ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6, Pages : 12-17 (2013)

Special Issue of ICETEM 2013 - Held on 29-30 November, 2013 in Sree Visvesvaraya Institute of Technology and Science, Mahabubnagar – 204, AP, India

Review on Wire-Cut EDM Process

Sreenivasa Rao M[1], Venkaiah N[2]

1. Research scholar, National Institute of Technology, Warangal, India-506004, Email: msraoie@gmail.com
2. Assistant Professor, National Institute of Technology, Warangal, India-506004, Email: n_venkaiah@nitw.ac.in

Abstract: Wire-cut electrical discharge machining (WEDM) is one of the most emerging non conventional manufacturing processes for machining hard to machine materials and intricate shapes which are not possible with conventional machining methods. This paper reviews the effects of various WEDM process parameters such as pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire speed, wire tension on different process response parameters such as material removal rate (MRR), surface roughness (Ra), Kerf (width of Cut), wire wear ratio (WWR) and surface integrity factors. This paper also reviews various optimization methods applied by the researchers and finally outlines the recommendations and future trends in WEDM research.

Key words: Optimization, Process parameters, Review, Wire-cut EDM

INTRODUCTION

WEDM is a thermo- electrical process in which material is removed by a series of sparks between work piece and wire electrode (tool). The part and wire are immersed in a dielectric (electrically non conducting) fluid, usually de-ionized water, which also acts as a coolant and flushes the debris away. The material which is to be cut must be electrically conductive.

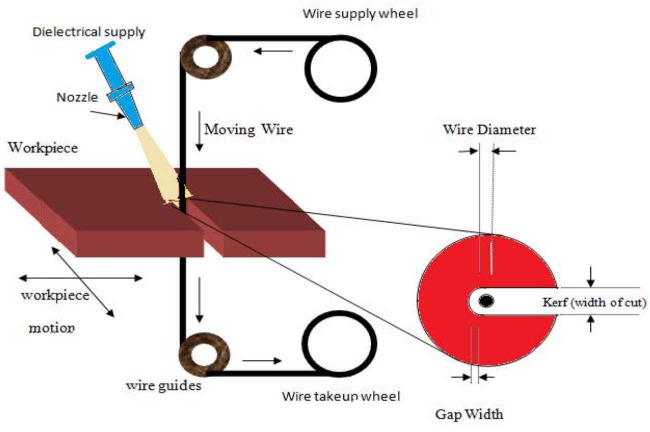

Fig 1: Working principle of WEDM

In WEDM, there is no direct contact between workpiece and tool(wire) as in conventional machining process, therefore materials of any hardness can be machined [1] and minimum clamping pressure is required to hold the workpiece. In this process, the material is eroded by a series of discrete electrical discharges between the workpiece and tool. These discharges cause sparks and result in high temperatures instantaneously, up to about 10000º C. These temperatures are huge enough to melt and vaporize the workpiece metal and the eroded debris cools down swiftly in working liquid and flushed away, the working principle is shown in the figure 1. In 1969, the Swiss firm Agie produced the world's first wire EDM machine. These early machines were extremely slow but today, machines are equipped with automatic wire threading and can cut over 20 times faster, Carl Sommer and Steev Sommer,[2].

The effectiveness of the whole process depends on number of input process parameters such as pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire feed, and wire tension. The important machining responses include material removal rate (MRR), surface roughness (Ra), Kerf (width of cut), wire wear ratio (WWR) and surface integrity factors. In this paper description of various process parameters and their influence respective responses have been presented. Literature is classified based on the response parameters. Different modeling and optimization methods proposed by various researchers are also discussed. Finally the recommendations and future trends in WEDM research have been outlined.

PROCESS PARAMETERS

1 Pulse duration

Pulse duration, also called pulse on time, is expressed in micro seconds. During the pulse on time, the voltage is applied in the gap between workpiece and the electrode thereby producing discharge. Higher the pulse on time, higher will be the energy applied there by generating more amount of heat energy during this period. Material removal rate depends upon the amount of energy applied during the pulse on time [3].

