International Journal of Materials, Manufacturing and Sustainable Technologies (IJMMST)
Vol. 1, Issue 2, page 31-42, 2022
https://doi.org/10.56896/IJMMST.2022.1.2.010

Study of Material Removal Rate Process Parameter in WEDM

***Amit Kumar[1], Ashwani Kumar[2], Varun Pratap Singh[3], Nitesh Dutt[4], S.P. Kutar[5]**
[1, 5]Kamla Nehru Institute of Technology Sultan, Uttar Pradesh India
[2]Technical Education Department Uttar Pradesh, Kanpur India
[3]School of Engineering, University of Petroleum and Energy Studies, Dehradun, India
[4]College of Engineering Roorkee Uttarakhand, India
Corresponding Author: Amit Kumar: E-mail: *ykamitk85@gmail.com

Abstract

Wire cut Electrical Discharge Machining is known as nontraditional machining process. It has broad application in complex part or geometry machining. It is known as a non-contact process. The main objective of this research work is to investigate the influence of process parameters of Wire cut Electrical-Discharge Machining in material removal rate. Die steel D3 has been selected as workpiece material for study. The process parameters are peak current, pulse on time and wire tension. In experimental analysis it was concluded that on MRR the most influential process parameter is peak current with contribution of 86.02 %. Pulse of time has 12.29 % contribution and wire tension has minimum contribution of 1.12 % with 0.57% error in the study.

Keywords: Process Parameter, ANNOVA, Peak Current, WEDM, Die Steel and Machining.

1. Introduction

Various researchers have studied different aspects of Wire cut Electrical Discharge Machining (WEDM) in previous research work. As Prajapati et al. [1-2] have used computer numerical control (CNC) based WEDM for machining the Tool steel. Ojha et al. [3] have performed the schematic literature review of WEDM process and studied the material removal rate (MRR) improvement in WEDM process. Researchers have studied wire pressure parameter caused by the WEDM in processing of steel [4-9]. N. Tosun et al [10] investigated the surface roughness properties of material machined by varying machining parameters. In continuation Ravindranadh Bobbili et al [11] concludes that peak current, wire tension (WT) and pulse on time are critical factors that impact the MRR and surface roughness (SR).

These critical parameters were further studied by Malik et al [12]. They have investigated peak current significance in WEDM. Authors have concluded that pulse on time also has significant impact on SR of the material [14]. In continuation K. Kumar et al [13] have decide the ideal variable (feed and speed) for SR in WEDM. In study they found that these variables are a fundamental part to influence the MRR and SR. Researchers [15 & 16] have studied the parametric settings and surface structure of materials machined by WEDM process. Further scientific models for MRR and SR anticipation were evolved [17-18] to study the machining of instrumental steel. Taguchi approach was also used to study the process and machining parameters of WEDM [19-20].

Anoop et al [21] have investigated the wire speed in WEDM process and found that wire speed has least impact in WEDM process. Baljit Singh et al [22] have studied WEDM for molybdenum composite wire in his research and various other researchers have used advance methods with experimental setup for evaluating process parameters of WEDM [23-29].

In previous years researchers have used finite element analysis (FEA), response surface method (RSM), artificial neural network (ANN), and Fuzzy Logic techniques in mechanical and biomedical engineering for different problem and parametric analysis. A. Kumar [30-33] et. al. have used RSM technique for parameter analysis of heavy vehicle medium duty transmission gearbox. Based upon same study, in present research work design of experiments and ANNOVA has been used. In continuation [34-36] they have studied the mechanical systems using modern tools like modal analysis, loose transmission gearbox bolt condition analysis, bone fracture analysis [37-39]. In this research work simulation and experimental work was performed and there results were compared for final conclusions.

