Experimental Investigations and Empirical Modelling for WEDM Process by Using ANN and RSM

K. Saikumar¹, Harinaik², R. Ramchandra³
PG Student¹, Associate Professor², Principal³

Abstract:
Wire electrical discharge machining (WEDM) is a widely used process in manufacturing industries to machine complex profiles. Wire electrical discharge machining (WEDM) own benefit in manufacturing of modern materials, particularly used in the space engineering technology as well as in aeronautical industries. With WEDM advancement, complex components can be able to cut easily those hard to machine with conventional process. Obtained high level of precision component and fine surface finish leads WEDM important. In any machining process, the machining parameters fundamentally in fluence quality; cost, time and production rate of a manufactured product. WEDM methodology includes more number of variables that influence its execution. The performance of any machining process is based on choosing the right combination of input parameters. Metal removal rate and surface roughness are the most important output parameters, which decide the performance of a machining process. The selection of optimal parameters in wire electrical discharge machining is difficult as it is a complex process and involves a large number of variables. The present work models the metal removal rate and the surface roughness in terms of the input variables using the response surface methodology and also by using Artificial Neural Networks and consequently, the mathematical models are developed using both the methods. L31 orthogonal array is used for experimentation. The present method is an integrated approach combining both the RSM and ANN in modelling the process.

I. INTRODUCTION:

Manufacturing technology plays a very important task for the development of an industrial growth. Liberalization and Globalization with new industrial trade policies have made manufacturing a key element to address the global competition. In the past 20 decades, strategic philosophy has been taken over the cost reduction in the field manufacturing and the overall objective is the cost minimization. Therefore, the quality, flexibility and reliability of the product has been replaced by the single ambitious that is cost minimization in manufacturing trend, which was the rule in manufacturing up to the 1970s. Customer's perspective is changed in recent times due to the awareness created in view of global competition in terms of design, appearance, new products, satisfaction, response and other goals. The needs of the present day customer are outlines the single pursuit objective is cost reduction. One of such processes is WEDM is the latest variant of EDM in which a thin wire is used as the electrode rather than the electrode as a replica of the component to be produced. Because of its cost, popularity and processing conditions, WEDM has confirmed its feasibility for optimum machining the hard materials. Complex and complicated geometries can be cut with ease and the process has become the most widely recognized in the industry today. This process can also be used as an alternative for conventional machining process and also for drilling, milling and grinding. Associated the growth of involuntary trends, the importance used for alloy resources containing high stiffness, roughness plus collision conflict are rising. Thus, such resources are hard to be cut by conventional metal working process. Therefore, non-conventional working process involves such as electrical discharging machine (EDM), electrochemical machining etc, are useful to cut such not easy to machine materials. WEDM method with a lean wire is a negative electrode converts electrical to thermal energies for cutting materials. From this method, alloy steel, conductive ceramic objects and aerospace resources can be metal work by irrespective to their toughness and hardness properties. Moreover, WEDM is capable of providing corrosion, exact and good surface Properties.

II. ELECTRICAL DISCHARGE MACHINE (EDM)

EDM uses the thermal energy to achieve a high-precision working method from a fine, correctly controlled electrical discharge. The negative electrode is stimulated towards the positive electrode till the space is low sufficient. So as to heightened, electrical energy is sufficient to ionize the dielectric. Small period of discharges are produced in a fluid dielectric space, those are divided by tool and work piece. EDM is usually utilized for metal working very tough and stiff materials, suchas tool steels and carbides which is used as final parts forth aerospace, automobile industry and surgical components. It is furthermore used to construct complicated shapes and small diameter holes, which are difficult or not possible to machine using traditional process. Since EDM uses an electric discharge to cut the material, its uses is restricted to conductive materials. The table 1 gives the list of some materials that can be machined with EDM.
### Table 1. List of Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Tool Steel/Ingot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inconel</td>
<td>Cold Roll Steel</td>
</tr>
<tr>
<td>Tool Steels: 01, A2, D2, S7</td>
<td>Hot Rolled Steel</td>
</tr>
<tr>
<td>Carbide</td>
<td>Vasconal 3000</td>
</tr>
<tr>
<td>Graphite</td>
<td>PCD Diamond</td>
</tr>
<tr>
<td>Stainless Steels</td>
<td>Beryllium Copper</td>
</tr>
<tr>
<td>Aluminium</td>
<td>Nitronic</td>
</tr>
<tr>
<td>Aluminium Bronze</td>
<td>Hastalloy</td>
</tr>
<tr>
<td>Copper</td>
<td>Stellite</td>
</tr>
<tr>
<td>Brass</td>
<td>Titanium</td>
</tr>
</tbody>
</table>

### III. Principle of WEDM Process

The WEDM machine device involves a primary worktable (X-Y) on which the work piece is fixed; it consists of a supporting table (U-V) and wire drive system. The primary table travels along X and Y-axis and it is run by the D.C servo motors. The moving wire is consistently sustained from wire feed spool and gathered on take up spool which moves, however the work piece is maintained under pressure among a set of wire guides situated at the reverse position of the work piece. The minor wire guide is fixed and U-V table is supported by higher wire guide, it can be expressed transversely along U and V-axis with respect to minor wire channel. The upper wire guide can also be placed vertically along Z-axis.

