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Application of Fuzzy Inference Systems in Turning Process of Inconel 718

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Abstract —
Inconel 718 is nickel based super alloy [2]. This is one the popular alloy mostly used in aerospace applications due to its various properties like sustainability, no corrosiveness, thermal stability and surface integrity when subjected to high temperature region. These properties can be possible because of 50 % nickel contain result in to high straight. High yield strength makes such alloys difficult for marching. Trial based machining is big challenge towards economic fusibility. It is economical to decide best suitable paramedic combination for getting desire machining responses through Artificial Intelligence approach. ANFIS modelling gives predictive results and built input-output relation to vary within range of machining. In this paper attempt has been made to develop predictive ANFIS model for machining of inconel 718
Keywords — Inconel718, fuzzy, ANFIS.

I. INTRODUCTION

Inconel 718 is having various engineering applications in gas turbine, aircraft engine parts [12], According to D. G. Thakur et al [17], approximately about 75% by weight in the case of aerospace applications and 50% by weight in the case of modern jet engines are the components made of Inconel 718. It in fact accounts for 40-50% of all superalloys produced [8]. Arguably, it is still the most successful superalloy even after nearly 50 years of its introduction [11, 1]. As machining of inconel 718 is difficult to cut [4, 10], huge cost impact is there on machining trials to set desire outcome. The alternative machining can reduces the trials by developing predictive models of ANFIS. Among the various elements of artificial intelligence fuzzy logic is effective tool. Generally, the word “fuzzy” can be defined as blurred, imprecisely defined, confuse or vague. Hence, fuzzy logic is defined as the mathematical means of representing vagueness and imprecise information. Fuzzy logic is widely used because of its ability in representing the vagueness and imprecise information. The rapid tool wears apples use of ANFIS for proper parametric selection with limited trials.

II. DESIGN OF EXPERIMENT

The wok piece material used was inconel 718 round bar of Φ40 mm diameter for turning using CNC Lathe machine. Carbide cutting tool insert (SNMG120408) is used. The chemical composition, mechanical and physical properties of inconel 718 is as in table1.

TABLE I

CHEMICAL COMPOSITION OF INCONEL 718

Element	***Ni (+Co)***	***Ti***	***Cr***	***Nb(+Ta)***	***Al***	***Fe + Other***
Weight (%)	50-55	0.65-1.5	17-21	4.75-5.5	0.2-0.8	Balance

Three level two factorial design of experiment is done. The allowable speed and feed ranges for machining Inconel 718 are at notably low levels [3]. The machining of inconel 718 carried out with cutting speed 55, 60,65 m/min and cutting feed 0.1, 0.12, 0.16 mm/rev for machining response parameter surface roughness.

S. No.	Speed	Feed	Ra
1	60	0.16	0.34
2	55	0.16	0.34
3	60	0.1	0.28
4	65	0.16	0.34
5	60	0.12	0.27
6	65	0.1	0.28
7	65	0.12	0.3
8	55	0.12	0.27
9	55	0.1	0.28

REGRESSION ANALYSIS:

Ra = 0.439 + 0.00236x Speed - 4.86 x Feed - 0.0107 Cs x F + 25.0 F x F

Predictor	Coef	SE Coef	T	P
Constant	0.4386	0.3091	1.42	0.229
Speed	0.002357	0.004428	0.53	0.623
Feed	-4.857	3.225	-1.51	0.207
Cs X F	-0.01071	0.03430	-0.31	0.770
F X F	25.000	9.433	2.65	0.057

S = 0.0104796 R-Sq = 94.4% R-Sq(adj) = 88.7%

ANALYSIS OF VARIANCE

Source	DF	Reduced DF	Seq SS
Cs X F	1	1	0.0063056
F X F	1	1	0.0004131
Speed	2	2	0.0004430
Feed	2	1+	0.0002490
Speed*Feed	4	2+	0.0002893
Total	8	8	0.0078000

S = 0.01 R-Sq = 98.72% R-Sq(adj) = 89.74%

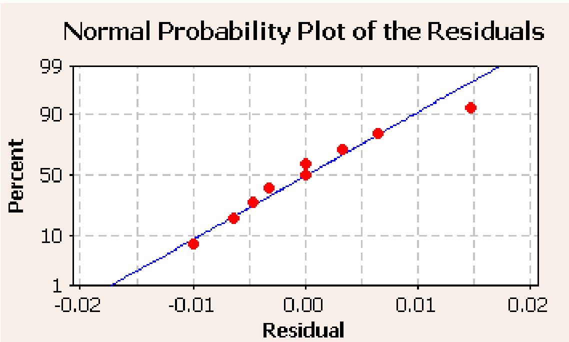


Figure 1: Normal probability plot

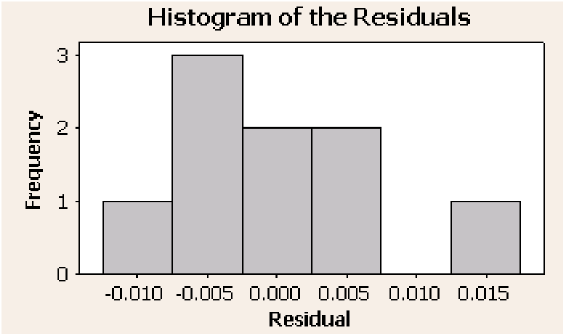


Figure 2: Histogram

Analysis of variance (ANOVA) is used to study the effect of process parameter and establish the correlation among the cutting speed, feed with respect to surface roughness. Two most influencing parameters that have a major impact on the surface roughness