2. **Material Removal Rate (MRR)**

The rate at which the material expulsion happens from the work piece is known as material removal rate [11]. Some metal is dissolved and after that heat dissipated. The material removal rate is ascertained by partitioning the loss of weight work piece amid machining (in grams) to the result of density of the work piece in gm/cc and the machining time in minutes. Higher is the material removal rate, more is the profitability. Along these lines it is most alluring to have bigger material removal rate. The formula used to compute material removal rate is as following:

$$\mathbf{MRR} = \frac{\textbf{(Workpiece weight loss (gm)) X 1000}}{\textbf{Density (gm/cc) X Machining Time}} \quad \text{........ (1)}$$

3. Experimental Setup and Material Properties

Figure 1-2 provides the specification of machine used for experimental work. The machine was accessed at Dilawar Engineering Works Lalbagh, Lucknow.

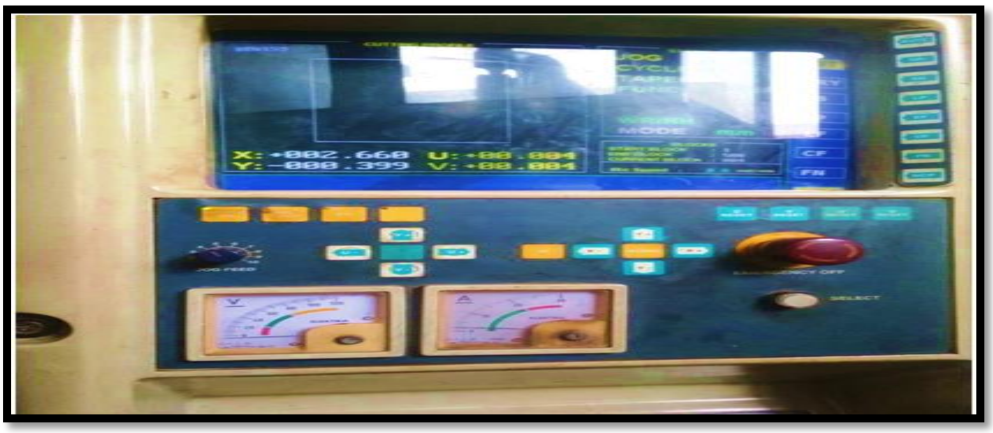

Figure 1 WEDM control panel

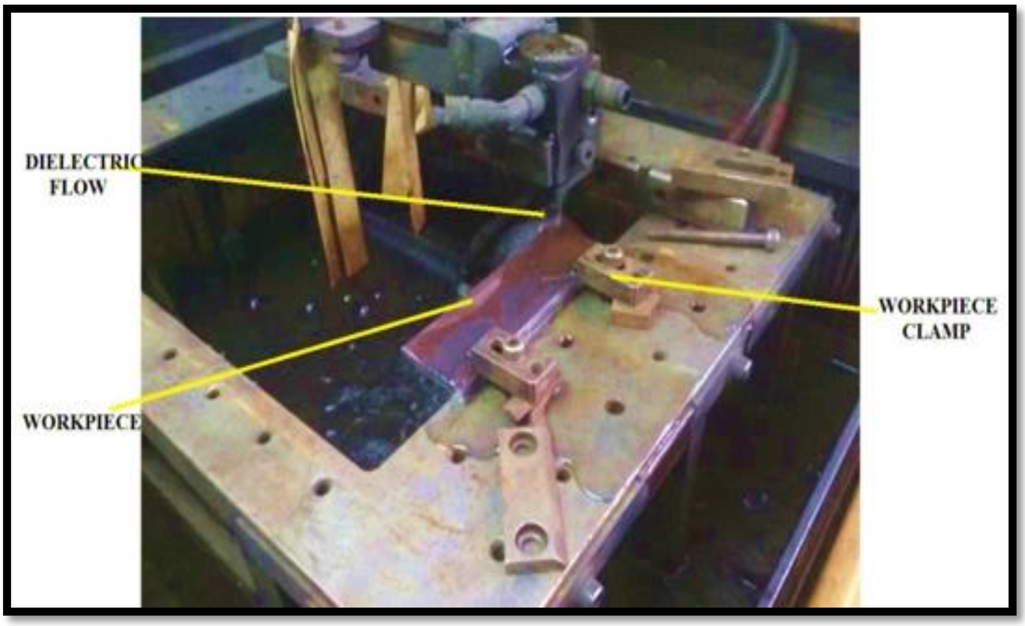

Figure 2 Schematic Diagram of WEDM

Dielectric liquids mostly water is important in WEDM process. It uses for heat dissipation purpose. In this research Die steel D-3 have been used as sample material for conducting experiments using Brass wire of width 0.18mm. Figure 3 shows processing of nine different sample cut by the WEDM experimentally in lab. The input parameters for working on this sample are listed in table 1.

