Journal of Mechanical Engineering: PRAKASH
Volume 01, Issue 01, pp. 7-13, August 2022

Experimental Study of Process Parameter for Surface Roughness in WEDM

[1]A. Kumar, [1]A. Kumar*, [2]N. Dutt, [3]V. Pratap Singh, [4]C.S. Meena, [5]A. Prasad

* [1]Technical Education Department, Uttar Pradesh, India
[2]Department of Mechanical Engineering, College of Engineering Roorkee, India
[3]School of Engineering, University of Petroleum and Energy Studies, Dehradun, India
[4]Central Building Research Institute, Roorkee, India
[5]Department of Mechanical Engineering, Katihar Engineering College, India

Abstract - Wire cut Electrical-Discharge Machining (WEDM) is a machining process which utilizes a thin wire (around 0.18mm) for material removal. In modern machining of complex object, it plays an important role. Process parameters have great in-fluence on WEDM. MRR, SR and WT are varying process parameters. In this article surface roughness (SR) in WEDM process was analysed using Taguchi method. To validate the results analytical and experimental results were investigated. In experiments it was observed, when peak current value was increased, SR value also increases and in resultant a rough surface was produced. Peak current was observed as most influential parameter with contribution of 82.12%.

Keywords - **WEDM, MRR, Surface Roughness, Process Parameter, ANNOVA, Die Steel, Machining.**

INTRODUCTION

Wire-EDM is a broadly acknowledged as a non-contact and non-traditional machining process utilized for formation of segments having unpredictable profiles. This process has large application in aviation sector while machining small scale gas turbine sharp edges and other electronic products. Various researchers have performed incremental research in this field. Prajapati et al. [1] have used WEDM for processing the AISI A2 Tool steel, in continuation this method has been automated using CNC wire EDM [2]. Ojha et al. [3] have performed the review study of WEDM process and inventory various research work in this field. They have conducted study for material removal rate (MRR) improvement in WEDM process. Apart from MRR study researcher have studied the lingering pressure caused by the WEDM in processing of hardware steel [4-9]. N. Tosun et al. [10] through their examination studied variety of workpiece surface roughness with different machining parameters. Ravindranadh Bobbili et al. [11] found that current, voltage and wire tension (WT) are critical factors to MRR and SR.
Malik et al. [12] have investigated the peak current significance in WEDM. They have concluded that pulse on time has significant impact on SR of the material. Kumar et al. [13] from their exploratory examination decide the ideal variable for SR in WEDM. The parameters chosen by them were speed and feed and they were found to assume a fundamental part to influence the MRR and SR. Singh et al. [14] have demonstrated in his study that wire feed and wire strain has no impact on the MRR, although pulse on time straightforwardly have positive impact on the MRR. Liao et al. [15] have conducted a test to study SKD11 compound steel to build scientific models relating the machine execution with different machining parameters and after that have decided the ideal parametric settings for WEDM process for utilization of practical bearing technique for non-straight programming. Spedding and Wang [16] have studied the surface structure of materials processed by WEDM.
Scott et al. [17] in their examination created scientific models for anticipating material removal rate and surface roughness amid machining D-2 instrument steel for various machining conditions. Lin et al. [18] gave another approach of streamlining for WEDM process having numerous removal attributes relying upon the symmetrical cluster. Researchers [19-20] have depicted the multi target advancement in their examination for WEDM process utilizing parametric plan of Taguchi approach. They examined the impact of different machining parameters like heartbeat on alternate parameters. Anoop et al. [21] have studied the wire speed in WEDM. They found that the effectiveness of pulse on time term, release current and wire speed were roughly 64.92 %, 18.83 % and 0.36 %, which shows wire speed has least impact. Baljit Singh et al. [22] have studied WEDM process. They have used molybdenum composite wire in his research. Various researchers have used advance methods with experimental setup for evaluating process parameters of WEDM [23-29]. In last one-decade, researchers have used various advanced tool like FEA, RSM, ANN, and Fuzzy Logic in mechanical engineering for different problem and parameter analysis. Kumar et. al. [30-33] have per-formed the parametric variation using RSM for heavy vehicle gearbox. They have used FEA for simulating the boundary conditions and for optimisation of process parameters RSM was used. Based upon same study the present research work design of experiments and ANNOVA hasve been used. In continuation, they have studied the thermal contact condition, loose transmission gearbox bolt condtion and calcu-lated natural frequency using FEA [34-39]. ANN tool was also used for mass flow sensor analysis. In this research article, surface roughness was analyzed using Taguchi design approach.

