# 볼 스크류 가공 파라미터의 최적화를 통한 소음 감소에 관한 연구

# The Improvement of Noise Performance by Optimizing Machining Process Parameters on Ball Screw

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## 1. Introduction

Ball screw system is a machine that uses steel balls between a screw and a nut to transfer the force and motion accurately which convert rotate into linear movement. Therefore, ball screw systems are largely used in industry for motion control and motor applications. And the problem of noise, perplexes us, is highly correlated with quality in ball screw systems all the way.

Generally, the noise of ball screws mainly cause of contact surface accuracy, thermal deformation, impact between ball and return system and lack of axial stiffness.

In order to improve the noise performance, many people conce ntrated on new grinding methods, adhesives, abrasives, grains. Dia mond, cubic boron nitride(CNB), aluminium oxide ($Al_2O_3$) and sili con carbide (SiC) are used as new kind of grains.

In order to get a high surface precision, improving grinding method is required. It is well known that diamond is the hardest natural material. But dressing of grinding wheels with diamond not only causes excessive wheel loss but also interrupts production during dressing[1]. Aluminium oxide ($Al_2O_3$) as the substitute of diamond, have advantages like low price, good wear resistance and so on[2]. In order to achieve nanometre surface roughness and submicron form accuracy, high-quality grinding protocols for polycrystalline silicon carbide is used[3]. Cubic boron nitride (CBN) grinding wheels have been used by industry for a few decades, often with very good results. CBN grains are much harder than aluminium oxide ($Al_2O_3$) and silicon carbide (SiC) grains and also can achieving nanometre surface roughness .

The above methods can make noise performance better. But the cost is high, not only money, but also manpower and research time. Therefore, improvements to existing production processes, methods and controls are needful.

## 2. Experimental

However, a mass-produced product is best in some respects. Even if most machining process parameters were confirmed by experiments and tests, nearly all parameters were adjusted by experience. In this study, machining process parameters were evaluated in respects of technical, business, produce and quality to verify which impacts on noise most. Nut dressing rpm, shaft grinding wheel rpm, shaft dressing rpm, shaft principal axis rpm, nut spindle rpm, shaft taper level have been selected as test elements with which scores the most points.

3 comparison groups have been set as table 1. With the present parameters benchmark, respectively, two groups of parameters were set. Based on the above data, 18 different ball screws have been pro duced as test specimens.

There are 2 rounds of noise tests did in this facility. First, 18 ball screws which machined by different parameters as table 2 did noise tests 2000rpm. On the basis of the analysis for noise performance in the machining process parameters respectively, a group of optimized machining process parameters is obtained. And then, 2 ball screws were produced again with present machining process parameters and optimized machining process parameters respectively to do noise tests to show how noise performance improved. At last, surface roughness tests were done to know how surface roughness is improved on optimum and present ball screws as the noise decreasing reason.

## 3. Results and discussion

Table 1 Three groups of machining process parameters

| | Factor | Unit | Parameters group 1 | Parameters group 2 | Parameters group 3 |
|---|---|---|---|---|---|
| Shaft | Taper level | um | 2 | 4 | 4 |
| | Grinding wheel | rpm | 1400 | 1650 | 1900 |
| | Principal axis | rpm | 15 | 20 | 25 |
| | dressing | rpm | 1000 | 1200 | 1400 |
| Nut | spindle | rpm | 13600 | 14000 | 14400 |
| | dressing | rpm | 13400 | 13800 | 14200 |

There are 6 parameters selected as test elements. Logically speaking, there must be 486 ball screws made to do the tests. But to some degree, it's impossible to make so many ball screws as specimens. Hence, modest number of ball screws as specimens to be confirmed to 18 through twice thought. Homogeneous distribution has been implemented in the 18 ball screws to make sure the parameter variables have equality.

