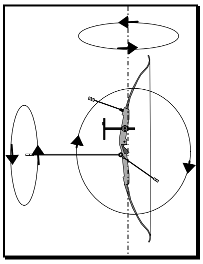

Controlling Bow Behaviour

with Stabilisers

Steve Ellison

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Controlling Bow Behaviour with Stabilisers

Introduction

Bows are simple mechanical objects in principle. But designing them for archers makes life surprisingly complicated. Archers cannot shoot the arrow through the centre of pressure (at least, not without injury), so the arrow leaves the bow above the grip, and the bow is consequently slightly out of balance when shot. The riser is cut away on one side, so stresses in the riser are asymmetric, and vibrations complex and difficult to control. The archer's 'grip' on the bow is hard to centre and reproduce, introducing variable torque. Muscles are best in motion, and perfect stability of aim is not humanly attainable. Different archers have different preferences for bow behaviour before, during and after the shot. All these things lead to a large range of bow movements, many of which are incidental to, or interfere with, the arrow reaching the target. So bowyers and archers have gone looking for ways to control bow movement.

Relatively early in modern bow design, it became clear that many movements could be controlled by adjusting the overall weight and the distribution of weight in the bow riser. This led by easy stages through 'points', lead or mercury inserts and 'bus-bars' to short, weighted metal rods replacing 'points', longer rods replacing short rods, centre-mounted 'long rods', counterbalances and V-bars, TFC's, internally damped rods and oil-filled dampers to the range of stabilisers and attachments now available. The problem facing the archer is to sort through all the options to get good control of the bow.

That does not mean that stabiliser systems are a necessary first resort. On the contrary, though they can undoubtedly reduce the effect of poor technique, **stabilisation is no substitute for good technique**. If bow behaviour is seriously and consistently faulty, the cause should be removed as far as possible before turning to stabilisation. For example, stabilisers can reduce the effect of torque, but it is a great deal better to adjust style or grip to avoid torque in the first place.

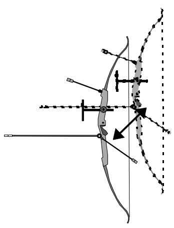
This note is intended to show how particular stabilisers and attachments control different types of bow motion, and how their effect can be adjusted to suit the archer's needs. The document covers different types of bow motion, then discusses the use of stabilisation to control them.

What behaviour needs controlling?

There is little point in bolting on every stabiliser set-up currently in use by the top 20 archers worldwide. If nothing else, not many people can lift twenty sets of stabilisers. More to the point, **the best stabiliser system is a personal decision**. Every archer has their own preferences and problems, and the best system for the archer is chosen to fit their preferences and solve their problems. As with any other part of archery technique, it pays to start by working out with what you intend to achieve, and why. Since different parts of a stabiliser system can be used to control different types of movement, it's useful to start by thinking about the different types of movement and what effects they have on the shot and the archer. I'll discuss different types of movement first, then look at where they become important during the shot.

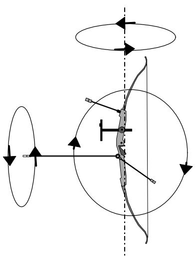
Bow movement

Displacement (Sideways, Forward, Vertical)



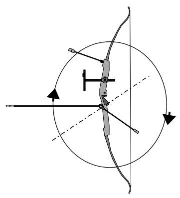
Displacement is a mathematician's word for movement from one place to another in a particular direction, without involving rotation, vibration or anything more exotic. The centre of gravity of the system moves along with the object. For archery, it's usually convenient to think about three pairs of directions: up and down (vertical movement), backwards and forwards (longitudinal), and left and right (lateral, or sideways). For those with a mathematical turn of mind, those directions are often associated with X-, Y- and Z-axes. Any of these movements can have a direct effect on where the arrow lands; the most serious are vertical and lateral movements. Some movement is inevitable as the arrow moves off, but the movement needs to be consistent from shot to shot. Often, 'consistent' will be best achieved by 'as small as possible'.

