Fifth IFSA World Congress (1993), 1155-1158

The Application of Fuzzy Set Theory into Precise Adjustment System

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Abstract

Proficiency in creating a knowledge base is required for high accuracy fuzzy control. To overcome this a fuzzy inference method is proposed that take these membership functions from the probability densities showing the distribution of the mesurement values. And a method using a rough fuzzy knowledge base auotmaticaly created from the basic measurement data and tuned using the gradient method is proposed. In actual tests,these were applied to automatic high accuracy adjustment devices for magnetic head and for high frequency circuits with good results.

1. Development of Automatic Adjustment Device for Magnetic Head[1, 2]

1.1 Introduction

Home electronics continue to move to higher functions as the years go by,so the adjustment work is becoming more difficult and the need for hight accuracy technology is increasing. Fuzzy control is well known for using the experience of skilled workers and its ability to make possible the control of phenomenon that are difficult to mathematically model. However,it was not thought to be applicable to hight accuracy control. Here,a high accuracy fuzzy logic method is proposed. This method takes the probability distribution of the measurement data as the membership functions.

As an example,an application of this method to a magnetic head adjustment device using elastic and plastic deformation characterisics will be discussed.

1.2 Outline of magnetic head adjustment

As shown in Fig.1,a head is made up of 2 head chips attached to a metallic head base. The gap between these 2 head chips,their heights(absolute height),and their relative positions(height step) are adjusted using high accuracy plastic deformations of head base to conform with specifications on the micron order.

Fig.2 shows the plastic deformation amount of the height step when the head undergoes an overall deformation (Plastic deformation amount+Elastic deformation amount) using the adjustment structure in the right hand height. In this way different plastic deformations are generated even from the same overall deformation amount. Also,at the same time,the gap undergoes as plastic deformation. On the other hand,when the gap distance is used for the adjustment,plastic deformation occurs up to and including the height direction.(mutual interference) Also,adjustment using multiple adjustment structures for 1 head can be

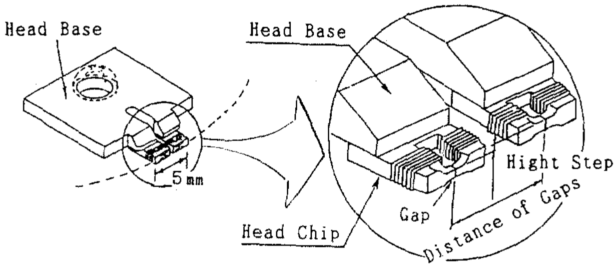

Fig.1 Magnetic Head Structure

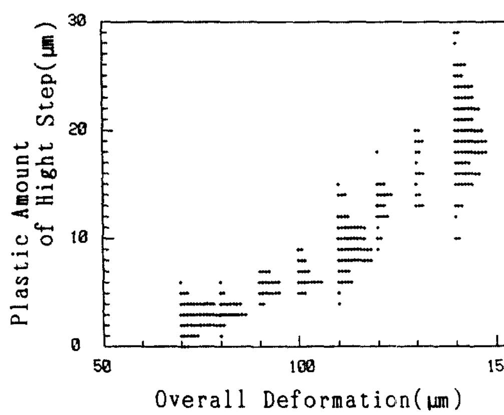

Fig.2 The Relation between Overall Deformation and Plastic Amount of Hight Step (Histogram)

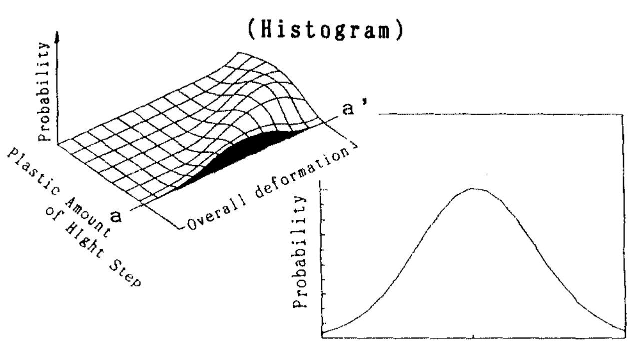

Fig.3 Distribution of Overall Deformation

used.[1] In that case,the adjustment parameters are influenced by the adjustment method of the previous adjustment structure and the adjustment amount.(Effect of adjustment history)

1.3 Outline of adjustment algorithm using fuzzy logic

1.3.1 Characteristics

This algorithm has the following characterisics.

