YASKAWA

4 Ways to Improve Production by Understanding the Physics of Servos

Considering the Science Behind Servo-Based Motion Control Systems Can Eliminate Inefficiencies

Breaking the Process Down

There is always a need to increase production in automation applications. Sometimes achieving improvements requires breaking the process down to its fundamental basics. The science behind the technology of servo-based motion control systems should be considered when attempting to eliminate inefficiencies.

Four fundamentals to examine are:

- Inertia
- Resonance
- Vibration suppression
- Regeneration

1. Inertia

Inertia is a critical part of the sizing, selecting, and tuning processes of a servo system. For high-performance applications, it's important to design a system where the ratio of the reflected load inertia to the motor's rotor inertia is low. The load inertia gets "reflected" through the transmission — it is reduced by the square of this ratio in the case of a gearbox or belt and pulley design.

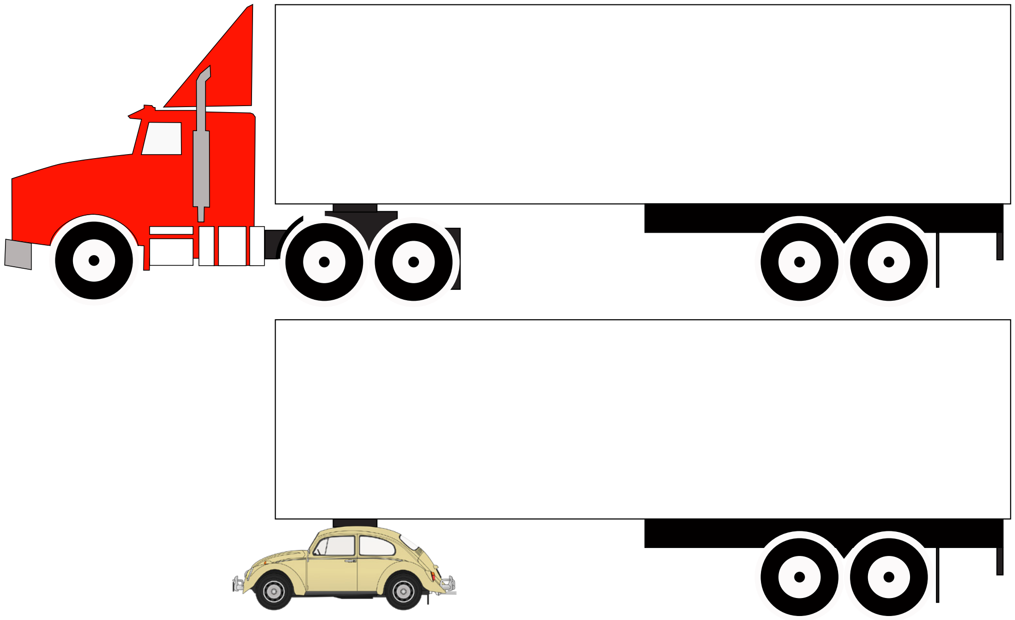

Figure 1: Inertia Mismatch: Top = Good Inertia Match, Bottom = Poor Inertia Match

If the ratio gets too high, then the servo system will quickly become unstable as the tuning gains increase. Even if the gains can be lowered to make it stable, the system will likely waste valuable production time as it oscillates to a stop. Designing a proper inertia ratio will allow higher tuning gains that will result in faster move times with minimal settling times.

2. Resonance

As servo technology advances, the speed at which the servo loops operate increases. This increase in bandwidth allows for a quicker response to disturbances, but can also excite higher mechanical oscillation frequencies in a machine. Every machine has a natural resonant frequency. When a machine shakes at or near this frequency, then it will respond with larger amplitude on the next oscillation. This can lead to violent oscillations and damage to the machine if left unchecked.

In an effort to reduce cost many machines are built with less rigid materials and construction methods that can create a lower natural frequency for the machine. As the servo systems become more responsive they can excite these frequencies. This is why notch filters are an important part of a servo system. See Figure 2.

