

Stage comparison guide

Introduction

We know that finding the right precision stage or actuator can be a challenge. Stage manufacturers tend to use different terminology in their specs, making it hard to compare two models of a different brand. As we believe you should be able to choose the product that suits you best, we have created this short stage selection guide. It will allow you to compare the right specs and hopefully guide you to the most suitable solution for your project. Here we go...

Terminology, the terms that really matter

Sensor resolution

The term sensor resolution indicates the smallest quantity detectable by the position sensor. This value is the lower limit for the stage resolution. Sensor resolution is also referred to as sensor sensitivity. It doesn't say anything about the motion specs, but only about the detection of the motion. Big difference.

⇒ *Don't be fooled, this is a spec of the sensor, but not of the stage or the actuator. It's an easy way to impress customers, but doesn't say a lot about the performance of the stage.*

Sensor accuracy

The accuracy of a position sensor represents the absolute deviation with respect to a calibrated, metrologically traceable standard. Sensor accuracy does not necessarily relate to sensor resolution. Sensor inaccuracy is mostly caused by the imperfectness of the sensor scale and by the alignment error of the sensor scale during assembly. The sensor accuracy error is to a great extent repetitive and can be compensated for by means of a lookup table.

⇒ *This is a tricky one and often misunderstood. You will typically find that these specs are much worse than the precision specs of the stage. But this shouldn't worry you too much, because the error is very repeatable, once the encoder is installed. Calibration of your system typically takes care of this. In 99% of the cases, this spec isn't very important.*

Stage resolution (= minimal step size)

Stage resolution is defined as the smallest, controlled mechanical displacement of a piezo positioning stage or actuator. The resolution is affected by the sensor resolution, mechanical influences (friction, compliance, contact point nonlinearities...) and position control performance. This value is the lower limit for the stage repeatability. Other terms for stage resolution are minimal step size or minimal incremental motion (MIM).

⇒ Now things are getting interesting. When people talk about precision, this is the one they mean: the smallest step size a stage can take. In some cases, there can be quite some difference between the stage resolution and the encoder resolution! Together with the stage repeatability, this is the most important parameter.

Stage repeatability

Repeatability is defined as the range of positions attained when the stage is repeatedly commanded to one specific location under identical conditions.

Unidirectional repeatability: the ability of the stage to return to a given point, always coming from the same previously defined point. The value specified is the standard deviation of many moves to the same point.

Bidirectional repeatability: the ability of the stage to return to a given point coming from a random previous point. The value specified is the standard deviation of many moves from random directions to the same point. The values given on the website concern the bidirectional repeatability, unless specified otherwise.

⇒ As said above, a small minimal step size is nice. But you also want to be sure that when you move to a certain position at any moment or from any starting position, you end up in the exact same position over and over. Open-loop systems struggle with this because the step error is cumulative. But also between closed-loop systems there can be huge differences, mainly due to the system control. Things get even worse if you move in two directions, because then the quality of the bearings starts to interfere. The longer the distance, the greater the effect. Therefore this is the second most important spec to look at: bi-directional stage repeatability

Stage accuracy

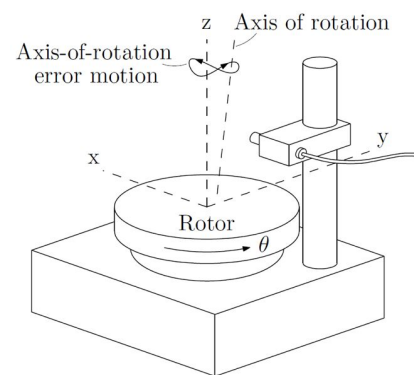
The accuracy of a stage is directly related to the sensor accuracy. This is a result of the direct-drive principle of our stages and the small distance between the position sensor and mounting surface.

⇒ Don't focus too much on this one. If you understand encoder accuracy, you also understand stage accuracy. Some manufacturers confuse stage accuracy with the stage error motion. This is a separate spec, and a very important one. See below!

Error motion of a rotation stage

According to the ANSI/ASME B89.3.4 standard, the error motion of a rotary stage's axis of rotation is defined as a change in position, relative to the reference coordinate axes, of the surface of a perfect workpiece, as a function of rotation angle, with the workpiece centerline coincident with the axis of rotation. In other words, a rotary stage ideally has one degree of freedom, i.e. a rotation about the z-axis.

