Performance Evaluation of Multi-type Five-axis Machine Tool With Recognizable Performance Evaluation by Fuzzy Theory

Han-Jui Chang
Lingnan Normal University
School of Mechanical and Electrical Engineering
Guangdong 524048, P.R.O.C
master.right@msa.hinet.net

Abstract—

There are many ways to evaluate the performance of a five-axis machine tool, but it can be done in a recognitive and multi-type comparison. It should be most practical with the Recognizable Performance Evaluation (RPE). The RPE is one of the current research methods that can derive accurate reference data in a quantitative and recognitive way, and is one of the evaluation methods for multi-type five axis machine tool models. Therefore, based on the RPE and the interface of the IT level distribution in the general mechanical design change, this paper attempts to introduce Fuzzy Theory to obtain the research results of excellence.

This study can calculate the attribution degree of the tested items. In other words, for the conflicts in the re-performance evaluation of various types of five-axis machine tools, a direct discriminant defuzzification attribution degree drop interval is provided; It is possible to directly judge and evaluate the prediction results. The experimental results show that the interval of the interval is 2σ. This result, for the quantifiable performance evaluation, further distinguishes the landing interval.

Keywords : Five-axis machine tool, Multi-type, Fuzzy Theory, RPE, Recognizable Performance Evaluation

I. INTRODUCTION

The mechanical system must have its theoretical design parameters before the cutting test; after the cutting test, it must have its actual cutting data. The difference between these theoretical and actual values is called the error. At present, all the tools and machinery in industrial history are hard to escape the fate of error. However, how we quantify these errors becomes the basis for our trustworthiness and reference. There must be an effective interpretation method as a reference for the overall quality assessment of the machine tool. The cutting test is the basis of the experiment and the source of the actual cutting data. Therefore, all actual cutting data should be imported into any logical thinking research method, as long as the cutting data formula is recognizable and well-founded. The so-called avenue to the broad, the research theory can not be limited to only a certain subject can be solved, after the numerous research methods cited, the trend of obtaining new evidence from new data will become more and more obvious.

II. LITERATURE REVIEW

Functionally oriented research methods are important, and research methods that yield the final comparable results are the main secrets that must be relied upon in the era of big data. for to get reliable and unchanging value manufacture, the buyer have to know who is stable maker before they are purchasing. which topic is quite interesting regarding the interaction effect of five-axis machine tool performance evaluations, no one hope it will be removed the overall objectivity of the valuation, and created the "pure" and "instinctive" decision under the affluence of the evaluation performance, In 2017, Luis Alberto Rodríguez-Picón [1]。The creation of a procedure is estimated from the original thinking to the ideal strategy of data manufacture. which the interaction between situation could see as a normal series that defines obedience for the practical necessities. Machine system has many direction discussing, In 2015, Xiaocong He [2]。NC machine tools are the basic facilities of the mechanical field, The recognizable data of NC machine tools straight effect the manufacture procedure, quality and effectiveness. This paper discussing about the newest research in the reliability study of NC machine tools. which major study methodology need created model skill using in reliability calculation of NC machine tools are demonstrated with experiment study. the referable of characteristic section parts of NC machine tools are deliberated. In 2017, Fábio Antonio Sartori Piran, [3]。Enhancements to effectiveness yield rates are quite important by industrial maker, the modular process will be admitted for new generation's innovative strategic. Thus, this requires for effectiveness of modular processing are important, which studies are created among on modular process and manufacture procedure. System ‘s RPE(Recognizable Performance Evaluation) function is useful, even for high risk of failure mode section. In 2017, Ali Nazeri and Reza Naderikia, [4]。In this paper mentioned the kind of achieved the maintenance to recognize on facilities failure style, and reduce the higher percentage risk of failure style, which propose are provided risk base methods for choose correct maintenance work, to get the relay tamping equipment in railway of Iran and also as fuzzy variables to assessed with fuzzy language and percentage. Finally, some strategies and submissions are regarding to decrease the risks and progress the facilities’ obtainability. In 2017, Roberto C. Quinino,