From figure 1 to figure 6 shows how the six parameters impact on noise in 2000rpm. Figure 1 shows the influence degree of shaft taper level to noise performance. The noise test results distributed essentially the same. So, an exact average test data testified that shaft taper level is 2 better than 4 as 73.93db to 74.12db. It can be ascertain that shaft taper level is not so important to the noise performance as machining process parameter. Figure 2 shows how the shaft grinding wheel rpm impacts on the noise performance. This figure is so apparent to understand which parameter variable makes the noise lowest. 1650rpm is the best as 74.41db, 73.27db and 74.39db in average respectively. Figure 3 is the same situation as last one. A judgment that when shaft principal axis rpm is 25 is best of all can be made simply. The noise performances are 75.27db, 74.15db and 72.66db in average and own a 2.61db differ from best worst. Figure 4 shows how shaft dressing rpm impacts on the noise performance. In this figure, most test results in 1000rpm congregated under 73.5db. A precise average noise data proved that shaft dressing rpm is 1000 better than 1200 and 1400 with 73.93db in average. Figure 5 and 6 are nut machining process parameters, shows the influence degree of nut spindle rpm and nut dressing rpm to noise performances. In figure 5, it shows clearly that 14400rpm is the optimum with 73.38db in average. In figure 6, the situation is a little ambiguous in 13400rpm and 13800rpm. An exact average test data testified that nut dressing rpm is 13800 better than 13400 as 73.48db to 73.80db in average.

Figure 7 and figure 8 shows noise test result in 1000rpm and 2000rpm. Figure 7 shows the noise performance improved from 74.12db to 67.47db. And figure 8 shows the noise performance improved from 78.52db to 72.28db. The optimization of machining process parameters bring about 6.65db improvement in 1000rpm and 6.26db improvement in 2000rpm.