(1) The probability density for the elastic deformation resulting from a certain overall deformation is taken as the membership functions.

(2) Mutual interference and the effect of adjustment history are taken into account using fuzzy logic.

(3) To calculate the rule compatibility during multiple inputs,a multiplication operation is used.

(4) It is possible to consider the ease of plastic deformation from the differences in head base thickness in a fixed manner.

1.3.2 Basic outline (1 input,1 output)

From Fig.2,the probability curve shown at the top left of Fig.3 can be projected. In reality,the overall deformation required to cause a certain amount of plastic deformation must be found. In other words,to obtain the desired plastic deformation,the most plausible deformation from among the probability distribution cross section a-a' in Fig.3 must be found. Fig.4 shows an example of the inference process when there is one input and one output. This rule and the membeship functions is fixed based on Fig.2. In this example the target hight step for the plastic deformation is 5 μm. The peak of the relation value for the overall deformation at the right hand bottom of Fig.4 is a part of the propability distribution cross section a-a'. If the overall deformation of this a-a' cross section is a Gaussian distribution, the value obtained by taking a weighted average(height method) becomes the adjustment amount. In this way,even somewhat scattered data can be adjusted for high accuracy.

1.3.3 Considering mutual interference (3 inputs, 3 outputs)

Even if only the right hand height is structurally adjusted to plastically deform the right hand head,the gap will also be plastically deformed to some extent. Of course,this is good if the goal is to adjust the right hand head height and the gap since both can be done with only the one adjustment. With that,the amount of mutual interference was set in IF-part and the phenomenon was compensated for by looking at the process as one adjustment pattern.

Fig.5 shows an example of the inference process for one rule when mutual interference is consideres(3 inputs,3 outputs). Conventionally,when there were multiple input values,the minimization operation was often used to find the relation value for the rule. However,in that case, values other than the applicable relation value were disregarded. This meant that other adjustment values could not be obtained. In the new method,by multiplying by the relation value found for each member,the relation values for the applicable relation value were also found.

1.4 Experimental results and comparison to conventional Method

Conventionally,sequential equations were solved using relation value from curves that weight the averages of scattered data to find the adjustment amount. In the new method,by using the previously mentioned fuzzy inferences, the accuracy of the plastic deformations has been improved 500 %. Also,by taking the effect of adjustment history into consideration,it was possible to improve the success rate by further 25%.

