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COMPRESSIVE LOADING OF A SNAKE FANG: SIMULATION AND EXPERIMENT

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Summary: Venomous snake fangs have evolved over millions of years into efficient shapes allowing the biting and envenomation of a diverse range of prey types. In this work a venomous snake fang is imaged using high resolution X-ray tomography, load simulation is applied to the tip to simulate a bite force and the resulting stress distributions are analysed. These are compared with *in situ* X-ray tomography of the same fang under compressive loading.

1. INTRODUCTION

Snake fangs provide a unique insight into snake evolution and ecological studies of snakes since the shapes of fangs are highly specialized for efficient envenomation of different prey types and for different bite behaviours [1]. High resolution X-ray tomography provides a detailed insight into the exterior and interior morphology of such structures. This allows not only morphological characterization, but also structural simulation of compressive loading, i.e. to simulate a bite force on the tip of the fang. Such simulations, in turn, allow the visualization of stress hotspots, which can be used to predict deformation or failure locations. Comparing different snake fang types in terms of strength might therefore be pivotal for the understanding of their evolutionary and ecological specializations.

In this work, structural compressive loading is simulated using X-ray tomography data of a single fang of a Berg Adder, *Bitis atropos*. Stress hotspots, where deformation and ultimately breakage, is to be expected, were identified. In order to validate the simulations, the same fang was placed in a compressive load cell and *in situ* X-ray tomography was performed. The comparison between the simulation results and that of the load-induced deformation of the fang provides a unique insight into the accuracy of such simulations for this type of sample. The capability of *in situ* X-ray tomography for biomechanical studies is also demonstrated for this unique application.

2. EXPERIMENTAL METHOD

The experiments were performed at the Stellenbosch University CT Scanner Facility [2]. The fang was first imaged at highest possible resolution using a NanoCT system without a load cell, in order to provide high quality data for simulation. The fang was subsequently loaded in a Deben 500N *in situ* load cell and imaged under compressive loading. Image analysis and load simulations were performed in Volume Graphics VGStudioMax 3.0. The fang of *Bitis atropos* was selected for *in situ* imaging in this work due to its relatively large size in comparison to other fangs which were available.

3. RESULTS

X-ray tomography images and simulation results of a similar fang to *Bitis atropos*, that of *Vipera berus* is shown in Figure 1. Figure 1 (A) shows the exterior morphology of the fang with the entrance orifice (where the venom gland

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ejects venom into the canal) near the base and the discharge orifice near the tip of the fang, resembling a hypodermic needle. Figure 1 (B) shows the interior cavities, specifically the venom canal in red and the pulp cavity in blue. Load simulations use only the fang material and exclude these cavities, but the shape of these cavities can influence the strength of the structure. The material is assumed to be isotropic and homogeneous, and the load is applied to the tip in a region is comprised of at least 27 voxels. Figure 1 (C) shows the Von Mises stress distributions showing lower stresses around the sides of the fang. Simulations also show that regions of high stress are found on the underside and topside near the exterior of the fang (in contrast to the inside near the venom canal), which can be explained by the fang's curvature. Correlations between simulation and physical loading experiments will be discussed, and in particular correlations between physical deformation and high stress points in the simulations.

References

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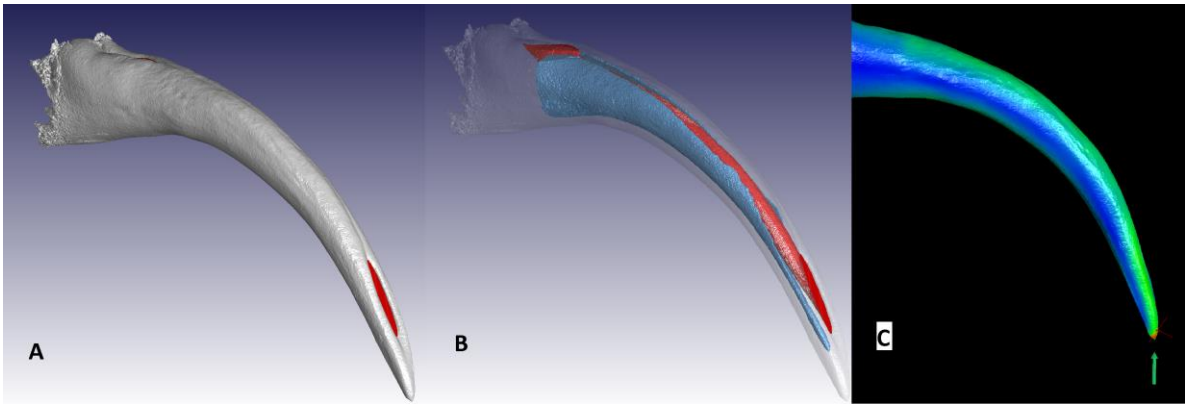

Figure 1: CT images of *Vipera* fang, showing in (A) the exterior morphology, (B) transparent view with venom canal in red as well as the pulp cavity in blue, and (C) a load simulation applied to the tip showing lower stresses around the sides (blue areas).