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OPTIMIZATION OF MACHINING PARAMETERS IN END- MILLING USING FUZZY LOGIC IN MATLAB

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ABSTRACT

In machining, surface quality is one of the most commonly specified customer requirements in which the major indication of surface quality on machined parts is surface roughness. The aim is prediction of surface roughness by using fuzzy logic in Matlab toolbox. The fuzzy logic can be effectively used to predict the best cutting parameter value for a specific cutting condition in milling operation and achieve minimum surface roughness. In the present work an experimental investigation of the end milling of M.S material up to 30 HRC with carbide tool by varying feed, speed and depth of cut and the surface roughness was measured using Tomlinson Roughness Meter. The fuzzy logic design and development was done using MATLAB. Fuzzy logic Graphical User Interface is used to establish the relationship between the surface roughness and the cutting input parameters (spindle speed, feed and depth of cut). The result from this experiment is useful to be implemented in industry to reduce time and cost in surface roughness prediction.

KEYWORDS - *End milling, Surface roughness, Fuzzy logic, GUI, MATLAB.*

1. INTRODUCTION

Among different types of milling processes, end milling is one of the most vital and common metal cutting operations used for machining parts because of its capability to remove materials at faster rate with a reasonably good surface quality. Also, it is capable of producing a variety of configurations using milling cutter. Surface roughness is a key factor in the machining process while considering machining performance and that is why in many cases, industries are looking for maintaining the good surface quality of the machined parts. Surface roughness is a measure of the technological quality of a product and a factor that greatly influences manufacturing cost and quality. It describes the geometry of the machined surface and combined with the surface texture, it can play an important role on the operational characteristics of the part. It also influences several functional attributes of a part, such as light reflection, heat transmission, coating characteristics, surface friction, fatigue resistance etc. However, the mechanism behind the formation of surface roughness is very dynamic, complicated and process dependent; therefore it is very difficult to calculate its value through analytical formulae. Various theoretical models that have been proposed are not accurate enough and apply only to a limited range of processes and cutting conditions.

2. LITERATURE REVIEW

Chen and Savage [2001] used fuzzy net-based model to predict surface roughness under different tool and work piece combination for end milling process. Speed, feed and depth of cut, vibration, tool diameter, tool material, and work piece material are used as input variables for fuzzy system. The authors found that the predicted surface roughness is within an error of 10%. Prakasvudhisarn et al. [2009] proposed an approach to determine optimal cutting condition for desired surface roughness in end milling. The approach consists of two parts: machine learning technique called support vector machine predict surface roughness and particle swarm optimization technique for parameters optimization. The authors found that PSO shows consistent near-optimal solution with little effort. Metin Kök (2010) has suggested an experimental investigation of the effects of cutting speed, size and volume fraction of particle on the surface roughness in turning of 2024Al alloy composites reinforced with Al2O3 particles. A plan of experiments, based on Taguchi method, was performed machining with different cutting speeds using coated carbide tools K10 and TP30. The objective was to establish a correlation between cutting speed, size and volume fraction of particle with the surface roughness in work-pieces. These correlations were obtained by multiple linear regressions. The analysis of variance was also employed to carry out the effects of these parameters on the surface roughness. The test results revealed that surface roughness increased with increasing the cutting speed and decreased with increasing the size and the volume fraction of particles for both cutting tools. The average surface roughness values of TP30 cutting tools were observed to be lower than those of K10 tools. For the average surface roughness values of TP30 tool, cutting speed was found to be the most effective factor while the volume fraction of particle was the most effective factor for those of K10 tool. A good agreement between the predicted and experimental surface roughness was observed within a reasonable limit. Limit.Brezocnik et al. [2004] proposed a GP approach to predict surface roughness in end milling process. The genetic programming is an evolutionary computation method that was first introduced by Koza [1992] in the year 1992. It aims to find out computer programs (called as chromosomes) whose size and structure dynamically changes during simulated evolution that best solve the problem. Cutting parameters, viz., spindle speed, feed, and depth of cut as well as vibration between tool and work piece, were used to predict the surface roughness and the authors found that the model that involves all these variables accurately predict the surface roughness.

3. EXPERIMENTAL STUDY

For developing models on the basis of experimental data three main machining parameters are considered to predict surface roughness of M.S material using carbide tool. The available literature reveals that spindle speed, feed rate and axial depth of cut are primary machining parameters on which surface roughness depends. These factors are considered for experimental study. End mill cutter with 12 mm diameter having 4 flutes with carbide tipped is used for machining M.S material work piece. Among the range of spindle speed, feed, and depth of cut available possible in the machine the following three levels are considered as shown in table I. The machining was carried out on Vertical milling machine, The M.S material work piece is clamped on vice mounted on the table of the machine. The machining process and work tool motion of the end milling process respectively. The machining is carried out by selecting proper spindle speed and feed rate during each experimentation. Experiment was carried out by varying the depth of cut.

