Comprehensive Review of Fatigue Behaviour on Highly Deformable Adhesives

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INTRODUCTION

Highly deformable adhesives, including silicones, polyurethanes, and rubber-based adhesives, are widely employed across various industries due to their exceptional flexibility and durability. This report examines the types and families of these adhesives, the factors contributing to their deformability, their applications, and their performance under fatigue loading. A comparison is also made between the fatigue behaviour of highly deformable adhesives and more brittle adhesives, such as epoxies, to highlight their respective advantages and failure mechanisms.

HIGHLY DEFORMABLE ADHESIVES

The utilisation of highly deformable adhesives is a crucial aspect of contemporary engineering and industrial applications, due to their distinctive capacity to accommodate substantial deformation while sustaining robust adhesive bonds. Some of these adhesives are categorized into:

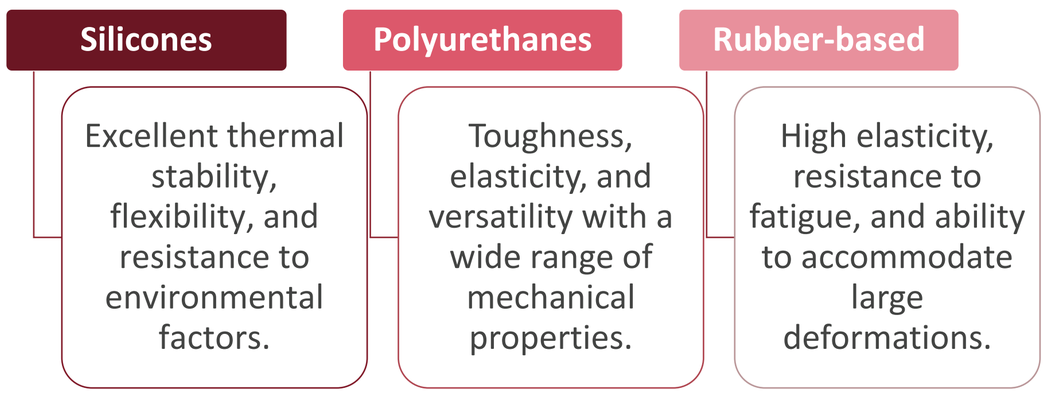

FIGURE 1. Different types and families of highly deformable adhesives.

The deformability of these adhesives is contingent upon a number of key factors:

- ✓ **Elastic Properties** – Enables the absorption and distribution of stresses more effectively than brittle adhesives, making them capable of undergoing significant deformations without fracturing.

- ✓ **Viscoelasticity** - The combination of viscous and elastic characteristics allows for the dissipation of energy during deformation, which serves to reduce stress concentrations and delay the onset of cracks.

- ✓ **Molecular Structure** - The complex network structures of these adhesives contribute to their flexibility and durability. The molecular architecture permits microscopic movement and deformation, thereby enhancing the overall toughness of the material.

FATIGUE OF HIGHLY DEFORMABLE ADHESIVES

In highly deformable adhesives, the propagation of cracks is influenced by non-uniform plastic deformation in the region ahead of the crack tip. This process involves a significant degree of shear deformation in the vicinity of the crack, which may result in the blunting of the crack tip. This phenomenon of **blunting reduces the concentration of stress** in the specimen, allowing the **accumulation of energy**.

Upon the eventual propagation of the crack, **the energy release rate surpasses the threshold for stable propagation**, resulting in **rapid and unstable crack growth**, which is subsequently arrested.

For instance, **rubber-based adhesives** are known to contain inherent flaws that can potentially lead to crack initiation through **decohesion or cavitation**. These flaws induce stress triaxialities that promote **plastic straining and crack tip blunting**, ultimately leading to failure as cavities coalesce.