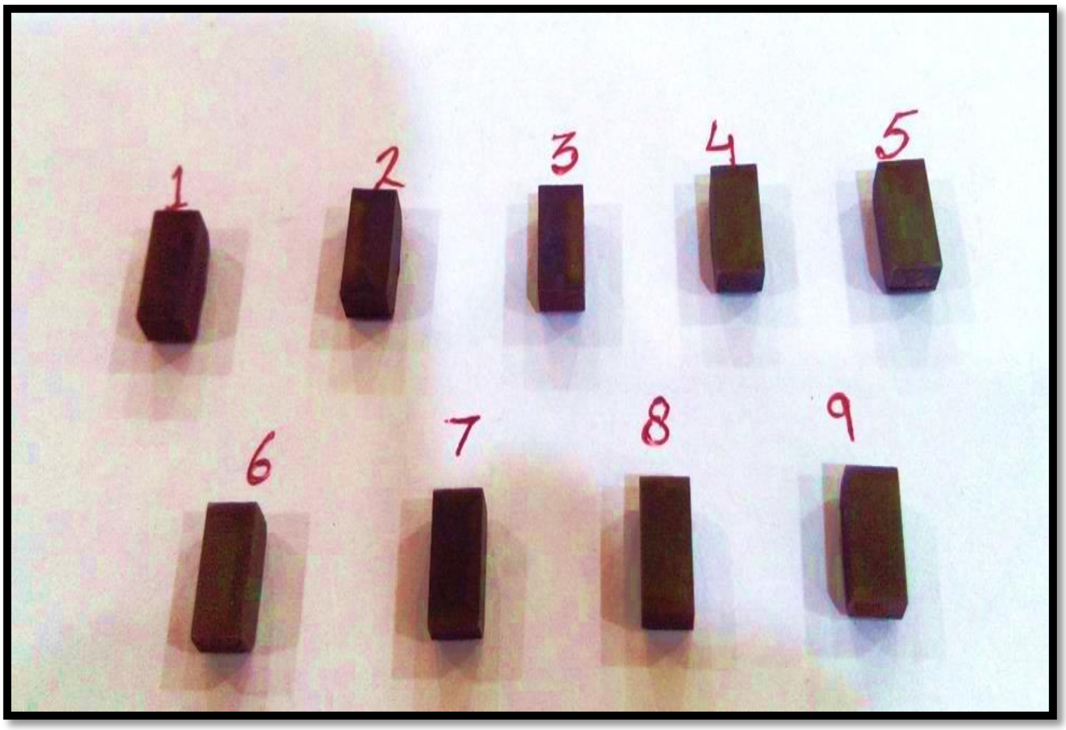

Figure 3 Die-Steel D3 work pieces processed by WEDM.

Table 1 Input Parameter variation in WEDM

S.No	Current (amp)	Pulse on Time	Wire Tension (N)	Weight loss (gm)	Machining Time in (minutes)
1	2	3	400	0.8	33.2
2	2	6	700	0.8	21.52
3	2	9	1000	0.8	17.25
4	4	3	700	0.8	10.43
5	4	6	1000	0.8	9.54
6	4	9	400	0.8	9.39
7	6	3	1000	0.8	15.26
8	6	6	400	0.8	12.72
9	6	9	700	0.8	10.83

4. Results & Discussion

4.1 Material Removal Rate (MRR)

Using equation 1 MRR has been calculated and its values are tabulated in Table 2.