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Lupércio F. Bessegato and Frederico R. B. Cruz, [5]。This paper mentioned the innovative and useful chart, and noted by X^{att}, for recognized the stable of a formula mean. on the same range times, collecting the n items samples, besides, the averages are assessed through mean value of X^{att} based exclusively on the gotten classification to make decision for procedure is under regulator. According to mathematical modeling formulation after analysis for X^{att} distribution, and to find the average control of maximum and minimize limits on the average run length (ARL) situation. In 2016, Weixin Hu, Yanlong Cao, Jiangxin Yang, Hui-chao Shang and Wen-bo Wang, [6]。Author provided a new faults forecast technique are combining the faults of the procedure structure, which with cutter faults rotating, geometric faults, and tools distortion faults, those faults are manufactured to make the motions of cutter edge in the test parts procedure structure. In 2017, Mozammel Mia, Md Awal Khan and Nikhil Ranjan Dhar, [7]。There are someone discussing about the study of regular surface roughness, machining power, and feed force of difficult to-machine Ti-6Al-4 Alloy by investigational study. In 2018, Issam Abu-Mahfouz, Omar El Ariss, A. H. M. Esfakur Rahman and Amit Banerjee, [8]。Author uses shaking sign and are experiment got within the end grinding of aluminum dish at dissimilar machining situation. Some characteristics were taken by procedure learned signs between on the times and frequency domain. The characteristics group consist of statistical data, FFT spectra and wavelet packets, which are supporting by vector machines to calculating the set of predict type. n 2018, Guang-Jun Jiang and Le Gao, [9]。Using Fuzzy theory is accepted to be active measurable study structure dependability, therefore the triangular fuzzy numbers to demo the fuzzy failure for every single motion. to got fuzzy failure possibility is important single event for every martial arts arena system. In 2018, V. Vakharia, S. Pandya and P. Patel, [10]。This studies trying to predicting the machine tools milling procedure technology, and use symlet wavelet to depth decomposed. also applied the best level permutation entropy criteria. In 2018, Mohammad Yazdi and Hamzeh Soltanali, [11]。The author provided the kind of 2-tuple intuitionistic Fuzzy and Bayes theory for estimate structure dependability, for handling faults case, and make difference on typical dangerous structure parts. the paper conclusion showing approaches of security and dependability analysis. In 2017, Jinsong Yu, Shuang Liang, Diyin Tang and Hao Liu, [12]。this paper give a specific probability to predict cutter wear and residual work life, which building on HMM-base to achieved truly parameters group of CNC milling cutter set, and test conclusion showed are useful on assessing cutter wear and forecasting cutter life, also are better than traditional HMM method. In 2017, Jesus Maudes, Andrés Bustillo, Antonio J Guerra and Joaquim Ciurana, [13]。Regarding the knowhow channel within useful data of NC system and value level of cutting workpieces. hence the first work is recognizing the quality items on linear Machines, besides to unchance predicting companies of deterioration chart for higher precision, this technology methods could excerpt valuable parameters through system and optimization finish report. In 2017, Fuyong Yang, Sun Jin, Zhimin Li, Siyi Ding and Xun Ma, [14]。The author applicating faults recompence mode for cutting procedure on corresponding feature thinking of difference moving vector. there basic faults and caused fault could be malformed equal fitting compensated in the process. In 2017, W. D. Cao, C. P. Yan, D. J. Wu and J. B. Tuo, [15]。this study mentioned a set of SVM/ALO/GH, combined several different component's optimates for cutting data and finished little batch parts problematic on the procedures, which methodology given a well concept of the experiments of the optimizing tactic. In 2017, Jyun-You Chiang, Jianping Zhu, Tzong-Ru Tsai, Y. L. Lio and Nan Jiang, [16]。This study mentioned a whole new sampling scheme for purifying RSSP presentation, besides there noted the second times submitted parameters of NRSSP. which NRSSP includes all parameters order of imperfect workpieces from the second times submitted and to accepted pronouncement. In 2017, Rundong Yan, Lisa M. Jackson and Sarah J. Dunnett, [17]。This study discussing about FMECA, the dependability of the AGV system are mentioned through FTA and car assignment dependability. after experiments test, the satisfactoriness percentage of car assignment dependability can be calculation, therefore, serve acceptability and unknow yield rate of the AGV system could be checking and assignment which at once the AGV system structure facing Unpredictable situation.

Recognizable Performance Evaluation (RPE) can approach the true maternal mean under gradual correction conditions, and can use existing evidence to modify existing views and import them into a five-axis machine tool for performance evaluation. To facilitate the development of subsequent artificial intelligence (AI). The sample concept could be using on different appearance model, [24]. In 2016, Chang HJ, Chen SL and Lee PY [18],[19],[20] tried to assess the cone frustum appearance model and pyramid appearance model to approaching on the Taguchi method of statistical, these analyzed the machining gesture faults parameters through the directly cut motioned and using MA value compared with the Taguchi method for S/N ratio. besides, there also have the interactive effect on the difference axis movements, which "VSM" can be defined recognized on two or more force mixed calculation. Chang HJ [21],[22],[23] Author has stepped into appraising about the different axis CNC machine, there statistical report appeared that are included operating opinion of "direct" and "intuitive". These useful and practical evaluation methods are quite suitable on different type machine tools. which co-procedures, interactive effects are also included.

