# Research of Ball Screw Pair of Noise Prediction Based on the Virtual Lab and Experimental Verification

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**Abstract.** This paper aims to analysis the ball screw pair in transient dynamics model based on the virtual acoustic prediction software. Its acoustic finite element model is established in the Lab to extract the transient dynamics analysis, which is concluded that the vibration response of the ball nut pair of time domain signals, and carries on the vibration signals of Fourier transform to obtain the frequency domain. As acoustic finite element boundary conditions are imposed to the acoustic model, which using acoustic finite element method. At last, the analysis of ball screw pair of outside sound field sound pressure value and experimental verification.

## Introduction

With high demands on the noise of the machine tool precision laboratory is getting higher and higher, the noise of the ball screw vice studies recently gathering everyone's attention[1]. Ball screw pair due to the ball in the process of running periodically hit back to the device can produce more obvious near the ball through the frequency rate of noise In addition, the friction between ball and raceway[2]. Ball bearings between the ball and hit strikes and other external motivation and interference is ball screw pair of noise sources, the main noise source of ball screw pair for ball frequency noise, periodic hit the ball to return to seize the main noise sources of noise and noise level prediction, can predict the noise level of ball screw pair[3].

## Theoretical analysis

### Ball screw pair of acoustic finite element model

DK4012 type to simplify the model of ball screw pair (such as: the sealing flange nut hole, the flange nuts washers and nut drawing for the parts of a whole, etc), and establish its simplified surface shell in Hyper-mesh grid file, import it into Virtual. The Lab of acoustic finite element module (Acoustics Harmonic FEM), as a foundation for subsequent production envelope of the grid As shown in Fig1, the grid of shell unit number is 15155, give priority to with four node quadrilateral grid, on the surface shape of transition region containing very little triangular grid:

Fig.1. The production of ball screw pair of acoustics meshes

On the basis of grid shell, use of Virtual Lab envelope grid generation command in the menu bar (Tools Meshing Create a Convex Mesh), set the appropriate grid parameters, the grid around the shell can generate the envelope of the grid, defined its grid attribute for Acoustical this is follow-up for acoustic has a limited amount of acoustic transmission grid, as shown in Fig.2. Envelope of the grid unit number is 315816, the grid is given priority to with tetrahedral mesh Envelope mesh generation, the grid above shell can be deleted.

 

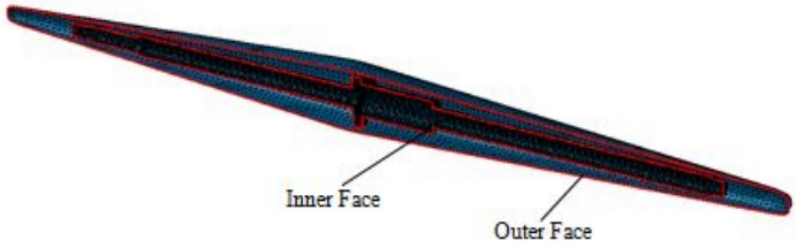


Fig.2. Ball screw pair of acoustic envelope grid before processing

Transient dynamics analysis results in the previous chapter file format. (RST) import. Virtual Lab, along with all the original import also has a structure finite element grid (as shown in Fig.3), structural properties, such as time domain vibration signal is attached on the junction structure finite element grid cell To carry out the follow-up frequency acoustic finite element calculation, need to use Virtual Lab data transformation of the order, time domain finite element data can be converted into frequency domain data At the same time, in order to bring the vibration of the structure on the finite element mesh data mapping to the acoustic finite grid, and the amount of acoustic space, need to have the limit element mesh generated above acoustical make internal and external surfaces of the two sides set of Inner Face and Outer Face. Among them, the Inner Face as vibration data mapping of the surface, the Outer Face as the edge of space radiation interface, and define it as the AML properties. Finally, you need to generate sites grid considering the shape of ball screw pair the consultation with the experiment, the place of the ball screw vice sites grid model is set to the rectangle, 1600 mm long, 240 mm wide, 200 mm high, as shown in the Fig.3:

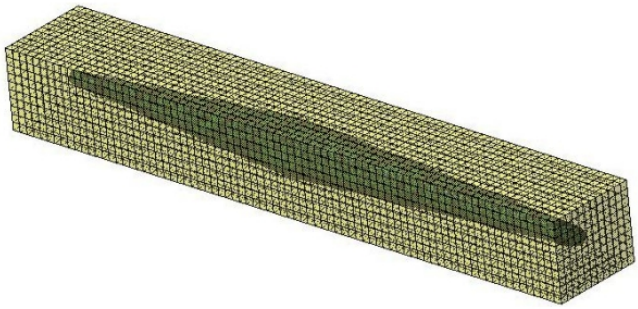

Fig.3. Sites grid model of ball screw pair.