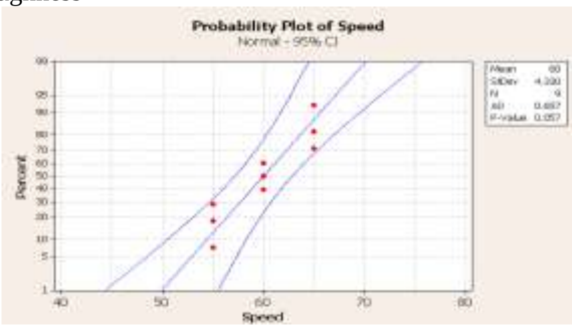


Figure 3: 95% CI Speed

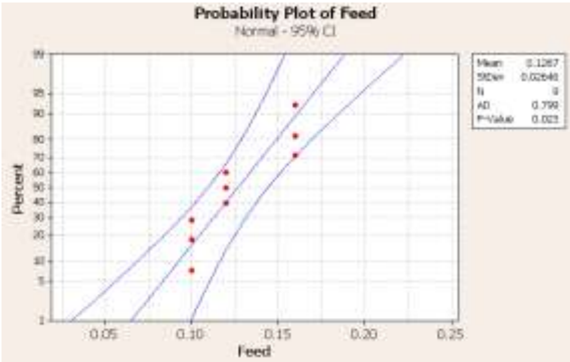


Figure 4: 95% CI Feed

III. ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM

The ANFIS architecture and its learning algorithm for the Sugeno fuzzy model are primarily described. For simplicity, let the fuzzy inference system under consideration has two inputs m and n and one output f. For a first-order Sugeno fuzzy model, a typical rule set with two fuzzy if–then rules can be expressed as
Rule 1: If (m is A1) and (n is B1) then f1 = p1m + q1n + r1…………… (2.1)
Rule 2: If (m is A2) and (n is B2) then f2 = p2m + q2n + r2 ………… (2.2)
Where p1, p2, q1, q2, r1 and r2 are linear parameter and A1, A2, B1 and B2 is nonlinear parameter.
The corresponding equivalent ANFIS architecture is as shown in Figure 7. The entire system architecture consists of five layers, namely, the fuzzy layer, product layer, normalized layer, de-fuzzy layer and total output layer. The following sections discuss in depth the relationship between the output and input of each layer in ANFIS.

Layer 1 is the fuzzy layer, in which m and n are the input of nodes A1, B1 and A2, B2, respectively. A1, A2, B1 and B2 are the linguistic labels used in the fuzzy theory for dividing the membership functions. The membership relationship between the output and input functions of this layer can be expressed as below:

O1,i = μAi(m), i = 1, 2, O1,j = μBj (n), j = 1, 2 ……. (2.3)

Where O1,i and O1,j denote the output functions and μAi and μBj denote the membership functions.

Layer 2 is the product layer that consists of two nodes labeled II. The output W1 and W2 are the weight functions of the next layer.

O2,i = wi = μAi(m) μBi(n), i = 1, 2 …..….. (2.4)

Where O2, i denotes the output of Layer 2.

Layer 3 is the normalized layer, whose nodes are labeled N. Its functions are to normalize the weight function in the following process:

O3,i = Wi = (wi / W1 + W2), I = 1, 2……. (2.5)

Where O3, i denotes the Layer 3 output.

Layer 4 is the de-fuzzy layer, whose nodes are adaptive. The output equation is W. (pm+qn+r), where pi, qiand ri denote the linear parameters or so-called consequent parameters of the node. The de-fuzzy relationship between the input and output of this layer can be defined as follows:

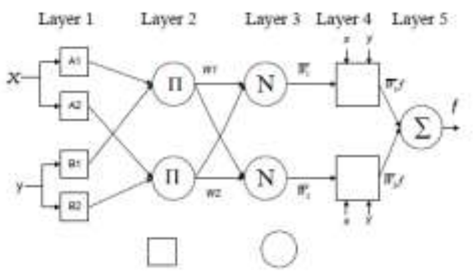
O4,i = Wifi = Wi (pim + qin + ri), i = 1, 2 ….... (2.6)

Where O4,i denotes the Layer 4 output.

Layer 5 is the total output layer, whose node is labeld as ∑. The output of this layer is the total of input signals, which represents the results of Ra

O5,i =∑Wifi = ∑iwifi / ∑iwi, i= 1, 2 ……… (2.7)

Where O5,i denotes the Layer 5 output must be justified, i.e. both left-justified and right-justified.



