การพัฒนาแบบจำลองเพื่อทำนายความน่าเชื่อถือของชั้นหล่อลื่นในฮาร์ดดิสก์ไดร์ฟ

นางสาวอนันตญา วงศ์คำลือ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตร์มหาบัณฑิต
สาขาวิชาวิศวกรรมเคมี ภาควิชาวิศวกรรมเคมี
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2556

MODELING OF RELIABILITY PREDICTION FOR LUBRICANT LAYER IN HARD DISK DRIVE

Miss Anantaya Wongkamlue

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Chemical Engineering
Department of Chemical Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2013

Thesis Title	MODELING OF RELIABILITY PREDICTION FOR LUBRICANT LAYER IN HARD DISK DRIVE
By	Miss Anantaya Wongkamlue
Field of Study	Chemical Engineering
Thesis Advisor	Assistant Professor Soorathep Kheawhom, Ph.D.

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

....Dean of the Faculty of Engineering

(Professor Bundhit Eua-arporn, Ph.D.)

THESIS COMMITTEE

....Chairman

(Assistant Professor Kasidit Nootong, Ph.D.)

....Thesis Advisor

(Assistant Professor Soorathep Kheawhom, Ph.D.)

....Examiner

(Pimporn Ponpesh, Ph.D.)

....External Examiner

(Pornchai Bumroongsri, Ph.D.)

อนันตญา วงศ์คำลือ : การพัฒนาแบบจำลองเพื่อทำนายความน่าเชื่อถือของชั้นหล่อลื่นในฮาร์ดดิสก์ไดร์. (MODELING OF RELIABILITY PREDICTION FOR LUBRICANT LAYER IN HARD DISK DRIVE) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร.สุรเทพ เขียวหอม, 65 หน้า.

งานวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนาแบบจำลองโครงข่ายประสาทเทียมในการทำนายความน่าเชื่อถือของชั้นหล่อลื่นในฮาร์ดดิสก์ไดร์ฟ โดยโครงข่ายประสาทเทียมที่ใช้เป็นแบบที่มีโครงสร้างหลายชั้น (Multilayer Perceptron) ด้วยเทคนิคการแพร่ย้อนกลับ (Back Propagation) และตัวแปรที่นำมาใช้คือค่าการเขียนทับ (Overwrite) ที่ได้จากการทดสอบฮาร์ดดิสก์ไดร์ฟเป็นระยะเวลาประมาณ 6 สัปดาห์ ผลการวิจัยพบว่าโครงสร้างของโครงข่ายประสาทเทียมที่เหมาะสมสำหรับการทำนายความน่าเชื่อถือของชั้นหล่อลื่นในฮาร์ดดิสก์ไดร์ฟ เป็นโครงข่ายประสาทเทียมแบบ 41,45,1 หรือโครงข่ายที่มีตัวแปรนำเข้า (Input) 41 ตัวแปร มีจำนวนหน่วยย่อย (Node) ในชั้นซ่อน (Hidden layer) เท่ากับ 45 หน่วยย่อยและมีข้อมูลส่งออก (output) เท่ากับ 1 ซึ่งให้ค่า Mean Square Error (MSE) น้อยที่สุด เท่ากับ 1.68 และ จากการทดสอบแบบจำลองที่ได้กับผลการทดลองจริง พบว่าแบบจำลองโครงข่ายประสาทเทียมที่สร้างขึ้นมีค่าสมรรถนะความถูกต้อง (Accuracy Performance) ประมาณ 91.74%

ภาควิชา วิศวกรรมเคมี ลายมือชื่อนิสิต ....

สาขาวิชา วิศวกรรมเคมี ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก ....

ปีการศึกษา 2556

5471046321 : MAJOR CHEMICAL ENGINEERING
KEYWORDS: NEURAL NETWORK / LUBRICANT LAYER / HARD DISK DRIVE / RELIABILIY

ANANTAYA WONGKAMLUE: MODELING OF RELIABILITY PREDICTION FOR LUBRICANT LAYER IN HARD DISK DRIVE. ADVISOR: ASST. PROF. SOORATHEP KHEAWHOM, Ph.D., 65 pp.

The artificial neuron network model with back propagation algorithm was developed successfully for reliability prediction of lubricant layer. The input variables are overwrite (OW) value by radius that collected from the hard disk drives which testing for 6 weeks. The result is indicated that the optimized artificial neural network model which is suitable for reliability prediction of lubricant layer is 41,45,1 that consistent of 41 input variables, 45 nodes in hidden layer and 1 output. The predicted results of this model provide the mean square error is 1.68. From the testing model results that compared the experiment output and predicted output observed the model can achieved the accuracy performance 91.74%.

Department:	Chemical Engineering	Student's Signature	....
Field of Study:	Chemical Engineering	Advisor's Signature	....
Academic Year:	2013		

ACKNOWLEDGEMENTS

This thesis will never be completed without the help and support of many people and organizer who are gratefully acknowledge here. Firstly, I would like to express my sincere gratitude to Assistant Professor Soorathep Kheawhom, my adviser for his suggestion, guidance, warm encouragement and generous supervision throughout my master program. I am also grateful to Assistant Professor Kasidit Nootong and Dr.Pimporn Ponpesh for their helpful and many valuable comments.

I wish to express my sincere indebtedness to my parents, everyone in my family and my friends for their inspiration and worthy support at all times.

CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 Research Motivation

In the past several years, the primary storage device for computers has been the hard disk drive (HDD). It has been continuous demands for high performance and high capacity HDD. These requirements lead to increase the areal density as well as increase in rotation speed of HDD. The areal density is the amount of data that can be packed onto a storage medium and generally measured in bits per square inch. Expected to reach 10 Tb/in^2 by the year 2014, because of the areal density increase, it was possible to make smaller HDD with larger capacities and cheaper prices. As HDD technology is rapidly year over year to support the highest customer demand which is require highest capacity to store the digital media information. To keep it in storage device, this is challenging for HDD industry to quickly lunch new product that able to support the requirement and highest product's reliability. As a result, HDD could find new applications in consumer electronics (CE) devices. MP3 player, video recorders, video camera and many other devices are using HDD to store information.

Basically, the key components of HDD are head and recording media. The conventional recording media typically consists of an Al or glass substrate, a Ni-P undercoat, Cr-X alloy under-layer, and a cobalt-based metal alloy magnetic layer. Then a carbon overcoat is added to enhance the wear and corrosion resistance. Finally, a molecularly thin layer of lubricant (widely-used perfluoropolyethers) is added to further reduce wear of the overcoat and friction between the head and media. The wear durability of the media depends strongly on retention and replenishment of the lubricant on the protective overcoat surface. With continuous increase in areal density, the head media spacing (HMS), containing head overcoat, media overcoat, lubricant film, and fly height, is expected to reduce to 6.5 nm. With such stringent space requirements within the HMS, intermittent contact phenomena between head and recording media during the operation become a critical issue, causing serious lubricant depletion on the film. Therefore, film thickness and self-healing ability of the lubricant becomes critical to head-disk interface (HDI) design to maintain long-term reliability of HDD.

Nowadays, the hard disk drive industry used to statistical technique for projection the failure of their products, which is depended on reliability demonstration result while product's qualification and ongoing reliability test monitoring result to determine the customer filed return. The ongoing reliability test is widely used to monitor the production performance based on the time to failure. Now new HDD generation has higher level of complexity, which is complicated to determine the failure. The failures escaped from the reliability test is the critical issue in the industry, with this problem the company got the complaint from the customers and need to returned the failures drives back for further investigated the root cause that charged the expensive cost. In order to meet and exceed customer expectations, a prediction modeling at early test duration needs to be taken that will help to protect the potential failure drives shipping to customers. Recently, there are 5 critical failures mode such as head degradation, lube material transfer to the head, media defects and head instability occurred in customer filed applications.

In this work, we will focus on lube migration of recording media. The Overwrite (OW) is one of critical parameter which is collected during reliability test. This parameter is a clear indicator for the lube migration failure. In order to predict the overwrite parameter pattern we will use the Artificial Neural Networks (ANN) or called Neural network (NN) models which widely used and famous intelligent system to discover the relationship between the variables. The learning and predicting of the networks are based on time series data which are collecting from ongoing reliability test.

So far reliability prediction of lubricant performance in Hard disk drives is not published in the paper due to the company confidential. As a result we are expected to be able to capture the potential failures drives before shipping to customer that can make the customer satisfactions and will be affected to the growth of demand.

1.2 Research Objectives

1.2.1 To study the overwrite parameter that relevant to lubricant performance in hard disk drive reliability testing.

1.2.2 To design the neural network models with back propagation algorithm for prediction the failure drive samples.

1.3 Research Scopes

1.3.1 To collect the data set of overwrite parameter by radius during the test operation for used as data input for neural network model.

1.3.2 To build up the neural network model with back propagation algorithm by using Pythia version 1.02 programs including training and verification model for prediction the amount of failure drive.

1.3.3 To compare the prediction data by neural network model with the real experiment data in reliability testing.

1.4 Expected Results

To be able to build up the neural network model for prediction the potential failure drive relevant to lubricant performance by overwrite parameter in hard disk drive reliability test before shipping the drives to customer in order to meet and exceed the customer expectation that will be affected to the demand growth.

CHAPTER II

LITERATURE REVIEW

This chapter is associated with literature reviews of representative report involving reliability of hard disk drive, reliability modeling and lubricant layers on media disk. Previously reports are initiation of this work and can be summarized as follow.

2.1 Reliability of hard disk drive

Yu Wang, Qiang Miao and Michael Pecht (2011) studied the potential failure mechanisms of hard disk drive based on Mahalanobis distance using S.M.A.R.T (Self-monitoring, Analysis, and Reporting technology) which measure the performance of drives characteristic. It collects the attributes of drives during operation that the keys attributes used for predict failures are track seek retires, read errors, write faults, reallocated sectors, head fly height and environmental temperature. For SMART algorithm now can detected the failures only 3-10% so this paper developed to improve the failure detection up to 63%. The majority of drives failures is mechanical and found 60% are head disk interface (HDI) the head disk space and head flying height decrease with magnetic recording density increase. The disk has a very thin layer of lubricant coated to prevent head touch the magnetic layer. Head in contact with the disk can cause lubricant depletion, build up, redistribution or modulation. The lubricant pattern formed on the media can lead the head soft contact or flying height modulation.

Andrei Khurshudov and Peter Ivett (2003) studied the different technique for head disk contact detection in hard disk drive. It can be caused by drives particulate contamination or wear product, disk lubricant via formation of liquid bridges or lubricant dewetting mechanism. In this paper is to test and compare traditional acoustic emission (AE) measurement to variable gain amplifier (VGA) signal and thermal asperity (TA) detection. The AE techniques based on measurement of elastic stress waves propagating in solids form, VGA signal is the signal from internal drive circuit during the read back from the disk and the TA is the event of the magneto-resistive (MR) read element of the slider touches the disk surface.

2.2 Reliability modeling

Waraporn Tepin and Yuttana Kidjaidure (2011) proposed the model for prediction the customer failure modes in hard disk drive by using neural network range level fusion. The key parameters as media roughness, number of thermal asperities (TA), head disk spacing, dynamic fly height, head touchdown, overwrite and testing temperature. The data are collected from pass and fail samples at customer integration station and used the principal component analysis (PCA) to screen the importance data. In this paper used feed forward neural network which assign 6 neurons as in put layer, 16 neurons as hidden layer and 2 neurons as output layer for predict the result in Pass or Fail that this model able to achieve 86.61% accuracy.

2.3 Lubricant layers on media disk

T. Liew et al. (2003) investigated the corrosion of magnetic recording head and media by used contact start stop (CSS) testing. The media disk and head protected the corrosion and wear by an ultrathin carbon overcoat but it will occur when the overcoat is defective due to deposition. The corrosion is accelerated by humidity, temperature and corrosive contaminants, to reduce this possibility, the galvanic mismatch between the magnetic layers and the overcoat is minimized and Cr is added to the Co-alloy and hydrophobic lubricant layers on the protective carbon coat. The corrosion products are mainly oxides or hydroxides of the various corrosion susceptible materials in the media disk and head.

CHAPTER III

THEORY

3.1 Hard Disk Drive Reliability test

The hard disk drive is a highly complex, electromechanical device. The diagram of a computer hard disk drive including the magnetic head, disk, spindle, head stack assembly, pivot bearing, voice coil motor and base as shown in Figure 3.1. Disk is made of aluminum or glass substrate, covered with three thin layers with different materials. Upon the substrate, a magnetic layer is deposited to store the actual data. The magnetic material is usually ferric oxide or cobalt alloy. A diamond like carbon (DLC) layer is coated on the magnetic layer to reduce wear and slow corrosion. A thin lubricant layer is applied to prevent the head disk from hard contact. Head in contact with the disk could cause lubricant depletion, buildup, redistribution modulation. The schematic of head disk interaction (HDI) are shown in Figure 3.2.

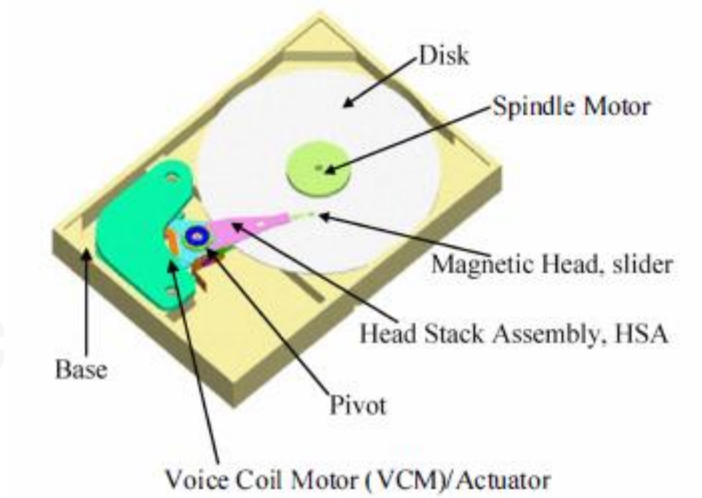


Figure 3.1 Diagram of Hard Disk Drive

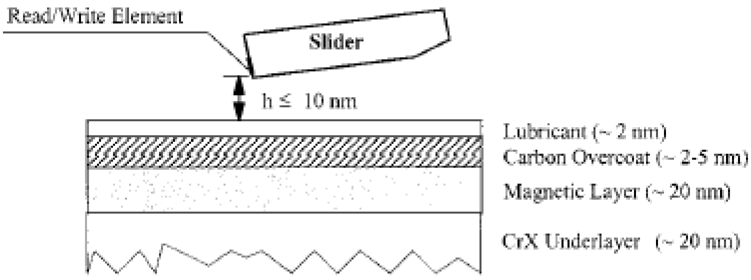


Figure 3.2 Schematic of head disk interaction

The accelerated life tests are methods for understanding reliability with the minimum sample size and the shortest test time. The JIS standard defines “accelerated tests” as “tests carried out under conditions more severe than standard conditions for the purpose of shortening the test time”. Conducting tests under these severe conditions makes it possible to predict market failure rates in a short time using few samples, thus reducing both the time and cost required to confirm reliability. Hard disk drive life is extremely sensitive to temperature so in this study used the acceleration by hot temperature. Several HDDs are installed in an environmental chamber, each HDD being connected to a central controller providing both power and data communication. During the operation the critical parameters has been monitored. The overwrite parameter is the one displaying the most degradation and lead to the performance of lubricant.

Traditionally, HDD industry used to weibull technique to predict AFR (annual filed failure rate) based on reliability true failures. The drives quality is independent of how long the drives runs, it is a basic property of the drives. TTF is mean how many hours an average drives will run until it fails. Generally, the reliability test can be classified in two categories, one is destructive test, and another one is accelerated test (parametric) as described in Figure 3.3.

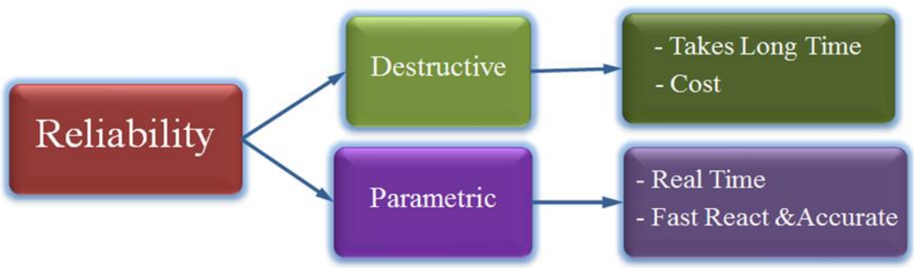


Figure 3.3 The construction of reliability test

3.1.1 Destructive test is one kind of reliability demonstration test in the past decade which is requires longer test time and waits until product is dead. This is to demonstration the drive life time service in field application however, it not flexible to gain the result.

3.1.2 Accelerated Test is one of electrical reliability test which recent used in HDD industry, this test perform with short time by force temperature, humidity voltage and current. This test is simulation of end-user when they use the hard disk drives in field.

In general, HDD industry was developed their products to meeting customer requirement from time to time, generation to generation in order to achieve the highest capacity demand for keep the information in some space and fastest access the data. The designer has increasing area density in magnetic spacing to gain the free space for storage the information, however, due to material property limitation both head and media to support this. The failure mechanism was changes from the particulate to the head disk interface failure so that it was affected to reliability demonstration testing which need to focus on reliability of head disk interface.

3.2 Ongoing Reliability test (ORT)

Ongoing Reliability test (ORT) is accelerated stress test for the head-disk interface that critically evaluates the robustness of any tribology design prior to shipment to the field. We have daily parametric monitoring and intelligent system trigger if any parametric data is over limits, MRR earliest indicator, SNR and Resolution (tracks head media spacing), MWW (writer degradation). ORT is reliability test to ensure product durability. This test is design used for head/media and interface improvement for check and early detection of reader, writer and interface issues. Due to current product has more complicated, complexity and the field failure behavior was changes compared to the past decade. This test provides visibility to cover expected drive life. The failure occurred during qualification can be separated in two category namely reliability true failure and reliability virtual failures.

3.2.1 Reliability True failures

Reader and Writer head is key driver for hard disk drives with retrieving and storing the data many times. Store mean write the data to device and retrieve mean read the data from device. This is basic function of hard disk drives. HDD manufacture used to reliability test to qualify their product in development phase and high volume build. Basically, a variety failure occur during reliability testing such as lubricant migration failure, particulate failure, head related failure which are critical issue for HDD manufacture the engineering team have to finding the root cause and provide the corrective action to address this issue to protect field. To ensure their product could be stand long in life time. They used true failure to project the annual failure rate (AFR) in field application. The reliability true failure is failed drives that fail during qualification and weilbull methodology is current used to projection the filed failure return rate.

3.2.2 Reliability Virtual failures

Reliability virtual failure is any drive that has violated a Critical Parameter limit on any head. This virtual failure rate (VFR) is key metric used by reliability engineering to monitor the head and media parametric performance. The degradation or change of critical parameter shown that this drives will become true drive failure in filed later. Virtual failures will be used during drive development testing to evaluate the integrity of the head-disk interface.

3.3 The Artificial Neural Networks

A neural net is an artificial representation of the human brain that tries to simulate its learning process. An artificial neural network (ANN) is often called a "Neural Network" or simple Neural Net (NN). A neuron is an information-processing unit that is fundamental to the operation of a neural network. We may identify three basic elements of the neuron model.

3.2.1 A set of synapses, each of which is characterized by a weight or strength of its own. Specifically, a signal x_j at the input of synapse j connected to neuron k is multiplied by the synaptic weight w_{kj}. It is important to make a note of the manner in which the subscripts of the synaptic weight w_{kj} are written. The first subscript refers to the neuron in question and the second subscript refers to the input end of the synapse to which the weight refers. The weight w_{kj} is positive if the associated synapse is excitatory; it is negative if the synapse is inhibitory.

3.2.2 An adder for summing the input signals, weighted by the respective synapses of the neuron.

3.2.3 An activation function for limiting the amplitude of the output of a neuron. The activation function is also referred to in the literature as a squashing function in that it squashes (limits) the permissible amplitude range of the output signal to some finite value. Typically, the normalized amplitude range of the output of a neuron is written as the closed unit interval [0, 1] or alternatively [-1, 1].

