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How viable is the use of 60 cm Dyneema slings in a Magic X anchor system?

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Abstract
In recent times, one of the most contentious issues within the climbing community is the building and form of belay anchors. Self-equilibrating anchors have seen a rise in popularity with the Magic X being one of the most common. Despite the popularity, the Magic X breaks the "no extension" rule of anchor construction. This means if one of the anchor points fails the system will be shock loaded with the weight of the climber. Therefore, this paper presents a simple mathematical model to show if this anchor system should be considered as an option. The results show that for a 30 cm fall, a force of 11.4 kN is exerted on the sling and anchor point. Whilst this will not break the sling, there is high chance of causing the failure of the last remaining anchor point. Consequently, this system should be only considered for high strength anchor points such as bolted sport climbing routes.

Introduction
As the sport of climbing has developed over the years, safety equipment and practice has also followed suit. Recently the concept of the self-equilibrating belay anchor has become popular amongst multipitch sport and winter climbers. Their simplicity and speed of assembly lend themselves well to these applications, buying into the 'fast and light' ethos often accompanying the climbers [1].

One of the most popular examples of these anchors is the Magic X or Sliding X. Constructed using a single

Figure 1 – A series of photos showing the Magic X anchor before clipping (left), fully constructed and clipped (middle), and it after the failure of one anchor point (right). The anchor is constructed by clipping two locking carabiners into two anchor points (two bolts in this case), attaching a sling to these, making a twist in one of the two strands created by this, and finally clipping another locking carabiner through the twisted and un-twisted strand. This third carabiner (red) is where the climber would attach themselves to. Professional instruction should be sought prior to using this technique on real rock.

sling and three locking carabiners, as shown in figure 1, the Magic X is by far one of the simplest options available to a climber. However, this simplicity comes at great cost, breaking one of the fundamental rules of anchor construction – 'no extension'. This means if one of the anchor points the sling it is connected to fails, the climber attached will drop to the end of the sling, extending the climbers distance from the anchor points and therefore shock loading the system [1]. Due to their lack of elasticity, nylon and more modern Dyneema (polyethylene) slings are notorious for their poor performance under sudden loads such as a falling climber [2].

Thus far there has been no attempt to numerically model how safe the use of Dyneema slings in a Magic X anchor is. To this end, the model presented will assume a climber of 70 kg [3] plus 5 kg of equipment is directly attached to the anchor at the mid-point of the sling. One of the anchor points will be modelled to fail causing the climber to fall half the length of the sling, modelled as a spring, before shock loading it. The force transferred to the sling can then be compared to its strength rating given by the manufacturer.

Calculating the spring constant

Whilst Dyneema slings have little elasticity, they do have a small amount of stretch in them [2]. Using real world data, collected by the renowned climbing equipment manufacturer DMM, a value for the stretch, and thus the spring constant, of an 11 mm wide Dyneema sling can be calculated.

In DMM's testing, an 80 kg mass was dropped 60 cm onto a 60 cm long sling giving a recorded force on the sling of 16.7 kN [2]. This allows the gravitational potential energy (E_p) of the object to be calculated using equation 1. Since the sling is being modelled as a spring, the work done (WD) by a spring can be calculated using its displacement, or stretch in this case, in equation 2.

$$E_p = mgh, \tag{1}$$

$$WD = \frac{1}{2}FS, \tag{2}$$

$$S = \frac{2mgh}{F}. \tag{3}$$

Since the WD by the sling will be equal to the E_p equations 1 and 2 can be equated, and rearranged for displacement (S), to give equation 3. By substituting in the mass of the object used (m), acceleration due to gravity (g), the height dropped (h) and the force exerted on the sling (F) a stretch of 56.4 mm can be found. Now using Hooke's law (equation 4) and rearranging for the spring constant, k, gives a value of 296.1 kN m^{-1}.

$$F = kS. \tag{4}$$

Will the sling break?

With the spring constant of a 60 cm sling calculated the model can now be completed. By rearranging equation 4 for displacement and substituting this into equation 3, an equation describing the force exerted on the sling can be found from equation 5.

$$F = \sqrt{2kmgh}. \tag{5}$$

Equation 5 gives a force of 11.4 kN. DMM rate their slings at 22 kN making the value of force calculated considerably less [4]. Even by increasing the fall distance to a maximum of 60 cm the force is 16.2 kN, again less than the rated strength. Therefore, it is unlikely that the sling would break under these circumstances.

Concluding remarks

These results suggest that for a climber with a total mass of 75 kg using a 60 cm sling the Magic X anchor is safe. However, more importantly these forces are still very high and could therefore cause the catastrophic failure of the second and only remaining anchor point. For example, traditional anchors such as nuts are generally rated for around 7-12 kN, meaning that even if the climber fell 30 cm the forces applied to the anchor point could realistically cause it to break [5].

Considering this, whilst the Magic X anchor system is unlikely to cause the failure of the sling its self, this type of anchor should only be considered on routes where the anchor points are known to be very strong, such as new professionally placed bolts on a sport route. In addition, climbers should always tie into the anchor point using dynamic rope as this will absorb some of the energy produced in the event of a fall [1]. Finally, climbing is an inherently high-risk sport and as such professional guidance and instruction should always be sought before attempting any of the techniques detailed in this paper in the real world.

References

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