Stabilisation

The purpose of stabilisation is to minimise the effects of inconsistencies of form. If the archer performs the same actions for every shot and all the arrows are the same, then the result will be the same every time (ignoring external influences such as the weather). In practice, the archer is slightly inconsistent from shot to shot with the result that the group of arrows exhibit a spread at the target. Stabilisation will reduce the spread but it is not a substitute for good form!

Inconsistencies can take the form of force variations and torque variations. To overcome inconsistencies in force, the obvious course is to add weight to the bow while to overcome inconsistencies in torque the solution is to increase the moment of inertia in the axes where the torque is inconsistent. The problem is to determine the best combination of weight and inertia to minimise the group size without undue fatigue setting in.

Stabilisation options

Modern bows with metal risers are designed to operate with stabilisers. The moment of inertia about the two horizontal axes is much higher than about the vertical axis (the bow being assumed to be held upright). This is because the bow resists being tipped forward or rotated much more than it resists being twisted in the hand. To overcome the tendency to twist in the hand on releasing the string, a long rod is almost universally used. The long rod has almost no effect on the inertia about the axis directed at the target. Further increase in inertia about this axis needs weight adding as far away from the long rod as possible. The two most popular methods of doing this are to use twin stabilisers attached to the riser or to use V-bars, usually with an extender and sometimes with a top rod as well. More personalised set-ups are possible by combining twins, V-bars and extra weights hung on at various places but they are all intended to have the same effect.

The main advice offered for the choice of stabiliser set-up is "Does it feel right?" Unfortunately, most people would not recognise what felt right! My aim is to show how to get a set-up which has characteristics which should give good stabilisation without introducing unwanted imbalances whose result is to magnify the very inconsistencies the stabilisation is intended to reduce.

Centre of Gravity

If the force applied to the bow could act exactly at the centre of gravity (C of G) of the bow then it would be impossible for that force to exert a torque on the bow. (To determine where the C of G lies is simple, just hang the bow with the required stabilisers and the C of G is vertically below the point of suspension: do this from two points to find the exact position of the C of G. Moving the C of G is a case of modifying the weight distribution of the stabilisers.) If the point of action of the force applied to the bow varies due to inconsistencies in hand position a torque is applied to the bow which is easiest to appreciate in pitch (i.e. the bow will tend to rotate forward or backward as the amount of heeling is varied). The components of the force applied to the bow are made up of the draw weight D towards the target and a force upwards to compensate for the physical weight W which may be considered to act at right angles to each other. Thus the resultant applied force is slightly upwards with the upward component exactly cancelling out the physical weight. When the string is released the same forces still apply so that the effect on the bow will then depend on the exact position of the C of G and the effective centre of the applied force. It is clear that no torque is applied to the bow if the C of G lies on the line of action of the resultant force from the archers arm so it is important to know where this line is.

Centre of Force

I shall define the centre of force (C of F) as the point at which the resultant force appears to act: in general it will be near the handle but the exact position depends on the contact between the bow hand and the handle. Three cases are considered:

- Case 1: no skin friction, high wrist
- Case 2: no skin friction, low wrist
- Case 3: skin friction (no slip), low wrist

Case 1: No Skin Friction, High Wrist

By having a high wrist, the contact between the hand and the bow is minimised. By having no friction there is no force tangential to the grip. In this case the force acts from the centre of the circle whose arc defines the shape of the throat of the handle. Since none of the hand is in contact with the straight part of the handle, the C of F is independent of D and W which serve only to determine the magnitude and direction of the resultant force.

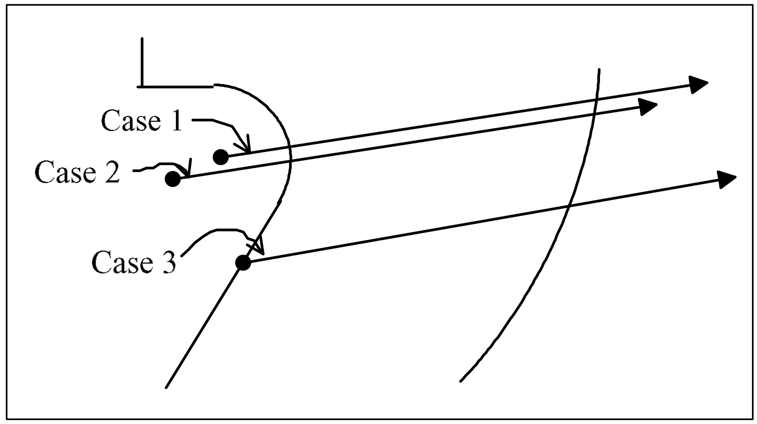
Case 2: No Skin Friction, Low Wrist

Strictly speaking, the resultant force can be found only by integrating the pressure exerted by the hand over the area of the handle. This is scarcely practicable. An approximation is to simplify the shape of the handle and work out the resulting components. Most handles have a roughly circular arc from the window to a point just below the centre of the throat, thereafter they are fairly straight.

