An Evaluation Method for Spindle Motor Runout Measurement

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Abstract— In order to study the spindle motor vibration characterization, the runout of the motor must be measured accurately. In this paper, a method based on measurement uncertainty is presented to evaluate different measurement systems performance and measurement confidence. The system was developed based on optical interference technology. The spindle runout in the hard disk drives with different form factors are measured by capacitance probe, LDV and optical interferometer, and comparison of measurement result measured is discussed.

Index Terms—Spindle motor, Uncertainty measurement, NRRO, Capacitance probe, LDV, Optical interference.

I. Introduction

Measuring accurately the runout is important in the performance analysis and fault diagnosis of spindle motor used in the hard disk drive (HDD) [1]. The non-repeatable runout (NRRO) is one of the major concern in realize high density data recording.

Accurate motor runout measurement and estimation have been considered as a very difficult topic in industry. The purpose of this paper is to investigate the spindle runout measurement results of several instruments, which include capacitance probe, LDV, optic interferometer. The optic interferometer is developed by DSI [3].

The measurement error is defined as the deviation between the measured value and the true value. The evaluation method justifies their accuracies by comparing to the directly measured. This paper gives a method for estimating errors and uncertainties of real measurements.

Three factors are important in accurate measurement: 1) measurement method; 2) the measuring instruments, and 3) the personnel who perform the experiment. All these factors induce errors in the measurement.

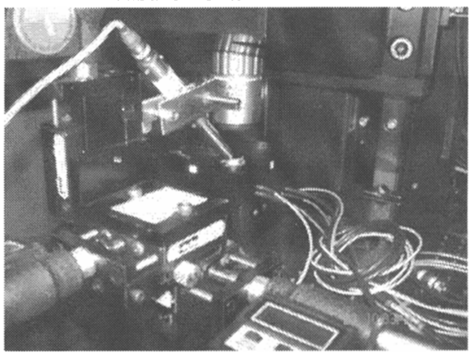

Fig. 1 Spindle motor runout measurement system

For comparing the measurement results from different instruments, the spindle runout should be measured using at the same time on the same stage. This can minimum the methodological error and personnel error. Figure 1 shows the basic experiment structure of a spindle motor runout measurement system.

II Measurement Uncertainty Evaluation Method

Statistical tools give the assessment of uncertainties associated to the results only if all the relevant quantities involved in the process are interpreted or regarded as random variables.

The measurement process is a Bayesian approach [4], in other terms all the sources of uncertainty are characterized by probability distribution functions, Assume intrinsic spindle runout X_{rro} distribution is prior density $f(X_{rro})$ and measurement process is the conditional joint density $f(Y_{rro}| X_{rro})$, the measurement result Y_{rro} posterior density is $f(Y_{rro})$.

$$f(Y_{rro}) = f(Y_{rro}| X_{rro})\, f(X_{rro}) \tag{1}$$

The measurement uncertainty is investigated through the Bayesian approach given by eq. (1). Once the results are obtained Bayes' theorem enables the experimenter to calculate a new set of probabilities which represents revised degrees of belief in the possible models, taking into account the new information involved in the measurements results.

The maximum entropy approach is a flexible and powerful tool for assigning a probability distribution to a measurable quantity treated as a random variable subjected to known moment constraints.

$$H = -\int_{-\infty}^{\infty} f(Y_r)\ln(f(Y_r))dY_r \tag{2}$$

where Yr is runout and f(Yr) is the probability distribution and H is entropy. If the Yr has lower control limit and upper control limit, thus

$$H = -\int_{LowerL}^{UpperL} f(Y_r)\ln(f(Y_r))dY_r \tag{3}$$

The constraints are the following:

$$LowerL \le Y_r \le UpperL$$

$$\int_{LowerL}^{UpperL} f(Y_r)dY_r = 1 \tag{4}$$

$$E\{Y_r\} = \int_{LowerL}^{UpperL} Y_r f(Y_r)dY_r = u_0 \tag{5}$$

Finally, we can get the following result

$$Var\{x\} = \frac{l_-^2 e^{\lambda l_-} - l_+^2 e^{\lambda l_+}}{e^{\lambda l_-} - e^{\lambda l_+}} \tag{6}$$

III Experiments

There are many factors to influence the measurement data in the nanometer measurement, for example, temperature, air flow, environmental vibration etc, especial the environmental vibration will cause the LDV measurement shift.

