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Preface

This book is intended to serve as a didactic tool to support both those teaching and learning the subject of adhesive bonding. While the companion book "*Introduction to Adhesive Bonding*" is mostly dedicated to the theoretical aspects of this joining technology, this book is more concise and highly focused on hands-on learning, with exercises and their solutions and multiple experimental activities.

The book is divided into four parts. The first is dedicated to simple practical demonstrations of adhesive bonding. These are all simple activities suitable to be carried out in a classroom setting, which quickly highlight the advantages and limitations of this technique. The second part is dedicated to production and testing of specimens that are used to characterize adhesives and the most commonly used types of joints. The third part describes in detail multiple laboratorial activities suitable for implementation in the laboratorial classes of engineering courses. These activities explore aspects such as the manufacture of defect-free bonded joints, the effects of geometry and materials properties in adhesive joint testing, surface preparation and joint design and strength prediction, among many others. Lastly, a set of exercises is provided in the form of developmental questions and multiple choice questions. This last part focuses on all of the knowledge areas discussed in the companion "*Introduction to Adhesive Bonding*" book. All problems are provided with solutions, and many are fully solved, helping bachelor or masters students in their study and providing evaluation reference materials for teachers.

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Simple Practical Demonstrations

1.1 Importance of Loading Mode on Bonded Joint Performance

1.1.1 Introduction

Adhesive bonding shows many advantages over more traditional methods of joining such as bolting, brazing, and welding or even the use of mechanical fasteners. No other joining technique is so versatile, and its transversality lies in its capacity to join different materials, its ability to ensure permanent assembly, and its ease of use. In fact, a well-designed bonded joint allows for a reduction in production costs, while maintaining proper mechanical properties of the joint.

Adhesives work by exploring the adhesion phenomena, and they are usually polymeric materials, typically thermosetting, that, compared to materials that are joined in structural applications (such as metals and composites), show a much lower strength. Nonetheless, adhesive joints can be applied to a wide diversity of structures, withstanding different types of loads. To understand the mechanics of a bonded joint, it is important to first establish that the behavior of the joint is highly dependent on the type of loads it is sustaining. In an attempt to obtain the highest joint strength, it is fundamental to load the adhesive under forces acting in the plane of the adhesive layer, minimizing peeling loads. Joints are generally more resistant when shear-stressed because the adhesive layer is relatively well aligned with the loading direction. In these conditions, the entirety of the adhesive layer can positively contribute to sustain the load (see Figure 1.1). Joints subjected to cleavage or peel stresses are much weaker than those subjected to shear because the stresses are concentrated in a very small area. All the stress is located at the edge of the joint (see Figure 1.1).

1.1.2 Equipment

- One set of scissors
- Tensile testing machine

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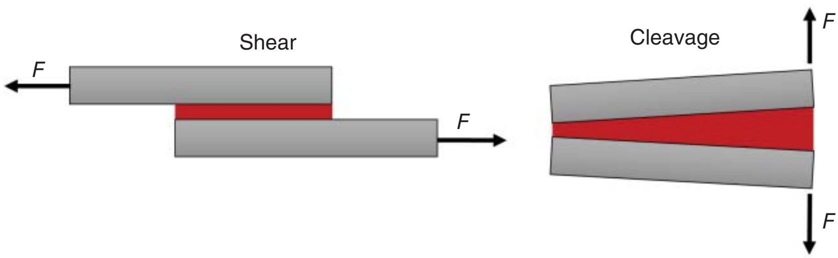

Figure 1.1 Schematic representation of the shear and cleavage loads acting on adhesive joints.

1.1.3 Materials

- One roll of double-sided foam adhesive tape
- Small aluminum beams

1.1.4 Safety Precautions

Apply the necessary safety procedures for operating a test machine.

1.1.5 Experimental Procedure

1.1.5.1 In Class

Peel the adhesive tape off the roll by applying a pulling force or "peeling" action as shown in Figure 1.2. See how easily it peels away, even if the adhesive is quite strong.

