Identification of Reader Failure Problem by Using Neural Network

Hathaichanok Tiptumyae, and Arthit Srikaew

***Abstract*—**The most important thing in Hard disk drive industry is the quality control of the products. Even the customers, when the products were shipped, they have their products quality evaluation in order to indicate the product's attributes are meet the required specifications or not by using their qualification/integration test process. The unit that failed at the test will be returned to the factory for analysis and investigation the root cause of the failure. Reading/writing head, the small parts of a disk drive that performs transfer between magnetic field and electrical current (reading and writing), is the most finding root cause of the failure symptom. Quasi-static test is a method of failure investigation on reading head. It results high quantity of complex data; time and proficiency are needed in order to summarize and conclude the symptom and the cause of the failure. The errors from analysis can be possible due to unequal proficiency of each analyst. This paper introduced the classification of reading head failure symptom using neural network process technique. This technique can classify the problem faster and more accurate which conduce to find the solutions to solve and prevent the problem, make reliability in the quality of the products.

***Keywords*—**Hard disk drive, Quasi-static test, Failure symptoms, Classification

I. Introduction

HARD disk drive is a data storage device that used widely nowadays. Day after day, demand from the consumer is higher; the manufacturer has to enlarge their capacity to support that need. The failure is higher according to the capacity, too. However, quality is the essential part of the production; every component must be passed the quality test process and meets the required specifications before brought to the drive assembly process. Hard disk drive calibration and performance tests i.e. reading in various environments will be performed after assembly process then only the drives that passed the tests will be shipped to the customers. At the customers' site, hard disk drive will be tested again; the drives that failed during the customers' test process will be shipped back to the factory for analysis and investigation the failure symptom.

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GMR/TMR[3] is giant magneto resistance/Thermal magneto resistance

HSA[4] is head stack assembly

HGA[5] is head gimbal assembly

II. Source Of The Problem And Incentives

Due to high demand of hard disk drives currently, the failures during customer applications have high possibility as well as relating to the product's reliability.

Defective hard disk drives will be returned to the manufacturer to investigate the cause of failure symptoms. One of the major causes is reading head which performance degraded at customers' tests process.

For analysis the results of reading head test, it is needed time and proficiency to summarize and conclude the symptom from the high quantity of complex data set which can slow the analysis process as well as relating to the reliability from the customer. Supposing we can analyze the test results faster and more accurate; we can find the solutions to prevent the failure from reading head both currently and the future so quickly, increasing reliability in the products from the customer.

III. Works And Related Theory

A. Quasi-static test

Quasi-static test is a tool that used for efficiency test of reading head by GMR/TMR[3] performance measurement in the form of hard disk drive and rather emphasize in reader part than writer part of the head due to its limitations of the tool. [1] For writer part of the head, it will be tested in the form of HSA[4] and HGA[5]. Quasi-static test will perform without movement of head on disk (media) and disk rotation commands (every component that is able to move will be static during the test)

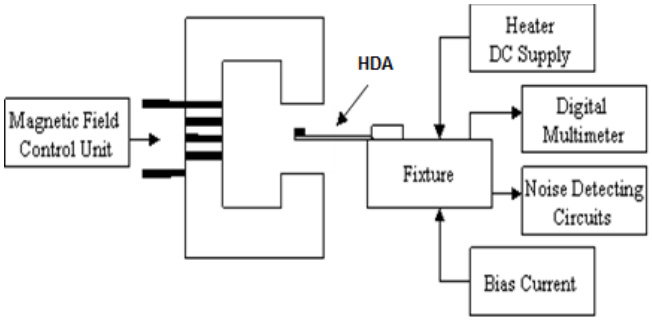

Fig. 1 The structure of Quasi-static test

Quasi-static test is divided into:

1) DC Measurements: a reading head test with low frequency measurement i.e. static head test that measures current or voltage with zero magnetic field. The results are following:

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- Head resistance
- Read fault and Write fault, fault detection function will indicates the problem on FLT or FLT register.
- Pre amp short Circuit i.e. Pin-Pin and Pin-Ground
- Transverse Curve graph

