Magnetic Counterbalances for High Performance Vertical Stages

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Why use a counterbalance?

Linear motor stages deliver excellent precision, dynamic performance, and reliability. Zaber's controllers combine this high performance with the easy-to-use Zaber ecosystem, providing seamless compatability with a wide range of motion control products and allowing even beginners to access nanometer level motion control in a matter of minutes.

Despite excellent performance, linear motor stages are not well suited for vertical applications without modification. Whereas fine-pitch leadscrew stages are inherently self-locking, the electromagnetic direct drive mechanism of linear motor stages means they will fall uncontrollably if power is lost while operating in a vertical orientation. Additionally, because linear motors cannot rely on mechanical drive reductions like screws or gearboxes, they must compensate for the full weight of a payload, resulting in significant heat generation.

Figure 1: Linear motor stages like Zaber's X-LDM-AE above will fall uncontrollably if power is cut in vertical orientation.

To make linear motor stages suitable for vertical applications, the addition of a counterbalance is required to compensate for the weight of the stage's moving mass and payload. Usually it is ideal for the counterbalance's force to perfectly balance the system's weight, but sometimes the force is slightly offset if gentle upwards or downwards retraction is desired in the event of power loss.

Types of Counterbalances

Zaber's Adjustable Magnetic Counterbalances

Nearly all magnetic counterbalances available in industry have fixed force outputs that are set at the factory, limiting the system to a very narrow payload range. To surpass this limitation, Zaber has developed a proprietary adjustable force magnetic counterbalance, allowing the force output to be finely tuned by a user in seconds. Not only does this allow a much wider range of payloads, but also means the counterbalance can be tuned to slightly rise or fall in the event of a power loss. This design provides the best of both worlds, combining the performance and reliability benefits of a magnetic counterbalance with the simple adjustability of a pneumatic counterbalance.

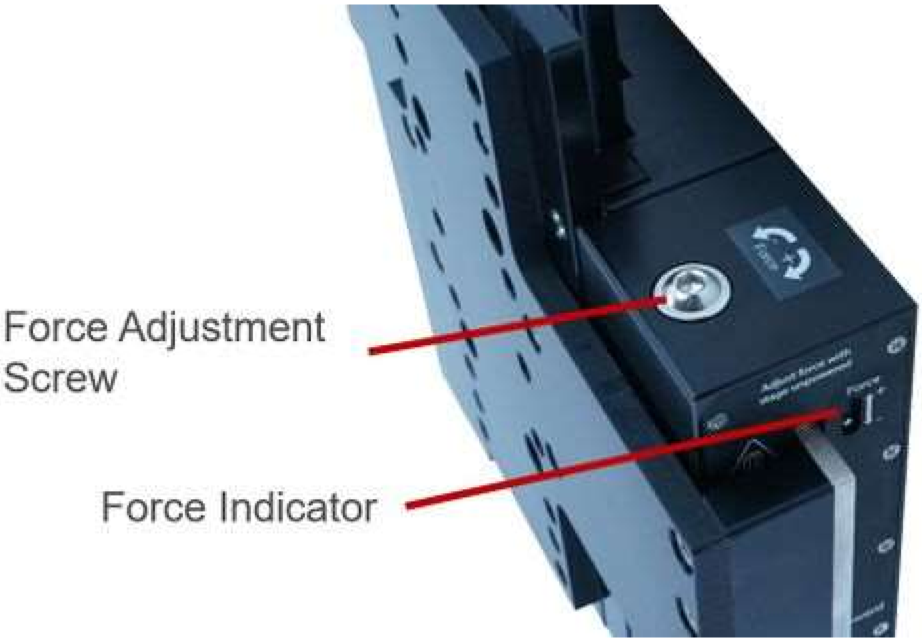

Figure 2: Zaber offers adjustable force magnetic counterbalances.

How it Works

The basic principle behind the adjustable magnetic counterbalance is remarkably simple. Consider two rectangular magnets spaced apart by distance D. Force F_N is required to keep the magnets separated. Force F_N is not suitable for lifting because it's highly dependent on distance D.

