Composites Gripping Guide

Introduction

The purpose of this guide is to provide an overview of the requirements and important issues that arise when gripping composite laminate coupons, as well as to outline multiple gripping solutions.

Composite Laminate Tensile Specimens (Coupons)

Most composite specimens (or coupons) are rectangular in shape. The nature of the composite material means that profiled, reduced-section specimens (i.e. dog bone shape) are not commonly used because this would involve cutting the longitudinal fibers, which will cause premature failure of the specimen.

The use of a parallel-sided coupon means that the stress is nominally the same along the length of the coupon, increasing the chances of failures at the jaw faces. For this reason, and to prevent the patterned surface of the jaw faces damaging the specimen, the usual practice is to bond tabs using a suitable adhesive to the specimen. Common materials for these tabs are a [0/90] E-glass fiber-reinforced composite material oriented at 45° to the loading direction, although other materials (e.g. tabs made out of the material being tested or aluminum) can also be used. The end profile (flat or tapered) and minimum lengths of the tabs are specified in the testing standards, but longer tabs may be required when testing high-strength materials to reduce the shear stresses in the adhesive between the coupon and the tab. For a maximum axial stress of σ_{max}, a specimen thickness of t_s and adhesive bond shear strength of τ_b the minimum tab length L_t is given by:

$$L_t = \sigma_{max} t_s / 2\tau_b$$

The need to increase the length of the tabs is greatest when testing at high temperatures due to the reduction in the shear strength of the adhesives.

In some cases, composite coupons without tabs can be tested by using sacrificial pieces of emery cloth or by using flat faces with a hard, high-friction coating, such as SurfAlloy, which is a hard, high-friction tungsten carbide coating.

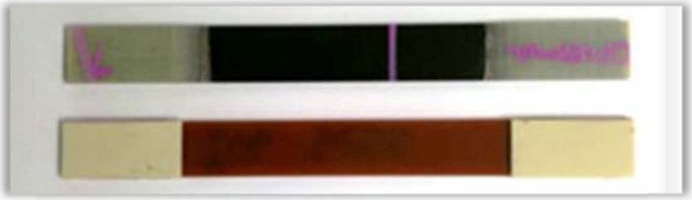

Figure 1: Tabbed Composite Specimens

Alignment Requirements for Tensile Testing

Fibers used in most high-performance composite materials are brittle, and if there are uneven stress distributions in a tensile test, it will cause premature failure. Therefore, maintaining good specimen alignment is important when tensile testing composite materials. The usual method of quantifying test specimen alignment is in terms of Percentage Bending Strain (PBS). PBS is defined as the maximum difference in strain across the specimen divided by the average strain at a representative applied load.

$$PBS = \left(\frac{|\epsilon_f - \epsilon_b|}{|\epsilon_f + \epsilon_b|}\right) \times 100$$

Where ϵ_f and ϵ_b are the strains on the front and back face of the specimen respectively.

ASTM E1012-12 describes detailed procedures for measuring the alignment of materials testing machines using strain gauged alignment cells located in the machine in place of the specimen. It also defines classifications according to the maximum bending strain.

Recommendations on specimen bending are included in many composites tensile test standards, such as:

- ASTM D3039 (Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials) "good testing practice is generally able to limit percent bending to a range of 3 to 5% at moderate strain levels (>1000 µ€)"

- ISO 527-4 (Test Conditions for Isotropic and Orthotropic Fibre-Reinforced Plastic Composites) and ISO 527-5 (Test Conditions for Unidirectional Fibre-Reinforced Plastic Composites); both recommend that the total bending strain is less than 3% at the mid-point of the modulus range (1500 µ€)

Limits on PBS are also defined in individual company test specifications and audit check lists, such as:

- Nadcap AC 7101 (Materials Testing Laboratories Mechanical Testing) – 10% for static tests and 5% for cyclic tests

- Nadcap AC 7122 (Non-Metallic Materials Testing Laboratories) – 8%

Satisfying alignment requirements requires a systems approach involving the test frame, load string, alignment device (e.g. Instron® AlignPRO), grips, and specimen. The discussion here is limited to the gripping requirements.

In general terms, accurate and consistent alignment of composite specimens requires:

- The means to accurately and repeatedly locate test specimens in the grips; this requires rigid specimen stops on both grips.
- Grips with a symmetrical mechanism (e.g. wedge grips) are preferred over grips with independent mechanisms (e.g. dual side-acting hydraulic grips).
- The jaw faces come into contact with the specimen in a repeatable manner. Moving body grips are preferred to moving face grips. In a moving body grip, the faces move in a direction normal to the specimen surface; whereas in a moving face grip, the faces move in a diagonal direction and friction effects can cause the faces to make an uneven contact, which results in misalignment.
- For grips to maintain good alignment under load, the body design should be symmetrical. Asymmetrical designs (e.g. an open front /closed back grip body) will introduce specimen bending under load due to uneven deflections.

Other Test Types

Composite materials are multi-phase (i.e. fibers and matrix) and anisotropic (i.e. properties that depend on direction), and along with tensile tests additional tests (e.g. compression, shear, flex) are usually required to fully characterize the material. Generally, these tests require specific test fixtures. Unless a laboratory is able to dedicate machines to specific test set ups, testing machines will need to be reconfigured when changing tests. The task of reconfiguring machines is made much easier by providing a means of mounting test accessories between the grips allowing the grips to remain in place when changing the test set up – this is a major advantage with heavy, high-capacity grips or grips that have previously been aligned and certified.

Gripping Solutions

Manual Grips for Composites

The Instron® 100 and 250 kN Precision Manual Wedge Grips have been designed to provide reliable gripping of composites and other materials while meeting Nadcap alignment requirements when installed on a suitable frame.

