Reduction of vibration for feed drive system using linear motor at high-speed driving

Daichi Hirabayashi¹, Takanori Yamazaki²
¹ Graduate School of Tokyo Denki University, Isizaka, Hatoyama, Hiki, Saitama, 350-0394 Japan
² School of Science and Engineering, Isizaka, Hatoyama, Hiki, Saitama, 350-0394 Japan
¹ 17rmt17@ms.dendai.ac.jp

Abstract. In all ages it is always required to improve the high speed and high accuracy for machine tools. In the field of machining, processing methods using lasers etc. have developed in recent years. As a result, it began to hear the request to operate a moving part that does not have so large mass at high speed. The feed drive system using a linear motor has focus as the device that satisfies this requirement. In generally, the trapezoidal acceleration/deceleration is used for the feed motion of machine tools, but there are not many researches quantitatively showing the relationship between acceleration/deceleration shape and machine vibration. In this study, the feed drive system using the linear motor was driven by trapezoidal and S-curve acceleration/deceleration exceeding 1 G, the acceleration method is evaluated by comparing the deviation, the maximum speed, and the maximum acceleration at that time.

1. Introduction

Many machine tools are driven by the AC servo motor and the ball screw, but there are lots of mechanical contacts and it is difficult to achieve the high speed. In recent years, it is note that the linear motor drive is suitable for the high speed reason for the mechanical contacts are limited to rolling guide and friction is small [1]. We adopted a coreless linear motor (hereinafter, referred to as "shaft motor") which is lightweight, capable of high response and easy to replace the ball screw, the one-axis feed drive system using the shaft motor was designed and manufactured.

If acceleration is increased in order to achieve high speed, the vibration occurs in the device by inertia force. As a result, the settling time for entering the in-position (the allowable range for shifting to the next command) becomes longer, so there is a limit to the high speed. Therefore, the reduction of vibration is important to realize high-speed [2][3]. In this study, measure the dynamic behavior when driving the manufactured feed drive system at high speed, It is aimed to propose an acceleration/deceleration method (speed command) for suppressing vibration to occur at high speed driving.
2. Device configuration

2.1. Feed drive configuration

Figure 1 shows a drawing of the apparatus and a photograph of an actual apparatus. The experimental apparatus consists of a machine base, a motor, a guide rail, and a top board, and is configured to drive the top board uniaxially. In the power distribution configuration, a single-phase AC 100 V is passed through a noise filter (manufactured by TDK Lambda: RSAN-2030D) and supplied to a servo amplifier (manufactured by Servoland: SVFM-4) via a magnetic contactor. In addition, +5 V is supplied to the limit switch and ±12 V are supplied to the higher-order device (manufactured by Delta tau: Power PMAC Clipper) with a DC/AC converter (manufactured by Cosel: RMC 30 A).

2.2. Control unit configuration

Figure 2 shows the block diagram of the drive system. Give the speed command to the servo amplifier from the host device. The servo amplifier converts the command to a voltage and drives a shaft motor (manufactured by GMC Hillstone: S250T). To measure the displacement of the shaft motor, a head attached to the top plate reads the scale using a linear encoder scale head with a signal period of 4 μm (manufactured by HEIDENHAIN: LIF 181). The signal output from the head is resolved to $4/2^{14}$ μm by a 14 bit multiplier (manufactured by HEIDENHAIN: EIB 392), converted to serial data, and fed back to the servo amplifier. From the servo amplifier, A/B/Z phase rectangular wave is fed back to the host device.

![Figure 1. High-speed feed drive mechanism](image1)

![Figure 2. Outline of feed drive system](image2)
3. experimental method

The trapezoidal acceleration/deceleration (hereinafter referred to as "trapezoidal") and S-shaped acceleration/deceleration (hereinafter referred to as "S-curve") commands by speed command are given by using the feed driving device described in Chapter 2 to drive the top board. For trapezoidal, measurements are taken at speed \( F = 100 \text{ mm/s} \), acceleration time \( t_a = 10 \text{ ms} \) (1 G) and speed \( F = 200 \text{ mm/s} \), acceleration time \( t_a = 10 \text{ ms} \) (2 G) to measure acceleration 1 G and 2 G. In the S-curve, the speed \( F \) is set to 100 mm/s, 200 mm/s, similarly to the trapezoidal shape, and the S curve time \( t_s \) is set to 5 ms in order to adjust the rise time. Movement distance is sufficient to obtain sufficient data, considering the maximum stroke of 340 mm, all at 200 mm. In order to measure the range to enter the imposition, pay attention to deceleration and compare the maximum speed when the actual speed overshoots the command speed with the maximum value of the position deviation at that time.

4. Experiment Results and Discussion

The results of 2 G in the experiments described in Chapter 3 are shown in Figure 3, the maximum value of overshoot when decelerating is shown in Table 1, and the maximum value of positional deviation at that time is shown in Table 2. As shown in Tables 1 and 2, it was found that the overshoot becomes large as the speed increases for both the trapezoidal shape and the S-curve, and the positional deviation also increases due to this. In comparison with the trapezoids in Figure 3(a), the overshoot became smaller in the S-curve of Figure 3(b), and the position shift became smaller accordingly. Since the S-curve is a command to suppress the vibration rather than the trapezoid, we could confirm its characteristics. However, since the inclination of the velocity waveform becomes steeper than the trapezoid, the acceleration increases [4]. Therefore, since instantaneously high responsiveness is required, there is a possibility that the output will be limited in the S-curve even at the same speed and rise time. Considering this fact, we will continue our research in the future.

![Figure 3. Output of decelerated waveform](image-url)
5. Conclusion
In this study, we designed and manufactured the one-axis feed drive system using the shaft motor. The command position was driven by trapezoidal and S-curve acceleration/deceleration exceeding 1 G using the manufactured feed drive system. Experimental results show that the S-curve deceleration can shorten the settling time by about 10 ms for the command position of 200 mm and the same deceleration time (10 ms). This is probably because the deceleration can be increased. Moreover, the overshoot value is reduced from 6.0 µm to 4.2 µm in case of the command velocity is 200 mm/s. In full paper, we will discuss the reduction of vibration for the feed drive system by analyzing the deviation, the maximum speed and the maximum acceleration with more experimental results.

6. References
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