# Inertia Balance in a Gearbox

*"When such an inertia relationship does not exist between gear and the pinion, at the point of irreversibility (self-locking), intermittent separation of the pinion and gear teeth occur and result in jerky operation because, alternatively, the pinion advances ahead of the gear through the gear clearance and then the descending load causes the gear to catch up with the pinion and engage with impact."*

*From 'Worm-drive Jitters can be Avoided' by S.J. Mikina*

"Stick slip" occurs when a *self-locking* gear set achieves *overhauling mode*. That is to say it occurs when the gear, for whatever reason, begins to drive the pinion.

To avoid the stick-slip phenomenon when designing a gearbox, it is important to design it in such a way that the cumulative mass moment of inertia of the input (pinion) side is always greater than the cumulative mass moment of inertia of the output (gear) side.

## Achieving *non*-stick-slip gearbox design

The kinetic energy (*KE)* of a non-rotating particle of mass $m$ travelling at speed $v$ is represented by *KE* = $\frac{1}{2}\, mv^2$

Per the law of conservation of energy:

$$\frac{1}{2}\, m_1 v_1{}^2 = \frac{1}{2}\, m_2 v_2{}^2 \qquad (1)$$

In rotary motion, mass (*m)* is replaced by mass inertia ($I$),while velocity ($v$) is replaced by angular velocity ($\omega$).

Substituting mass inertia ($I$) and angular velocity ($\omega$) into equation (1) ➔ $\frac{1}{2}\, I_1\omega_1{}^2 = \frac{1}{2}\, I_2\omega_2{}^2$ (2)

For reduction ratio ($R$), $\frac{1}{2}\, I_1(R\omega_2)^2 = \frac{1}{2}\, I_2(\omega_2)^2$ ➔ $I_1R^2 = I_2$

Taking efficiency into account, $\frac{I_1(31)^2}{eff} \geq I_2$ (3)

Where $I_1$ = cumulative moment of inertia of the input
$I_2$ = cumulative moment of inertia of the output

The inertias $I_1$ and $I_2$ are calculated for the entire shaft assembly. For example, the output side inertia $I_2$ must include the gear, shaft, bearing races, etc. Essentially, it must include everything rotating at that output speed. Further, while calculating the cumulative output side moment of inertia, it is also important to consider the maximum output torque. See below:

$I_2 = I_{gear} + I_{shaft} + I_{bearing\ races} + I_{output\ torque} + etc.$

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