III. PROPOSED METHOD

This is a threshold that has been difficult to solve for traditional performance evaluation. Thus, in the fourth line of Section 2, it is clearly stated that "performing five-axis machine performance verification cannot be based on obtained cutting error data only; the performance verification must be based on quantifiable analysis techniques that can be compared." As if the experimental results do not obtain quantifiable values that can be compared, we will be comparing apples and oranges, and so can't derive any meaning from the results.

A. *Recognizable Performance Evaluation*

In this regard, we must have a common comparison of the analysis techniques. Chang HJ [21],[22],[23] used the statistical-based Taguchi methods, combined with workpiece direct cutting, to obtain the signal-to-noise (S/N) ratio and dimension error theoretical design values, and then acquire a single machine's five-axis machine tool performance evaluation. We would like to use geometric errors for analysis evaluation.

This a comprehensive combined process assessment that includes the Taguchi-based statistical approach and the variables separable model comparative interaction method. The results gained from the assessment are not necessarily final, but these results can be used to determine superior and inferior cutting motions in five-axis machine tools. The emphasis of the overall performance and trend analysis should still be placed on the main features, or the ability find instability within the cutting process.

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y})^2}{n}} \tag{1}$$

The S/N ratio converts the average quality loss. If n has the same product index, then the smallest value can be written as (2):

$$\frac{S}{N}\ ratio = -10log[(SD)^2 + (Ave)^2] \tag{2}$$

S/N ratio is reference from Taguchi method, using these value just need to compare data size, because the greater S/N ratio is better.

$$MSD = \frac{1}{N}\sum_{i=1}^{n}(SD) \tag{3}$$

Let set population X to a set of 2 essentials, there any essentials x of population X, typical function $\mu A(x)$ is equal to 1, if x is an essentials of set A, and is equal to 0 if x is not an essentials of A. Regarding the fuzzy theory, fuzzy set A of population X is definite by function $\mu A(x)$, called the membership function of set A.

$\mu A(x) : X \rightarrow [0,1]$,

Where

$\mu A(x) = 1$ if x is totally in A;

$\mu A(x) = 0$ if x is NOT in A;

$0 < \mu A(x) = 1$ if x is partly in A.

B. *Defuzzification*

The final work in the fuzzy inference procedure are defuzzification, Fuzziness can improve us to knowing rule well. but than again, the last producing out of fuzzy system must be a clearly amount. The defuzzification procedure is total input fuzzy set and the output is a only one amount. Here got a fact which a upright line will share total set to 2 same masses and which center of gravity (COG) can be written as:

$$COG = \frac{\int_a^b \mu_A(x)x\,dx}{\int_a^b \mu_A(x)\,dx} \tag{4}$$

At this moment, the COG can analysis on continuous points in the total output association function. but then in training. a practical evaluation could be got by analysis on continuous points, the following formula is applied:

$$COG = \frac{\sum_{x=a}^{b} \mu_A(x)x}{\sum_{x=a}^{b} \mu_A(x)} \tag{5}$$

IV. METHOD PROCEDURES

Standardize the error size and error offset of mechanical parts and components during the manufacturing process, so that mechanical component manufacturers and users can select the appropriate error level according to the principle of optimal economy to achieve the desired assembly fit or The scope of interchangeability. In the RPE-based analysis and evaluation method, there can be more comprehensive and single-depth evaluation interpretation, but Fuzzy theory requires the actual interval to defuzzify, so we refer to the IT tolerance level in the standard mechanical design manual [25]. The interval can be directly compared with the analysis and evaluation, as shown in the following list, and the corresponding IT level is obtained. 1 sigma tolerance standard is about 68.27%, 2 sigma tolerance standard is about 95.45%, 3 sigma tolerance standard is about 99.73%, 4 sigma tolerance standard is about 99.99366%, 5 sigma tolerance standard is about At 99.99994%, the tolerance standard for 6 sigma is approximately 99.9999993%. Among them, the accuracy of 5-6 sigma is too high, and the JIS basic tolerance system in the mechanical design manual does not meet such standards. Therefore, in this paper, we can directly define 68.27% or less for 1 sigma (on the right side of the green block) and give 1 effective score; 68.27% ~ 95.45% or less can be directly defined as 2 sigma (on the right side of the blue block). And give 2 effective scores; 95.45% ~ 99.73% or less we can directly define 3 sigma (on the right side of the red block), and give 3 effective scores; 99.73% or more (especially between IT0-01) we can be directly defined as 4 sigma (left of the red block) and give 4 valid scores.