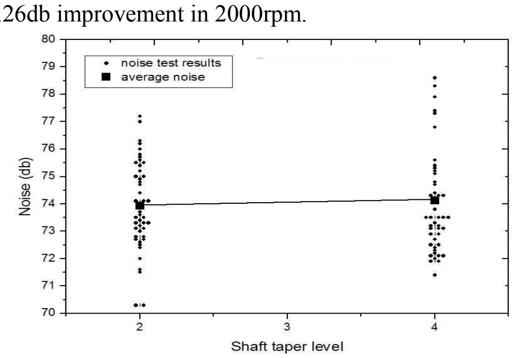


Fig. 1 Influence degree of shaft taper level to noise

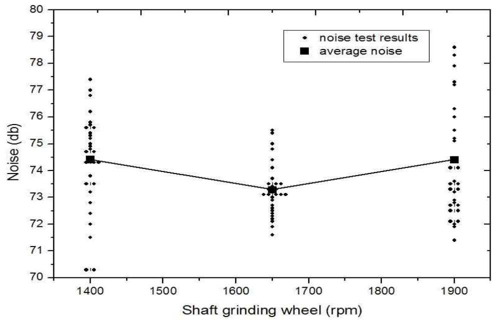


Fig. 2 Influence degree of shaft grinding wheel rpm to noise

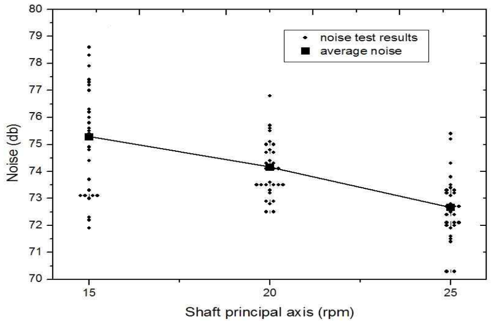


Fig. 3 Influence degree of shaft principal axis rpm to noise

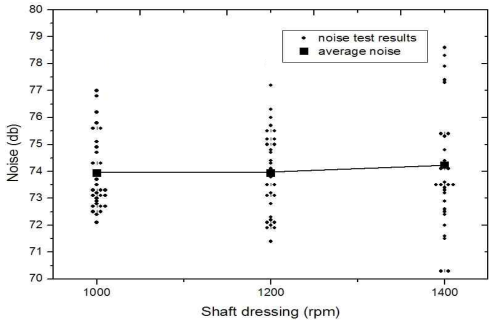


Fig. 4 Influence degree of shaft dressing rpm to noise

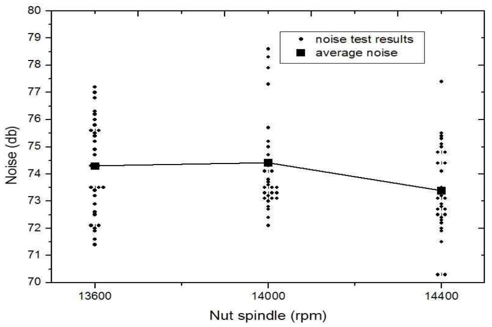


Fig. 5 Influence degree of nut spindle rpm to noise

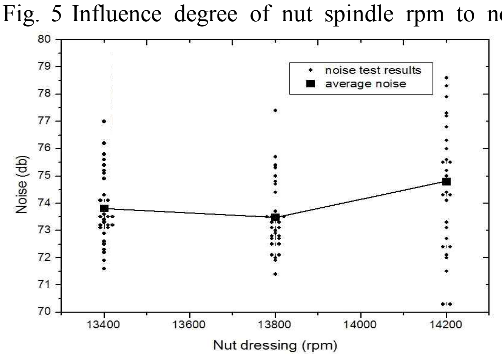


Fig. 6 Influence degree of nut dressing rpm to noise

There are many factors that can affect the magnitude of noise. The surface roughness is maybe the essential point. Fig.9 shows the improvement of surface roughness on optimum and present ball screws. As the result in present ball screw, the average number of $R_a$ was 0.2494um. And at the optimum processing situation, the result became 0.2304um in average.

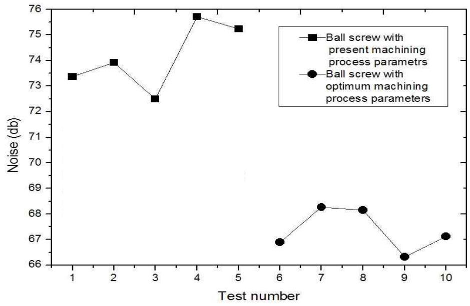


Fig. 7 Noise test comparison in 1000rpm

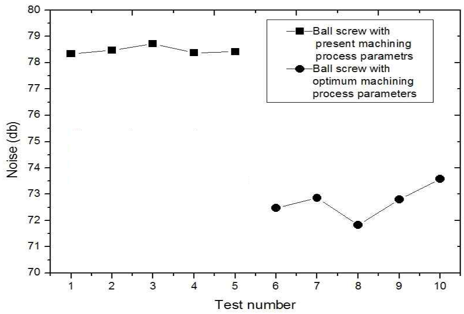


Fig. 8 Noise test comparison in 2000rpm

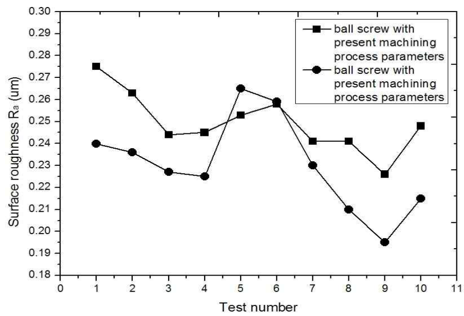


Fig. 9 Surface roughness comparison

## 4. Conclusion

In this paper, 6 machining process parameters were selected as test elements. Among the rest, shaft taper level and shaft dressing rpm behave a trifling impact on noise, and shaft grinding wheel rpm, nut spindle rpm and nut dressing rpm show a non-ignorable impact on noise. Shaft principal axis rpm shows a considerable impact on noise as 2.61db differ best worst. The second round of noise test brings about 6.65db improvement in 1000rpm and 6.26db improvement in 2000rpm. The surface roughness test in present ball screw, the average number of $R_a$ is 0.2494um. And at the optimum processing situation, the result became 0.2304um in average. A considerable surface roughness improvement, 8.246% happened though optimizing machining process parameters.

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