2 Pulse Interval

Pulse interval, also referred as Pulse off time, is also expressed in micro seconds. This is the time between discharges. Off Time has no effect on discharge energy. Off Time is the pause between discharges that allows the debris to solidify and be flushed away by the dielectric prior to the next

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6, Pages : 12-17 (2013)

Special Issue of ICETEM 2013 - Held on 29-30 November, 2013 in Sree Visvesvaraya Institute of Technology and Science, Mahabubnagar – 204, AP, India

discharge. Reducing Off Time can dramatically increase cutting speed, by allowing more productive discharges per unit time. However, reducing Off Time, can overload the wire, causing wire breakage and instability of the cut by not allowing enough time to evacuate the debris before the next discharge.

3 Servo Voltage

Servo voltage acts as the reference voltage to control the wire advances and retracts. If the mean machining voltage is higher than the set servo voltage level, the wire advances, and if it is lower, the wire retracts. When a smaller value is set, the mean gap becomes narrower, which leads to an increase in number of electric sparks, resulting in higher machining rate. However, the state of machining at the gap may become unstable, causing wire breakage.

4 Peak Current

Peak current is the amount of power used in discharge machining and is measured in unit of amperage. The current increases until it reaches a preset value during each pulse on time, which is known as peak current, is shown in figure 2. Peak current is governed by surface area of cut. Higher peak current is applied during roughing operation and details with large surface area.

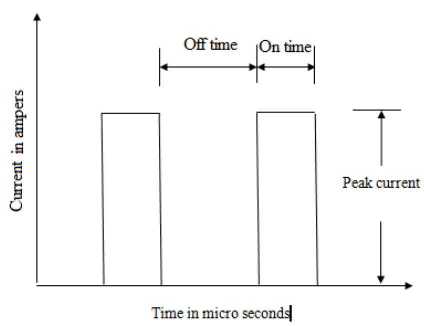

Fig 2: Shows peak current, pulse-off time and on time

5 Gap Voltage

Gap voltage, also called open circuit voltage specifies the supply voltage to be placed on the gap. Greater the gap voltage, greater will be the electric discharge. If the gap voltage increases, the peak current will also increase. In some WEDM machines both of these factors show machining voltage.

6 Dielectric flow rate

Dielectric flow rate is the rate at which the dielectric fluid is circulated. Flushing is important for efficient machining. Flushing pressure is produced from both the top and bottom nozzles.

7 Wire Feed rate

As the wire feed rate increases, the consumption of wire as well as cost of machining will increase. Low wire speed will cause wire breakage in high cutting speed.

8 Wire Tension

If the wire tension is high enough the wire stays straight otherwise wire drags behind. Within considerable range, an increase in wire tension significantly increases the cutting speed and accuracy. The higher tension decreases the wire vibration amplitude and hence decreases the cut width so that the speed is higher for the same discharge energy. However, if the applied tension exceeds the tensile strength of the wire, it leads to wire breakage.

LITERATURE BASED ON RESPONSE PARAMETERS

1 Surface roughness

Surface roughness is one of the most important responses in any machining process. Surface roughness affects several functional attributes of parts, such as friction, wear and tear, light reflection, heat transmission, ability of distributing and holding a lubricant, coating etc. Therefore, the desired surface finish is usually specified and appropriate processes are required to maintain the quality. There are many different roughness parameters in use, but R_a is by far the most common. Other common parameters include R_z, R_q, R_v, R_p, Rt, R_{ku} and R_{sk} and is usually expressed in μm. Lot of work has been done by different researchers on decreasing the surface roughness by different approaches. Surface roughness is greatly affected by pulse on time, peak current and cutting speed in WEDM. Among these pulse on time is found to be the most significant parameter affecting the surface roughness.

Scott et al.,[4], presented a methodology to determine the optimal combination of control parameters such as discharge current, pulse duration, pulse frequency, wire speed, wire tension and dielectric flow rate in WEDM of D2 tool steel. The performance measures were surface roughness and MRR. They used explicit enumeration method, and dynamic programming metods to obtain the set of non dominated combinations. From the experimental results and ANOVA they found that discharge current, pulse duration and pulse frequency were significant control factors for both MRR and surface finish, where as wire speed, wire tension and dielectric flow rate were relatively insignificant. Liao et al.,[5], carried out an experimental investigation to determine the parameters setting during the machining of SKD11 alloy steel. By applying regression analysis, mathematical model is developed for surface roughness. Konda et al., [6], carried out experiments to optimize the WEDM process performances such as machining speed and surface roughness. Complimentary optimization technique was used to solve the multi-objective optimization problem. Tarng et al.,[7], used feed forward neural network to construct the WEDM process model to associate the cutting parameters and the responses include machined surface roughness and machining speed. Simulated annealing algorithm is then applied to the neural network for solving the optimal cutting parameters. Spedding and Wang [8], also used neural networks (ANN) to model the

WEDM process, and the developed model is used to process performance prediction and parameter optimization. Other important works related to neural network surface roughness are Sarkar et. al. [9] and Li et. al.,[10].