Adaptive node Fixed node

Figure 5: ANFIS architecture

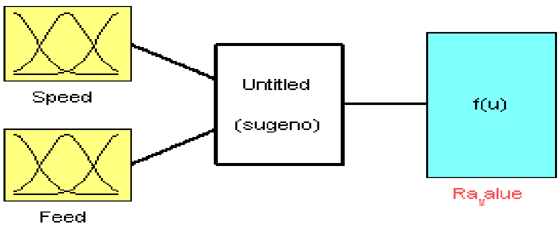


Figure 6: The Sugeno model Fuzzy rule architecture of the triangular membership function.

A. Fuzzy Control Rules

The nine fuzzy control rules with linguistic grades for each attribute are constructed under the following considerations

RULE 1: If medium speed and low feed rate, then the surface roughness is excellent.
RULE 2: If low machining speed and medium feed rate, then the surface roughness is good.
RULE 3: If low machining speed and high feed rate, then the surface roughness is fair.
RULE 4: If medium speed and medium feed rate, then the surface roughness is fair.
RULE 5: If medium machining speed and high feed rate, then the surface roughness is poor.
RULE 6: If medium machining speed and low feed rate, then the surface roughness is good.
RULE 7: If high machining speed and high feed rate, then the surface roughness is worst.
RULE 8: If high machining speed and low feed rate, then the surface roughness is fair.
RULE 9: If high machining speed and medium feed rate, then the surface roughness is worst.

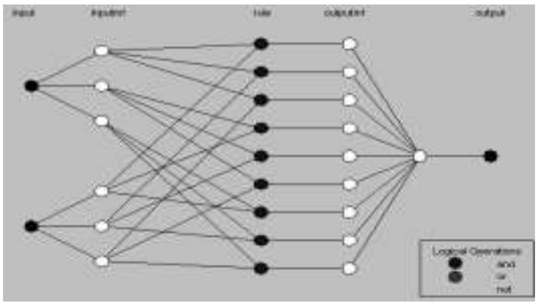


Figure 7: ANFIS structure

B. *Fuzzy Membership Functions*

Fuzzy membership function is the combination relational combination of parametric range. Figure 8 and 9 shows initial membership function of cutting speed and feed. The triangular membership function shows low medium and high values of range of trials.

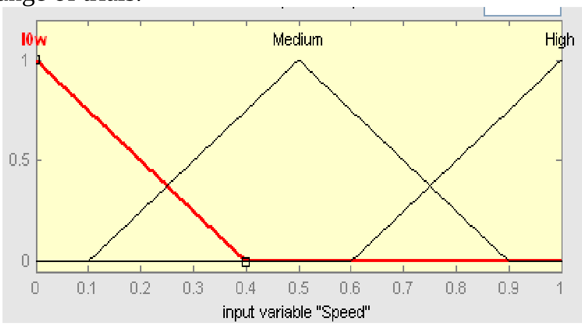


Figure 8: Membership function of cutting speed

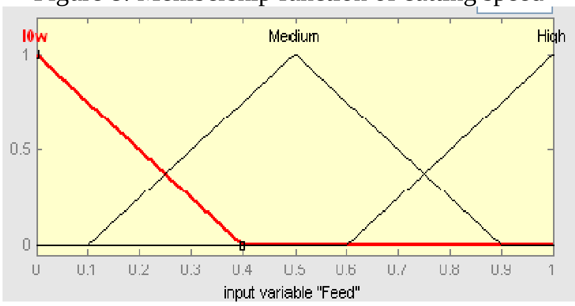


Figure 9: Membership function of cutting Feed

C. *Fuzzy Rules Viewer*

The fuzzy rule combinations for various relational membership function as shown in figure 10. The triangular membership can vary by sliding red line. Last column shows predictive outcome of machining responses.

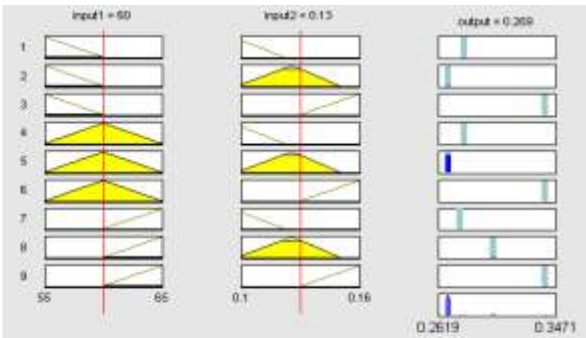


Figure 10: Rule viewer

The predictive model of ANFIS shows best agreement with response outcome of turning process of inconel 718. The model adequacy improves to get predictive values other than actual conduct.

IV. CONCLUSIONS

The Fuzzy logic is conceptually easy to develop predictive model. The mathematical concepts behind fuzzy reasoning are very useful for costly machining process like turning of inconel 718. Fuzzy logic is flexible that makes easy to select suitable parameters. With any given system, it is easy to layer on more functionality without starting again from scratch. Fuzzy logic is tolerant of imprecise data that covers non addressed influencing factors of machining. Fuzzy reasoning builds this understanding into the process instead tacking it onto the end. It is possible to create a fuzzy system to match any set of input-output data. This process is made particularly easy by adaptive techniques like Adaptive Neuro-Fuzzy Inference Systems (ANFIS).

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