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Mechanical characterisation of the adhesion between a silicone elastomer film and silicone gels

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Introduction

According to their degree of cross-linking, silicone polymers can be elastomers, gels or oils. Due to their versatility, they have a wide range of applications. They are used in building, adhesives and medical industry. In the medical field, polydimethylsiloxane (PDMS) are often used as solid elastomer or gels. For some applications, such as self-adhesive gel sheet (Fig.1) that helps improve the appearance of hypertrophic and keloid scars, both forms must be assembled and used together. In our study we consider a PDMS solid elastomer and two silicon gels, all used in the biomedical field. The aim of this study is to understand and characterize the adhesion between the elastomer and the gels. The ultimate objective is to determine a criterion that can predict a delamination at the interface between the gel and the membrane.



Fig.1 Medical grade adhesive silicone gel for keloids scars

2. Material and methods

Materials. The membrane and the gels are industrial products. Both were prepared according to the manufacturer's recommendations. The gels are a mixture of two silicone oils. The cohesiveness of a gel is controlled by the ratios of the mixture. In order to assess the influence of this property on the adhesion with the membrane, two different ratios were used. Gel A is less cohesive than Gel B. The membrane is a rubber-like polydimethylsiloxane (PDMS).

Peel tests. A peel test is commonly used to measure the adhesive strength between the bonded surface of a flexible and rigid substrates. The flexible substrate often consists of tape or film, whereas the rigid substrate is commonly a type of metal, rigid plastic or composite. In order to perform the test, both materials are placed into peel test grips that move in two opposite directions (T-peel test). In our case, the gels cannot be gripped and are highly deformable, as well as the membrane. Thus this configuration is not suitable for them and new tests have to be proposed. Two different cases, coupled with a digital image correlation system (DIC), were chosen: a simple shear test (Fig.2a) and a tensile test (close to a probe-tack test) (Fig.2b). DIC method was used to observe the real strain at the outer surface of the samples. These tests required to design new “sandwich-shaped” specimens, in order to limit the membrane deformation during the test and make data analysis easier.

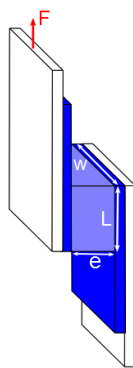


Fig.2a

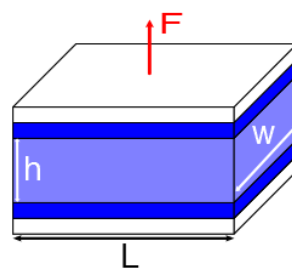


Fig.2b

Fig.2 Shearing and tensile test specimen

□ Metal sheets
■ Silicone membrane
■ Silicone gel

Sample preparation. First, two pieces of membrane were glued to rigid metal plates (that will be inserted inside the grips). A mould, consisting of 2 L-shaped pieces, was then placed in between. The two silicon oils

were mixed and put inside the mould through a hole. To increase the contrast between the speckle pattern and the transparent gels, we added a white dye into the gel. This dye is a single component material with a fixed Titanium Dioxide concentration that should not modify the mechanical behaviour of the gel. The interior walls of the mould were coated with some Teflon adhesive strip to prevent wall sticking of the gel. Then the part was heated for gel curing and the mould was removed once the gel is formed. Forty samples were prepared to carry out the peeling tests.

Methods. Random speckle patterns were applied to the samples using black paint spray for further DIC measurements. The mechanical tests were performed on a Zwicki ProLine (Zwick Roell, Germany) tensile test machine equipped with a 100 N loading cell. The specimens were stretched up to failure. The tests were carried out in by controlling the displacement at different velocities (0.32 mm/s and 3.2 mm/s). For each test and each configuration, 5 samples were tested. The force and the displacement were measured. The stress and deformation were computed using the following equations.

For both experiments, the stress (σ for the tensile test or τ for the shear test) was deduced, by convention [1], from the force (F) applied to the specimen by dividing it by the surface of contact between the gel and the membrane (Eq.1).

$$\sigma \text{ (respectively } \tau) = \frac{F}{w \times L} \quad (1)$$

, w being the width and L the length of the contact surface.

By convention, the strain (ε and γ respectively for the tensile and the shear tests) was determined from the displacement (d) by dividing it by respectively the initial thickness (e) and height of the gel (h) (Fig.2).

$$\varepsilon = \frac{d}{e} \text{ and } \gamma = \frac{d}{h} \quad (2)$$

DIC measurements gave an estimate of the strain at the surface of each specimen during the tests.

Results and discussions

In both shear and tensile tests, specimens can withstand significant deformation. Even if results are quite scattered, in each case, there is a delamination that takes place at the interface between the gel and the membrane. The adhesion force between them seems to be lower than that required to break the gel. Regarding the two gels, the trend is clear: gel A (less cohesive) tends to peel off at a higher strain than gel B, but the corresponding stress is lower. These results are valid for both shear and tensile tests. As a conclusion, gel's cohesiveness plays a key role on the adhesion between the membrane and the gel.

Thanks to DIC measurements, we obtain the maximum strain at the interface. We will use it to compute a delamination's criterion between the gel and the membrane.

References

- [1] L. Picard, P. Phalip, E. Fleury, and F. Ganachaud, « Chemical adhesion of silicone elastomers on primed metal surfaces: A comprehensive survey of open and patent literatures », *Prog. Org. Coat.*, vol. 80, p. 120-141, mars 2015.