Tail Aerodynamics in Cheetahs and Robots

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I. INTRODUCTION

The cheetah (*Acinonyx Jubatus*) is capable of incredible feats of maneuverability while moving at high speed. These movements have often been attributed to the active use of its lengthy tail, yet the exact mechanisms for doing this are not well understood. Further, it is possible that mobile robots employing such an appendage could benefit from an increase maneuverability.

Roboticists have successfully utilized tails for various maneuverability tasks. Most of these efforts have employed the use of tail inertial effects on the body [1] [2], while some have used the tail in a sail-like fashion, keeping it fixed at an angle [3]. The cheetah tail however, only accounts for 2% of the body mass but its fur has the capability of providing angular impulse by means of aerodynamic effects during rapid swings [4].

II. BIOLOGICAL TAILS

Previous work studying cheetah tails, tested the tail in a quasi-static configuration in a wind tunnel [4]. These tests could not quantify the effects of rapidly swinging the tail into the wind as the cheetah does. To build upon this work, a new test rig was developed. Three cheetah tails were obtained from the National Zoological Gardens (NZG) of South Africa (Fig 1A). These tails were preserved using conventional taxidermy methods and mounted to a test rig which utilized a Maxon DCX-35L for actuation and Optoforce 3-axis force sensor (OMD-45-FH-2000N) for force measurement. The rig was mounted in the three configurations of typical tail flicks (roll, pitch and yaw) as done in [4].

III. ROBOTIC TAILS

Three different approaches were taken in the design of the robotic tail. Firstly, a biomimetic tail was developed which utilized *faux fur* to emulate the cheetah's morphology (Fig 1B). This fur was mounted to a mechanical test rig and spun at a constant velocity. It was shown that the *faux fur* could increase the torque by 40% at moderate rotational velocities. Further analysis to verify if this is due to the increased area.

A second approached was to develop tails based bio-inspired plastic tails. Several tail configurations were built using laser cut plastic sheet to maximize drag. These included designs with with varying size holes and slots within the tail.

The third approach was to develop aerodynamic tails utilizing computational fluid dynamics (CFD) simulations were employed to inform the construction of the tails. Preliminary results indicate that a half circle tail configuration provides the most drag torque.

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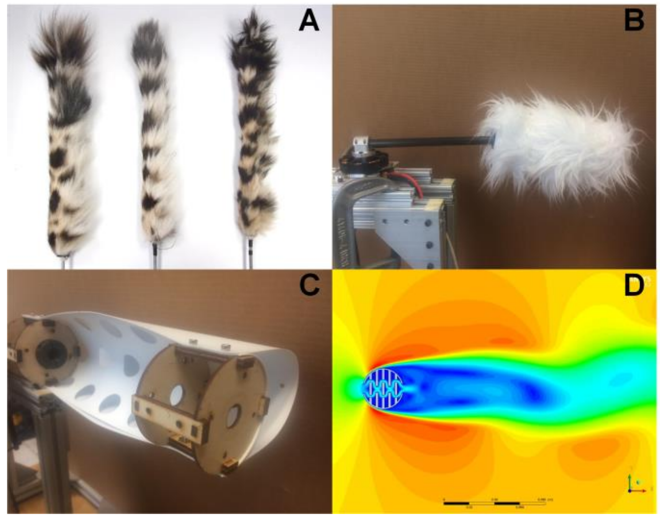

Fig. 1. (A) Three cheetah tails were dynamically tested in a wind tunnel. (B) The biomimetic tail developed attached to the mechanical rig. (C) The plastic tail with slots for creating drag. (D) CFD simulation snapshots of the first 1 minute of a slotted design for the tail.

IV. DISCUSSION

The results are encouraging and indicate that aerodynamics could be harnessed by terrestrial animals and robots to assist rapid maneuvers. However, there are still some questions which remain. Additional animals are required to broadly examine aerodynamic tails in the nature. For example, animals such as snow leopards or squirrely have large tail volumes and should be tested. Further, our robotic tail tests have only examined steady state behavior and the tail's acceleration could also have a significant effect. Lastly, the implications for terrestrial robotic design should be further investigated as a lightweight aerodynamic tail could potentially provide a weight saving when compared to heavy inertial tails.

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