Experimental Investigations into Wire Electrical Discharge Machining of 16mncr5 and 20mncr5 Steels

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Abstract— Wire EDM is one of the most popular techniques of the advanced machining processes in the present global manufacturing scenario. The Wire EDM utilizes the wire which acts as a tool upon passing the current so as to erode the work material by the generation of sparks between the work and tool. The work and the tool are immersed in a die-electric fluid and then allowed to pass through to remove the material by erosion and such machining helps to produce parts with good surface quality and dimensional accuracy. Wire EDM is new innovation of the EDM process. By using Wire EDM process, the highest accuracy can be achieved and my desertion to investigate the response parameters volumetric material removal rate(MRRv), and surface roughness(Ra) by experimentation on 16MnCr5 and 20MnCr5 metals in wire EDM process. The design of experiment is carried out considering Taguchi technique with four input parameters namely, pulse on, pulse off, current and bed speed. The experiments are conducted considering the above two materials for L_{16} and then the impact of each parameter is estimated by ANOVA. A comparison made between the two materials indicates that the 20MnCr5 material is more sui for better MRR_V and 16MnCr5 for better surface finish.

Key words: Electrical discharge machining (EDM), Wire Electrical Discharge machining (WEDM), volumetric material removal rate (MRRv), surface roughness (Ra), signal (S) to noise (N) ratio (S/N).

I. INTRODUCTION

Non-traditional machining processes is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional machining processes. Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping and milling. Nontraditional machining processes, also called advanced machining processes, are employed where traditional machining processes are not feasible, satisfactory or economical due to special reasons. Very hard fragile materials difficult to clamp for traditional machining. When the work piece is too flexible or slender. When the shape of the part is too complex. Wire Electrical Discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts of hard materials with complex shapes. Parts having sharp edges that pose difficulties to be machined by the main stream machining processes can be easily machined by WEDM process. Technology of the WEDM process is based on the conventional EDM sparking phenomenon utilizing the widely accepted non contact technique of material removal with a difference that spark is generated at wire and work piece gap. Since the introduction of the process, WEDM has evolved as a simple means of making tools and dies to the best alternative of producing micro-scale parts with the highest degree of dimensional accuracy and surface finish. This study outlines the development of a model and its application to optimize WEDM machining parameters. Experiments are conducted to test the model and satisfactory results are obtained. The methodology described here is expected to be highly beneficial to manufacturing industries, and also other areas such as aerospace, automobile and tool making industries.

II. WIRE CUT ELECTRIC DISCHARGE MACHINING

Wire Electrical Discharge Machining (WEDM) is one of the greatest innovations affecting the tooling and machining industry. This process has brought to industry dramatic improvements in accuracy, quality, productivity, and earnings. Before wire EDM, costly processes were often used to produce finished parts. Now with the aid of a computer and wire EDM machines, extremely complicated shapes can be cut automatically, precisely, and economically, even in materials as hard as carbide.

III. WORKING OF WIRE EDM

Wire EDM uses a traveling wire electrode that passes through the work piece. The wire is monitored precisely by a computer-numerically controlled (CNC) system. Figure.1 shows the movement of wire while machining.

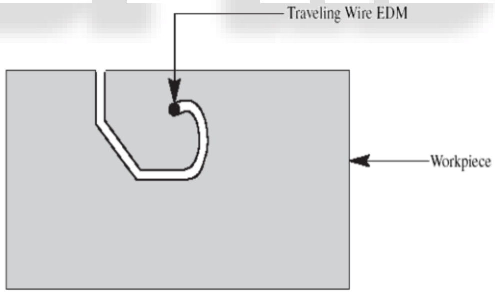

Fig. 1:Wire EDM: The wire EDM process uses a wire electrode Monitored by a CNC system to remove material.