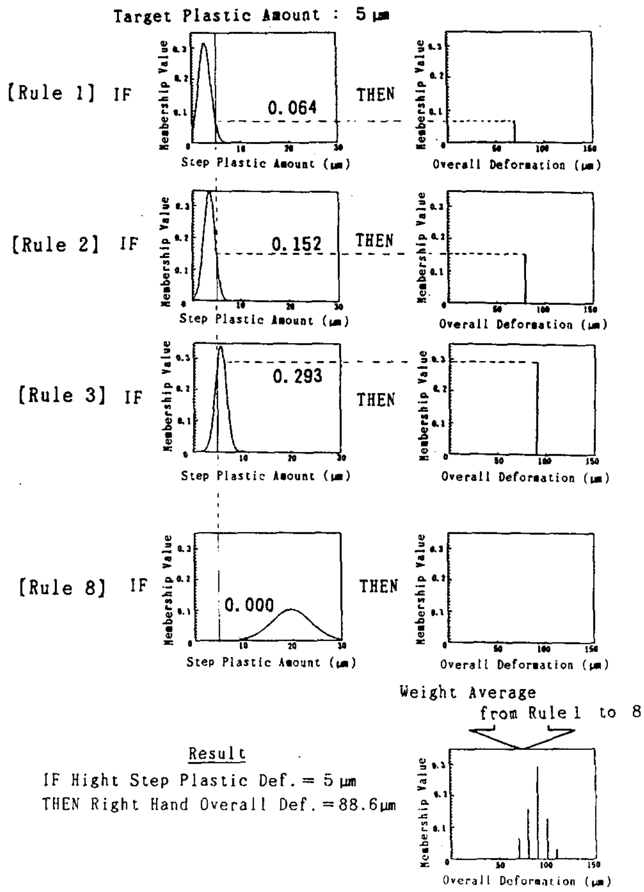

Fig.4 Example of Fuzzy Inference

(1 input , 1 output)

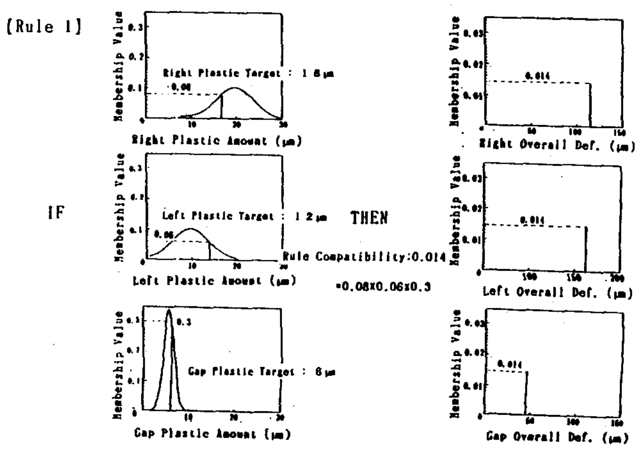

Fig.5 Example of Fuzzy Inference

(3 inputs , 3 outputs)

1.5 Conclusion

This device is presently operating on an actual production line. The adjustment accuracy and success rate are both very good. In the future, when high accuracy adjustment is required,along with taking a mechanical approach, the mesurement procedures for the parameters(shape deviation,etc.)that cause differences in plastic deformation must be set. Such additions to the fuzzy inference would be effective.

2. Development of Automatic Adjustment Device for High Frequency Circuits[3)4)]

2.1 Introduction

High frequency circuits are adjusted by highly accurate plastic deformations done to the coil set on the board. The adjustment items mutually interfere with each other so the adjustment operation requires a high level of skill. Fuzzy control is well known for using the experience of skilled workers and its ability to make possible the control of phenomenon that are difficult to make mathematical model. However,since the creation of the knowledge base depends on skilled workers,it was not thought to be applicable to products that are rapidly changing. To overcome this,a method using a rough fuzzy knowledge base automatically created from the basic measurement data and tuned for high accuracy using the gradient method is proposed.

As an example,an application of this method to an automatic adjustment device for high frequency circuits will be discussed.

2.2. Outline of high frequency circuit adjustment

As shown in Fig.6, high frequency circuits are adjusted by plastically deforming,on the order of 20 to 30 microns, the 6 coils set on the board. As shown in Fig.7,for one frequency range there are 8 adjustment items including target frequency,peak offset,and width of frequency range. These must be adjusted for 6 diffrent frequency ranges.

For each product,the condition of the frequencies before adjustment can be separated into the following two types.

(1) Inductance differences caused by differences in the coil shape when attached.

(2) Differences in the circuits for such areas as resistance and capacitor.

In adjustment,first the coil shape is plastically deformed to standard form. Next,a fine adjustment is done based on the circuit coefficients. When 2 coils are arranged in series (Fig.8),the coil shape is represented by the gap in the coils(L1 and L3) and the gap between coils(L2).

For example, as shown in Fig.9, when L1 is spread,L2 is also changes. For high accuracy adjustment of the coil gaps,this type of mutual interference must be considered.

