Comparative analysis of Head-Banging Behavior in *Reticulitermes flavipes* and *Coptotermes formosanus* (FST) using high-speed imaging and accompanying acoustic data.

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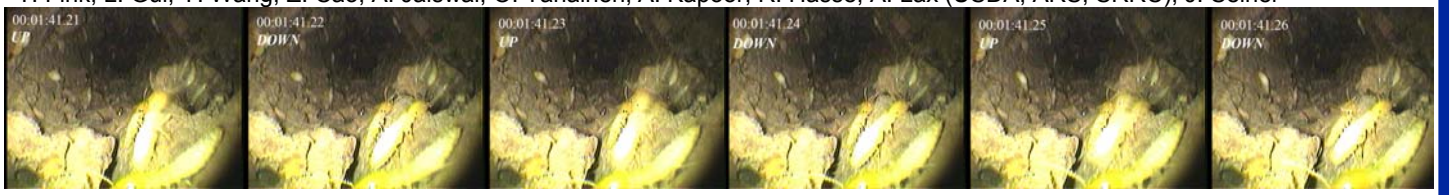


Fig. 1. . ***Coptotermes formosanus*** **(FST) Head-Banging in a Camphor tree**

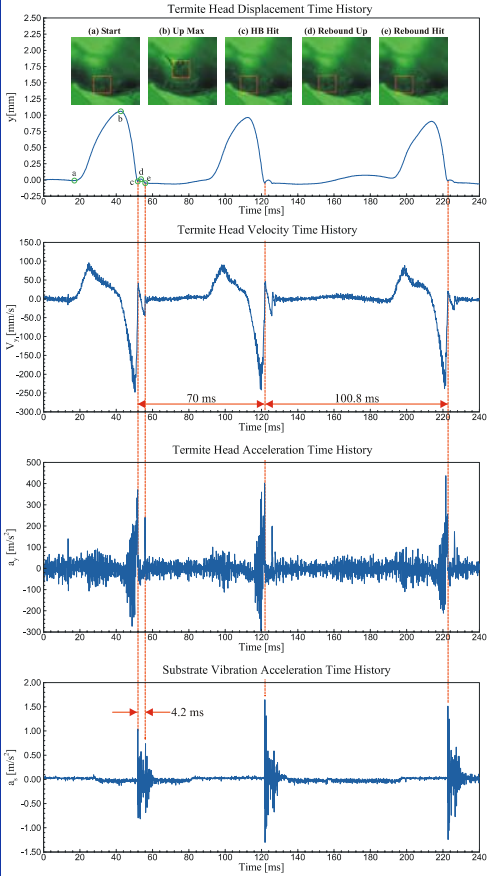


Fig. 2. ***Coptotermes formosanus*** **(FST) Head-Banging (three shown in plots above)**

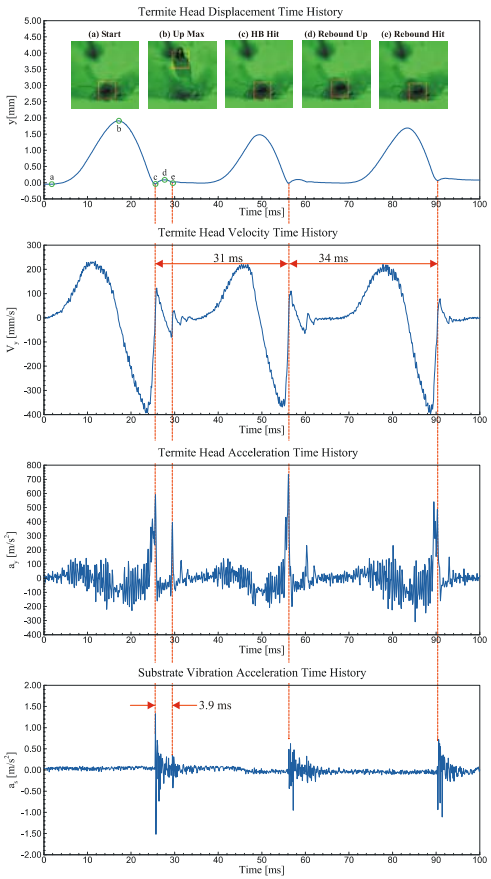


Fig. 3. ***Reticulitermes flavipes*** **Head-Banging (three shown in plots above)**

Introduction

In many species of termites, soldiers bang their heads against the substratum as an alarm response ([1,2]) Soldiers of the Formosan termite readily head-bang in their galleries and carton nests when they detect the vibrations or soil movement from insertion of a waveguide into the soil or into a tight space in close proximity to their galleries and carton nest. The native subterranean termite not only head-bangs in their galleries and carton nests, but also will readily head-bang in an artificial chamber when provoked by a brush, breathing or other stimulus. Details of the Head-Banging behavior can only be viewed with High-Speed Videography. In this paper we examine in detail the motion and correlated substrate vibrations.