*Corresponding Author:
E-mail: drashwanikumardte@gmail.com

SURFACE ROUGHNESS (SR)

Surface roughness portrays the quality surface of the machined work. It is attractive to lessen the surface roughness of the work surface. The more we bring down the surface roughness the surface smoothness of the work piece will get upgraded and accordingly the nature of the machining will get different parameters. In present experimental work Surface roughness estimation was done using Mitutoyo 178-602 surface roughness analyzer.

EXPERIMENTAL SETUP AND MATERIAL PROPERTIES

Figure 1-3 shows the details of machine used for experimental work. Table1 shows specification of WEDM machine. The machine for tests was accessible at Dilawar Engineering Works Lalbagh, Lucknow.

Table 1. Specifications of Electronica Wire-EDM Machine.

S.N.	Specification	Dimension
1.	Length Table	250 x 320
2.	Workpiece Size Lx W (mm)	380 x 525
3.	Maximum Workpiece Thickness (mm)	300
4.	Maximum Workpiece Weight (gm)	300
5.	Machine Weight (Kg)	1600
6.	Display	LCD Display
7.	Control System	CNC
8.	Axis Control	A Axis (X, Y, U and V)
9.	Guide Ways	Linear Motion
10.	Resolution	0.001 mm
11.	Wire Diameter	0.18mm (standard), 0.15mm and 0.12 mm (optional)
12.	Interpolation	Linear and Circular
13.	Programming	Incremental
14.	Power Input	3 Phase, 415 Volts
15.	Total MAchione Load	1.5 KVA
16.	Processing and Data Entry	Dual Screen
17.	Dielectric Fluid	Soft Water
18.	Dielectric Tank Capacity	55 Litre

Fig. 1. Electronica Wire-EDM Computer panel.

Fig. 2. Machining on Electronica Wire-EDM.

Dielectric liquids assume an essential part in EDM procedure. The dielectric medium additionally cools the machining zone via diverting overabundance warm slopes from the instrument terminal and the work piece. In experimental work the material used for study is Die steel D-3 (Table 2-3) which has following properties and the wire utilized for this work is Brass wire of width 0.18mm.

Table 2. Mechanical Properties of Die Steel D-3.

Density (g/cm^3)	Melting point (°C)	Yield strength (MPa)	Elastic modulus (GPa)	Poisson's Ratio	Hardness
7.87	1421	470	190	0.28	58-64

https://doi.org/10.56697/JMEP.2022.1109 JMEP © Jalpaiguri Government Engineering College 2022 *http://www.prakash.jgec.com*

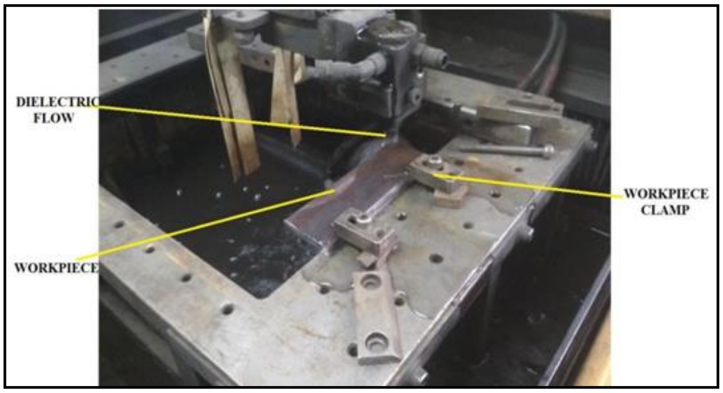

Fig. 3. Parts of Electronica Wire-EDM.

Table 3. Chemical composition of the work piece material (DIE STEEL D-3) by weight.

Material	C	Mn	Si	Cr	Ni	W	V	P	S	Cu
% Composition	2.00-2.35	0.60	0.60	11.00 -13.50	0.30	1.00	1.00	0.03	0.03	0.25

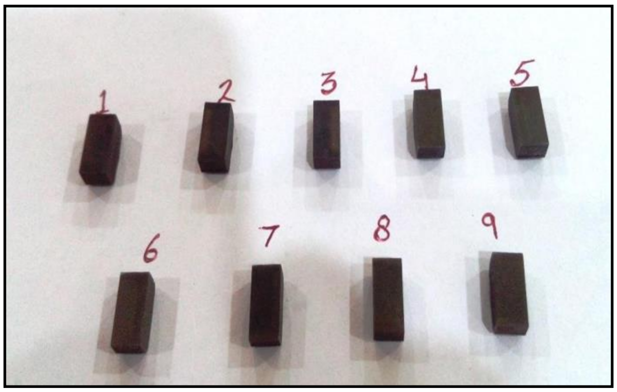

Fig. 4. Die-Steel D3 pieces cut by Wire-EDM.