TABLE I. LOW AND HIGH LIMIT OF IT TOLERANCE RELATIONSHIP [25]

Below 500mm limit of IT tolerance,(unit: μ=0.001mm)							
	Low Limit				*High Limit*		
	3 sigma	*2 sigma*	*1 sigma*		*3 sigma*	*2 sigma*	*1 sigma*
Yield	99.73	95.45	68.27		99.73	95.45	68.27
Non-Yield	0.27	4.55	31.73		0.27	4.55	31.73
-	-	-	-	3	0.81	13.65	95.19
3	0.81	13.65	95.19	6	1.62	27.30	190.38
6	1.62	27.30	190.38	10	2.70	45.50	317.30
10	2.70	45.50	317.30	18	4.86	81.90	571.14
18	4.86	81.90	571.14	30	8.10	136.50	951.90
30	8.10	136.50	951.90	50	13.50	227.50	1586.50
50	13.50	227.50	1586.50	80	21.60	364.00	2538.40
80	21.60	364.00	2538.40	120	32.40	546.00	3807.60
120	32.40	546.00	3807.60	180	48.60	819.00	5711.40
180	48.60	819.00	5711.40	250	67.50	1137.50	7932.50
250	67.50	1137.50	7932.50	315	85.05	1433.25	9994.95
315	85.05	1433.25	9994.95	400	108.00	1820.00	12692.00
400	108.00	1820.00	12692.00	500	135.00	2275.00	15865.00
500mm to 3150mm limit of IT tolerance,(unit: μ=0.001mm)							
	Low Limit				High Limit		
	3 sigma	2 sigma	1 sigma		3 sigma	2 sigma	1 sigma
Yield	99.73	95.45	68.27		99.73	95.45	68.27
Non-Yield	0.27	4.55	31.73		0.27	4.55	31.73
500	135.00	2275.00	15865.00	630	170.10	2866.50	19989.90
630	170.10	2866.50	19989.90	800	216.00	3640.00	25384.00
800	216.00	3640.00	25384.00	1000	270.00	4550.00	31730.00
1000	270.00	4550.00	31730.00	1250	337.50	5687.50	39662.50
1250	337.50	5687.50	39662.50	1600	432.00	7280.00	50768.00
1600	432.00	7280.00	50768.00	2000	540.00	9100.00	63460.00
2000	540.00	9100.00	63460.00	2500	675.00	11375.00	79325.00
2500	675.00	11375.00	79325.00	3150	850.50	14332.50	99949.50

V. CASE STUDY

Fuzzy theory is a revolutionary scientific thought and method. The traditional science of "excellence" makes the technology more and more precise, and the more it can cut the key, but it is also getting away from the ambiguity, making the fuzzy phenomenon become the dead end of scientific research. The fuzzy theory is inherently fuzzy, but it can also reproduce its original color, so that the information of the fuzzy phenomenon itself can be completely captured. On the other hand, the fuzzy theory also humanizes the mechanical interface, making the communication and relationship between human and computer more closely related. The machine is no longer a "one password and one action", it can better understand the human language and feelings, so that artificial intelligence can be obtained. A more reasonable solution. According to fuzzy logic to solve problems, the most common three process sequences are as follows:

[1] Obtain fuzzy rules.
[2] attribution function setting.
[3] Defuzzification.