Table 1: Experimental Study

FACTORS	LEVELS	VALUES
Speed(m/min.)	3	100,120,140
Feed Rate Per Tooth (mm/min.)	3	0.03, 0.04, 0.06
Depth Of Cut(mm)	3	0.1, 0.2 ,0.3

Surface roughness values of work pieces were measured by Tomlinson Roughness Meter by a proper procedure while measuring instrument and measurements are repeated three times.

Table 2: Input values and Experimental values

S.No	Feed (mm/min.)	Spindle Speed (m/min)	Depth of cut (mm)	Experimental Roughness Value Ra (μm)
1	0.03	100	0.1	0.20
2		100	0.2	0.21
3		100	0.3	0.22
4		120	0.1	0.19
5		120	0.2	0.21
6		120	0.3	0.22
7		140	0.1	0.18
8		140	0.2	0.19
9		140	0.3	0.20
10	0.04	100	0.1	0.26
11		100	0.2	0.25
12		100	0.3	0.23
13		120	0.1	0.25
14		120	0.2	0.24
15		120	0.3	0.21
16		140	0.1	0.23
17		140	0.2	0.22
18		140	0.3	0.20
19	0.06	100	0.1	0.31
20		100	0.2	0.30
21		100	0.3	0.32
22		120	0.1	0.29
23		120	0.2	0.30
24		120	0.3	0.31
25		140	0.1	0.27
26		140	0.2	0.29
27		140	0.3	0.31

4. FUZZY LOGIC

The concept of Fuzzy Logic (FL) was conceived by Lotfi Zadeh, a professor at the University of California at Berkley, and presented not as a control methodology, but as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership. This approach to set theory was not applied to control systems until the 70's due to insufficient small-computer capability prior to that time. Professor Zadeh reasoned that people do not require precise, numerical information input, and yet they are capable of highly adaptive control. If feedback controllers could be programmed to accept noisy, imprecise input, they would be much more effective and perhaps easier to implement. Unfortunately, U.S. manufacturers have not been so quick to embrace this technology while the Europeans and Japanese have been aggressively building real products around it.

FL is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. FL's approach to control problems mimics how a person would make decisions, only much faster.

FL incorporates a simple, rule-based IF X AND Y THEN Z approach to a solving control problem rather than attempting to model a system mathematically. The FL model is empirically-based, relying on an operator's experience rather than their technical understanding of the system. For example, rather than dealing with temperature control in terms such as "SP =500F", "T <1000F", or "210C <TEMP <220C", terms like "IF (process is too cool) AND (process is getting colder) THEN (add heat to the process)" or "IF (process is too hot) AND (process is heating rapidly) THEN (cool the process quickly)" are used. These terms are imprecise and yet very descriptive of what must actually happen. Consider what you do in the shower if the temperature is too cold: you will make the water comfortable very quickly with little trouble. FL is capable of mimicking this type of behavior but at very high rate.

FL requires some numerical parameters in order to operate such as what is considered significant error and significant rate-of-change-of-error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them. For example, a simple temperature control system could use a single temperature feedback sensor whose data is subtracted from the command signal to compute "error" and then time-differentiated to yield the error slope or rate-of-change-of-error, hereafter called "error-dot". Error might have units of degs F and a small error considered to be 2F while a large error is 5F. The "error-dot" might then have units of degs/min with a small error-dot being 5F/min and a large one being 15F/min. These values don't have to be symmetrical and can be "tweaked" once the system is operating in order to optimize performance. Generally, FL is so forgiving that the system will probably work the first time without any tweaking.

