

FS (Butterfly) vs CS (Clamshell) Folding/Flexing

There are two different types of folding or flexing test machines, Butterfly and Clamshell. Both are "Tension-Free™". The Butterfly has U-shape folding similar to the wings of a butterfly, using "Tilt Controllers" to shape the folding to eliminate tension on the sample. The Clamshell folds in a manner similar to a clam, but has a double hinge movement to eliminate tension on the sample. To understand which machine might best fit a specific need, it is necessary first to know the differences in their mechanisms.

To help understand tension-free folding, Figure 1 shows the classical case of folding a sample around a rod. The sample is mounted directly to the folding clamp. The clamp rotates around the rod.

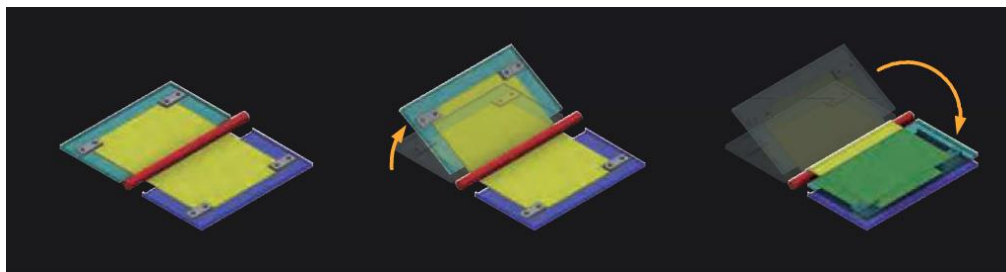


Figure 1. Folding a Sample Around a Rod

As the clamp rotation begins, the length of the sample is too short compared to the movement track of the clamp. See Figure 2. This creates tension on the sample.

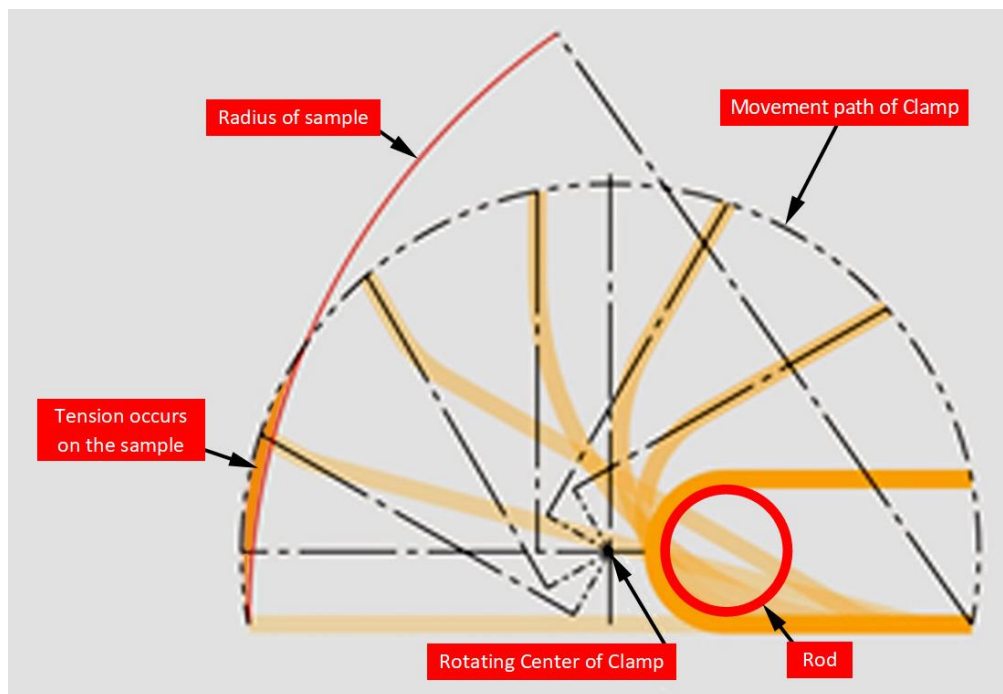


Figure 2. Tension from Folding a Sample Around a Rod

The tension is created because the sample is held rigidly to the clamp and the clamp trajectory is different from the folded sample's desired trajectory.

U-shape folding is illustrated in Figure 3. Only the ends of the sample are held rigidly to the clamp. As the clamp on the left moves toward the clamp on the right, the clamping plates are forced to fold down by the folding action of the "Tilt Controllers" on each side of the sample. The folding shape is set by the Tilt Controllers. The Tilt Controllers are similar to a metallic plate spring. The Tilt Controllers cause the sample to fold in a natural U-shape and without tension. The length of the clamps keeps the sample from folding "backwards" and gradually the sample is held between two vertical walls. The distance between the clamps and the walls will be the diameter of the semicircle-shaped folding sample.