Rotation



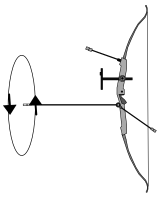
Rotation is movement around an *axis.* There are three axes of rotation important in archery; approximately parallel to the arrow, approximately down the centre of the riser, and through the grip from left to right. The next few sections cover these in turn.

i) Forward/backward Roll



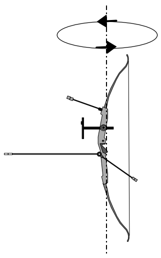
Draw a line through the grip from left to right. Rotation around that line, visible as the bow tipping backwards or forwards, is forward or backward roll. Some movement occurs as a direct result of the arrow leaving the bow above the hand position, causing the bow to ‘kick’ upward slightly; that movement is usually compensated in part by careful tillering. Other rolling movements may be caused by a centre of gravity well above or below the hand position (see below), and, after the shot, by the centre of gravity forward or behind the grip. For example, a heavy weight on a long rod will cause forward roll after the shot.

ii) Rotation around the arrow line.



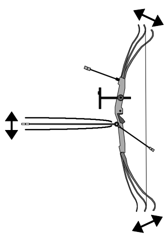
Rotation round the arrow line would appear as clockwise or anticlockwise movement viewed from directly behind the archer. Though not normally a consequence of the bow’s natural mechanics, this movement may, for example, be visible later in the shot as a sharply rotated bow arm returns to rest. It is worth remembering that rotation about this axis is usually slight both because there are few forces acting in the relevant directions and because the riser is hard to move quickly about either horizontal axis.

ii) Rotation around the riser



Often called ‘torque’, rotation around the vertical axis is probably the single most important movement stabilisers were intended to reduce. The bow itself is easiest to rotate about its long axis, being long but narrow (more on why later), and the archer’s hand position can vary enough to add a lot of torque - after all, an off-centre force of 30-40 lb. is hard to resist!. Symptoms of torque include lateral spread of impact on the target, lateral movement of the long rod if fitted, impact of the string on the bracer and reported lateral movement of an extension-mounted sight. Notice that rotating the bow around the riser moves the string sideways; that becomes important during the shot itself.

Vibration



For practical purposes, a bow wobbling about or rattling is undergoing vibration. The shot itself puts considerable stress on the bow, and most of the energy not transmitted to the arrow is left in the bow and string as vibration. Limbs flexing asymmetrically after the shot, a long rod vibrating, or even a rhythmic ‘wobble’ as the archer aims, are all types of vibration.

***Timing -** When is movement important?*

Having looked at which movements are possible, we need to see when they most need to be under control to identify what needs to be done to help the archer. To take a simple example, residual limb vibration is not important before the bow has been shot! To help in thinking about bow behaviour and stabilisation, I find it useful to break up the shot into three main time periods:

- Before the shot

The archer is close to or at full draw, intending to achieve a steady aim. Motion of any kind is undesirable; lateral and vertical movement are particularly to be avoided. The main forces on the bow are the (approximately equal and opposite) forces exerted by the archer on string and bow hand respectively, and gravity. This period lasts a few seconds (though it may seem like hours if the clicker is mis-set!).

- During the shot

The bow limbs move sharply forward, propelling the arrow out of the bow. The arrow slides past the pressure button and rest for a few inches, then moves away from the bow as the shaft flexes. As the string passes its rest position, the arrow leaves the string, and in a properly tuned bow, is unaffected by further bow movement as it's not in contact with the bow at all. (It's worth remembering that the only part of the bow in contact with the arrow for most of this period is the string.) The main force on the bow is the pressure of the bow hand on the grip, which starts of almost exactly equal to the draw weight of the bow. The whole movement takes about 15 milliseconds.

- After the shot

The limbs stop and rebound under tension from the string, and the string and limbs continue to vibrate, along with the riser, until all the 'loose' energy is dispersed by assorted friction, air damping, as sound, and by transmission to parts of the archer. Asymmetric limb vibrations may continue for some time. The archer 'follows through'. The bow, if left free, travels forward under the continuing pressure from the bow hand. Gravity takes over and the bow falls, pivoting round the bow sling or hand to bring the bow's centre of gravity directly below the pivot point (exactly as a dropped plumb line comes to rest below its suspension point). The bow comes to rest and stops vibrating in a second or so.

Time and Motion

When are different motions important?

