PRIORITIZATION OF WIRE EDM RESPONSE PARAMETERS USING ANALYTICAL NETWORK PROCESS

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ABSTRACT *Wire-electro discharge machining (WEDM) plays an important role in machining of difficult-to-machine hard materials and complex profiles. Wire Electrical Discharge machining (WEDM) is very complex process due to the presence of large number of machining characteristics involved. Mostly, WEDM is used for machining of hard material parts that are extremely difficult to machine by conventional machining process. The main aim of present work is to prioritization of Wire EDM response parameters using Analytical Network Process. Generally, the traditional Taguchi approach is insufficient tosolve a multi objective optimization problem. In order to overcome this limitation researchers try applying different multi-objective optimization techniques. In those techniques they have assign weightages to response parameters. Generally, Most of the researchers assigning equal weightages to all response parameters. To overcome the intuition and judgment of the decision maker the multi- criteria decision making approach Analytical Network Process is applied for assigning weightages to more accurate of results.*

Keywords: *Wire EDM, Analytical Network Process, MCDM, Response Parameters*

1. INTRODUCTION

Analytic Network Process (ANP) was proposed by Prof. Saaty to overcome the problem of interdependence and feedback between criteria and alternatives. It is a multi-criteria approach for decision making and it may transform qualitative judgments into quantitative values. The ANP is a coupling of two parts. The first consists of a control hierarchy or network of criteria and sub criteria that control the interactions. The second is a network of influences among the elements and clusters. The network varies from criterion to criterion and a different super matrix of limiting influence is computed for each control criterion. Finally, each of these super matrices is weighted by the priority of its control criterion and the results are synthesized through addition for all the control criteria [1].ANP has been applied to various fields such as strategic decision,decision making problems, product planning, optimal scheduling etc. In this paper adopted ANP technic for with prioritization of Wire EDM response parameters (RPs)i.e Surface Roughnes (R_a), Cutting Speed (CS), Material Removal Rate (MRR), Kerf Width (KW) and Angular Error (AE). Part Thickness (PT), Taper Angle (TA), Pulse-ON time (T_{ON}), Pulse-OFF time (T_{OFF}), Wire Feed (WF), Wire Tension (WT) and Servo Voltage Gap (SV) are considered as process parameters (PPs).

2. ANALYTIC NETWORK PROCESS

The Analytic Network Process (ANP) is a multi-criteria decision making (MCDM) technique, which considers the interdependence among criteria and alternatives and it may transform qualitative judgments into quantitative values. The ANP generalizes the AHP by replacing hierarchies with networks. AHP employs a unidirectional hierarchical relationship among clusters, while ANP enables interrelationships not only among the clusters but also between the elements of a cluster [2].A decision problem is analyzed with the ANP is often studied through a decision network which is structured of clusters, elements, and links. A cluster is a collection of relevant elements within a network or sub-network. For each control criterion, the clusters of the system with their elements are determined. All interactions and feedbacks within the clusters are called inner dependencies whereas interactions and feedbacks between the clusters are called outer dependencies. Inner and outer dependencies are the best way decision-makers can capture and represent the concepts of influencing or being influenced, between clusters and between elements with respect to a specific element. Then pair-wise comparisons are made systematically including all the combinations of element/cluster relationships.

ANP uses the same fundamental comparison scale (Saaty scale) that is used in the AHP. This comparison scale enables the decision-maker to incorporate experience and knowledge intuitively and indicate how many times an element dominates another with respect to the criterion. It is a scale of absolute (not ordinal, interval or ratio scale) numbers. The decision maker can express his preference between each pair of elements verbally as equally important, moderately more important, strongly more important, very strongly more important, and extremely more important. These descriptive preferences would then be translated into numerical values 1, 3, 5, 7, 9, respectively, with 2, 4, 6, and 8 as intermediate values for comparisons between two successive judgments. Reciprocals of these values are used for the corresponding transposed judgments.

