International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-07, Issue-01, APR 2021

Machining of Titanium Grade 2 by using Unconventional Machining Process

Mr. S. Rajadurai, Asst. Prof, Loyola Institute of Technology, Palanchur, Chennai, India
Mr. K. Thanigavelmurugan, Asst. Prof, Loyola Institute of Technology, Palanchur, Chennai, India
Mr. S. Arun Nivas, Loyola Institute of Technology, Palanchur, Chennai, India
Mr. P. Rajkumar, Loyola Institute of Technology, Palanchur, Chennai, India
Mr. L. Yazeen Ahemed, Loyola Institute of Technology, Palanchur, Chennai, India

Abstract--- **Titanium Grade 2 is a most common grade of the commercially pure titanium in manufacturing industry. This grade of titanium is the low elastic modulus of Titanium allows relatively large deflections of the work piece, which affect adversely the tool life. In this paper we study the machinability aspects of titanium grade 2 (commercially pure titanium). Titanium and its alloys are among the most difficult materials to machine, mainly because of the metal reactivity at medium to high temperatures. It has outstanding corrosion resistance and useful strength (similar to austenitic stainless steels) at low density. It has good ductility, light weight, non-magnetic, excellent welding properties and has excellent resistance to oxidation and corrosion and is easily formable. It is the most commonly used in heat exchangers, where in spite of the low thermal conductivity of titanium and the efficiency of heat transfer is high due to good strength, fouling resistance of the hard and smooth surfaces.**

Keywords —low elastic modulus, machinability, titanium grade 2, tool life,

I. INTRODUCTION

1.1 CONVENTIONAL MACHINING

A technique in which raw material is cut into desired final shape and size in a controlled manner is called as machining. The basic feature of conventional machining is that there is a direct contact between the tool and work piece. This means that the tool has to be harder than the work piece. Machining operation which uses a sharp cutting tool to obtain the required geometry is called as conventional machining.

1.2 UNCONVENTIONAL MACHINING

A special type of machining process where there is no direct contact between the tool and the work piece is known as Non-conventional machining or non-traditional machining. Non-conventional machining uses a form of energy for material removal. Based on this form of energy, non-conventional machining can be classified as shown below:

i. **Mechanical processes:** Here material removal is achieved by abrasion and shearing.

ii. **Thermal processes:** In these processes, material removal is due to thermal energy which leads to the melting and evaporation of work piece material.

iii. **Chemical and electrochemical processes:** In chemical processes, material is removed from the work piece as result of ablative reaction. On the other hand, in electrochemical processes, material removal occurs due to anodic dissolution.

1.3 WIRE CUT ELECTRICAL DISCHARGE MACHINING (WEDM)

A non-conventional machining process which allows a thin strand of metal wire to machine through the work piece in presence of a dielectric fluid (used to conduct electricity) is known as wire cut electrical discharge machining (WEDM). In this process, material removal is obtained by heat generated due to electrical sparks. The generated heat vaporizes the material and removes it as debris.

