



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 11, November 2022

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.118

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com



Optimization of Process Parameters of Micro EDM Machining of Ti-6Al-4V by Taguchi Method

Vipin Kumar Gaurav, Ajeet Kumar

Department of Mechanical Engineering, Suyash Institute of Information Technology, Gorakhpur, India

Department of Mechanical Engineering, Suyash Institute of Information Technology, Gorakhpur, India

ABSTRACT: In this experimental work the EDM cutting variables i.e. diameter, peak current pulse on time and pulse off time are considered. The experiment was performed using the Taguchi (L9) method. The results obtained after the completion of the experiment show that the surface roughness of the Ti-6Al-4V alloy is highly affected by the diameter of the tool and the time pulse. Optimization of the improved material removal rate and surface finish of titanium alloys was performed with the multi-reaction optimization tool entropy-integrated-VIKOR method. In order to approve the review, confirmation analysis has been done on the ideal arrangement of the limitation's findings.

KEYWORDS: EDM; Surface roughness; VIKOR; MRR

I. INTRODUCTION

Large scale manufacturing reduces the cost of manufacturing. Where accuracy is of paramount importance, EDM delivers impressive results in this area that meets the greatest efficiency with the least cost [1]. The surface honing of machined parts significantly affects their utilitarian performance [2]. As well as with the quality of the object [3] or with being developed again. While titanium alloys are difficult to fabricate using routine strategies, along these lines, non-traditional machining is often chosen in many applications. Electrical Discharge Machining (EDM) is one of those non-traditional machining often used to fabricate titanium compounds with their distinct advantages and disadvantages. EDM is a high-level method for metal removal in the light of the thermal hypothesis. Material clearance depends on the interpretation of electrical energy in thermal power through an arrangement of discrete electrical discharges between terminals created in thermal power by means of a liquid dielectric [4,5]. A small pause on the machined surface increases with the pulse of time. The system of short pauses diminishes with a drop-in pulse off time [6]. The test was performed on Ti6Al4V alloy using electro discharge machining as a surface treatment process for bio clinical use. EDM offers more prominent surface durability with a relatively higher peak current and better surface working carbon [7]. The surface roughness in EDM machining increases with increasing pulse over time and decreases to the top flow with an expansion in the stream tension of the dielectric liquid [8]. Multivariate advancement was led using the Grey-relational Taguchi system [9].

In this assessment, GRCs are assessed by generalized characteristics to represent relationships between different outcomes. [10]. Until then the overall gray relational grade is determined by the average of the GRCs prioritizing the optimal response. In requesting basic considerations using minimum assets, GRA is particularly prominent for pursuing various strategy factors. Various outcomes can be avoided by setting ideal limits for a particular outcome. With these sentences a multi-target movement should be done to create an ideal boundary condition. In the Gray related investigation, the research assessment of the thinking quality part is standardized within a degree of zero to one. It was identified as "GRG". Then find "loose social coefficient". [11]. Overall performance should be governed by the determination of the trademark "GRG". Thus, a multiple process improvement is adapted for a specific purpose object as advised by S Tripathi et al. [10, 12].

Researchers coordinated the investigations using Taguchi L₉ balanced show with different factor and level. The process parameters were dia. meters, peak current, pulse on time and pulse off time to measure the effect of response parameters material removal rate and surface roughness (MRR and SR). this research paper is divided in 4 section start with introduction, in the rest of the paper, materials and method followed by results and discussing, and the conclusion.

II. MATERIAL AND METHOD

In this work Ti-6Al-4V Alloy was precured from the market in the form of circular plate as shown in the Fig.1(a, c). Taguchi L₉ orthogonal array used to design the experiment, the experiment considers four factors with three respected



levels as shown in the Table 1. Taguchi experimental runs (Total 9) are shown in the Table 2 in coded form. All the others parameters i.e. dielectric fluid, voltage, tool electrode materials (Copper) etc. are consider as constant. Before going to conduct the experiment, the workpiece was cleaned with the acetoin to remove the oxide on the surface, and the similar process for tool electrode material.

Table 1. Independent process parameters and their respected levels.