### Mechanism of Material Removal in WEDM Process

In WEDM the machining of metal working takes place owing to melt plus vaporization of the substance, it effects due to discharge of electric spark provided through energetic power deliver system among the positive and negative electrode. In WEDM, wire is taken as negative electrode and work piece is taken as positive electrode. The sparks will produced between two electrodes in the presence of dielectric fluid. Due to fast cooling rate and low viscosity in WEDM, water is taken as dielectric medium. According to Lok and Lee in 1997.

### Artificial Neural Networks (ANN)

An artificial neuron is a multiplication process to stimulate in the natural neurons. These accept indications via synapses situated upon the dendrites. While the indicator innermost bounce are powerful as much as necessary (exceed a definite entry), the neuron is make active as well as give off an indicator via the axon. This indicator may be send towards the other synapse, moreover this formulate energetic additional neurons. While designing ANN the difficulty of actual neurons is extremely distracted. These fundamentally consist of synapses as inputs, those are multiplied by weights further calculated by a numerical functions those estimate the commencement of the neuron. One more function calculate the production of the simulated neuron, ANNs merge non-natural neurons in order to precede data. However it can possible to locate the algorithms that can modify the loads of the ANN in proposition towards to get the essential yield from the network. This method of...
regulating the loads is named as learning. The foremost thing to be responsive of in consideration of utilizing the ANNs is the nature of the difficulty we are annoying to resolve, does the difficulty need a supervised or an unsupervised approach. The supervised crisis means to facilitate the chemist has previously a set of trials with well-known effect for precise control factors at hand, while the unsupervised crisis means that one covenant with a set of trial data which have no exact linked responds (or supplemental information) attached. Typically, unsupervised problems arise when the chemist has to explore the experimental data collected during pollution monitoring, or always he or she is faced with the measured data at the first time or if one must find a good method to display the data in a most appropriate way. Usually, first problems associated with handling data require unsupervised methods. Only further after we became more familiar with the measurement space (the measurement regions) of input and output variables and with the behaviours of the responses, we can select sets of data on which the supervised methods (modelling for example) can be carried on.

IV. IDENTIFICATION OF THE PROBLEM

Now way days, there is greater demand for the product with higher correctness in machining parts. long life and ease of operation for both the parts and machines. Based on the objective CNC WEDM is a machine that can satisfy all the requirements. The accurate machining of complicated shapes can be easily solved with minimum operations. WEDM is widely using in manufacturing industries to machine very complicated shapes with varying hardness. Machines with Large scale can hold work pieces weight nearly 5000 kilograms and can cut over 500 millimetres thick. Automatic wire threading is a common feature usually that is being supplied as a part of standard equipment with most of the models of WEDM machines. WEDM machines are fabricated in different dimensions and way of colour and flooded form of equipment to robust the requirements of the customer. The current technology of WEDM machines contain a CNC managing system, current supply along with anti-electrolysis path, usual cable fibre, hand held pendant, programmable Z-axis, water chillers and filtration system etc. In view of this, trial experiments are conducted on WEDM to understand the process and to know the control factors and lacunae in the process by picking-up widely used material, AISI D3. Subsequently, an idea is originated to consider WEDM, to analyze the process, to find the important parameters and their effects on responses and to optimize the process by developing a suitable methodology.

V. PROPOSED METHODOLOGY TO SOLVE THE PROBLEM

The present study job is in order to find out the best possible metal working conditions intended for WEDM. To optimize the process, the output response are determined in form of process parameters. WEDM contain numerous control variables such as pulse frequency, wire feed, water pressure, pulse-on time, wire tension, pulse-off time, duty factor etc.

Pulse-on time: The pulse on time is composed of the rising and falling edge times and the pulse width time. The actual pulse signal is generated using me/Q waveform data and a marker signal to drive the signal generator pulse modulator.

Pulse-off time: It is the point among two successive expulsions. A phase is finished while enough off-time is permitted previous to the initiate of the subsequent path. Off time will affect the speed and the stability of the cut. Shorter the off-time, the quicker will be the metal working method. Though, if the off-time is too short, the ejected work piece material will not be swept away by the flow of the dielectric and the fluid will not be deionised.