Now consider the case where the right magnet is also offset vertically by height H. An additional re-centering force, F_T, is developed between the magnets. Force F_T depends on distance D, but is constant for a large range of offset H. If bearings are used to compensate for force F_N, force F_T can be used to provide a constant lifting force. The lifting force can be adjusted with a mechanism that changes distance D.

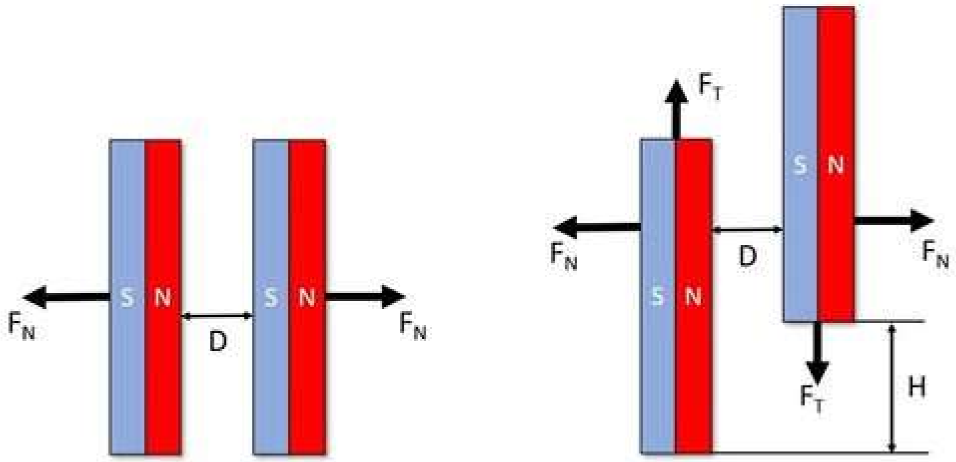

Figure 3: Basic working principle of the magnetic counterbalance.

It is worth pointing out that when the magnets fully overlap or stop overlapping the lifting force drops off rapidly. However, there is a large range of constant force output in the middle which is suitable for use as a counterbalance. The interaction between distance D, offset H, and lifting force F_T is shown below.

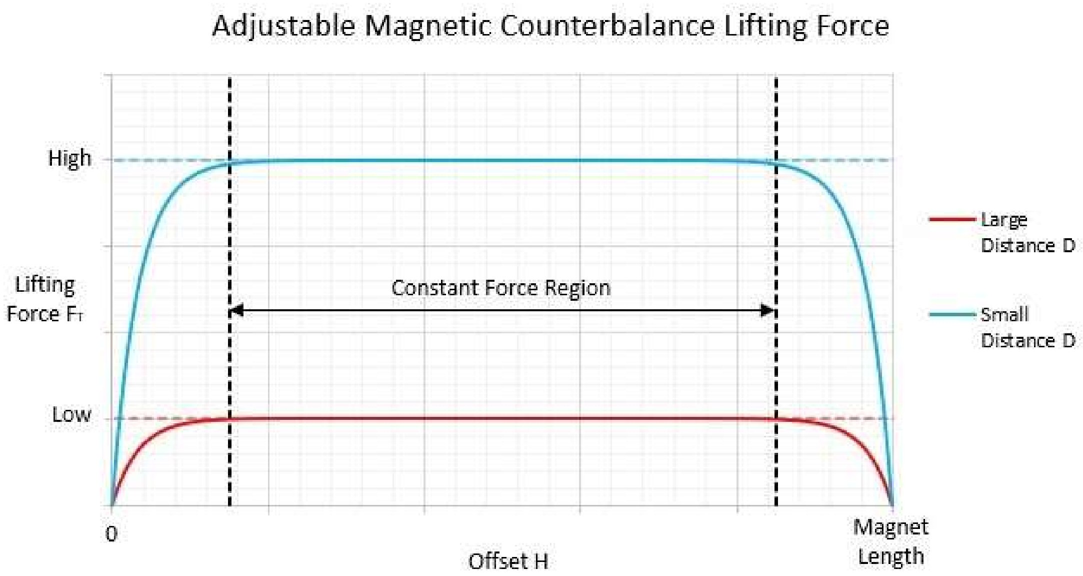

Figure 4: There is a large range of constant force when the magnets partially overlap. Adjusting D changes the force.