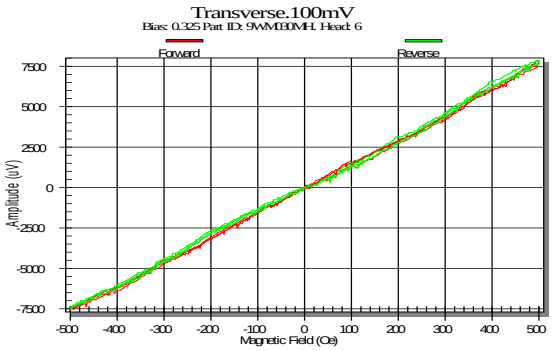

Fig. 2 Transverse graph from the result of head test with low frequency measurement

2) AC Measurements: a reading head test with high frequency measurement during external stimulation i.e. data recording simulation or magnetic field produced or both. The results are following:

- Popcorn Noise
- MAN / SMAN
- FFT Frequency Response

B. Preparation of information

Quasi-static test will result data set in two types, qualitative and quantitative data. The neural network can learn only quantitative data; qualitative data must be normalized to be quantitative data first. Such as, the test results 'PASS' and 'FAILED'; they should be normalized to be '1' for 'PASS' and '0' for 'FAILED'. Normalization data is an important step, complexity deduction and to make the neural network can learn the data. Additionally, normalization an incomplete data makes the neural network can learn faster and more accurate. In this paper, the attribute mean will be used to fill in the missing value.

C. Artificial Neural Networks

Artificial Neural Networks is the mathematical models that developed to simulate the mechanism of neural network in the human brain. Single Layer Perceptron is an Artificial Neural Networks model that consists of one artificial network cell or neural. Figure 3 shows the structure of a perceptron.

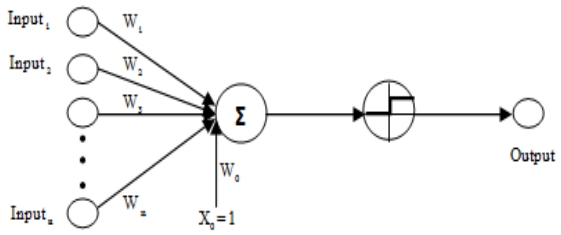

Fig. 3 Structure of a perceptron

Learning algorithm: Perceptron obtains input which is the real number. The corresponding weight is calculated by linear summation of input where (W1, W2, … , W3) is the weight of the stimulating binary function input. If the summation of the input which multiplied by the corresponding weight is over threshold; the output will be '1'. If not, it will be '0'. This algorithm is called 'Supervised Learning' as the learning of student is led by teacher. [3]

Multilayer Perceptron: MLP is widely used due to it can solve more complex problems; it can be applied with almost every type of work. However, the number of layer and neural must appropriate with that problem. Figure 4 illustrates the Multilayer Perceptron

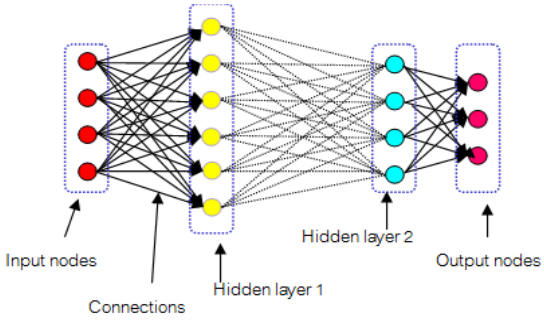

Fig. 4 Multilayer Perceptron

Learning Algorithm: Inputs of the first layer are the inputs to the network while the outputs of the last layer form the outputs of the network.

An input will be multiplied by every corresponding weight of each node and then sum. If the sum is over threshold; the neuron will send the output to be the input of another neuron that connected within the network. If not, the neuron will send nothing. The important variables are 'weight' and 'threshold' which correspond with the required value for the computer learning and let it can customize those variables itself and know 'back propagation' or 'feed-forward neural networks', a pattern that has algorithm to update network weight from output of the previous neural and compare with the threshold then calculate the error that will be sent back to the neural to update network weight further.

Transfer function: there are many transfer function used in neural networks i.e. Hard limit transfer function, Purelin transfer function, Log Sigmoid transfer function. Figure 5, 6 and 7 are transfer functions as the sample above which each function will give the different output according to the required output and this paper uses Log Sigmoid transfer function because the required output is between 0 and 1.