So far, we have identified three main types of motion (displacement, rotation and vibration) and divided the shot into three periods, (before, during and after). It's worth looking at the different types of motion and when they are most important, to get a clear idea of priorities in picking a stabiliser set-up.

Effect on arrow flight

It takes little thought to see that, as we progress through the shot, bow motions have successively less effect on arrow flight. Before the shot, bow motions literally control where the bow is pointed. During the shot itself, there is very little time to change the arrow direction. Though the full force of the bow hand would move the bow about 5mm during that time, lateral forces are substantially smaller, and the arrow is in any case barely in contact with the riser. So motion during the shot is normally less important than before the string is loosed. Movement after the shot, of course, has no effect on arrow flight. There are, however, a few more things to consider before assuming that we only need consider motion before the shot!

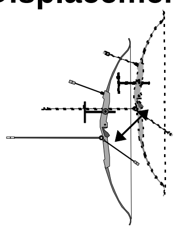
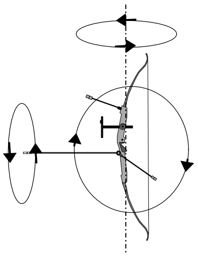
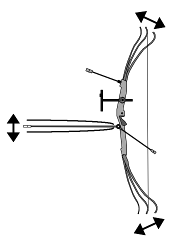
Effects after the shot

Uncontrolled Bow movement after the shot may still be damaging to overall performance. Factors to think about include:

- The archer ‘anticipating’ rapid movement before loosing
- Distraction of other competitors (especially indoors)
- Wear and tear, or loosening, of parts of the bow (eg a sight working loose)

The table (next page) shows where the different types of movement are most important.

Time and Motion - When are particular movements important?

	Before the shot	During the shot	After the shot
Displacement 	✓ Movement directly affects aim	✓ Movement affects aim to some extent	✓ Large movements may cause the archer to modify style to anticipate and 'pre-empt' movement.
Rotation 	The bow's rotation is largely restricted by the archer	✓ The bow is free to rotate, especially about the vertical axis. Rotation of the bow affects the string, which is the only part of the bow in contact with the arrow.	✓ As above
Vibration 	✓ Relatively low frequency vibrations induced by the archer make aiming difficult and may leave the bow 'rocking'	Low-frequency vibrations have no significant effect in the time. Higher frequencies appear mainly as the limbs come to rest.	✓ Though there is no effect on the arrow just shot, vibration increases wear and tear, and may disturb sight settings. Badly 'damped' vibration may also contribute to poor 'feel', as the archer feels the shock from the bow.

Controlling displacement

Principles i) - Weight, Mass and Inertia

Weight, mass and inertia are different things. The differences are explained below, but unless you intend tuning bows on the moon, the distinction is not very important. The main point to be aware of is that **more mass makes things harder to move,** and **not** just because gravity pulls them towards the floor. They are harder to move sideways as well.

Weight

Weight is the force gravity exerts on things. It always acts towards the ground. Weight, and the way it is spread around a bow, is responsible for the bow's balance in the hand and the effort needed to hold the bow up.

Mass

Mass is the amount of material. Because (on Earth) weight is proportional to mass, mass is usually expressed as a weight (!). The distinction is easier to see in films of astronauts in space - they weigh less, but have the same mass. Since it's the amount of **mass** that controls how hard you need to push something to move it, mass is important when stabiliser effects are considered.

Inertia

Inertia is how we describe the difficulty of moving an object. It's another way of thinking about the effect of weights. Isaac Newton's view would be that, because the mass is higher, the same force moves things less. Before Newton came along, Inertia was a force that resisted movement. So we commonly use 'high-inertia' to describe a stabiliser system that is hard to move quickly. That may not only be due to the amount of mass; a very rigid system is harder to move a small distance than a flexible one. More on that below.

Principles ii) - Static and Dynamic properties

Objects take time to start moving, and while they are being pushed about fast, they don't behave in quite the same way as when stationary. Think about what happens if you push a rubber ball slowly. It seems to move immediately at the speed of your hand. But if it is struck hard, say with a baseball bat, the ball flattens a bit against the bat, so although the whole thing is very quick, for a very short while after contact, the bat is moving faster than the ball.