Like any other machining tool, wire EDM removes material; but wire EDM removes material with electricity by means of spark erosion. Therefore, material to be cut using WEDM must be electrically conductive. Rapid DC electrical pulses are generated between the wire electrode and the work piece. Between the wire and the work piece is a shield of de ionized water, called the dielectric fluid. Pure water is an insulator, but tap water usually contains minerals that cause the water to be too conductive for wire EDM. To control the water conductivity, the water goes through a resin tank to remove much of its conductive elements; this is called de ionized water. When sufficient voltage is applied, the fluid ionizes. Then a controlled spark precisely erodes a small section of the work piece, causing it to melt and vaporize. These electrical pulses are repeated thousands of times per second. The pressurized cooling fluid, the dielectric, cools the vaporized metal and forces there solidified eroded particles from the gap. The dielectric fluid goes through a filter which removes the suspended solids. Resin removes dissolved particles; filters remove suspended particles. To maintain machine and part accuracy, the dielectric fluid flows through a chiller to keep the liquid at a constant temperature. Figure.2 shows the path of wire generated by CNC automated computer system. A DC or AC servo system maintains a gap from 0.002 to 0 .003" (0.05 1 to 0.076 mm) between the wire electrode and the work piece.

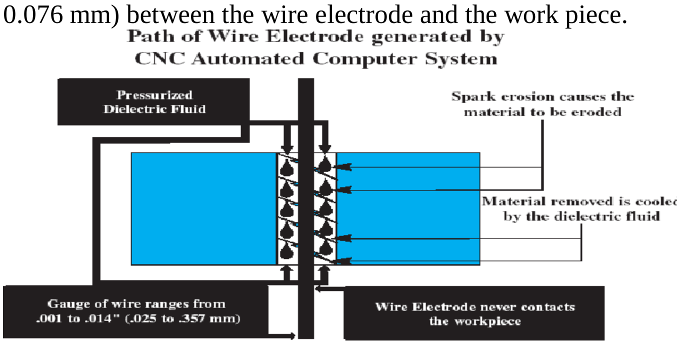

Fig. 2:

Fig. 2: precisely controlled sparks erode the metal using de ionized water. Pressurized water removes the eroded material. The servo mechanism prevents the wire electrode from shorting out against the work piece and advances the machine as it cuts the desired shape. Because the wire never touches the work piece, wire EDM is a stress-free cutting operation.

IV. Steps Involved in Wire EDM Process

A. *Power Supply Generates Volts and Amps:*

De ionized water surrounds the wire electrode as the power supply generates volts and amps to produce the spark. Figure.3 shows how power supply generates volts and amps.

B. *During on time controlled spark erodes material:*

Figure.4 shows how Sparks precisely melt and vaporize the material.

C. *Off time allows fluid to remove eroded particles:*

During the off cycle, the pressurized dielectric fluid immediately cools the material and f1ushes the eroded particles as shown in Figure.5

D. *Filter Removes Chips While the Cycle is repeated:*

The eroded particles are removed and separated by a filter system as shown in Figure.6