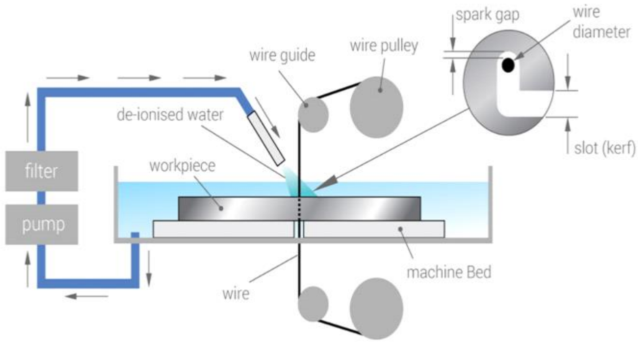


Fig1.1 Wire Cut Electrical Discharge Machining setup

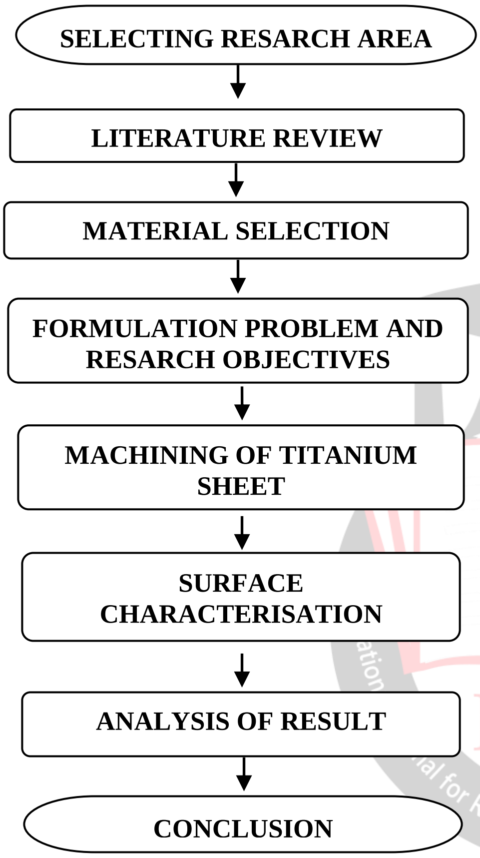
 DOI : 10.35291/2454-9150.2021.0146

1.4 CHEMICAL COMPOSITION

Table 1.1 chemical composition

Element	Content%
Titanium (Ti)	≥ 98.9
Iron (Fe)	≥0.30
Oxygen (O)	≥0.25
Carbon (C)	≥0.080
Nitrogen (N)	≥0.030
Hydrogen (H)	≥0.015

II. METHODOLOGY



III. EXPERIMENTAL WORK

3.1 WIRE CUT EDM SETUP

The work piece that was machined in this wire EDM setup as shown in figure 3.1 is TITANIUM sheet. The model of the wire EDM setup used is maxicut-e. The wire used in this setup is zinc-coated brass wire with the diameter of 0.25mm. The dielectric fluid is demineralized water. The work piece that was cut has a width of 0.6mm.

Fig 3.1 WIRE CUT EDM SETTUP

3.1.1 STEPS IN WIRE EDM MACHINING

i. The wire was made aligned 90 degrees with the help of a vertical block.
ii. The work piece was mounted using fixture and then using a dial indicator to make work piece horizontally 90 with work table.
iii. A reference point on the work piece was set for setting work coordinate system (WCS).
iv. The programming was done with the reference to the WCS.
v. The reference point was defined by the ground edges of the work piece.
vi. The program was made for cutting operation of the work piece.

3.1.2 WIRE-CUT EDM SPECIFICATION

Table 3.1: Wire EDM Specifications

S.NO	DESCRIPTION	SPECIFICATION
1	Equipment	CNC Wire cut EDM machine
2	Accommodating job size	400 x 500 x 200 mm
3	Maximum taper cutting angle	+/- 30deg on 50 mm job height
4	Wire diameter	0.25 mm
5	Maximum wire spool capacity	6 kg
6	Maximum cutting speed	120 mm/min
7	Best surface finish	0.8 μ Ra
8	Simultaneously controlled axes	X, Y, u, v
9	Minimum resolution X, Y, u, v axes	0.001 mm
10	Precision LM guides for	X, Y, u, v axes
11	Dielectric fluid	Deionized water
12	Tank capacity	250 liters

The specifications of the maxicut wire cut EDM setup is as shown in above table 3.1

3.2 TAGUCHI METHOD

The Taguchi method optimizes design parameters to minimize vibration before optimizing design to hit mean target values for output parameters. The Taguchi method uses special orthogonal arrays to all the design factors with minimum of experiments.

3.2.1 DESIGN OF EXPERIMENT (DOE)

From the outcomes of literature review, it is understood that the process parameters which made significant impact on

 DOI : 10.35291/2454-9150.2021.0146

ISSN : 2454-9150 Vol-07, Issue-01, APR 2021

the performance are wire tension (WT), pulse on time(Ton), pulse off time(Toff). The experiments were conducted as the Taguchi's L_9 orthogonal array with Grey Relational Analysis. The levels of the process parameters and their orthogonal array with process parameter values are given in Table 3.3 and 3.4. The optimum value of grey relational analysis is calculated in table 3.5.