Ashan et al.[11], conducted experimental investigations to establish relationships for surface finish with current and voltage. They concluded that the machined surface becomes rougher with increase in current and voltage. Nishat [12], experimented on AISI 4140 steel to study the variation of cutting performance with cutting parameters in WEDM. The surface quality of the workpiece increased with decrease in pulse duration, open circuit voltage and wire speed, and with increasing dielectric fluid pressure. Other relevant contributions on surface roughness have been carried out by Manna and Bhattacharya [13], Po-Huai et al.,[14], Fuzhu et al.,[15], Probir et al.,[16], Satishkumar et al.[17] and Aqueel et al.,[18].

2 Material removal rate

In WEDM the material erodes from the workpiece by a series of discrete sparks between the work and the tool electrode immersed in the liquid dielectric medium. These electrical discharges melt and vaporize minute amounts of the work material, which are then ejected and flushed away by the dielectric fluid. MRR directly increases with increase in pulse on time (T_{on}) and peak current (IP) while decreases with increase in pulse off time (T_{off}) and servo voltage (SV) [19].

Manna and Bhattacharyya [20], carried out an experimental investigation to determine the parameters setting during the machining of aluminium-reinforced silicon carbide metal matrix composite (Al/SiC-MMC). Mathematical models relating to the machining performance such as MRR and Ra are established using the Gauss elimination method for the effective machining of Al/SiC-MMC. Nithin et al.,[21] used Taguchi's experimental design to obtaining the optimum machining parameters for the maximization of MRR and minimization of surface roughness separately in WEDM of brass material. They found that, the significant factors are pulse time and feed rate in both MRR and Surface finish. At higher values of feed rate and pulse duration increases the MRR and decreases the surface roughness. Rong et al.,[22], tried to analyze variations in metal removal rate MRR, surface roughness Ra, and corner deviation in relation with WEDM process parameters in cutting pure tungsten. This research proposes an effective process parameter optimization approach that integrates Taguchi's parameter design method, response surface methodology (RSM), back propagation neural network (BPNN), and simulated annealing algorithm (SAA) on WEDM processes. Furthermore, the field-emission SEM images show that a lot of built-edge layers were presented on the finished surface after the WEDM process. The results showed that, with the higher pulse on time, which leads to the discharge energy becoming more intense, the MRR was increased and the brass wire of cutting tool accelerates depletion, generates a larger built-up layer, and therefore produces rougher surfaces. Simultaneously, increasing the wire tension results in the decrease of corner deviation. Other relevant contributions on MRR have been carried out by Manna and Bhttacharyya [13], Satishkumar et al.[17], Hari and Rajesh[23] and Susanta and Shankar [24].

3 Kerf (Width of cut)

Kerf is one of the important performance measures in WEDM. Kerf is the measure of the amount of the material that is wasted during machining. It affects the dimensional accuracy of the finished part. Kerf of EDMed workpiece depends on gap voltage, pulse on time, pulse off time, wire feed and flushing pressure [25].

Shandilya et.al. [26], attempted to optimize the Kerf in machining of SiC/6061 Al MMC using response surface methodology (RSM). Mathematical model have been developed for response parameter and properties of the machined surface have been examined by using SEM. Sourav and Siba [27], applied response surface methodology to developed quadratic mathematical models to represent the behavior of WEDM process parameters for the process responses such as MRR, surface roughness and kerf on D2 tool steel. Grey relational analysis has been adopted for multi-objective optimization. Other relevant contributions on kerf have been carried out by Po-Huai et al.,[14], Aqueel et al.,[18] Susanta and Shankar [24], Mahapatra and Patnaik [28], and Muthu et. al.[29].