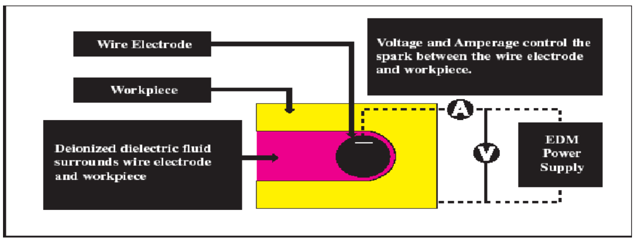

Fig. 3: Power supply generates Volts and amps

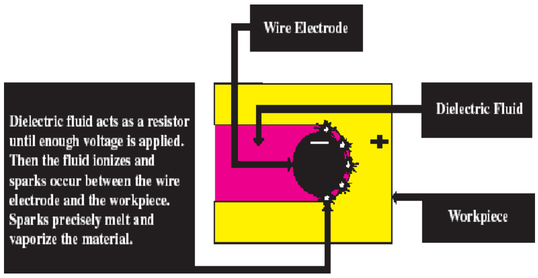

Fig. 4:During in time controlled spark erodes the material

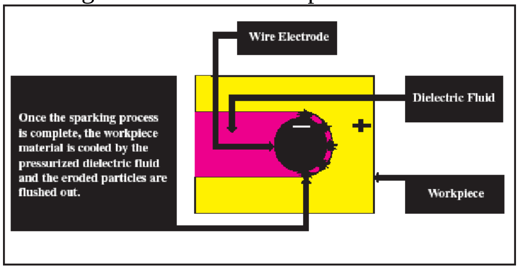

Fig. 5: off Time Allows Fluid to Remove Eroded Particles

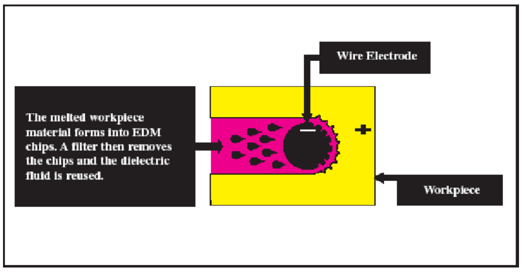

Fig. 6: Filter Removes Chips While the Cycle is repeated

This efficient design of experiments is based on a fractional factorial experiment which allows an experiment to be conducted with only a fraction of all possible experimental combination of parameter values. Taguchi has developed a family of experimental arrays to minimize the number of total experimental runs.

V. The Taguchi Method of Design of Experiments (DOE)

Taguchi methods of experimental design provide a simple, efficient and systematic approach for the optimization of experimental designs for performance quality and cost. It has been proved successful in many manufacturing situations. Dr. Taguchi is a Japanese quality management consultant who has developed and promoted a philosophy and methodology for continuous quality improvement in product and processes. With this philosophy, Taguchi shows how the statistical design of experiments (SDOE) can help industrial engineers design and manufacture products that are both of high quality and low cost. His approach is primarily focused on eliminating the causes of poor quality and on making product performance insensitive to variation. DOE is a powerful statistical technique for determining the optimal factor settings for a process and thereby achieving improved process performance, reduced process variability and improved manufacturability of products and process. The traditional experimental design procedures focus on the average product or process performance characteristics. Instead, the Taguchi method concentrates on the effect of variation on the product or process quality characteristics rather than on its averages. He designed certain standard orthogonal arrays (OAs) by which simultaneous and independent evaluation of two or more parameters for their ability to affect the variability of a particular product or process characteristics can be done in a minimum number of tests. The most commonly used orthogonal array designs are L_8, $L_{16}$and L_{18}. Here the notation "L" implies that the information is based on the Latin square arrangement of factors. A Latin square arrangement is a square matrix arrangement of factors with separable factor effects. The experimental observations are transformed into a signal-to-noise (S/N) ratio. There are several S/N ratios available depending on the type of characteristics. The characteristics that higher value represents better machining performance. The choice of a sui orthogonal array (OA) design is critical for the success of an experiment and depends on the total degrees of freedom required to study the main and interaction effect.

VI. STEPS IN PERFORMING A TAGUCHI EXPERIMENT

The process of performing a Taguchi experiment follows a number of distinct steps STEP 1: Formulation of the problem STEP 2: Identification of the output performance characteristics most relevant to the problem. STEP 3: Identification of control factors, noise factors and signal factors (if any). STEP 4: Selection of factor levels, possible interactions and the degree of freedom associated with each factor and the interaction effects. STEP 5: Design of an appropriate orthogonal array. STEP 6: Preparation of the experiment. STEP 7: Running of the experiment with appropriate data collection. STEP 8: Statistical analysis and interpretation of experimental results. STEP 9: Undertaking a confirmatory run of the experiment.

VII. SIGNAL TO NOISE RATIO

There are two different methodologies in carrying out the complete OA analysis. A common approach is to analyze the average result of repetitive runs, or a single run, through ANOVA analysis. Another approach, which is a better method for multiple runs, is to use signal (S) to noise (N) ratio (S/N) for the same steps in the analysis. The objective of S/N analysis is to determine the most optimum set of the operating conditions, from variations of the influencing factors within the results. Taguchi created a transform function for the loss-function which is named as signal -to-noise (S/N) ratio. The S/N ratio, as stated earlier, is a concurrent statistic. A concurrent statistic is able to look at two characteristics of a distribution and roll these characteristics into a single number or figure of merit. The S/N ratio combines both the parameters (the mean level of the quality characteristic and variance around this mean) into a single metric. A high value of S/N implies that signal is much higher than the random effects of noise factors. Process operation consistent with highest S/N always yields optimum quality with minimum variation.