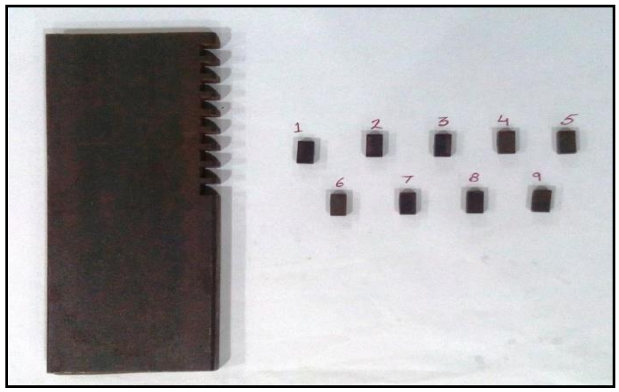

Fig. 5. Die-Steel D3 bar and the cut pieces by WEDM

Fig. 4 and 5 shows the different sample (1-9) processed by the WEDM in lab. For processing these samples input parameters are listed in table 4.

Table 4. Input Parameter Variations for cutting samples using WEDM in lab.

S.No	Current (amp)	Pulse on Time	Wire Tension (N)	Weight loss (gm)	Machining Time (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

RESULTS & DISCUSSION

Evaluation of Surface Roughness (SR)

https://doi.org/10.56697/JMEP.2022.1109 JMEP © Jalpaiguri Government Engineering College 2022 http://www.prakash.jgec.com

Material removal rate can be calculated by dividing the work piece weight loss (in grams) to the product of density of the work piece (gm/cc) and the machining time. The calculated values of SR are shown in table 5.

Table 5. Calculation of Surface Roughness (SR).

Exp. No	Current (amp)	Pulse on Time	Wire Tension (N)	Surface Roughness Ra (µm)
1	2	3	400	6.69
2	2	6	700	6.94
3	2	9	1000	7.18
4	4	3	700	7.28
5	4	6	1000	7.72
6	4	9	400	7.37
7	6	3	1000	7.83
8	6	6	400	7.76
9	6	9	700	8.14

Calculations of S/N ratio for Surface Roughness

S/N ratio for SR smaller is better, is shown in table 6. The calculation was performed using following equation:

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

Table 6. Calculation of S/N ratio for Surface Roughness.

S.No	Surface Roughness Ra(µm)	Signal to noise ratio (db)
1	6.69	-16.5085
2	6.94	-16.8272
3	7.18	-17.1225
4	7.28	-17.2426
5	7.72	-17.7523
6	7.37	-17.3493
7	7.83	-17.8752
8	7.76	-17.7972
9	8.14	-18.2125

Table 7. Calculation of mean S/N ratio for SR.

Level	Current	Pulse on Time	Wire Tension
1	-16.82	-17.21	-17.22
2	-17.45	-17.46	-17.43
3	-17.96	-17.56	-17.58
Delta	1.14	0.35	0.36
Rank	1	3	2

Table 8. ANOVA of Surface Roughness.

Source	DOF	S.S.	Adj.MS	F.Value	P.Value	Contribution
Current	2	1.42329	0.71164	45.20	0.022	82.12
Pulse on Time	2	0.13882	0.06941	4.41	0.185	8.01
Wire Tension	2	0.13962	0.06981	4.43	0.184	8.05
Error	2	0.03149	0.01574	-	-	1.82
Total	8	1.73322	-	-	-	100%

https://doi.org/10.56697/JMEP.2022.1109 JMEP © Jalpaiguri Government Engineering College 2022 http://www.prakash.jgec.com

Table 7-8 and fig. 6 show the impact of input parameters. All the three parameters demonstrate an expanding pattern with surface roughness i.e. with increment in the levels of WEDM parameter, the surface roughness of the machined surface increases. By expanding the current the surface roughness increments and rough surface is produced. Peak current (Ip) is the most important factor having a contribution of 82.12%. The base surface harshness was seen at 2A. With increment in Pulse on time and wire tension the surface roughness increases. The base surface roughness was seen at 3 µ sec pulse on time and 400 N wire pressures. The contributions of pulse on time and wire pressure are 8.01% and 8.05%, individually. The current having p value is 0.022 is most prominent parameter for surface roughness and pulse on time with p value is 0.185 and wire tension with p-value is 0.184. Optimum level of three parameters is shown in table 9.