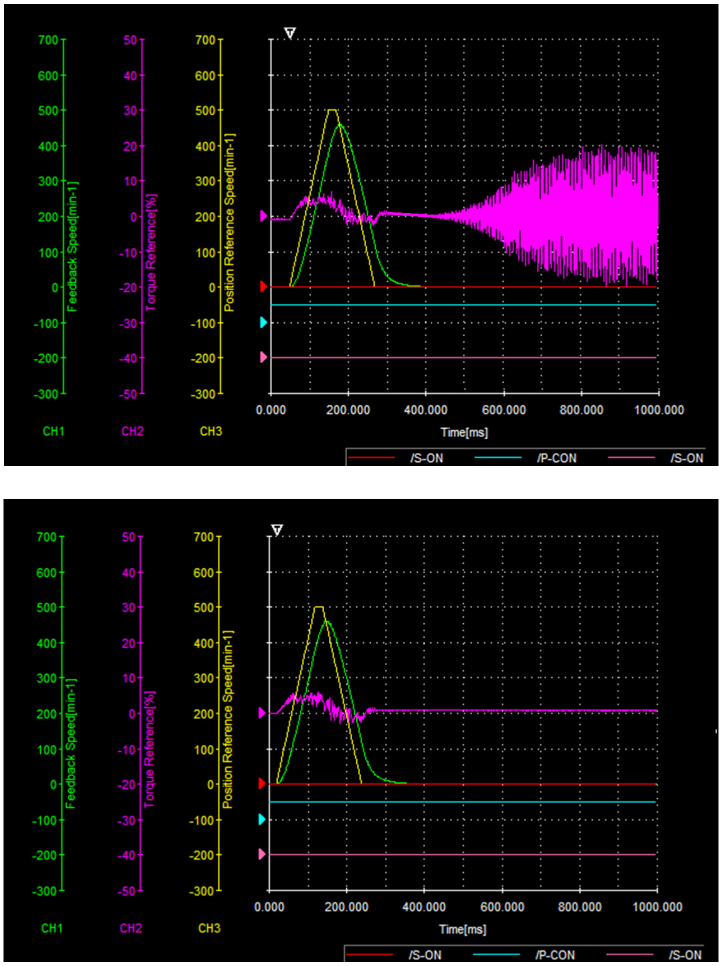

Figure 2: Before and after application of the notch filter. These waveforms show a move causing the axis to resonate (top), and the results of having the notch filter active (bottom)

A notch filter can be tuned by changing parameters to "notch" or cut out the frequency in the feedback loop so that it is not amplified by the servo system. It is important for a modern servo to have multiple notch filters because several harmonic frequencies may exist that also need to be notched. Notching these frequencies can allow you to increase the tuning gains and achieve higher production rates.

3. Vibration Suppression

The settling time of a mechanism when performing fast accurate moves can hurt production even if it doesn't cause violent oscillations. In the cases of a long end effector it is common to experience an oscillation of tip of the arm at the end of a move.

Modern servo systems have a feature typically know as Vibration Suppression that can detect this vibration and inject an opposing signal into the servo loops that will greatly reduce and possibly eliminate this oscillation. Severely reducing this oscillation minimizes settling time and can significantly increase production rates.