Level	Process Parameter			
	D	I _p	T _{on}	T _{off}
Units	mm	A	μs	μs
1	3	20	150	15
2	5	40	250	30
3	7	60	350	45



Figure 1. EDM setup with workpiece (a) Circular workpiece with workpiece holder, (b) EDM tool holder with workbench, (c) final machined workpiece.

2.1 Measurement of response

2.1.1 Material removal rate (MRR)

The difference in weight of the workpiece to processing time and density of the material is called material removal rate (MRR) it is given by Equation 1.

$$\text{Material Removal Rate} = \frac{\Delta W}{\rho \times t} \tag{1}$$

Where ΔW is the weight difference in mm³/min. and ‘t’ is the machining time in minutes, and ρ is density of the work piece.

2.1.2 Surface roughness (R_a)

It is the measure of smoothness of the surface. Smoothness of the work piece is measure by surface roughness tester. Minimum value of surface roughness shows that the surface has higher degree of smoothness. It was denoted by R_a, and measured in μm. Surface roughness was estimated by Mitutoyo Surface Roughness Tester SJ – 410.

2.2 Entropy integrated VIKOR method

In the multi-criteria-decision-method (MCDM), the weight of criteria is selected by higher management. It is one of the most difficult tasks for the managers. It changes with the personal opinion of the managers. Biased decisions may be the cause of the organization's economic losses, so the subjective weights determined from the criterion measure has been suggested [13, 14]. The basic steps to calculate entropy weight is as

Step.1 In the First step desired Decision matrix *D* is formed by *m* experimental runs and *n* response parameters. Decision matrix i.e. *D* [R_i(*k*)] *m* × *n* where ‘*D*’ is the Decision matrix and R_i(*k*) is the *k*th response of the *i*th experimental run. *D* [R_i^{*}(*k*)] *m* × *n* is the normalized decision matrix.



Step 2. After normalization find $T_i(k)$ using Equation 2.

$$T_i(k) = \frac{R_i^+(k)}{\sum_i^M R_i^+(k)} \tag{2}$$

Step 3. Entropy index $E(k)$ is explored for k^{th} response by the following Equation 3.

$$E(k) = -\frac{1}{(\ln M)} \left(\sum_i^M T_{ik} \times \ln T_{ik} \right) \tag{3}$$

Step 4. Entropy weight (w_k) for each k^{th} response is calculated by Equation 4.

$$W(k) = \frac{1-E(k)}{N-\sum_k^N E(k)} \tag{4}$$

In a complex decision-making situation, decision-makers use a tool MCDM to achieve optimal response. In 1982, Zeleny introduced a technique named VIKOR (VlseKriterijumska Optimizacija Kompromisno Resenje)[15]. VIKOR and TOPSIS method are worked on the relative closeness distance from an ideal point and, non-ideal point. In the case of conflicting criteria. VIKOR gives compromises solution to find the optimal solution in the form of VIKOR index. Weight of the criteria was calculated by the entropy method. The basic steps to find VIKOR index from Entropy-integrated-Grey-VIKOR is as presented in steps 1-5.

Step 1. Formation of Decision matrix

The normalization of decision matrix X was done as suggested by the Kumar et al. [14]. The normalized matrix X is given by Equation 5.

$$X = [X_i^*(k)]_{m \times n} \tag{5}$$

Where $X_i^*(k)$ is the normalized value for i^{th} experiment and k^{th} response

Step 2. Determination of positive ideal solution and negative-ideal solutions for decision matrix X is as positive ideal solutions (best) X^+ (Equation 6), and the negative ideal (Worst) solution given by X^- (Equation 7).

$$X^+ = [(Max X_i(k) / k \in K) \text{ or } (Min X_i(k) / k \in K')] \tag{6}$$

$$X^- = [Min X_i(k) / k \in K) \text{ or } (Max X_i(k) / k \in K')] \tag{7}$$

where

$K = (k = 1, 2, \dots, n)$, if response is maximum. $K' = (k = 1, 2, \dots, n)$, if response is minimum.

Step 3 Calculation of Utility measure and Regret measure.