VIII. RESULTS

A. Comparison of Accuracy for 16mncr5 And 20mncr5 Materials:

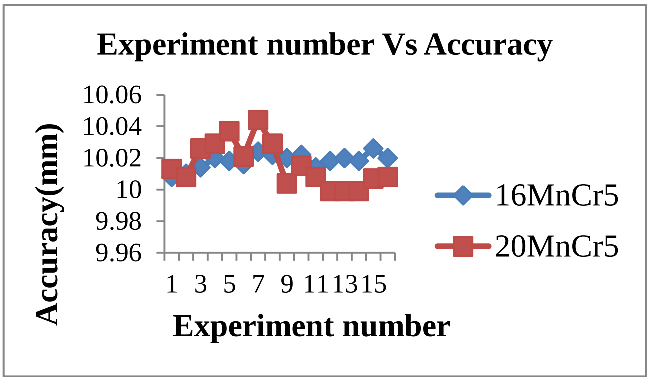

Fig. 7: Comparison of accuracy for 16MnCr5 and 20MnCr5 materials.

Figure.7 gives experimental result of accuracy for 16MnCr5 and 20MnCr5. Comparison of accuracy for 16MnCr5 and 20MnCr5 materials is shown in figure .from the above figure.7 it can be predicted that for 16MnCr5 material for any experiment there is no substantial variation in accuracy so with in this for experimental number 1(pulse on 12 µ sec, pulse off 4 µ sec, current 3 amps, bed speed 25 µ/sec) will give better accuracy and for experiment number 15(pulse on 24 µ sec, pulse off 6 µ sec, current 4 amps, bed speed 40 µ/sec) will give poor accuracy so that experiment no.15 is not preferred for better accuracy.

B. Comparison of Surface Roughness for 16mncr5 And 20mncr5 Materials:

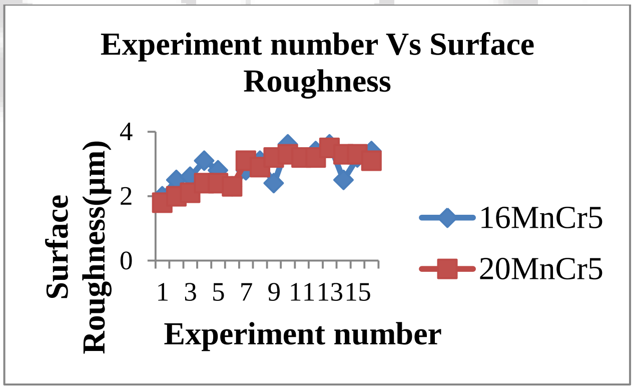

Fig. 8: Comparison of surface roughness for 16MnCr5 and 20MnCr5 materials.

Comparison of surface roughness of 16MnCr5 and 20MnCr5 is shown in figure.8 From the figure for 16MnCr5 material we can observe that there is lot of variation in accuracy for different experiments. However for experiment number 2(pulse on 12 µ sec, pulse off 5 µ sec, current 4 amps, bed speed 30 µ/sec)will give better surface finish and for experiment number 10(pulse on 20 µ sec, pulse off 5 µ sec, current 6 amps, bed speed 35 µ/sec) and experiment number 13(pulse on 24 µ sec, pulse off 4 µ sec, current 6 amps, bed speed 30 µ/sec)will give poor surface finish so that experiment number 10 and 13 are not preferred for better surface finish. From figure for 20MnCr5 material we can observe that for 20MnCr5 material for any experiment there is no substantial variation in accuracy so with in this for experimental number 1(pulse on 12 µ sec, pulse off 4 µ sec, current 3 amps, bed speed 25 µ/sec) will give better surface finish and for experiment number 13(pulse on 24 µ sec, pulse off 4 µ sec, current 6 amps, bed speed 30 µ/sec)will give poor surface finish so that experiment number 13 is not preferred for better surface finish.