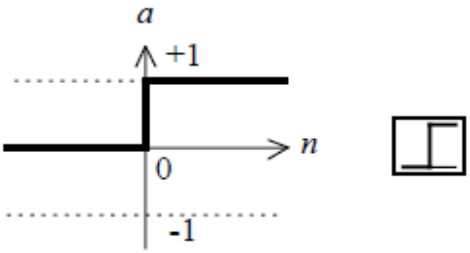

Fig. 5 Hard limit transfer function

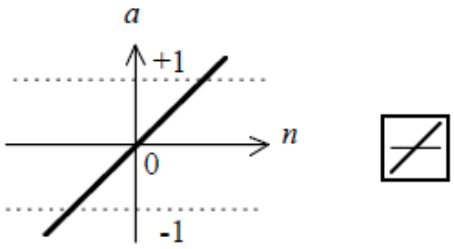

Fig. 6 Purelin transfer function

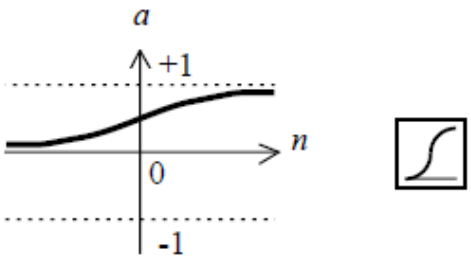

Fig. 7 Log Sigmoid Transfer Function

D.The Efficiency Evaluation by ROC (Receiver Operating Characteristic Curve)

It is a tool used to evaluate the prediction efficiency of accuracy. ROC graph is the relation between True Positive Rate (TPR) and False Positive Rate (FPR) as shown in Figure 8. The efficiency of neural network from the prediction can be evaluate by terms of Sensitivity and Specificity underneath sample size n considering the number of prediction result in Table I [4]

TABLE I
THE PREDICTIONS OF THE NUMBER OF EVENTS IN CONFUSION MATRIX

		Failure symptom of QST from Expert	
		True	False
Prediction failure symptom from neural network	Positive	A True positive	B False positive
	Negative	C False negative	D True negative

From Table I other values can be calculated from

$$\text{Sensitivity} = \frac{a}{a+c} \quad (1)$$

$$\text{Specificity} = \frac{d}{b+d} \quad (2)$$

$$\text{Accuracy} = \frac{(a+d)}{(a+b+c+d)} \quad (3)$$

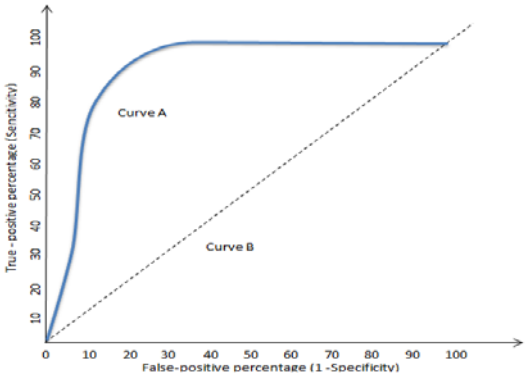

Fig. 8 ROC curve

From Figure 8: X-axis is False-Positive rate that means the finding root cause of the failure symptom of hard disk drive is not related to reading head. Y-axis is True-Positive rate that means the root cause is related to reading head and the system can predict the root cause precisely. The area under the ROC curve is the indicator of reliability of the system which showing the efficiency of head failure symptom classification in hard disk drive.

IV. Process of Conducting Research

A. Problem Study and Procedures

Complex and difficult knowledge and proficiency are needed in order to investigate and analyse the failure symptom of reading head; the error can be possible if the analyst has those attributes not enough. To prevent that error; multilayer perceptron neural network is applied to classify the failure symptom of reading head. The procedures of the study starting from normalization of the result data from Quasi-static test following the conclusions that specified by the experts including choosing interesting conclusions and normalize the data, the data is divided into two sets including learning and testing data set. From data grouping technique, next procedure is making neural network. The procedures is shown in Figure 9