At least 95% confidence:

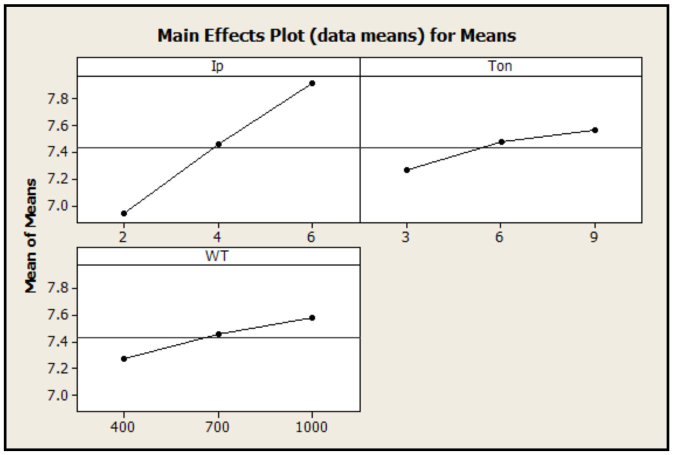

Fig. 6. Mean Effect Plot for Surface Roughness.

Table 9. Optimal level of parameter for Surface Roughness.

Process variables of factors		Optimum level
Peak Current	Ip (A)	2
Pulse on Time	Ton (µsec)	3
Wire Tension	WT	400

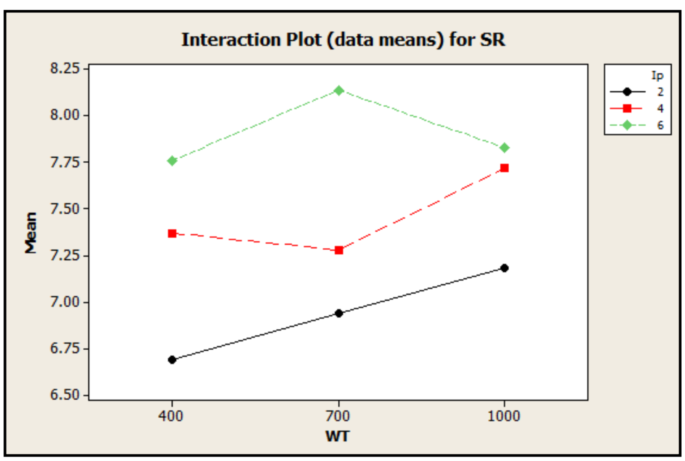

Fig. 7. Interaction plot between Surface Roughness and WEDM parameters.

The above plot in fig. 7 shows the interaction plot between surface roughness and wire tension at various levels of peak current. The graph elucidates that at lowest level of peak current, the material removal rate of the workpiece follows an increasing trend with wire tension. Moreover, when the value of peak current is increased i.e. at 4A, surface roughness first decreases and then tends to increase with wire tension. At 6A peak current, the surface roughness first increases and then decreases with wire tension.

https://doi.org/10.56697/JMEP.2022.1109 JMEP © Jalpaiguri Government Engineering College 2022 *http://www.prakash.jgec.com*

Confirmation tests have been performed for Surface Roughness with their optimum levels of process variables and only 2.09% deviation was observed (table 10).

Table 10. Confirmation of expected and actual values of Surface Roughness.

Experiment No.	Optimum Machining Parameters			Surface Roughness	
	Current (A)	Pulse on Time (μsec)	Wire Tension	Actual	Expected
1	2	3	400	6.69	6.83
				Error (%)	2.09%

CONCLUSION

From the above analysis following conclusions were drawn: The experiment depicts the advancement of machining parameters in Wire- Electrical Discharge Machining of Die Steel D-3 with metal wire as terminal utilizing L9 symmetrical cluster of Taguchi technique. Components like Current, Pulse on time (Ton) and Wire Tension and their collaborations have been found to impact MRR. All the three parameters demonstrate an expanding pattern with surface roughness i.e. with increment in the levels of WEDM parameter, the surface roughness of the machined surface increases.

