Design of Microspine-Enhanced Spring Legs for Robotic Running and Climbing

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I. Introduction

Many robotic platforms are capable of either robust dynamic locomotion or high slope angle mobility, but to date there are few that achieve both. This work aims to marry the dynamic ground locomotion of RHex, a cockroach-inspired hexapod [1], with the wall climbing capability of microspine robots such as RiSE, [2], in a single, robust platform. Robots using microspines for adhesion function best when individual spines are able to move independently to enable load sharing. RHex's high mobility is partly due to its relatively compliant legs, which allow it to store energy for dynamic motions such as running or jumping. A relatively simple robot architecture can accomplish both of these by using the same structure for energy storage in the leg as translation of the microspines, as both require a relative stiffness of approximately 10. This work builds on an initial concept for such a robot, T-RHex (Fig. 1) [3], and improves on the design through systematic material and geometry selection.

Fig. 1: The T-RHex robot hanging from a tree (left), and the testbed used for comparing leg designs equipped with a single T-RHex leg (right).

II. motivation

The first generation of T-RHex served as a demonstration of the high angle mobility that a RHex-like robot could achieve with the addition of microspines, with ascent of up to 55° slopes and static hanging on up to 45° overhangs. Each of the T-RHex robot's 6 legs is comprised of stacked semicircular slices with microspines embedded in the tip. The microspines only engage with the terrain when the robot is being run backwards so as not to interfere with flat-ground mobility. The legs are fabricated from 1/8" acrylic, but these legs are far stiffer than those of RHex, which prevents the robot from performing dynamic maneuvers and climbing to its full potential. By reducing the relative stiffness of the legs, the goal in this work is to give T-RHex the dynamic capabilities of the RHex platform while maintaining and improving wall climbing ability.

III. Approach

RHex owes much of its dynamic locomotion capabilities to its springy legs, which have a relative stiffness constant $k_{rel} \approx 10$ [4]. By contrast, the acrylic T-RHex legs are much stiffer, with $k_{rel} \approx 200$. A small amount of deflection (1-2 mm) parallel to the attachment surface allows multiple microspines to independently catch on asperities on the surface, which is necessary for secure adhesion during climbing [3]. Assuming load sharing among 5-10 spines, this means that $k_{rel} \approx 10$ is also a good relative stiffness for climbing. In this work, we redesign T-RHex's legs to have a lower relative stiffness through material and geometry selection. For each potential material, Castigliano's theorem is used to determine the set of crossectional dimensions that deflect 1-2 mm for a semicircular leg with 100 mm diameter. The dimensions are additionally subject to manufacturing constraints such as the thickness of stock material. Feasible leg designs are identified by selecting the combinations of materials and geometries for which the max stress is sufficiently below the material yield stress. Prototypes of full leg assemblies will be tested for climbing capability by observing the force and method at which they fail, such as leg fracture or spine disengagement. These tests will be performed in a test bed where the leg is actuated with a single motor, as on the robot, and the system is free to slide parallel to the wall (Fig. 1). Finally, T-RHex will be outfitted with a full set of the newly designed legs in order to demonstrate improved dynamic capabilities.

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References

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