Table 3.2 list of abbreviations

1	**Ton**	**PULSE ON TIME**
2	**Toff**	**PULSE OFF TIME**
3	**WF**	**WIRE FEED**
4	**WT**	**WIRE TENSION**
5	**MRR**	**MATERIAL REMOVAL RATE**
6	**SR**	**SURFACE ROUGHNESS**
7	**HRA**	**HARDNESS**

Table 3.3: WEDM Process Parameter Table for Taguchi Method and Grey Relational Analysis

S NO	PARAMETER	LEVEL 1	LEVEL 2	LEVEL 3
1	Pulse-on time (Ton) µs	**1**	**2**	**3**
2	Pulse-off time (Toff) µs	**8**	**9**	**10**
3	Wire feed (F) m/min	**1**	**2**	**3**
4	Wire tension (WT) N	**300**	**400**	**600**

Machining operation was done on 2 mm thick TITANIUM sheet using a zinc coated brass wire. Spark voltage was set at a constant value of 6. Servo speed was set at a constant value of 4. Electrode gap was set at 0.5 mm and the Z-Axis was at 30 mm.

Table 3.4: Taguchi's L_9 Orthogonal Array with grey relational analysis and Process Parameters Values

EX NO	T ON	T OFF	(WF)	(WT)	MRR	RA	HRA
1	1	10	1	300	20.67	1.66	380
2	1	9	2	400	17.40	1.49	422
3	1	8	3	600	19.94	1.38	471
4	2	10	2	600	18.57	1.30	522
5	2	9	3	300	12.79	1.54	489
6	2	8	1	400	19.51	2.30	422
7	3	10	3	400	16.11	1.70	412
8	3	9	1	600	13.90	1.89	427
9	3	8	2	300	20.84	1.79	437

3.3 GREY RELATIONAL ANALYSIS

Grey theory is an essential uncertain knowledge acquisition method for small sample, poor information. The classic grey theory does not adequately take into account the distribution of data set and lacks the effective methods to analyze and mine big sample in multigranularity. Grey clustering is a method to divide some observation index or object into several undefined categories according to the grey number relational matrix or whiten weight function of grey number. Finally, experiments fully prove that it is an effective knowledge acquisition method for big data or multigranularity sample.

Table 3.5: OPTIMUM LEVEL

S NO	PARAMETER	LEVEL 1	LEVEL 2	LEVEL 3
1	Pulse-on time (Ton) µs	0.43153	**0.64748**	0.48747
2	Pulse-off time (T off) µs	0.50338	0.49698	**0.56612**
3	Wire feed (F) m/min	**0.54352**	0.52689	0.49607

The optimum level is 2 3 1 and its corresponding surface roughness (Ra) value is 2.30 and Hardness (HRD) value is 422. At the experiment number 6 the machining of titanium is more efficient.

IV. RESULTS AND DISCUSSION

4.1 MACHINED WORK PIECE

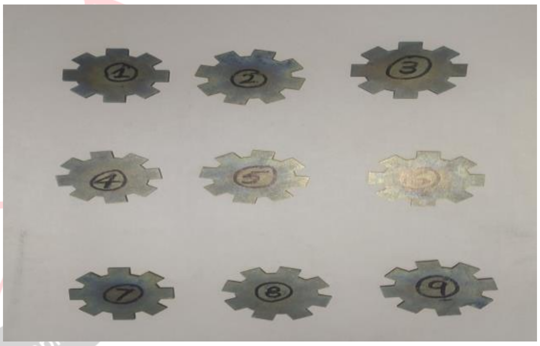


Figure 4.1 Machined Work Piece in WEDM

4.2 HARDNESS TEST

The basic principle, as with all common measures of hardness, is to observe a material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness tests.