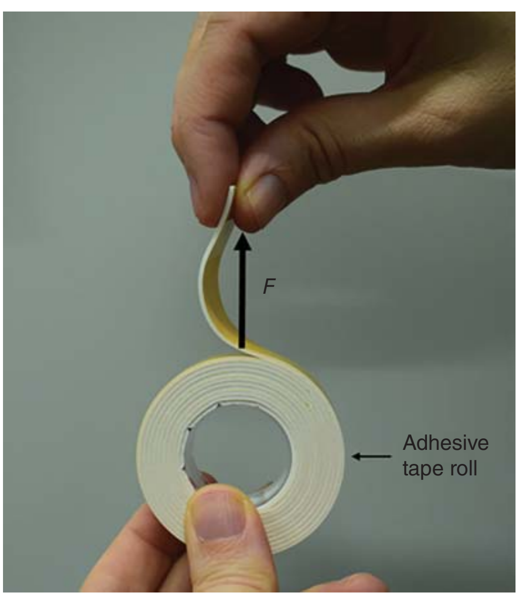

Figure 1.2 Adhesive joint under pull-out force.

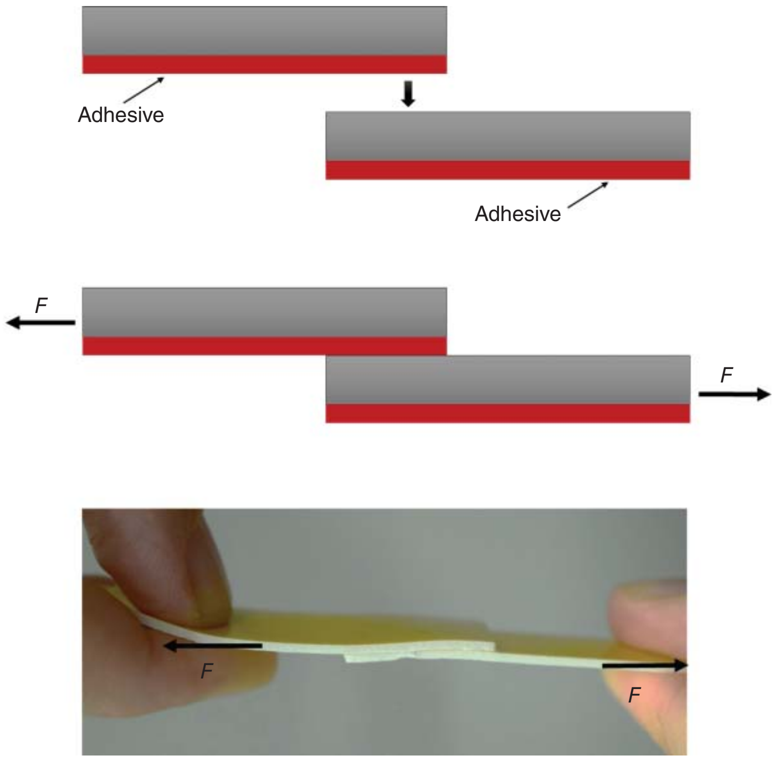

Figure 1.3 Adhesive joint subjected to shear stress, with the area being overlapped with and without the adhesive.

Now, cut two strips of adhesive tape, approximately 10 cm long. Bond the two strips parallel to each other with an overlap of approximately 3 cm. Bond the glued side of one strip to the unglued side of the other strip (see Figure 1.3). Pull on the joint in order to try to separate the strips by loading them parallelly to the adhesive layer, thereby subjecting the adhesive to shear, as schematically represented in Figure 1.3. It will be much harder to separate the joint as we are now loading it in shear; however, because of the low stiffness of the tape, it will bend and introduce some peeling loads, as shown in Figure 1.3, and this peeling can promote debonding.

Repeat the same procedure, but this time, join the strips so that the sides that have adhesive are in direct contact, as represented in Figure 1.4. When the joint is made between the glued side of both strips, it is impossible to separate the strips under shear. Ultimately, the strips will break, while the bonded area remains intact.

1.1.5.2 In the Laboratory

In order to better understand the influence of load type when an adhesive joint is used, the same tape will be bonded to an aluminum plate, and the response for two different types of load (shear and peel) will be studied using a universal tensile machine.