ANP consists of two stages.The first one is the construction of the network, and the second one is the calculation of the priorities of the elements [3].The interactions among the elements should be evaluated by pair-wise comparisons. The pair-wise comparison in ANP is performed in a matrix framework. In order to verify the consistency of the pair-wise comparison matrix, Satty proposed consistency index (CI) and consistency ratio (CR).

The CI and CR are defined as follows:

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1} \qquad \text{.......................... (1)}$$

λ_{max}= maximum principal eigenvalue of the comparison matrix

n = number of elements (order of the pair-wise comparison matrix)

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \qquad \text{.......................... (2)}$$

The value of $\lambda_{max}$is obtained by first multiplying the pair-wise comparison matrix with the matrix of the relative importance weights. Then divide the first element of the resulting matrix by the first element of the matrix of relative importance weights, the second element of the resulting matrix by the second element in the matrix of relative importance weights, and so on. A single column matrix is obtained and the average of the elements of the matrix gives the value of λmax.The RI in the equation (2) represents the average consistency index for numerous random entries of same-order reciprocal matrices [4]. The table 1 presents the average RI for various matrix sizes (n).

Table 1: Average value of RI for corresponding matrix order

n	RI	*n*	RI	*n*	RI	*n*	RI
1	0	5	1.12	9	1.45	13	1.56
2	0	6	1.24	10	1.49	14	1.57
3	0.58	7	1.32	11	1.51	15	1.59
4	0.90	8	1.41	12	1.48		

When a network consists of only two clusters apart from goal, namely criteria and alternatives, the matrix manipulation approach proposed by [5] can be employed to deal with the dependencies of the elements of a system. In this approach, the super matrix is represented as follows:

$$\mathbf{W} = \begin{array}{l} \\ \text{Goal (G)} \\ \text{Criteria (C)} \\ \text{Alternatives (A)} \end{array} \begin{array}{c} \begin{array}{ccc} \mathrm{G} & \mathrm{C} & \mathrm{A} \end{array} \\ \begin{bmatrix} 0 & 0 & 0 \\ \mathbf{w}_1 & \mathbf{W}_3 & 0 \\ 0 & \mathbf{W}_2 & \mathbf{W}_4 \end{bmatrix} \end{array}$$

In the above super matrix, $w21$ is a vector that represents the impact of the goal on the criteria, $W32$ is a matrix that represents the impact of the criteria on each of the alternatives and I is the identity matrix. After forming the super matrix, the weighted super matrix is derived by transforming all columns sum to unity exactly. Next, the weighted super matrix is raised to limiting powers to get the global priority vector or called weights [6].

3. METHODOLOGY

The following ANP procedure [7]is adopted to obtain the priority structure of Process Parameters.

Step 1: Establish the matrix (W_1) which shows the degree of relative importance of the RPs with respect to each PP

- *Establishment of pair-wise comparison matrix*
  Setup the pair-wise comparison matrix of ordern ×n consists of n elements (requirements) in the rows and columns whose priorities are to be determined.
- *Perform pairwise comparisons of all the elements*
  Saatyscale [8]is used to perform pair-wise comparisons. Thedescriptive preferences of the decision maker would then be translated into numerical values 1, 3, 5, 7, 9 respectively, with 2, 4, 6 and 8 as intermediate values for comparisons between two successive judgments. Reciprocals of these values are used for the corresponding transposed judgments. For a matrix of order n, $n\ n-1\ /2$ comparisons are required. After the pair-wise comparisons are completed, proceed for the next step to estimate the eigen values of the matrix.
- *Estimation of Eigen values of the matrix*
  The normalized pair-wise comparison matrixes is developed and then sum the elements in each row of the normalized pair-wise comparison matrix and divide the sum with the number of elements. The result of this computation is referred to as the priority matrix (w) and is an estimation of the Eigen values of the matrix.
- *Checking the consistency of pair-wise judgments*
  In order to verify the consistency of the pairwise comparison matrix, Saaty proposed consistency index (CI) and consistency ratio (CR). If CR is less than or equal to 0.1, then the estimate is accepted; otherwise, a new comparison matrix is solicited until CR is greater than equal to 0.1 (Chang et al., 2007).