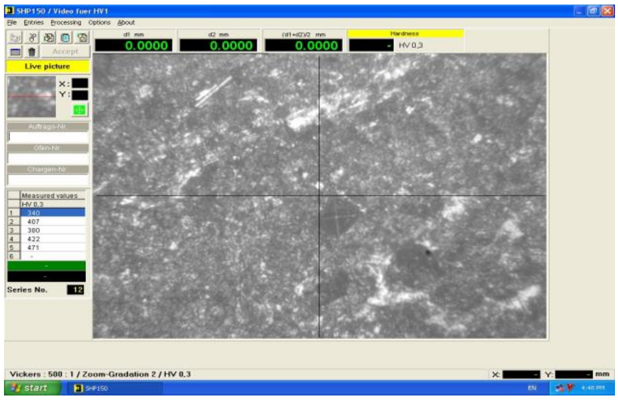


Figure 4.2 Hardness images corresponding to (ex no 3) in table 3.5

DOI : 10.35291/2454-9150.2021.0146

ISSN : 2454-9150 Vol-07, Issue-01, APR 2021

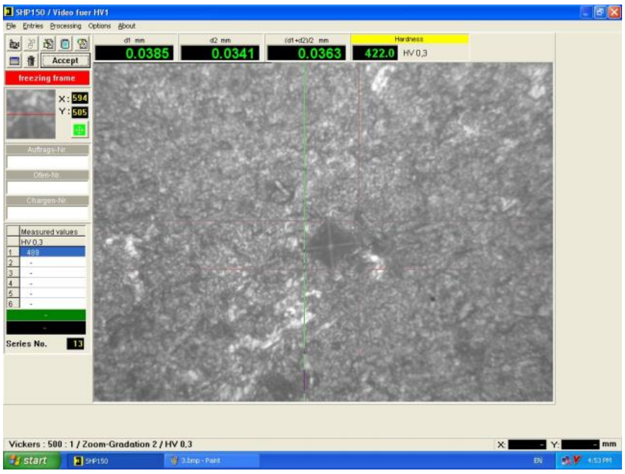


Figure 4.3 Hardness images corresponding to (ex no 6) in table3.5

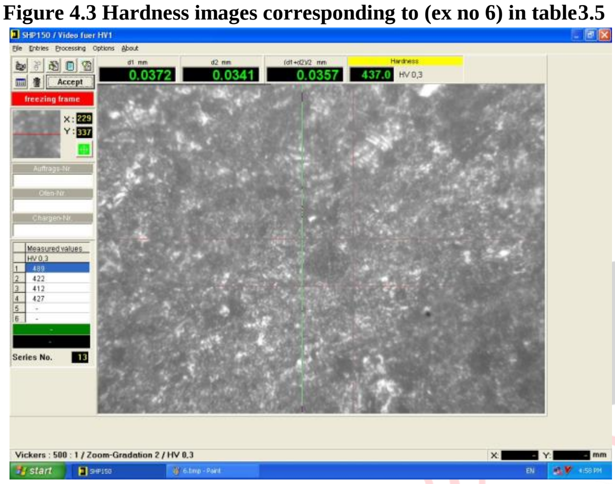


Figure 4.4 Hardness images corresponding to (ex no 9) in table 3.5

4.3 EFFECT OF WIRE TENSION ON TITANIUM SURFACES

Increase in wire tension reduces the transversal vibrations on the wire which cause homogeneous spark erosions and leads to increase in MRR. As a result, these surfaces showed more disorientation.

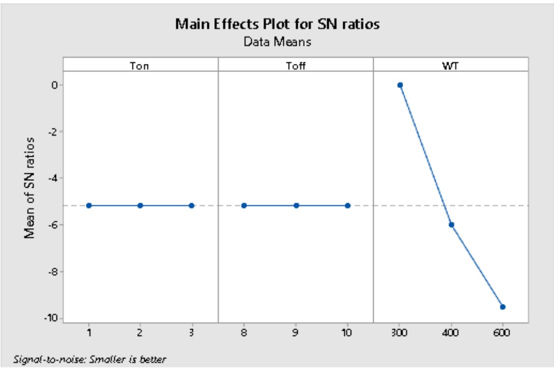


Figure 4.5 Effect Graph of Wire Tension

4.4 EFFECT OF WIRE FEED ON TITANIUM SURFACES

As wire feed increases the speed at which wire moves increases, which causes faster melting and evaporation of the material leading to deep penetration on surface of material. When wire feed is increased, the amount of discharge energy also increases and the TITANIUM starts melting which provides large gap for flushing of material hence MRR increases.

