PIEZO ACTUATOR DRIVE (PAD)

- tutorial

Noliac’s Piezo Actuator Drive (PAD) technology differs significantly from any other electro-magnetic or piezoelectric motor on the market. A PAD system is composed of a PAD (drive) and a NDR (driver).

This tutorial focuses on Noliac's own motor, the piezo actuator drive (PAD). The tutorial describes the unique, basic principles of operation of the PAD. Also, the tutorial describes the static as well as the dynamic performance of the PAD.

Index of the tutorial on piezo actuators for the piezo actuator drive (PAD):

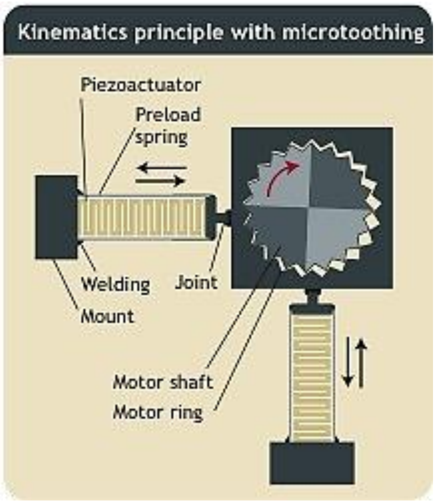
PRINCIPLE OF OPERATION

Internal construction

The principle of the PAD technology rests upon the conversion of the periodic elongation of powerful multilayer actuators into precise rotation of a motor shaft. To improve the performance of the PAD even further, a newly developed micromechanical interlock between the motor ring and the motor shaft was applied, increasing torque and precision while avoiding backlash and slippage.

The approach, as shown in the figure below, is an arrangement of two orthogonally orientated piezo multilayer stacks attached to a motor ring covering a motor shaft, the diameter of the shaft being slightly smaller than the internal diameter of the ring.

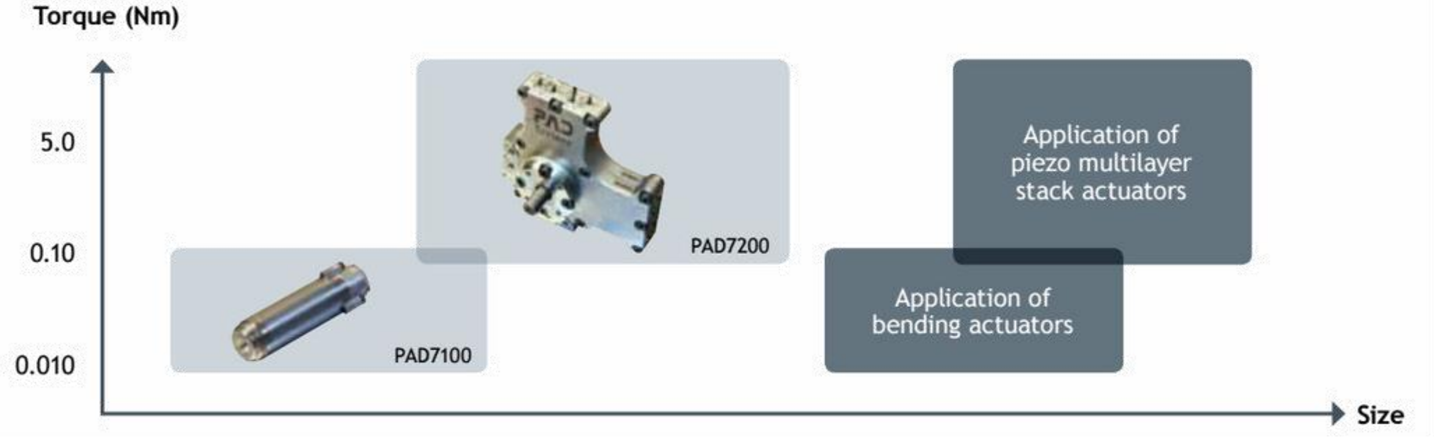
Thanks to the innovative design, the PAD drive uses very few components compared to servo--controlled drive systems, allowing a more straightforward, compact and reliable design.