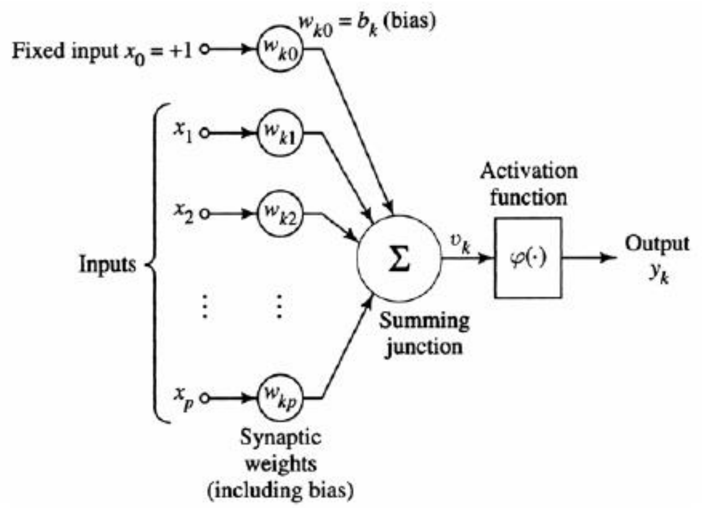


Figure 3.4 The Non-Linear model of a neural $V_k = \sum_{j=0}^{p} W_{kj} X_j$

3.4 Back-propagation networks

Multilayer perceptron have been applied successfully to solve some difficult diverse problems by training them in a supervised manner with a highly popular algorithm known as the error back-propagation algorithm. This algorithm is based on the error-correction learning rule. Basically, the error back-propagation process consists of two passes through the different layers of the network: a forward pass and a backward pass. In the forward pass, activity pattern (input vector) is applied to the sensory nodes of the network, and its effect propagates through the network layer by layer. Finally, a set of outputs is produced as the actual response of the network. During the forward pass the synaptic weights of network are all fixed. During the backward pass, on the other hand, the synaptic weights are all adjusted in accordance with the error-correction rule. Specifically, the actual response of the network is subtracted from a desired (target) response to produce an error signal. This error signal is then propagated backward through the network, against direction of synaptic connections hence the name "error back-propagation". The synaptic weights are adjusted so as to make the actual response of the network move closer the desired response. The error back propagation algorithm is also referred to in literature as the back-propagation algorithm or simply back-prop. The feed-forward back-propagation neural network in Figure 3.4 is fully connected which means that a neuron in any layer is connected to all neurons in the previous layer. Signal flow through the network progresses in a forward direction, from left to right and on a layer by layer basis.

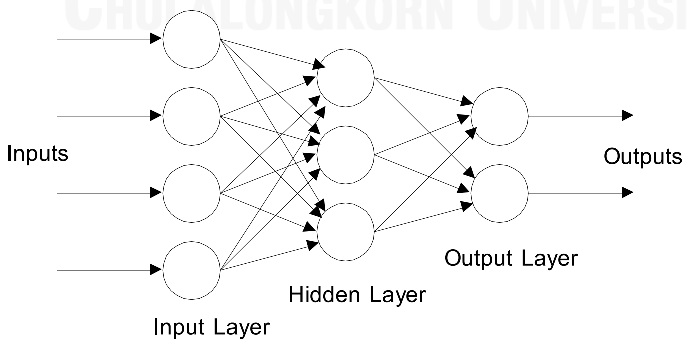


Figure 3.5 Diagram of a feed-forward back-propagation neural network.

The performance of neural network based upon the result of the testing set. For this study the mean square error (MSE) and root mean square error (RMS) will be used for verification the neural network model as the lowest value is the best of model. The MSE and RMS equation are shown as below.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - p_i)^2 \tag{3.1}$$

$$RMS = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - p_i)^2} \tag{3.2}$$

The accuracy performance of model can be calculated from root mean square percent error index (RMSP error index) and maximum percent error index (MP error index) as the equation below.

$$RMSP = \sqrt{\frac{\sum_{i=1}^{n}(y_i - p_i)^2}{\sum_{i=1}^{n}(p_i)^2}} x100 \tag{3.3}$$

$$MP = \frac{\max|y_i - p_i|}{\max|p_i|} x100 \tag{3.4}$$

$$Accuracy = 100 - \frac{\sum_{i=1}^{n}(RMSPxMP)}{n} \tag{3.5}$$

CHAPTER IV

METHODOLOGY

This chapter is contributed to reliability test method for the data set collection and build up the neural network as prediction the lube migration failure is proposed. Pythia program is used for neural network designer and the network performance also investigated as follow.

4.1 Reliability test method

The hard disk drives are installed in an environment chamber as shown in Figure 4.1, each hard disk drive being connected to a central controller providing both power and data communication. The overwrite parameter will be collected during the test operation. The average delta value will be measured by radius in decibel (dB) unit and data transferred every 24 hrs. A recording media divided into 3 zone of radius which are outer diameter (OD), middle diameter (MD) and inner diameter (ID) so during the test operation among 1008hrs, the data set will be collected as the matrix [3x42]. The failure drive definition in this study is the average delta value of overwrite changed more than 3 dB that associated with lube migration problem. The testing conditions are summary in Table 4.1.

Figure 4.1 The environment chamber or Single Plug tester (SPT)

Table 4.1 Reliability testing condition

Items	Detail
Reliability test name	Ongoing Reliability Test (ORT)
Tester type	Single Plug Tester (SPT)
Temperature setting	60°C
Test duration	1008hrs (42 loops)
Test operation	Read and Write data
Data collection	overwrite by radius (OD, ID and MD zone)
Data transfer	1 time (loop) / 24 hrs
Fail criteria	Average delta overwrite decrease or increase > 3 dB

The definition of overwrite (OW) is write a pattern with frequency f1 and measured its average amplitude A1, then write another pattern with frequency f2 on the same track over the same pattern. A residual signal at frequency f1 is measured. The pattern has amplitude A2. The overwrite ratio = 20 log (A2/A1) and reported in reverse OW for perpendicular media recording (PMR) that the current we used in the factory.

4.2 The neural network models

In this work, the neural network models with back propagation algorithm will design by Pythia program. The key steps for build up the networks can be summary as follows.

4.2.1 Data set collection

The input data for neural network models will be collected from 1000 drives passed samples and 250 drives failed samples which are completed test for 1008hrs or 42 loops in ongoing reliability test. The overwrite value by radius are measured during the test operation and transferred to the server in each of hard disk drive. The failed drives criteria in this work means the average delta overwrite value variance more than 3 dB both of negative and positive values as shown in Figure 4.2. For neural network designed, the data set collection will divided into 3 groups as 70% of data set will be used for training, 20% for verification and 10% for testing the neural network models.

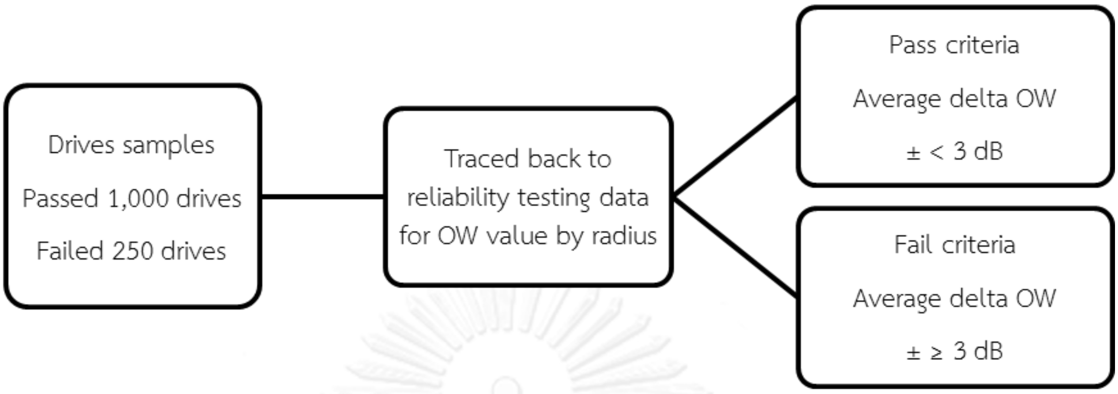


Figure 4.2 Diagram of data set collection in reliability test

4.2.2 Design the neural network models.

Pythia program is used for design the neural network with back propagation algorithm. The key parameters of network are input, weights, activation function and output. In this work the input is OW value and output is average OW value. The network parameters are summary in Table 4.2.

Table 4.2 Summary of the network parameters

Network parameters	Details
Training algorithm	Back Propagation
Input data	OW value by radius for 41 loops tested
Weights	[-1,1]
Activation function	Sigmoid function
Output data	Average OW value
Prediction	Percent of failure drives

4.2.3 Training and Verification the neural network models

The neural network models will learn the input and output patterns from all the network parameters which are input to design the models. The Pythia program will be generated the models which are corresponding to the setting value. The models need to verify by the verification data. The models which have mean square error (MSE) and root mean square error (RMS) lowest will be selected for this work.

4.2.4 Testing the neural network models

The selected model will be tested by unknown data set and compared with the experiment data for 125 drives samples. The accuracy performance of models will be calculated from RMSP error index and MP error index.

CHAPTER V

RESULTS AND DISCUSSION

This chapter is explained the method of data collection and accuracy performance of neural network model which are tested with the unknown data and compared with the experiments data. The proposed of this model is reliability prediction for lubricant layer.

5.1 Data set collection

We are studied the customer field return failures in year 2012-2013 as shown in Figure 5.1, found that the lube issue is the most critical issue as 33.5% of total failures followed by head issue 31.8%, media defect 15.2%, others 12%, contamination 5% and mechanical 2.5% respectively. So in this work, the lube issue failures will be focused to find out the method to capture the failures in reliability test to avoid the failures drives escape to the customers.

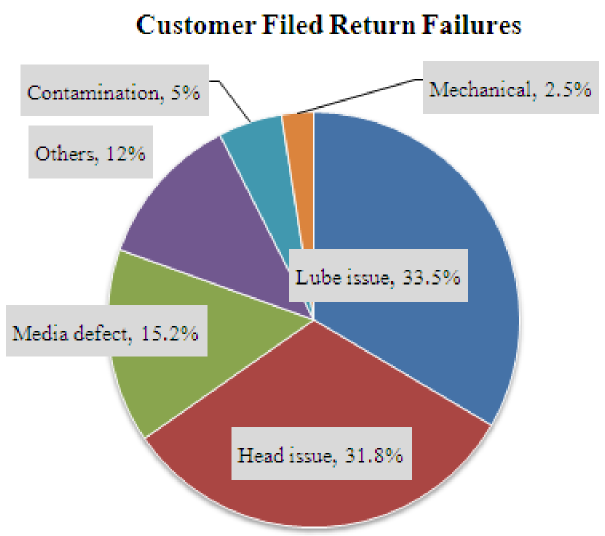


Figure 5.1 The customer field return failures in year 2012-2013

Currently, there are 5 critical parameters that are collected during hard disk drive ongoing reliability test. There is Error margins (EM), Voltage gain amplitude (VGA), Magneto resistive resistance (MRR), Overwrite (OW) and Signal to noise ratio

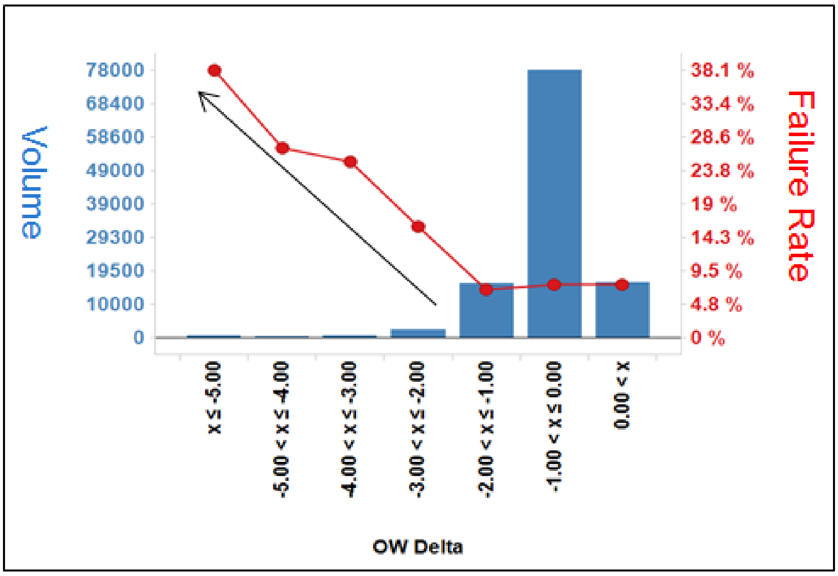
(SNR) as summarized in Table 5.1. The relevant of each parameter to customer filed return failures are not clearly indicated and under investigated. So far we had known that EM, VGA and MRR indicated to the head degradation symptom. The OW and SNR indicated to the Head disk interaction issue. Each of parameters is monitored and collected the data purpose to design the limit specification in future work. So in this work, we are pulled data the critical parameter of the drives which are passed and failed with Lube migration issue at the customer filed return during tested in ongoing reliability test.

Table 5.1 The critical parameter of ongoing reliability test

Parameters	Error margins (EM)	Voltage gain amplitude (VGA)	Magneto resistive resistance (MRR)	Overwrite (OW)	Signal to noise ratio (SNR)
Unit	dB	dB	dB	dB	Ohms
Data type	By Head	By Radius	By Head	By Radius	By Radius
Measurement	Delta	Average Delta	Percent change	Average Delta	Average Delta
Change	Decrease	Increase / Decrease	Increase / Decrease	Decrease	Decrease

The correlation of customer field return and ongoing reliability test for overwrite parameter as shown in Figure 5.2. The stack is represented the drives volume that shipped to customer and tested in ORT in year 2012-2013. The line is represented the Lube migration failures and also breakdown by overwrite delta value. Based on the trend chart observed the high risk of Lube migration failures more than 10% had the overwrite delta value < -3dB for customer field data and we also did the further statistical analysis to ensure the accuracy and precision of the limit change of overwrite parameter. The overwrite parameter is indicated the write ability of the head to re-write on the existing signal with no old signal left or it is characterizes the ability of a writer to write or erase over old data. The factor of write ability that is depend on recording layer properties and write gap while writing or head media spacing which are following dynamic high fly and touchdown values. So, the probability of overwrite degradation are writer properties degraded, media queerness or write gap changed.

ORT Data



Customer Field Data

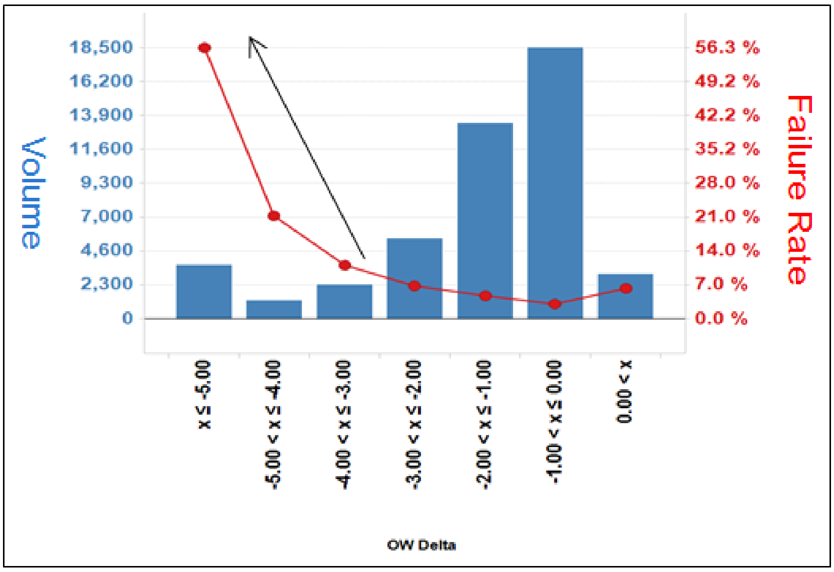


Figure 5.2 The correlation of ORT data and customer field data

The lube migration failure drives and passed drives were pulled the value of their parameters and used statistical analysis tool (JMP) for partition analysis which is extremely useful for both exploring relationships and for modeling. The partition analysis is a statistical method for multivariable analysis that created the decision tree as shown in Figure 5.3. The others trees fitting methodologies found in high-end and very expensive data mining package are CART, CHAID and C5.0. Since convenience data sets are often messy and unruly. The JMP display capabilities support the user in data cleaning. JMP partition platform is a version of classification and regression tree analysis. Both response and factors can be either continuous or nominal. The nominal factors are split into two groups of level and continuous factors are split into two partitions according to cutting values. The splits are determined by maximizing the likelihood ratio chi-square statistic reported in the JMP output as G^2 or a related value called the Log Worth. The G^2 square is the probability ratio chi-square for the best split and Log Worth defined as -log10 (p-value) that the optimal split is the one that maximizes the G^2 and Log Worth. As the result of decision tree the delta overwrite showed the maximize value of G^2 and Log Worth are 449.58 and 201.50 respectively that means the overwrite parameter is clearly indicator for the lube migration failure with the delta value more than 3dB.

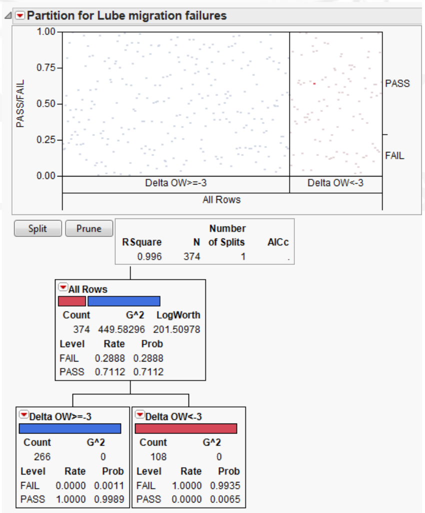


Figure 5.3 The decision tree of Lube migration failures drives and passed drives.

To understand the systematic of lube migration failure, we are also studied the media construction as shown in Figure 5.4 by transmission electron microscope (TEM). The key construction of media are substrate which is AlMg or glass, Recorded or magnetic layers that consisted of Soft magnetic under layer (~20 nm), seed layer and hard magnetic layer (~20 nm), carbon overcoat (COC) with thickness ~5 nm and the top layer is lubricant layer that coated with thickness ~ 2nm. The Lubricant that varied used in the industry is shown in Figure 5.5.

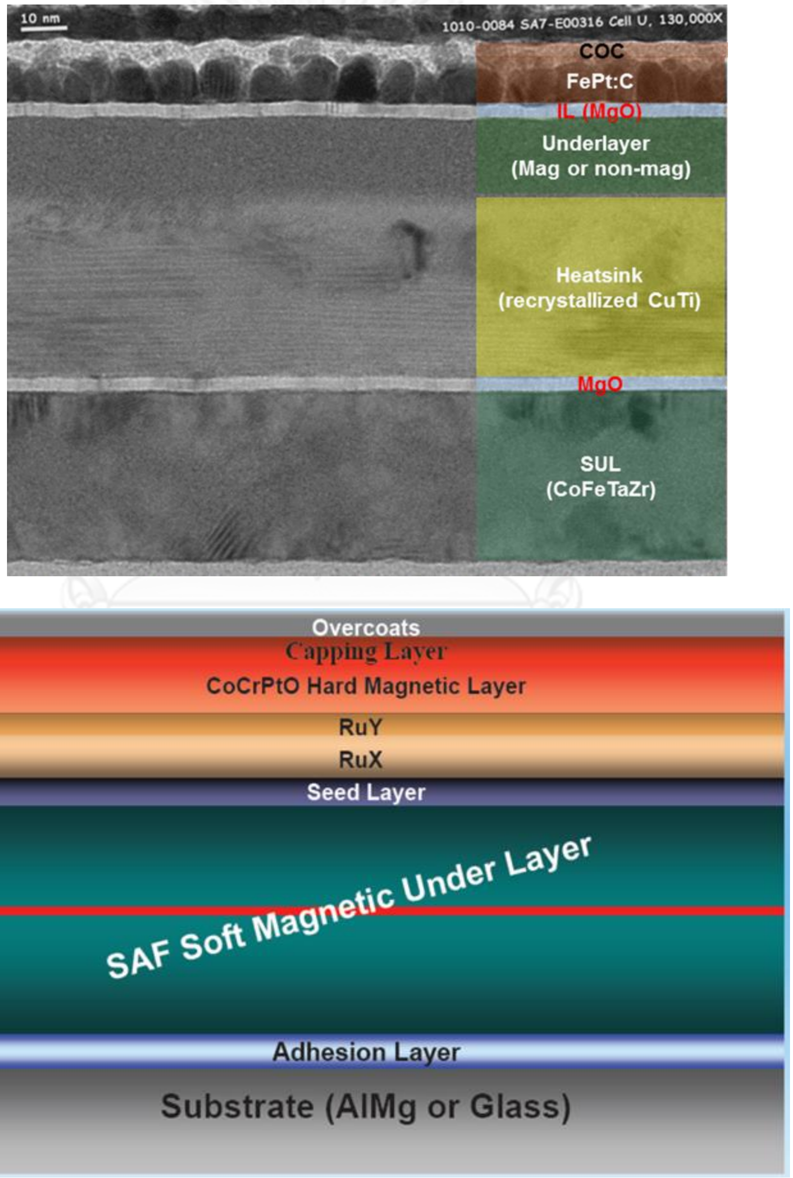


Figure 5.4 The recording media construction by TEM (cross section)

To ensure the overwrite parameter that delta changed more than 3dB indicated to Lube migration failure so we are sampled the failure drives and analyzed by Scanning electron microscope (SEM). The failure drives are observed a lot of lube migration at the trailing edge of the slider in Figure 5.6 and lube build up to disc material as shown in Figure 5.7.