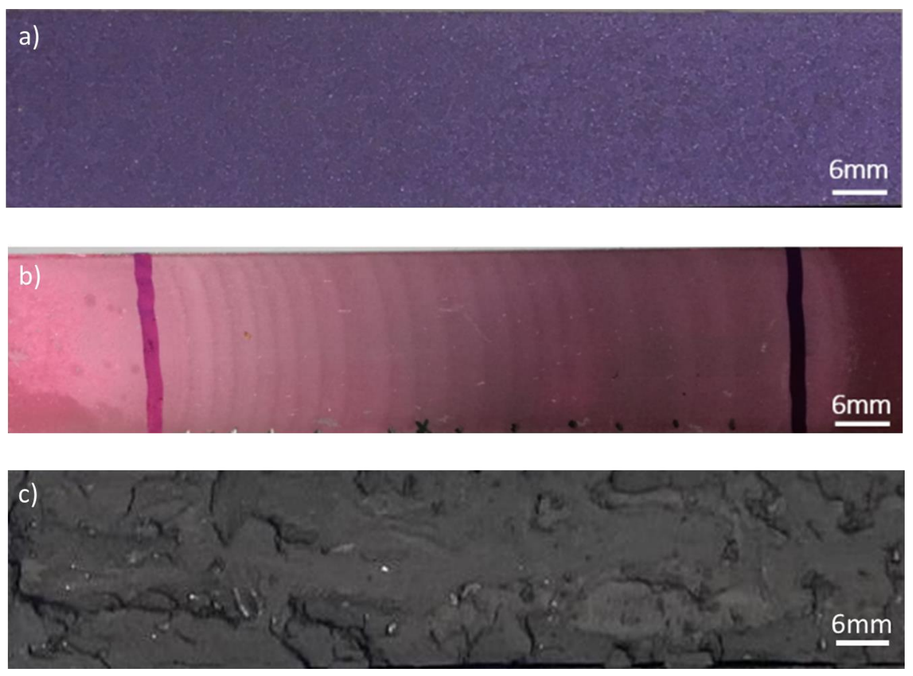

FIGURE 2. Fracture surface of: a) one-part epoxy adhesive b) rubber-like adhesive c) two-part polyurethane adhesive.

In contrast, **brittle adhesive** joints exhibit early crack initiation and rapid propagation under cyclic loading due to **their lack of energy dissipation mechanisms**. This brittle behaviour results in a **shorter fatigue life** and the **potential for catastrophic failure once cracks initiate and propagate**.

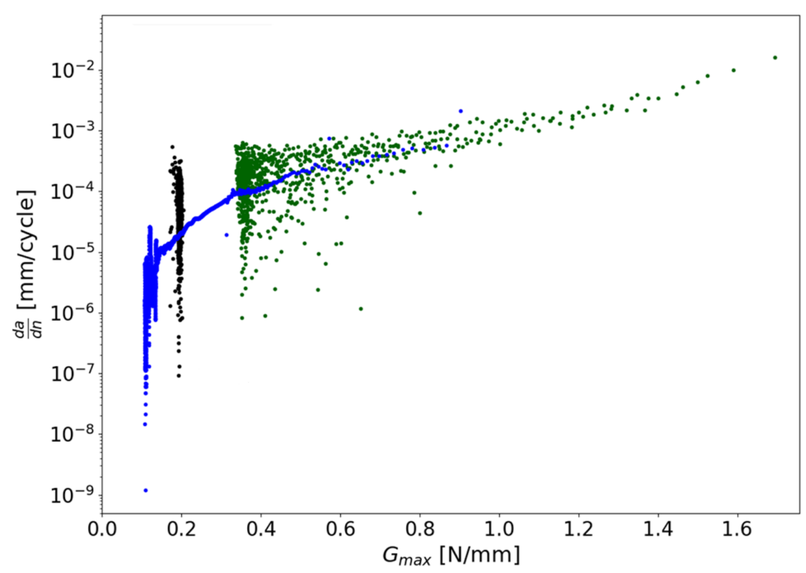

FIGURE 3. Paris-law curve for a 2-component polyurethane adhesive.

CONCLUSION

Overall, highly deformable adhesives with viscoelastic properties delay crack initiation and dissipate energy effectively, resulting in longer fatigue life. Conversely, brittle adhesives are deficient in the capacity for dissipating energy, resulting in a shorter fatigue life span, an increased susceptibility for rapid crack growth and failure under conditions of repeated loading.

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