The weight of the criteria is calculated by the entropy method. These criteria weight used to calculate Utility measure and Regret measure.

$$S_i = \sum_{k=1}^n W_k \times \left[\frac{X_i^+(k) - X_i(k)}{X_i^+(k) - X_i^-(k)} \right] \tag{8}$$

If the criteria measure required maximum, Equation 8 is applicable but in the case of minimization criteria measure, it is changed by Equation 9.

$$S_i = \sum_{k=1}^n W_k \times \left[\frac{X_i(k) - X_i^-(k)}{X_i^+(k) - X_i^-(k)} \right] \tag{9}$$

Regret measure Re_i is calculated using Equation 10.

$$Re_i = \max \left\{ W_k \times \left[\frac{X_i^+(k) - X_i(k)}{X_i^+(k) - X_i^-(k)} \right] \right\} \tag{10}$$

Step 4. Measure of VIKOR index (Q_i) using Equation 11.

$$Q_i = v \left(\frac{S_i - S_{i-min}}{S_{i-max} - S_{i-min}} \right) + (1 - v) \left(\frac{Re_i - Re_{i-min}}{Re_{i-max} - Re_{i-min}} \right) \tag{11}$$

Where

S_{i-max} = minimum value of S_i , and S_{i-min} = maximum value of S_i .

Re_{i-max} = minimum value of Re_i , Re_{i-min} = maximum value of Re_i .



The Value of ν is lies between 0 to 1. It depends upon maximum group utility and minimum regret measure. Value of ν depended on decision-makers ' decisions based on specific requirements. Its value is unity for maximum group utility and zero for minimum regret. Mostly ν is taken as 0.5.

III. RESULTS AND DISCUSSION

3.1 Analysis of response parameters

In this work, researchers coordinated the investigations using Taguchi L_9 balanced show with four factors with threelevel. In this paper, discussion is carried about the effects or influence of machining parameter, i.e. diameters (D) pulse-on-time (T_{on}), Current (A), Voltage (V_o) on material removal rate (MRR) and surface roughness (SR). MRR was calculated by the Equation 1 and given in Table 2, along with SR [16, 17].

Table 2. Taguchi L_9 orthogonal array with the response parameters.

Experiment Number	Factor Assign				MRR (mm ³ /min.)	SR μ m
	D (mm)	I _p (A)	T _{on} (μ s)	T _{off} (μ s)		
1	1	1	1	1	0.026	1.53
2	1	2	2	2	0.061	2.35
3	1	3	3	3	0.119	2.59
4	2	1	2	3	0.034	2.65
5	2	2	3	1	0.025	2.71
6	2	3	1	2	0.010	2.45
7	3	1	3	2	0.180	3.70
8	3	2	1	3	0.040	2.99
9	3	3	2	1	0.065	3.43

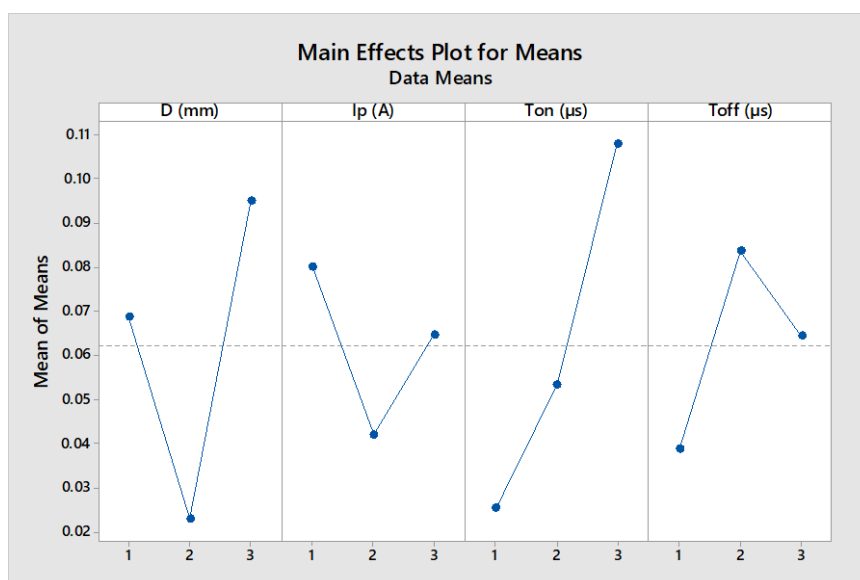


Figure 2. Mean effect plot for material removal rate.