4 Wire wear ratio

As WEDM is a thermo- electrical process in which material is eroded by a series of sparks between the work piece and the wire electrode, along with the workpiece material some particles from wire also will erode, this phenomenon is called wire wear and this should be kept to a minimum. Wire failure occurs in wire-EDM process as a result of severity in wire wear rate, which is a function of discharge current and discharge time [30].

Tosun and Cogun [31], experimented to study the effect of cutting parameters on wire wear of AISI 4140 steel in WEDM process. It is found experimentally that the increasing pulse duration and open circuit voltage increase the WWR, however the increase in wire speed and dielectric fluid pressure decrease the WWR. Ranganath et. al.[30], Wire failure occurs in wire-EDM process as a result of severity in wire wear rate, which is a function of discharge current and discharge time. Ramakrishnan and Karunamoorthy [32], identified that the pulse on time and ignition current intensity have influenced more than the other parameters considered in their study on WWR.

LITERATURE ON MULTI OBJECTIVE OPTIMIZATON OF WEDM

Kapil and Sanjay [33], applied Multi-objective genetic algorithm NSGA-II to optimize the multiple objectives of MRR and surface roughness on machining high speed steel(M2,SKH9). Experiments, based on Taguchi's parameter

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6, Pages : 12-17 (2013)

Special Issue of ICETEM 2013 - Held on 29-30 November, 2013 in Sree Visvesvaraya Institute of Technology and Science, Mahabubnagar – 204, AP, India

design, were carried out to study the effect of various parameters and mathematical models were developed between machining parameters and responses like metal removal rate and surface finish by using nonlinear regression analysis. These mathematical models were then optimized by using multi-objective optimization technique based on NSGA-II to obtain a Pareto-optimal solution set. The results of optimization indicate that the MRR and surface finish are influenced more by pulse peak current, pulse duration, pulse-off period and wire feed than by flushing pressure and wire tension. Results also indicate that the surface quality decreases as the MRR increases and they vary almost linearly. Other relevant contributions on multi objective optimization have been carried out by Konda et al., [6], Susanta and Shankar [34], Prasad and Gopala Krishna [35], Susanta and Shankar [36] and Pandu et.al.,[37]

LITERATURE ON OTHER CONTRIBUTIONS

Kuriakose et al., [38], experiments were carried out and applied data mining technique to model the WEDM process. A data mining technique C4.5 was used to study the effect of various input parameters on the outputs, namely the cutting speed and surface finish.

Tosun et al.[39], conducted experimental investigation to study the effects different process parameters on craters in the wire in WEDM process. From the experimental results it was found that increasing the pulse duration, open circuit voltage, and wire speed increases the crater diameter and crater depth, whereas increasing the dielectric fluid pressure decreases these factors.

Lee and Liao [40], developed a gain Self-tuning fuzzy control system to cope with the conditions that often occur with wire rupture in WEDM process, such as an improper setting of machining parameters, machining the workpiece with varying thickness etc.

Antar et al.,[41], presented experimental data for workpiece productivity and integrity while machining Udimet 720 nickel based super alloy and Ti-6Al-2Sn4Zr-6Mo titanium alloy, using Cu core coated wires (ZnCu50 and Zn rich brass). It was found that up to a 40% for Udimet 720 and 70% for Ti-6Al-2Sn4Zr-6Mo titanium alloy increase in productivity was possible compared to when using uncoated brass wires with the same operating parameters.

Neeraj et al.[42], conducted experiments to investigate the effect of process parameters on cutting speed and dimensional deviations in cutting high-strength low-alloy steel(HSLA). To optimize the process parameters for cutting speed and dimensional deviation, Response Surface Methodology was used. From the experimental results it is found that pulse-on time was the most prominent factor for cutting speed and dimensional deviation.

