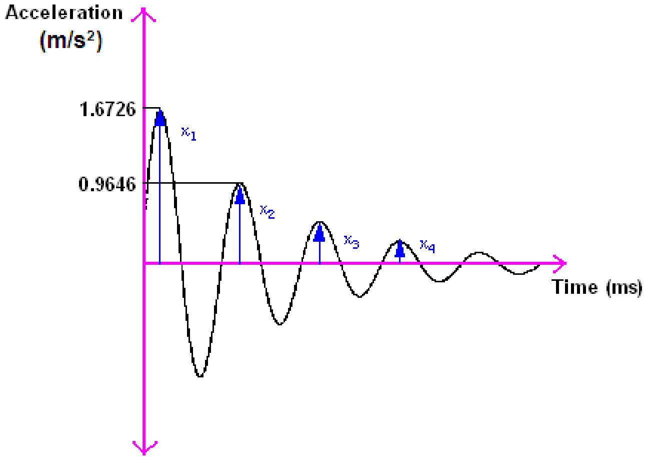
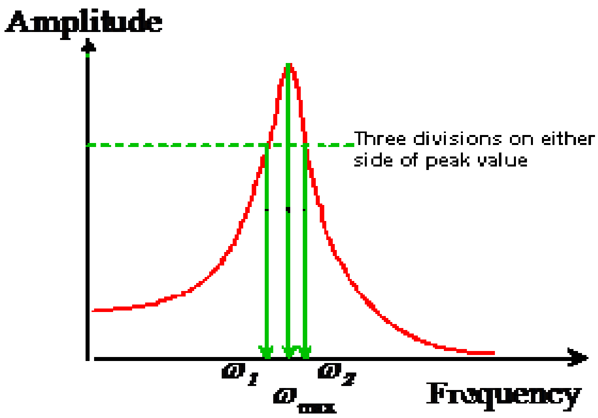


Fig 4: Logarithmic decrement

Fig 5: Modal damping



From Figure 4,

$\delta=(1/n)\{\ln X_1/X_2)\}$

$=(1/n)\{\ln(X_0/X_n)\}$ (i.e. X_0, X_n represent amplitudes of two consecutive peaks, $X_0=X_1$, $X_n=X_2$ in our case)

$=(1/3)\{\ln(1.6726/0.9646)\}$

$=0.1834$

$\xi=1/[1+(2\pi/ \delta)]^{1/2}$

$=1/[1+(2\pi/0.1834)]^{1/2}$

$=0.0291$

$\omega_d = \omega_n(1- \xi^2)^{1/2}$

$=1.859(1-0.0291^2)^{1/2}$

$= 1.857$ KHz

$\xi_{(modal)}= (\omega_2- \omega_1)/(2\omega_{max})$ (Refer Figure 5)

$=(1.9-1.75)/(2\times1.835)$

$=0.0408$

IV. EXPERIMENTAL RESULTS

It was found that, the amplitude of vibration was lower in the solid bar than the hollow bar. Ref. Table1 & 2

Table 1: Results of trials on empty hollow and solid boring bars

Trial	X_0 (m/s^2)	$X_n(m/s^2)$	δ	ξ
Solid Bar	0.3951	0.1769	0.2678	**0.0425**
Hollow Bar	0.9533	0.6183	0.7699	0.0147

Table 2: Results of trials on empty hollow and solid boring bars

ω_n(kHz)	ω_d(kHz)	ξ(modal)	Amplitude $(m/s^2/N)$
1.955	1.953	0.0228	645.8×10^{-3}
1.852	1.851	**0.0229**	1.867

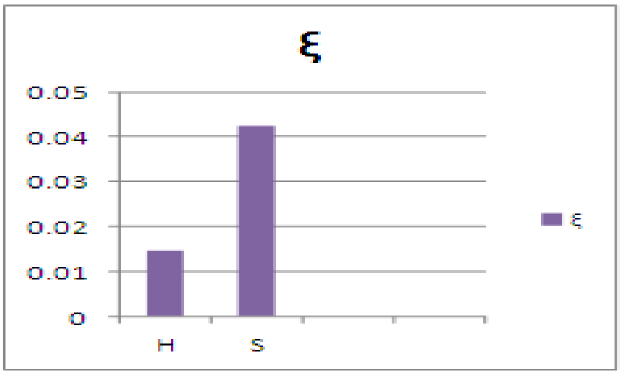


Figure 6: Bar Graph showing ξ values for trials on solid and empty hollow boring bars, where H-Hollow bar, S-Solid bar

During the trials on the solid and hollow boring bars, it was observed that the solid bar provided greater damping when compared to the empty hollow bar. This can be observed in the Figure 6. The amplitude of vibration of the solid bar was lesser in comparison with the hollow bar, also can be observed from Table 1 and 2.

V. TRAILS WITH 4MM STEEL BALLS AND OIL IN HOLLOW BAR

The amplitude of vibration was considerably reduced with the addition of oil when compared to the dry condition. Thus, implying better damping, refer Fig 7 which is showing highest value of damping factor with SAE40 oil

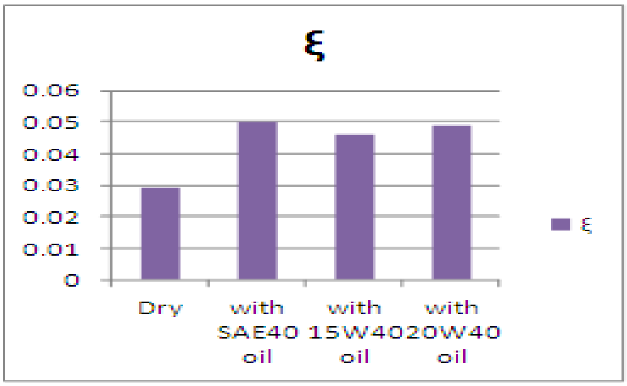


Figure 7: Bar Graph showing ξ values for trials on 4mm balls in dry and viscous medium

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