Wire tension: It is needed to hold the negative electrode in a chosen place opposite to the entity since the cable recur multifaceted oscillations owing to electro discharge among the negative electrode and positive electrode. Therefore the cable is to be making sure it stiff towards to remove contraction of the plane.

Dielectric flow rate: water is usually taken as a dielectric fluid. The dielectric acts as an insulator in the spark gap before the spark is generated. Once machining process is started, the dielectric fluid does not allow the debris to adhere to the surface of work piece. In addition, the dielectric fluid prevents the work piece from distortion due to heat and subsequently maintains the thermal equilibrium of entire system.

Wire feed: Wire feed indicates the speed at which the wire is supplied to cutting zone. During cutting, both the work piece and the tool get eroded. Wire once used is usually discarded in order to maintain higher accuracy. In the process, heat energy is delivered through wire in the spark gap and the feed control has to maintain the movement of wire in such a way that the heating temperature to melt work piece material is consistent and uniform.

Surface roughness (Ra) – Surface coarseness is a process of measuring a plane texture of a manufactured component. It can be measured by using surface roughness comparator.

Metal removal rate (MRR) -Metal elimination rate choice the velocity of production plus the finances of the metal working process. It is viewed that to facilitate the above yield reaction are precious by the selected method parameters. A full investigation on each yield reaction by the separate procedure parameters is finished in the job. The difficulty of taking decision of the best possible process is by means of the finding the best possible performance of surface coarseness (Ra) as well as metal elimination rate. To reduce the number of experiments design of experiments is required to do the analysis with same correctness and precision. Once the experiments are conducted, then the machining is transversely sectioned for the measurement of output responses. After the metallurgical preparation of machining, the profiles are traced onto the optical profile projector and the machining dimensions will be calculated correctly.

VI. RESULTS AND DISCUSSIONS

The following section explains the main and interaction effects of the machining parameters on the chosen responses. Design Expert, 8v, statistical analysis software is used for evaluating the effects. The results show the general trends between cause and effect.
Main Effects

The above developed models have been employed to predict the material removal rate and surface roughness for the range of parameters used in the investigation. Based on these models, the main effects of the process parameters on material removal rate and surface roughness are computed and plotted.

Effects of process parameters on material removal rate

The individual effect of cutting rate is found to have an increasing trend with the increase of pulse on time can be observed from Fig.3. And at the same time it can be observed from Fig.4 that decreases with the increase of pulse off time. This establishes the fact that cutting rate is proportional to the energy consumed during machining and is dependent not only on the energy contained in a pulse determining the crater size, but also on the applied energy rate or power. Therefore to obtain a good rate of metal removal, pulse-on time should be large but large pulse-on time leads to poor surface finish.

![Figure 3: Effect of Pulse ON time on metal removal rate](image1)

![Figure 4: Effect of Pulse off time on metal removal rate](image2)

The deflection of wire is minimized at high wire tensions which ensure more stabilized discharge of heat in the spark gap.

![Figure 5: Effect of wire tension on metal removal rate](image3)

![Figure 6: Effect of water pressure on metal removal rate](image4)

VII. CONCLUSION

In the present study, Design based experiments and analysis have been carried out in order to optimize the process parameters considering the effects of metal removal rate and surface roughness in machining of SS304 using WEDM. Experiments were carried out by as per Central Composite Rotatable factorial design to substantially reduce the number of experiments. The total number of experiments carried out was 31.

The following conclusions are drawn from the present work:

1) The effects of the process parameters viz. pulse on time, pulse off time, wire tension on response characteristics viz. cutting rate, surface roughness were studied after plotting the graphs using Design Expert software.
2) Pulse on time, Pulse off time, water tension and dielectric flow rate significantly affecting machining geometry.
3) The four-level factorial quadratic responses surface modelling has been used to develop mathematical models between output responses and input control variables within the workable region of process parameters for WEDM.

4) Design-expert software has been found very useful to calculate the coefficients and constants of the model. The significance of the important coefficients can also be checked and reduced models with significant factors and coefficient can also be developed by design expert.

5) Response surface methodology (RSM) was applied for developing the mathematical models in the form of multiple regression equations correlating the dependent parameters with the independent parameters (pulse on time, pulse off time, dielectric flow rate, and wire tension) on machining of SS304 steel in WEDM. From the experimental data of RSM, empirical models were developed and the confirmation experiments were performed, which were found within 95% confidence interval.

6) Also ANN is used for modelling the process. The ANN predicted values were found out and also compared with the experimental data.

7) It is found that the error percentage is within the reasonable limit, and hence ANN can be one of the choice for finding the optimal process parameters inorder to automate the process.

8) The proposed methodology helps the overall improvements in the entire process.

VIII. REFERENCES


[8] Don Moulton, “ONA Wire EDM-The fundamentals”, ONA EDM USA, Addison, IL, USA.