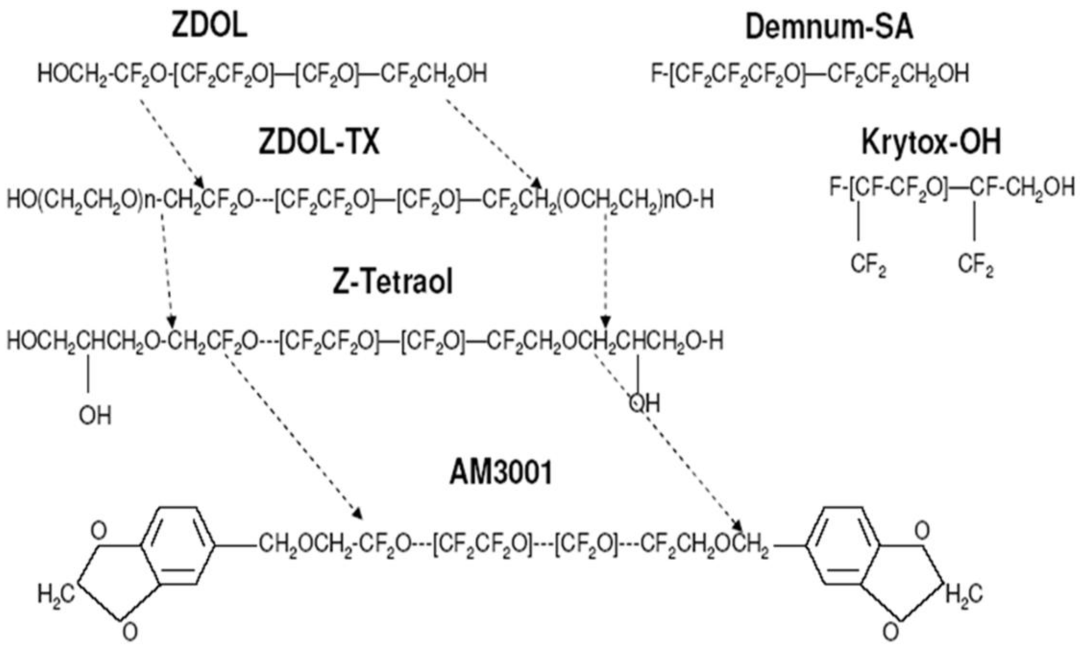


Figure 5.5 The commercial lubricant chemical structure

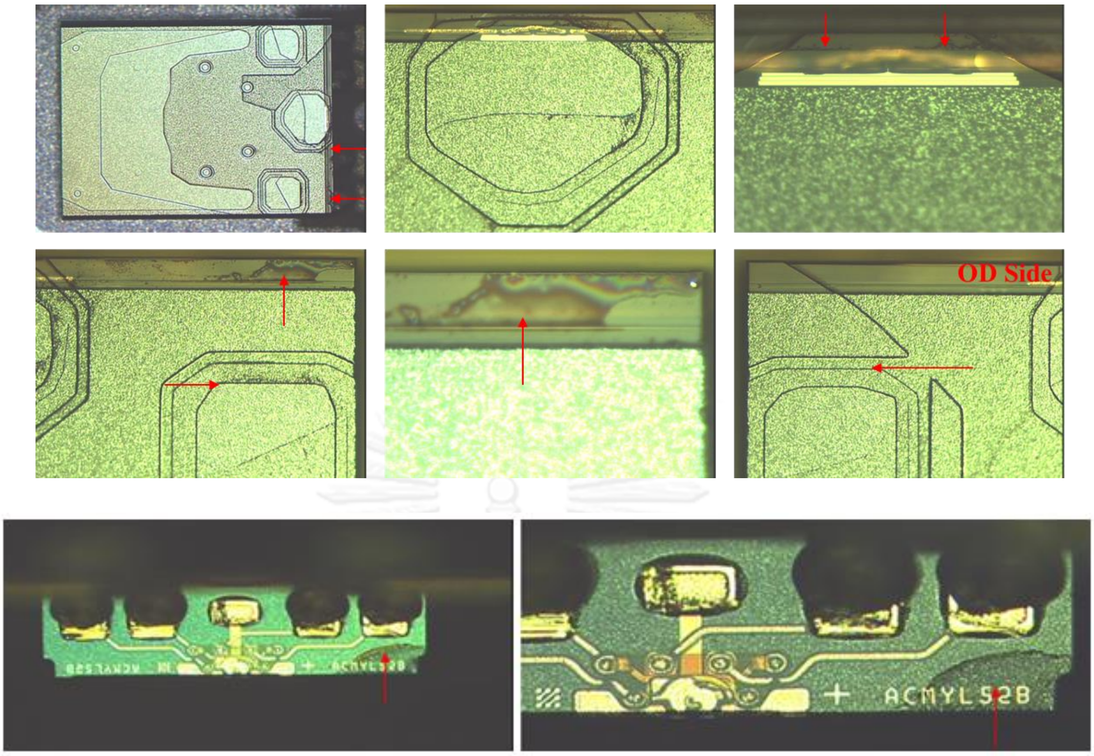


Figure 5.6 The lube migration at the trailing edge of the slider

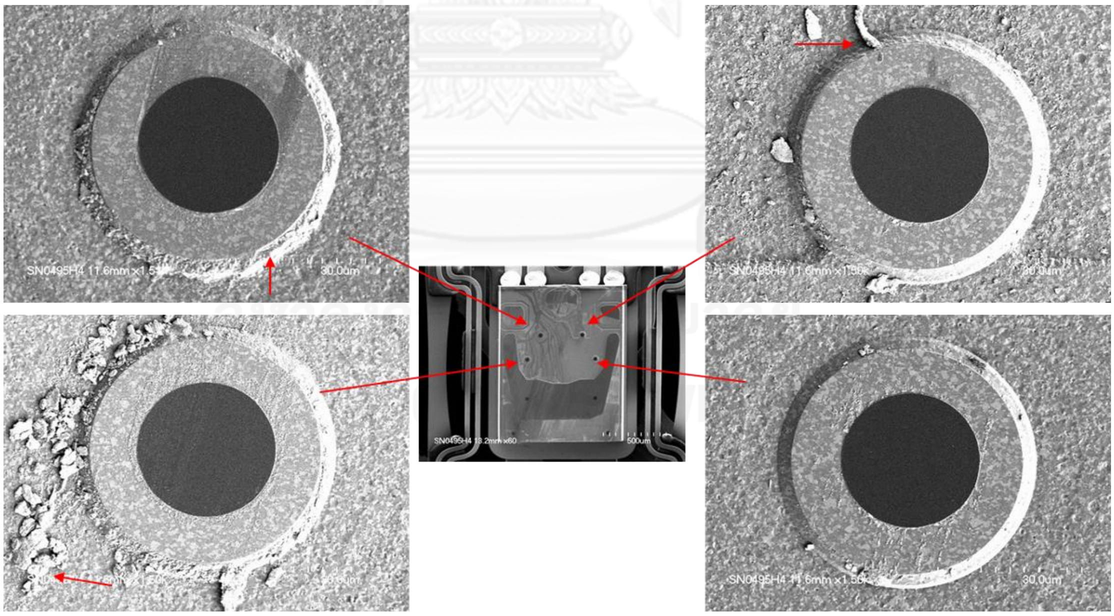


Figure 5.7 Lube build up to disc material

The value of overwrite parameter will be collected during the ongoing reliability test (ORT) which is measured by radius. There are outer diameter (OD), middle diameter (MD) and inner diameter (ID) in decibel (dB) unit. The data will be transferred at the end of every loop of reliability test which estimated a day per loop. The reliability required the total test time for 6 weeks or 42 loops test that this data will be used for input of neural network model. In this work the passer drives 1,000 samples and failed drives 250 samples will be collected the overwrite value for input data into the Pythia program.

5.2 Design the neural network model

In this work, the back propagation algorithm will be used. This algorithm allow signals to travel one way only from input to output, the output of any layers does not affect that same layer. This is extensively used in pattern recorgnition. The overwrite values by radius for 42 loops are input into the Pythia program for learning the pattern data set (See in Appendix A). The neural number and hidden layer are starting with trial input with the design goals of the square of max deviation and medium deviation less than 0.1 dB and 0.001 dB respectively as shown in Figure 5.8. The Pythia program is generated the neuron number and hidden layers that optimized with the goal as called topology. The four topology are generated that can be summary in Table 5.2.

Table 5.2 The optimized topology that generated from Pythia

Models	Topology	Hidden layers	Neurons
1	41,45,1	2	46
2	41,33,22,1	3	56
3	41,10,9,10,1	4	30
4	41,16,12,12,18,1	5	59

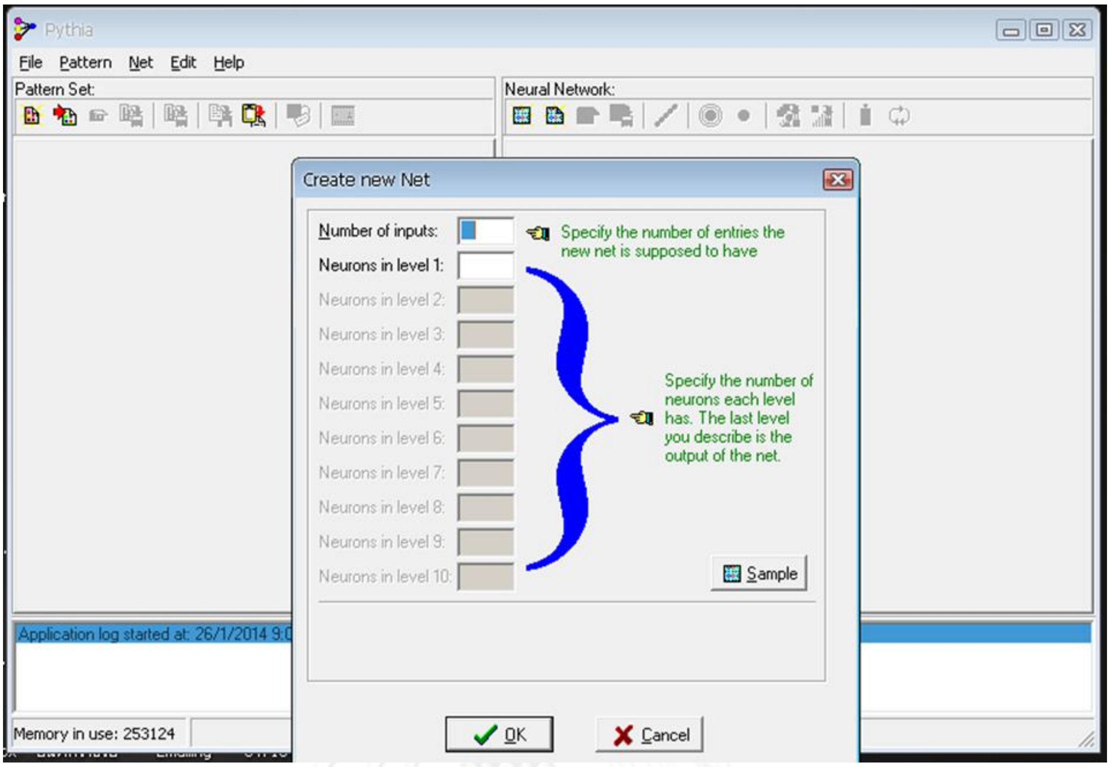


Figure 5.8 The trial input neural number and hidden layer into Pythia program

The activation function can be categorized to three types, there are linear, threshold and sigmoid. In this work we used sigmoid function that the output varies continuously but not linear as the input changes. Sigmoid bear a greater resemblance to real neurons than do linear or threshold. The optimized neural network models will be tested with the verification data set for compared the precision, the model that have the lowest of mean square error (MSE) and root mean square error (RMS) will be selected for this work.

5.3 Verification the neural network model

All of the optimized neural network models are verify with the same data set and setting parameter as shown in Table 5.3. The verification results, mean square error (MSE) and root mean square error (RMS) of all models can be summarized in Table 5.4 and full data set in Appendix A.

Table 5.3 Setting parameters

Parameters	Setting value
Activation function	Sigmoid
Weight	[-1,1]
Learn rate	0.5
Learn repetition	10,000 times

Table 5.4 Summary the MSE and RMS of all models

Models	Topology	Hidden layers	Neurons	MSE	RMS
1	41,45,1	2	46	1.68	1.30
2	41,33,22,1	3	56	1.85	1.36
3	41,10,9,10,1	4	30	3.64	1.91
4	41,16,12,12,18,1	5	59	1.73	1.31

From the verification models result showed that the neural network with topology (41,45,1) have the lowest mean square error (MSE) and root mean square error (RMS) so we will selected this model for this work. The number of neurons is the most significant affected to the MSE and RMS of models as the models no.3 has 30 neurons showed worst in class while the hidden layers slightly impacted. The disadvantage of higher number of neurons is longer processing time and limited application.

The data analysis for the overwrite output value of all models and compared with the actual output by box plot are shown in Figure 5.9. The neuron network models topology (41,33,22,1) and (41,16,12,12,18,1) showed higher amount of outlier data in negative while the topology (41,10,9,10,1) showed comparable amount of outlier data both of positive and negative. The median line which is the single line inside the box of the topology (41,45,1) showed the middle of value is -1.5 dB not statistically significant as compared with the middle of value of the actual output is -1.0 dB. The box position that represent the data distribution of topology (41,45,1) also showed 50% of data distribution overlapping with the box position of actual value that indicated smallest error as compare with the others models.

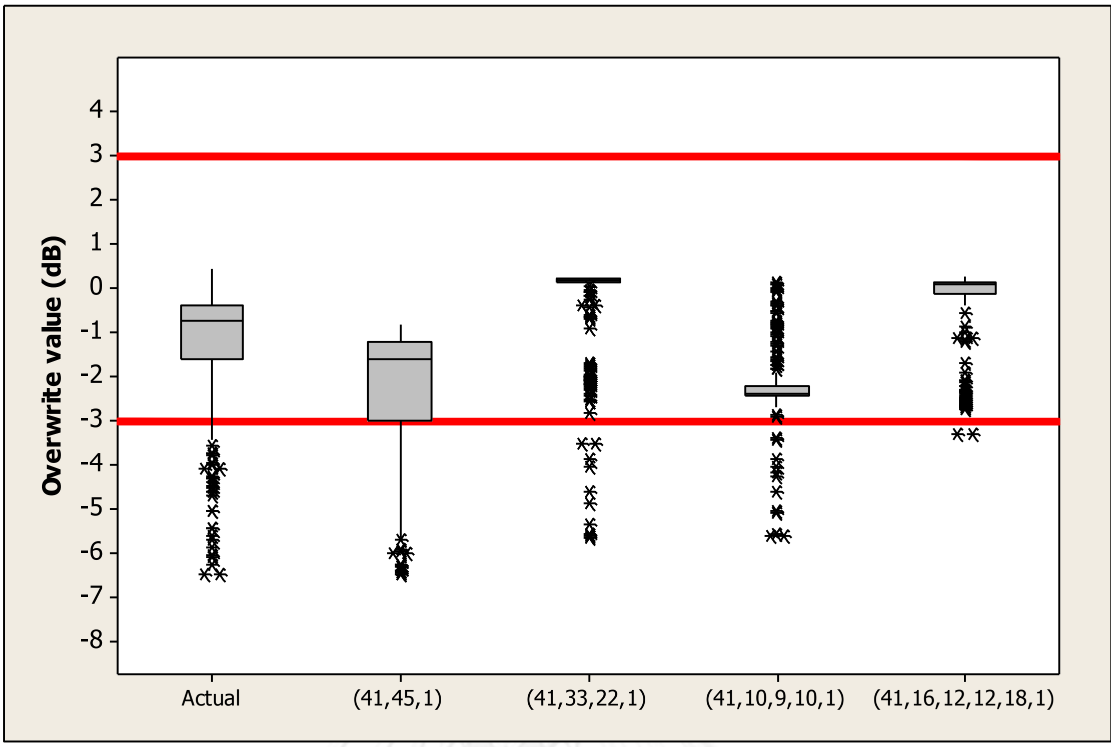


Figure 5.9 The box plots of overwrite output value of all models

5.4 Testing the neural network model

In this work, the neuron network model with 46 neurons and 2 hidden layers was developed for reliability prediction of lubricant layer as shown in Figure 5.10. The experiment was induced for testing this model. The 125 drives samples put into the chamber for 1008hrs and compare the result with the prediction output of (41,45,1) neural network model (See in Appendix B). The models predicted the failure rate is 21.6% while the experiment failure rate is 20% as shown in Table 5.5. Although the prediction output about 1.6% over the actual value but in manufacturing the over prediction is have the benefit for early trigger the problem.

Table 5.5 The percent of failure drives from the experiment and prediction output

Lubricant layer failure rate from experiment (%)	Prediction lubricant layer failure rate (%)
20.00%	21.60%

The Root mean square percent error index is 0.45 and maximum percent error index is 23.03 so this model have the accuracy performance is 91.74%. The detail of neural network model can be summarized in Table 5.6 and full detail in Appendix C.

Table 5.6 The detail of neural network model (41,45,1)

Items	Details
Neuron number	46 neurons
Hidden layers	2 layers
Mean Square Error (MSE)	1.68
Root Mean Square Error (RMS)	1.3
Root Mean Square Percent Error Index	0.45
Maximum Percent Error Index	23.03
Accuracy Performance	91.74%

The data analysis for the overwrite outputs value of (41,45,1) neural networks model compared with the actual output from the experiment are shown in Figure 5.11. The middle of value from the prediction output is -1.5 dB while the experiments output is -0.5 dB. The median delta is 1.0 dB is in acceptable level in the industry which is the maximum allowed at 3.0 dB. The box position of neural network model showed 80% of data distribution overlapping with the experiment data.

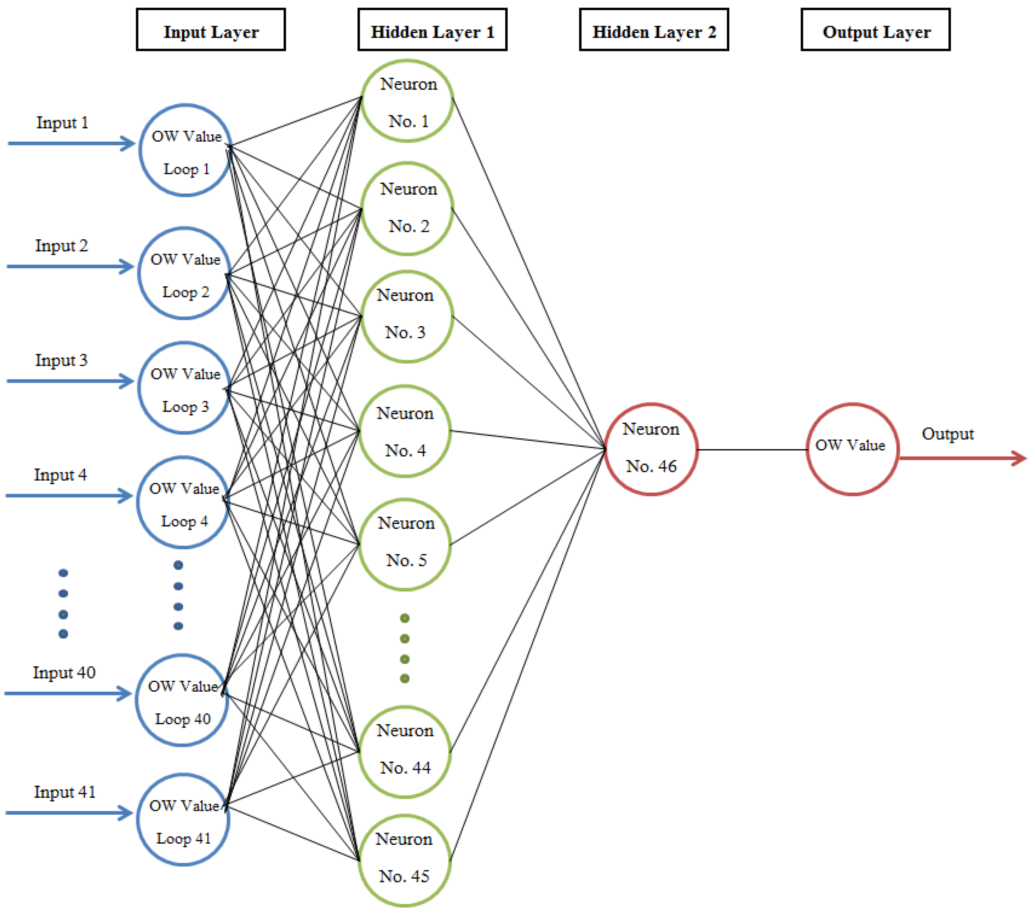


Figure 5.10 The neuron network model with topology (41,45,1) for reliability prediction the lubricant layer

The failure drives that the overwrite parameter delta change more than 3 dB from the prediction model, we are selected a drive for analyzed by scanning electron microscope (SEM). The lube migration was observed on the ABS surface of the head component and media surface that suspected the media lubricant was induced into head due to head disc interaction as shown in Figure 5.12 – 5.13.