CONCLUSIONS

Wire-cut electrical discharge machining is one of the most emerging non conventional manufacturing processes for machining hard to machine materials and intricate shapes which are not possible with conventional machining methods. This is more efficient and economical for machining hard to machine materials. The effect of various parameters and setting of various parameters at their optimal levels is very much required for manufacturers. From the literature, the parameters and their effects observed are given as under

1. Higher the pulse-on time, higher will be the energy applied there by generating more amount of heat energy during this period. Material removal rate and wire wear rate increase with increase in pulse on time where as surface finish will decrease.
2. Reducing pulse off time can increase cutting speed, by allowing more productive discharges per unit time. However, reducing Off time, can overload the wire, causing wire breaks and instability of the cut by not allowing enough time to evacuate the debris before the next discharge.
3. Servo voltage acts as the reference voltage to control the wire advances and retracts. At higher value of SV the gap between workpiece and wire becomes wider and it decreases the no of sparks, stabilizes electric discharge and the rate of machining slows down. Whereas at smaller value of SV, the mean gap becomes narrow which leads to an increase in number of electric sparks, speed up the machining rate and unstable discharge results in wire breakage.
4. Peak current is the amount of power used in discharge machining and is measured in unit of amperage. The current increases until it reaches a preset value during each pulse on time, which is known as peak current. Peak current is governed by surface area of cut. Higher peak current is applied during roughing operation and details with large surface area. MRR directly increases with increased peak current.
5. Gap voltage is also called open circuit voltage and specifies the supply voltage to be placed on the gap, greater this value, the electric discharge becomes greater. If the gap voltage increases, the peak current will also increases, which leads to higher MRR.
6. Dielectric flow rate is the rate at which the dielectric fluid is circulated. Flushing is important for efficient machining.
7. As the wire feed rate increases, the consumption of wire and cost of machining will increase. Low wire speed will cause wire breakage in high cutting speed.
8. If the wire tension is high enough the wire stays straight otherwise wire drags behind. Within considerable range, an increase in wire tension significantly increases the cutting speed and accuracy. The higher tension decreases the wire

vibration amplitude and hence decreases the cut width so that the speed is higher for the same discharge energy. However, if the applied tension exceeds the tensile strength of the wire, it leads to wire breakage.

From the literature it has been observed that most of the researchers concentrated on very few number of process parameters at a time to model and optimize various responses, which may not yield accurate optimal values for the process, as the process includes number of process parameters. Further, most of the researchers have given the importance to individual response modeling and its optimization. There is a lot of scope for effective multi objective optimization. Most of the researchers experimented with tool steels, tungsten carbide, titanium alloys and aluminum metal matrices, very less work is reported on nickel base alloys (super alloys). Hence there is a scope in research on nickel based alloys using WEDM.

REFERENCES

[1] Kuriakose shajan, M. S. Shunmugam. (2004). Characteristics of wire-electro discharge machined Ti6Al4V. *Materials letters*. 58, pp. 2231-2237.

[2] Carl Sommer, Steeve Sommer, The complete EDM Handbook, www.ReliableEDM.com.

[3] Kansal HK, Singh S, Kumar P. (2005). Parametric optimization of powder mixed electrical discharge machining by response surface methodology. *Journal of Material Processing Technology*. 169(3), pp. 427-436.

[4] Scott Dan, Sreedhar Boyina, K.P. Rajurkar. (1991). Analysis and optimization of parameter combinations in wire electrical discharge machining. *International Journal of Production Research*. 29:11, pp. 2189-2207.

[5] Liao Y S., J.T. Huang, H.C. Su. (1997). A study on the machining-parameters optimization of wire electrical dischargs machining. *Journal of Materis Processing Technology*. 71, pp. 487-493.

[6] Konda .R, K.P. Rajurkar, R.R. Bishu, A. Guha, M. Parson. (1999). Design of experiments to study and optimize process performance. *International Journal of Quality & Reliability Management*. 16:1, pp. 56-71.

[7] TarngY.S.,S. C.Ma, L.K. Chung. (1995). Determination of optimal cutting parameters in wire electrical discharge machining. *International Journal of Machine Tools & Manufacture*. 35:12, pp. 1693-1701.

[8] Spedding T. A, Z.Q. Wang. (1997). Parametric optimization and surface characterization of wire electrical discharge machining process. *Journal of Precision Engineering*. 20, pp. 5-15.

[9] Sarkar,S, S. Mitra, B. Bhattacharyya. (2005). Parametric optimisation of wire electrical discharge machining of γ titanium aluminide alloy through an artificial neural network model. *International Journal of Advanced Manufacturing Technology*. 27, pp. 501–508.

[10] Li Guiqin, Kong Fanhui, Lu Wenle, Yuan Qingfeng, Fang Minglun, "The Neural-Fuzzy modeling and Genetic Optimization in WEDM," presented in IEEE International Conference on Control and Automation, May 30 to June 1, 2007.