The grip is a moving body wedge design, which ensures accurate and consistent centering of the jaws. Actuation is via a compact worm gear driven by a front-mounted ratchet handle. The mechanism is capable of producing a high initial preload (5 kN for the 250 kN grip), which reduces the possibility of a specimen with a hard surface slipping before the wedge action takes over from the initial pre-load. The body is guided to maintain good alignment. The depth of the jaw faces used in 100 kN grips is 75 mm and in the 250 kN grips 100 mm – making the grips usable with specimens with long tabs.

The grips can operate reliably over a temperature range of –80 to +250°C (-112 to +482°F) without the need to change lubricants. Extenders are available to allow the grips to be used inside an environmental chamber.

Compression platens and adaptors allow the use of composite test fixtures to be fitted to the top face of the grip body, which is locked in position by loading the top face of the jaws against the bottom of the adaptor.

Flat jaw faces have a 25 TPI (Teeth per Inch) diamond serrated pattern and are suitable for a wide range of composites, plastics, and metals testing. Flat SurfAlloy coated faces and Vee faces with serrations for round metal specimens are also available.

Powered Grips for Composites

The Instron fatigue-rated hydraulic wedge grips are ideal for high throughput composites tensile testing. This is a symmetrical moving body wedge grip actuated by a hydraulic piston.

As well as offering powered operation, the hydraulic pressure can be adjusted to alter the initial gripping force. With a low-pressure setting, the wedge action will produce most of the gripping force as the load increases; by increasing the hydraulic pressure the initial force can be increased. The ability of the hydraulic piston to apply a full gripping force means that these grips can be used in compression as well as tension. When suitably configured, these grips can be used for “free gauge length” (i.e. without anti-buckling fixture) compression testing of short composite coupons.

These hydraulic wedge grips can be adapted for use inside temperature cabinets. In this case, the hydraulic pistons are located outside the temperature chamber and water cooling is provided to keep the temperature of the hydraulic systems within safe limits. The hydraulic pistons are connected to the grip wedge heads inside the chamber via coaxial extenders. NOTE: The extended versions of these grips are not suitable for “free gauge length” compression testing because of the reduction in lateral stiffness due to the extenders.

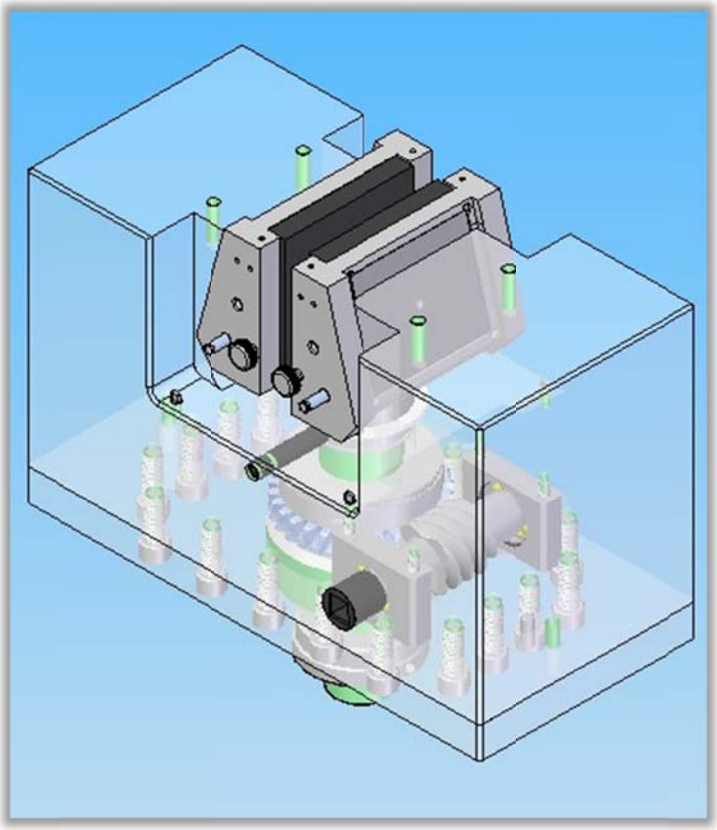

Figure 2: Precision Manual Wedge Grips

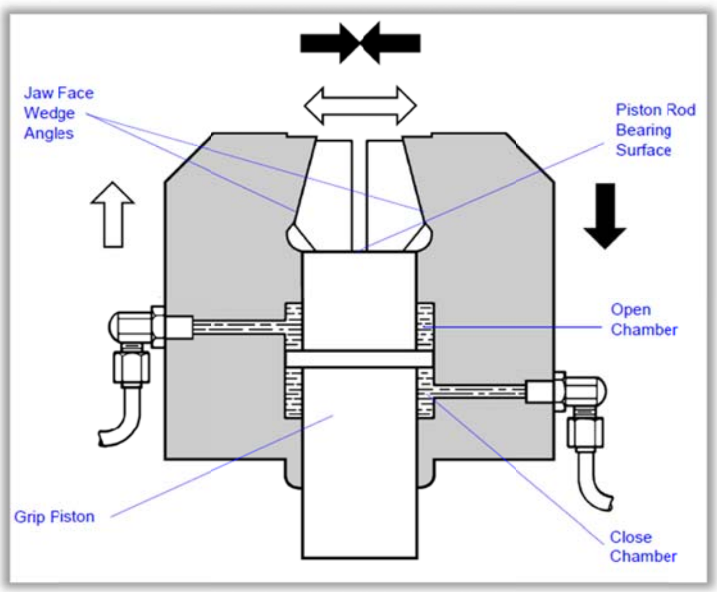

Figure 3: Moving Body Hydraulic Wedge Grips