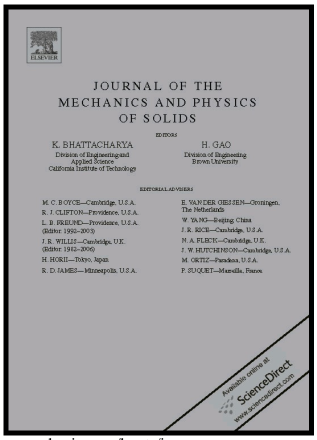
Author's Accepted Manuscript



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PII: S0022-5096(16)30150-8
DOI: http://dx.doi.org/10.1016/j.jmps.2016.04.008
Reference: MPS2861

To appear in: *Journal of the Mechanics and Physics of Solids*

Received date: 4 March 2016
Revised date: 6 April 2016
Accepted date: 6 April 2016

Cite this article as: Mattia Bacca, Jamie A. Booth, Kimberly L. Turner anc Robert M. McMeeking, Load sharing in Bioinspired fibrillar adhesives wit backing layer interactions and interfacial misalignment, *Journal of the Mechanic and Physics of Solids,* http://dx.doi.org/10.1016/j.jmps.2016.04.008

Load sharing in bioinspired fibrillar adhesives with backing layer interactions and interfacial misalignment

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Abstract
Bio-inspired fibrillar adhesives rely on the utilization of short-range intermolecular forces harnessed by intimate contact at fibril tips. The combined adhesive strength of multiple fibrils can only be utilized if equal load sharing (ELS) is obtained at detachment. Previous investigations have highlighted that mechanical coupling of fibrils through a compliant backing layer gives rise to load concentration and the nucleation and propagation of interfacial flaws. However, misalignment of the adhesive and contacting surface has not been considered in theoretical treatments of load sharing with backing layer interactions. Alignment imperfections are difficult to avoid for a flat-on-flat interfacial configuration. In this work we demonstrate that interfacial misalignment can significantly alter load sharing and the kinematics of detachment in a model adhesive system. Load sharing regimes dominated by backing layer interactions and misalignment are revealed, the transition between which is controlled by the misalignment angle, fibril separation, and fibril compliance. In the regime dominated by misalignment, backing layer deformation can counteract misalignment giving rise to improved load sharing when compared to an identical fibrillar array with a rigid backing layer. This result challenges the conventional belief that stiffer (and thinner) backing layers consistently reduce load concentration among fibrils. Finally, we obtain analytically the fibril compliance distribution required to harness backing layer interactions to obtain ELS. Through fibril compliance optimization, ELS can be obtained even with misalignment. However, since misalignment is typically not deterministic, it is of greater practical significance that the array optimized for perfect alignment exhibits load sharing superior to that of a homogeneous array subject to misalignment. These results inform the design of fibrillar arrays with graded compliance capable of exhibiting improved load sharing over large areas.

Keywords: Fibrillar adhesion, gecko adhesion, biomimetics, load sharing, contact mechanics

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1. Introduction

The prevalence of fibrillar structures in nature for the generation of robust adhesion has long been noted. Various species of beetle, spider, and gecko have independently evolved to have specialized adhesive systems of this kind [1-3]. Despite being an active area of research for well

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