Also,since a characteristic of plastic deformations for coils is the non-linear body,non-linear simultaneous equations must be solved. It has already been mentioned that fuzzy logic is effective in this case. Since the coil deformation characteristics change depending on the coil wire materials, the problem becomes creating a knowledge base corresponding to the many different types. Next, an example will be presented using the fuzzy inference for plastic deformation of coils.

2.3. Outline of fuzzy algorithm for automatic creation method

2.3.1 Characteristics

The characteristics of the automatic creation method are listed below.

(1) Creates rough fuzzy knowledge based on measurement data of plastic deformation for each multiple coil deformation pattern(about 50 datas).
(Sigmoid relation fuzzy inference)

(2) Using the gradient method, after the above knowledge base is created,tuning for the membership function (THEN part) is done.

2.3.2 Creation of rough fuzzy knowledge base

A flow chart is shown in Fig.10. First,the some plastic deformation amounts for each coil deformation pattern is found by experiment. This measurement data Dn is taken as the basic knowledge base. However,in this case the input space is not absolutely covered without exception. And, it is difficult to set the membership function without

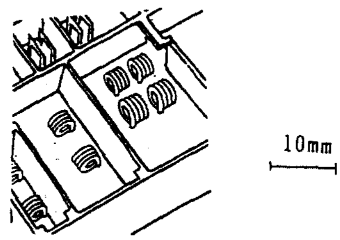

Fig.6 Coils on High Frequency Circuit Board

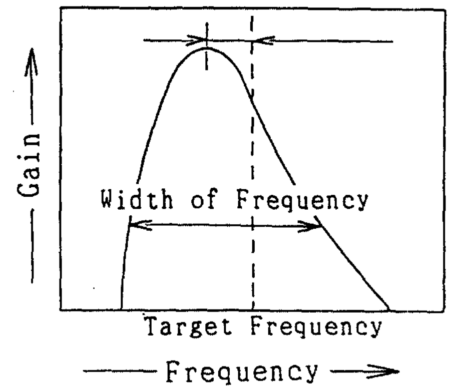

Fig.7 Example of Adjustment Items

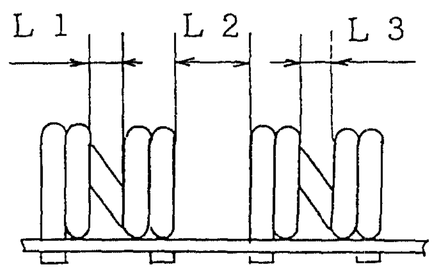

Fig.8 Parameters of Coil Shape

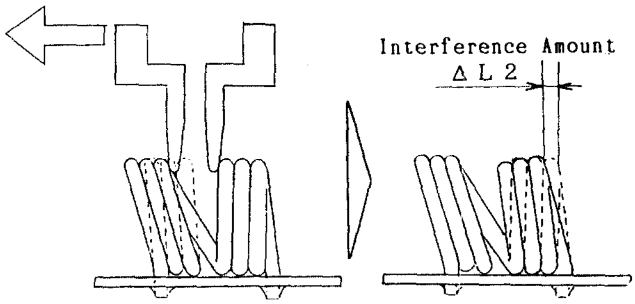

Fig.9 Example of Coil Deformation Interference

unnessary duplication. Therefore the distance l between the measured data and the input value was used to define the membership function. The sigmoid function that takes the distance l as a parameter was used for easy correlation to the non-liner characteristics. The following equation is used to calculate the compatibility with each rule.

$$Fn=1/(1+\exp(-a(1/ln-b)))$$

Fn : Compatibility with rule n

ln : Distance between measurement data Dn and input value I

a,b : coefficients

Since the output value is the amount of morter rotation, the consequent membership function was defined as singleton. And defuzzyfication methods is the weighted average. (Sigmoid relation inference)

To create the rough data base, the membership functions that sufficiently divides the input space are previously set. In this case, the l input was devided 17 times(Fig. 11). The rule is a combination of all the membership functions.In this case(2 inputs), the rule is 17×17=289. First an inference is made using the sigmoid relation for the point taken by l for each rough knowledge base membership value (289 points). The results of this inference are taken as the consequent value of the rough knowledge base.

