TRANSMISSION ERROR IN THE SYSTEMS OF MECHATRONICS

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Abstract

The characteristics of angle transmission mechanisms exert a great influence on the servo performance in the robotic or mechatronic mechanism. Especially, the backlash of angle transmission mechanism is preferable the small amount. This system has been applied to the testing process in the production line of gear reducers for robots, and it has been effective for reducing the backlash of the gear trains.

Key words: Backlash, Measurement, Mechatronic system, Transmission error.

INTRODUCTION

Backlash is one of the most important nonlinearities that limit the performance of speed and position control in industrial, robotics, automotive, automation and other applications. The control of systems with backlash has been the subject of study since the 1940's.

BACKLASH IN THE MECHATRONICS SYSTEMS

It is immediately clear that control of a load behind a backlash is complicated in particular if high precision is desired. There are instances when the backlash gap opens, and the motor loses contact with the load. This may happen when a disturbance acts on the load, or when the motor has to take corrective action in the opposite direction to where the load is moving or is positioned at the moment. When the backlash gap is open, the movement of the load is autonomous, and in addition, the force or moment generated by the motor drives only the motor itself (and the parts of the transmission before the backlash) and not the load. One might claim that in those instances the load is 'uncontrollable' and that the controlled dynamics is different.

Controlled systems with backlash often exhibit steady state errors or, even worse, limit cycles whereby the system oscillates, often in an irregular fashion, with a peak-peak amplitude that may exceed the total size of the backlash gap.

PRINCIPLE OF THE MEASUREMENT

To make difference between the values of different rotation directions, we use "+" for clockwise rotation and "-" for counterclockwise rotation. Then, the transmission errors in two rotation directions can be written as Eqs. (1) and (2).

\[
\begin{align*}
\varepsilon^+ (\theta_2) &= \theta_2 + \frac{1}{k} \theta_1^+ \\
\varepsilon^- (\theta_2) &= \theta_2 - \frac{1}{k} \theta_1^-
\end{align*}
\]

where

\[
\begin{align*}
\theta_1^+ &\text{: Measured angular position of input axis of angle transmission mechanism} \\
\theta_2 &\text{: Measured angular position of output axis of angle transmission mechanism} \\
k &\text{: Reduction ratio (=input angle/output angle) of angle transmission mechanism}
\end{align*}
\]

By subtracting Eq. (3) from Eq. (2), Eq. (4) can be obtained.

\[
\begin{align*}
\varepsilon^+ (\theta_2) - \varepsilon^- (\theta_2) &= \theta_2 + \frac{1}{k} \theta_1^+ - \left( \theta_2 - \frac{1}{k} \theta_1^+ \right) \\
\varepsilon^+ (\theta_2) - \varepsilon^- (\theta_2) &= \theta_2 - \frac{1}{k} \theta_1^+ - \left( \theta_2 + \frac{1}{k} \theta_1^- \right)
\end{align*}
\]

By measuring \( \theta_1^+ \), \( \theta_2 \) at the condition of \( \theta_1^+ = \theta_1^- \) in measurement, following equation can be derived.

\[
\begin{align*}
\varepsilon^+ (\theta_2) - \varepsilon^- (\theta_2) &= \theta_2 - \frac{1}{k} \theta_1^+
\end{align*}
\]

It is obvious that the right side of Eq. (4) represents the backlash of angle transmission mechanism.

Figure 1 shows the basic configuration of prototype of composite single flank meshing test system for gear reducers.
and $\theta_2$. The measured angular positions are inputted to computer, and transmission errors are calculated by Eqs. (1), (2) and (4). The input axis is driven by servo motor and its angular position is measured by an encoder (1 500 P/R) built in the motor. The angular position of output axis is measured by an encoder (5 000 P/R), and a resolution of 50 000 P/R (25.92")/P) is realized by using interpolating circuit of 10 times. Pulse from each encoder is counted by up/down counter so that the value of counter always shows the angular position from the starting point, independent of rotation direction. The transmission error is calculated and displayed on CRT by computer in real time. The rotation direction of input axis can be changed at arbitrary pre-assigned angular position. [2]

EXAMPLES OF EXPERIMENTS

As the preliminary experiment, one pair of spur gears with pre-set backlash is tested. The measured result is shown in Fig. 2. [4]

![Fig. 2 Measured result on one pair of spur gears](image)

Fig. 2 Measured result on one pair of spur gears [3, edited and supplemented by author]

The reducer is developed for the usage in robot and has small backlash. The measured results with different pinion shafts are shown in Figs. 3 (a) and (b). [4]

![Fig. 3 Measured results on the parallel axis gear reducer](image)

Figure 4 shows the variation of measured transmission error and backlash while reducing the backlash by adjusting the screw which is used to determine the value of backlash in the parallel axis gear reducer. A backlash near zero is achieved in Fig. 4 (c). [4]
Fig. 4 Variation of measured transmission error and backlash with backlash adjusting mechanism [4, edited and supplemented by author]

CONCLUSION

New measurement system the transmission error of angle transmission mechanism for mechatronic systems, including its availability, is shown by experimental measurements and industrial use. By this system, the measurement of transmission error and backlash at all meshing positions becomes possible. Besides, it is useful for inspecting and evaluating the dynamic characteristics of angle transmission mechanism.

From experimental measurements have been obtained the following results:

1. The value of backlash varies with the meshing point in gear reducer. It is difficult to evaluating true value of backlash by measuring only at several meshing points in one revolution according to old measuring method.

2. Dynamic transmission error is influenced greatly by the value of backlash and test conditions. Complicated behavior including contact, noncontact and collision due to backlash is observed.

References


[4] Materials provided by company,