Something similar happens when a bow fitted with flexible stabilisers or TFC's is shot. It takes time for the stabiliser weight to be affected, as the flexible stabiliser takes up the initial bow movement. So the full effect of the stabiliser weight is not felt immediately by the bow which, for a very short time, behaves almost as if unstabilised. That is one reason for the development of the TFC, or 'torque flight compensator', and also part of the reasoning behind the recent move back to shorter, more rigid stabiliser rods - to make sure the weight affects the shot.

Exercise: Set up your bow without stabilisers. Without letting the bow rotate, move the bow smoothly back and forth (along the arrow line rather than sideways). Then fit all your stabilisers and repeat the experiment. Was the bow as easy to move?

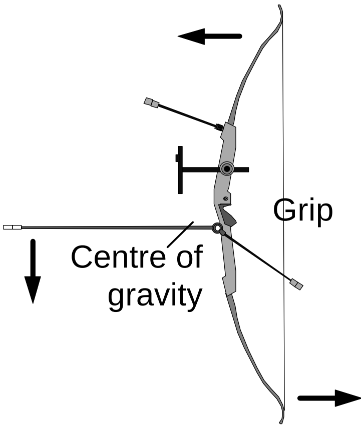
The misnamed TFC

Torque flight compensators don't add torque, can't fly and don't compensate for either. One account of their introduction is that as archers added increasing stabiliser weight, bows felt less smooth to shoot and harder to tune. So a flexible joint was introduced between bow and weight, so that the balance and feel before and after the shot was retained (static balance), but the bow behaved 'normally' for the few milliseconds of the shot. It is now recognised that there are other features of TFC action that are also important. In particular, TFC's can be used to absorb vibration, and variable TFC's can be 'tuned' to get a good compromise between damping, stabilisation and feel. These points will be covered later.

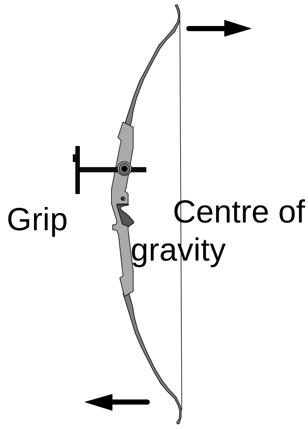
Controlling balance

Balance is the way the bow 'hangs' in the hand. The balance, and particularly the static balance, of the bow determines how fast, and in which direction, the bow rolls after the shot. The principles are simple; if the *centre of gravity* is in front of the suspension point (the grip, when held in the hand, or the point of attachment of the bow sling if used) the bow rolls forward, and vice versa. Without stabilisers, the centre of gravity is usually behind the grip (further behind in compounds than recurves). The diagrams overleaf show the approximate position of the centre of gravity on a recurve with or without stabilisers.

So to control the forward and backward movement of the bow after the shot, all that is needed is to control the position of the centre of gravity, by adding or subtracting weights. So what, and where, is the 'centre of Gravity'?



Centre of Gravity in front of grip: Bow rolls FORWARD after shot



Centre of Gravity BEHIND grip: Bow rolls BACKWARD after shot

Principles iii) - Centre of Gravity

The centre of gravity of any object is a point (not necessarily in the solid part of the object) through which the weight always acts, no matter which way up the object is. If the object is suspended from this point, the object will not rotate unless pushed. For any other suspension point, the centre of gravity ‘prefers’ to be directly below the suspension point.

This has two implications. First, a bow will feel more stable if the centre of gravity is level with or below the grip (though it’s bad practice to overdo this). Second, if the bow is freely suspended from any point, the centre of gravity will be directly below the suspension point. Picking two different points, such as the top limb nock and the string nocking point, and seeing how the bow hangs from each, is the standard way to locate the centre of gravity (see below).

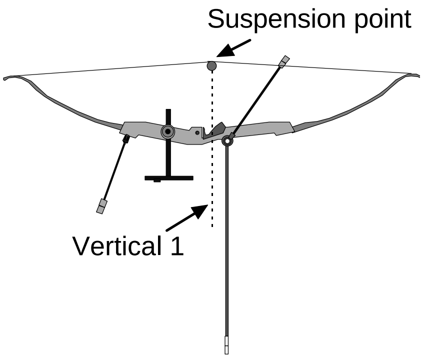
For most purposes, a bow will behave reasonably well with the centre of gravity within about four inches (20cm) forward of and below the grip.