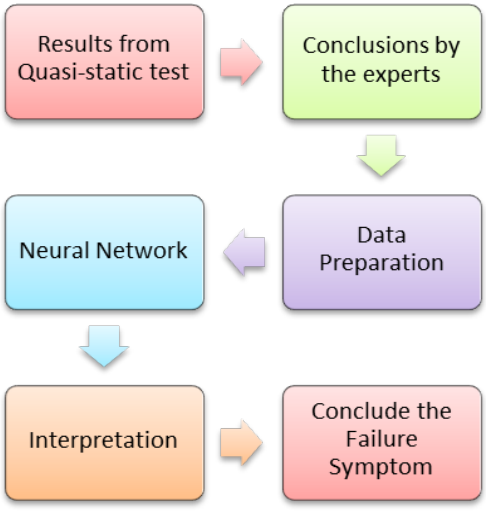

Fig. 9 Research Procedures

B. Data Preparation

This paper used the results from Quasi-static test to test reading head in the form of hard disk drive with both high and low frequency by zero magnetic field. This study used Multilayer Perceptron neural network, supervised learning, to learn the neural networks. There are 1000 of data set used in this study, 18 conclusions from the expert. Output from variation is between 0 – 1.5 as shown in Figure 10

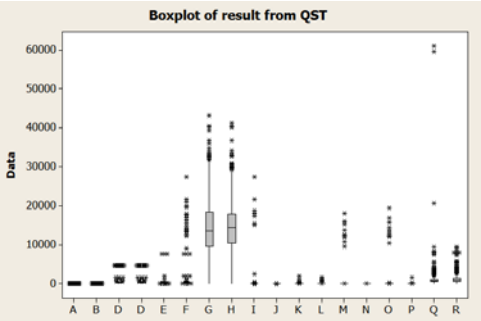

Fig. 10 Box plot shows the distribution of data result variation from Quasi-static test

Output data for learning is equal to input; 1000 unit. The output data will be only 0 and 1 (0 means the failure is not caused by head and 1 means the failure is caused by head). The expert distinguished failure from head to 18 types i.e. High write resistance, Write fault, Head asymmetry and so on. 2000 unit of data was used in the test which the data that used for learning and testing are different.

V. Overall Results

Feed forward back propagation neural network is applied in this study and chose Trainbr (Bayesian regularization) algorithm because its improvements of memory usage and speed of learning that is better than other algorithms [5]. The number of neural in hidden layer that used in this study derived from randomization 10 – 20 of neural that gives the lowest of SSE (Sum Squared Error) while the learning of the neural network

TABLE III
SSE FROM THE RANDOMIZATION

The number of neural	SSE
20	1190
19	1110
18	1050
17	1130
16	1100
15	1140
14	1120
13	1130
12	1180
11	1190
10	1110
20	1190
19	1110
18	1050
17	1130

Calculated the appropriate number of hidden layer after getting the number of neural in the hidden layer, by testing the accuracy of head failure prediction from hidden layer 1 to 3 as shown in Table III

TABLE IV
THE ACCURACY PERCENTAGE OF HEAD FAILURE PREDICTION IN EACH LAYER

Number of neural	Hidden Layer Layer1	Layer 2	Layer3
18	82.8%	86.9 %	96.06%

The highest accuracy percentage is layer 3 and the number of neural in each layer is 18 cells. Table 5.3 shows the accuracy percentage of the neural networks for each form that transfer functions placed in each layer.

TABLE V
ACCURACY PERCENTAGES OF NEURAL NETWORKS FOR EACH FORM OF TRANSFER FUNCTION

LAYER 1	LAYER 2	LAYER 3	Accuracy (%)
TANSIG	TANSIG	LOGSIG	96.06
TANSIG	PURLIN	LOGSIG	63
TANSIG	LOGSIG	LOGSIG	89.7
PURIN	PURIN	LOGSIG	95.6
PURIN	TANSIG	LOGSIG	79.9
PURIN	LOGSIG	LOGSIG	92
LOGSIG	LOGSIG	LOGSIG	92.1
LOGSIG	TANSIG	LOGSIG	92.1
LOGSIG	PURIN	LOGSIG	92

According to the table, the highest is 96.06% with Layer 1: TANSIG, Layer 2: TANSIG, and Layer 3: LOGSIG for producing the output to be 0 and 1.