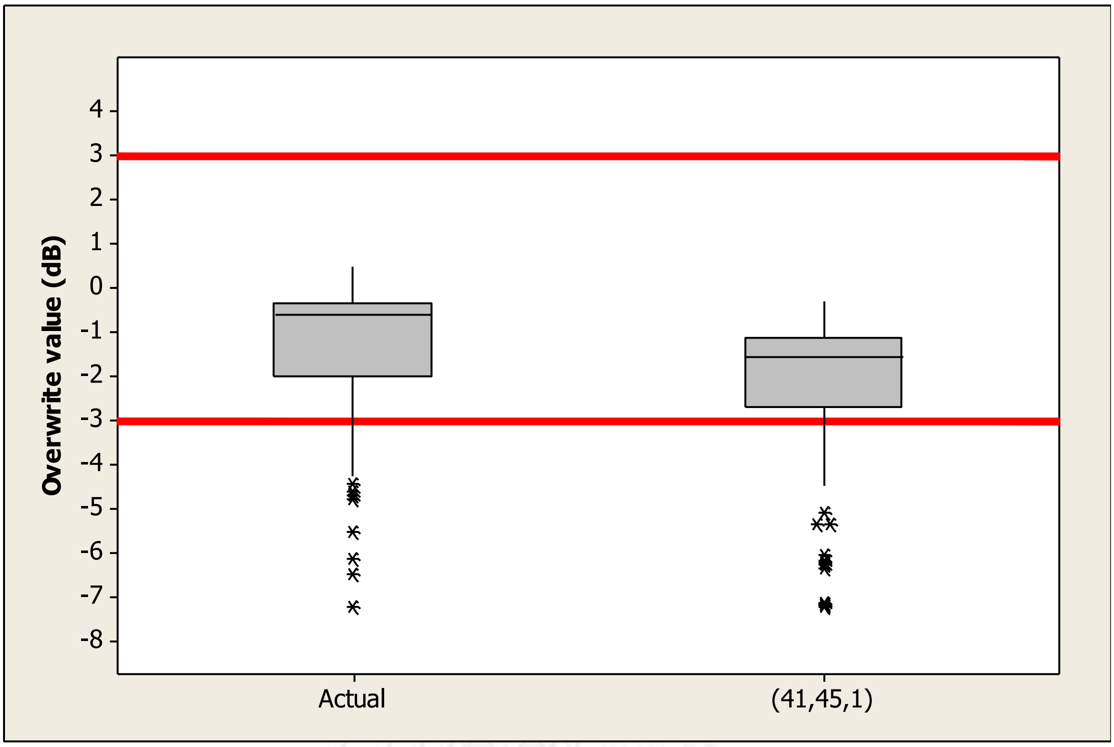


Figure 5.11 The box plots of overwrite output value from (41,45,1) neural network model

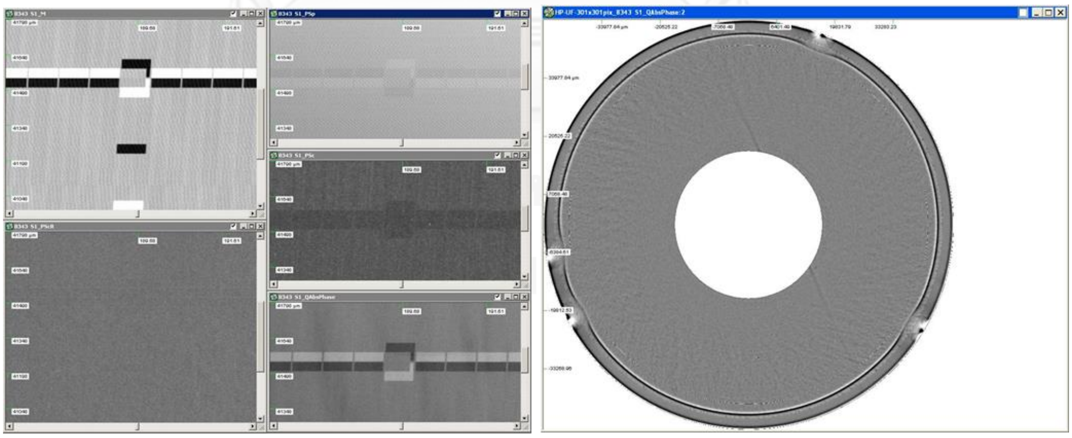


Figure 5.12 The lube moguls on media surface

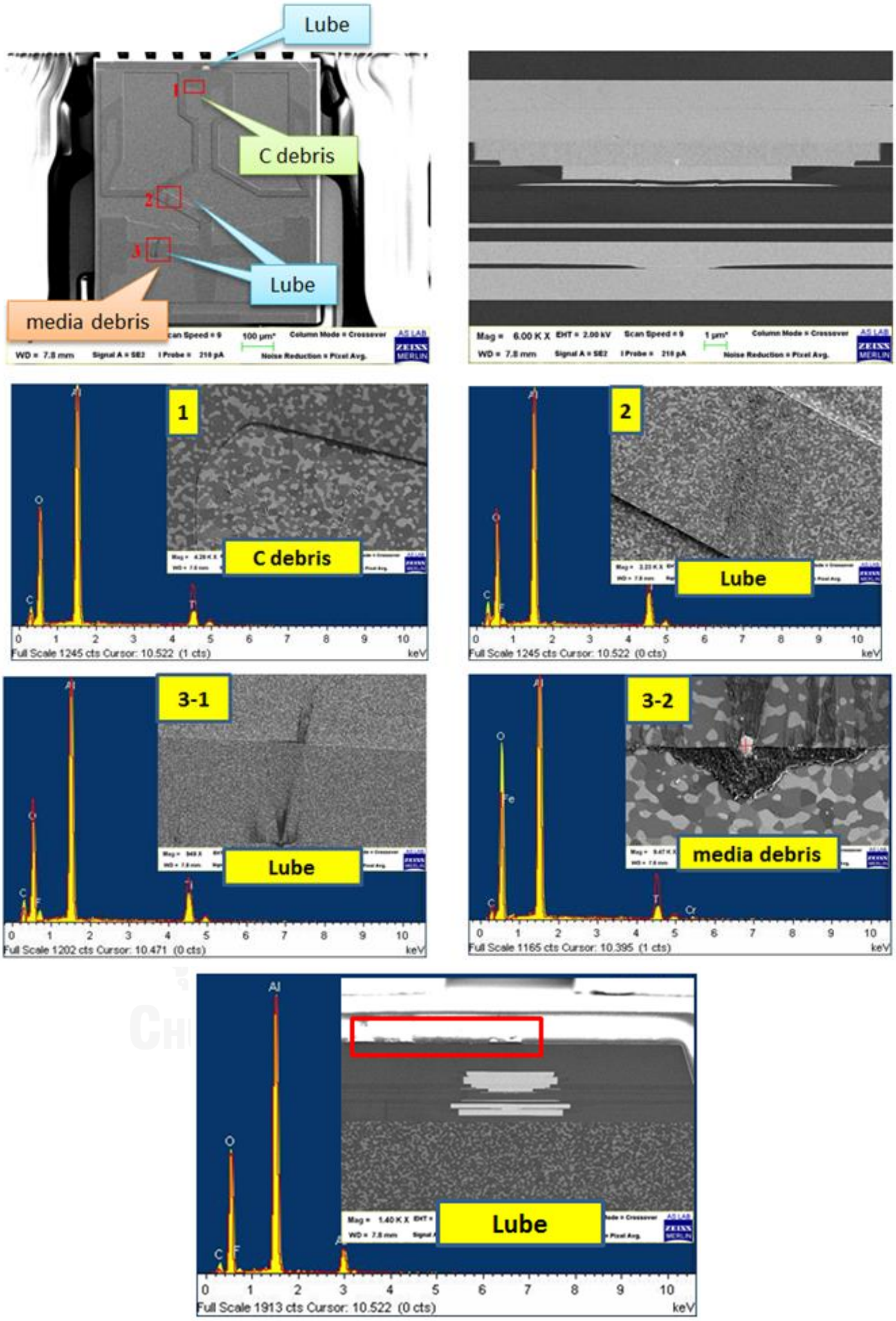


Figure 5.13 The Lube migration failures analyzed by SEM

CHAPTER VI

CONCLUSION AND RECOMMENDATION

The neuron network model with back propagation algorithm was developed successfully for reliability prediction of lubricant layer. The models are contributed to input layer is overwrite value by radius, output layer is average overwrite which have 46 neurons and 2 hidden layers as topology (41,45,1) and used the sigmoid function as the activation function. Prediction the percent of failure drives that relevant to lubricant layer is proposed. Based on the verification model results, the mean square error and root mean square error are 1.68 and 1.30 respectively. The accuracy performance of the neural network models is achieved 91.74%.

From the comparison results of experiment data and prediction output was observed the neural networks model able to capture 21.6% of failures drives while the experiment result is 20% of failure drives. The over prediction has benefits to early warning the process problem in the manufacturing.

REFERENCES

(1) Deqing Huang et al. **Modeling and Compensation of Low Fly-Height Vibrations in High Density Hard Disk Drive Servo Systems**. IEEE.2012; 900-905.

(2) Piramanayagam S.N., Srinivasan K. **Recording media research for future hard disk drives**. Journal of Magnetism and Magnetic Materials, 321(2009): 485–494.

(3) Robert L. Smith et al. **Atomistically Tuning Lubricant Adhesion on Carbon Overcoat Surface**. IEEE transaction on Magnetics, Vol. 48, No.11, November 2012: 4273-4276.

(4) Pil Seung Chung, Hakhee Park and Myung S. Jhon. **The Static and Dynamic Responses of Binary Mixture Perfluoropolyether Lubricant Films Molecular Structural Effects.** IEEE transaction on Magnetics, Vol. 45, No.10, October 2010: 3644-3647.

(5) Yu Wangi, Qiang Mia, Michael Peche. **Health Monitoring of Hard Disk Drive Based on Mahalanobis Distance**. 2011 Prognostics & System Health Management Conference (PHM2011 Shenzhen).

(6) Hertz J., Krogh A., Palmer R.G.: **Introduction to the theory of neural computation**, Addison-Wesley, Redwood City, CA 1991

(7) Freeman J.A., Skapura D.M.: **Neural networks - Algorithms, applications, and programming techniques**, Addison-Wesley, Reading, MA 1991

(8) Xiaoding Ma et al. **Contribution of Lubricant Thickness to Head–Media Spacing**. IEEE transaction on Magnetics, Vol. 37, No. 4, July 2001: 1824-1826

(9) Somchai Akararuttanapong. **Improvement of energy consumption efficiency in solvent deasphalt process**, Master's Thesis, Department of Chemical Engineering Faculty of Engineering, Chulalongkorn University, 2010

(10) Andrei Khurshudov, Peter Ivett. **Head-disk contact detection in the hard disk drives**. Wear 255 (2013): 1314-1322

(11) Waraporn T, Yuttana K. **Customer failure modes prediction for hard disk drive using neural networks rank-level fusion**. Computer Telecommunications and Information Technology (ECTI) Association of Thailand conference 2011: page 476-479

(12) T. Liew et al. **Corrosion of magnetic recording heads and media**. Tribology international 36 (2003): 447-454

(13) A. Khurshudov, V. Raman. **Roughness effects on head-disk interface durability and reliability.** Tribology international 38 (2005): 646-651

(14) Dae Young Lee et al. **Effect of relative humidity and disk acceleration on tribocharge build-up at a slider-disk interface.** Tribology international 40 (2007): 1253-1257

(15) Jin Zhu, Bo Liu. **In situ FH analysis at disk drive level**. Journal of Magnetic Materials 303 (2006): e97-e100

(16) Sachin Kumar et al. **Parameter selection for health monitoring of lectronic products**. Microelectronics Reliability 50 (2010): 161-168

(17) Brain D. Storm et al. **Hard disk drive reliability modeling and failure prediction.** IEEE transaction on Magnetics, Vol. 43, No. 9, September 2007: 3676-3684

APPENDIX

APPENDIX A

The input and output data for neural network models
The verification models result of different topology

Table A-1 Example of input and output data for neural network models

No	Test loops																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.00	0.05	0.00	0.21	0.05	0.10	0.03	-0.04	-0.10	-0.11	-0.01	-0.25	-0.25	-0.40	-0.32	-0.20	-0.62
2	0.00	-0.33	-0.51	-0.53	-0.41	-0.99	-0.45	-0.56	-0.83	-0.54	-0.25	-0.94	-0.95	-0.66	-0.89	-0.88	-0.89
3	0.00	-0.34	-0.17	-0.57	-1.21	-0.79	-1.06	-0.94	-1.25	-1.21	-1.12	-0.55	-1.15	-0.83	-1.01	-0.90	-1.16
4	0.00	-0.27	0.00	0.15	-0.15	0.24	0.18	0.09	0.02	-0.36	-0.85	-0.37	-0.56	-0.33	-0.51	-0.21	-0.89
5	0.00	0.04	0.05	-0.18	-0.40	-0.06	-0.80	-1.00	-0.97	-1.18	-1.11	-0.77	-0.96	-1.54	-0.98	-0.96	-1.16
6	0.00	-1.09	-0.91	-0.65	-0.28	-0.57	-0.87	-0.71	-1.22	-1.13	-1.21	-1.90	-1.12	-1.30	-1.35	-1.33	-1.12
7	0.00	0.09	-0.09	-0.21	0.03	-0.55	-0.48	-0.61	-0.67	-0.97	-0.73	-1.08	-1.00	-0.84	-1.15	-1.25	-1.31
8	0.00	-0.24	-0.78	-0.58	-0.76	-1.05	-0.73	-1.22	-1.23	-0.95	-0.76	-1.54	-1.30	-1.23	-1.18	-1.35	-1.40
9	0.00	0.30	0.00	-0.27	-0.43	-0.64	-0.62	-0.48	-0.53	-0.75	-0.39	-1.27	-1.28	-1.11	-1.29	-1.68	-1.36
10	0.00	0.05	0.00	0.21	0.05	0.10	0.03	-0.04	-0.10	-0.11	-0.01	-0.25	-0.25	-0.40	-0.32	-0.20	-0.62
11	0.00	0.10	-0.23	0.22	0.06	0.06	0.00	-0.09	-0.21	-0.28	0.06	-0.16	-0.18	-0.07	-0.05	-0.01	-0.13
12	0.00	-0.15	-0.48	-0.51	-0.41	-0.33	-0.58	-0.18	-0.27	-0.47	-0.34	-0.60	-0.54	-0.18	-0.49	-0.18	-0.47
13	0.00	-0.06	-0.06	-0.05	-0.29	-0.17	-0.45	-0.21	-0.49	-0.30	-0.30	-0.37	-0.30	-0.49	-0.43	-0.33	-0.43
14	0.00	0.03	0.03	0.05	0.00	0.00	-0.23	-0.17	-0.19	-0.07	-0.30	-0.33	-0.35	-0.46	-0.30	-0.52	-0.54
15	0.00	0.67	0.03	-0.15	0.18	-0.30	0.30	-0.25	-0.16	0.04	0.01	-0.21	-0.03	-0.08	-0.08	-0.10	-0.69
16	0.00	-0.22	-0.42	-0.15	-0.44	-0.25	-0.48	-0.48	-0.23	-0.34	-0.42	-0.82	-0.52	-0.79	-0.60	-1.02	-0.74
17	0.00	-0.23	0.26	-0.03	-0.13	-0.21	-0.08	-0.12	-0.16	0.06	-0.07	0.01	-0.03	-0.32	-0.43	-0.26	-0.26

Table A-1 (Con't)

No	Test loops																
	18	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**
1	-0.54	-0.79	-0.62	-0.71	-1.14	-1.15	-1.29	-1.58	-1.88	-2.07	-2.32	-2.27	-2.65	-2.97	-3.06	-3.26	-3.40
2	-1.09	-0.79	-0.85	-0.90	-1.20	-1.20	-1.07	-1.15	-1.32	-1.18	-0.96	-0.85	-1.46	-1.56	-1.84	-2.01	-2.02
3	-1.08	-0.66	-0.94	-1.26	-2.73	-3.40	-2.19	-1.69	-2.70	-2.38	-1.51	-2.54	-1.52	-2.70	-2.40	-3.16	-2.52
4	-0.67	-0.91	-1.08	-1.02	-0.86	-1.31	-1.19	-1.66	-1.52	-1.73	-1.54	-1.81	-2.07	-2.44	-2.21	-2.60	-2.94
5	-1.28	-1.45	-1.39	-1.57	-1.57	-1.82	-1.82	-1.48	-1.86	-2.09	-2.06	-2.07	-2.53	-2.30	-2.45	-2.52	-2.75
6	-1.77	-1.93	-1.79	-1.46	-1.98	-2.26	-1.94	-2.15	-2.51	-2.83	-2.94	-2.96	-2.75	-3.61	-3.60	-3.56	-3.49
7	-1.24	-1.19	-1.09	-1.05	-1.33	-1.20	-1.51	-1.43	-1.23	-1.30	-1.61	-1.60	-1.43	-2.02	-1.93	-1.98	-2.18
8	-1.73	-2.05	-1.95	-2.30	-2.38	-2.29	-2.16	-2.77	-2.47	-3.22	-3.04	-3.61	-3.48	-3.68	-3.55	-3.42	-3.89
9	-2.13	-2.32	-2.09	-3.05	-3.38	-3.60	-5.04	-5.33	-5.52	-5.66	-5.85	-5.17	-4.82	-5.47	-4.81	-5.95	-6.73
10	-0.54	-0.79	-0.62	-0.71	-1.14	-1.15	-1.29	-1.58	-1.88	-2.07	-2.32	-2.27	-2.65	-2.97	-3.06	-3.26	-3.40
11	0.02	-0.24	-0.07	-0.17	-0.16	0.05	0.16	-0.16	0.01	-0.20	0.10	-0.13	-0.17	-0.41	-0.18	-0.31	-0.37
12	-0.67	-0.33	-0.34	-0.75	-0.83	-0.51	-0.87	-0.32	-0.53	-0.45	-0.77	-0.48	-0.21	-0.72	-0.70	-0.91	-0.43
13	-0.43	-0.69	-0.56	-0.58	-0.64	-0.61	-0.53	-0.70	-0.39	-0.66	-0.67	-0.54	-0.89	-0.69	-0.79	-1.21	-1.30
14	-0.58	-0.30	-0.66	-0.59	-0.81	-0.98	-0.74	-0.80	-0.66	-1.00	-0.95	-0.96	-0.99	-1.12	-1.05	-1.00	-0.99
15	-0.37	-0.45	-0.52	-0.30	-0.36	-0.06	-0.60	-0.40	-0.45	-0.49	-0.18	-0.62	-0.69	-1.00	-0.81	-0.59	-0.55
16	-0.92	-0.37	-0.72	-0.23	-0.57	-0.38	-0.99	-0.53	-0.64	-0.78	-0.79	-1.09	-0.69	-0.72	-0.73	-0.82	-0.79
17	-0.22	-0.21	-0.39	-0.45	-0.23	-0.06	-0.35	-0.42	-0.29	-0.55	-0.47	-0.54	-0.44	-0.38	-0.52	-0.40	-0.42

Table A-1 (Con't)

No	Test loops							Output
	35	36	37	38	39	40	41	
1	-3.58	-3.42	-3.78	-3.90	-4.02	-4.22	-4.28	-4.51
2	-1.68	-2.61	-2.31	-2.58	-2.96	-3.28	-3.55	-3.25
3	-1.71	-2.22	-2.08	-1.92	-2.75	-2.33	-2.10	-3.13
4	-3.17	-3.38	-3.38	-3.99	-4.19	-4.45	-4.69	-4.87
5	-2.98	-2.84	-2.93	-3.34	-3.25	-3.32	-3.56	-3.45
6	-4.12	-3.36	-4.23	-3.95	-4.54	-4.25	-4.45	-4.37
7	-2.30	-2.29	-2.78	-3.44	-3.57	-3.48	-4.03	-3.92
8	-4.28	-4.48	-4.26	-4.70	-5.00	-4.63	-5.03	-5.36
9	-6.44	-6.37	-6.31	-6.67	-6.60	-6.51	-6.58	-6.57
10	-3.58	-3.42	-3.78	-3.90	-4.02	-4.22	-4.28	-4.51
11	-0.49	-0.64	-0.60	-0.65	-0.73	-0.65	-0.81	-0.53
12	-0.61	-0.67	-0.65	-0.75	-1.03	-0.73	-0.94	-0.91
13	-1.17	-1.08	-1.04	-0.91	-1.03	-0.98	-1.22	-1.10
14	-1.01	-1.28	-1.22	-1.08	-1.30	-1.19	-1.31	-1.45
15	-0.37	-0.75	-0.51	-0.77	-0.56	-0.72	-0.92	-0.65
16	-1.32	-1.11	-0.72	-0.35	-0.54	-0.62	-1.05	-1.05
17	-0.29	-0.19	-0.57	-0.09	-0.38	-0.39	-0.29	-0.62

Table A-2 The verification model result of topology (41,45,1) MSE=1.68 and RMS=1.30

Actual	Prediction	Actual	Prediction	Actual	Prediction
-5.87	-6.47	-3.19	-4.00	-0.77	-2.64
-6.04	-6.47	-4.47	-5.68	-0.80	-1.96
-3.39	-3.27	-4.07	-3.87	-0.11	-1.55
-3.38	-4.54	-5.41	-6.29	-0.68	-1.10
-3.28	-1.21	-3.38	-3.62	-1.10	-1.38
-3.71	-4.05	-4.58	-4.85	-0.19	-1.09
-3.73	-3.01	-3.37	-4.05	-0.82	-0.96
-4.23	-4.33	-3.15	-3.57	-0.72	-1.03
-5.40	-6.24	-5.59	-6.30	-0.46	-1.51
-4.35	-5.23	-4.68	-6.36	0.46	-1.13
-6.23	-6.37	-6.48	-6.00	-0.73	-1.33
-3.78	-5.08	-5.67	-6.38	-0.66	-1.23
-4.07	-3.87	-3.18	-2.99	-0.69	-1.21
-3.23	-2.62	-5.03	-5.95	-0.27	-1.22
-3.92	-4.74	-6.06	-6.25	-0.84	-1.78
-3.13	-4.46	-4.59	-4.47	-1.13	-2.00
-3.29	-2.71	-0.98	-1.90	-0.94	-1.01
-6.48	-6.00	-3.96	-5.20	-0.47	-1.11
-5.01	-6.22	-3.42	-5.57	-0.79	-1.19
-3.22	-3.27	-3.33	-4.12	-0.79	-1.83
-3.12	-3.47	-1.57	-1.60	0.13	-1.64
-3.24	-4.02	-0.66	-1.09	-0.34	-2.47
-4.27	-5.60	-0.82	-1.38	-0.31	-1.51
-3.27	-2.97	-0.30	-0.96	-0.06	-1.07
-4.29	-6.41	-1.40	-2.00	-2.47	-2.02
-3.54	-3.85	-0.43	-5.62	0.05	-1.38
-4.49	-5.06	-0.83	-1.07	0.03	-1.53
-3.39	-3.24	-0.42	-1.14	-0.71	-1.30
-3.32	-3.36	-0.14	-1.22	-2.23	-2.43
-4.28	-4.92	-0.56	-3.77	-0.98	-1.18