The next section shows how to locate centre of gravity. But remember that there are no hard and fast rules about where it *should* be, so the location is less important than which way it needs to be moved. The best guide to the best location for centre of gravity will always be the bow performance.

Finding the centre of gravity

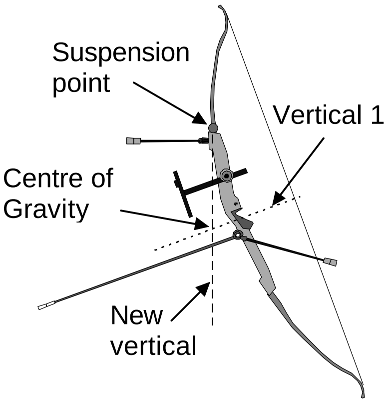
To locate a bow's centre of gravity, you can take advantage of the fact that the centre of gravity is always directly below a free suspension point. If the bow (or any other object) is hung freely from two different points on the bow, the vertical lines through those points cross at the centre of gravity. The diagrams below show how to find the centre of gravity on a bow.

Centre of Gravity - step 1



Let the bow hang freely from some point on the string, near the nocking point. Note where the vertical goes. It's most useful to move the suspension point so that the bow is nearly horizontal - that way, the vertical will be close to a right angle to the string, and is much easier to mark or remember. It may also be useful to clip a bracing height gauge to the string to mark the line.

Centre of Gravity - step 2



Allow the bow to hang from some other point, well away from the first. The top of the riser, top limb or (if the sight is good and robust) the sight mounting bar will all work. Note where the vertical goes, and particularly where it crosses the vertical found in part 1 (above). The point where the two lines meet is the centre of gravity.

Changing the balance 1 - using weight

Moving centre of gravity using weights is simple. To move it forwards, place more weight in front of the centre of gravity or take weight off behind the centre of gravity. To move centre of gravity backwards, place more weght behind or remove weight in front. The same principles apply for upwards and downwards - add weight in the direction you want to move, or take it away from 'behind'. Notice that the reference point is the centre of gravity, not necessarily the riser itself, though in most cases weights are added so far out as to make the distinction unimportant. But remember when adding weight very close to the riser that the centre of gravity may not change in the direction expected.

Exercise 1: Without stabiliser weights fitted, suspend your own bow from the top limb nock. Note whether the vertical line from the suspension point falls. Is it in front of, or behind, the grip? Now suspend the bow from the string, near the grip. Does the vertical pass above or below the normal hand position?

Exercise 2: Fit your normal stabiliser weights and repeat the exercise above. Where is the centre of gravity now? Experiment with different weight combinations to see how far different weight arrangements move the centre of gravity.

Principles iv) - Weights and Distances - 'Moment'

The balance of the bow, or the position of the centre of gravity, can also be understood in terms of the 'moments' of all the weights in the system (including the riser, limbs etc. The 'Moment' of a force about a point is the force multiplied by the distance to the point (measured at right angles to the direction of the force). For understanding balance, this is almost easy; all the forces are downwards, so all that matters is how far away from the suspension point the weights are, and how heavy they are. In practice, there is one simple rule of thumb:

"Half the weight at twice the distance has the same effect on balance"

Changing the balance 2 - using distance

What the above principle means for controlling bow 'balance' is that there is an alternative to adding weight. It may be possible to get the same effect by *moving* the weights already in place. For example, to reduce forward roll without changing overall weight, fit a shorter long rod with the same weight or place v-bar weights on longer rods. The table overleaf summarises the options for changing the balance of the bow.

Principles v) -"Dynamic" balance

There is one other point to make about the bow's balance. During the shot, the biggest force acting on the bow is the forward force of the bow hand (about five to ten times the effect of gravity downward). During this time, the balance of the bow affects the way the bow 'kicks'. Briefly, if the centre of gravity is high, the bow will tend to kick upward, and vice versa.

This has implications for adding top and bottom stabilisers. Normally, we ask a bow to move straight forward during the shot. A heavy TOP stabiliser will actually tend to make the bow kick UPWARDS initially - even though, after the shot, gravity takes over again and the bow starts to roll forwards once more.