Table 2 Calculation of Material Removal Rate

Exp. No	Current (amp)	Pulse on Time	Wire Tension (N)	Material Removal Rate (mm^3/min)
1	2	3	400	3.062
2	2	6	700	4.724
3	2	9	1000	5.893
4	4	3	700	9.746
5	4	6	1000	10.655
6	4	9	400	10.825
7	6	3	1000	6.661

8	6	6	400	7.992
9	6	9	700	9.825

4.2 Calculations of S/N ratio for Material Removal Rate

S/N ratio for MRR Larger is Better condition is opted as shown in Table 3. The equation (2) has been used for the S/N ratio calculation for material removal rate:

$$S/NLB = -10 \log (\Sigma (1/yi^{2})) \quad .....(2)$$

Table 3 Calculation of S/N ratio for MRR

S. No	Material Removal Rate (mm³/min)	Signal to noise ratio (db)
1	3.089	9.7201
2	4.766	13.4862
3	5.946	15.4067
4	9.834	19.7765
5	10.751	20.5511
6	10.934	20.6886
7	6.721	16.4721
8	8.063	18.0531
9	9.470	19.4496

Table 4 Calculation of mean S/N ratio for MRR

Level	Current (amp)	Pulse on Time	Wire Tension (N)
1	12.87	15.32	16.15
2	20.34	17.36	17.57
3	17.99	18.51	17.48
Delta	7.47	3.19	1.42
Rank	**1**	**2**	**3**

Table 5 ANOVA of MRR

Source	DOF	SS	MS	F Value	P Value	Contribution
Current	2	51.877	25.938	151.05	0.007	86.02
Pulse on Time	2	7.411	3.705	21.58	0.044	12.29
Wire Tension	2	0.678	0.339	1.97	0.336	1.12
Error	2	0.343	0.172			0.57
Total	8	60.308				100%

