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 fu...
### Regression Analysis:

Ra = 0.439 + 0.00236 \times \text{Speed} - 4.86 \times \text{Feed} - 0.0107 \times \text{Cs} \times \text{F} + 25.0 \times \text{F} \times \text{F}

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.4386</td>
<td>0.3091</td>
<td>1.42</td>
<td>0.229</td>
</tr>
<tr>
<td>Speed</td>
<td>0.002357</td>
<td>0.004428</td>
<td>0.53</td>
<td>0.623</td>
</tr>
<tr>
<td>Feed</td>
<td>-4.857</td>
<td>3.225</td>
<td>-1.51</td>
<td>0.207</td>
</tr>
<tr>
<td>Cs X F</td>
<td>-0.01071</td>
<td>0.03430</td>
<td>-0.31</td>
<td>0.770</td>
</tr>
<tr>
<td>F X F</td>
<td>25.000</td>
<td>9.433</td>
<td>2.65</td>
<td>0.057</td>
</tr>
</tbody>
</table>

S = 0.0104796 \quad \text{R-Sq} = 94.4\% \quad \text{R-Sq(adj)} = 88.7\%

### Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Reduced DF</th>
<th>Seq SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs X F</td>
<td>1</td>
<td>1</td>
<td>0.0063056</td>
</tr>
<tr>
<td>F X F</td>
<td>1</td>
<td>1</td>
<td>0.0004131</td>
</tr>
<tr>
<td>Speed</td>
<td>2</td>
<td>2</td>
<td>0.0004430</td>
</tr>
<tr>
<td>Feed</td>
<td>2</td>
<td>1+</td>
<td>0.0002490</td>
</tr>
<tr>
<td>Speed*Feed</td>
<td>4</td>
<td>2+</td>
<td>0.0002893</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>8</td>
<td>0.0078000</td>
</tr>
</tbody>
</table>

S = 0.01 \quad \text{R-Sq} = 98.72\% \quad \text{R-Sq(adj)} = 89.74\%
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.

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 $A_1$) and ($n$ is $B_1$) then $f_1 = p_1m + q_1n + r_1$………… (2.1)

Rule 2: If ($m$ is $A_2$) and ($n$ is $B_2$) then $f_2 = p_2m + q_2n + r_2$ ………… (2.2)

Where $p_1$, $p_2$, $q_1$, $q_2$, $r_1$ and $r_2$ are linear parameter and $A_1$, $A_2$, $B_1$ and $B_2$ 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 $A_1$, $B_1$ and $A_2$, $B_2$, respectively. $A_1$, $A_2$, $B_1$ and $B_2$ 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, qi and 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 labeled as Σ. The output of this layer is the total of input signals, which represents the results of Ra

O5,i = ΣWifi = Σiwifi / Σwi, i = 1, 2 ……… (2.7)

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

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.
B. Fuzzy Membership Functions

Fuzzy membership function is the combination relatiional 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.

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.

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.
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 tackling 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).

ACKNOWLEDGMENT

Special thanks to COET Akola and Pioneer Engineering Aurangabad for availing research facilities.

REFERENCES