Exercise: Set up your bow without stabilisers. Fit a single stabiliser in the bottom limb bush. Holding the bow vertical and lightly at the throat, move the bow sharply forward. The bow will initially tilt away from the vertical. Which way did the bow tip? Now, move the stabiliser to the top limb bush and repeat the experiment. Did the bow tip the same way?

Exercise 2: Hold the bow pointing vertically upwards, with your hand as nearly as possible in the normal position on the grip. Is the bow balanced on your hand, or does it tend to tilt forward or backward? From this experiment, which way will the bow tend to kick during the shot?

Changing the bow balance

To move centre of gravity	Using weight	Using distance
Forwards	Add weight in front of the centre of gravity *or* Remove weight from behind the centre of gravity	Move weights forwards (for example, add a longer long rod, shorter counterbalance rods, or v-bar extensions)
Backwards	Add weight behind the centre of gravity *or* Remove weight from in front of the centre of gravity	Move weights backwards (for example, add a shorter long rod, longer counterbalance rods, or remove or shorten v-bar extensions)
Upwards Carefully! - this may also change effective tiller	Add weight above the centre of gravity *or* Remove weight from below the centre of gravity	Move weights upwards (for example, rotate v-bar upwards, or perhaps move weight from bottom to top rod)
Downwards Carefully! - this may also change effective tiller	Add weight below the centre of gravity *or* Remove weight from above the centre of gravity	Move weights downwards (for example, rotate v-bar downwards, or perhaps move weight from top to bottom rod)

Controlling Torque (rotation)

Principles vi) - Weights and distances

Rather in the way that more mass is harder to move in a straight line, mass in a rotating system makes the system harder to rotate. But *how much* harder depends very strongly on where the weight is. The section on *balance* talked about 'moment'. When talking about rotation, the right quantity is called *moment of inertia*. The moment of inertia of a small weight rotated round an axis some distance away (like a long rod weight swung in the hand) is the mass multiplied by the **square** of the distance. This boils down to another simple rule of thumb:

"A QUARTER of the weight at TWICE of the distance has the same effect on rotation"

So if you want to cut rotation a lot with minimum weight, **use small weights on long rods**!

Another consequence of the dependence on distance is that a long, narrow object (like a bow riser) has a rather small moment of inertia about its longest axis and small forces will cause large rotations about that axis.

Exercise: Take an unstabilised bow and, holding by the grip, rotate the bow quickly back and forth. Now fit a light long rod and repeat. What was the difference in the bow's rotation? If possible, compare with the same bow fitted with twin stabilisers and V-bar only.

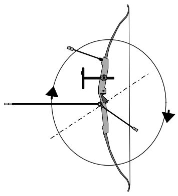
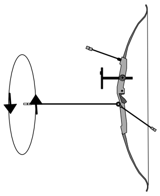
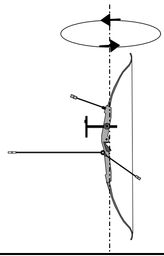
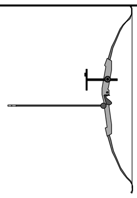
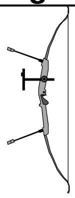
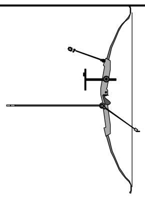
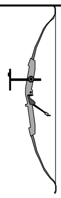
Rods, weights and risers

The Table overleaf shows the relative effects of adding different rods on rotation in different directions. Be careful when reading the table; the forward/backward rotation discussed is the rotation induced by the shot or the archer, NOT any rotation due to gravity. Gravity-induced rotation is chiefly due to balance.

Notice that the main effects of stabilisation are on rotation around the vertical axis. That is mainly because **the largest stabiliser in the system is the riser itself**; it often weighs two or three times the total of all other weights and is about 20-26" long, with a lot of mass near the limb fittings. That makes it a very effective stabiliser for all but rotation about its own long axis.

Stabilisers and Rotation*

How big is each stabiliser's effect on each rotation?