C. Comparison of MRRv for 16mncr5 and 20mncr5materials:

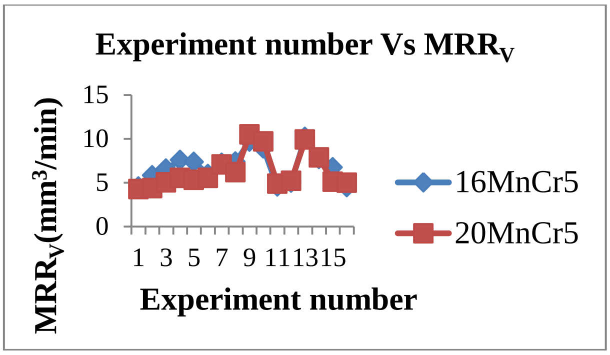

Fig. 9:

Fig. 9: Comparison of MRRv for 16MnCr5 and 20MnCr5 materials. From figure.9 for 20MnCr5 material we can observe that there is lot of variation in MRRv for different experiments. However for experiment number 9(pulse on 20 µ sec, pulse off 4 µ sec, current 5 amps, bed speed 40 µ/sec) and experiment number 13(pulse on 24 µ sec, pulse off 4 µ sec, current 6 amps, bed speed 30 µ/sec) will give better MRRv and for experiment number 11(pulse on 20 µ sec, pulse off 6 µ sec, current 3 amps, bed speed 30 µ/sec), experiment number 12(pulse on 20 µ sec, pulse off 7 µ sec, current 4 amps, bed speed 25 µ/sec) and experiment number 16(pulse on 24 µ sec, pulse off 7 µ sec, current 3 amps, bed speed 35 µ/sec) will give poor MRRvso that experiment numbers 11, 12, 16 are not preferred for better MRRv.

IX. STATISTICAL ANALYSIS

A statistical analysis is performed to study the effect of parameters which are significantly affecting the responses (Accuracy, surface roughness and MRRv). Experiments were planned according to Taguchi's L_{16} orthogonal array, which has 16 rows corresponding to the number of test.

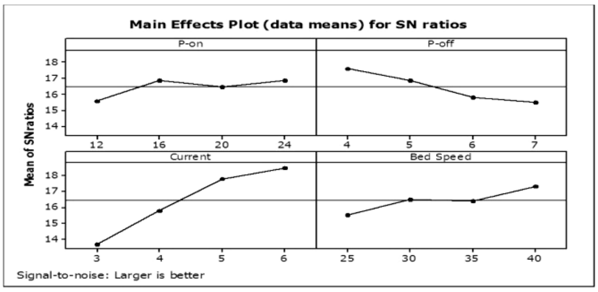

Fig. 10: Effect of Process parameters on MRRv for 16MnCr5 material.

Main effects plot for the effect of process parameters on MRRv for 16MnCr5 material is shown in figure. 10.The larger is better condition is used for find the optimum values. The pulse on is 24 µs,pulse off is 4 µs, current 6 Amp and bed speeds 40 µ/s are the optimum values. These combinations of optimum value will give better volumetric material removal rate. The current is more effecting factor on MRRv. When current is increases and volumetric material removal rate also increases. From the figure.10 it is clear that By increasing the pulse on value from 12 µs to 24 µs,MRRv is increases. The low pulse off level gives the better MRRv. By increasing the Current from 3 Amps to 6 Amps the MRRv is also increasing by increasing the Bed Speed from 25 µ/s to 40 µ/s the MRRv is increasing. Analysis of variance of MRRv for 16MnCr5 material using adjusted SS for TestsS=0.194974 R-Sq=99.85% R-Sq(adj)=99.27% By observing the values obtained in the ANOVA , it is very clear that current is most contributing parameters in deciding MRRv with 71.36 %. This indicates MRRv was greatly affected by current where high current produce betterMRRv and low current produce poor MRRv. Pulse on, pulse off and bed speed are also significant parameters, but their percentage of contribution was less. S/N ratio response for MRRv on 20MnCr5 material shows the S/N ratio response for MRRv on 20MnCr5 material. From the figure.10 conclude that pulse on time is the most effecting factor. When the current increases the volumetric material removal rate also increases. Because material erosion is influenced by spark energy, as current increases volumetric material removal rate increases.

