Improvement of the Indirect Measuring Capability of the Spindle Test Stand

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Abstract

In media technology, a Track-Per-Inch (TPI) index is estimated as capabilities of the spindle test stand to verify such a higher capability of hard disk storage. The test stand in this study is capable of testing the media with up to approximately 200 kTPI. There are several methods to test TPI capacity of the test stand. In this research, two methods are studied for their possibilities to implement. The first method, an indirect method, is developed as a technique for the measurement of radial runout of the spindle using the capacitance probe that measures the representative of mechanical motion between the head and the media to account for the tolerance of the spindle installation. The second method, a direct method, uses the read/write features between the head and the media to measure and estimate from the accessed data. The data could be calculated back to a position error of the media track as the capability of the spindle test stand. In either method, a statistical approach is utilized to estimate for TPI capability of the steady state track holding for the high TPI media. Nevertheless, the indirect method is the preferred technique for implementation due to time consumption and complexity of measurements. This study is reported the improvement of the indirect method to close as the direct method.

Introduction

The capability of the spindle test stand is very important because it must be higher capabilities than of the head and the media under testing. The indicator parameter is the TPI index estimated from Non-Repeatable Run-Out (NRRO). The Total Indicated Run-out (TIR) could be defined as the distance difference between the head and the media during read/write tasks. It consists of Repeatable Run-Out (RRO) which is repeated at each revolution and NRRO. The NRRO is the major source of track misregistration which prevents high capabilities of the spindle test stand. The direct method, utilized the head/media in interaction, is resulted in the complexity of measurement procedures, time consumption and variation of the head/media pairs.

Richter and Talke (1988) has investigated the relation between the radial and axial NRRO in 5 1/4″ disk drive motor in both time and frequency domains. The standard deviation of the radial and axial NRRO is found that changing with the running speed of the spindle with similar magnitude.

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For previous works (Bouchard et al., 1987;Gunhee Jang,et al., 1999 ; Ono et al., 1991), the studies are performed in laboratory and measured only the spindle run-out. However, this study is to develop a measurement technique to obtain more precise measurement data of the spindle radial run-out in production line environment. The capacitance probe is installed on the base table of the spindle test stand and on the receiver unit to measure the relative motion of those. It showed that the indirect method could improve the measurement data and then the TPI index to close as the direct method and provide agreement on the spindle test stand capability.

Spindle motor dynamic characteristics.

Parameters described the spindle motor dynamic characteristics, TIR, RRO, and NRRO. The TIR is sampled with N numbers data per revolution spindle motor and Measuring M revolutions. TIR(m,n) can defined as the total indicated runout corresponding to n-th sector of spindle motor at the m-th revolution. RRO is independent of m, because it is repeated at each revolution so TIR(m,n) can be written as follows,

$$\mathrm{TIR}(m,n) = \mathrm{RRO}(n) + \mathrm{NRRO}(m,n) \qquad (1)$$

RRO(n) is the repeatable runout at n sector of spindle can be obtained by averaging the TIR at each sector M revolutions.

$$\mathrm{RRO}(n) = \frac{1}{M}\sum_{1}^{M}\mathrm{TIR}(m,n) \qquad (2)$$

Then , the NRRO can be obtained as follow

$$\mathrm{NRRO}(m,n) = \mathrm{TIR}(m,n) - \mathrm{RRO}(n) \qquad (3)$$

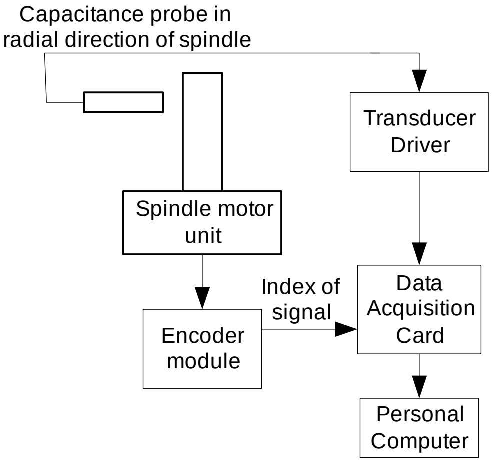

Figure 1. Test equipment setup for measuring radial run-out of spindle

Experiment Studies

Figure 1 illustrates the test equipment setup for measuring the radial motion of the spindle using the capacitance probe to measure the radial run-out of the spindle. The capacitance probe is hold on the fixtures which will be described later.