Step 2: Establish the matrix (W_2) which is the inner dependence matrix of the PPs with respect to each PP
Step 3: Establish the matrix (W_3) which is the inner dependence matrix of the RPs withrespect to each RP
Step 4: Calculate the interdependent priority matrix (W_C) of the customer needs by using

$W_C = W_2 \times w$

Where w = matrix of importance values of customer needs

Step 5: Calculate the interdependent priority matrix (W_A) of the RPs by using

$W_A = W_3 \times W_1$

Step 6: Calculate the overall priorities of the Engineering Characteristics $W^{ANP}$by using

$W^{ANP} = W_A \times W_C$

4. RESULTS AND DISCUSSIONS

The Analytical Network Process technique is successfully adopted for assigning weightages to Wire EDM response parameters. Prepare the pair-wise comparison matrix of Wire EDM process parameters. The pair-wise comparison matrix and the normalized pair-wise comparison matrices of the service quality dimensions are shown in tables 2 and 3.

Table 2: Pair-wise comparison matrix of the process parameters

PP \ PP	PT	TA	T_{ON}	T_{OFF}	WF	WT	SV
PT	1	3.0000	0.7500	0.6666	2.0000	1.5000	2.0000
TA	0.3333	1	0.6666	2.0000	3.0000	1.5000	0.6600
T_{ON}	1.3333	1.5002	1	0.5000	2.0000	3.0000	1.5000
T_{OFF}	1.5002	0.5000	2.0000	1	3.0000	0.6666	1.5000
WF	0.5000	0.3333	0.5000	0.3333	1	0.3333	0.5000
WT	0.6667	0.6667	0.3333	1.5002	3.0003	1	1.3333
SV	0.5000	1.5152	0.6667	0.6667	2.0000	0.7500	1
SUM	5.8335	8.5153	5.9166	6.6668	16.0003	8.7499	8.4933

Table 3: Normalized Pair-wise comparison matrix

PP \ PP	PT	TA	T_{ON}	T_{OFF}	WF	WT	SV	**SUM**
PT	0.1714	0.35231	0.12676	0.09999	0.125	0.17143	0.23548	1.28239

TA	0.0571	0.11744	0.11267	0.3	0.1875	0.17143	0.07771	1.02387
T_{ON}	0.2286	0.17617	0.16902	0.075	0.125	0.34286	0.17661	1.29322
T_{OFF}	0.25716	0.05872	0.33803	0.15	0.1875	0.07618	0.17661	1.2442
WF	0.08571	0.03915	0.08451	0.05	0.0625	0.03809	0.05887	0.41883
WT	0.11428	0.07829	0.05634	0.22502	0.18752	0.11429	0.15698	0.93272
SV	0.08571	0.17793	0.11268	0.1	0.125	0.08572	0.11774	0.80478

To normalize the sum of the rows, divide the each row sum of the table 3 with the number of elements (i.e., 7). The priority matrix of the quality dimensions is obtained and given as follows.

$$\omega = \frac{1}{7} \times \begin{bmatrix} 1.282 \\ 1.024 \\ 1.293 \\ 1.244 \\ 0.419 \\ 0.932 \\ 0.804 \end{bmatrix} = \begin{bmatrix} 0.183 \\ 0.146 \\ 0.185 \\ 0.178 \\ 0.060 \\ 0.133 \\ 0.115 \end{bmatrix}$$

In order to weightage the response parameters, the step by step procedure discussed in methodology section is implemented and the degree of relative importance weights for all RPs with respect to each PP are calculated and presented as matrix W_1 shown in Table 4.