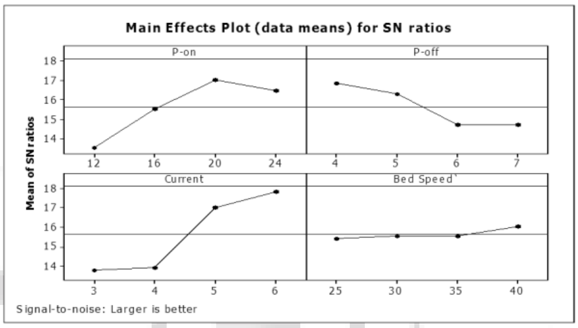

Fig. 11: Effect of Process parameters on MRRv for 20MnCr5 material.

Main effects plot for the effect of process parameters on MRRv for 20MnCr5 material is shown in figure.11.The larger is better condition is used to find the optimal values. The pulse on is 20 µs, pulse off is 4 µs, current 6 Amp and bed speeds 40 µ/s are the optimum values. This combination of optimum values will give the better volumetric material removal rate. The current is more effecting factor on MRRv for 20MnCr5. The current is increases and volumetric material removal rate also increases. From the figure.11 it is clear that by increasing the pulse on value from 12 µs to 20 µs, MRRv is increasing. The low pulse off level gives the better MRRv than By increasing the Current from 3 Amps to 6 Amps the MRRv is also increasing By increasing the Bed Speed from 25 µs to 40 µs the MRRv is increasing. The optimum levels of the control factors which give better MRRv are summarized in the for the 16MnCr5 and 20MnCr5 materials Optimized parameters level for MRRv of 16MnCr5 and 20MnCr5 materials Analysis of variance of MRRv for 20MnCr5 material using adjusted SS for Tests S=0.645612 R-Sq=98.72% R-Sq(adj)=93.62% By observing the values obtained from ANOVA, it is very clear that current and pulse on are the most contributing parameters in deciding MRRv with 54.17% and 28.96%, respectively. This indicates MRRv was greatly affected by current and pulse on where lower pulse on and higher current produce better

MRRv and higher pulse on and lower currentresult in poor MRRv. Pulse off and bed speed, are also used significant parameters, but their percentage of contribution was less. Accuracy analysis on 16MnCr5 and 20MnCr5 materials is carried out using S/N ratios and ANOVA analysis. The responses are Pulse on, Pulse off, Current and Bed Speed. Figure.12 shows the S/N ratios responses for Accuracy used minitab16 software. From figure.12 conclude that the most effecting factor is Pulse on. When Pulse on increases Accuracy also increases. The other factors have less effect on Accuracy. Because of increase in pulse on time supply current also increases. This leads to higher energy per pulse this results increases wire wearing. Thus when pulse on time low better accuracy can be achieved.

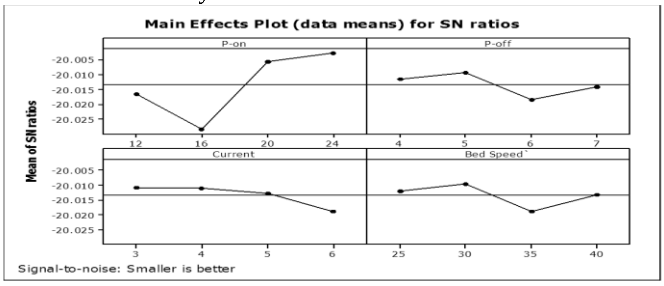

Fig. 12: Effect of Process parameters on Accuracy for 20MnCr5 material.