Scalability

The same principle can be applied with smaller actuators such as plate benders or stacks of larger cross-section. By doing so, the power output of a PAD system can be scaled.

Furthermore, the internal gearing can be modified. This allows different speed/torque characteristics with sensibly the same power capability.



STATIC PERFORMANCE

Backlash

A PAD is inherently backlash-free. Whenever the drive is powered, the piezo actuators apply a radial force on the ring, pushing it in firm contact with the shaft. There is no gap within the microgear, therefore no backlash.

If an external torque is applied on the shaft, the mechanical parts will deflect elastically. However stiffness is very high, so deflection is very low even in open-loop configuration.

Resolution

Electromagnetic stepper motors generate discrete "steps" and can "microstep" between these stable positions by modulating the input signals. As opposed to that, when a PAD rotates, the contact point between ring and shaft moves continuously on a circular path. This means that at any point in time, the PAD is in the same mechanical configuration so characteristics are homogeneous. Thanks to this, position can be controlled with an extremely high resolution.

Resolution of a PAD system depends on the internal gearing of the PAD and the output resolution of the NDR. The angular resolution (in degrees) can be expressed:

$$\theta_{\min} = \frac{360}{N_{PAD} * NN_{DR}}$$

With:

N_{PAD}: Number of teeth on the shaft of the PAD

N_{NDR}: Number of points per PAD cycle generated by the NDR

For example, a PAD with N_{PAD}=312 teeth on the output shaft combined with a NDR generating N_{NDR}=1024 points per PAD cycle can achieve a resolution of 312*1024=319488 points per turn. In other words 0,0011°, 20µrad or 4arcsec.

Jitter

When holding position, electrical noise from the NDR converts into small movement of the output shaft. This jitter (in degrees) can be estimated by:

$$\delta_\theta = \frac{360 * \sqrt{2} * \delta_U}{\pi * N_{PAD} * U_{p-p}}$$

N_{PAD}: Number of teeth on the shaft of the PAD

δ_U: Voltage jitter on output of NDR

U_{p-p}: Nominal peak-peak voltage of the PAD

Axial loads on output shaft

Most PADs are not designed to sustain axial loads. The shaft provides some axial play.

In many cases, it is more effective to include an application-specific thrust bearing in parallel to the PAD. If an axial load is present, additional friction in the thrust bearing can lead to some hysteresis in position of the output shaft.

DYNAMIC PERFORMANCE

Speed and overload

Up to the rated torque, the running speed of a PAD is directly given by the frequency of the input signal. Speed (in degrees per second) follows the relationship:

$$\theta_{\min} = \frac{360}{N_{PAD} * NN_{DR}}$$

With:

N_{PAD}: Number of teeth on the shaft of the PAD

f: Frequency of the input signals

Above the rated torque, at some point the force generated by the actuators pressing ring and shaft together will not be sufficient to maintain position. The contact point will be forced to move rapidly, resulting in a sudden motion of the shaft, or in other words, a tooth will "jump".

The PAD is protected against overload, so this jump will not affect reliability. However, unless this jump is recorded and compensated for, the open-loop position information will be lost.

Heat generation

Heat generation in a PAD is proportional to speed, regardless of the load. This means that a PAD doesn't consume any power when holding a load. On the other hand, a PAD can heat-up significantly when operated at high frequency, even without a load.

Specifications indicate a maximum continuous speed, which corresponds to the speed that will cause the PAD to reach its maximum operating temperature in laboratory conditions (room temperature, natural convection). Depending on the environmental conditions (ambient temperature, cooling…) this speed can be increased or decreased. It is advisable to monitor temperature in actual conditions when designing the application.

Because of the thermal inertia of the system, it is possible to drive the PAD well above the maximum continuous speed for a short duration.