냉각형 볼 스크류 이송장치 표면 온도분포에 관한 연구

Study on the Surface Temperature Distribution of Cooling Type Ball Screw

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1. Introduction

Ball screw is a precision mechanical linear actuator that uses steel balls between a screw shaft and a nut to transfer the motion which convert rotary into linear movement when screw is rotated. Different from any conventional power transmission screw, which needs to overcome sliding friction between the screw and the nut threads, ball screw operates similar to bearing components could achieve high mechanical efficiency since it moves in relatively low rolling friction. As a tried and tested technology, ball screw drive systems are still used in a majority of machine tools which can meet the demands of higher productivity and tight part tolerances due to their low cost and high degree of stiffness. High speed ball screw drive system generates more heat and it results in greater positioning error, adversely affecting the accuracy of high precision machined parts.

Generally speaking, the ball screws are made to close tolerances and are therefore suitable for use in situations in which high precision is necessary. The demand for higher productivity and tight part tolerances requires machine tools to have faster and more accurate feed drive systems. A high-speed ball screw drive system generates more heat and results in greater positioning error, and for this, our research team carried out a novel heat source control method named "center hole cooling" on high precision ball screw drive system. In our previous research, all possible heat gain-loss sources were analyzed and air, water, coolant oil, light oil and cutting oil were used as coolants in the center hole cooling method. The most important find from research of our team is that the center hole cooling brings temperature equilibrium faster to the ball screw system which means when cooling was done, very little temperature rise appeared after some preheating.

In a ball screw drive system used in machine tool, there are many possible heat sources such as ball screw nut, fixing bearing, support bearing, clutch and servo motor. The heat productivity of nut is the most predominant heat source in the system. Thus, in this paper, we tried to design an effective, direct, simple and durable cooling type nut to control the main heat source of the ball screw system and achieve temperature equilibrium as soon as we can. In order to avoid thermal errors which affect the positioning accuracy and the temperature rise of ball screw, a well designed nut air cooling ball screw system was developed. And in the product design step, in consideration of the strength of the ball screw nut body, the cover thickness and the air inlet methods were optimized.

2. Experimental

A schematic diagram of the experimental set up is shown in Fig. 1 which containing a ball screw, driving unit, data gathering unit, control unit and screw/nut air cooling system. Here, the operator was able to control the motor to execute ball screw advance and return movement, and a computer was used to collect data from thermal sensor, displacement transducer and thermal image camera. The screw/nut air cooling system consisted of an air compressor, pressure regulator and flexible pipes. The compressed air used as coolant flowed through the pipe, the screw center hole and designed cooling type nut to achieve cooling.

In order to discuss the effectiveness of the developed high speed/high precision nut/screw air cooling ball screw system, a series of tests was carried out in several kinds of working condition which involves big stroke, small stroke and multy stroke. Big stroke case is a simple reciprocating motion with 0.5 s pause, small stroke consists four 50 mm stroke (225 mm ~ 275 mm) and one 500 mm stroke (0 mm ~ 500 mm) and multy stroke consists three 50 mm stroke (225 mm ~ 275 mm) and two 500 mm stroke (0 mm ~ 500 mm) as shown in Fig.5. Temperature measuring points #3~#7 locate on -10 mm, 215mm, 250 mm, 285 mm and 510 mm position of 500 mm full stroke as shown in this figure.