Main effects plot for the effect of process parameters on Accuracy for 20MnCr5 material is shown in figure.12.The Smaller is better condition is used to find the optimum values. Pulse on 24 µs, pulse off 5 µs current 3 Amps and bed speed 30 µ/s are the optimum values. These combinations of optimum values will give the good Accuracy. The pulse on is more effecting process parameter on Accuracy for 20MnCr5 material. The pulse on increases than Accuracy decreases. Achieve the good Accuracy. From Figure.12 it is clear that By increasing the pulse on value from 16 µs to 24 µs, Accuracy is decreases. The low pulse off level gives the better Accuracy. By increasing the Current from 3 Amps to 6 Amps the Accuracy is also increasing By increasing the Bed Speed from 30 µ/s to 40 µ/s the Accuracy is increasing The optimum levels of the control factors which give better Accuracy are summarized from figure.12 for the 16MnCr5 and 20MnCr5 materials. 3 Optimized parameters level for Accuracy of 16MnCr5 and 20MnCr5 materials. Analysis of variance of Accuracy for 20MnCr5 material using adjusted SS for Tests S=0.00511040 R-Sq=96.50% R-Sq (adj)=82.48% By observing the values obtained from ANOVA, it is very clear that pulse on is most contributing parameters in deciding accuracy with 72.70%. This indicates accuracy was greatly affected by pulse on where higher pulse on produce poor accuracy. And lower pulse on result better accuracy. Pulse off, current and bed speed, are also used significant parameters, but their percentage of contribution was less.

X. SURFACE ROUGHNESS ANALYSIS ON 16MNCR5 AND 20MNCR5 MATERIALS

Surface Roughness analysis on 16MnCr5 and 20MnCr5 materials is carried out using S/N ratios and ANOVA analysis. The responses are Pulse on, Pulse off, Current, Bed Speed. shows the S/N ratios responses for surface roughness used minitab16 software. From figure.13 conclude that the most effecting factor is Pulse on. When Pulse on increases Surface Roughness also increases. The other factors have less effect on Surface Roughness. Because increase in pulse on time supply current also increases. This leads to higher energy per pulse this results increases wire wearing. Thus when pulse on decreases to achieve the better Surface finish.S/N ratio response for surface roughness on 16MnCr5 material

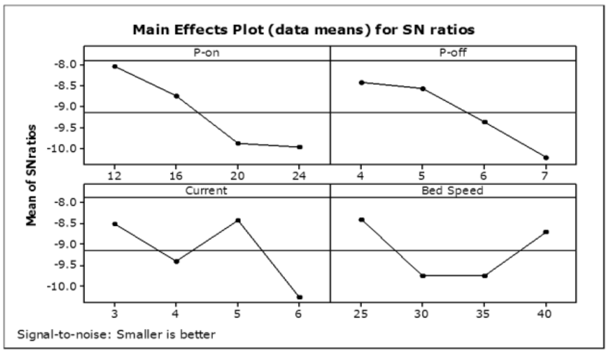

Fig. 13: Effect of Process parameters on Surface Roughness for 16MnCr5 material.

Main effects plot for effect of process parameters on surface roughness for 16MnCr5 material is shown in figure.13 The smaller is better condition is used to find the optimal values. Pulse on 12 µs, pulse off 4 µs current 5 amps and bed speed 25 µs are the optimum values. These combinations of optimum values will give the better surface finish. The pulse on is more effecting process parameter on surface roughness for 16MnCr5 materials. The pulseon increases than surface roughness increases. In the above figure.13 pulse on decreases to achieve the good surface finish from figure it is clear that By increasing the pulse on value from 12 µs to 24 µs, to achieve good Surface Finish. The low pulse off level gives the better Surface finish by increasing the Current from 5 Amps to 6 Amps the Surface finish is Increasing. By increasing the Bed Speed from 30 µs to 40 µs the Surface finish is increasing Analysis of variance of Surface Roughness for 16MnCr5 material using adjusted SS for Tests S=0.491585 R-Sq=97.89% R-Sq (adj)=89.47% By observing the values obtained from ANOVA, it is very clear that pulse on, current, pulse off and bed speed are the most contributing parameters in deciding surface roughness with 30.12%, 26.09%, 24.09% and 17.60% respectively. This indicates surface roughness was greatly affected by pulse on, current, pulse off and bed speed where lower current and higher pulse on produce poor accuracy and higher current and lower pulse on result better accuracy. Pulse off and bed speed, are also significant parameters, but their percentage of contribution was less. S/N ratio response for surface roughness on 20MnCr5 material shows the S/N ratio responses for surface roughness on 20MnCr5 material. From the figure.13 it clear that pulse on time most effecting factor on surface roughness. When Pulse on time increases surface roughness also increases. Because increase in pulse on time supply current also increases. This leads to higher energy per pulse this results increases wire wearing. Thus when pulse on time is low better surface finish can be achieved.

