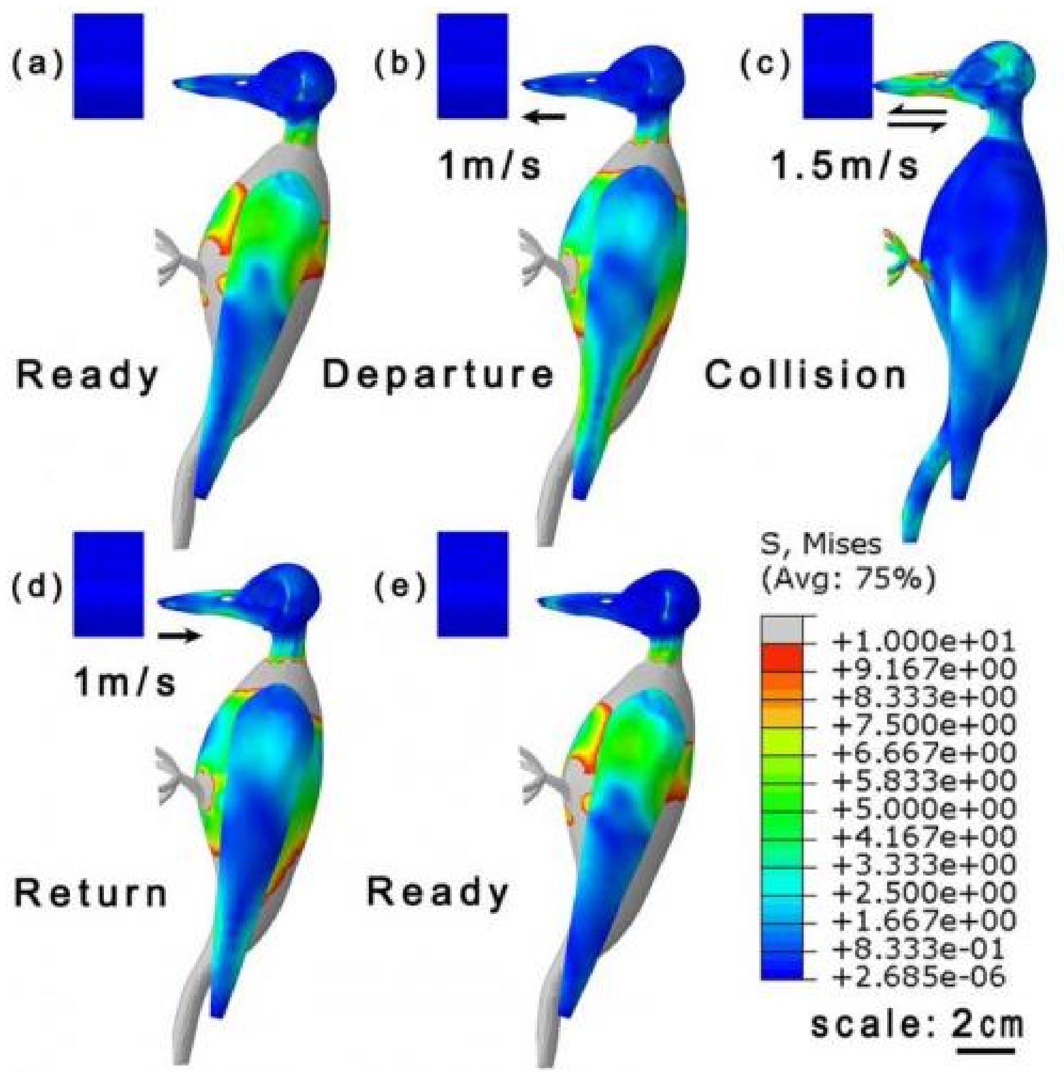
How the woodpecker avoids brain injury despite high-speed impacts via optimal anti-shock body structure

August 11 2014



Schematic of the pecking process of a woodpecker and the Mises stress at different times: (a) and (e) are moments of readiness to peck; (b) and (d) are the moments of departure and return, respectively; (c) is the moment of collision; arrows on the beaks show velocity direction. Credit: ©Science China Press

Designing structures and devices that protect the body from shock and vibrations during high-velocity impacts is a universal challenge.