After the above four steps of setting, that is, to generate the acoustic finite element mesh model of ball screw pair of acoustic material properties defined for Air (Air) acoustic finite element calculation requirements within a sound wavelengths is 6 units, so the acoustic grid cell size and the material attribute determines the calculation of the model Frequency selective Maximum Frequency Report, but to see this model allows for calculating Frequency: 2833.3 Hz.

Before the acoustic calculation, need to map the structure vibration data on the grid to acoustics meshes, coupling relationship But different nodes and elements between the grid is usually not one-to-one, so you need to choose mapping algorithm defined the mapping relationship between grid mapping algorithm selection should be based on the attribute of grid, generally has the following several ways: the Node Number: this algorithm show that two kinds of grid geometry correspond completely, no interpolation Maximum short: two grid geometry is the same, but different Element Node density Maximum short: both grid geometry and Node density are different Conservative Maximum short: this is a mapping algorithm without energy loss, usually used in pneumatic acoustics. After selection algorithm, often need to define the influence node Number (the Number of Influenced Nodes) and Maximum Distance (Maximum of short) two parameters affect the Number of Nodes represents the target in the grid data of a node. By how many original mesh mapping. Maximum distance is targeting grid node for the circle circle radius value, only covered by this circle to get original data grid nodes before it can be mapped to the target grid nodes in the model, the vibration of the structure of the grid to data mapping to the acoustics meshes, set affect the number of nodes is 4, maximum distance of 20 mm, said acoustic grid in a radius of node for 20 mm round within the scope of four structure as a mesh of nodes on the grid Standard data source node, if less than 4 nodes in the range, only three nodes, such as using the three nodes as a data

source for the target node, as shown in Fig.4.

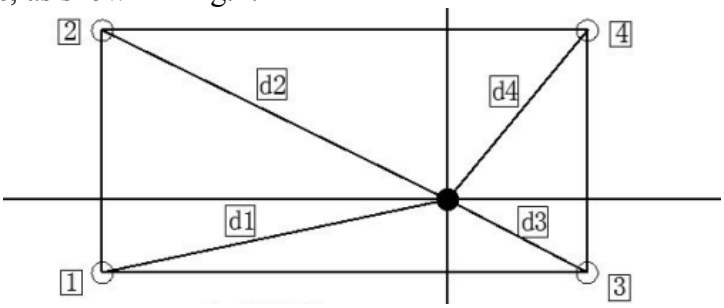


Fig.4. Ball screw pair of data transfer.

In addition, still need to solve related parameters (such as the precision of the solution space and the analysis of the frequency range, etc.) of the set, and the limit of the space, here no longer thin to elaborate, after the completion of the ball screw pair of acoustic finite element model that can be in line outside the ball screw vice sound field sound pressure level of the forecast.

**Ball screw pair of acoustic simulation results**

By the finite element model of ball screw pair of acoustic detailed Settings, can be related to the amount of acoustic calculation is made up of acoustic finite element model is not hard to find, the sound pressure distribution of the surface outside ball screw pair and the sound of subsection space sound field Cloth is what we focus on the detailed simulation results is given below, and analysand.

Ball screw pair outside surface acoustic volume calculation results is the basis of sites spatial sound pressure prediction, using the finite element model to calculate the amount of ball screw pair of exterior acoustic respectively after further solving play sound pressure value of the space below sound pressure of the ball screw vice sites space (as the sound pressure distribution of the mean, expressed in the RMS) forecast Fig.5.