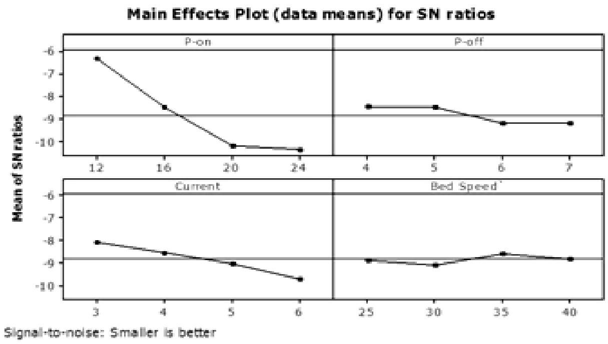

Fig. 14: Effect of Process parameters on Surface Roughness for 20MnCr5 material.

Main effects plot for effect of process parameters on Surface Roughness for 20MnCr5 material is shown in figure.14.The Smaller is better condition is used to find the optimum values. Pulse on 12 µs, pulse-off 4 µs current 3 Amps and bed speed 35 µ/s are the optimum values.These combinations of optimum values will give the better Surface finish. The pulse on is more effecting process parameter on Surface Roughness for 20MnCr5 material. The pulse on increases surface roughness also increases.In the above figure.14 pulse on decreases to achieve the better surface finish. From Figure.14 it is clear that By increasing the pulse-on value from 12 µs to 24 µs, to achieve good Surface finish. The low pulse-off level gives the better Surface finish By increasing the Current from 3 Amps to 6 Amps the Surface finish is increases. By increasing the Bed Speed from 25 µs to 35 µs the Surface finish is increasing. The optimum levels of the control factors which give better surface roughness are summarized in the for the 16MnCr5 and 20MnCr5 materials. Optimized parameters level for Surface Roughness of 16MnCr5 and 20MnCr5 materials Analysis of variance of Surface Roughness for 20MnCr5 material using adjusted SS for Tests S=0.261729 R-Sq=99.60% R-Sq (adj)=98.00% By observing the values obtained from ANOVA.

XI. CONCLUSIONS

In this project work, experimental set up of Wire EDM is developed and experiments were conducted on 16MnCr5 and 20MnCr5using pulse on,pulse off, current and bed speed optimization of process parameter is performed using Taguchi technique, ANOVA and analysis has been done using Minitab 16 Software. From the experimental investigation and analysis, the following results are concluded Better surface finish for 16MnCr5(pulse on 12µ sec, pulse off 4µ sec, current 5amps, bed speed 25 µ/sec) and better accuracy for 16MnCr5(pulse on 12µ sec, pulse off 4µ sec, current 3amps, bed speed 30 µ/sec) obtained by using the optimum value obtained from analysis. For better MRRv for 20MnCr5 (pulse on 20µ sec, pulse off 4µ sec, current 6amps, bed speed 40 µ/sec) obtained from analysis. The optimized parameters for better accuracy are low Pulse-on (12 µ sec), medium Pulse-off (5 µ sec), low current (3 amps), medium Bed speed (30 µ/sec) for 16MnCr5 and low Pulse on (24 µ sec), medium Pulse-off (5 µ sec), low Current (3 amps) and low Bed speed (30 µ/sec) for 20MnCr5 material. Better surface finish for 20MnCr5 attained by the use optimal values of parameters are (pulse on 12µ sec, pulse off 5µ sec, current 3amps, bed speed 35 µ/sec) The optimized parameters for better MRRv are (pulse on 20µ sec, pulse off 4µ sec, current 6amps, bed speed 40 µ/sec) for 16MnCr5 material.

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