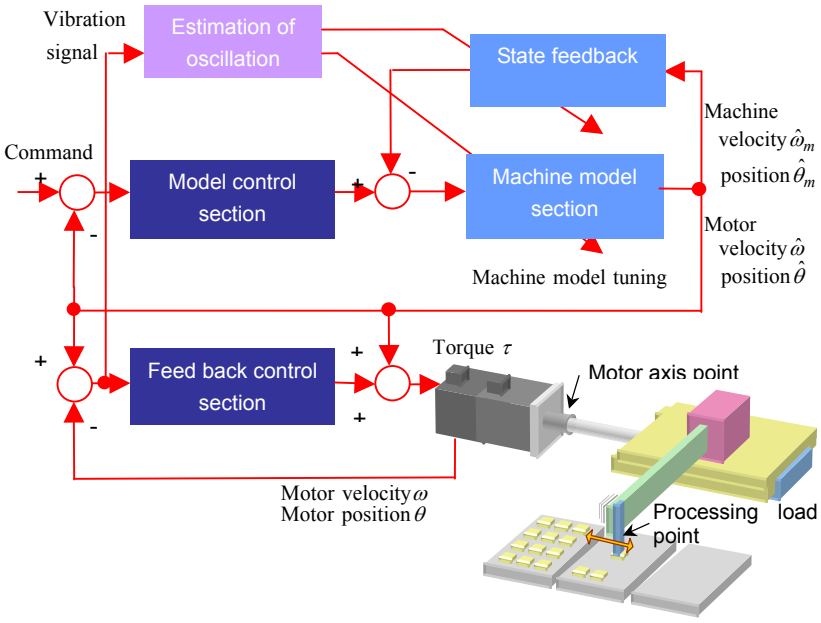
Auto-Tuning Servo:
More Simplified, More Accurate

Real-time auto tuning with load vibration suppression realizes desirable high production rate.

The MR-J3 servo controller drives the servomotor from 50W to 7kW. The features include advanced load suppression auto tuning, adaptive filter-2, robust disturbance compensator, USB-1.1 interface and application software MR-Configrator, which has a high speed-sampling graph and diagnostic monitor.

The servo amplifier with auto-gain tuning function is beneficial for setting up the machine. However, it is questionable whether the current model servo can achieve a desirable response for any machine using the auto-tuning function only. Especially when the processing point is away from the motor axis like a robot arm, the processing point may continue to vibrate even though the motor axis has stopped. This phenomenon makes it difficult to adjust the auto tuning so that the processing point of machine, which is still in vibration, will stop vibrating. Furthermore, the servo encoder cannot detect how much the processing point is vibrating. When this happens, the system might not be able to start the next operation until the vibration goes down to the tolerance level.

Fig. 1: Load Vibration Suppression Tuning



Load Vibration Suppression Tuning Control

It is ideal for the user to control the motor axis and processing point of a machine to have as little vibration as possible and to improve the production rate of the system.

However, it is not easy to realize by manually tuning the servos on machines of low stiffness. A measuring instrument may be required to know how it vibrates for higher accuracy at the processing point. Until recently, all we could do to control the vibration was decrease the servo gains until the vibration reduced to the acceptable range in spite of the low production rate.

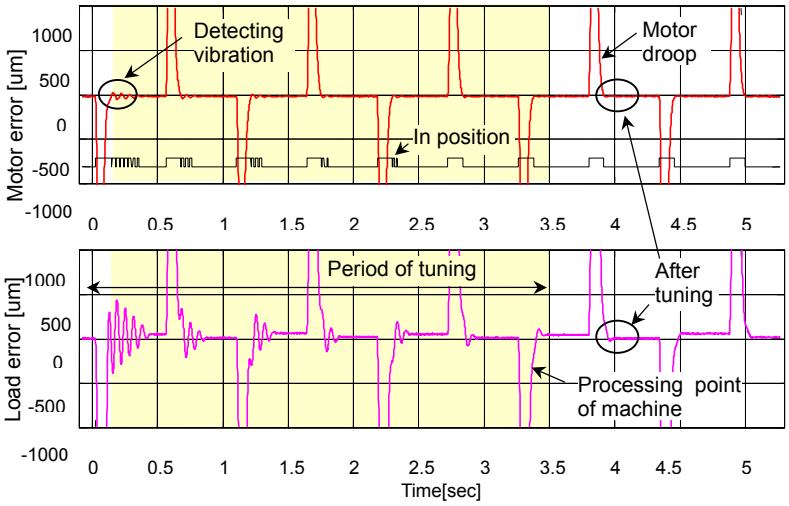
MR-J3 now has new control

loop blocks called "Load Vibration Suppression Tuning", which can determine these vibration suppression parameters automatically. With this new control function, higher response for low stiffness machines is feasible.

The diagram on the previous page shows MR-J3's load vibration suppression tuning. The amplifier has load model blocks that stimulate a machine structure, and those blocks describe the structural relation between the motor and load characteristic. The tuning section estimates the frequency of load vibration from the encoder position signal and calculates the structural parameters and optimized feedback gains.

The graphs on the right (Fig. 2) show an example of the auto tuning: the upper one shows the motor position error signal from the encoder, and the bottom one shows the error of a robot arm at the processing point. The motor error unit is converted from encoder pulses to micrometers, which are theoretical travel distances of the load when the motor rotates. The external measuring instrument is used for the sake of simplicity, but is it not necessary for actual tuning. The vibration at the processing point is much larger than at the motor before tuning. When the tuning-mode is on, the servo detects the machine vibration if the vibration is larger than a certain threshold and begins the suppression tuning.