DOF: Degrees of Freedom, SS: Sum of Squares, MS: Mean Squares

At least 95% confidence

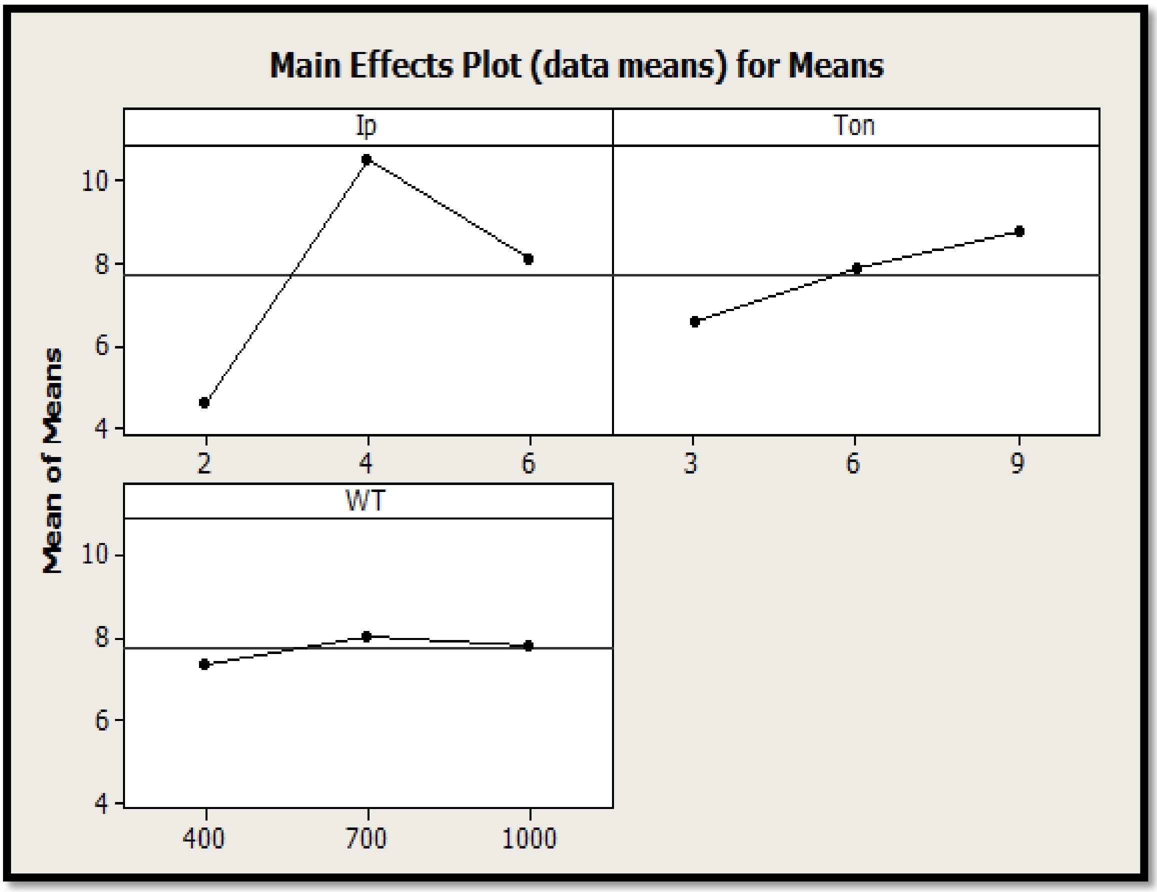

Figure 4 Mean Effect Plot for MRR

Table 4-5 and Figure 4 show the parametric variations and its impact on WEDM. As we increase the peak current (Ip), the MRR tends to increase at a higher rate than pulse on time and voltage. It demonstrates that peak current is the most critical factor for MRR.

MRR at first increases with peak current however with further increment in its value MRR has a tendency to decrease. The purpose behind such behaviour is that the workpiece does not permit adequate sparks to strike the surface of work.

On account of wire tension, at first the MRR tends to increase, however additionally increment in its value, MRR has a tendency to decrease. Wire tension has relatively no impact on MRR.

Wire tension is the minimum affecting parameters for material removal rate. The contribution of wire tension towards the material removal rate is just 1.12% (Table 5).

Table 5 shows the P-value, which describes that current having p value 0.007 is most prominent parameter for MRR analogous by pulse on time with p value 0.044 and least comic parameter is wire tension with p-value 0.336. Optimum level of three parameters is shown in Table 6.

Table 6 Optimal level of parameter for Material Removal Rate

Process variables of factors		Optimum level
Peak Current	**Ip (A)**	4
Pulse on Time	**Ton (µsec)**	9
Wire Tension	**WT**	700