	Forwards/ backwards 	**Around arrow line** 	**Around riser** 
 **Long rod**	**MODERATE***	**NONE**	**LARGE**
 **Twin short rods**	**SMALL**	**MODERATE**	**MODERATE-LARGE**
 **V Bar**	**SMALL**	**SMALL-MODERATE**	**MODERATE-LARGE**
 **Short counterbalance**	**V. SMALL**	**V. SMALL**	**SMALL**

*Remember that this table relates to the effect on rotation induced by torque. For the long rod, the effect on balance is large, but the rod adds relatively little to the *moment of inertia* about the lateral axis.

Controlling Vibration

Principles vii) - Vibration

'Vibration' is any periodic movement. Vibrational motion has a *frequency* and an *amplitude*. Frequency tells you how fast something is vibrating, and amplitude is how large the movement is. Generally it takes more energy to drive higher frequencies, so higher frequencies typically produce smaller vibrations in practice. Frequency is usually measured in cycles per second, or Hertz (Hz). For example, a clock pendulum which swings from one side to the other and back four times a second has a frequency of four cycles per second. In archery, frequencies range from a few Hertz to many thousand Hertz. (The human ear is sensitive to frequencies between about 25Hz and 20,000Hz - the higher the frequency, the higher the note you hear).

Controlling frequency

The frequency of a vibrating system depends on two main factors; the mass being moved and the force which returns it to its rest position. The 'restoring force' is usually the 'strength' or stiffness of a spring or, in archery, the bow limb or stabiliser rod. There are two simple rules to remember:

"A STIFFER or SHORTER spring gives a HIGHER frequency"

"A HEAVIER weight gives a LOWER frequency"

So if we need to change a stabiliser vibration frequency, for example (we'll come to *why* later) either a stiffer rod or a lighter weight will increase the frequency and vice versa.

But what causes different frequencies and vibrations?

Causes of bow vibration

- The archer

  Most people depend on one particular vibration - your heartbeat - to stay alive. That's at about 1Hz, sitting still. Further up the frequency range are oscillations caused by poor bow control at around 2 to 10 Hz (related to typical reaction time) then muscular tremor at perhaps 10 to 30 Hz.

- Limbs

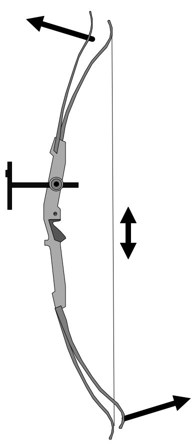
  Slight imbalance in the limbs will result, after the shot, in visible asymmetric limb vibration (ie as the top limb moves forwards, the bottom limb moves back, so the nocking point moves up and down rapidly) (see diagrams below). This movement produces a frequency around 10-20 Hz depending mostly on bow weight and limb material and mass. Notice that this natural frequency for the limb vibration is not far from some of the archer's movement frequencies, and as the bow is drawn, the natural frequency drops.

- String

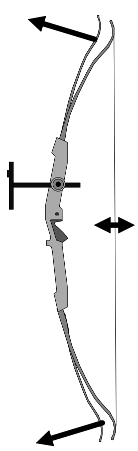
  The string has a natural frequency in the range of a few hundred Hertz when near rest. It is set in motion by the shot.

- Riser

  Shooting the bow causes a lot of flexion in the limbs and riser as the limbs reach the limit of movement imposed by the string. The shock starts a whole set of different vibrations off, mostly at high frequencies.



Asymmetric vibration



Symmetric vibration

Principles viii) - Reducing Vibration - 'Damping'

In principle, vibration will continue until stopped. A vibrational movement which is being reduced by some external force is said to be 'damped'. Very often, the time vibrations take to stop is too long, so engineers spend a lot of effort in inventing methods of controlling or slowing vibration more quickly. The basic principle of all these methods is to provide a method of transferring energy away from the vibrating object and into some system that dissipates the energy without adding more vibration. Some common examples include:

- Friction.
  Any friction slows vibration by dissipating energy as heat. Frictional force is constant, so the final resting point of the object is slightly uncertain. Powder filled stabilisers use the friction between powder particles to dissipate energy.

- Fluid, or 'viscous', damping.
  Movement through a fluid needs a force proportional to speed of movement, making fluid damping very useful when an object is to be brought progressively to a known rest point. A piston or weight moving through oil transfers energy to the oil, which dissipates the energy as heat. Most of the energy is lost in overcoming fluid viscosity (or thickness), hence the alternative term.