The simple theory behind this counterbalance ultimately translates into a highly reliable design. Some moving parts are needed to adjust distance D, but once the force is set the interaction is purely magnetic. Because most linear motor stages have oversized bearings to provide stiffness rather than load capacity, the normal force F_N is not a concern.

Zaber’s Vertical Stage Offerings

Zaber offers adjustable magnetic counterbalances on it’s X-LDA-AEZ and X-LDM-AEZ series vertical stages. These ultra-precision linear motor stages feature low friction crossed-roller bearings, making them particularily well suited for the magnetic counterbalance design because there is no additional friction to degrade small step performance or repeatability. Due to the non-influencing nature of these counterbalances, accuracy, repeatability, and minimum incremental move specifications of the stages are unchanged by it’s addition.

The magnetic counterbalances are also an excellent complement for the reliability of the moving magnet track linear motor design. Even with the counterbalance, the linear bearings are the only moving parts on these stages.

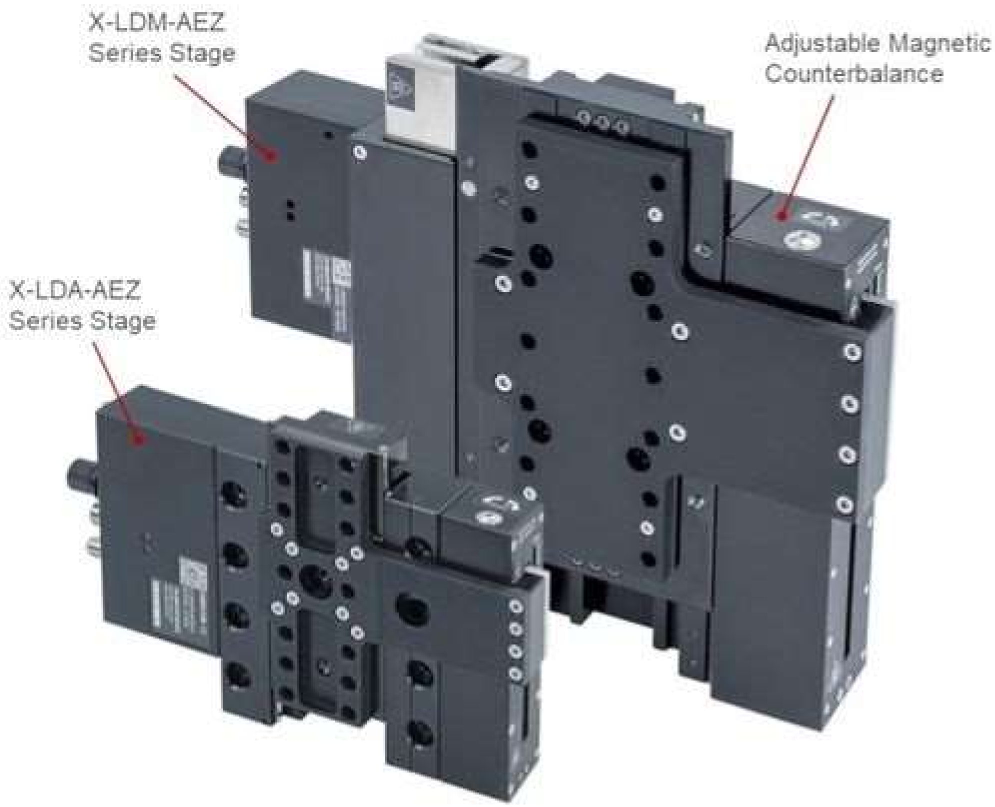

Figure 5: Zaber's X-LDA-AEZ and X-LDM-AEZ series stages feature adjustable magnetic counterbalances.