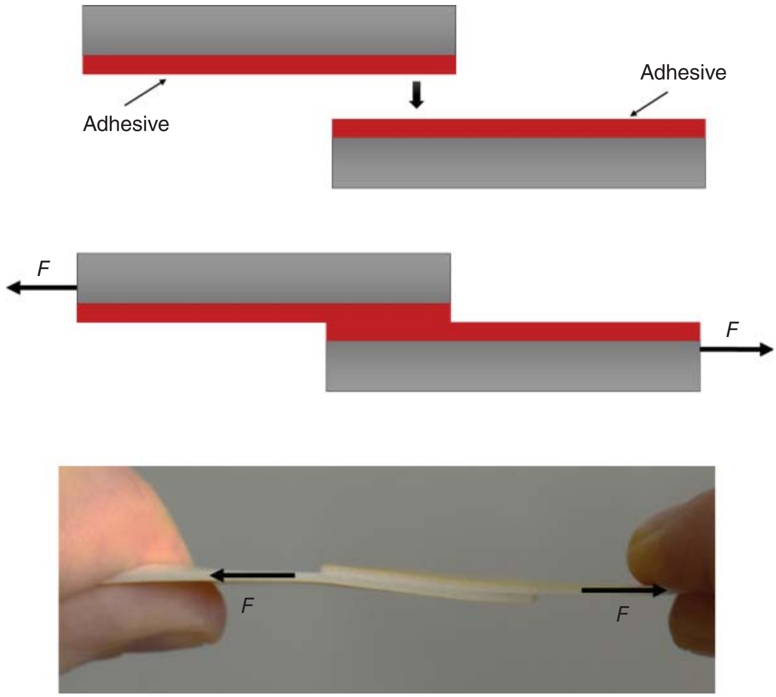

Figure 1.4 Adhesive joint subjected to shear stress, with the area being overlapped with the adhesive on both strips.

To this aim, the same tape will now be applied to metal (aluminum) adherends. Cut an adhesive tape strip, approximately 10 cm long, and join it to the surface of an aluminum adherend with a 3 cm overlap. This adhesive joint is subjected to shear stress, as shown in Figure 1.5. As the adherend is much stiffer, this adhesive joint is now subjected to an almost uniform shear stress.

The procedure will now be replicated, but this time, the forces exerted will be in a peeling direction. Therefore, it is recommended for the tape strip to be slightly longer so that it can be easily pulled off. Cut an adhesive tape strip, approximately 15 cm long, and join it to the surface of an aluminum adherend with 3 cm of overlap. This adhesive joint can now be subjected to peeling stress, as shown in Figure 1.6.

A comparison of the loads applied on the manufactured joints can be done manually or using a testing machine. Manually, it is possible to "feel" that the forces are different, but they cannot be quantified. Therefore, using a universal testing machine, the behavior of the joints loading under different types of stresses and different surface states can be easily quantified, leading to different results. Figure 1.7 shows a schematic representation of the peel and shear forces. As "felt" in a manual test, when an adhesive joint is tested in peel stress, at first, it is necessary to exert a greater force to peel off the adhesive, but over the course of the test, the force required decreases and the joint eventually fails. In turn, when the adhesive joint is being tested at shear, the force required gradually increases until failure occurs.

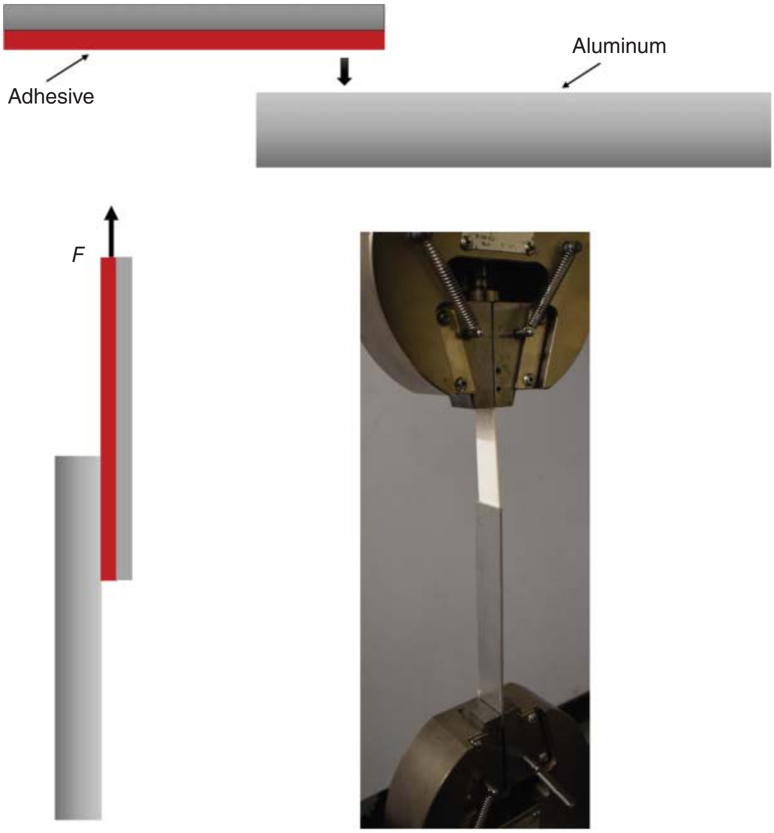

Figure 1.5 Adhesive joint using adhesive tape and aluminum adherends, subjected to shear stresses.