There are of three parts of experimental studies as follows.

1. The test is utilized two probe fixtures to obtain the measurement data for comparing the spectrum of the TIR. The first fixture is to hold the capacitance probe on the base table which the spindle is installed, such that the measurement data is the relative motion of the spindle run-out to its base. The second fixture is to hold the capacitance probe on the receiver of the head unit, such that the measurement data is the relative motion of the spindle run-out to the receiver. The spindle speed is at 15000 RPM.

The Comparison of the TIR spectrum between those two-fixture configurations is showed in Figure 2. Noted that the TIR spectrum are resulted with difference in amplitudes of the measured data relative to its base and to the receiver, especially in frequency range of 0-300 Hz. The higher spectrum in the frequency range is of NRRO and suspected to other mechanical motion in production environment. The capacitance probe fixture relative to the receiver is then preferred to provide more correctness of the TPI index.

2. Another suspecting effect to more correctness of the TPI index, is the capacitance probe capability. The time response captured by the capacitance probe is of 200 kHz sampling rate. This high sampling frequency is to account for resolution of the index pulse signal with narrow pulse width from the spindle motor encoder. Then test setup is performed to illustrate the characteristics of the capacitance probe at the high frequency range.

The time response of relative motion between the spindle and the receiver is shown in Figure 3. This non-stationary signal is starting from rest at 0 to 33 sec. and run-up the spindle speed to 15000 RPM and run-down from 64 sec. until stop the spindle movement. Figure 4 is illustrated a waterfall plot of the TIR spectrum in frequency range of 10 to 18 kHz. Noted that while spindle at rest, there is of high amplitude in band around 16 kHz and when spindle run-up to 15000 RPM, this amplitude is still exist and not changed.

The TIR spectrum in band 16 kHz is not come from a vibration of mechanical part and the limitation of capacitance probe also have only up to 15kHz frequency range. The measurement data must be filtered out for the higher frequency than 15 kHz. Moreover, in Figure 3, after the spindle stop, the signal offset is present. This is due to the drifting phenomenon from the driver unit of the capacitance probe. The removal of this trend data will be mentioned on conclusion.

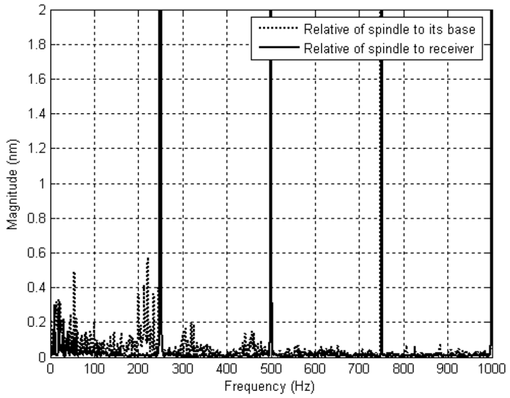

Figure 2. Comparison of TIR spectrum between relative motion of the spindle to its base and to receiver

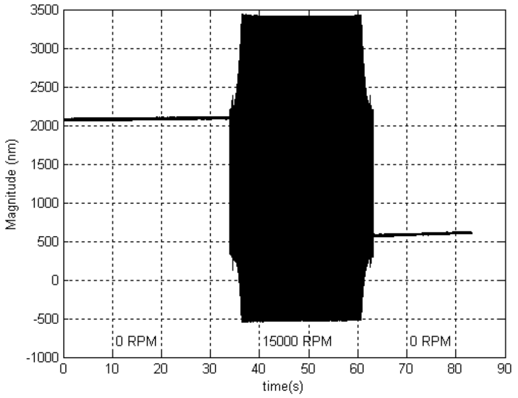

Figure 3. Time response of relative motion of spindle and receiver during spindle run-up/ rundown