Scientists and engineers focusing on this challenge might make advances by studying the unique morphology of the woodpecker, whose body functions as an excellent anti-shock structure.

The woodpecker's brain can withstand repeated collisions and deceleration of 1200 g during rapid pecking. This anti-shock feature relates to the woodpecker's unique morphology and ability to absorb impact energy. Using computed tomography and the construction of high-precision three-dimensional models of the woodpecker, Chinese scientists explain its anti-shock biomechanical structure in terms of energy distribution and conversion.

Their findings, presented in a new study titled "Energy conversion in the woodpecker on successive pecking and its role in anti-shock protection of the brain" and published in the Beijing-based journal *SCIENCE CHINA Technological Sciences*, could provide guidance in the design of anti-shock devices and structures for humans.

To build a sophisticated 3D model of the woodpecker, scientist Wu Chengwei and colleagues at the State Key Lab of Structural Analysis for Industrial Equipment, part of the Department of Engineering Mechanics at the Dalian University of Technology in northeastern China, scanned the structure of the woodpecker and replicated it in remarkable detail.

"CT scanning technology can be used to obtain the images of internal structures of objects … which is widely used in the medical field and expanded to mechanical modeling of biological tissue," they explain in the study.

"Based on the CT scanning technology (CT scanner, LightSpeed VCT XT, GE, USA), detailed inner structure images of the head were obtained and then imported to Mimics software to form a scattered-points model," they state. "Then a geometric model of the head was set up using the facet feature and remodeling module of Pro/E for the surface fitting. After the geometric repairs, the FE [finite element] model meshed by tetrahedron elements was established using Abaqus software."

The woodpecker's structure was recreated through intricate geometric modeling. "The final FE model has 940000 fine elements with a minimum size of 0.07 mm in the head, 70000 coarse elements with a maximum size of 3.5 mm in the body and 20000 elements with a minimum size of 0.16 mm in the trunk," the researchers state.

Discoveries made during the study could have applications in the design of spacecraft, automobiles, and wearable protective gear, explains Professor Wu.

"High-speed impacts and collisions can destroy structures and materials," Wu states. "In the aerospace industry, spacecraft face the constant danger of collisions with space debris and micrometeoroids," Wu adds. "If a spacecraft's structure or scientific instruments were destroyed by impact, the economic loss would be huge."

In cities worldwide, Wu says, automobile accidents are a persistent threat to human safety, and head injuries are common.

Challenges presented in minimizing these threats and injuries have led to widespread efforts to understand and replicate or improve on anti-shock mechanisms found in nature.

The woodpecker stands out in this field of study: it can peck trees at high frequency (up to 25 Hz) and high speed (up to 7 m/s and 1200 g deceleration) without suffering any brain injury.

"This unique anti-shock ability inspires scientists to uncover the related bio-mechanisms," Wu states, for potential engineering of similar devices and structures based on principles of biomimicry.

Wu and colleagues used 3D models of the woodpecker to test how impact energy was handled by its specially adapted structure.

Figure 1 shows the pecking process of a woodpecker and the Mises stress at different times.

The results showed that the body not only supports the woodpecker to peck on the tree, but also stores the majority of the impact energy in the form of strain energy, significantly reducing the quantity of impact energy that enters the brain.

"Most of the impact energy in the pecking is converted into the strain energy stored in the body (99.7%) and there is only a small fraction of it in the head (0.3%)," the researchers reported.

Structures in the head including the beak, skull, and hyoid bone further reduce the strain energy of the brain. The small fraction of impact energy that enters the brain will be eventually dissipated in form of heat, causing a rapid temperature increment in the brain. As a consequence of this, the woodpecker has to peck intermittently.

More information: Zhu Zhaodan, Zhang Wei and Wu Chengwei.

"Energy conversion in the woodpecker on successive peckings and its role on anti-shock protection of the brain." *SCIENCE CHINA Technological Science*. 2014, 57(7): 1269-1275. link.springer.com/article/10.1007%2Fs11431-014-5582-5

Provided by Science China Press