Fig. 2: Load Vibration Suppression Tuning Example



During the course of the tuning, the residual vibration is gradually suppressed at each movement. The machine should be operated for several cycles consecutively because the tuning ends when the controller determines that the residual vibration has become small. After tuning, the servo suppresses the motion of both motor and load.

Adaptive Filter-2

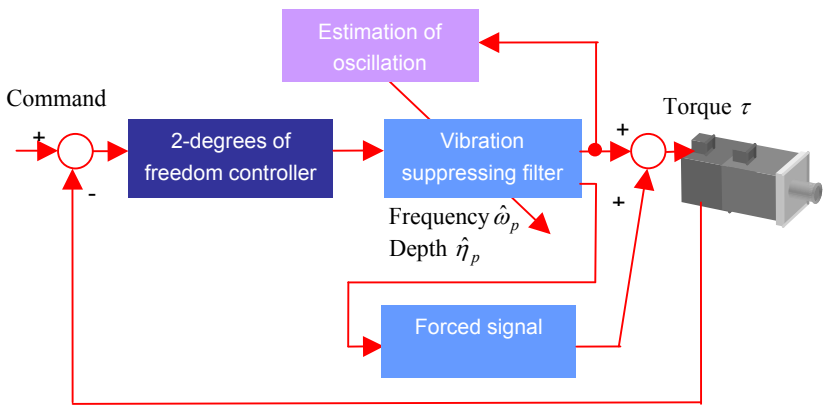
Users may have to give up increasing the servo response due to a resonance sound. In that case, users can use the "Machine Resonance Suppression Filter", which is often called a notch-filter. The notch filter can remove the specific frequency only. However, finding the resonance frequency is not easy: users may have to do it by trial and error, or simply give up using the filter.

MR-J3 has an improved notch filter tuning function called "Adaptive Filter-2" which can easily be set with the application software called "MR-Configurator".

The figure on the left (Fig. 3) shows a block diagram of the Adaptive Filter-2. When the tuning is on, a slight forced signal is output to the motor, the motor goes into a vibration state for a short time, and the Adaptive Filter-2 estimates which filter frequency is the most appropriate for removing the vibration, by using a search algorithm. After a certain period, the controller stops the forced signal and determines the filter frequency and its depth.

The following page shows the data (Fig. 4). The upper graph shows the motor speed, and the bottom one shows the motor torque. The vibration of the motor torque reduces 2.5 seconds after the tuning begins, and it means that the filter frequency is set correctly. It is also preferable to continue regular operation during the tuning.

Fig. 3: Adaptive Filter-2 Diagram

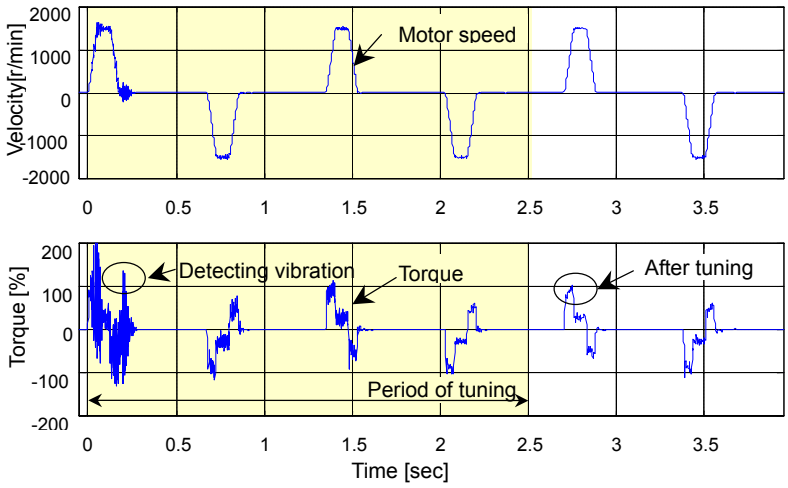


Robust Disturbance Compensator

When the load inertia is much bigger than the motor inertia, like the roller axis of a printing press, the servo response would not be able to be increased as expected. Furthermore, the other axes also need to have lower servo response in order for all axes to be synchronized, causing extremely low performance. MR-J3 provides a special control function as standard to solve this problem.

Below is the usual Bode diagram for high load inertia (Fig. 5). If the velocity gain is increased, the gains of lower frequency and higher frequency with resonance peak are raised, and the resonance appears. It prevents the velocity gain from being increased as expected. The Robust Disturbance Compensator function calculates the optimized parameters to increase the gain without increasing the resonance frequency gain. This function is included in the application software called "MR-Configurator". To get the optimized answer, this function requires the "machine analyzer" function in order to identify the machine characteristics and to obtain accurate optimized answers. The function in the application software inputs the machine-analyzer data and writes the optimized parameters to the amplifier. These operations are semi- automated and easy to check its effectiveness.

Fig. 4: Notch Filter Auto Tuning



Other Features

As described above, MR-J3 has not only high response but also the advanced functions that support users in performing difficult setups.

Furthermore, MR-J3 has a USB 1.1 interface, and the application software "MR-Configurator" can measure graphs that are 200 times longer than the current MR-J2-Super model. Users can tune the axis as quickly as possible without an external measuring instrument.

HF-KP is part of the new servo motor HF Series and is IP65 compliant with 6000r/min maximum speed. HF-SP is IP67 with 3000r/min maximum speed. The encoder resolution has been upgraded to 262,144 (pulses/rev), which is twice that of MR-J2-Super series. The new servo motor HF series would contribute to the high accuracy of the system. ■

Fig. 5: Robust Disturbance Compensator