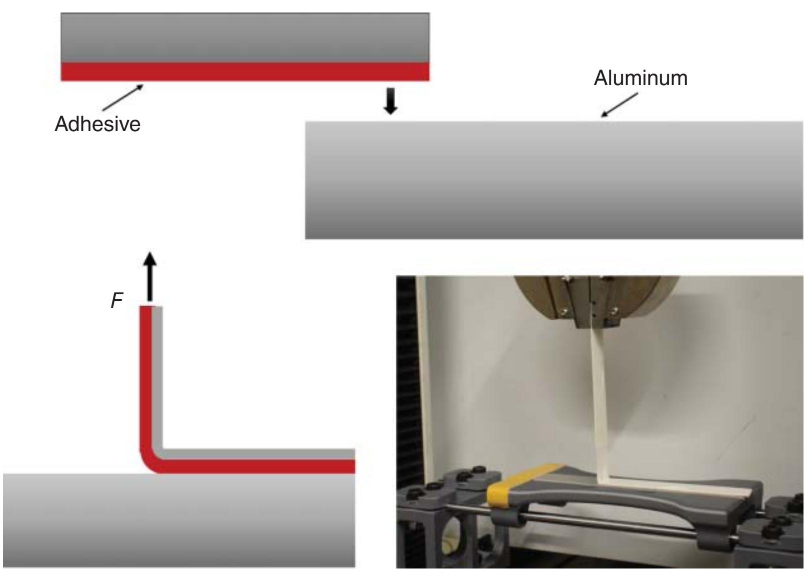

Figure 1.6 Experimental testing procedure of an adhesive joint using adhesive tape and aluminum adherends, subjected to shear stresses.

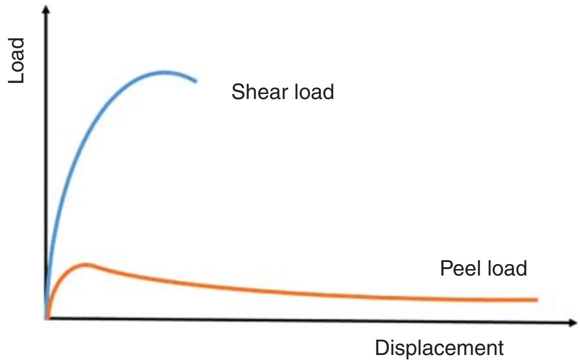

Figure 1.7 Schematic representation of the shear and peel behavior of an adhesive joint.

1.2 Surface Treatments and Methods to Evaluate Surface Energy

1.2.1 Introduction

Surface preparation of an adherend is key to achieve a strong and durable adhesive joint, and it is a process step that should never be taken lightly. The type and the quality of surface preparation will unequivocally determine the behavior of the joint. Surface treatments can be divided into two major groups: passive and active treatments. Briefly, we can explain this categorization by saying that passive treatments do not change the chemical nature of the material surface and the active processes chemically change the adherend by cleaning and removing weak layers on the surface.

How a liquid will wet a surface will mainly dictate the level of adhesion between the adhesive and the adherend. The formation of a drop of liquid on a solid surface is described by the contact angle, θ, between the solid surface and the tangent to the surface of the liquid at the point of contact as schematically presented in Figure 1.8. The aim of surface treatments is to obtain a clean and wettable surface. Unfortunately, there is no standardized procedure or equipment to assess surface cleanliness. Furthermore, a clean surface is difficult to define and sometimes even quantify. One way of evaluating the level of cleanliness is to say that a surface is clean when no dirt is visible to the naked eye. However, this is a very subjective process, and the quality of the surface treatment should always be subject to a strict control.

The value of θ can vary from zero – when there is complete liquid spreading, and we are experiencing perfect wetting – to 180° when the liquid assumes the shape of a spherical drop and does not wet the solid at all, as shown in Figure 1.9.

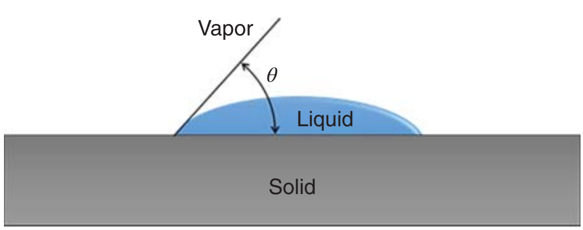

Figure 1.8 Angle of contact (θ) formed between an adherend surface and a liquid.