- Hysteresis effects.
  When you stretch and squash a material like rubber, you store energy in the material. Each time you let the rubber return to rest, much of the energy comes back in the form of movement. But some is lost and, as usual, turns up as heat in the rubber, so you can't just let go and let the material keep oscillating. Systems which move from one state to another and exactly back to the first with loss of energy at each cycle (as the rubber moves from squashed to stretched and back to squashed) are exhibiting 'hysteresis'. The effect is used in TFC rubber to damp oscillation. Some manufacturers even sell special 'high hysteresis' rubber parts to improve damping.

- Structural effects
  Some materials, particularly composites like carbon fibre, soft foam rubber and wood, absorb energy well through combinations of the effects above. So Carbon rods tend to absorb high-frequency, post-shot vibration more effectively than aluminium rods

All these methods rely on one essential fact. To damp movement, the movement must be transferred quickly and effectively to the damping device. To make this happen with vibrational movement, we often need to think about *resonance*.

Principles ix) - Resonance

Vibrating systems - wine glasses, road bridges, stabiliser rods and so on - have a natural frequency (usually more than one) at which they will vibrate if disturbed. Resonance is a condition in which two or more separate systems with similar natural frequencies of vibration will tend to vibrate in concert. Under these circumstances, energy transfers efficiently from the most strongly vibrating system to the other(s). This effect can be used effectively to make sure that TFC's or other stabiliser components are efficiently controlling unwanted movement in the bow.

The same effect can amplify or exaggerate movement, sometimes disastrously. An archer with a muscle tremor at around 15 Hz will transfer energy efficiently into a bow/stabiliser system with a natural frequency close to 15Hz, resulting in greatly increased bow oscillation during aiming. In these circumstances, we need to change the offending natural frequency of the bow to avoid the archer's natural frequency.

Avoiding resonance

Avoiding resonance when it occurs is simple. Almost any change in the system - increasing or decreasing weight, changing rod stiffness or length, or changing limb stiffness in either direction - will change the natural frequency of the bow. Changing stabiliser length or weight is usually the most effective as there is scope for larger changes.

Finding resonance

Deliberately achieving resonance is harder. But the options are the same; change any part of the system you want to 'tune'. The difficulty is simply that to identify resonance, one or other part of the system must be allowed to vibrate, and the other part observed. When the 'undisturbed' part immediately picks up and continues the vibration of the first, resonance has been located. To tune a *damping* system, damping is most effective when the damping system matches the vibration frequency - the system *stops* vibrating fastes when the vibrating and damping parts are close to resonance. This needs to be repeated for a series of small adjustments, and is easiest with a continuously adjustable unit - like the ubiquitous TFC.

Tuned damping - more on TFC's

The continuous adjustment on TFC tension allows a very wide range of tuning to suit different needs. Tightening the unit leads to a higher frequency and vice versa. Since a TFC is an effective damping device, that means a TFC/stabiliser combination can be set to achieve the most effective damping for a wide range of frequencies.

Exercise 1: Fit a single short rod and TFC in either top or bottom limb mounts. Slacken the TFC as far as possible. Tap the upper limb of the bow smartly, so that the limbs vibrate, and note how quickly they come to rest. By degrees (eg a turn at a time, tighten the TFC and repeat the procedure. What happens? If you observe a reduction in the oscillation time, continue tightening the TFC, and note what happens.

Exercise 2: Set the TFC to achieve the best damping. Add or remove weight (remove a cap weight or add a middle weight, for example). Test the damping again. What happens?

The short table below shows what sort of TFC tension will be needed to control different effects.

Movement	**Frequency**	**TFC tension**	**Rod length**
Aiming 'wobble'	Low	Low	Med/long
Limb vibration	Medium	Medium	Med/Short
Post-shot vibration	High	Tight	Short

Conclusion

Stabilisation offers an enormous range of methods of controlling movement. With some thought, that range of control can be used to find and eliminate particular unwanted movements or adjust 'feel' to the archer's preferences. The result will be a more contented archer and, if the system is properly chosen, higher scores.
But remember that stabilisation is not a substitute for technique; consistent bow movements need to be minimised through technique first.