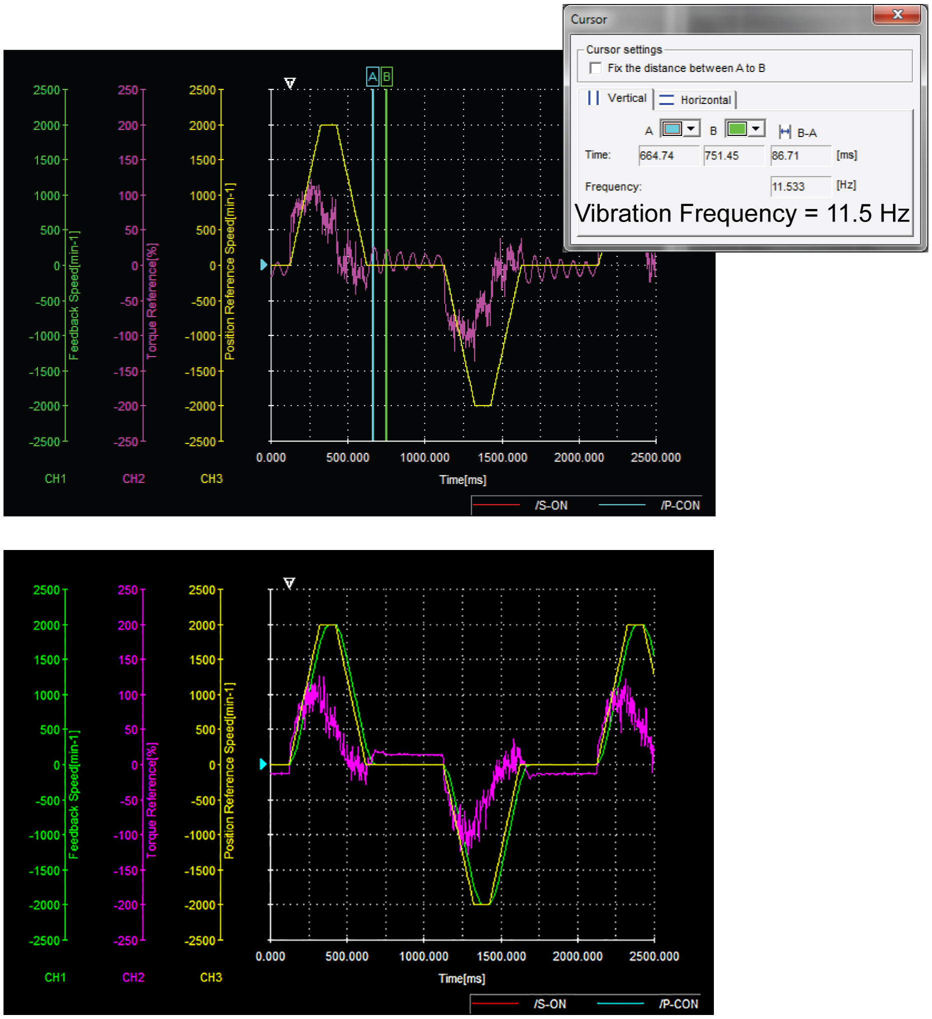

Figure 3: Before and after use of vibration suppression. These waveforms show the axis resonating in the mechanism at ~11.5 Hz after stopping (top), and the axis response to a move with vibration suppression applied at 11.5 Hz (bottom).

Visit http://budurl.me/vibsup to watch a video showing vibration suppression capability in action

4. Regeneration

In general terms, the electrical design of a motor and a generator are the same. In the case of a motor, current is injected into the windings and the shaft rotates. If the shaft is rotated instead, it will induce electrical currents in the motor windings. This is all due to the physical properties of a conducting material in a moving magnetic field.

Difficulties can arise when the motor regenerates energy back to the amplifier in a servo system. Applications trying to stop high inertial loads quickly or that have vertical motion are examples of systems that may have excess regeneration. Any time a motor's torque and its rotational direction are opposed, the motor is regenerating energy back to the amplifier.

In the case of vertical applications, the constant pull of gravity can be offset with a counter balance. This does increase the inertia of the load, but if the inertia ratio is designed properly it can be a very effective solution to eliminate the excessive regeneration. If the designer can't find a way to design out the creation of this excessive energy, then it must be dealt with in some other way.

Most amplifiers can handle some regenerated energy with internal capacitors or resistors. If the internal capacity is exceeded, then an external means must be employed, such as adding an external resistor or use of a device that can convert this power back to AC and return it to the power line. This type of a device can convert the excessive energy for multiple axes at the same time. There are also common bus servo solutions that allow a servo to use the regenerated energy from another servo on the same bus. Resolving regeneration issues can allow for faster decelerations and therefore faster move times and increased production.

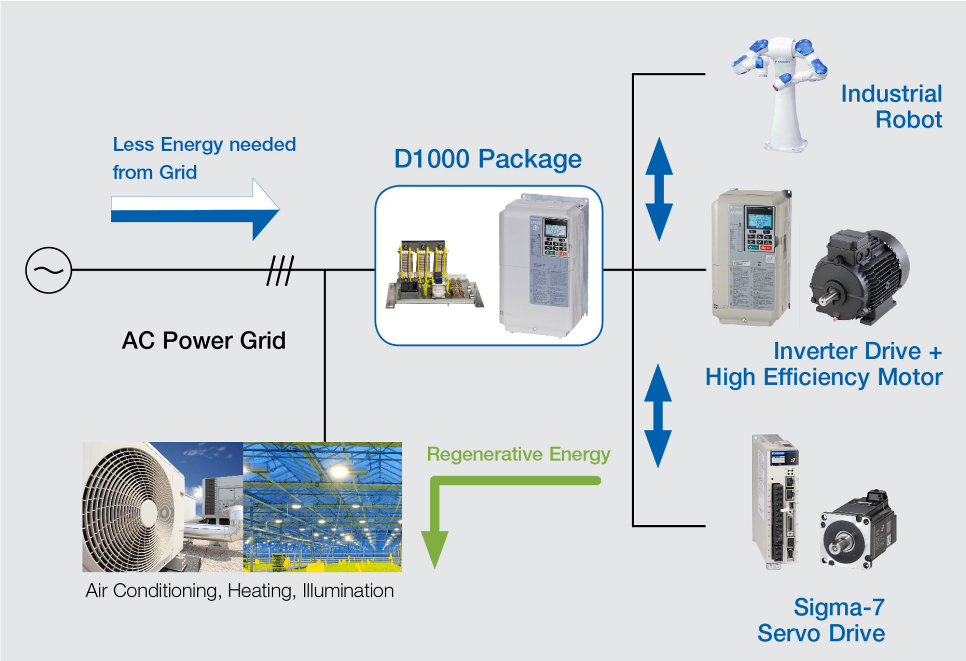

Figure 4: Multi-configuration regeneration system. Energy that would typically be burned across a resistor is returned to the line.