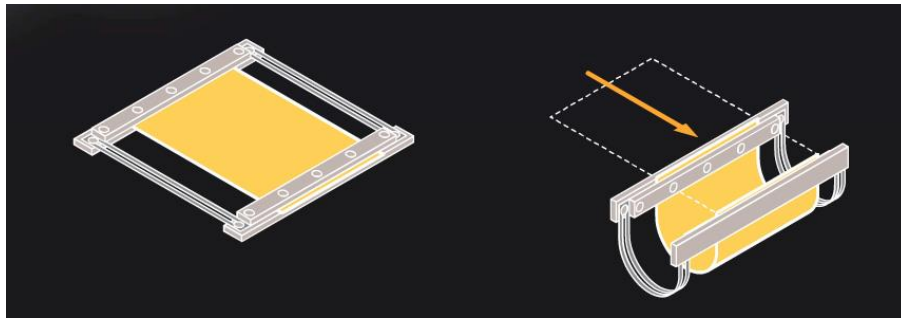


Figure 3. U-shape Folding

As shown in Figure 4, as the sample begins to fold the entire length of the sample folds slightly. As the clamps move closer together, the sample is being folded more tightly and the folding is being concentrated more and more in the center of the sample. The folding shape is similar to the motion of the wings of a butterfly.

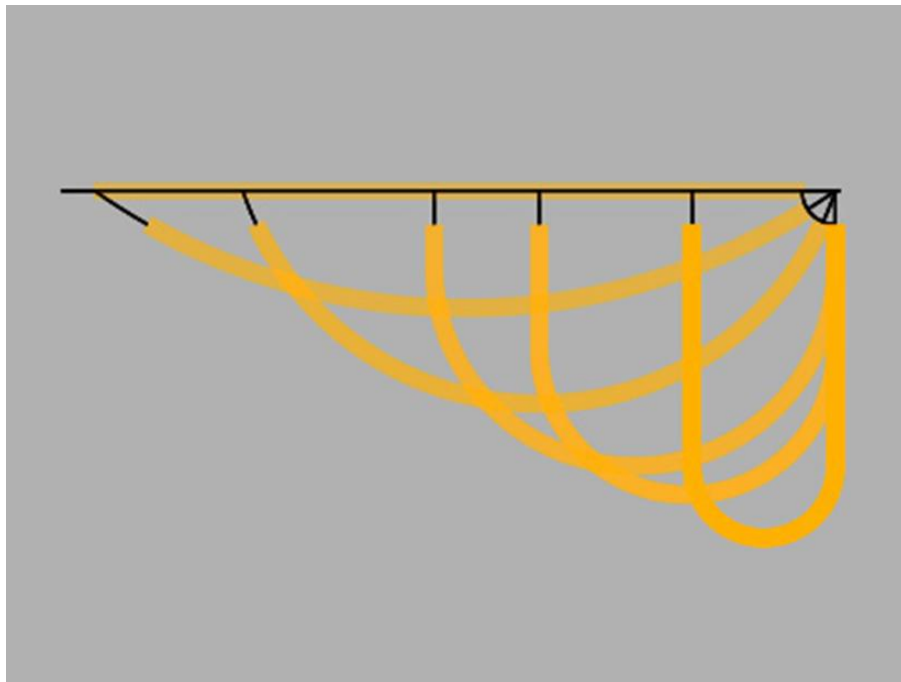


Figure 4. U-shape Folding Profile

Figure 5 is a photo of the FS illustrating the Tilt Controllers in the early portion of the folding cycle. Basically, the Tilt Controllers determine the folding shape and absorb any tension resulting from the folding.