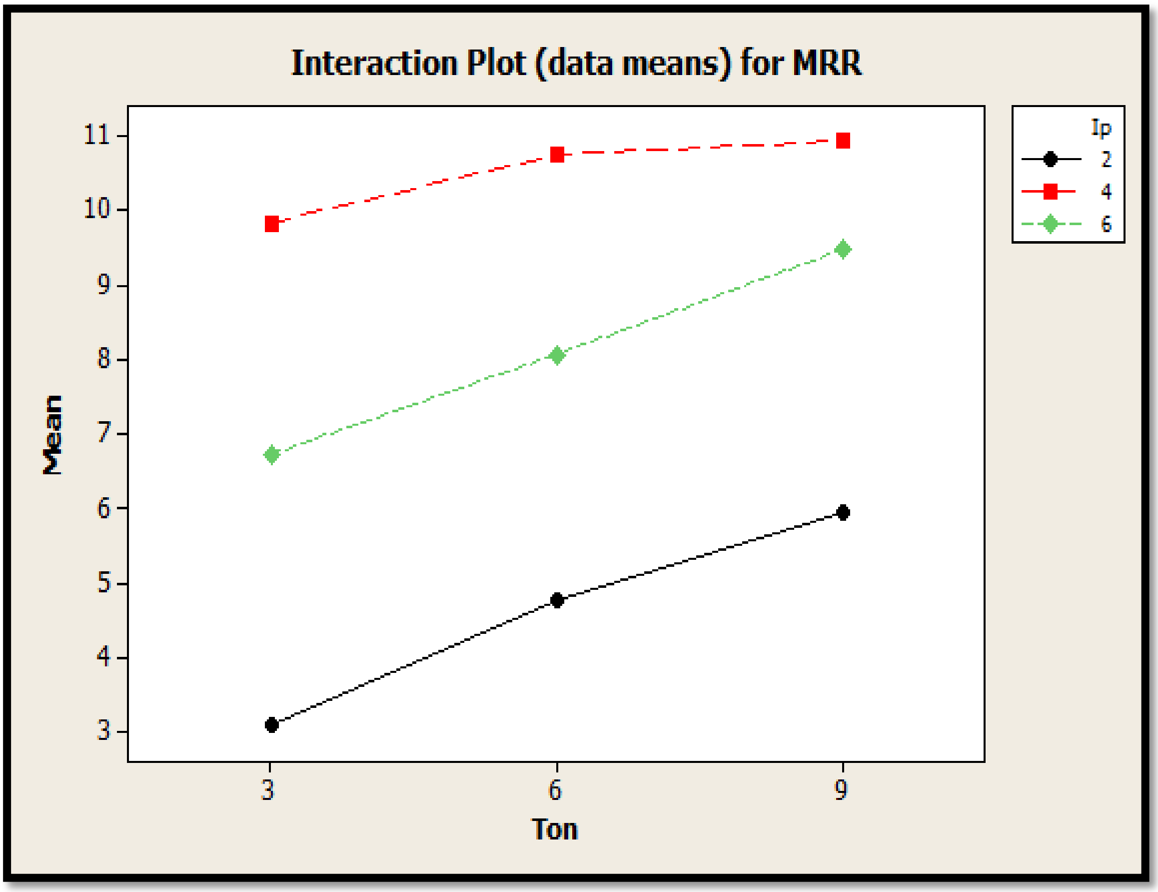

Figure 5 Interaction plot between WEDM parameters and MRR

Figure 5 shows the interaction plot between MRR and pulse on time at various levels of peak current. The graph indicates that at each level of peak current, the material removal rate of the workpiece follows an increasing trend with pulse on time. Moreover, it is also observed that with increase in the value of peak current, there is a gradual increase in the MRR.

5 Conclusion

From the above analysis following conclusions were drawn:

The experiment shows that the advancement of machining parameters in WEDM of Die Steel D-3, parametric components like peak current, pulse on time and Wire Tension have large impact on MRR.

MRR at first increases with peak current however with further increment in peak current the MRR has a tendency to decrease. The explanation behind such behaviour is that the metal chips introduce between the terminal wire and the workpiece does not permit adequate sparks to strike the surface of work.

With Wire Tension, at first the MRR tends to increase, however further increment in its value has a tendency to decrease the MRR. Wire tension has relatively no impact on MRR and is the minimum affecting parameters with a contribution of just 1.12%.

References

[1] S. B. Prajapati , N. S. Patel (2013)"Effect of Process Parameters on Performance Measures of Wire EDM for AISI A2 Tool Steel" International Journal of Computational Engineering Research, Vol. 3 I (4), pn. 274-278.

[2] G. Amitesh, K. Jatinder "An Investigation Into the Machining Characteristic of Nimonic 80 A Using CNC Wire EDM" International Journal of Advanced Engineering Technology, Vol. 3 I (1), pn. 170-174, 2012, E-ISSN 0976-3945

[3] K. Ojha, R. K. Garg, K. K. Singh "MRR Improvement in Sinking Electrical Discharge Machining: A Review" Journal of Minerals and Materials Characterization and Engineering,

Vol. 9, 2010

[4] J.P. Kruth, Ph. Bleys "Estimating lingering pressure caused by Wire EDM of hardware steel" Int. conf. on remaining stresses,Germany, 1991

[5] M. Durairaja, D. Sudharsunb, N. Swamynathan "Investigation of Process Parameters in Wire EDM with Stainless Steel utilizing Single Objective Taguchi Method and Multi Objective Gray Relational Grade" International Conference On DESIGN AND MANUFACTURING, IConDM 2013.