The Fig. 2 shows the effect of machining parameters on the MRR. On increase in the diameter first MRR decrease and then increase, and maximum MRR was found on factor level 3 corresponding (dia.7mm). similar patten was found for the peak current, and maximum MRR was on the level 1(20 A). On increase in T_{on} , value of MRR increases, and maximum at level 3 (350 μ s). On increase in T_{on} duration of large energy discharge increases which melts large amount of metals from the work peace surface. The effect of T_{off} gives that from factor level 1 to 2, initial the MRR increase



and then decrease, it is because on increase in off time, flushing of debris particle improve so MRR increase but beyond a limit it again decreases due to decrease in duty cycle.

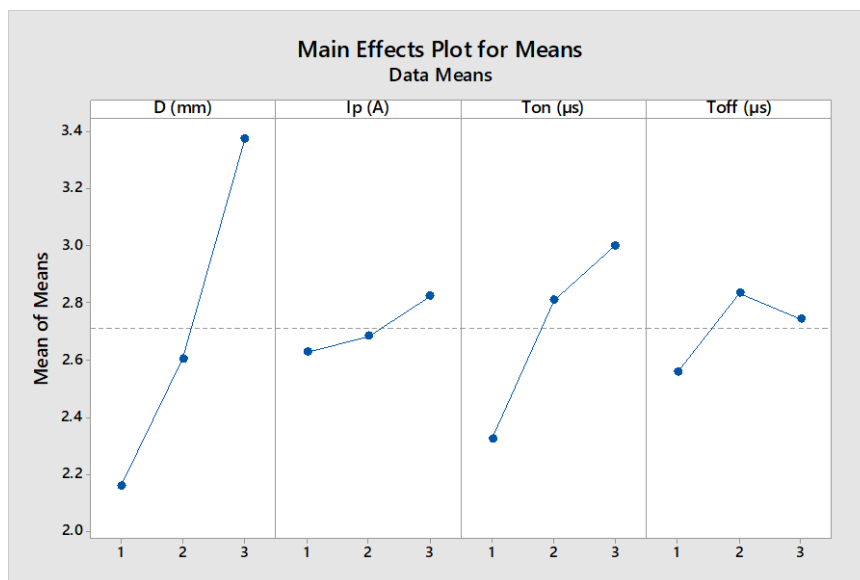


Figure 3. Mean effect plot for surface roughness.

The Fig.3 shows the effect of machining parameters on the SR. minimum value of SR is desire in the experimentation. On increase in the diameter SR value increases, and minimum SR was found on factor level 1 corresponding (dia.3mm). On increase in peak current discharge energy increase the value of SR, and minimum SR was on the level 1(20 A). On increase in T_{on} , value of SR increases, and minimum at level 1 (150µs). On increase in T_{on} duration of large energy discharge increases so this discharge energy create large crater on the surface, increases the value of SR. The effect of T_{off} gives that from factor level 1 to 2, initial the SR value increase and then decrease a little bit, it is because on increase in off time, flushing of debris particle improved so SR value decreases. Minimum value of SR was found on level 1 (45 µs).

3.2 Multi- response optimization using Entropy integrated VIKOR method

Basic steps of Entropy integrated VIKOR method was discussed in previous section, initially the subjected weight was calculated by the Entropy method (Eq. 2-4) after that these were utilised in the VIKOR method. This integration reduces the vagueness of the decision makers in the decision. In this work two conflicting criteria (MRR and SR) was optimize using this technique. Weight calculated by the Entropy method was 0.95 and 0.05 for MRR and SR respectively. Entropy weight then utilized in VIKOR method, Table 3 shows regret measure and utility measure with VIKOR index (Q_i). Minimum value of VIKOR index gives the best possible compromised solution.

Table 3. Result obtained by Entropy integrated VIKOR method with ranks.