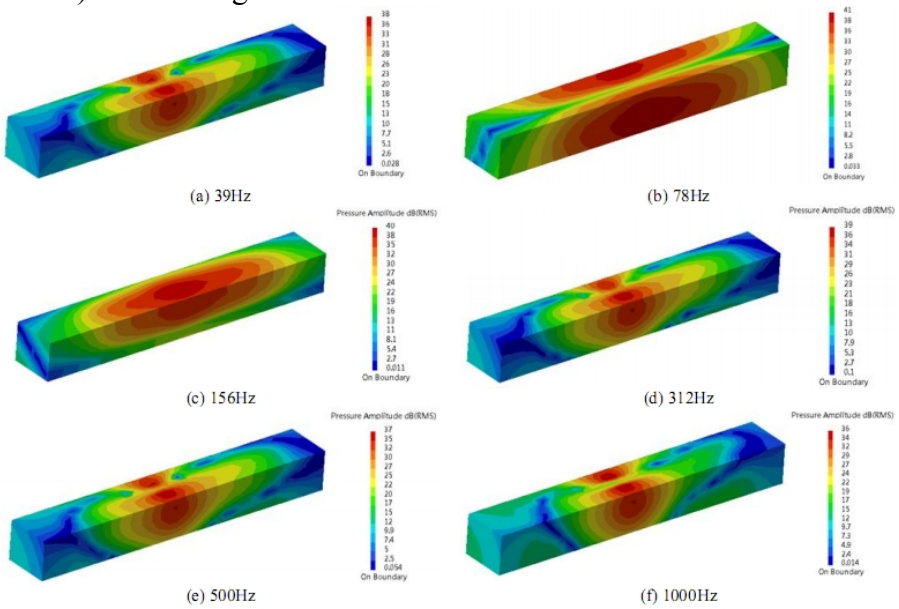


Fig.5 The relative position between the ball and raceway

By the graph, you can see that around the cube space of ball screw pair, maximum sound pressure values, near the nut to screw Gradually decay on both ends, and, at the ball pass frequency (78 Hz) space corresponding to the maximum sound pressure value, this is consistent with the analysis results of the previous section In addition, the maximum sound pressure field space than the external surface of the ball screw pair of maximum sound pressure low 10 db left right, this is mainly due to the attenuation of the sound in air Nut near point in space sound field is given below (and the following section experiment in middle phase one to put microphone position) of the frequency response curve (screw rotation speed is 1000 RPM to 1500 RPM to 2000 RPM and 1500 RPM when the response curve of the Fig.6), further illustrate the ball pass frequency and the

frequency doubling place there will be a higher sound pressure values.

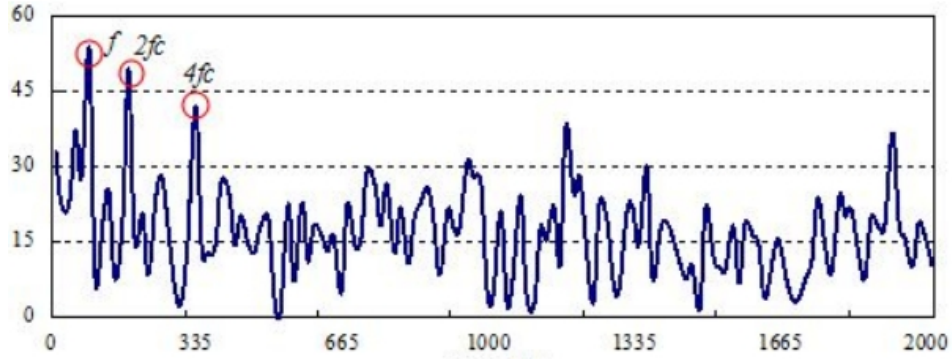


Fig.6 Spatial sound pressure frequency response curve.

**Ball screw pair of noise experimental research**

This experiment in the laboratory of high-speed ball screw pair of vibration and noise comprehensive test bench, the structure of the test bench Intentions as shown in Fig.7. 1 is fixed on the ground, bed screw 6 installed on both ends of bearing, the left 9 for the double row angular contact ball bearing, right side is a deep groove ball bearing 5, 10 by coupling two servo motor drive screw rotation 6, 7 fixed nut on the table 4, table 4 ends supported by linear rolling guide 3 by controlling the servo motor rotation 10, screw 6 driven worktable moving back and forth on the linear guide 3 and 4.

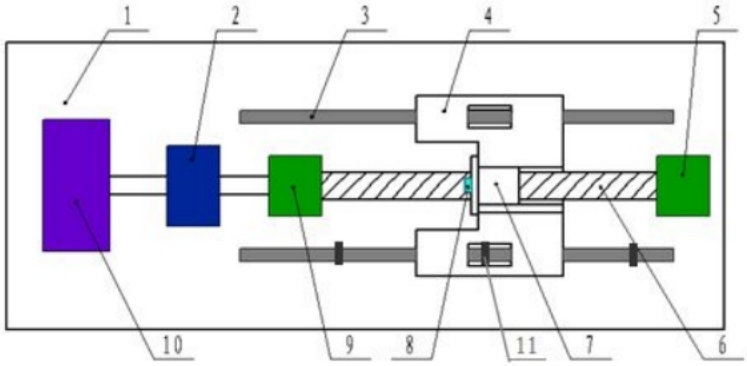


Fig.7 High-speed ball screw vice comprehensive test-bed structure diagram of vibration and noise.

Noise signal through the microphone (Type: the Type 4165, measuring range: 0 ~ 20 KHZ) acquisition and transmission to data collector (model: NI pxi 446), computer data terminal connections, signal analysis and processing experiments of microphone layout as shown in Fig.8, its level about 10 cm higher than the ball screw, the screw axis of about 12 cm, middle microphone positions and acoustic finite element analysis of acoustic pressure in the process of frequency response points.