Methods

We used the Photron FASTCAM-ultima APX high-speed video camera at 10,000 frames per second. Termites were placed in a 0.25 inch diameter hole in a wood block and induced to head-bang by touching them with a small artist's brush. Head-banging produced vibrations in the wood were directed by a nail wave-guide to the stud or magnetically mounted PCB Piezotronics 352B accelerometer. These vibration signals were then received by the Photron Multi-Channel-Data-Link (MCDL) apparatus which then superimposes the vibration waveform on the video frames corresponding to the visual movement. Thus movement of the head can be correlated with the vibrations produced. Image tracking and analysis algorithms were written by Dr. Lichuan Gui.

Results/Discussion

The top six sequential conventional video frames show an FST soldier head-banging after violation of its carton nest in a Camphor tree by our drill bit and videoborescope (**Fig. 1**). Upward and downward movements of the head take about one video frame each, or 1/30 second (= **33 milliseconds**). Thus between hits or bangs on the carton nest substrate there is one up movement (**33 ms**.) and one downward movement (**33 ms**.) for a total elapsed time of approximately **66 ms**. This relative minimum time frame of 66 ms between successive head-bangs is supported by many acoustic (accelerometer) recordings (**Figs. 5**) and by the high-speed videography. In the FST figure (**Fig. 2**), head-bang two follows head-bang one by **70 ms**, and **101 ms** separates head-bangs two and three. The duration between successive head-bangs in *Reticulitermes* is generally much faster at **30** to **40 ms**. In the Reticulitermes figure (**Fig. 3**) **31** and **34 ms** separates head-bangs 1-2 and 2-3 respectively. This duration data is supported by many acoustic measurements (**Fig. 6**).

High-speed video results are shown for two representative termite specimens, one Formosan (**Fig. 2**, FST) and the other *Reticulitermes* (**Fig. 3**). The top of the four graphs in each group represents the vertical displacement of the head in mm. While similar in body size (but larger in head size), the native termite generally raises its head higher (up to **2 mm**) than the Formosan termite (about **1mm**). The raising of the head in both species apparently occurs with little contribution from the legs, but rather appears to be mostly due to raising the prothorax with the head held stiffly (**Fig. 4**). The prothroax is raised by pivoting upward at the prothroacic/mesothoracic junction. In both species head-rebounding may occur in which after the initial hit (position **c** in both FST and *Reticulitermes*) the head bounces up or rebounds to the height at position **d** and then hits again at position **e**. Head-rebounding in many *Reticulitermes* specimens is very noticeable as the head may bounce up considerably and may even rebound two or three times. Head-rebounding results in vibrations that can be seen in the bottom plot of both figures. Head-rebound duration in both species is about **4 ms**.

In order for *Reticulitermes* to head-bang faster (shorter duration between successive head-bangs) it must accelerate its head faster and show a higher velocity than for FST specimens. This is shown in the high-speed video plots (**Figs. 2 and 3**). Upward and downward head velocities in the FST specimen are respectively **100** and **240 mm/sec**, while the values for *Reticulitermes* are over **200** and about **400 mm/sec**. Similarly acceleration values for the FST specimen is about **400 mm/sec** vs up to **700 mm/sec** for *Reticulitermes*.

Literature Cited

[1]Kirchner, W.H., I. Broecker and J. Tautz. 1994. Vibrational alarm communication in the Damp-wood termite *Zootermopsis nevadensis*. Physiological Entomology 19: 187-190.

[2]Connetable, S., A. Robert, F. Bouffault and C. Bordereau. 1999. Vibratory alarm Signals in two sympatric higher termite species: *Pseudacanthotermes spiniger* and *P. Militaris* (Termitidae, Macrotermitinae). Journal of Insect Behavior 12: 329-342.

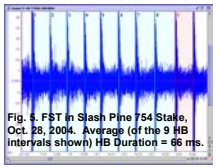


Fig. 5. FST in Slash Pine 754 Stake, Oct. 28, 2004. Average (of the 9 HB intervals shown) HB Duration = 66 ms.

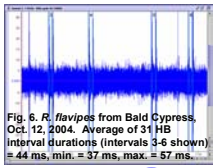
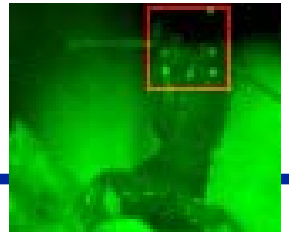


Fig. 6. ***R. flavipes*** **from Bald Cypress, Oct. 12, 2004. Average of 31 HB interval durations (intervals 3-6 shown) = 44 ms, min. = 37 ms, max. = 57 ms.**



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