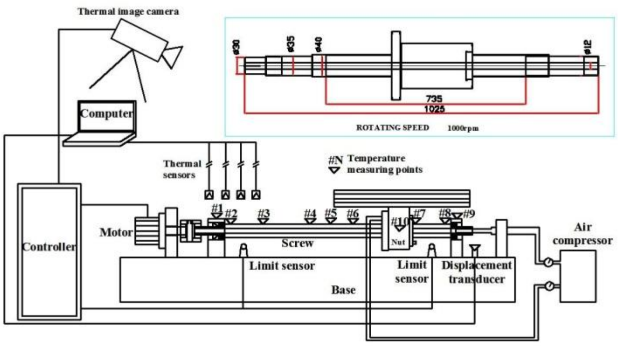

Fig. 1 Experimental set up

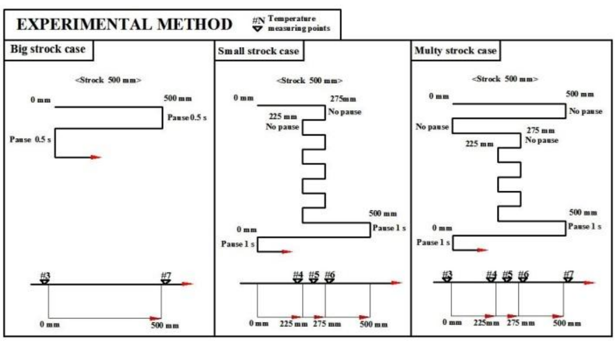

Fig. 2 Experimental method

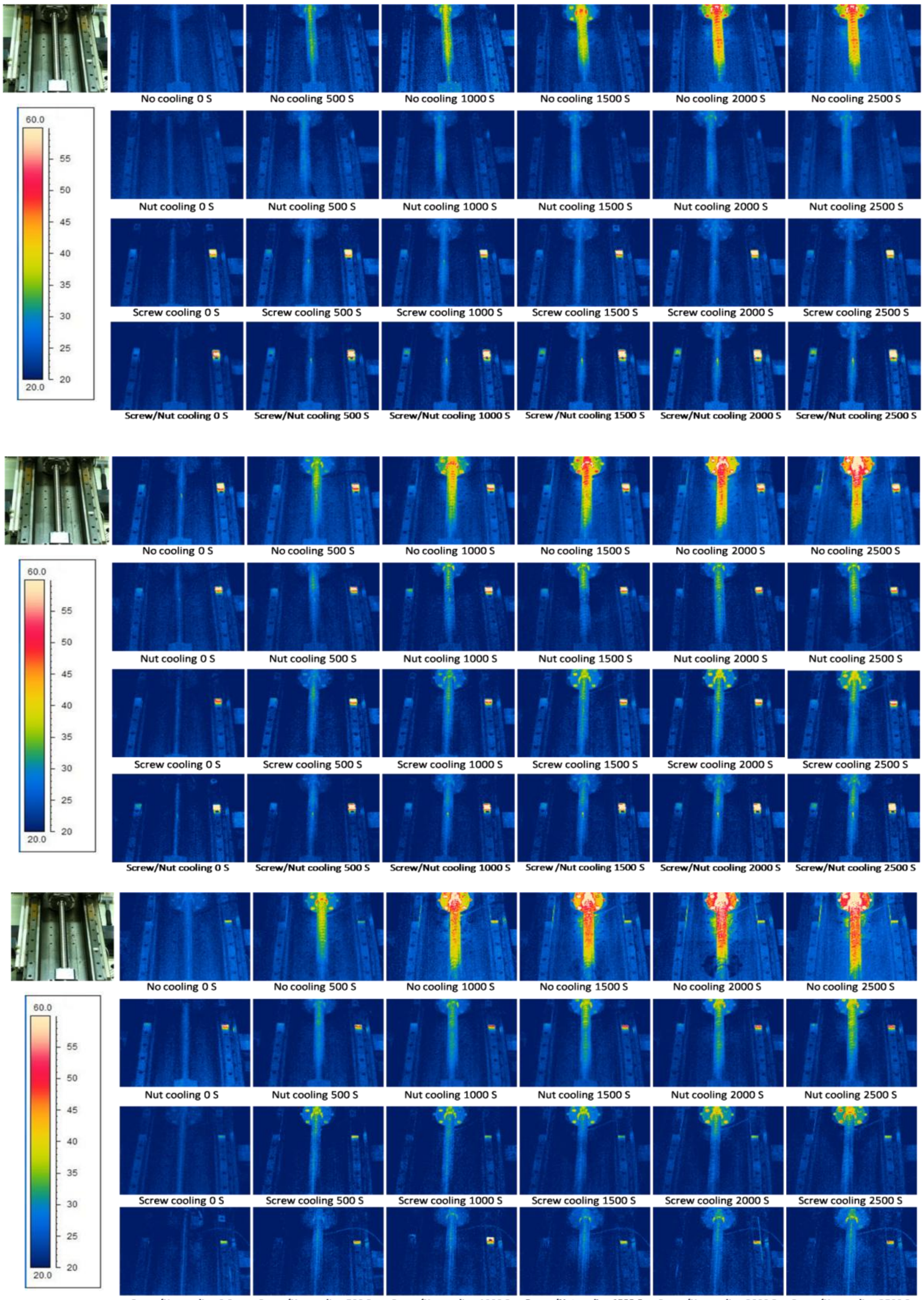

Fig. 3 Thermal image of ball screw in big/small/multy stroke cases

3. Results

Fig. 3 shows the thermal images of ball screw surface in big/small/multy stroke cases which recorded every 500 s by a thermal image camera. The temperature distribution in no cooling, nut cooling, screw cooling and nut/screw cooling conditions is shown in this figure. A considerable cooling performance can be seen intuitively in these figures and the high temperature area covered the nut moving range completely. There is a grease sealing ring made by plastic on the nut part which results in the abnormal high temperature phenomena for the different emissivity of steel and plastic as shown in this figure.

4. Conclusion

In this paper, experimental thermal behavior of nut/screw air cooling ball screw system for precision positioning which contains temperature distribution was discussed. We can see from the results, the dominated temperature rising area covered the nut moving range completely.

Acknowledgements

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