Exp. No.	Response parameters		Normalized matrix(D)		Utility measure S_i	Regret measure Re_i	VIKOR index Q_i	Entropy integrated VIKOR Ranks
	MRR (mm ³ /min)	SR (µm)	MRR	SR				
1	0.026	1.53	0.094	1.000	0.861	0.861	0.893	7
2	0.061	2.35	0.300	0.622	0.684	0.665	0.694	3
3	0.119	2.59	0.641	0.512	0.365	0.341	0.351	2
4	0.034	2.65	0.141	0.484	0.842	0.816	0.859	6
5	0.025	2.71	0.088	0.456	0.893	0.866	0.914	8
6	0.010	2.45	0.000	0.576	0.971	0.950	1.000	9



7	0.180	3.70	1.000	0.000	0.050	0.000	0.000	1
8	0.040	2.99	0.176	0.327	0.816	0.782	0.828	5
9	0.065	3.43	0.324	0.124	0.791	0.643	0.741	4

The experiment which have minimum value of VIKOR index have highest ranks. A plot for VIKOR index with experiment no. was shown in the Fig.4. From the plot, experimentation no. 7 was found most suitable, so it was given to highest rank 1. It means that process parameters corresponding to experiment no 7 was best process parameters for maximum MRR and minimum SR.

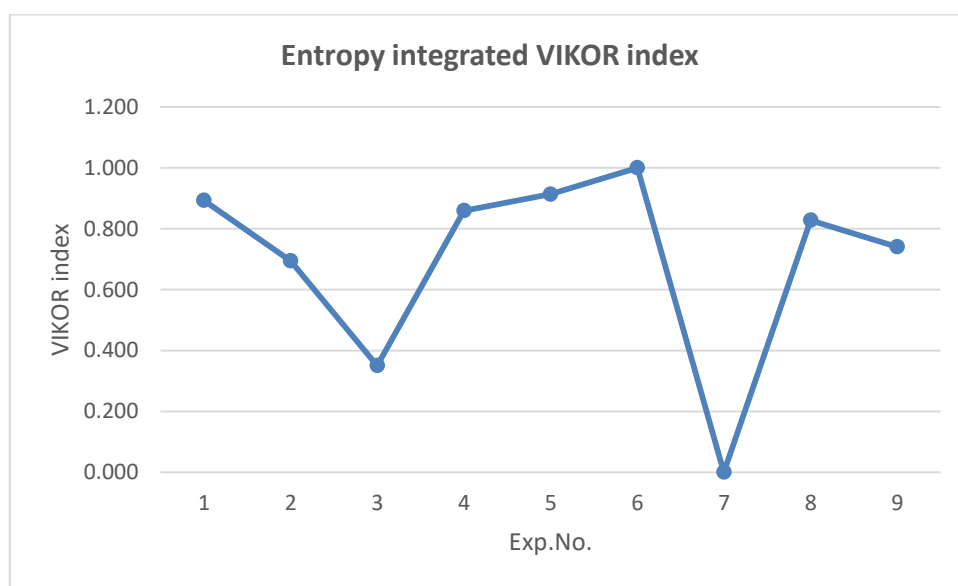


Figure 4. Plot for VIKOR index with Exp. Number.

A confirmation test was performed on best process parameters suggested by the Entropy integrated VIKOR index (D- 7mm, I_p - 20A, T_{on} - 350 μ s, T_{off} - 30 μ s). The error between experimental result and confirmation test result is 5.56 and 8 % for MRR and SR respectively (Table 4).

Table 4. Confirmation tests performed on optimal process parameters.

Sr. No.	Optimal Machining Parameters					
	D mm	I_p A	T_{on} μ s	T_{off} μ s	MRR mm^3/min	SR μ m
1	7	20	350	30	0.170	3.404
				Error (%)	5.56%	8%

IV. CONCLUSION

The response parameters, i.e. MRR and SR was explored considering along with changing machining parameters on work material Ti-6Al-4V Alloy. The copper tool with 3, 5, 7mm diameter has been used as an electrode in EDM along with I_p 20, 40 and 60A, T_{on} - 150, 250 and 350 μ s, T_{off} - 15, 30 and 45 μ s. on the base of experimentation, the following conclusion was drawn.

- Taguchi L9 orthogonal array has been used for experimental design.
- The machining parameters T_{on} have highest impact on the MRR follower by dia. (D), T_{off} and I_p .
- The machining parameters dia. (D) have highest impact on SR follower by T_{on} , T_{off} and I_p .
- Experiment no 7 have found most suitable by the multi-response optimization analysis (Entropy integrated VIKOR method)
- Average error in the experimentation (6.78%) was less than 15%, so it is in considerable limit.