A particularly simple case is where the angle of the handle slope is 30 degrees from the vertical. If a constant pressure is applied in the region of the throat from the vertical to the point where the straight part of the handle begins, i.e. over an angle of 120 deg. the resultant from this section acts from the centre of the circle at an angle of 30 deg. Similarly, if a constant pressure is applied to the straight region of the handle over a length l, say, then there is a force acting from the centre of this region at an angle of -30 deg. Defining the origin of co-ordinates (x and y) as the centre of the handle arc, we can find the C of F by finding the point where these two lines meet. By co-ordinate geometry and a few simplifications resulting from the angles used, the upward (throat) component is found to be $y = \frac{1}{\sqrt{3}}x$ while the downwards (straight) component is found to be $y = -\frac{1}{\sqrt{3}}(x+l)$. they meet at the point $x = -\frac{1}{2}l,\ y = -\frac{1}{2\sqrt{3}}l$. (Note that this is from the centre of the arc and that the radius of the arc is not in the equations for the point). The parameter l may be estimated in a number of ways. For example, if the amount of contact between the hand and the straight part of the handle is 2 cm then l = 2 cm. Another estimate is by assuming the pressure on the handle is constant over the whole of the area in contact with the hand and finding how far the pressure has to extend to achieve the resultant force magnitude required to hold the bow. When this is done it turns out that $l = \frac{r\sqrt{3}\left(p-\sqrt{3}\right)}{p+\sqrt{3}}$ where r *is* the radius of the throat and p = D/W. Typical values of p in the range 7 to 9 and r = 1.6 cm gives l as about 1.8 cm. In this case the C of F is located at the point x=-0.9 cm, y=-0.5 cm with respect to the centre of the throat arc (or 2.5 cm behind and 0.5 cm below the throat itself).

Case 3: Skin Friction (no slip), Low Wrist

When the hand is placed on the handle in such a way that it does not slip then the assumption that the tangential force is zero no longer applies and the force can be at any angle. An extreme case is where the hand is held away from the throat of the handle when the effective C of F is on the handle where the pressure is applied

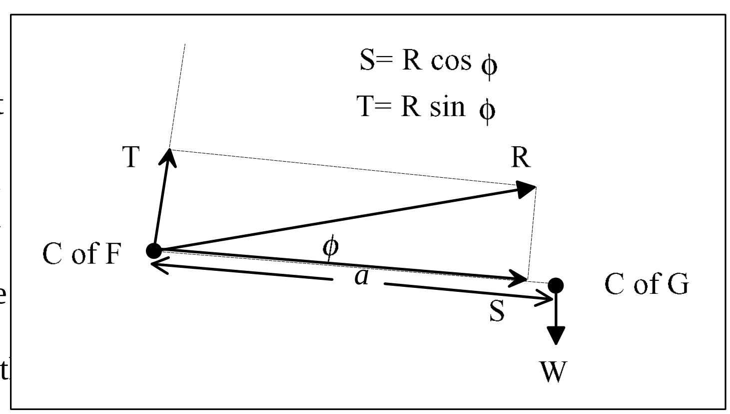


The easiest way to see the difference between the three cases is by referring to the picture. Here, the three centres of force are shown, together with the magnitude and direction of the force itself. The drawing clearly shows that if the hand is free to slide on the handle, it makes little difference whether the wrist is held high or low, the force vectors are close together. Contrast this with the difference between the low wrist with and without friction and the problem of consistency is clear: where there is no slip between hand and handle, the force vector could be anywhere between cases 1 and 3. A recipe for inconsistencies in elevation.

Combined effect

To determine the best combination of stabilisation from a theoretical viewpoint, we need to consider the position of the C of G and forces vectors together. As pointed out earlier, if the archer is perfectly consistent on every shot, there is no need to worry as long as the arrows are identical. We are only concerned with finding a set-up which is tolerant to variations of C of F. To illustrate the type of variations I shall again consider three cases:

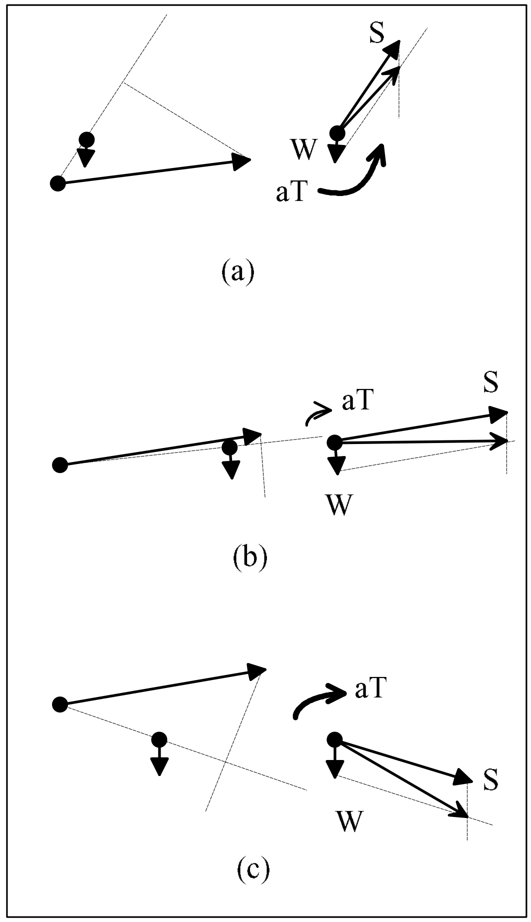
- Case a: C of G above the C of F (unstabilised bow)
- Case b: C of G on or near the resultant force vector (typical of long rod and twins)
- Case c: C of G forward and below the resultant force vector (typical of long rod and V-bars)



In the general case illustrated, the resultant force is applied from a point situated at a from the C of G and at such an angle that it can be resolved into two orthogonal components S in the direction of the C of G and T at right angles to this direction and so giving a torque equal to $a \times T$. The effect of the three components W, S and $a \times T$ will determine t effectiveness of the stabilisation in reducing variations of form.