However, as perfect rotary stages do not exist, any motion in the remaining five degrees of freedom is referred to as an axis-of-rotation error motion or simply error motion. Depending on the error direction, one can distinguish two radial contributions, one axial and two tilt or wobble contributions. Furthermore, the error motion of stage can be separated into a synchronous and asynchronous component. The error motion of a stage is often incorrectly referred to as stage runout. A more elaborate explanation of these terms can be found [here](#).



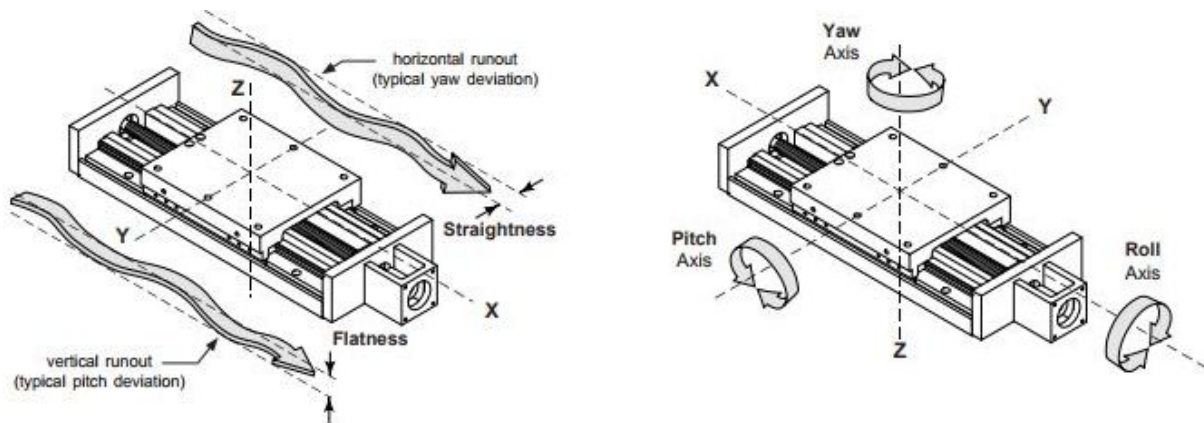
⇒ If you're looking for a rotary stage, make sure to take the error motion into account. A wobbly behaviour of the rotary disk will obviously have a huge impact on your results.

Error motion of a linear stage

The error motion of a linear stage is the undesired motion, as a function of the stage position, in all five degrees of freedom other than the direction of motion. The error motion in the horizontal plane is referred to as straightness error, and the error in the vertical plane as flatness error. The

angular error motion components in the different orthogonal directions are called pitch, roll and yaw. Another term for the error motion of linear stage is the stage guiding error or travel error.

⇒ *Same remark as for the rotary error motion. What's the point of having great precision when the stage has unwanted movements? The error motion specs of a stage are very important, as even small error motions can have a huge effect on your final results. Important for specific projects, but often not the decisive parameter.*



Stage speed

The maximum travel speed of the stage.

⇒ *Not a difficult one, but often overlooked. If you want to do a lot of measurements, the stage speed can have a huge impact on your throughput. For scanning measurements (measuring during movement), the speed stability is very important.*

Kind of piezo technology

99% of the piezo precision products on the market are driven by a stick-slip piezo motor or an ultrasonic piezo motor. If you want to know more about the differences, have a look [here](#).

⇒ *Stick slip piezo is the oldest technology, but has a lifetime problem. The wear of the motor is a weakness. The modern variant is called ultrasonic piezo. It has a better lifetime, can move very fast and is silent. It is a little bit more expensive, but worth the cost!*

Stage comparison table

We have tried to come up with an easy to use stage comparison table, with the parameters that really matter. Feel free to use it!

Manufacturer				
Model				
Travel range				
Piezo technology (stick-slip vs ultrasonic)				
Stage precision (min. step size)				
Bi-directional repeatability				
Stage speed				
Lifetime				
Error motion				
Controller price				
Stage price				

Additional useful information

Accuracy vs. repeatability

Accuracy is how close a stage can position to the actual (true) value. Repeatability is a measure of the stage's ability to sequentially position to the same target value. It is important to understand that accuracy and repeatability are two different properties of a positioning system.

In a number of applications, the repeatability of a motion system is more important than the accuracy. Systematic errors can be taken into account and compensated, but the repeatability is the ultimate limit that is reached after all compensation.

Accuracy is also referred to as trueness. Other terms for repeatability are reproducibility or - slightly confusing - precision.