Figure 1. Experiment of Dimension tolerance

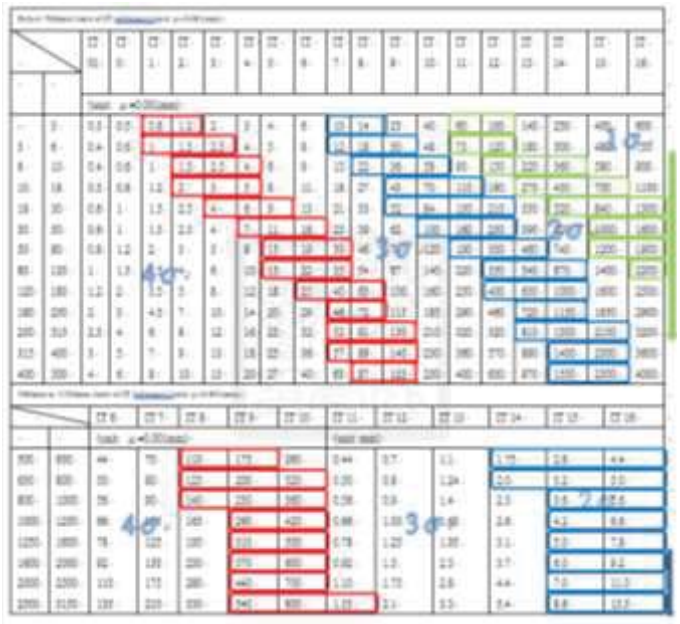

Figure 2. Group of IT tolerance relationship [25]

Here, the performance evaluation of the cross-five-axis machine tool in this study is the Case Study example, and the ：

[A] fuzzy rule can be directly obtained. The detailed data is related to the IT tolerance level distribution [25].
[B] attribution function setting: The functional relationship is a Gaussian distribution, so the presupposition is based on the Degree of 1.0, and the distribution yield of each IT tolerance level (Yield ratio) is the abscissa, and the following relationship diagram can be drawn.

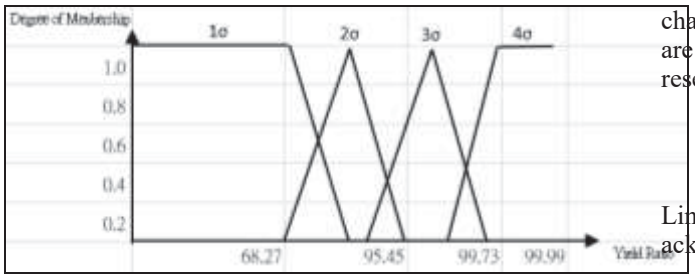

Figure 3. Graph of Degree of membership with Yield ratio (Under 500mm)

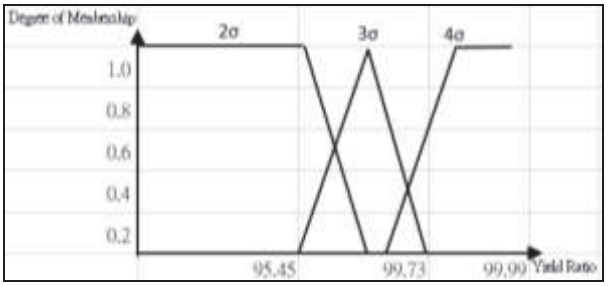

Figure 4. Graph of Degree of membership with Yield ratio (Higher 500mm)

[C] Defuzzification: There are many data on the IT tolerance level distribution, which cannot be listed one by one. However, here we take the IT15 level 1400 of 80-120mm randomly sampled below 500mm as an example, assuming that the lower limit of each σ(Sigma) is σLL (Low Limit), the middle limit is σML (Middle Limit), and the upper limit is σHL (High). Limit), try to belong to the attribution of 1σ, 2σ, 3σ and 4σ.
1σ (Sigma): (0/1σLL, 1/1σHL)
2σ (Sigma): (0/1σLL, 1/2σCL, 0/3σHL)
3σ(Sigma): (0/2σLL, 1/3σCL, 0/4σHL)
4σ (Sigma): (0/3σLL, 1/4σHL)
The ambiguity can be solved as:

1σ (Sigma): not in this range, the degree of attribution is 0
2σ(Sigma): (0/2σLL, 1/3σCL, 0/4σHL)

$$= \frac{x-0}{1400-(1\sigma LL)} = \frac{1-0}{(2\sigma CL-1\sigma LL)}$$

= x=0.6404, so the attribution is 0.6404

3σ (Sigma): not in this range, the degree of attribution is 0
4σ (Sigma): not in this range, the degree of attribution is 0

VI. Conclusions

This is a follow-up intelligent extension of the RPE method. The concept is proposed to effectively help the development of AI artificial intelligence in today's big data. I hope that through this research puzzle, which get more completely "Recognizable Performance Evaluation methods". The research case proves that the RPE method can generate recognition effects in the fuzzy theory application because of its recognizable characteristics. This is just one of many applicable fields. There are still many places where RPE can continue to invest in research.

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