EFFECTS OF KNOB END LOADING AND BARREL LENGTH ON SELECTED MECHANICAL CHARACTERISTICS OF ALUMINUM SOFTBALL BATS

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INTRODUCTION

Studies by Noble and Eck (1985, 1986) examined the effects of interior loading on the location of the center of percussion (COP) of aluminum softball and baseball bats and recommended procedures for the systematic displacement of the COP. However, these studies did not consider the effects of loading strategies on vibrational characteristics which may be related to bat effectiveness and annoyance. Further understanding of the vibrational characteristics of bats, and how to control them, will be beneficial in identifying methods to improve the overall effectiveness of bats. The purpose of this study was to determine the effects of knob end loading and barrel length on fundamental frequency and location of the nodes and COP.

METHODOLOGY

Subjects were 18 aluminum softball bats especially constructed for this study by a bat manufacturing firm. All bats were made from CU31 aluminum alloy with a barrel diameter of 57 mm and a length of 0.864 mm. Six of the bats were fitted with conventional hollow aluminum knobs (21.9 ± 0.5 g), six were fitted with solid aluminum knobs (74.5 ± 0.1 g) and six were fitted with solid steel knobs (190.8 ± 0.1 g). Two bats of each knob type had barrel lengths of 0.492 m, 0.441 m, and 0.343 m. All bats were tapered to a handle of 0.022 m in diameter using a 0.25 m taper.

Standardized procedures were used to measure the length, mass, and barrel length of each bat. Physical pendulum procedures, using a specially-constructed clamping assembly, were used to measure the moment of inertia and center of percussion of each bat (axis - 0.168 m from knob end).

It has been shown that the fundamental frequency mode of vibration of a hand-held bat can be approximated as that of a free-free beam (Brody, 1990). A discussion of this mode for a prismatic (constant cross-section) beam can be found in any standard text on the vibration of continuous systems. The approximate location of the nodes for the first mode of a prismatic beam are expected to be one-fourth of the bat length from each end. To experimentally determine the frequency of this mode and the location of the nodes, the bat was supported in a horizontal position by threads (light flexible supports) attached to the ceiling. A vibration exciter and velocity sensor were provided in the horizontal plane as shown in Figure 1. The placement of the exciter and pickup are unimportant so long as neither is located at one of the nodes.

A resistor was put in series with the exciter coil and the voltage across the resistor was displayed on the horizontal axis of an oscilloscope. This voltage is proportional to the current through the resistor (and the exciter coil) and is assumed proportional to the force applied by the exciter. The output of the velocity sensor was displayed on the vertical axis of the oscilloscope. The resultant display of these two signals, in general, is an ellipse whose axes are oriented at an angle determined by the gain setting of the oscilloscope, the phase relationship of the two signals, and the location of the velocity pickup. The input was gradually increased in frequency until resonance was achieved. At resonance the exciting force and the velocity are in phase and the ellipse reduces to a straight line. The straight line changes slope as the velocity sensor is moved along the long axis of the bat. The slope changes from positive to negative as the sensor passes over the node. The line is horizontal when the location of the sensor is coincident with the node. This procedure was followed to locate both nodes.

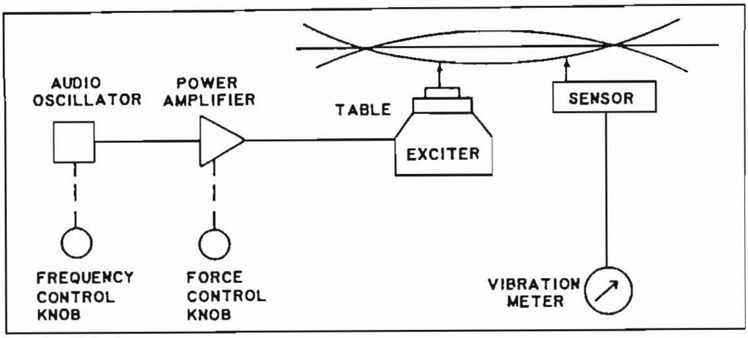

Figure 1. Vibrational measurement system.

RESULTS and DISCUSSION

Data from all measurements are presented in Table 1. The nearly identical measurements of the nine pairs of bats indicates high reproducibility in aluminum bat manufacture.

Figure 2 shows the effect of knob end loading on the location of the COP and fundamental mode for bats of different barrel lengths. It can be seen that COP location is not affected by barrel length and that node location is affected only slightly. There appears to be a linear relationship between COP location displacement toward the barrel end of the bat and knob end loading, as expected (slope coefficient=0.521 g/mm). Also, both nodes were displaced toward the added weight on the knob end of the bat (proximal node slope coefficient=-0.352 g/mm; distal node slope coefficient=-0.0883 g/mm). This resulted in an increased distance between the distal node and the COP. It would appear that impacts on the COP of knob end loaded bats would tend to excite the fundamental node to a greater degree than would impacts on the COP of unloaded bats. Also, the weighted knobs displaced the proximal node to a point near the middle of the bat.