By expanding the current the surface roughness increases and rough surface is produced as we increment the current. Peak current is the most critical factor having a contribution of 82.12%. The base surface harshness was seen at 2A. With increment in pulse on time and wire pressure the surface roughness increase. The base surface roughness was seen at 3 μsec pulse on time and 400 N wire Tension. The contributionS of pulse on time and wire tension are 8.01% and 8.05%separately.

REFERENCES

[1] S.B. Prajapati and N.S., Patel Effect of Process Parameters on Performance Measures of Wire EDM for AISI A2 Tool Steel, Int. J. Comput. Eng. Res., 3I (4), pp. 274-278, 2013.

[2] G. Amitesh and K. Jatinder, An Investigation Into the Machining Characteristic of Nimonic 80 A Using CNC Wire EDM, Int. J. Adv. Eng. Tech., 3I(1), pp. 170-174, 2012, E-ISSN 0976-3945.

[3] K. Ojha, R.K. Garg and K.K. Singh, MRR Improvement in Sinking Electrical Discharge Machining: A Review, J. Min. Materials Cha-ract. Eng., 9, 2010.

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

[5] M. Durairaja, D. Sudharsunb and N. Swamynathan, Investigation of Process Parameters in Wire EDM with Stainless Steel utilizing Single Objective Taguchi Method and Multi Objective Gray Relational Grade, Int. Conf. Des. Manufac., IConDM 2013.

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

[7] H. Singh and R. Khanna, Parametric Optimization of Cryogenic-Treated D-3 for Cutting Rate in Wire Electrical Discharge Machin-ing, J. Eng. Tech., 2011.

[8] R. Kumar and S. Singh, Ebb and flow Research Trends in Wire Electrical Discharge Machining: An Overview, Int. J. Emerging Tech. ISSN: 0975-8364.

[9] L. Li, Y.B. Guo, X.T. Wei and W. Li, Surface trustworthiness qualities in wire-EDM of inconel 718 at various release vitality, Seven-teenth Int. Symp. Electro machining.

[10] N. Tosun, C. Cogun and A. Inan, The Effect of Cutting Parameters on Workpiece Surface Roughness in Wire EDM, Machin. Sci. Tech., 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, Mat. Manufac. Proc., 2013. ISSN: 1042-6914.

[12] M. Malik, R. K. Yadav, N. Kumar, D. Sharma, M. Sharma, Enhancement of process parameters of wire edm utilizing zinc-covered metal wire, Int. J. Adv. Tech. Eng. Res., 2(4), 2012. ISSN No: 2250-3536.

[13] K. Kumar and R. Ravikumar, Demonstrating and Optimization of Wire EDM Process, Int. J. Modern Eng. Res., 3(3), pp-1645-1648, 2013. ISSN: 2249-6645.

[14] H. Singh and R. Garg, Impacts of process parameters on material expulsion rate in WEDM, J. Achieve. Mat. Manufac. Eng., 32(1), 2009.

[15] Y.S. Liao, J.T. Huang and Y.H. Chen, An investigation to accomplish a fine surface complete in Wire-EDM, J. Mat. Proc. Tech., 149, pp. 165-171, 2004.

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

[17] D. Scott, S. Boyina and K.P. Rajurkar, Examination and improvement of Parameter Combination in Wire Electrical Discharge Ma-chining, Int. J. Prod. Res., 29, pp. 2189-2207, 1991.