[6] D. Ghodsiyeh, A. Golshan, J. A.Shirvanehdeh "Audit on Current Research Trends in Wire Electrical Discharge Machining (WEDM)" Indian Journal of Science and Technology 2013 ISSN:0974-6846

[7] H. Singh, R. Khanna "Parametric Optimization of Cryogenic-Treated D-3 for Cutting Rate in Wire Electrical Discharge Machining" Journal of Engineering and Technology, 2011

[8] R. Kumar and S. Singh "Ebb and flow Research Trends in Wire Electrical Discharge Machining: An Overview" International Journal on Emerging Technologies ISSN : 0975-8364

[9] L. Li, Y.B.Guo, X.T. Wei, W. Li "Surface trustworthiness qualities in wire-EDM of inconel 718 at various release vitality" Seventeenth International Symposium on

Electromachining

[10] N. Tosun, C. Cogun, and A. Inan "The Effect of Cutting Parameters on Workpiece Surface Roughness in Wire EDM" Machining Science And Technology 2003

[11] R. Bobbili, V. Madhu, and A. K Gogi "Impact of Wire-EDM Machining Parameters on Surface Roughness and Material Removal Rate of High Strength Armor Steel"

Materials and Manufacturing Processes, 2013, ISSN: 1042-6914

[12] M. Malik, R. K. Yadav, Nitesh Kumar, Deepak Sharma, Manoj; "Enhancement of process parameters of wire edm utilizing zinc-covered metal wire" International Journal of Advanced Technology and Engineering Research (IJATER) ISSN No: 2250-3536 Volume 2, Issue 4, July 2012.

[13] K. Kumar, R. Ravikumar; "Demonstrating and Optimization of Wire EDM Process" International Journal of Modern Engineering Research (IJMER) Vol. 3, Issue. 3, May.- June. 2013 pp-1645-1648 ; ISSN: 2249-6645.

[14] H. Singh, R. Garg "Impacts of process parameters on material expulsion rate in WEDM" Journal of Achievements in Materials and Manufacturing Engineering VOLUME 32 ISSUE 1 January 2009.

[15] Liao,Y.S., Huang, J.T., Chen, Y.H. (2004), " An investigation to accomplish a fine surface complete in Wire-EDM" , Journal of Materials Processing Technology, 149,165– 171.

[16] Spedding, T. A., Wang, Z.Q. (1997), "Parametric improvement and surface portrayal of wire electrical release machining process", Precision Engineering, 20(1), 5-15.

[17] Scott, D., Boyina, S., Rajurkar, K.P. (1991), "Examination and improvement of Parameter Combination in Wire Electrical Discharge Machining", International Journal of Production Research, 29, 2189-2207.

[18] Lin, H.C.,Lin, K.M., Chen, Y.S., Chu, C.L. (2005) ,"The wire electro-release machining attributes of Fe– 30Mn– 6Si and Fe– 30Mn– 6Si– 5Cr shape memory amalgams", Journal of Materials Processing Technology, 161, 435– 439.

[19] Miller, S. F., Chen, C.K., Shih, A. J., Qu, J. (2005), "Examination of wire electrical release machining of thin cross-areas and consistent instruments", International Journal of Machine Tools and Manufacture, 45, 1717– 1725.

[20] R. Ramakrishnan, furthermore, Karunamoorthy, L. (2006), "Multi reaction enhancement of wire EDM tasks utilizing strong outline of investigations", International Journal of Advanced Manufacturing Technology, 29, 105– 112

[21] A. Mathew Kurian, Dr. Binu C.Yeldose, Ernest Markose Mathew, "Impact of Wire EDM Parameters on Surface Roughness of Stainless Steel 15-5 PH", International Journal of Engineering and Innovative Technology (IJEIT) Volume 4, Issue 2, August 2014.

[22] B. Singh, Dr. B.S. Pabla, M. Saroha, "Examining the impacts of process parameters on MRR in WEDM utilizing Molybdenum wire", International Journal of Engineering, Business and Enterprise Applications (IJEBEA), ISSN (Online): 2279-0039.

[23] D. H. Gajjar , J. V. Desai "Improvement of MRR, Surface Roughness and KERF Width in wire EDM Using Molybdenum Wire" International Journal for Research in Education (IJRE) (Impact Factor 1.5), ICV: 6.30, Vol. 4, Issue: 2, February : 2015.