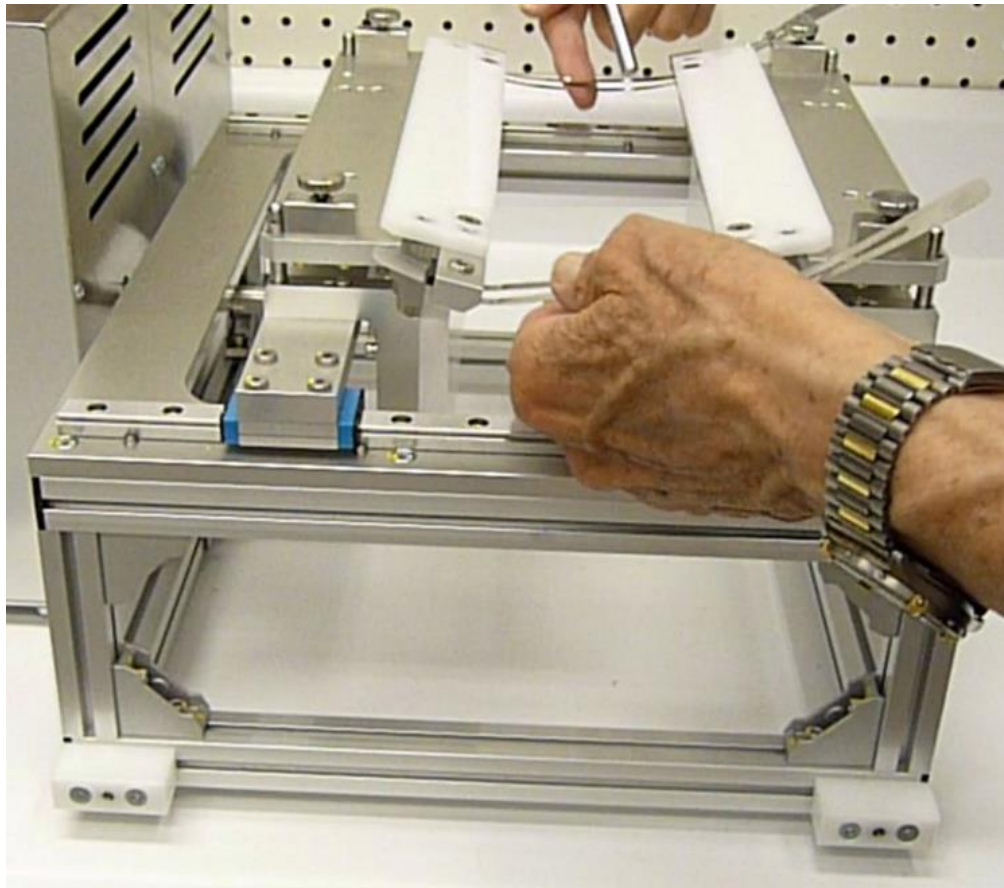


Figure 5. The FS with Tilt Controllers.

The CS uses an entirely different flexing method to avoid tension on the sample, folding in a manner similar to a clam. See Figure 6. The mechanism uses two hinges rather than the single hinge that is illustrated in Figure 1 and Figure 2.

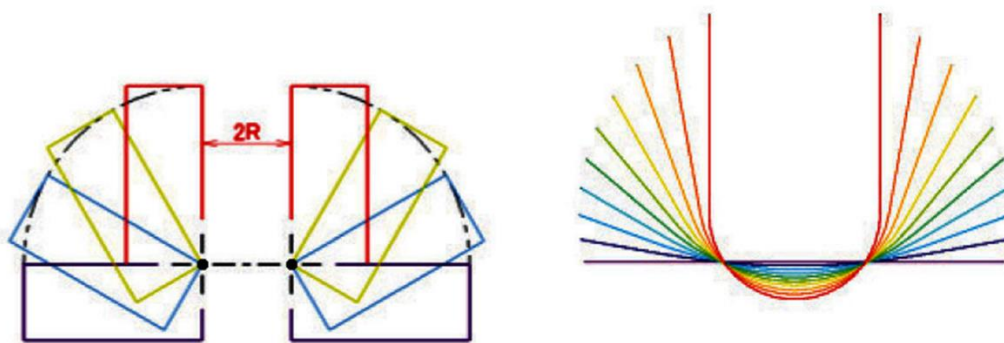


Figure 6. Double Hinge Folding

The hinges are at the inside edges of the two clamps, or Holding Plates. Each holding plate rotates around the edge of the holding plate. The space between the hinges is kept constant at double the flexing radius.

Figure 6 illustrates the double hinge movement and shows the profile of the flexing sample as the folding cycle proceeds.