The first character in the bat identification code indicates the knob type: L - light weight, hollow conventional knob; M - medium weight, solid aluminum knob, and H - heavy weight, solid steel knob. The second character in the identification code indicates the barrel length: 1 and 2 - long barrel; 3 and 4 - medium length barrel; 5 and 6 - short barrel hand-bat interface region, possibly resulting in less vibrational amplitude on the parts of the bat interfacing with the hands of the hitter. Determination of the significance of the effect of these changes on sensations of pain and comfort awaits further study.

Table 1. Descriptive measurements of all bats.

	Size			Physical Pendulum		Vibration		
Bat	Barrel Length (m)	Mass (kg)	Length (m)	Moment of Inertia (g.m^2)	COP (m)	Freq.of Fund. Mode (Hz)	Prox. Node (m)	Dist. Node (m)
L1	.865	.863	.505	.126	.691	359	.151	.674
L2	.864	.865	.492	.125	.691	355	.151	.671
L3	863	.860	.441	.124	.691	313	.145	.661
L4	.865	.859	.441	.125	.692	311	.147	.661
L5	.864	.854	.343	.125	.692	237	.151	.655
L6	.854	.854	.343	.124	.694	235	.151	.659
M1	.876	.904	.495	.132	.714	316	.131	.677
M2	.879	.905	.492	.133	.715	314	.132	.677
M3	.880	.905	.441	.135	.717	273	.132	671
M4	.881	.908	.441	.135	.716	272	.132	.671
M5	.879	.912	.334	.141	.722	208	.136	.668
M6	.880	.910	.343	.141	.722	207	.138	.667
H1	.869	1.029	.489	.132	.774	279	.088	.659
H2	.869	1.027	.502	.132	.776	280	.089	.657
H3	.870	1.024	.431	.133	.779	242	.088	.651
H4	.869	1.024	.441	.132	.777	242	.087	.651
H5	.869	1.018	.341	.133	.783	185	.092	.649
H6	.869	1.018	.341	.132	.783	186	.096	.647

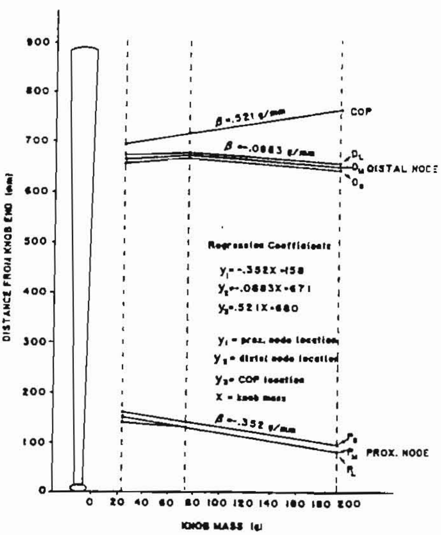

Figure 2. Effects of knob end loading on node and COP locations for differential barrel lengths.

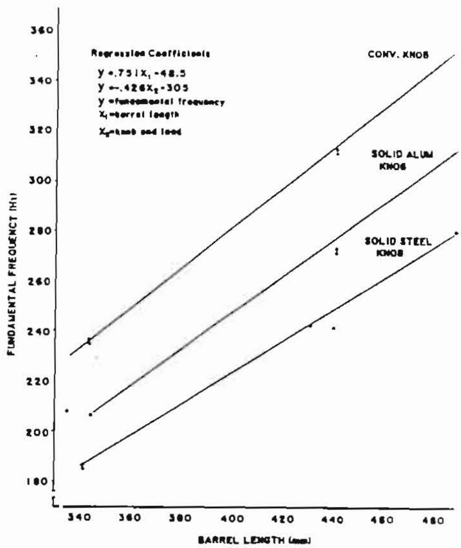

Figure 3. Effects of barrel length and knob end loading on fundamental frequency.

The effect of knob end loading and barrel length on the frequency of the fundamental node is shown in Figure 3. The frequency was dramatically affected by both barrel length (slope coefficient=0.751 mm/Hz) and knob end loading (slope coefficient=-0.426 g/Hz), decreasing an average of 22 percent for the solid steel knob, and by an average of 35 percent by decreasing barrel length from 0.395 m 0.343 m. Both variables resulted in a decrease of approximately 50 percent in the fundamental frequency. Within the observed range of these variables, the effects appear to be linear and additive with no interactions. It should be noted that barrel length can practically be decreased significantly beyond the range used in this study.

CONCLUSIONS

This study demonstrated that: a) locations of nodes of the fundamental mode can be significantly displaced with knob end loading and, to a lesser degree, with changing barrel lengths; and b) both knob end loading and barrel length appear to be practical and effective means of controlling the fundamental frequency of aluminum bats.

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