



The amazing strength and structure of woodpecker's tongue

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1. Introduction

Nature evolution after millions of years has produced listless of biomaterials that exhibit unusual mechanical properties. Bone, teeth and nacre are nanocomposites of protein and mineral, but give a significantly higher strength than either the protein or the mineral (Ji and Gao, 2004). Nephila spider dragline silk gives a surprising strength as high as 1.3GPa, a breaking elongation of 40%, and a toughness of 160kJ/kg (Vollrath *et al.*, 2001). For an artificial composite material, the interface connection strength is always the issue that we met now. However, for the interfaces of biomaterial material connections, such as the connections between the teeth roots and the tissue and those between the bone and tendon, the interfacial strength is even stronger than the biomaterials to be connected. In fact, what has been found is only a small corner in the nature Here we report that the tongue of a woodpecker exhibits an amazing strength and flexibility due to its special composite micro/nanostructure. The tongue consists of a flexible cartilage-and-bone skeleton covered with a thin layer tissue of high strength and elasticity. At the interface of the cartilage-and-bone skeleton and the tissue layer, there is a nano-hierarchical

fiber-typed structure connection. It is this special design of the tongue with its amazing tensile length that makes the woodpeckers efficient in catching the insects inside trees. The special micro/nanostructures of the woodpecker's tongue shows us a very good idea how to enhance the interface connection strength between the fibers and the matrix material for an artificial composite material.

In the nature, different kinds of animals have their own special skills to escape from predators or to search for food. Woodpeckers have some certain unique and interesting features adapted to drilling holes in trees to search for insects and other prey (Goodge, 1972; Homberger and Meyers, 1989; Bock, 1999; Villard and Cuisin, 2004). One of the most fascinating adaptations is the tongue of woodpeckers.

2. Experimental

The woodpecker investigated here is a female gray-faced one living in the Northern China. The length of the woodpecker's tongue is 171mm, which is about 2.8 times the length of its mouth (~60mm), and is even longer than its body length (~165mm, measured from the mouth tip to the buttock). The cartilage-and-bone skeleton supporting the woodpecker's tongue is called the hyoid apparatus, a