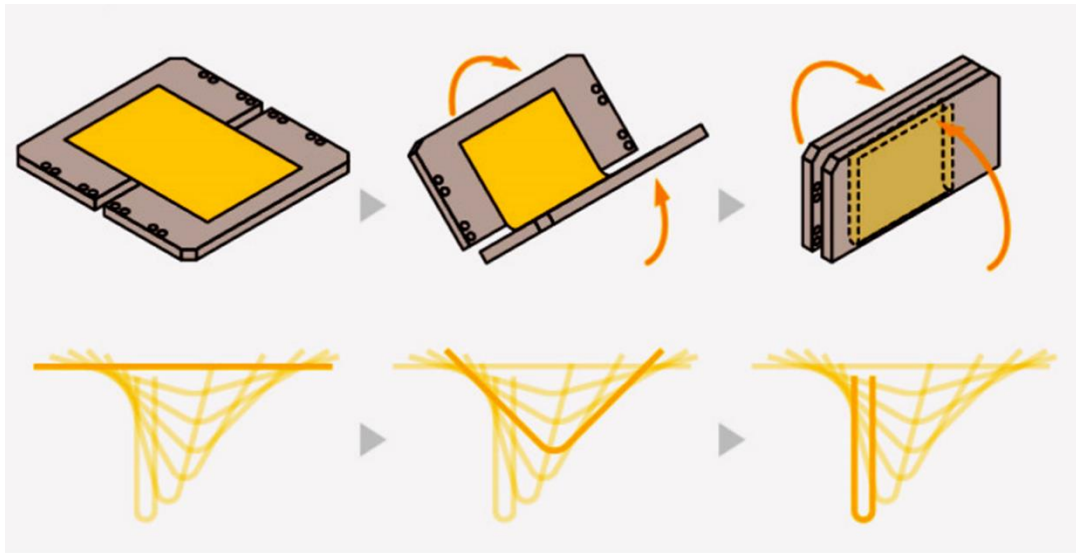


Figure 6. Double Hinge Movement

Figure 7 is a photo of the CS showing the mechanism that causes the holding plates to rotate while maintaining the double-radius spacing.



Figure 7. The CS with Double Hinges

The axle on the right is visible, the bright metallic circle. The axle on the left is hidden, but it is at the top of the vertical rod seen below the left holding plate. Each holding plate rotates around its axis, and the axes are kept a constant distance apart.

From examining the mechanisms, several points can be seen and are listed in Figure 8.



Comparison of Clamshell and Butterfly



- **Both the Clamshell and Butterfly are Tension-Free™**
- **Clamshell flexes only the center $\pi \cdot R$ portion of sample**
- **Butterfly folds entire sample, maximum folding at center of sample**
- **Clamshell radius can be set more precisely using shims**
- **Clamshell flexes at any angle up to 180°**
- **Butterfly folds at any angle up to 180°**
- **Most often folding/flexing is done at 180° for both**
- **Clamshell can accept shorter samples**
- **Butterfly can flex at larger radii**

Figure 8. Comparison of CS and FS Flexing Test Machines

Both the Clamshell and Butterfly are Tension-Free.

Perhaps the most significant differences of the CS and FS are that the Clamshell flexes only the center $\pi \cdot R$ portion of the sample while the Butterfly folds the entire sample with the maximum folding at the center of the sample; and that the Clamshell can flex to a more accurate radius, especially with a very small radius, for example, sub-millimeter, because the CS uses shims to set the flexing radius.

How does one choose which style to use based on these points?

One example might be flexing a sample like a display. In this case, the Clamshell will be selected most often because the sides of the sample remain somewhat rigid during the folding cycle; the radius can be set more precisely; and with multiple layers, the neutral layer can be selected by using custom-made holding plates. And the CS can flex in a teardrop shape using custom-made holding plates.

Another example might be folding a sample like an e-textile, or a flexible battery. In this case, often the Butterfly is selected.

Both the Clamshell and the Butterfly can flex or fold at any angle up to 180°, but most often the choice is 180°.

The Clamshell can accept shorter samples.

The Butterfly can fold at a larger radius. The radius is set by mechanically positioning the fixed clamp. And the Butterfly can operate at higher speeds.

COMPARE FOLDING / FLEXING JIGS

	FS	FS-C	CS
Linear Samples	✓	✓	✓
Planar Samples	✓	✓	✓
Tension-Free Folding	✓	✓	✓
Stretch	✓	-	-
Sample Thickness (max)	3 mm	3 mm	1 mm
Sample Width (max)	224 mm	220 mm	130 mm
Sample Length (min)	$56 + CL^*$ mm	$36 + CL^*$ mm	$\pi \cdot R + CL^*$ mm
Bending Radius	0 ~ 18 mm	0 ~ 22 mm	0.5 ~ 5.0 mm
Bending Angle	0 ~ 180°	0 ~ 180°	0 ~ 180°
Operating Speed	10 ~ 90 rpm	10 ~ 90 rpm	5 ~ 30 rpm

* CL => clamping distance

Figure 9. Comparison of Butterfly and Clamshell

Figure 9 shows some of the specifications of each test system.

The Butterfly comes in two different styles. The FS-C has a cartridge so the sample can be removed from the test machine to closely examine the sample, and then replaced in exactly the same position. The FS does not have a cartridge, but it also can fold with variable radius folding where the two ends of the sample are held vertically and the plates move closer and closer together tightening the radius as the plates get closer. The FS also can be used as a stretching test machine.

While only the basic versions of the FS and CS Jigs are shown in Figure 9, there are other versions of each.

The FSC90 can be operated in an environmental chamber and can handle larger samples.

The CS-Twin has two sets of holding plates to allow more samples to be tested at one time. The CS-M has larger holding plates. The CS-Cam can be used to capture pictures of the sample during testing.