Table A-2 (Con't)

Actual	Prediction	Actual	Prediction	Actual	Prediction
-0.96	-1.80	-0.21	-1.21	-1.18	-1.18
-0.34	-0.91	-0.59	-1.31	-0.07	-1.56
-0.55	-0.90	-0.29	-2.65	-0.21	-1.34
-1.46	-1.51	-1.01	-3.36	-1.23	-3.28
-0.52	-3.12	-0.22	-1.22	0.05	-0.90
-1.79	-1.84	-1.49	-1.78	-0.81	-1.20
-0.43	-1.31	0.13	-0.88	-0.23	-1.18
-0.99	-1.22	-0.55	-2.44	-0.53	-3.99
-0.71	-1.74	-0.50	-1.26	-0.18	-1.49
-0.65	-1.39	-0.73	-2.11	-1.09	-1.57
-0.62	-1.54	-0.49	-1.11	-0.53	-1.27
-1.25	-1.68	-0.29	-1.18	-0.64	-0.85
-0.95	-1.30	-0.16	-1.60	-0.37	-1.12
-0.76	-1.10	-0.97	-1.11	-0.05	-1.64
-0.16	-1.85	-0.32	-1.07	-0.49	-1.11
-0.36	-5.31	-1.50	-3.08	-0.75	-1.38
-0.63	-1.08	-0.69	-1.91	-0.55	-1.30
-1.44	-1.94	-0.33	-1.17	-1.14	-1.12
-0.97	-1.15	-0.64	-1.91	-0.81	-1.54
-2.02	-1.95	-0.36	-1.89	-0.44	-1.13
-0.97	-2.16	-1.26	-2.58	-0.65	-1.29
-0.98	-1.40	-0.57	-1.69	-0.39	-1.11
-0.72	-1.70	-0.19	-1.03	-0.73	-1.40
-0.44	-1.15	-0.59	-2.30	0.17	-1.68
-0.64	-1.21	-0.72	-1.36	-0.05	-1.98
-0.52	-1.10	-0.90	-2.38	-0.08	-1.73
-0.58	-1.10	-0.84	-1.52	0.02	-1.53
0.00	-1.10	-1.04	-1.17	-0.14	-1.12
-0.42	-1.46	0.21	-1.66	-0.25	-3.88
-0.32	-1.04	-0.53	-1.00	-1.28	-1.26

Table A-2 (Con't)

Actual	Prediction	Actual	Prediction	Actual	Prediction
-0.78	-0.92	-0.29	-1.99	-0.33	-0.93
-0.67	-1.46	0.12	-5.90	-0.41	-2.07
-0.68	-1.24	0.29	-0.87	-0.94	-1.01
-2.84	-3.75	0.20	-1.28	-1.53	-2.34
-0.13	-1.10	-0.91	-2.96	-0.94	-1.60
-2.12	-2.00	-2.09	-1.96	0.00	-1.44
0.29	-0.87	-0.75	-1.11	-0.41	-1.01
-0.22	-3.67	-0.62	-0.85	0.30	-1.28
-0.35	-1.23	-0.21	-1.95	-0.69	-1.66
0.16	-0.98	-2.74	-3.74	-0.73	-1.54
-0.14	-1.05	-0.04	-1.27		
-0.50	-4.62	0.11	-1.05		
-0.45	-3.79	-0.26	-1.13		
-1.63	-1.78	-1.64	-1.79		
-1.08	-1.12	-0.55	-1.43		
0.01	-0.95	-0.43	-1.09		
-0.99	-1.65	-2.01	-1.90		
-0.16	-1.77	-0.84	-2.73		
-1.89	-1.49	-0.40	-2.67		
-2.00	-1.81	-0.38	-2.04		
-1.16	-1.47	-0.41	-1.85		
-0.46	-0.80	-0.85	-2.68		
-0.89	-1.53	-0.82	-3.09		
-0.62	-1.05	-0.66	-1.20		
-0.01	-1.45	-1.03	-1.54		
-0.80	-1.17	-0.30	-1.21		
-0.24	-1.05	-0.63	-1.19		
-0.14	-1.21	-0.25	-1.25		
-0.99	-1.54	-0.64	-3.24		
-0.69	-1.91	-1.05	-2.41		

Table A-3 The verification model result of topology (41,33,22,1) MSE=1.85 and RMS=1.36

Actual	Prediction	Actual	Prediction	Actual	Prediction
-5.87	-5.32	-3.19	-2.05	-0.77	0.14
-6.04	-5.53	-4.47	-2.18	-0.80	0.21
-3.39	-0.88	-4.07	-0.38	-0.11	0.21
-3.38	-2.04	-5.41	-5.64	-0.68	0.20
-3.28	0.09	-3.38	-0.64	-1.10	0.22
-3.71	0.21	-4.58	-1.77	-0.19	0.20
-3.73	-2.09	-3.37	-2.15	-0.82	0.21
-4.23	-2.30	-3.15	-2.06	-0.72	0.22
-5.40	-3.85	-5.59	-4.58	-0.46	0.20
-4.35	-2.14	-4.68	-2.82	0.46	0.19
-6.23	-4.86	-6.48	-3.48	-0.73	0.21
-3.78	0.13	-5.67	-5.60	-0.66	0.20
-4.07	-0.38	-3.18	0.18	-0.69	0.21
-3.23	-2.00	-5.03	-2.42	-0.27	0.19
-3.92	-0.15	-6.06	-4.02	-0.84	0.20
-3.13	-0.42	-4.59	-2.55	-1.13	0.21
-3.29	-1.97	-0.98	0.21	-0.94	0.22
-6.48	-3.48	-3.96	-2.09	-0.47	0.22
-5.01	-2.50	-3.42	-2.15	-0.79	0.21
-3.22	-1.81	-3.33	-1.98	-0.79	0.20
-3.12	-2.04	-1.57	0.20	0.13	0.20
-3.24	-0.59	-0.66	0.22	-0.34	0.20
-4.27	-1.96	-0.82	0.21	-0.31	0.22
-3.27	0.13	-0.30	0.20	-0.06	0.22
-4.29	-0.65	-1.40	0.23	-2.47	0.22
-3.54	-2.11	-0.43	0.18	0.05	0.22
-4.49	-2.36	-0.83	0.22	0.03	0.18
-3.39	-1.92	-0.42	0.23	-0.71	0.22
-3.32	-0.67	-0.14	0.22	-2.23	-0.07
-4.28	-2.23	-0.56	0.20	-0.98	0.22

Table A-3 (Con't)

Actual	Prediction	Actual	Prediction	Actual	Prediction
-0.96	0.21	-0.21	0.19	-1.18	0.19
-0.34	0.22	-0.59	0.22	-0.07	0.21
-0.55	0.20	-0.29	0.22	-0.21	0.20
-1.46	0.23	-1.01	0.19	-1.23	0.17
-0.52	0.21	-0.22	0.20	0.05	0.22
-1.79	0.19	-1.49	0.22	-0.81	0.20
-0.43	0.21	0.13	0.23	-0.23	0.22
-0.99	0.19	-0.55	0.21	-0.53	0.15
-0.71	0.11	-0.50	0.21	-0.18	0.21
-0.65	0.22	-0.73	0.21	-1.09	0.21
-0.62	0.19	-0.49	0.22	-0.53	0.20
-1.25	0.21	-0.29	0.22	-0.64	0.22
-0.95	0.21	-0.16	0.23	-0.37	0.22
-0.76	0.22	-0.97	0.22	-0.05	0.22
-0.16	0.13	-0.32	0.22	-0.49	0.23
-0.36	0.21	-1.50	0.06	-0.75	0.23
-0.63	0.23	-0.69	0.20	-0.55	0.21
-1.44	0.20	-0.33	0.22	-1.14	0.21
-0.97	0.20	-0.64	0.22	-0.81	0.23
-2.02	0.17	-0.36	0.21	-0.44	0.20
-0.97	0.16	-1.26	0.21	-0.65	0.23
-0.98	0.19	-0.57	0.23	-0.39	0.21
-0.72	0.22	-0.19	0.22	-0.73	0.21
-0.44	0.21	-0.59	0.19	0.17	0.21
-0.64	0.15	-0.72	0.20	-0.05	0.21
-0.52	0.22	-0.90	0.19	-0.08	0.19
-0.58	0.22	-0.84	0.22	0.02	0.22
0.00	0.22	-1.04	0.22	-0.14	0.22
-0.42	0.21	0.21	0.16	-0.25	0.20
-0.32	0.21	-0.53	0.22	-1.28	0.21

Table A-3 (Con't)

Actual	Prediction	Actual	Prediction	Actual	Prediction
-0.78	0.22	-0.29	0.22	-0.33	0.16
-0.67	0.20	0.12	-1.67	-0.41	0.22
-0.68	0.19	0.29	0.23	-0.94	0.22
-2.84	-1.73	0.20	0.22	-1.53	-1.87
-0.13	0.21	-0.91	0.20	-0.94	0.22
-2.12	0.21	-2.09	0.18	0.00	0.22
0.29	0.23	-0.75	0.22	-0.41	0.22
-0.22	0.13	-0.62	0.22	0.30	0.22
-0.35	0.22	-0.21	0.21	-0.69	0.22
0.16	0.22	-2.74	-0.05	-0.73	0.21
-0.14	0.23	-0.04	0.22		
-0.50	0.22	0.11	0.22		
-0.45	0.16	-0.26	0.21		
-1.63	0.23	-1.64	-0.25		
-1.08	0.22	-0.55	0.21		
0.01	0.22	-0.43	0.22		
-0.99	0.20	-2.01	0.17		
-0.16	0.21	-0.84	0.20		
-1.89	0.21	-0.40	0.00		
-2.00	0.18	-0.38	0.21		
-1.16	0.21	-0.41	0.22		
-0.46	0.20	-0.85	0.21		
-0.89	0.22	-0.82	0.19		
-0.62	0.20	-0.66	0.21		
-0.01	0.21	-1.03	0.22		
-0.80	0.22	-0.30	0.22		
-0.24	0.23	-0.63	0.20		
-0.14	0.22	-0.25	0.23		
-0.99	0.21	-0.64	0.19		
-0.69	0.21	-1.05	-0.17		

Table A-4 The verification model result of topology (41,10,9,10,1)

MSE=3.64 and RMS=1.91

Actual	Prediction	Actual	Prediction	Actual	Prediction
-5.87	-5.55	-4.28	-1.42	-0.56	-2.48
-6.04	-5.01	-3.19	-0.78	-0.77	-1.74
-3.39	-0.78	-4.47	-2.90	-0.80	-2.38
-3.38	-1.56	-4.07	-1.89	-0.11	-2.25
-3.28	-2.66	-5.41	-3.87	-0.68	-2.32
-3.71	-2.55	-3.38	-0.38	-1.10	-2.18
-3.73	0.00	-4.58	-1.82	-0.19	-2.19
-4.23	-0.32	-3.37	-0.97	-0.82	-2.42
-5.40	-4.17	-3.15	0.00	-0.72	-2.36
-4.35	-0.38	-5.59	-5.07	-0.46	-2.35
-6.23	-4.61	-4.68	-3.36	0.46	-2.31
-3.78	-2.15	-6.48	-5.58	-0.73	-1.99
-4.07	-1.89	-5.67	-4.23	-0.66	-2.42
-3.23	0.17	-3.18	-0.55	-0.69	-2.33
-3.92	-1.82	-5.03	-2.44	-0.27	-2.20
-3.13	-2.30	-6.06	-3.44	-0.84	-2.28
-3.29	-0.83	-4.59	-1.61	-1.13	-2.22
-6.48	-5.58	-0.98	-2.39	-0.94	-2.13
-5.01	-4.01	-3.96	-1.18	-0.47	-2.26
-3.22	0.09	-3.42	-2.37	-0.79	-2.41
-3.12	-0.28	-3.33	-2.19	-0.79	-2.36
-3.24	-0.51	-1.57	-2.43	0.13	-2.36
-4.27	-1.91	-0.66	-2.41	-0.34	-2.39
-3.27	-0.91	-0.82	-2.38	-0.31	-2.40
-4.29	-2.64	-0.30	-2.36	-0.06	-2.36
-3.54	-0.78	-1.40	-2.35	-2.47	-2.11
-4.49	-1.60	-0.43	-2.42	0.05	-2.31
-3.39	-0.08	-0.83	-2.29	0.03	-2.14
-3.32	-1.08	-0.42	-2.40	-0.71	-2.33

Table A-4 (Con't)

Actual	Prediction	Actual	Prediction	Actual	Prediction
-0.98	-2.35	-0.14	-2.46	-2.23	-1.04
-0.96	-2.34	-0.32	-2.16	0.21	-2.34
-0.34	-2.38	-0.21	-2.41	-0.53	-2.37
-0.55	-1.81	-0.59	-2.42	-1.18	-1.96
-1.46	-2.42	-0.29	-2.42	-0.07	-2.29
-0.52	-2.45	-1.01	-2.32	-0.21	-2.22
-1.79	-1.90	-0.22	-2.32	-1.23	-2.33
-0.43	-2.35	-1.49	-2.45	0.05	-2.39
-0.99	-2.17	0.13	-2.42	-0.81	-2.35
-0.71	-1.71	-0.55	-2.40	-0.23	-2.39
-0.65	-2.25	-0.50	-2.40	-0.53	-2.46
-0.62	-2.41	-0.73	-2.43	-0.18	-2.39
-1.25	-2.33	-0.49	-2.42	-1.09	-2.28
-0.95	-2.39	-0.29	-2.37	-0.53	-2.40
-0.76	-2.35	-0.16	-2.40	-0.64	-2.41
-0.16	-2.55	-0.97	-2.41	-0.37	-2.35
-0.36	-2.43	-0.32	-2.34	-0.05	-2.40
-0.63	-2.42	-1.50	-2.17	-0.49	-2.40
-1.44	-2.47	-0.69	-2.42	-0.75	-2.22
-0.97	-2.25	-0.33	-2.34	-0.55	-2.36
-2.02	-1.62	-0.64	-2.06	-1.14	-2.24
-0.97	-2.33	-0.36	-2.34	-0.81	-2.36
-0.98	-2.24	-1.26	-2.02	-0.44	-2.34
-0.72	-2.44	-0.57	-2.40	-0.65	-2.28
-0.44	-2.39	-0.19	-2.40	-0.39	-2.32
-0.64	-2.29	-0.59	-2.46	-0.73	-2.43
-0.52	-2.30	-0.72	-2.36	0.17	-2.38
-0.58	-2.35	-0.90	-2.25	-0.05	-2.41
0.00	-2.35	-0.84	-2.43	-0.08	-2.14
-0.42	-2.29	-1.04	-2.40	0.21	-2.34

Table A-4 (Con't)

Actual	Prediction	Actual	Prediction	Actual	Prediction
0.02	-2.41	-0.24	-2.38	-0.63	-2.13
-0.14	-2.37	-0.14	-2.17	-0.25	-2.42
-0.25	-2.41	-0.99	-2.24	-0.64	-2.41
-1.28	-2.49	-0.69	-2.35	-1.05	-2.20
-0.78	-2.39	-0.29	-2.33	-0.33	-2.40
-0.67	-2.42	0.12	-2.45	-0.41	-2.39
-0.68	-2.42	0.29	-2.36	-0.94	-2.24
-2.84	-1.24	0.20	-2.38	-1.53	0.12
-0.13	-2.32	-0.91	-2.36	-0.94	-2.36
-2.12	-2.18	-2.09	-0.49	0.00	-2.44
0.29	-2.40	-0.75	-2.29	-0.41	-2.42
-0.22	-2.48	-0.62	-2.27	0.30	-2.42
-0.35	-2.40	-0.21	-2.36	-0.69	-2.32
0.16	-2.29	-2.74	-2.84	-0.73	-2.43
-0.14	-2.38	-0.04	-2.33		
-0.50	-2.49	0.11	-2.38		
-0.45	-2.41	-0.26	-2.37		
-1.63	-2.05	-1.64	-0.71		
-1.08	-2.25	-0.55	-2.14		
0.01	-2.33	-0.43	-2.28		
-0.99	-2.32	-2.01	-1.28		
-0.16	-2.30	-0.84	-2.29		
-1.89	-1.88	-0.40	-2.43		
-2.00	-1.97	-0.38	-2.32		
-1.16	-2.20	-0.41	-2.39		
-0.46	-2.40	-0.85	-2.37		
-0.89	-2.31	-0.82	-0.87		
-0.62	-2.31	-0.66	-2.36		
-0.01	-2.41	-1.03	-2.38		
-0.80	-2.42	-0.30	-2.46		

Table A-5 The verification model result of topology (41,16,12,12,18,1)
MSE=1.73 and RMS=1.31

Actual	Prediction	Actual	Prediction	Actual	Prediction
-5.87	-2.59	-4.28	-2.67	-0.42	0.15
-6.04	-2.42	-3.19	-2.63	-0.14	0.16
-3.39	-2.58	-4.47	-2.21	-0.56	0.11
-3.38	-2.32	-4.07	-1.09	-0.77	0.10
-3.28	-0.06	-5.41	-2.52	-0.80	0.15
-3.71	-0.27	-3.38	-2.05	-0.11	0.08
-3.73	-2.66	-4.58	-2.22	-0.68	0.20
-4.23	-2.70	-3.37	-2.65	-1.10	0.22
-5.40	-2.09	-3.15	-2.66	-0.19	0.21
-4.35	-2.67	-5.59	-2.49	-0.82	0.01
-6.23	-2.38	-4.68	-2.34	-0.72	0.06
-3.78	-1.17	-6.48	-3.29	-0.46	-0.16
-4.07	-1.09	-5.67	-2.32	0.46	0.14
-3.23	-2.58	-3.18	-0.56	-0.73	0.18
-3.92	-2.44	-5.03	-2.31	-0.66	0.07
-3.13	-0.84	-6.06	-2.52	-0.69	0.23
-3.29	-2.56	-4.59	-2.71	-0.27	0.06
-6.48	-3.29	-0.98	0.17	-0.84	0.12
-5.01	-2.28	-3.96	-2.53	-1.13	0.20
-3.22	-2.47	-3.42	-1.67	-0.94	0.23
-3.12	-2.56	-3.33	-2.63	-0.47	0.17
-3.24	-1.19	-1.57	-0.03	-0.79	0.14
-4.27	-2.12	-0.66	0.18	-0.79	0.14
-3.27	-0.26	-0.82	0.10	0.13	0.28
-4.29	0.26	-0.30	0.16	-0.34	0.19
-3.54	-2.66	-1.40	0.29	-0.31	0.15
-4.49	-2.28	-0.43	0.14	-0.06	0.18
-3.39	-2.65	-0.83	0.05	-2.47	0.08
-3.32	-2.27	0.03	0.25	0.05	0.19

Table A-5 (Con't)

Actual	Prediction	Actual	Prediction	Actual	Prediction
-0.71	0.24	0.00	0.14	-1.04	0.15
-2.23	-0.99	-0.42	0.03	0.21	0.18
-0.98	0.19	-0.32	0.03	-0.53	0.14
-0.96	0.08	-0.21	-0.12	-1.18	0.10
-0.34	0.17	-0.59	0.12	-0.07	0.17
-0.55	-0.18	-0.29	0.14	-0.21	0.20
-1.46	-0.02	-1.01	0.14	-1.23	-0.04
-0.52	0.15	-0.22	-0.01	0.05	0.14
-1.79	-0.24	-1.49	0.28	-0.81	-0.06
-0.43	0.13	0.13	0.15	-0.23	0.14
-0.99	0.16	-0.55	0.12	-0.53	0.14
-0.71	0.25	-0.50	0.09	-0.18	0.14
-0.65	0.22	-0.73	0.15	-1.09	0.18
-0.62	0.08	-0.49	0.11	-0.53	0.08
-1.25	0.15	-0.29	0.20	-0.64	0.12
-0.95	0.09	-0.16	0.16	-0.37	0.10
-0.76	0.14	-0.97	0.03	-0.05	0.13
-0.16	0.12	-0.32	0.17	-0.49	0.20
-0.36	0.18	-1.50	0.14	-0.75	0.20
-0.63	0.14	-0.69	0.17	-0.55	0.14
-1.44	0.10	-0.33	0.16	-1.14	0.12
-0.97	-0.01	-0.64	0.29	-0.81	0.16
-2.02	0.03	-0.36	0.17	-0.44	0.09
-0.97	-0.10	-1.26	0.02	-0.65	0.23
-0.98	0.07	-0.57	0.16	-0.39	0.13
-0.72	0.14	-0.19	0.12	-0.73	0.00
-0.44	0.14	-0.59	0.15	0.17	0.12
-0.64	-0.18	-0.72	-0.01	-0.05	0.14
-0.52	0.24	-0.90	-0.16	-0.08	0.26
-0.58	0.12	-0.84	0.13	0.02	0.16

Table A-5 (Con't)