[24] R.Nagaraja, K.Chandrasekaran, S.Shenbhgaraj, "Improvement of parameters for metal grid composite in Wire-EDM", IJESRT ISSN: 2277-9655 Nagarajal, 4(2): February, 2015

[25] R.Pandithurai, I. Ambrose Edward, "Improving surface harshness in Wire-EDM utilizing machining parameters", IJIRSET Volume : 3, March 2014, ISSN (Online) : 2319 – 8753, ISSN (Print) : 2347 – 6710.

[26] P. Kr. Saini, M. Verma, "Exploratory Investigation of Wire-EDM Process Parameters on MRR of Ti-6al-4v Alloy", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-4, Issue-5, October 2014.

[27] M. Qaiser Saleem, M. Awais, "An Investigation for Better Machining Performance in Low Range Tapering Mode", Technical Journal, University of Engineering and Technology (UET) Taxila, Pakistan Vol. 20(SI) No.II(S)- 2015.

[28] R. N. Marigoudara and K.Sadashivappa, "Impact of Machining Parameters on MRR and Surface Roughness in Machining of ZA43/SiCp Composite by WEDM", International Journal of Applied Science and Engineering 2013. 11, 3: 317-330.

[29] U. Esme, A. Sagbas And F. Kahraman, "Forecast of Surface Roughness in Wire EDM utilizing Design of Experiments and Neural Networks", Iranian Journal of Science and Technology, Transaction B, Engineering, Vol. 33, No. B3, pp 231-240 Printed in The Islamic Republic of Iran, 2009.

[30] A. Kumar, P.P. Patil. FEA Simulation Based Performance Study of Multi-speed Transmission Gearbox. International Journal of Manufacturing, Materials, and Mechanical Engineering, 2016, Vol. 6(1), pp. 57-67, DOI: 10.4018/IJMMME.2016010103.

[31] A. Kumar, P.P. Patil. Dynamic Vibration Analysis of Heavy Vehicle Truck Transmission Gearbox Housing Using FEA. Journal of Engineering Science and Technology Review. **2014**, Vol.7, Issue (4), pp. 66–72.

[32] A. Kumar, P.P. Patil. FEA Simulation and RSM Based Parametric Optimization of Vibrating Transmission Gearbox Housing. Perspective in Science, 2016, Vol. 8 pp. 388-391 http://dx.doi.org/10.1016/j.pisc.2016.04.085.

[33] A. Kumar, P.P. Patil. Modal Analysis of Heavy Vehicle Truck Transmission Gearbox Housing Made from Different Materials. Journal of Engineering Science and Technology. **2016**, 11, 252–266.

[34] S. Bhoi, A. Kumar, A. Prasad, C.S. Meena, R.B. Sarkar, B. Mahto, A. Ghosh. Performance Evaluation of Different Coating Materials in Delamination for Micro-Milling Applications on High-Speed Steel Substrate Micromachines 2022, 13, 1277. doi: 10.3390/mi13081277.

[35] Y. Gori, R.P. Verma, A. Kumar, P. Patil. FEA Based Fatigue crack Growth Analysis. Materials Today Proceedings 2021, 46, 10575–10581.

[36] R. Kumar, A. Kumar, L. Kant, A. Prasad, S. Bhoi, C.S. Meena, V.P. Singh, A. Ghosh. Experimental and RSM-Based Process-Parameters Optimisation for Turning Operation of EN36B Steel. Materials **2023**, 16, 339. doi: 10.3390/ma16010339.

[37] A.K.S. Gangwar, P.S. Rao, A. Kumar. Bio-Mechanical Design and Analysis of Femur Bone. Materials Today Proceedings, 2021, Volume 44, Part 1, Pages 2179-2187, https://doi.org/10.1016/j.matpr.2020.12.282.

[38] A. Kumar, S.I. Behmad, P.P. Patil. Vibration Characterization and Static Analysis of Cortical Bone Fracture Based on Finite Element Analysis. Engineering and Automation Problems, 2014, No 3-2014, pp. 115-119. UDC- 621.

[39] A.K.S. Gangwar, P.S. Rao, A. Kumar, P.P. Patil. Design and Analysis of Femur Bone: BioMechanical Aspects. Journal of Critical Reviews, 2019, Vol. 6, Issue 4, p.n. 133-139.