[11] Ashan Alikhan , Munira Bt.Mohd Ali and Norhasmimah Bt.Mohd Shaffiar. (2006). Relationship of Surface Roughness with current and voltage during Wire EDM. *Journal of applied Sciences*. 6(10), pp. 2317-2320.

[12] Nishat Tosun. (2003). The Effect of the Cutting Parameters on Performance of WEDM. *KSME International Journal*. 17:6, pp. 816-824.

[13] Manna · B. Bhattacharyya. (2005). Taguchi and Gauss elimination method: A dual response approach for parametric optimization of CNC wire cut EDM of PRAlSiCMMC. *International Journal of Advanced Manufacturing Technology*. 28, pp. 67–75.

[14] Po-Huai-Yu, Hsiang-Kno Lee, Yang-Xin Lin, Shi-Jie Qin, Biing-Hwa Yan, Fuang-Yuan Huang. (2011). Machining Characteristics of Polycrystalline Silicon by wire Electrical Discharge Machining. *Journal of Materials and Manufacturing Process*. 26:12, pp. 1443-1450.

[15] Fuzhu Han & Jun Jiang & Dingwen Yu. (2007). Influence of machining parameters on surface roughness in finish cut of WEDM. *International Journal of Advanced Manufacturing Technology*. 34, pp. 538–546.

[16] Probir Saha, Abhijit Singha, Surjya K. Pal Partha Saha. (2008). Soft computing models based prediction of cutting speed and surface roughness in wire electro-discharge machining of tungsten carbide cobalt composite. *International Journal of Advanced Manufacturing Technology*. 39, pp. 74–84.

[17] Satishkumar, D, M. Kanthababu, V. Vajjiravelu, R. Anburaj, N. Thirumalai Sundarrajan, H. Arul. (2011). Investigation of wire electrical discharge machining characteristics of Al6063/SiCp composites. *International Journal of Advanced Manufacturing Technology*. 56, pp. 975–986.

[18] Aqueel Shah, Nadeem A. Mufti, Dinesh Rakwal, and Eberhard Bamberg. (2011). Material Removal Rate, Kerf, and Surface Roughness of Tungsten Carbide Machined with Wire Electrical Discharge Machining. *Journal of Materials Engineering and Performance*. 20(1), pp. 71-76.

[19] Singh, H., Garg, H. (2009). Effect of process parameters on material removal rate in WEDM. *Journal of Achievements in Materials and Manufacturing Engineering*. 32, pp. 70-74.

[20] Manna, A, B. Bhattacharyya. (2006). Taguchi and Gauss elimination method: A dual response approach for parametric optimization of CNC wire cut EDM of PRAlSiCMMC. *International Journal of Advanced Manufacturing Technology*. 28, pp. 67–75.

[21] Nithin Aravind, R, S. Sowjanya, K.P. Yuvaraj, "Optimization of metal removal rate and surface roughness on Wire EDM using Taguchi method," presented in *IEEE International Conference on Advances in Engineering Science and Management(ICAESM-2012)*, March 30,31,2012.

[22] Rong Tai Yang, Chorng Jyh Tzeng, Yung Kuang Yang, Ming Hua Hsieh. (2012). Optimization of wire electrical discharge machining process parameters for cutting tungsten, *International Journal of Advanced Manufacturing Technology*. 60, 135–147.

[23] Hari Singh, Rajesh Khanna. (2011). Parametric Optimization of Cryogenic-Treated D-3 for Cutting Rate in Wire Electrical Discharge Machining. *Journal of Engineering and Technology*. Vol. 1, 59-64.

[24] Susanta Kumar Gauri, Shankar Chakraborty. (2010). A study on the performance of some multi-response optimization methods of WEDM processes. *International Journal of Advanced Manufacturing Technology*. 49, pp. 155–166.

[25] Parashar, V, A. Rehman, J.L. Bhagoria, Y.M. Puri. (2010). Kerfs width analysis for wire cut electro discharge machining of SS 304L using design of experiments. *Indian Journal of Science and Technology*. Vol. 3 No. 4, pp. 369-373.