REFERENCES

1. Jovane F, Yoshikawa H, Alting L, Boer CR, Westkamper E, Williams D, Tseng M, Seliger G, Paci AM. The incoming global technological and industrial revolution towards competitive sustainable manufacturing. *CIRP Annals - Manufacturing Technology*. (2008) 57(2):641-659.
2. Jawahir I.S., Brinksmeier, E., M'Saoubi, R., Aspinwall, D.K., Outeiro, J.C., Meyer, D., Umbrello, D., Jayal, A.D. Surface integrity in material removal processes: Recent advances, *CIRP Annals - Manufacturing Technology* 60:(2011): 603- 626.
3. Jayal AD, Badurdeen F, Dillon Jr OW, Jawahir IS Sustainable Manufacturing: Modeling and Optimization Challenges at the Product, Process and System Levels. *CIRP Journal of Manufacturing Science and Technology*. (2010) 2(3):144-152.
4. P. Bleys, J. Kruth, B. Lauwers, A. Zryd, R. Delpretti, C. Tricarico, *CIRP Annals-Manufacturing Technology* 51 (1) (2002)157-160.
5. A. Perumal, A. Azhagurajan, S. Baskaran, R. Prithvirajan, P. Narayanasamy, *Mater. Res. Express* 6 (5) (2019) 056552.
6. J.Z. Li, F.H. Shen, Z.Y. Yu, W. Natsu, Influence of microstructure of alloy on the machining performance of micro EDM, *Surface & Coatings Technology*, 228 (2013) 460-465.
7. J.Strasky, M Janeceketc, Electric discharge machining of Ti-6Al-4V alloy for biomedical use WDS'11, *Proc. of Contri*, 3 (2011) 127-131.
8. V. Verma, R. Sahu, Process parameter optimization of die-sinking EDM on Titanium grade – V alloy (Ti6Al4V) using full factorial design approach, *Materials Today: Proceedings*, 4 (2017) 1893-1899.
9. M. Priyadarshini, K. Pal, Grey -taguchi based optimization of EDM process for titanium alloy, *Mater. Today Proc.* 2 (4-5) (2015) 2472-2481.
10. Tripathy S., Tripathy D.K., Multi-attribute optimization of machining process parameters in powder mixed electro-discharge machining using TOPSIS and grey relational analysis, *Eng. Sci. Technol., Int. J.* 19 (2016) 62–70.
11. Kuldip Singh Sangwan, Sachin Saxena, Girish Kant, Optimization of machining parameters to minimize surface roughness using integrated ANNGA approach, *The 22nd CIRP conference on Life Cycle Engineering, Procedia CIRP* 29 (2015) 305–310.
12. Kumar A., Soota T., Kumar J. Optimisation of Wire-cut EDM Process Parameter by Grey-based Response Surface Methodology. *J. Indu. Eng. Int.* 2018, 14(4), 821–829. 10.1007/s40092-018-0264-8.
13. Deng, H., Yeh, C. H., & Willis, R. J. (2000). Inter-company comparison using modified TOPSIS with objective weights. *Computers & Operations Research*, 963-973.
14. Kumar J., Soota T., Rajput SK., Saxena KK. Machining and optimization of Zircaloy-2 using different tool electrodes. *Mater. Manuf. Process.* 2021. 10.1080/10426914.2021.1905829
15. Majumdar, G., Biswas, N., Pramanik, A., Sen, R. S., & Chakraborty, M. (2017). Optimization of mass deposition and surface roughness for ternary Ni-Cu-P electroless coating using VIKOR method. *Advances in Materials and Processing Technologies*, 186-195.
16. Anish Nair, P. Govindan, H. Ganesan, A comparison between different optimization techniques for CNC end milling process, 12th Global Congress On Manufacturing And Management, Gcmm 2014 *Procedia Engineering* 97 (2014) 36–46.
17. Khare, S.K., Agarwal S., Optimization of machining parameters in turning of AISI 4340 steel under cryogenic condition using Taguchi technique, *The 50th CIRP Conference on Manufacturing Systems, Procedia CIRP.* 63 (2017): 610–614.



INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.118



ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 **9940 572 462**  **6381 907 438**  **ijirset@gmail.com**



www.ijirset.com

Scan to save the contact details