[18] H.C. Lin, K.M. Lin, Y.S. Chen and C.L. Chu, The wire electro-release machining attributes of Fe– 30Mn– 6Si and Fe– 30Mn– 6Si– 5Cr shape memory amalgams, J. Mat. Proc. Tech., 161, pp. 435-439, 2005.
[19] S. F. Miller, C.K. Chen, A. J. Shih and J. Qu, Examination of wire electrical release machining of thin cross-areas and consistent in-struments, Int. J. Machine Tools and Manufac., 45, pp. 1717-1725, 2005.
[20] R. Ramakrishnan and L. Karunamoorthy, Multi reaction enhancement of wire EDM tasks utilizing strong outline of investigations, Int. J. Adv. Manufac. Tech., 29, pp. 105-112, 2006.
[21] A.M. Kurian, B.C. Yeldose and E.M. Mathew, Impact of Wire EDM Parameters on Surface Roughness of Stainless Steel 15-5 PH, Int. Eng. Innovative Tech., 4(2), 2014.
[22] B. Singh, B.S. Pabla and M. Saroha, Examining the impacts of process parameters on MRR in WEDM utilizing Molybdenum wire, Int. Eng., 2006. ISSN (Online): 2279-0039.
[23] D.H. Gajjar and J.V. Desai, Improvement of MRR, Surface Roughness and KERF Width in wire EDM Using Molybdenum Wire, Int. Res. Education, 4(2), 2015.
[24] R. Nagaraja, K. Chandrasekaran and S. Shenbhgaraj, Improvement of parameters for metal grid composite in Wire-EDM, IJESRT, 4(2), 2015. ISSN: 2277-9655.
[25] R. Pandithurai and I.A. Edward, Improving surface harshness in Wire-EDM utilizing machining parameters, IJIRSET, 3, pp. 23198753, 2014.
[26] P.K Saini and M. Verma, Exploratory Investigation of Wire-EDM Process Parameters on MRR of Ti-6al-4v Alloy, Int. J. Inn. Tech. Exploring Eng., 4(5), 2014. ISSN: 2278-3075.
[27] M. QaiserSaleem and M. Awais, An Investigation for Better Machining Performance in Low Range Tapering Mode, Technical J., Uni-versity of Engineering and Technology (UET) Taxila, Pakistan, 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, Int. J. App. Sci. Eng., 11(3), pp. 317-330, 2013.
[29] U. Esme, A. Sagbas and F. Kahraman, Forecast of Surface Roughness in Wire EDM utilizing Design of Experiments and Neural Networks, Iranian J. Sci. Tech., Trans. B, Eng., 33(B3), pp. 231-240, 2009.
[30] A. Kumar, H. Jaiswal, P.P. Patil, Connecting Bolt Constraint Based Design Parametric Optimisation of Vibrating Transmission Gear-box Housing Using RSM, World J. Model. Simulation, 13(3), pp. 228-240, 2017.
[31] A. Kumar, H. Jaiswal and P.P. Patil, Parametric Optimization of Vibrating Heavy Vehicle Medium Duty Transmission Gearbox Housing Using Response Surface Method, Int. J. Vehicle Struc. Systems, 9 (3), pp. 149-153, 2017. doi:10.4273/ijvss.9.3.04
[32] A. Kumar, P. P Patil, FEA Simulation and RSM Based Parametric Optimization of Vibrating Transmission Gearbox Housing, Persp. Sci., 8 pp. 388-391, 2016. http://dx.doi.org/10.1016/j.pisc.2016.04.085.
[33] A. Kumar, S. Rana, Y. Gori, N. K. Sharma, Thermal Contact Conductance Prediction Using FEM Based computational Techniques, Adv. Comp. Methods in Mech. Materials Eng, CRC Press, pp. 183-220, 2021. DOI: 10.1201/9781003202233-13, ISBN: 9781032052915.
[34] A. Kumar, P.P. Patil, Dynamic Structural and Thermal Characteristics Analysis of Oil Lubricated Multi Speed Transmission Gearbox: Variation of Load, Rot. Speed Conv. Heat Trans., Iranian J. Sci. Tech. Trans. Mech. Eng., pp. 1-11, 2016. DOI: 10.1007/s40997-016-0063-z.
[35] A. Kumar, P.P. Patil, Modal Analysis of Heavy Vehicle Truck Transmission Gearbox Housing Made from Different Materials, J. Eng. Sci. Tech., 11(2), pp. 252-266, 2016.
[36] A. Kumar, P.P Patil, FEA Simulation Based Performance Study of Multi-Speed Transmission Gearbox, Int. J. Manufac. Mat. Mech. Eng., 6(1), pp. 57-67, 2016. DOI: 10.4018/IJMMME.2016010103.
[37] P. Patil, S. Sharma, A. Saini, A. Kumar, ANN Modelling of Cu Type Omega Vibration Based Mass Flow Sensor, Procedia Tech., 14, pp. 260-265, 2014. DOI: 10.1016/j.protcy.2014.08.034.
[38] P. Patil, S. Sharma, H. Jaiswal, A. Kumar, Modeling Influence of Tube Material on Vibration based EMMFS using ANFIS, Procedia Mat. Sci., 6, pp. 1097-1103, 2014. DOI: 10.1016/j.mspro.2014.07.181.
[39] A. Kumar, H. Jaiswal, P. P Patil, FEM Simulation Based Computation of Natural Frequencies and Mode Shapes of Loose Transmission Gearbox Casing, Int. Rev. Model. Simulations, 7(5), pp. 900-905, 2014. DOI: http://dx.doi.org/10.15866/iremos.v7i5.3932.