[26] Pragya Shandilya, P.K. Jain, N.K. Jain, (2012), Parametric optimization during wire electrical discharge machining using response surface methodology, *Procedia Engineering*, 38, SciVerse Science Direct, pp. 2371 – 2377.

[27] Saurav Datta, Siba Sankar Mahapatra.(2010). Modeling, simulation and parametric optimization of wire EDM process using response surface methodology coupled with grey-Taguchi technique. *International Journal of Engineering, Science and Technology*. Vol. 2, No. 5, pp. 162-183.

[28] Mahapatra, S, S, Amar Patnaik. (2007). Optimization of wire electrical discharge machining(WEDM) process parameters using Taguchi method. *International Journal of Advanced Manufacturing Technology*. 34, pp. 911–925.

[29] Muthu Kumar V, Suresh Babu A, Venkatasamy R, Raajenthiren M. (2010). Optimization of the WEDM Parameters on Machining Incoloy800 Super alloy with Multiple Quality Characteristics.

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6, Pages : 12-17 (2013)
Special Issue of ICETEM 2013 - Held on 29-30 November, 2013 in Sree Visvesvaraya Institute of Technology and Science, Mahabubnagar – 204, AP, India

International Journal of Engineering Science and Technology. Vol. 2(5), pp. 162-183.

[30] Ranganath B.J, K.G. Sudhakar, A.S. Srikantappa, “WIRE FAILURE ANALYSIS IN WIRE-EDM PROCESS”, in *Proc. of the International Conference on Mechanical Engineering (ICME2003),* Dhaka, Bangladesh, December 2003, pp.26- 28.

[31] Tosun Nishat, Can Cogun. (2003). An investigation on wire wear in WEDM. *Journal of Materis Processing Technology*. 134, pp. 273-278.

[32] Ramakrishnan, R, L. Karunamoorthy. (2006). Multi response optimization of wire EDM operations using robust design of experiments. *International Journal of Advanced Manufacturing Technology*. 29, pp. 105–112.

[33] Kapil Kumar & Sanjay Agarwal. (2012) Multi-objective parametric optimization on machining with wire electric discharge machining. *International Journal of Advanced Manufacturing Technology*. 62, 617–633.

[34] Susanta Kumar Gauri, Shankar Chakraborty. (2009). Multi-response optimization of WEDM process using principal component analysis, *International Journal of Advanced Manufacturing Technology*. 41, 741–748.

[35] Prasad D. V. S. S. S. V., A. Gopala Krishna.(2009). Empirical modeling and optimization of wire electrical discharge machining. *International Journal of Advanced Manufacturing Technology*. 43, 914–925.

[36] Susanta Kumar Gauri, Shankar Chakraborty. (2009). Optimization of multiple responses for WEDM processes using weighted principal components. *International Journal of Advanced Manufacturing Technology*. 40, 1102–1110.

[37] Pandu R. Vundavilli, J. Phani Kumar, Ch. Sai Priyatham “Parameter Optimization of Wire Electric Discharge Machining Process using GA and PSO,” presented at the IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM -2012) March 30, 31,180-185.

[38] Kuriokose Shajan, Kamal Mohan, M. S. Shunmugam. (2003). Data mining applied to wire-EDM process. *Journal of Materials Processing Technology*. 142, pp. 182-189.

[39] Tosun N, C. Cogun, H. Pihtili. (2003). The Effect of Cutting Parameters on Wire Crater Sizes in Wire EDM. *International Journal of Advanced Manufacturing Technology*. 21, pp. 857-865.

[40] Lee, W, M, Y S Liao.(2003). Self-tuning fuzzy control with a grey prediction for wire rupture prevention in WEDM. *International Journal of Advanced Manufacturing Technology*. 22, pp. 481-490.

[41] Antar M T, S.L. Soo, D.K. Aspinwall, D. Jones, R. Perez, “Productivity and workpiece surface integrity when WEDM aerospace alloys using coated wires,” in *Procedia Engineering, 1st CIRP Conference on Surface Intigrity(CSI), Science Direct* 2011, 19, pp. 3-8.

[42] Neeraj Sharma, Rajesh Khanna, Rahul Dev Gupta, Renu Sharma.(2012). Modeling and multiresponse optimization on WEDM for HSLA by RSM. *International Journal of Advanced Manufacturing Technology*. Published online:28 November 2012