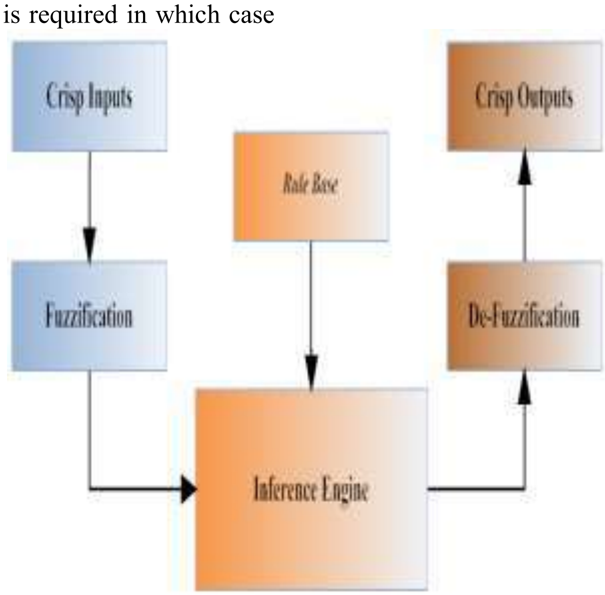

Fig.1. General Operation Of Fuzzy Logic Technique

5. FUZZY LOGIC TOOLBOX

Fuzzy Logic Toolbox software does not limit the number of inputs. However, the number of inputs may be limited by the available memory of your machine. If the number of inputs is too large, or the number of membership functions is too big, then it may also be difficult to analyze the FIS using the other GUI tools.

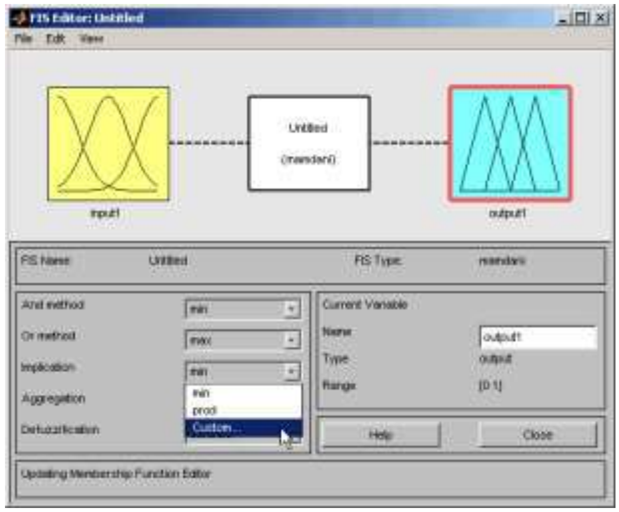

Fig.2. Fuzzy Inference System (FIS) Editor

The FIS Editor opens and displays a diagram of the fuzzy inference system with the names of each input variable on the left, and those of each output variable on the right i.e. the three input variables as feed, spindle speed and depth of cut and also the output variable as surface roughness.

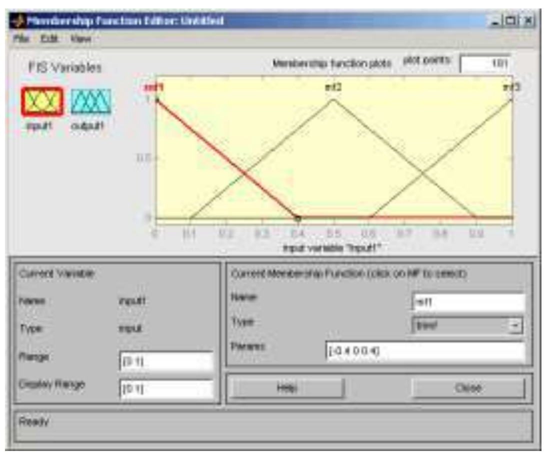

Fig.3. Membership Function Editor

The Membership Function Editor is the tool that lets you display and edit all of the membership functions associated with all of the input and output variables for the entire fuzzy inference system. The Membership Function Editor shares some features with the FIS Editor. Here the input range and display range values are entered as membership functions. The values are set as low, medium and high.

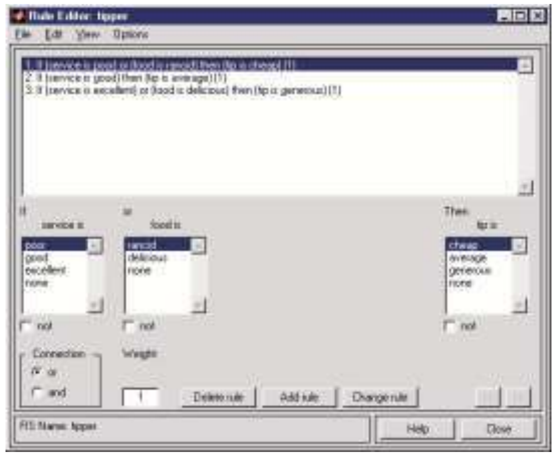

Fig.4. Rule Editor

Constructing rules using the graphical Rule Editor interface is fairly self evident. Based on the descriptions of the input and output variables defined with the FIS Editor, the Rule Editor allows you to construct the rule statements automatically. Here all the various combinations of three input variables are entered as rules based on the input values and experimental values.

At this point, the fuzzy inference system has been completely defined, in that the variables, membership functions, and the rules necessary to calculate the surface roughness are in place.