Fig.8 Microphone layout diagram.

Through experimental instrument to collect the ball screw pair is the direct signal noise in the time domain signal, the time domain signal can visually see the average noise level, given here screw 500 RPM, a period of stable state of time domain signal(as shown Fig.9).

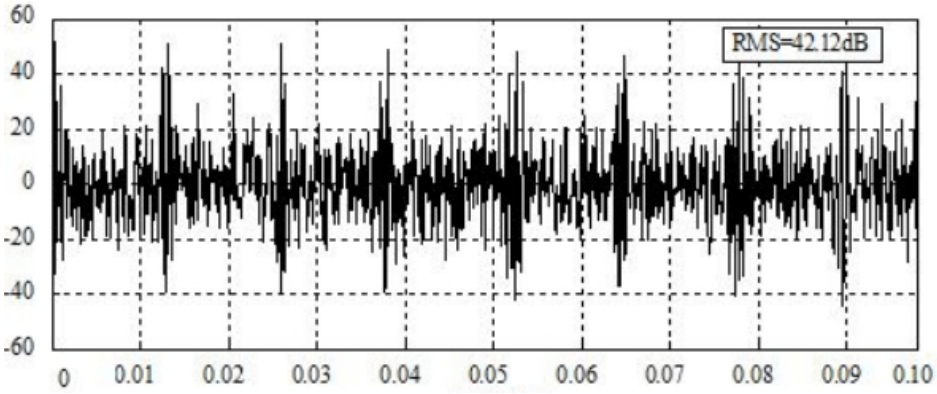


Fig.9 Noise signal time domain figure when rotating speed is 500 RPM.

Fig.10 can be found from the time domain signal, the noise of the screw rotation speed is 500 RPM average of 42.12 dB (with sound pressure when the RMS), noise signal has obvious cyclical, period T 0.0125 s extraction time domain noise is measured under different rotational speed RMS values, fitting curve simulation it is concluded that the average sound pressure level, as shown in the Fig.10.

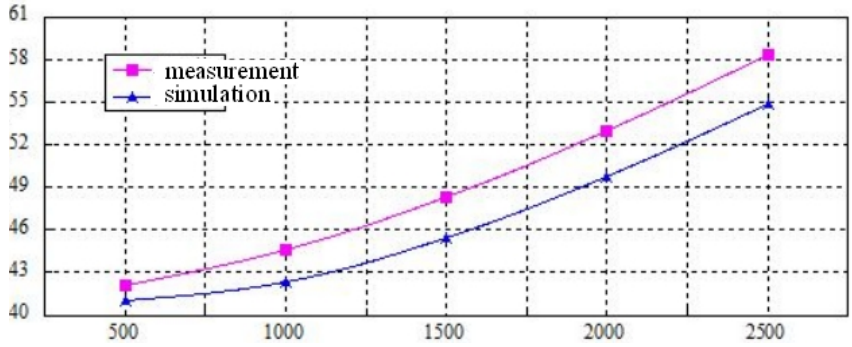


Fig.10. Ball screw pair of average sound pressure level of the simulation value compared with the experimental value.

It can be seen from the above, with the increase of screw speed, ball screw pair of noise levels are increasing, and the higher the speed, the faster sound pressure increase Experimental value than the simulation value is larger, the main reason should be in the process of the experiment with its it noise caused by acoustic finite element simulation only considers the ball cyclical impact to return to the main noise, while ignoring the friction between ball and raceway, ball and the ball hit the other types of noise, therefore, the experimental value slightly higher than that of the simulation is reasonable it is important to note: nut vice is a reciprocating motion in the process of experiment, and simulation is the main noise source in time domain signal is loaded on the fixed nut vice, so the simulation and experiment are compared when extract only the average noise sound pressure level, there must be between approximate composition So the later scholars can try to predict the ball screw pair of noise movement condition Sound level, with the more close to actual situation

## References

[1]Lambert R J , Pollard A , Stone B J. Some characteristics of rolling-element bearings under oscillating conditions. Part 1: theory and rig design[C]. Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-Body Dynamics, 220(3): 157-170.

[2]Okwudire C E, Altintas Y. Hybrid Modeling of Ball Screw Drives With Coupled Axial, Torsional, and Lateral Dynamics [J]. Journal of Mechanical Design, 2009, 131(7): 071-082.

[3]Jen Fin Lin. Impact failure analysis of re-circulating mechanism in ball screw[J]. Engineering Failure Analysis，2004，11（4）：561-573.