Actual	Prediction	Actual	Prediction	Actual	Prediction
-0.14	0.17	-0.14	0.12	-0.25	0.17
-0.25	0.16	-0.99	0.15	-0.64	0.06
-1.28	0.11	-0.69	0.21	-1.05	0.02
-0.78	0.16	-0.29	0.09	-0.33	0.07
-0.67	0.14	0.12	0.06	-0.41	0.22
-0.68	-0.04	0.29	0.11	-0.94	0.18
-2.84	-2.64	0.20	0.17	-1.53	-2.47
-0.13	0.12	-0.91	-0.02	-0.94	0.06
-2.12	-0.28	-2.09	-0.35	0.00	0.18
0.29	0.18	-0.75	0.15	-0.41	0.14
-0.22	0.12	-0.62	0.07	0.30	0.15
-0.35	0.16	-0.21	0.05	-0.69	0.15
0.16	0.18	-2.74	0.21	-0.73	0.12
-0.14	0.25	-0.04	0.20		
-0.50	0.14	0.11	0.25		
-0.45	-0.01	-0.26	0.20		
-1.63	0.23	-1.64	-1.90		
-1.08	0.20	-0.55	0.27		
0.01	0.18	-0.43	0.06		
-0.99	-0.02	-2.01	0.00		
-0.16	0.18	-0.84	0.18		
-1.89	-0.09	-0.40	0.02		
-2.00	-0.13	-0.38	0.25		
-1.16	0.11	-0.41	0.13		
-0.46	0.14	-0.85	0.15		
-0.89	0.27	-0.82	-0.15		
-0.62	0.10	-0.66	0.15		
-0.01	0.14	-1.03	0.14		
-0.80	0.15	-0.30	0.16		
-0.24	0.17	-0.63	0.18		

APPENDIX B

Table B-1 The testing result of neuron network model and compare with experiment RMSP=0.45, MP=23.03, Accuracy=91.74%

Actual	Prediction	Actual	Prediction	Actual	Prediction
-3.00	-3.37	-0.84	-1.25	-0.58	-1.55
-3.97	-5.08	-0.70	-1.09	-0.10	-1.14
-5.49	-6.00	0.28	-1.55	-0.36	-1.03
-3.13	-6.22	-0.06	-0.98	-1.92	-3.27
-3.16	-1.78	-0.38	-1.17	-0.60	-1.07
-3.00	-3.42	-0.93	-1.13	-0.43	-1.27
-4.68	-6.17	0.06	-1.01	-0.90	-1.18
-7.19	-7.15	-0.70	-2.95	-0.60	-1.56
-6.48	-7.14	-0.52	-1.09	-0.28	-1.77
-3.70	-6.20	-0.04	-1.77	-0.79	-1.20
-3.12	-3.90	-0.35	-1.29	-0.17	-1.76
-3.06	-3.24	-0.51	-0.98	-0.47	-1.47
-3.21	-6.33	-0.32	-1.54	-1.33	-2.59
-3.65	-3.15	-0.54	-1.30	0.15	-0.76
-6.10	-7.17	-0.52	-1.75	-0.64	-1.69
-3.71	-5.32	-2.34	-1.67	-0.37	-1.19
-4.76	-3.20	-0.45	-1.06	-0.71	-1.21
-4.42	-7.10	-0.88	-1.36	-0.53	-1.02
-3.21	-3.01	-0.41	-1.44	-0.34	-1.02
-3.33	-4.46	-0.05	-0.56	-0.39	-1.57
-4.61	-7.17	-0.68	-1.16	-0.56	-1.12
-4.24	-7.18	-0.53	-1.18	-0.81	-1.24
-3.71	-5.32	0.06	-2.53	0.29	-1.01
-3.43	-0.85	-1.17	-1.40	-1.60	-2.28
-4.15	-7.10	-0.31	-1.30	-0.34	-1.92
-0.47	-1.58	-2.10	-2.40	-0.39	-0.58

Table B-1 (Con't)

Actual	Prediction	Actual	Prediction	Actual	Prediction
-1.73	-1.67	-0.50	-1.54	-0.44	-1.22
-1.11	-1.63	-0.53	-3.98	-1.47	-2.70
-0.50	-1.52	-0.56	-1.36	-1.54	-2.15
0.21	-1.04	-0.14	-1.08	-0.18	-1.42
-0.54	-2.78	-0.03	-2.35	-0.19	-1.50
-0.69	-1.15	-0.41	-1.03	-1.02	-1.12
-0.58	-1.25	-0.20	-0.98	-0.57	-1.56
0.36	-0.78	-1.14	-1.87	-2.00	-2.65
0.47	-1.02	-1.58	-1.70	-0.63	-1.92
-0.07	-0.89	-2.15	-2.99	-0.97	-1.38
0.17	-1.30	-2.37	-3.65	-0.77	-1.40
-0.34	-0.92	-0.16	-1.51	0.51	-0.95
0.35	-1.11	-0.44	-1.07	-0.55	-1.75
-2.40	-3.95	-0.61	-0.27	-0.69	-1.79
-0.52	-1.69	-0.23	-1.07	-0.36	-1.18
0.32	-1.21	0.42	-1.00		

APPENDIX C

The neural network model detail of topology 41,45,1 (46 neurons and 2 hidden layer)

Table C-1 The detail of neuron network model layer 1 (Total 45 nodes)

Neuron 'N1_001'

INPUTS	WEIGHTS	
0.000000	0.128864	ACTIVITY
0.000000	0.360203	0.000000
0.000000	0.917547	FUNCTION
0.000000	-0.533290	FERMI
0.000000	-0.518375	OUTPUT
0.000000	0.494379	0.000000
0.000000	-1.001889	
0.000000	-0.484090	
0.000000	0.790929	
0.000000	-0.694377	
0.000000	-0.990736	
0.000000	0.220649	
0.000000	0.285595	
0.000000	-0.213139	
0.000000	0.950651	
0.000000	0.673389	
0.000000	0.316935	
0.000000	-0.357664	
0.000000	-0.773208	
0.000000	-0.852738	
0.000000	-0.867672	
0.000000	-0.593073	
0.000000	0.901666	
0.000000	-0.255991	
0.000000	-0.628456	
0.000000	0.451859	
0.000000	0.012361	
0.000000	-0.129764	
0.000000	0.866359	
0.000000	-0.398530	
0.000000	0.920504	
0.000000	-0.464254	
0.000000	0.317444	
0.000000	-1.144330	
0.000000	-0.675287	
0.000000	-1.174888	
0.000000	0.436100	
0.000000	-0.292884	
0.000000	-0.249050	
0.000000	-0.092663	

Neuron 'N1_002'

INPUTS	WEIGHTS	
0.000000	-0.815512	ACTIVITY
0.000000	-0.959405	0.000000
0.000000	-0.539218	FUNCTION
0.000000	-0.612872	FERMI
0.000000	0.521802	OUTPUT
0.000000	0.800340	0.000000
0.000000	-0.712407	
0.000000	-0.605597	
0.000000	0.377463	
0.000000	-0.324224	
0.000000	-0.523886	
0.000000	0.431205	
0.000000	-0.353478	
0.000000	-0.422762	
0.000000	0.717996	
0.000000	0.879469	
0.000000	-0.563551	
0.000000	0.778841	
0.000000	0.745827	
0.000000	0.605897	
0.000000	-0.819510	
0.000000	0.201120	
0.000000	-0.712027	
0.000000	0.208343	
0.000000	0.245167	
0.000000	0.438426	
0.000000	-1.042467	
0.000000	-0.368599	
0.000000	-0.713931	
0.000000	0.313229	
0.000000	-0.512734	
0.000000	0.711262	
0.000000	0.725351	
0.000000	-0.032590	
0.000000	-0.473308	
0.000000	-0.235884	
0.000000	0.491979	
0.000000	0.659356	
0.000000	-0.376752	
0.000000	-0.083863	

Neuron 'N1_003'

INPUTS	WEIGHTS	
0.000000	-0.173836	ACTIVITY
0.000000	0.730857	0.000000
0.000000	0.365841	FUNCTION
0.000000	0.089767	FERMI
0.000000	-0.437708	OUTPUT
0.000000	-0.440952	0.000000
0.000000	-0.535795	
0.000000	-0.954402	
0.000000	-0.634543	
0.000000	0.481995	
0.000000	-0.490413	
0.000000	0.220855	
0.000000	0.311851	
0.000000	-0.765880	
0.000000	0.526988	
0.000000	0.651476	
0.000000	-0.012019	
0.000000	0.418123	
0.000000	0.181110	
0.000000	0.441707	
0.000000	-0.124147	
0.000000	0.251611	
0.000000	-1.087521	
0.000000	0.036299	
0.000000	-0.654462	
0.000000	-0.628875	
0.000000	0.164913	
0.000000	-0.428650	
0.000000	-0.837264	
0.000000	-0.234721	
0.000000	0.395457	
0.000000	0.573899	
0.000000	-1.139766	
0.000000	0.049312	
0.000000	0.424906	
0.000000	-0.442688	
0.000000	-1.112521	
0.000000	-0.165460	
0.000000	0.006604	
0.000000	-0.182874	

Neuron 'N1_004'

INPUTS	WEIGHTS	
0.000000	-0.007374	ACTIVITY
0.000000	0.923024	0.000000
0.000000	0.133328	FUNCTION
0.000000	-0.606806	FERMI
0.000000	-0.512980	OUTPUT
0.000000	0.277653	0.000000
0.000000	0.524422	
0.000000	0.223290	
0.000000	-0.515673	
0.000000	0.417918	
0.000000	-0.451083	
0.000000	0.694047	
0.000000	0.159344	
0.000000	0.147519	
0.000000	0.030933	
0.000000	0.703897	
0.000000	0.789212	
0.000000	0.168211	
0.000000	1.021273	
0.000000	0.339892	
0.000000	0.994592	
0.000000	-0.532769	
0.000000	0.059860	
0.000000	-0.094160	
0.000000	0.162065	
0.000000	0.787709	
0.000000	-0.702061	
0.000000	0.744014	
0.000000	0.913418	
0.000000	0.741421	
0.000000	0.009417	
0.000000	0.669689	
0.000000	0.814973	
0.000000	-0.493013	
0.000000	0.333056	
0.000000	0.550335	
0.000000	-0.316867	
0.000000	0.607317	
0.000000	-0.324850	
0.000000	0.657312	

Neuron 'N1_005'

INPUTS	WEIGHTS	
0.000000	-9.531781	ACTIVITY
0.000000	0.968644	0.000000
0.000000	0.486332	FUNCTION
0.000000	-0.709447	FERMI
0.000000	0.184174	OUTPUT
0.000000	-1.048546	0.000000
0.000000	-0.383392	
0.000000	-0.511762	
0.000000	0.063127	
0.000000	0.611951	
0.000000	-0.670057	
0.000000	0.349304	
0.000000	-0.705923	
0.000000	-0.256473	
0.000000	0.250953	
0.000000	-0.977133	
0.000000	0.078100	
0.000000	0.673461	
0.000000	-0.246705	
0.000000	0.598063	
0.000000	0.979155	
0.000000	0.509784	
0.000000	-0.506758	
0.000000	0.318510	
0.000000	0.258979	
0.000000	0.180535	
0.000000	-0.753305	
0.000000	-0.304285	
0.000000	-0.473712	
0.000000	-0.799390	
0.000000	1.096286	
0.000000	-0.766275	
0.000000	0.389361	
0.000000	0.553885	
0.000000	0.561298	
0.000000	0.280735	
0.000000	0.112765	
0.000000	1.307477	
0.000000	0.270359	
0.000000	0.058846	

Table C-1 (Con't)

Neuron 'N1_006'

INPUTS	WEIGHTS	
0.000000	0.268723	**ACTIVITY**
0.000000	-0.672967	0.000000
0.000000	-0.680672	**FUNCTION**
0.000000	-0.984716	FERMI
0.000000	-0.228722	**OUTPUT**
0.000000	0.081094	0.000000
0.000000	0.770156	
0.000000	0.839037	
0.000000	0.397393	
0.000000	-0.018121	
0.000000	-0.302486	
0.000000	0.682545	
0.000000	0.598657	
0.000000	-0.721928	
0.000000	-0.929360	
0.000000	-0.866599	
0.000000	-0.824925	
0.000000	-0.881006	
0.000000	0.743333	
0.000000	-0.045164	
0.000000	-0.189096	
0.000000	-0.110834	
0.000000	-0.335027	
0.000000	-0.657022	
0.000000	0.218553	
0.000000	-0.026164	
0.000000	-0.636506	
0.000000	-0.136393	
0.000000	-0.511202	
0.000000	-0.692015	
0.000000	0.122501	
0.000000	-0.487352	
0.000000	-0.309870	
0.000000	-0.012337	
0.000000	0.929826	
0.000000	0.375231	
0.000000	-0.439784	
0.000000	0.078940	
0.000000	-0.880482	
0.000000	-0.650807	

Neuron 'N1_007'

INPUTS	WEIGHTS	
0.000000	0.466446	**ACTIVITY**
0.000000	-0.782778	0.000000
0.000000	-0.807745	**FUNCTION**
0.000000	0.330925	FERMI
0.000000	-0.725605	**OUTPUT**
0.000000	0.564643	0.000000
0.000000	-0.242209	
0.000000	0.658155	
0.000000	0.827791	
0.000000	0.635385	
0.000000	-1.075909	
0.000000	0.687894	
0.000000	-0.519565	
0.000000	-0.822241	
0.000000	0.805023	
0.000000	-0.739958	
0.000000	0.098990	
0.000000	0.136662	
0.000000	0.662156	
0.000000	-0.965877	
0.000000	-0.331704	
0.000000	0.964156	
0.000000	-0.687255	
0.000000	-0.581075	
0.000000	-0.102224	
0.000000	-0.374520	
0.000000	-0.885102	
0.000000	-0.175516	
0.000000	0.578629	
0.000000	-0.977941	
0.000000	-0.400307	
0.000000	-0.855407	
0.000000	-0.604991	
0.000000	0.356742	
0.000000	0.286856	
0.000000	-0.809030	
0.000000	0.544834	
0.000000	-0.926799	
0.000000	-0.536431	
0.000000	-0.002864	

Neuron 'N1_008'

INPUTS	WEIGHTS	
0.000000	-0.451557	**ACTIVITY**
0.000000	0.513108	0.000000
0.000000	-0.208865	**FUNCTION**
0.000000	-0.198753	FERMI
0.000000	-0.569775	**OUTPUT**
0.000000	-0.343557	0.000000
0.000000	-0.609075	
0.000000	0.119009	
0.000000	0.279909	
0.000000	-0.800465	
0.000000	-0.597598	
0.000000	0.854430	
0.000000	0.789338	
0.000000	0.607386	
0.000000	0.380706	
0.000000	-1.103843	
0.000000	-0.165384	
0.000000	0.642779	
0.000000	-0.572470	
0.000000	0.674281	
0.000000	0.180913	
0.000000	0.220535	
0.000000	-0.839389	
0.000000	-0.461373	
0.000000	-0.936361	
0.000000	-0.256675	
0.000000	0.934382	
0.000000	0.120647	
0.000000	-0.132905	
0.000000	-0.734708	
0.000000	-0.513907	
0.000000	-0.052512	
0.000000	0.630824	
0.000000	-0.861198	
0.000000	0.278844	
0.000000	0.348636	
0.000000	0.890724	
0.000000	-1.005413	
0.000000	0.320648	
0.000000	0.506754	

Neuron 'N1_009'

INPUTS	WEIGHTS	
0.000000	-0.117547	**ACTIVITY**
0.000000	-0.594915	0.000000
0.000000	-0.263932	**FUNCTION**
0.000000	0.397893	FERMI
0.000000	-0.855152	**OUTPUT**
0.000000	1.145626	0.000000
0.000000	0.135432	
0.000000	0.783750	
0.000000	-0.830509	
0.000000	1.605298	
0.000000	-0.037209	
0.000000	0.201102	
0.000000	1.049292	
0.000000	-0.498261	
0.000000	-1.054819	
0.000000	-1.206545	
0.000000	-0.089901	
0.000000	0.803804	
0.000000	0.419176	
0.000000	-0.476177	
0.000000	-0.088471	
0.000000	-0.338763	
0.000000	-0.842418	
0.000000	1.302149	
0.000000	0.672946	
0.000000	0.334301	
0.000000	-0.838673	
0.000000	-0.508922	
0.000000	-0.447181	
0.000000	-0.268581	
0.000000	-0.436663	
0.000000	-0.968306	
0.000000	0.496538	
0.000000	0.476508	
0.000000	0.584769	
0.000000	0.828325	
0.000000	-0.622104	
0.000000	0.996677	
0.000000	-0.399464	
0.000000	-0.854245	

Neuron 'N1_010'

INPUTS	WEIGHTS	
0.000000	-3.000485	**ACTIVITY**
0.000000	-0.411932	0.000000
0.000000	0.179953	**FUNCTION**
0.000000	-0.556968	FERMI
0.000000	-0.413486	**OUTPUT**
0.000000	0.827939	0.000000
0.000000	1.420990	
0.000000	-1.394013	
0.000000	-1.593656	
0.000000	0.285216	
0.000000	-0.400874	
0.000000	-0.311694	
0.000000	0.228224	
0.000000	0.102580	
0.000000	-0.516234	
0.000000	0.935286	
0.000000	-1.200129	
0.000000	0.961364	
0.000000	-0.318646	
0.000000	0.950627	
0.000000	-0.160383	
0.000000	0.661001	
0.000000	-0.358805	
0.000000	-0.489998	
0.000000	-0.875865	
0.000000	0.281424	
0.000000	-0.075017	
0.000000	-0.626370	
0.000000	-0.039165	
0.000000	-1.177140	
0.000000	-0.535122	
0.000000	-0.037514	
0.000000	-0.998810	
0.000000	0.411217	
0.000000	0.671569	
0.000000	0.632331	
0.000000	0.894015	
0.000000	-0.104543	
0.000000	-0.900513	
0.000000	-0.870879	

Table C-1 (Con't)

Neuron 'N1_011'

INPUTS	WEIGHTS	
0.000000	0.285070	**ACTIVITY**
0.000000	0.687002	0.000000
0.000000	-0.558378	**FUNCTION**
0.000000	-0.388065	FERMI
0.000000	-0.194829	**OUTPUT**
0.000000	-0.151530	0.000000
0.000000	-0.014250	
0.000000	-0.782088	
0.000000	0.192049	
0.000000	-1.145088	
0.000000	-0.613730	
0.000000	0.868263	
0.000000	0.349448	
0.000000	-0.361707	
0.000000	0.566768	
0.000000	0.673288	
0.000000	-1.047660	
0.000000	-0.809076	
0.000000	-0.478838	
0.000000	0.722255	
0.000000	-0.443837	
0.000000	-0.172937	
0.000000	-0.891083	
0.000000	-0.564989	
0.000000	-0.816906	
0.000000	0.592690	
0.000000	0.526881	
0.000000	-0.986481	
0.000000	0.210133	
0.000000	0.404959	
0.000000	0.045188	
0.000000	-0.039421	
0.000000	-0.697492	
0.000000	0.809928	
0.000000	-0.445539	
0.000000	-0.424603	
0.000000	0.157578	
0.000000	-0.552841	
0.000000	-1.022911	
0.000000	0.575709	

Neuron 'N1_012'

INPUTS	WEIGHTS	
0.000000	0.719442	**ACTIVITY**
0.000000	-0.696765	0.000000
0.000000	-0.919470	**FUNCTION**
0.000000	0.560019	FERMI
0.000000	0.481450	**OUTPUT**
0.000000	-0.178252	0.000000
0.000000	0.603208	
0.000000	0.102734	
0.000000	0.998368	
0.000000	-0.380449	
0.000000	-0.866107	
0.000000	-0.007108	
0.000000	0.352551	
0.000000	-0.992271	
0.000000	0.019410	
0.000000	-0.411335	
0.000000	-0.197830	
0.000000	-0.201362	
0.000000	0.342912	
0.000000	0.669154	
0.000000	-0.506235	
0.000000	-1.129052	
0.000000	0.524340	
0.000000	0.586118	
0.000000	0.722164	
0.000000	0.772421	
0.000000	0.277461	
0.000000	-0.612748	
0.000000	0.262449	
0.000000	-0.912445	
0.000000	0.070486	
0.000000	-0.985770	
0.000000	-0.097410	
0.000000	-0.201013	
0.000000	0.361850	
0.000000	-1.117617	
0.000000	0.076376	
0.000000	0.544388	
0.000000	-0.646762	
0.000000	0.348379	

Neuron 'N1_013'

INPUTS	WEIGHTS	
0.000000	-4.240555	**ACTIVITY**
0.000000	-0.580144	0.000000
0.000000	0.742023	**FUNCTION**
0.000000	0.223063	FERMI
0.000000	-0.970697	**OUTPUT**
0.000000	0.427811	0.000000
0.000000	0.428677	
0.000000	0.962728	
0.000000	-0.357918	
0.000000	-0.762460	
0.000000	0.532195	
0.000000	-0.665308	
0.000000	-0.189353	
0.000000	0.861198	
0.000000	-0.197206	
0.000000	0.331769	
0.000000	-0.549888	
0.000000	0.263713	
0.000000	0.071110	
0.000000	0.424459	
0.000000	0.056036	
0.000000	-0.304024	
0.000000	-0.147606	
0.000000	0.366323	
0.000000	0.260933	
0.000000	-0.692096	
0.000000	0.528970	
0.000000	-0.364050	
0.000000	-0.099764	
0.000000	0.504236	
0.000000	1.046546	
0.000000	-0.768068	
0.000000	0.393194	
0.000000	0.719510	
0.000000	-0.663596	
0.000000	0.747461	
0.000000	-0.666465	
0.000000	0.859683	
0.000000	0.496613	
0.000000	0.214746	

