

**Gear Precision**  
**How positioning-accuracy & repeatability is effected by a gearhead**  
**Neugart USA LP**

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It is a frequent misconception that the backlash of a gearbox the measure of the quality or precision. The fact is that the backlash has practically nothing to do with the quality, precision of a gear. Only the consistency of the backlash has some up to certain degree a measure of quality.

From the application point of view the relevant question is, what gear properties are influencing the precision of a motion.

**1 Positioning accuracy** - a measure how exact a desired position is reached.

-in a closed loop system the prime determining / influencing factor of the positioning accuracy is the accuracy and resolution of the feedback device and where the position is measured. In case the position is measured at the final output of the actuator the influence of the mechanical components can be practically eliminated. (Direct position measurement is used mainly in very high precision applications such as machine tools)

In applications with lower positioning accuracy requirement the feedback signal generated by a feedback device (resolver, encoder) in the motor. In this case The motor attached mechanicals components (gearbox, coupling, pulleys, belts etc) all will influence the positioning accuracy.

**Influence of the gearbox :**

**1.1 Gearbox stiffness / rigidity.** The elastic deformation ("the wind-up") of the components under load will effect the positioning accuracy. The positioning error is load dependant since the wind-up depends on the load.

**1.2. Backlash** - the clearance between mechanical components - (such as the backlash of a gearbox) can contribute to the positioning error if the sense of the rotation or torque is changed during the positioning move. The overall rotational backlash of a gearbox is determined not only by the clearance between the gear teeth in mesh, it is influenced also by the other components of the gearbox- (housing, bearing, shafting, shaft / hub connection, etc.)

**1.3 Transmission error – (TE)** can be also described as "the fluctuation of the theoretical reduction ratio" - the output does the not follow input rotation exactly at the theoretical reduction ratio but is fluctuating (+/-) during the rotation, due to the inconsistencies of the gears (gear errors) - such as the different pitch errors, lead

error, eccentricity, profile error etc; .i.e the TE of a gear depends strongly in the gear precision (precision class). Again, just like the backlash the overall gearbox TE it is influenced by the other components of the gearbox.

**1.4 Gear precision** - a large number of measurements and its deviations / tolerances of the gear geometry determines the precision class. To classify the precision grade of a gear, standardized, widely recognized precision classes are established base on different standardization bodies ISO, DIN AGMA, JGMA.

It is a frequent misconception that the low backlash is a prerequisite for high precision. The Fact is that the gear precision class has little to no influence on the backlash. On the other hand it has a determining influence on the TE as indicated already above.

Example:

Neugart PLS 115 4:1 ratio; worst case backlash 3 min, torsional stiffness 20Nm/arcmin; torque rating 200 Nm , Neugart 115 measured gearbox transmission error TE about +/- 1.25 arc min

- 1) What is the worst case positioning error due to the Backlash in a motion cycle with motion direction reversal at rated torque load?

Answer: 3 arc min

- 2) What is the worst case positioning error due to the wind-up in a motion cycle with motion direction reversal at nominal torque load?

Answer:  $200 \text{ [Nm]} \times 2 / 20 \text{ [Nm/arc min]} = 20 \text{ arc min}$

- 3) What is the worst case positioning error from the TE

Answer: 1.25 arc min

Conclusion:

The stiffness has a considerably higher influence upon the positioning error than the Backlash or the TE

**2 Repeatability** – a measure how exact a certain position is reached when repeating a positioning cycle over and over.

**Influence of the gearbox :**

**2.1 Gearbox stiffness / rigidity.** If the repeated motion cycle is performed with different loads the stiffness has a large influence on the repeatability

**2.2 Backlash** – if the motion cycle is repeated the backlash of the gearbox has theoretically no influence on the repeatability; not even at fluctuating loads.

**2.3 & 2.4 Transmission error and gear precision** - the above statement in item 2.2. also applies here.