Case a: C of G above C of F

An unstabilised bow has its C of G just above the handle and may be illustrated as shown in (a) of the accompanying figure. The force on the C of G is seen to act upwards with a magnitude significantly bigger than the weight of the bow. in addition, the torque is tending to tilt the top of the bow backwards. The combined result is that the bow tends to fly upwards on releasing the string and at the same time tilt backwards. A small change in the hand position has negligible effect on the upwards force exerted on the bow but can have a large effect on the rate of tilting since T is quite large in this case.



Case b: C of G On or Near the Resultant Force Vector

In (b) of the illustration, the vertical component of S is roughly equal to W so that the bow is thrust forwards towards the target. The applied torque is small since the component T is small so that even if the C of F changes slightly the tendency to pitch the bow forwards or backwards is slight.

Case c: C of G Forward and Below the Resultant Force Vector

By employing a long rod and V-bars, the C of G moves forward and down from the unstabilised bow. Generally, if no extender is used, the C of G is near the front of the handle as illustrated in (c) of the figure. In this case, when the string is released, the bow will fall away from the hand and tip forward because of the significant torque. Changes in the bow hand position are not as serious as for the unstabilised bow for two reasons: firstly, the extra inertia provided by the stabilisers reduces the angular acceleration caused by the torque and secondly, the relative change in *a* is smaller than the unstabilised case.

Note

The analysis applies to what happens after releasing the string. I accept that the approach ignores the torque applied by the asymmetrical loading of the string: this serves only to cancel the asymmetry set up by the hand position prior to releasing the string and has no effect on the results.

Other Considerations

Stabilisation in Other Planes

The above analysis has concentrated on stabilising in the plane containing the bowstring and the target. Both the other major planes are improved by the methods proposed and if the advice of using talc etc. to reduce friction is adopted, the torque in the horizontal plane by twisting the handle laterally is also eliminated. The main source of trouble in this plane is the asymmetry due to the sight window putting extra weight on the thumb side of the bow. Some compensation could be achieved if a V-bar is used with an asymmetry used to compensate for the lack of weight on the little finger side of the bow. Whether this is an effective approach is questionable if the overall C of G is required to be well in front of the bow.

Dampers, TFCs and Doinkers

Any form of damping applied to the stabilisers adds weight to the bow and reduces the effect of the stabilisers. However, by setting the stiffness sufficiently hard that while the arrow is on the string the deflection of the dampers is negligible, the effectiveness of the stabilisers is maintained. In this case the dampers serve to absorb the shock of energy that hits the bow when the string stops and the arrow leaves it. Thus the dampers have two effects, firstly they increase the weight in the hand without contributing to the stabilisation effect and secondly they protect the bow from potentially damaging shocks which could cause fatigue and breakage in the limbs or riser. A secondary effect could be that they prevent shock to the archer which causes an anticipatory flinch. Soft stiffness in the dampers could have the effect of reducing the resonant shake sometimes experienced when hanging on to the string too long. These effects are defects in form and should be eliminated and not masked by degrading the effectiveness of the stabilisers.

Conclusions

It is clear from the above analysis of special cases that the following points are generally true:

1. The nearer the C of G is to the resultant force vector applied by the hand on the handle, the lower the torque tending to tip the bow towards or away from the target.
2. The nearer the C of G is to the resultant force vector applied by the hand on the handle, the less the bow is pushed off line upwards or downwards.
3. The further the C of G is in front of the C of F, the smaller the angle ϕ and hence the force tending to turn the bow.
4. Minimising the friction between the hand and the handle of the bow gives a more consistent C of F than preventing the hand from slipping.
5. The use of dampers reduces the effectiveness of stabilisers and adds weight in exchange for protecting the bow and archer from shocks generated when the string stops.

From these points we may conclude that the most effective stabiliser set-up for a given weight in the hand is not to employ dampers, to have the C of G as close to the resultant force vector and as far in front of the C of F as possible and to employ some form of lubricant between the hand and the handle (e.g. talc or a woollen glove in winter!). Clearly, there is a limit on how far in front of the handle the C of G can be put but for a given overall bow weight, the most satisfactory stabiliser set-up seems to be a long rod and twin stabilisers. If the feel of the long rod and V-bar arrangement is preferred, then the V-bars should be angled upwards or compensated for using a top rod and preferably an extender as well. If the extra security of dampers is thought desirable, they should be as stiff as possible.