Neuron 'N1_014'

INPUTS	WEIGHTS	
0.000000	0.668367	**ACTIVITY**
0.000000	-0.843983	0.000000
0.000000	-0.130688	**FUNCTION**
0.000000	0.608103	FERMI
0.000000	0.394280	**OUTPUT**
0.000000	0.558678	0.000000
0.000000	-0.617082	
0.000000	0.202301	
0.000000	0.298904	
0.000000	-0.733816	
0.000000	-0.244702	
0.000000	0.929401	
0.000000	-0.246817	
0.000000	-0.882929	
0.000000	-0.509208	
0.000000	0.628757	
0.000000	-0.158214	
0.000000	0.079210	
0.000000	-0.040894	
0.000000	-0.643184	
0.000000	0.222231	
0.000000	0.512436	
0.000000	-0.929278	
0.000000	-0.114484	
0.000000	-0.450005	
0.000000	-0.899980	
0.000000	-0.755710	
0.000000	-0.799622	
0.000000	-0.595576	
0.000000	-0.565477	
0.000000	-0.535226	
0.000000	0.077379	
0.000000	0.535621	
0.000000	-0.487161	
0.000000	0.410209	
0.000000	-0.458940	
0.000000	0.037287	
0.000000	-0.537709	
0.000000	-0.199541	
0.000000	0.493710	

Neuron 'N1_015'

INPUTS	WEIGHTS	
0.000000	-0.781760	**ACTIVITY**
0.000000	0.836465	0.000000
0.000000	-0.933082	**FUNCTION**
0.000000	0.255393	FERMI
0.000000	0.029550	**OUTPUT**
0.000000	-0.524302	0.000000
0.000000	0.570604	
0.000000	-0.616353	
0.000000	0.815299	
0.000000	-0.454376	
0.000000	-0.002828	
0.000000	-0.691622	
0.000000	-0.122241	
0.000000	-0.190438	
0.000000	-0.806391	
0.000000	-0.109141	
0.000000	-0.977103	
0.000000	-0.274350	
0.000000	0.746946	
0.000000	-0.678384	
0.000000	0.573705	
0.000000	0.723663	
0.000000	0.485968	
0.000000	0.513569	
0.000000	-0.224942	
0.000000	0.757006	
0.000000	-0.608544	
0.000000	-1.147940	
0.000000	-0.874756	
0.000000	0.611146	
0.000000	-0.590784	
0.000000	0.797874	
0.000000	0.386332	
0.000000	-0.176475	
0.000000	-0.555681	
0.000000	-0.183337	
0.000000	0.109113	
0.000000	-0.189523	
0.000000	0.758847	
0.000000	-0.064707	

Table C-1 (Con't)

Neuron 'N1_016'

INPUTS	WEIGHTS	
0.000000	-0.766395	**ACTIVITY**
0.000000	-0.638625	0.000000
0.000000	0.844264	**FUNCTION**
0.000000	-0.141033	FERMI
0.000000	-0.057350	**OUTPUT**
0.000000	-0.645805	0.000000
0.000000	0.580253	
0.000000	0.323448	
0.000000	0.223934	
0.000000	0.553976	
0.000000	-0.811348	
0.000000	-0.312155	
0.000000	-1.024680	
0.000000	-0.869667	
0.000000	-0.310112	
0.000000	-0.670142	
0.000000	0.548815	
0.000000	0.716798	
0.000000	-0.037973	
0.000000	-0.590891	
0.000000	-1.088173	
0.000000	-1.006653	
0.000000	0.609224	
0.000000	0.244553	
0.000000	-0.028254	
0.000000	-0.803588	
0.000000	0.407252	
0.000000	-0.297803	
0.000000	-0.931407	
0.000000	0.857969	
0.000000	0.093408	
0.000000	-0.643110	
0.000000	-0.434120	
0.000000	-0.161063	
0.000000	0.883809	
0.000000	0.314935	
0.000000	0.793738	
0.000000	-0.638832	
0.000000	0.051593	
0.000000	-0.818268	

Neuron 'N1_017'

INPUTS	WEIGHTS	
0.000000	0.356448	**ACTIVITY**
0.000000	0.091774	0.000000
0.000000	0.447110	**FUNCTION**
0.000000	-0.164742	FERMI
0.000000	0.851474	**OUTPUT**
0.000000	0.963730	0.000000
0.000000	-0.630527	
0.000000	0.759914	
0.000000	-0.325614	
0.000000	0.762102	
0.000000	-0.496781	
0.000000	-0.911557	
0.000000	0.601441	
0.000000	-0.141777	
0.000000	-0.213069	
0.000000	0.183667	
0.000000	-0.533136	
0.000000	-0.509284	
0.000000	0.470712	
0.000000	-0.259924	
0.000000	-0.206088	
0.000000	0.359794	
0.000000	-0.590094	
0.000000	0.148595	
0.000000	0.816930	
0.000000	-0.537365	
0.000000	0.256823	
0.000000	-0.855643	
0.000000	-0.655596	
0.000000	-0.339934	
0.000000	-0.740178	
0.000000	-0.536923	
0.000000	0.727850	
0.000000	0.367982	
0.000000	-0.020837	
0.000000	-0.050111	
0.000000	-0.703034	
0.000000	-0.542936	
0.000000	-0.230862	
0.000000	-0.790594	

Neuron 'N1_018'

INPUTS	WEIGHTS	
0.000000	0.713236	**ACTIVITY**
0.000000	-1.332471	0.000000
0.000000	0.220270	**FUNCTION**
0.000000	1.091425	FERMI
0.000000	-0.072210	**OUTPUT**
0.000000	-0.135414	0.000000
0.000000	-0.108142	
0.000000	0.509726	
0.000000	-0.419106	
0.000000	1.302595	
0.000000	0.498993	
0.000000	0.810430	
0.000000	-0.160847	
0.000000	1.598369	
0.000000	-0.902480	
0.000000	-0.459322	
0.000000	-0.862585	
0.000000	-0.766624	
0.000000	0.587233	
0.000000	0.252649	
0.000000	0.943631	
0.000000	-0.634595	
0.000000	-0.222170	
0.000000	-0.620251	
0.000000	2.052047	
0.000000	-0.027555	
0.000000	-0.255772	
0.000000	0.885397	
0.000000	-0.154488	
0.000000	1.017300	
0.000000	-0.025819	
0.000000	0.725494	
0.000000	-0.141015	
0.000000	-1.046519	
0.000000	-1.185748	
0.000000	-0.441333	
0.000000	0.514221	
0.000000	0.092116	
0.000000	0.117350	
0.000000	-0.385392	

Neuron 'N1_019'

INPUTS	WEIGHTS	
0.000000	-0.498384	**ACTIVITY**
0.000000	0.069355	0.000000
0.000000	-1.971433	**FUNCTION**
0.000000	0.014517	FERMI
0.000000	-0.391676	**OUTPUT**
0.000000	-0.029559	0.000000
0.000000	-1.595067	
0.000000	1.766448	
0.000000	0.139148	
0.000000	1.622865	
0.000000	0.071454	
0.000000	-0.417829	
0.000000	0.365860	
0.000000	-3.993459	
0.000000	0.480161	
0.000000	0.381318	
0.000000	-0.267793	
0.000000	0.906232	
0.000000	0.604886	
0.000000	-2.229068	
0.000000	0.563033	
0.000000	0.550442	
0.000000	-1.586327	
0.000000	-0.759010	
0.000000	-0.611282	
0.000000	0.933240	
0.000000	0.159776	
0.000000	0.858319	
0.000000	-0.461735	
0.000000	-0.461135	
0.000000	0.589456	
0.000000	1.196661	
0.000000	-0.102056	
0.000000	0.222431	
0.000000	0.667476	
0.000000	-0.801915	
0.000000	0.644263	
0.000000	0.642111	
0.000000	0.606834	
0.000000	0.253742	

Neuron 'N1_020'

INPUTS	WEIGHTS	
0.000000	-1.170191	**ACTIVITY**
0.000000	-0.131118	0.000000
0.000000	-0.260896	**FUNCTION**
0.000000	-0.255170	FERMI
0.000000	-0.498503	**OUTPUT**
0.000000	-1.631393	0.000000
0.000000	-0.926264	
0.000000	-0.269351	
0.000000	0.738980	
0.000000	0.441917	
0.000000	-0.341537	
0.000000	0.546061	
0.000000	0.668172	
0.000000	0.967997	
0.000000	1.355400	
0.000000	-0.503021	
0.000000	0.539102	
0.000000	-0.507397	
0.000000	0.117307	
0.000000	0.654325	
0.000000	-0.961319	
0.000000	-0.189470	
0.000000	-0.387936	
0.000000	-0.104915	
0.000000	-0.113663	
0.000000	0.322708	
0.000000	-0.144273	
0.000000	-1.386433	
0.000000	-0.427395	
0.000000	-0.467875	
0.000000	-0.003250	
0.000000	0.485718	
0.000000	-0.198291	
0.000000	-0.441163	
0.000000	0.773365	
0.000000	0.188058	
0.000000	-0.688927	
0.000000	0.560638	
0.000000	1.040535	
0.000000	1.122145	

Table C-1 (Con't)

Neuron 'N1_021'

INPUTS	WEIGHTS	
0.000000	-0.676415	**ACTIVITY**
0.000000	-1.299092	0.000000
0.000000	-0.231545	**FUNCTION**
0.000000	-0.979634	FERMI
0.000000	0.680550	**OUTPUT**
0.000000	-0.437745	0.000000
0.000000	0.292251	
0.000000	0.563978	
0.000000	-0.879389	
0.000000	-0.250415	
0.000000	-0.545141	
0.000000	0.673460	
0.000000	0.160435	
0.000000	-0.587126	
0.000000	0.365943	
0.000000	-0.455028	
0.000000	-0.155981	
0.000000	-0.501415	
0.000000	0.381570	
0.000000	1.151835	
0.000000	-0.542743	
0.000000	-0.388696	
0.000000	0.086260	
0.000000	-0.389362	
0.000000	0.128898	
0.000000	-0.123056	
0.000000	-0.192776	
0.000000	-0.240904	
0.000000	0.782717	
0.000000	-1.102343	
0.000000	-0.204349	
0.000000	0.390808	
0.000000	0.867601	
0.000000	-0.737927	
0.000000	-0.899086	
0.000000	0.070855	
0.000000	-0.456143	
0.000000	-0.122538	
0.000000	-1.214760	
0.000000	-0.535731	

Neuron 'N1_022'

INPUTS	WEIGHTS	
0.000000	-0.268914	**ACTIVITY**
0.000000	0.682612	0.000000
0.000000	-0.532050	**FUNCTION**
0.000000	-0.004170	FERMI
0.000000	0.548567	**OUTPUT**
0.000000	-0.765519	0.000000
0.000000	0.769767	
0.000000	-1.432325	
0.000000	-0.420513	
0.000000	-0.612832	
0.000000	0.756213	
0.000000	-0.118642	
0.000000	0.182742	
0.000000	-0.493855	
0.000000	0.873199	
0.000000	0.259937	
0.000000	-0.522725	
0.000000	0.583020	
0.000000	-1.274964	
0.000000	1.110517	
0.000000	-0.160358	
0.000000	0.375496	
0.000000	-0.097745	
0.000000	-0.059484	
0.000000	-1.035890	
0.000000	0.065267	
0.000000	-0.950398	
0.000000	-1.766637	
0.000000	0.250374	
0.000000	0.045355	
0.000000	-0.463346	
0.000000	0.366450	
0.000000	0.326230	
0.000000	2.369134	
0.000000	0.242172	
0.000000	0.498268	
0.000000	0.368552	
0.000000	-1.461050	
0.000000	0.913906	
0.000000	0.531668	

Neuron 'N1_023'

INPUTS	WEIGHTS	
0.000000	0.262284	**ACTIVITY**
0.000000	0.139422	0.000000
0.000000	0.458096	**FUNCTION**
0.000000	-0.303383	FERMI
0.000000	-0.258369	**OUTPUT**
0.000000	0.174673	0.000000
0.000000	0.322516	
0.000000	-1.050851	
0.000000	0.084556	
0.000000	0.034312	
0.000000	0.550109	
0.000000	-0.234684	
0.000000	-0.930785	
0.000000	-1.141124	
0.000000	-0.744955	
0.000000	-0.863560	
0.000000	-0.251023	
0.000000	0.138370	
0.000000	-0.545980	
0.000000	-1.044460	
0.000000	-0.827077	
0.000000	0.467351	
0.000000	0.523324	
0.000000	-0.748287	
0.000000	-0.606367	
0.000000	0.703559	
0.000000	0.528052	
0.000000	0.283092	
0.000000	0.747780	
0.000000	0.811514	
0.000000	0.586771	
0.000000	0.160547	
0.000000	-0.981666	
0.000000	0.141807	
0.000000	-0.846580	
0.000000	-0.175694	
0.000000	0.557606	
0.000000	0.098622	
0.000000	0.848348	
0.000000	0.318251	

Neuron 'N1_024'

INPUTS	WEIGHTS	
0.000000	0.418771	**ACTIVITY**
0.000000	0.123416	0.000000
0.000000	0.490891	**FUNCTION**
0.000000	-0.706245	FERMI
0.000000	-1.096804	**OUTPUT**
0.000000	0.350531	0.000000
0.000000	-0.522889	
0.000000	0.197432	
0.000000	-0.459690	
0.000000	0.402074	
0.000000	-0.320414	
0.000000	0.812035	
0.000000	-0.750039	
0.000000	0.654377	
0.000000	-0.073005	
0.000000	1.591951	
0.000000	-0.174244	
0.000000	0.123117	
0.000000	0.587560	
0.000000	-0.482442	
0.000000	-0.871947	
0.000000	-0.074739	
0.000000	0.353554	
0.000000	0.160949	
0.000000	-0.310810	
0.000000	0.290497	
0.000000	0.334740	
0.000000	-1.157799	
0.000000	-0.527208	
0.000000	0.872177	
0.000000	0.403942	
0.000000	0.080575	
0.000000	-0.422243	
0.000000	-0.960454	
0.000000	0.792648	
0.000000	0.268429	
0.000000	1.378902	
0.000000	0.900376	
0.000000	-0.367358	
0.000000	-1.575987	

Neuron 'N1_025'

INPUTS	WEIGHTS	
0.000000	0.071420	**ACTIVITY**
0.000000	0.506742	0.000000
0.000000	-0.355310	**FUNCTION**
0.000000	-0.615942	FERMI
0.000000	0.491055	**OUTPUT**
0.000000	-0.324994	0.000000
0.000000	-0.600029	
0.000000	0.245996	
0.000000	1.121755	
0.000000	-0.411380	
0.000000	0.648017	
0.000000	-0.860507	
0.000000	0.489268	
0.000000	0.177562	
0.000000	0.870052	
0.000000	0.048637	
0.000000	-1.015507	
0.000000	-1.034871	
0.000000	-0.574858	
0.000000	-0.770497	
0.000000	-0.129691	
0.000000	0.933727	
0.000000	-0.518218	
0.000000	0.797500	
0.000000	1.118858	
0.000000	-0.347950	
0.000000	-0.958830	
0.000000	-0.173522	
0.000000	-0.220435	
0.000000	-0.355090	
0.000000	1.163306	
0.000000	0.079845	
0.000000	0.743995	
0.000000	0.473198	
0.000000	0.568732	
0.000000	-0.364215	
0.000000	0.309187	
0.000000	-0.007358	
0.000000	-0.076671	
0.000000	-1.318793	

Table C-1 (Con't)

Neuron 'N1_026'

INPUTS	WEIGHTS	
0.000000	-0.185457	ACTIVITY
0.000000	-0.028865	0.000000
0.000000	0.042541	FUNCTION
0.000000	0.422494	FERMI
0.000000	0.591305	OUTPUT
0.000000	-0.637729	0.000000
0.000000	0.505448	
0.000000	0.105528	
0.000000	0.471786	
0.000000	-0.149566	
0.000000	-0.179105	
0.000000	-0.648405	
0.000000	-0.818159	
0.000000	-0.303382	
0.000000	-0.408025	
0.000000	1.044567	
0.000000	-1.061837	
0.000000	-0.702207	
0.000000	0.209757	
0.000000	0.577611	
0.000000	0.249290	
0.000000	-0.067887	
0.000000	0.390653	
0.000000	0.329151	
0.000000	0.530152	
0.000000	-0.891872	
0.000000	0.161710	
0.000000	0.580676	
0.000000	-0.363511	
0.000000	0.691963	
0.000000	0.346665	
0.000000	-0.864558	
0.000000	0.434447	
0.000000	-0.499046	
0.000000	-0.332687	
0.000000	0.652822	
0.000000	0.736945	
0.000000	0.378136	
0.000000	-1.146746	
0.000000	-0.840869	

Neuron 'N1_027'

INPUTS	WEIGHTS	
0.000000	-0.934127	ACTIVITY
0.000000	0.733757	0.000000
0.000000	0.911399	FUNCTION
0.000000	0.765501	FERMI
0.000000	-0.770174	OUTPUT
0.000000	0.099406	0.000000
0.000000	-0.186716	
0.000000	-0.727792	
0.000000	0.102733	
0.000000	-0.605468	
0.000000	0.513835	
0.000000	-0.609686	
0.000000	0.220772	
0.000000	-0.123955	
0.000000	0.629084	
0.000000	-0.524011	
0.000000	-0.602889	
0.000000	0.183099	
0.000000	-0.590615	
0.000000	-0.737121	
0.000000	-0.614832	
0.000000	0.951636	
0.000000	-0.313105	
0.000000	-0.248210	
0.000000	-0.053428	
0.000000	0.819078	
0.000000	-0.408745	
0.000000	-0.533585	
0.000000	-0.023764	
0.000000	0.273975	
0.000000	-0.844442	
0.000000	-0.775922	
0.000000	-0.204297	
0.000000	0.033562	
0.000000	-0.137737	
0.000000	-0.356670	
0.000000	-0.946629	
0.000000	0.169252	
0.000000	0.140391	
0.000000	-0.026042	

Neuron 'N1_028'

INPUTS	WEIGHTS	
0.000000	0.677872	ACTIVITY
0.000000	-0.280652	0.000000
0.000000	-0.014159	FUNCTION
0.000000	-1.033488	FERMI
0.000000	-0.804233	OUTPUT
0.000000	-0.775465	0.000000
0.000000	0.638067	
0.000000	0.653663	
0.000000	0.336310	
0.000000	-0.662892	
0.000000	-0.806701	
0.000000	0.553100	
0.000000	0.337646	
0.000000	-0.766518	
0.000000	-0.600307	
0.000000	0.772970	
0.000000	0.644121	
0.000000	-0.055601	
0.000000	-1.095350	
0.000000	0.311301	
0.000000	-0.112273	
0.000000	0.626433	
0.000000	-0.811703	
0.000000	0.463476	
0.000000	-0.883101	
0.000000	0.627285	
0.000000	-0.975220	
0.000000	0.467678	
0.000000	-0.022690	
0.000000	0.305132	
0.000000	-0.212424	
0.000000	-0.640867	
0.000000	-0.556997	
0.000000	-0.977859	
0.000000	0.223652	
0.000000	0.759987	
0.000000	0.888051	
0.000000	-0.593636	
0.000000	0.682806	
0.000000	0.548471	

Neuron 'N1_029'

INPUTS	WEIGHTS	
0.000000	0.667382	ACTIVITY
0.000000	-0.088426	0.000000
0.000000	-0.145812	FUNCTION
0.000000	-0.565729	FERMI
0.000000	-0.103353	OUTPUT
0.000000	0.485493	0.000000
0.000000	-0.862600	
0.000000	-0.748430	
0.000000	-0.978491	
0.000000	0.581365	
0.000000	-0.504205	
0.000000	-1.135471	
0.000000	0.516952	
0.000000	0.770296	
0.000000	-0.573461	
0.000000	0.752562	
0.000000	0.756327	
0.000000	0.800837	
0.000000	0.587019	
0.000000	-1.054516	
0.000000	0.120581	
0.000000	-0.972815	
0.000000	0.748627	
0.000000	-0.002321	
0.000000	-0.033117	
0.000000	-0.973639	
0.000000	-0.613958	
0.000000	0.142263	
0.000000	-0.922398	
0.000000	0.250205	
0.000000	-0.772293	
0.000000	0.321385	
0.000000	-0.634841	
0.000000	-0.118124	
0.000000	0.565112	
0.000000	0.802014	
0.000000	0.864627	
0.000000	-0.571712	
0.000000	0.596317	
0.000000	0.100657	

Neuron 'N1_030'

INPUTS	WEIGHTS	
0.000000	0.284694	ACTIVITY
0.000000	-0.279431	0.000000
0.000000	0.037076	FUNCTION
0.000000	-1.058332	FERMI
0.000000	-0.543262	OUTPUT
0.000000	0.487246	0.000000
0.000000	0.319118	
0.000000	0.215191	
0.000000	-1.017726	
0.000000	0.564293	
0.000000	0.470701	
0.000000	-0.177291	
0.000000	0.855829	
0.000000	0.549598	
0.000000	-1.021512	
0.000000	0.046013	
0.000000	-0.861038	
0.000000	0.604919	
0.000000	-1.286610	
0.000000	-0.167164	
0.000000	-0.595843	
0.000000	-0.668717	
0.000000	0.094586	
0.000000	0.652795	
0.000000	0.083096	
0.000000	-1.118164	
0.000000	-1.762583	
0.000000	1.647742	
0.000000	-0.405001	
0.000000	0.577074	
0.000000	-0.225544	
0.000000	-0.848391	
0.000000	-0.043397	
0.000000	0.759730	
0.000000	1.326074	
0.000000	-0.035656	
0.000000	1.869339	
0.000000	-0.915776	
0.000000	0.001415	
0.000000	-2.079816	