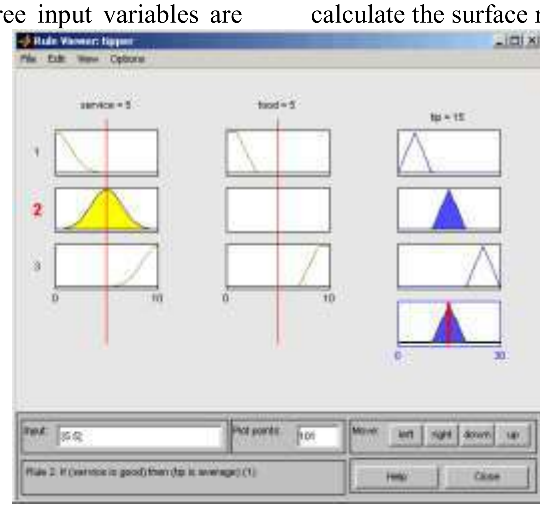

Fig.5. Rule Viewer

The Rule Viewer displays a roadmap of the whole fuzzy inference process. It is based on the fuzzy inference diagram described in the previous section. You see a single figure window with 10 plots nested in it. The three plots across the top of the figure represent the antecedent and consequent of the first rule. Each rule is a row of plots, and each column is a variable. The rule numbers are displayed on the left of each row. You can click on a rule number to view the rule in the status line.

- ➢ The first two columns of plots (the six yellow plots) show the membership functions referenced by the antecedent, or the if-part of each rule.
- ➢ The third column of plots (the three blue plots) shows the membership functions referenced by the consequent, or the then-part of each rule.
- ➢ The fourth plot in the third column of plots represents the aggregate weighted decision for the given inference system.
- ➢ This decision will depend on the input values for the system. The defuzzified output is displayed as a bold vertical line on this plot.

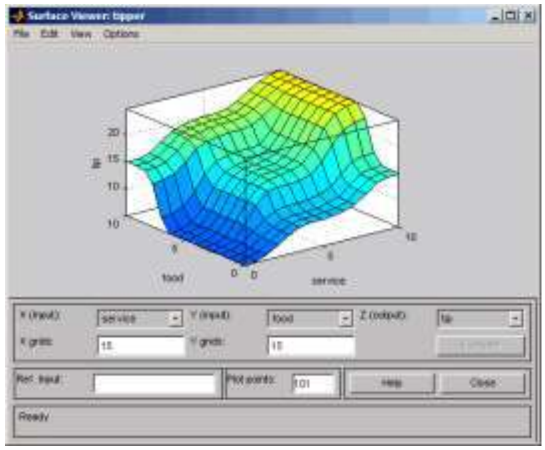

Fig.6. Surface Viewer

The Surface Viewer can generate a three-dimensional output surface where any two of the inputs vary, but two of the inputs must be held constant because computer monitors cannot display a five-dimensional shape. In such a case, the input is a four-dimensional vector with NaNs holding the place of the varying inputs while numerical values indicates those values that remain fixed. A NaN is the IEEE® symbol for Not a Number. When the surface obtained is decoded, the required results are obtained.

Now the predicted surface roughness values are obtained using the fuzzy logic toolbox. Then the actual values obtained in the experiments are compared with the predicted ones and the percentages of errors are observed. These values are summarized in the given below.

Table 3: Percentage Error

Speed *(m/min)*	**Feed *(mm/min.)***	**Depth of cut *(mm)***	**Experimental Roughness Ra *(µm)***	**Predicted Roughness Ra *(µm)***	**Error %**
100	0.03	0.1	0.23	0.2319	0.82
120	0.04	0.2	0.20	0.2116	6.0
140	0.05	0.3	0.28	0.2608	6.85

Thus the following observations are made

- Minimum surface roughness value 0.20 µm was obtained at the value of 120m/min., 0.03mm/min., 0.1 mm for cutting speed, feed rate and depth of cut respectively.
- Maximum surface roughness value 0.31 µm was obtained at the value of 140 m/min.,0.05 mm/min., 0.30 mm for cutting speed, feed rate and depth of cut respectively.
- Surface roughness increase as feed rate increase.
- These models can be used to prediction of surface roughness in end milling process.

6. CONCLUSION

In doing this, experimental measurements, fuzzy logic are exploited in an integrated manner. The goal is prediction of surface roughness in milling process by using fuzzy logic and roll of main parameters (spindle speed, feed rate and depth of cut). Generally a good correlation is observed between the predicted and the experimental measurements. This survey will help in another important factor that greatly influences production rate and cost. So, as a whole, there is a need for allow the evaluation of the surface roughness before the machining of the part and which, at the same time, can be easily used in the production floor environment for contributing to the minimization of required time and cost and the production of desired surface quality.

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