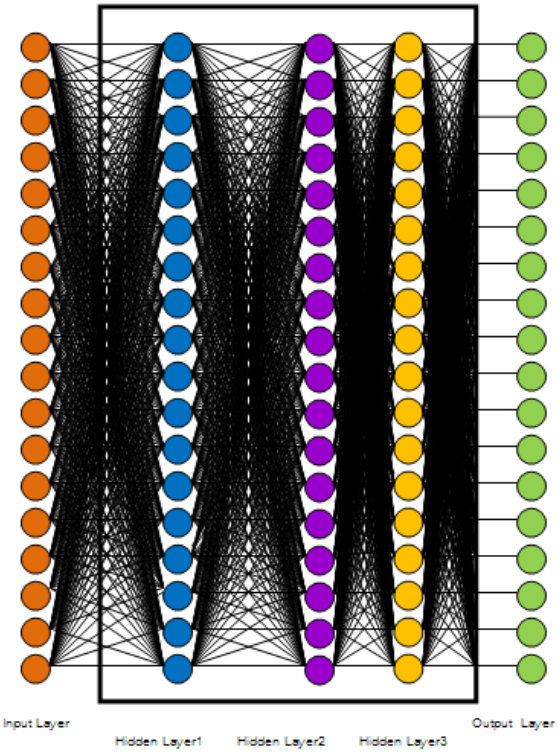

Fig. 11 Neural Network diagram that used in this study

There are many tools that used for reliability verification. Receiver Operating Characteristic is the method that brings the relation between the results (conclusions), True Positive Rate (TPR) and False Positive Rate (FPR) from the experiment and be placed in the confusion matrix [6] as shown in Table 5

TABLE IV
HEAD FAILURE PREDICTIONS BY NEURAL NETWORK IN CONFUSION MATRIX

		Head failure conclusions by the experts	
		Correct	Correct
Head failure predictions by neural network	True Positive	85.16	2.56
	True Negative	14.83	97.43

According to the results, the cause of failure of hard disk drives that is from reading head, faulty head; the neural network could predict that the faulty head is the head that will be found the abnormality truly (True positive) with accuracy percentage at 85.16%. In contrast, it could predict that the good head is the head that will not be found the abnormality (True negative) with accuracy percentage at 97.43%. The accuracy percentage mean from the confusion matrix is 91.3%. Sensitivity or True Positive Rate of this study which is the ratio of the defective hard disk drive that the cause is reading head with all defective hard disk drive. For reliability and suitability of the algorithms application in the study; the result with high sensitivity should be used wherewith it is properly for the result that is negative value, hard disk drive that has the inexplicit result or similar to the cut off value that used to separate the failure symptom. Figure 12 illustrates graph of the relation between true positive rate (Sensitivity) and false positive rate (1-Specificity)

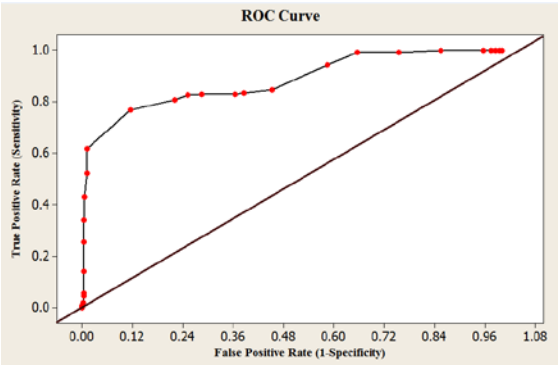

Fig. 12 Graph of the relation between true positive rate (Sensitivity) and false positive rate (1-Spectifity)

VI. CONCLUSIONS

This research is the usage of artificial neural network with feed forward back propagation in order to predict the failure symptom of reading head in hard disk drives using the result of Quasi-static test that measures the reading head of hard disk drive in the form of HDA as well as to create the tool that help to analyse the cause of failure symptom from reading head faster and more accurate. It is very useful wherewith the increase of data storage demand caused more and more hard disk drive capacity. To prevent the slow data access and storage and make it faster; the number of reading/writing head for each hard disk drive is higher which produced higher quantity of the complex data that needed more time to analyse and conclude by the experts. Each expert has unequal competency and experience; the conclusion from each one might be different. Especially, when analyse with the high quantity of the defect hard disk drive, the error can be easily possible. This study contributes the experts in order to increase the efficiency and decrease the time of data analysis. According to the algorithms that used in this study, it can predict the failure symptom similarly to the experts' conclusion which towards the further application of failure symptom analysis in other forms such as HSA and HGA.

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