Table C-1 (Con’t)

Neuron 'N1_031'

INPUTS	WEIGHTS	
0.000000	0.740283	**ACTIVITY**
0.000000	-0.327862	0.000000
0.000000	0.892053	**FUNCTION**
0.000000	-0.992125	FERMI
0.000000	-0.058986	**OUTPUT**
0.000000	-0.403895	0.000000
0.000000	0.076488	
0.000000	-0.186287	
0.000000	-0.262323	
0.000000	-0.713164	
0.000000	0.462296	
0.000000	0.073398	
0.000000	-0.580134	
0.000000	0.264174	
0.000000	-0.947672	
0.000000	0.112359	
0.000000	-0.607056	
0.000000	-0.873380	
0.000000	0.815419	
0.000000	0.184979	
0.000000	-0.119152	
0.000000	0.204685	
0.000000	0.608163	
0.000000	-0.188633	
0.000000	-0.394224	
0.000000	0.752585	
0.000000	-0.823227	
0.000000	-0.747963	
0.000000	-0.846625	
0.000000	0.930536	
0.000000	-0.612871	
0.000000	-0.814463	
0.000000	0.826737	
0.000000	-0.680007	
0.000000	-0.053175	
0.000000	0.251675	
0.000000	-0.453451	
0.000000	0.190682	
0.000000	-0.915031	
0.000000	0.861265	

Neuron 'N1_032'

INPUTS	WEIGHTS	
0.000000	-0.067603	**ACTIVITY**
0.000000	0.284156	0.000000
0.000000	0.668306	**FUNCTION**
0.000000	0.151061	FERMI
0.000000	-0.001568	**OUTPUT**
0.000000	-0.929099	0.000000
0.000000	0.362670	
0.000000	0.374585	
0.000000	0.565184	
0.000000	-1.202440	
0.000000	0.893944	
0.000000	-0.460024	
0.000000	0.029147	
0.000000	0.158823	
0.000000	0.008601	
0.000000	-0.674909	
0.000000	-0.729620	
0.000000	-0.974949	
0.000000	-0.043950	
0.000000	0.148633	
0.000000	-0.437468	
0.000000	-0.619228	
0.000000	-1.130569	
0.000000	-0.588924	
0.000000	-1.038953	
0.000000	0.149083	
0.000000	0.939374	
0.000000	-0.669423	
0.000000	0.115468	
0.000000	-0.158253	
0.000000	0.860235	
0.000000	-0.891399	
0.000000	0.659081	
0.000000	-0.351976	
0.000000	0.344860	
0.000000	-0.828529	
0.000000	-0.277093	
0.000000	1.426370	
0.000000	-0.422294	
0.000000	-0.341388	

Neuron 'N1_033'

INPUTS	WEIGHTS	
0.000000	0.186981	**ACTIVITY**
0.000000	0.214783	0.000000
0.000000	-0.208183	**FUNCTION**
0.000000	0.335690	FERMI
0.000000	0.234103	**OUTPUT**
0.000000	-0.460565	0.000000
0.000000	-0.180710	
0.000000	-0.335352	
0.000000	-0.073494	
0.000000	-0.172440	
0.000000	-0.182994	
0.000000	-0.406581	
0.000000	-0.198000	
0.000000	0.394492	
0.000000	0.549073	
0.000000	0.660636	
0.000000	-0.336669	
0.000000	0.381154	
0.000000	-0.105154	
0.000000	0.860390	
0.000000	-0.533793	
0.000000	-0.029566	
0.000000	-0.763430	
0.000000	-0.779437	
0.000000	-0.413441	
0.000000	0.727191	
0.000000	0.115857	
0.000000	0.190490	
0.000000	0.496908	
0.000000	-0.553980	
0.000000	0.844486	
0.000000	0.071426	
0.000000	-0.666341	
0.000000	-0.037137	
0.000000	-0.327541	
0.000000	-0.541180	
0.000000	-0.292149	
0.000000	0.149722	
0.000000	0.019605	
0.000000	0.463738	

Neuron 'N1_034'

INPUTS	WEIGHTS	
0.000000	-0.407883	**ACTIVITY**
0.000000	-0.714796	0.000000
0.000000	0.406448	**FUNCTION**
0.000000	-0.140135	FERMI
0.000000	0.534964	**OUTPUT**
0.000000	-0.957688	0.000000
0.000000	0.617285	
0.000000	0.223543	
0.000000	-0.454765	
0.000000	-0.506993	
0.000000	0.720234	
0.000000	-0.862153	
0.000000	-0.656576	
0.000000	0.034075	
0.000000	0.062329	
0.000000	0.390262	
0.000000	-0.842751	
0.000000	-0.117621	
0.000000	-0.650053	
0.000000	0.437958	
0.000000	-0.897384	
0.000000	0.630746	
0.000000	-0.469431	
0.000000	0.039210	
0.000000	0.954850	
0.000000	-0.995858	
0.000000	-0.979465	
0.000000	-0.549493	
0.000000	-0.682910	
0.000000	-0.908027	
0.000000	-0.387043	
0.000000	-0.190343	
0.000000	0.599927	
0.000000	0.456626	
0.000000	0.788574	
0.000000	-0.961776	
0.000000	0.514250	
0.000000	-0.687103	
0.000000	0.734528	
0.000000	-0.328914	

Neuron 'N1_035'

INPUTS	WEIGHTS	
0.000000	-0.579880	**ACTIVITY**
0.000000	0.297887	0.000000
0.000000	0.673037	**FUNCTION**
0.000000	0.651905	FERMI
0.000000	-1.057854	**OUTPUT**
0.000000	0.783879	0.000000
0.000000	-0.836344	
0.000000	1.028199	
0.000000	-0.297199	
0.000000	-1.047273	
0.000000	-0.667267	
0.000000	0.701386	
0.000000	-0.496913	
0.000000	0.457364	
0.000000	-0.767687	
0.000000	-0.828315	
0.000000	-0.087274	
0.000000	-0.732175	
0.000000	0.718348	
0.000000	0.529328	
0.000000	1.011286	
0.000000	0.937812	
0.000000	0.667686	
0.000000	-0.198605	
0.000000	-0.474787	
0.000000	0.572827	
0.000000	-0.094205	
0.000000	0.219439	
0.000000	-0.239327	
0.000000	-0.086347	
0.000000	-0.043047	
0.000000	0.623826	
0.000000	-0.229947	
0.000000	-0.183084	
0.000000	-0.928628	
0.000000	-0.184503	
0.000000	0.527060	
0.000000	-0.269838	
0.000000	-0.651048	
0.000000	0.003879	

Table C-1 (Con’t)

Neuron 'N1_036'

INPUTS	WEIGHTS	
0.000000	-0.683296	**ACTIVITY**
0.000000	0.028021	0.000000
0.000000	0.236862	**FUNCTION**
0.000000	-0.263090	FERMI
0.000000	0.178111	**OUTPUT**
0.000000	-0.223961	0.000000
0.000000	0.376644	
0.000000	0.228898	
0.000000	0.550918	
0.000000	0.004770	
0.000000	0.034318	
0.000000	0.140784	
0.000000	-0.492604	
0.000000	1.041645	
0.000000	0.160288	
0.000000	-1.208270	
0.000000	0.854830	
0.000000	-0.454480	
0.000000	-0.439240	
0.000000	-0.717032	
0.000000	-0.828227	
0.000000	0.634571	
0.000000	-0.284283	
0.000000	0.653093	
0.000000	0.837434	
0.000000	0.132109	
0.000000	-1.079519	
0.000000	0.135729	
0.000000	0.464812	
0.000000	0.364740	
0.000000	0.537390	
0.000000	-0.485910	
0.000000	-0.110691	
0.000000	-0.447558	
0.000000	-0.099559	
0.000000	-0.003750	
0.000000	-0.483084	
0.000000	0.492301	
0.000000	-0.244756	
0.000000	0.100162	

Neuron 'N1_037'

INPUTS	WEIGHTS	
0.000000	0.778685	**ACTIVITY**
0.000000	-0.196644	0.000000
0.000000	0.648615	**FUNCTION**
0.000000	0.305555	FERMI
0.000000	0.285620	**OUTPUT**
0.000000	0.663470	0.000000
0.000000	-0.428078	
0.000000	-0.920527	
0.000000	-0.666497	
0.000000	-0.692519	
0.000000	-1.398825	
0.000000	0.176075	
0.000000	0.523547	
0.000000	0.242745	
0.000000	-1.073583	
0.000000	0.718271	
0.000000	0.899774	
0.000000	0.334435	
0.000000	0.899236	
0.000000	0.255925	
0.000000	-0.222683	
0.000000	-0.926004	
0.000000	-0.373346	
0.000000	-0.521488	
0.000000	0.095972	
0.000000	-0.148327	
0.000000	-1.193230	
0.000000	0.960508	
0.000000	0.462762	
0.000000	0.680259	
0.000000	0.516409	
0.000000	-0.702754	
0.000000	-0.585836	
0.000000	-0.707040	
0.000000	0.635783	
0.000000	-0.517628	
0.000000	0.766913	
0.000000	-0.466464	
0.000000	0.736803	
0.000000	0.293590	

Neuron 'N1_038'

INPUTS	WEIGHTS	
0.000000	-0.835630	**ACTIVITY**
0.000000	0.372113	0.000000
0.000000	-1.023060	**FUNCTION**
0.000000	0.216694	FERMI
0.000000	-0.091110	**OUTPUT**
0.000000	0.246778	0.000000
0.000000	0.207580	
0.000000	-0.828689	
0.000000	-1.363685	
0.000000	-0.126251	
0.000000	-2.033970	
0.000000	0.530368	
0.000000	0.928314	
0.000000	0.150658	
0.000000	-0.057063	
0.000000	-0.295094	
0.000000	-0.223928	
0.000000	0.637302	
0.000000	0.313206	
0.000000	-0.352166	
0.000000	-0.783825	
0.000000	-0.088829	
0.000000	1.045351	
0.000000	-0.357472	
0.000000	-0.265733	
0.000000	0.244746	
0.000000	0.796125	
0.000000	-0.305215	
0.000000	-0.989857	
0.000000	-0.519229	
0.000000	-0.838753	
0.000000	-0.899356	
0.000000	0.927762	
0.000000	0.667766	
0.000000	-0.456122	
0.000000	0.443246	
0.000000	1.315831	
0.000000	-0.373335	
0.000000	0.357122	
0.000000	1.554109	

Neuron 'N1_039'

INPUTS	WEIGHTS	
0.000000	1.021184	**ACTIVITY**
0.000000	-0.241161	0.000000
0.000000	0.119303	**FUNCTION**
0.000000	0.359770	FERMI
0.000000	0.436959	**OUTPUT**
0.000000	-0.455436	0.000000
0.000000	-1.292693	
0.000000	-2.192615	
0.000000	0.526225	
0.000000	-0.887348	
0.000000	0.665351	
0.000000	-1.124446	
0.000000	-0.372450	
0.000000	-0.952035	
0.000000	-1.074343	
0.000000	0.541472	
0.000000	0.707762	
0.000000	0.629715	
0.000000	-0.280543	
0.000000	0.717216	
0.000000	-0.587376	
0.000000	0.448426	
0.000000	0.701852	
0.000000	0.043279	
0.000000	-0.200299	
0.000000	0.536001	
0.000000	-0.475900	
0.000000	0.484773	
0.000000	0.081892	
0.000000	-0.052128	
0.000000	-0.858684	
0.000000	-0.564661	
0.000000	-0.567212	
0.000000	0.113496	
0.000000	0.539304	
0.000000	-0.224948	
0.000000	-1.047811	
0.000000	0.436180	
0.000000	-0.458875	
0.000000	0.651528	

Neuron 'N1_040'

INPUTS	WEIGHTS	
0.000000	0.388893	**ACTIVITY**
0.000000	-1.066240	0.000000
0.000000	0.629768	**FUNCTION**
0.000000	0.759623	FERMI
0.000000	-0.300777	**OUTPUT**
0.000000	0.313945	0.000000
0.000000	0.545350	
0.000000	0.793926	
0.000000	0.082738	
0.000000	0.667918	
0.000000	-0.853132	
0.000000	-0.230659	
0.000000	0.261451	
0.000000	-0.025607	
0.000000	-0.479925	
0.000000	0.443094	
0.000000	0.656057	
0.000000	0.238619	
0.000000	0.382818	
0.000000	-1.079463	
0.000000	-0.324897	
0.000000	0.095340	
0.000000	-0.582249	
0.000000	-0.881457	
0.000000	0.332365	
0.000000	-0.613574	
0.000000	-0.840548	
0.000000	-0.950519	
0.000000	-0.443252	
0.000000	-1.017306	
0.000000	-0.561988	
0.000000	-0.638637	
0.000000	0.672480	
0.000000	-0.820986	
0.000000	0.686202	
0.000000	0.284473	
0.000000	0.775497	
0.000000	0.148440	
0.000000	-0.447399	
0.000000	0.742256	

Table C-1 (Con't)

Neuron 'N1_041'

INPUTS	WEIGHTS	
0.000000	-3.615276	ACTIVITY
0.000000	0.177212	0.000000
0.000000	-0.083280	FUNCTION
0.000000	0.167091	FERMI
0.000000	1.089971	OUTPUT
0.000000	0.494577	0.000000
0.000000	0.117520	
0.000000	-0.281886	
0.000000	-0.457895	
0.000000	0.222624	
0.000000	-0.127592	
0.000000	-0.314687	
0.000000	-0.376613	
0.000000	0.180232	
0.000000	0.217656	
0.000000	0.232931	
0.000000	0.090224	
0.000000	0.551116	
0.000000	-0.697256	
0.000000	-1.307208	
0.000000	0.234892	
0.000000	-0.770375	
0.000000	0.548941	
0.000000	-0.952658	
0.000000	-0.207957	
0.000000	-0.123388	
0.000000	-0.127904	
0.000000	0.977412	
0.000000	-0.019397	
0.000000	0.011771	
0.000000	-0.319283	
0.000000	-0.131844	
0.000000	-0.001729	
0.000000	0.878034	
0.000000	0.677430	
0.000000	-0.886628	
0.000000	0.935800	
0.000000	1.362955	
0.000000	0.031219	
0.000000	-0.342789	

Neuron 'N1_042'

INPUTS	WEIGHTS	
0.000000	-1.494412	ACTIVITY
0.000000	1.029574	0.000000
0.000000	-1.047604	FUNCTION
0.000000	-0.345646	FERMI
0.000000	0.732954	OUTPUT
0.000000	0.307599	0.000000
0.000000	-0.208064	
0.000000	-0.883208	
0.000000	0.552766	
0.000000	0.410854	
0.000000	-0.450840	
0.000000	0.329286	
0.000000	0.664874	
0.000000	0.048620	
0.000000	-0.422931	
0.000000	0.126943	
0.000000	-0.203716	
0.000000	0.085720	
0.000000	-0.785095	
0.000000	0.251253	
0.000000	-1.258910	
0.000000	-0.479948	
0.000000	0.805281	
0.000000	-0.480022	
0.000000	-0.146256	
0.000000	0.123096	
0.000000	0.388347	
0.000000	-1.004810	
0.000000	0.723495	
0.000000	-0.097947	
0.000000	0.577024	
0.000000	0.201387	
0.000000	0.012642	
0.000000	0.622318	
0.000000	0.091885	
0.000000	-0.342706	
0.000000	0.966090	
0.000000	-0.613445	
0.000000	0.062363	
0.000000	1.038859	

Neuron 'N1_043'

INPUTS	WEIGHTS	
0.000000	-0.028293	ACTIVITY
0.000000	-0.043184	0.000000
0.000000	-0.006393	FUNCTION
0.000000	0.250138	FERMI
0.000000	0.082239	OUTPUT
0.000000	0.322214	0.000000
0.000000	0.208775	
0.000000	0.163269	
0.000000	-0.592932	
0.000000	-0.001342	
0.000000	-0.801885	
0.000000	0.324773	
0.000000	-0.001381	
0.000000	-0.826373	
0.000000	0.608559	
0.000000	0.125495	
0.000000	-0.692172	
0.000000	-0.462589	
0.000000	0.272973	
0.000000	-0.116413	
0.000000	-0.490179	
0.000000	0.092962	
0.000000	0.045452	
0.000000	-0.544787	
0.000000	0.664427	
0.000000	-0.689508	
0.000000	-0.587541	
0.000000	1.169163	
0.000000	0.864344	
0.000000	0.688097	
0.000000	-0.166723	
0.000000	-0.218956	
0.000000	-0.034552	
0.000000	-0.956986	
0.000000	0.344727	
0.000000	-0.451325	
0.000000	0.835025	
0.000000	-0.019230	
0.000000	0.463330	
0.000000	-0.226497	

Neuron 'N1_044'

INPUTS	WEIGHTS	
0.000000	-0.030865	ACTIVITY
0.000000	0.155844	0.000000
0.000000	-0.133319	FUNCTION
0.000000	-0.461328	FERMI
0.000000	0.520246	OUTPUT
0.000000	0.192662	0.000000
0.000000	-0.020119	
0.000000	-0.263546	
0.000000	-0.509287	
0.000000	0.317527	
0.000000	0.316332	
0.000000	-1.012168	
0.000000	0.779737	
0.000000	-0.118792	
0.000000	0.366466	
0.000000	-0.685089	
0.000000	-0.262104	
0.000000	0.678077	
0.000000	-0.082660	
0.000000	0.487840	
0.000000	-0.519995	
0.000000	0.519205	
0.000000	0.109052	
0.000000	-1.032458	
0.000000	0.584896	
0.000000	0.843882	
0.000000	-0.513972	
0.000000	0.080710	
0.000000	-0.799791	
0.000000	-0.061592	
0.000000	-0.684622	
0.000000	0.655963	
0.000000	-0.655991	
0.000000	0.038616	
0.000000	0.740662	
0.000000	-0.030081	
0.000000	-0.193301	
0.000000	-0.244633	
0.000000	0.148271	
0.000000	0.271632	

Neuron 'N1_045'

INPUTS	WEIGHTS	
0.000000	0.124462	ACTIVITY
0.000000	-0.927711	0.000000
0.000000	-0.356252	FUNCTION
0.000000	-0.891161	FERMI
0.000000	0.581282	OUTPUT
0.000000	0.229091	0.000000
0.000000	0.031520	
0.000000	0.204048	
0.000000	0.089966	
0.000000	-0.134346	
0.000000	-1.014200	
0.000000	-0.760675	
0.000000	0.988562	
0.000000	-0.867364	
0.000000	0.449068	
0.000000	0.788151	
0.000000	0.704579	
0.000000	-0.240679	
0.000000	0.686996	
0.000000	0.009215	
0.000000	-0.636888	
0.000000	-0.562747	
0.000000	0.740737	
0.000000	0.211580	
0.000000	0.418219	
0.000000	-0.290442	
0.000000	-1.039414	
0.000000	-0.176806	
0.000000	0.005019	
0.000000	0.483908	
0.000000	-0.900975	
0.000000	-0.898565	
0.000000	0.189799	
0.000000	-0.976210	
0.000000	-0.764919	
0.000000	0.153234	
0.000000	-0.347412	
0.000000	-0.876145	
0.000000	0.766304	
0.000000	0.835099	

Table C-2 The detail of neuron network model layer 2

Neuron 'N2_046'

INPUTS	WEIGHTS	
0.000000	-0.073418	**ACTIVITY**
0.000000	0.762074	0.000000
0.000000	0.678624	**FUNCTION**
0.000000	0.704185	FERMI
0.000000	-0.658986	**OUTPUT**
0.000000	0.494381	0.000000
0.000000	0.816194	
0.000000	0.022511	
0.000000	-1.473660	
0.000000	-0.771353	
0.000000	-0.594706	
0.000000	-0.367463	
0.000000	0.265807	
0.000000	0.539201	
0.000000	0.318667	
0.000000	-0.257030	
0.000000	-0.589500	
0.000000	-0.206701	
0.000000	-1.092956	
0.000000	0.187124	
0.000000	0.620917	
0.000000	-1.340203	
0.000000	-0.073518	
0.000000	-0.623325	
0.000000	-1.409757	
0.000000	-0.521754	
0.000000	-0.058959	
0.000000	0.549082	
0.000000	0.469273	
0.000000	-1.387622	
0.000000	0.690468	
0.000000	0.172527	
0.000000	-0.691697	
0.000000	-0.623599	
0.000000	0.295893	
0.000000	-1.686529	
0.000000	-0.484938	
0.000000	0.404266	
0.000000	0.694727	
0.000000	0.715639	
0.000000	0.277608	
0.000000	0.156550	
0.000000	-1.156460	
0.000000	-0.920572	

VITA

Miss Anantaya Wongkamlue was born on 4th December, 1983 in Bangkok. She finished her secondary course from Sawan-ananwittaya school in March 2001. After that, she studied in major of chemistry in faculty of science at King Mongkut's University of Technology Thonburi. She continued her further study for Master's degree in chemical engineering at Chulalongkorn University. At present she work for Western Digital Thailand in Reliability engineer.