2.3.3 Tuning the consequent value with gradient method

Since there are many reports explaining the gradient method in detail[5],it will be abbreviated here. For this example, the measurement data was used and the consequent values of the rough data base were tuned.

2.4 Experimental Result

Since there is no conventional method,it is difficult to evaluate this method. But the success rate is about 95%.

2.5. Conclusion

Since the fine adjustment section requires teaching data, previous experece is used and an algorithm is determined.

In the future, learning of fine adjustment without teaching will be required.

Since coefficients,a,b, are not defined acuuracyly,gradient method is used. To define a,b,the net-type sigmoid relation inference is proposed. In this case,Nuro learning method,back propagation method,is available. Since a,b will be defined precicely,only the net-type sigmoid relation inference will be enough.

3. References

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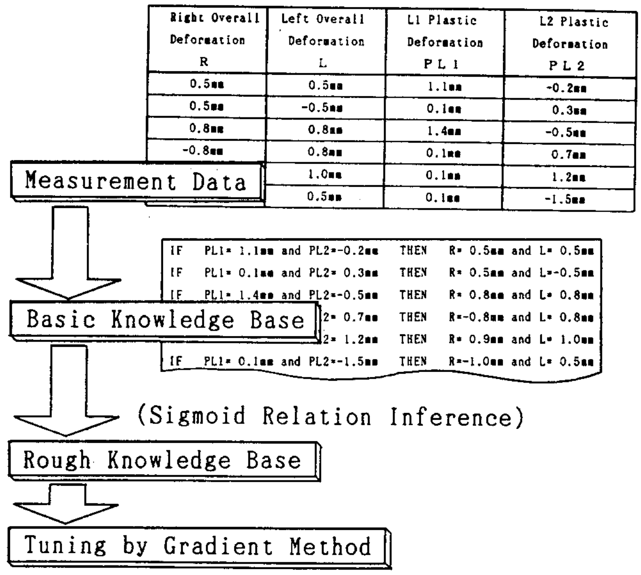

Fig.10 Fuzzy Algorithm Generate Flow Chart

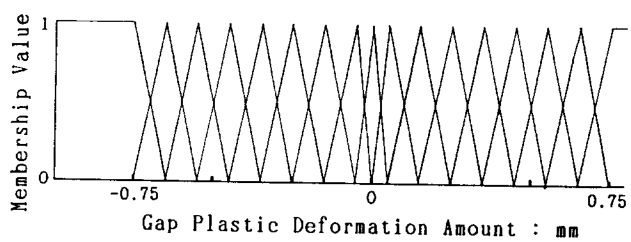

Fig.11 Rough Fuzzy Knowledge Base Membership Function

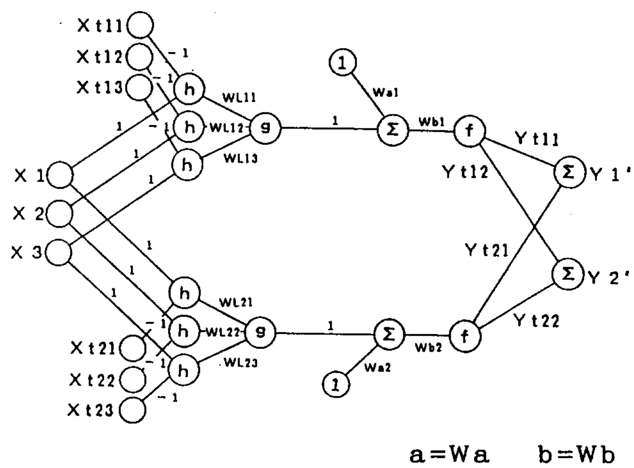

Fig.12 Example of Net-Type Sigmoid Relation Inference

(3 inputs,2 outputs, 2 rules(=2 mesurement datas))