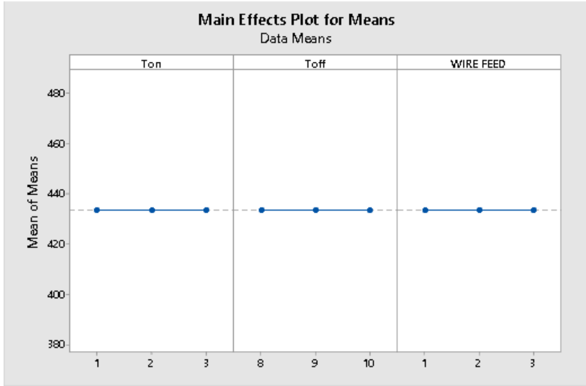


Figure 4.6 Effect Graph of Wire Feed

4.5 MAIN EFFECT PLOT FOR MRR

The rate of stock removal depends on the amount of spark energy, flow of electrons and frequency of sparks, which erodes larger amount of metal through melting and vaporization process. MRR value obtained with normal wire electrode is low as compared with cryogenic treated wire electrode. This is due to additional energy expanded to the process, which is provided by more electron emission due to high conductivity cryogenic treated wire.

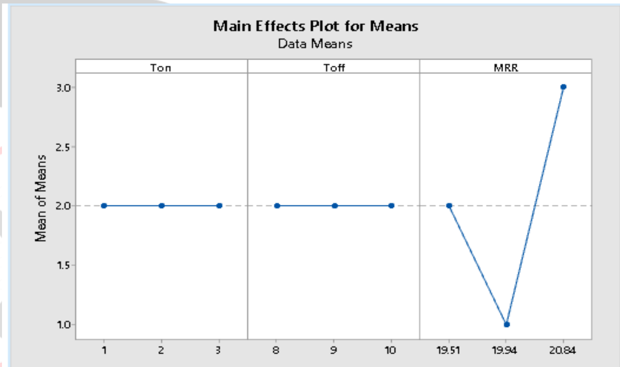


Figure 4.7 Effect plots Graph of Material Removal Rate (MRR)

4.6 MAIN EFFECT PLOT FOR SURFACE ROUGHNESS

The Surface Roughness increases with increase in discharge current and pulse on time. This is due to more spark energy generates higher current density which erodes larger material and surface layers, .that after each pulse on time, the bubbles that are formed, explode and ejects the material from work surface, creating large and deep craters. These craters have surface irregularities resulting in increased surface roughness.

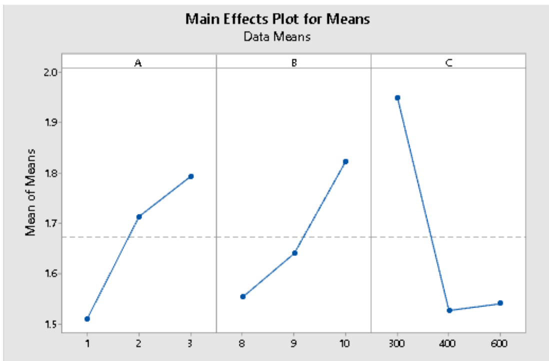


Figure 4.8 Effect Plot Graph for Surface Roughness (SR)

DOI : 10.35291/2454-9150.2021.0146

V. CONCLUSION

The analysis of Titanium machined surfaces at different conditions using wire EDM setup gives us the following conclusions:

I. As pulse on time increases more discharge energy is generated, which causes melting and evaporation of the material leads to deep penetration on surface of material.

II. With increase in pulse off time the amount of discharge energy decreases which leads to decreases in amount of material removed, hence there is less change in MRR with increase in pulse off time.

III. Increase in wire tension reduces the transversal vibrations on the wire which cause homogeneous spark erosions and leads to increase in MRR.

IV. As wire feed increases the speed at which wire moves increases, which causes faster melting and evaporation of the material leading to deep penetration on surface of material

ACKNOWLEDGMENT

Thanks to god almighty for bringing us to completion of our course. We express our sincere thanks to our beloved chairman Rev. Fr. Dr. J. E. ARUL RAJ, OMI, for providing immense facilitate in our institution.

We thank to our correspondent Rev. Sr. TERESA for establishing all the facilities to complete our project.

We render our respected principal, Dr. SUJATHA ANAND, M.E., Ph.D., for the encouragement given towards the progress and the completion of our project work,

We present and place on record our gratitude to the Head of the Department Dr. BALAJI. V, M.E., Ph.D., for his effective leadership and guidance in the project work.

Our heartfelt thanks to our guide Mr. RAJADURAI, M.E., for his valuable ideas, encouragement and supportive guidance throughout the project work.

We wish to acknowledge the help received from the lab assistant of our department and various individuals during fabrication of the project work.