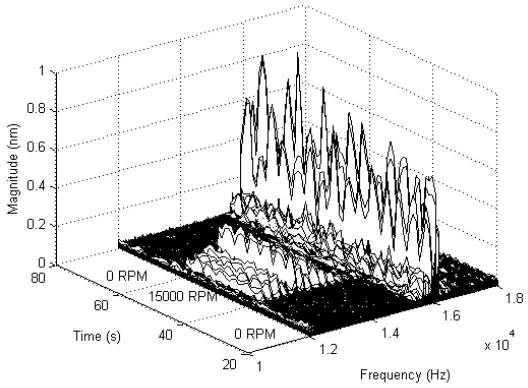

Figure 4. Waterfall plot of relative motion between spindle and receiver in high frequency range

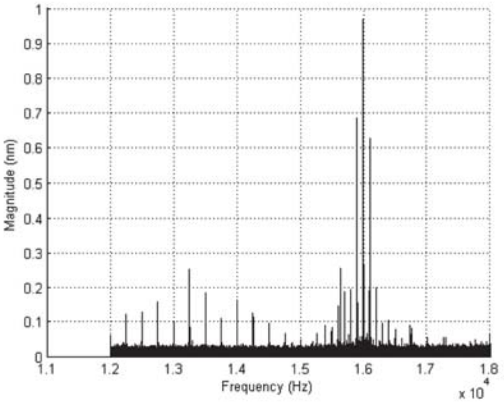

Figure 5. Waterfall of relative motion between spindle and receiver in frequency axis only of Figure 4.

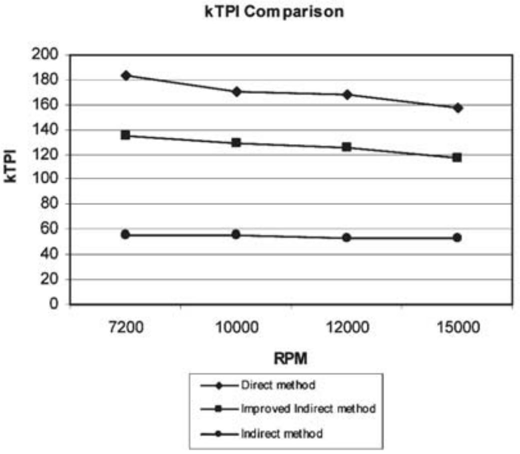

Figure 6. TPI index in comparison among indirect method, improved indirect method and direct method with varying spindle speed

3. After describing the effects on improvement of the measurement data to account for spindle run-out above, a comparison between the TPI index obtained from the direct method utilized the Head/media technique according to the techniques developed by the manufacturer and the improved indirect method with varied running speed of the spindle, is shown in Figure 6. All tests on the spindle test stand are performed in production line environment. The comparison is included the indirect method utilized the capacitance probe fixture relative to its base(spindle) without further processing of the measured data as in section 3.2.

The TPI index by the improved indirect method is to be the same trend to the direct method as varying the spindle speed. Also, the TPI index is more close to the direct method than that of no improvement.

Conclusions

The estimation of TPI of the spindle test stand by the indirect method can be improved to its correctness as comparing to the head/media interaction by the direct method. The relative motion measurement and high frequency noise rejection are in consideration of the study. Trending of the TPI index to the spindle speed is satisfied with the direct method.

Further work is to study on reliability of this improvement technique by taking correlation with more the head/media pairs and the spindle test stand. Further improvement on drifting phenomenon, such as removal of trending data will be implemented and other effects will be studied.

Acknowledgement

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References

Bouchard, G., Lau, L. and Talke, F. E., 1987. "An Investigation of Nonrepeatable Spindle Run-out", *IEEE Trans. Magn.*, Vol. 23, No. 5,

Gunhee Jang,Dongkyun Kim and Jae-Eung Oh, 1999. "New Frequency domain method of Nonrepeatable runout measurement in a Hard disk drive spindle", *IEEE Trans. Magn.*, Vol. 35, pp833-838.

Ono, K., Saiki, N., Sanada, Y. and Kumano, A., 1991. "Analysis of Nonrepeatable Radial Vibration of Magnetic Disk Spindles", *Trans. ASME Journal of Vibration and Acoustics*, Vol. 133, pp292-298.

Richter, W. O. and Talke, F. E.,1988 "Nonrepeatable Radial and Axial Runout of 5 1/4 in. Disk Drive Spindles", *IEEE Trans. Magn.*, Vol. 24

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