An experiment is set up to diminish the above disturbance. All the measurement data are collected synchronization and all instruments are installed on an anti-vibration stage. The motor will be run twenty minute before the data collection. The measurement result of spindle motor runout is illustrated in Fig. 2.

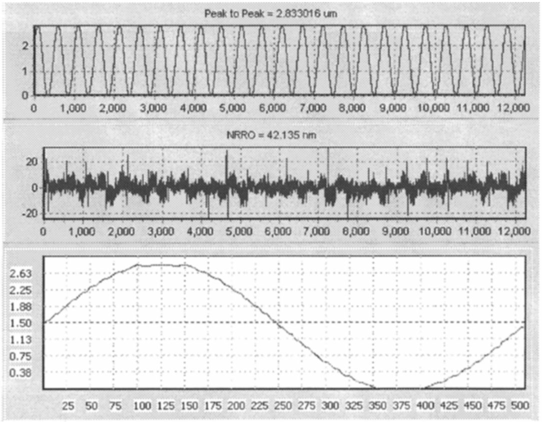

Fig. 2 (1) Total runout,(2) NRRO, (3)repeatable runout of a 1.8 inch spindle motor.

Table 1 NRRO measurement in various form factor hard disk drives

value	iRVM(nm)	Ldv(nm)	Capacitance Probe(nm)
1	4.013189	9.090665	12.05667
2	4.583146	9.121484	13.14889
3	4.585977	9.433618	11.54772
4	4.425188	9.064864	12.02252
5	4.773291	9.140127	12.21144
6	4.233206	9.230782	12.65293
7	4.222199	11.85558	11.35699
8	4.954987	9.606304	12.56781
9	5.24433	10.54771	12.99574
10	4.560652	9.738162	12.28492
11	5.567772	9.882205	12.75413
12	5.869908	9.874432	12.84722
13	5.979848	10.01533	14.66441

Table 1 indicates the spindle motor NRRO uncertainty measurement using various form factor hard disk drives.

The iRVM has minimum uncertainty as it utilizes the optical interference principle and combines with the 2D sensor [3]. 2D sensor measurement with spatial correlation has noise limit benefit.

The spindle motor NRRO is also measured under various spin speed, as the results shown in table 2. The uncertainty at specification speed 5400rpm is minimum value which utilizes iRVM, LDV and capacitance probe.

Table 2 NRRO measurement in various spin speed of hard disk drives

Frequency(rpm)	iRVM(nm)	LDV(nm)	Capacitance Probe(nm)
3600	5.088508	14.38102	11.67939
4200	4.73736	20.4653	19.62571
4800	4.872504	19.90827	17.98761
5400	4.222199	10.85558	11.46451
6000	4.626834	11.01088	11.69568
6600	4.320094	11.14649	8.627105
7200	5.198161	17.90068	17.26213

IV Conclusions

This paper presents an in-depth discussion on the measurement uncertainty analysis of instruments for spindle motor runout based on measurement probabilities maximum entropy approach.

The results from three measurement instruments are discussed, which include capacitance probe, LDV and optical interferometer.

In the high precision measurement instrument with nanometer scale resolution, the uncertainty of the measurement system is used to instead of system measurement errors or system accuracy.

iRVM utilizes 2D sensor measurement [3] with spatial correlation and has noise limit benefit.

The spindle motor runout can be measured more accurately under rated speed than other speeds.

The results presented in the paper are helpful to determine using reasonable instruments for runout measurement.

References

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