Table 4: Degree of relative importance weights of the RPs with respect to PPs (W_1)

PP / RP	PT	TA	T_{ON}	T_{OFF}	WF	WT	SV
R_a	0.2162	0.1949	0.2284	0.1507	0.1070	0.3025	0.1281
CS	0.1678	0.2568	0.1404	0.1605	0.3383	0.0996	0.3355
MRR	0.1795	0.1406	0.1755	0.1990	0.1646	0.1723	0.1260
KW	0.0999	0.1190	0.0935	0.4156	0.2017	0.1003	0.1480
AE	0.3366	0.2888	0.3621	0.0742	0.1884	0.3253	0.2623

The inner dependency matrix of the customer needs with respect to each PP is established with the help of pair-wise comparisons. The inner dependencies among the customer needs are calculated by analyzing the impact of each customer need on other customer need. The inner dependence matrix (W_2) of the customer needs with respect to PPs is developed and relative importance weights are presented in the table 5.

Table 5: Inner dependence matrix of the PPs (W_2)

PP / PP	PT	TA	T_{ON}	T_{OFF}	WF	WT	SV
PT	0.2138	0.2459	0.2697	0.1985	0.1304	0.3076	0.2696
TA	0.1826	0.1391	0.2254	0.1140	0.1575	0.1414	0.2046
T_{ON}	0.2629	0.1226	0.1393	0.2203	0.1032	0.1268	0.1674
T_{OFF}	0.0976	0.1531	0.1034	0.1695	0.0779	0.1685	0.1491
WF	0.1010	0.2031	0.0747	0.0728	0.1919	0.0673	0.0863
WT	0.0847	0.0839	0.1337	0.1021	0.0890	0.1062	0.0554
SV	0.0576	0.0524	0.0539	0.1229	0.2501	0.0823	0.0676

The inner dependency matrix (W_3) of the RPs with respect to each RPis developed and is shown in Table 6.

Table 6: Inner dependence matrix of the RPs (W_3)

RP / RP	R_a	CS	KW	AE	MRR
R_a	0.2438	0.2966	0.2437	0.2795	0.1832
CS	0.1160	0.0966	0.1194	0.1811	0.1147
MRR	0.2259	0.1745	0.2101	0.2089	0.3512

KW	0.2599	0.1178	0.1105	0.1307	0.1517
AE	0.1544	0.3145	0.3162	0.1998	0.1992

The interdependent priority matrix W_C of the customer needs is obtained by the product of W_2 and w and then the interdependent priority matrix W_A of engineering characteristics is obtained by multiplying the matrix W_3 and W_1. Finally the priorities of the engineering characteristics (W^{ANP}) are determined by using $W_A \times W_C$.

$$W^{ANP} = \begin{bmatrix} 0.236 & 0.244 & 0.233 & 0.263 & 0.258 & 0.232 & 0.250 \\ 0.119 & 0.119 & 0.120 & 0.140 & 0.130 & 0.120 & 0.119 \\ 0.255 & 0.245 & 0.259 & 0.216 & 0.226 & 0.257 & 0.237 \\ 0.160 & 0.155 & 0.162 & 0.145 & 0.140 & 0.171 & 0.145 \\ 0.236 & 0.236 & 0.225 & 0.234 & 0.252 & 0.217 & 0.246 \end{bmatrix} \times \begin{bmatrix} 0.240 \\ 0.168 \\ 0.173 \\ 0.134 \\ 0.105 \\ 0.096 \\ 0.083 \end{bmatrix}$$

$$W^{ANP} = \begin{bmatrix} 0.244 \\ 0.123 \\ 0.245 \\ 0.155 \\ 0.235 \end{bmatrix}$$

The Response parameters of Wire EDM are weighted and are shown in table 7.

Response Parameters	R_a	CS	MRR	KW	AE
Weightage	0.244	0.123	0.245	0.155	0.235
Priority Rank	2	5	1	4	3

5. CONCLUSIONS

In this paper a methodology is proposed prioritization of Wire EDM response parameters using Analytical Network Process for weightages is successfully adopted. The priority ranks of Response parameters are calculated and ranked. The results concluded that the highest priority obtained for Material Removal Rate with weightage 0.245 and followed by Surface Roughness is 0.244, Angular Error is 0.235, kerf width is 0.155 and Cutting Speed is 0.123.

6. FUTURE SCOPE

The Proposed methodology may be applied for all multi-response optimization techniques like Grey Relational Analysis, TOPSIS, TLBO, etc.,

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