REFERENCES

[1] Alagarsamy S V , Chanakyan C, Dinesh Kumar S , Meignanamoorthy M, Ravichandran M and Sakthivelu S (2020) , 'A Taguchi coupled desirability function analysis of wire cut EDM behaviour of titanium dioxide filled aluminum matrix composite' , Materials Today: Proceedings.

[2] Alessandra Varone , Antonio Gloria , Maria Richetta and Roberto Montanari (2019), 'Journal of Materials science', Alloys for Aeronautic Applications: State of the Art and Perspectives, pp.1-26.

[3] Ravikanth Raju P, Saritha P, Satyadevi A and Swapna Sri N (2018), 'Effect of Zirconium on Mechanical Behavior of Aluminum7075' , International Journal of Science and Research (IJSR), Volume 7, Issue 3, pp.945-948.

[4] Ankit Darji and Vaibhav Kumar Patel (2017) , 'An experimental investigation of wire- edm for aluminum 7075', Global Research for Journal Analysis, Volume-6 Issue-3 , pp. 709-711.

[5] Thella Babu Rao (2016) , 'Optimizing machining parameters of wire-EDM process to cut Al7075/SiCp composites using an integrated statistical approach', Advances in Manufacturing.

[6] Ahilan C and Michael Rajan H B (2016) , 'Optimization of mrr and surface roughness of in-situ formed AA7075/TiB2 composite – grey based taguchi method', International Journal of Chemical Science, Vol (2),pp.1026-1040.

[7] Aruna Devi M, Kishore G C and Prakash C P S (2015) , 'Parametric Optimization of Wire Electrical Discharge Machining by Taguchi Technique on Composite Material', International Journal of Engineering Research & Technology, Vol. 4 Issue 09, pp.407-412.

[8] Arpit Kumar, Husain Mehdi and Vipin Kumar (2015) , 'Effect of Silicon content on the Mechanical Properties of Aluminum Alloy', International Research Journal of Engineering and Technology (IRJET), Volume:2, Issue:4, pp.1326-1330.

[9] Arshad N Siddiquee, Shyam Lal , Sudhir Kumar and Zahid A Khan (2014) , 'Multi-response optimization of wire electrical discharge machining process parameters for Al7075/Al2O3/SiC hybrid composite using Taguchi-based grey relational analysis', Journal of Engineering Manufacture.

[10] Anwar Khan A R , Mohammed Imran (2019), 'Characterization of Al-7075 metal matrix composites: a review', Journal of Materials Research and Technology, pp 3347-3356.

[11] Ankit Darji , Vaibhav Kumar Patel (2017), 'An experimental investigation of wire - edm for aluminum 7075', Global Research for Journal Analysis, Volume-6 Issue.

[12] Gohil A V , Pujara J M (2015) , 'Optimization of Process Parameters in Wire Electrical Discharge Machining of MMC: A Review', Int. Journal of Engineering Research and Applications, Vol. 5, Issue 7, (Part - 2), pp.34-41.

[13] Aykut Özbölük, Ceyhun Karpuzoğlu, Emre Öksüz K, Hanlar Bağırov, Hayrettin U. Bilgin, Mehmet Şimşir, Yusuf Z. Demirhan (2013), 'Investigation of Mechanıcal Propertıes and Mıcrostructure of AA2024 and AA7075', Applied Mechanics and Materials, Vol 390, pp 547-551.

[14] S. Oliver Nesa Raj & S. Prabhu (2016) , "Modelling and analysis of titanium alloy in wire cut EDM using Grey relation coupled with principle component analysis", Australian Journal of Mechanical Engineering, Vol:1448,Issue :4846.

[15] Vijay D. Patel, Dr.D.M.Patel, Prof. U.J.Patel , Biraj Patel , Nilesh Butani (2014), "Review of Wire-Cut EDM Process on Titanium alloy" , Int. Journal of Engineering Research and Applications, Vol. 4, Issue 12, pp.112-121.

[16] Paaka Vidyanand Sai, Samatham Madhukar , Malis Krishna Prasad Reddy, N V S Ramachandra Rao(2017), "A Review on Machinability Aspects of Titanium Grade-2", The International Journal of Scientific Research in Science, Engineering and Technology, Volume 3, Issue 2, pp: 270-275.

 DOI : 10.35291/2454-9150.2021.0146