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"Non-conventional machining of composite metals with multi-target optimization to improve efficiency"

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Abstract: *In this paper, non-conventional machining process has been optimized. When we have seven NCMP method as criteria available for a composite metal, we have to choose the best NCMP method, then a decision making task is required. When we have five alternatives available for seven criteria, this task becomes even more difficult. Now we have to decide how to optimize these seven criteria for decision making for five alternatives. For this, Moora method was used to select the best. To validate these results, TOPSIS method was used. The best NCMP method ECM was found by Moora Technique and the rank of all the seven NCMP methods was selected. The same rank was also found by the TOPSIS. In this, material removal rate, tolerance, surface finish, surface damage and corner radius were considered as alternate.*

Key Words: *NCMP, composite material, MOORA, TOPSIS, Material removal, Surface finish.*

1. INTRODUCTION:

Non-conventional Machining is used in the industry to make various types of dies and molds. The main reason for this is high accuracy and surface finish. Various types of non-conventional machining are classified on the basis of principle, accuracy, application, advantages and energy as follows

2. Classification of non conventional process :

Chip less machining operation can be classified based on the type of energy used.

1 Electrical energy

a) Electro chemical Machining
b) Electro chemical Grinding

2 Mechanical Energy.

a) Water jet Machining
b) Abrasive water Jet Machining
c) Ultrasonic Machining

3 Thermal Energy

a) Electric Discharge Machining
b) Electron Beam Machining

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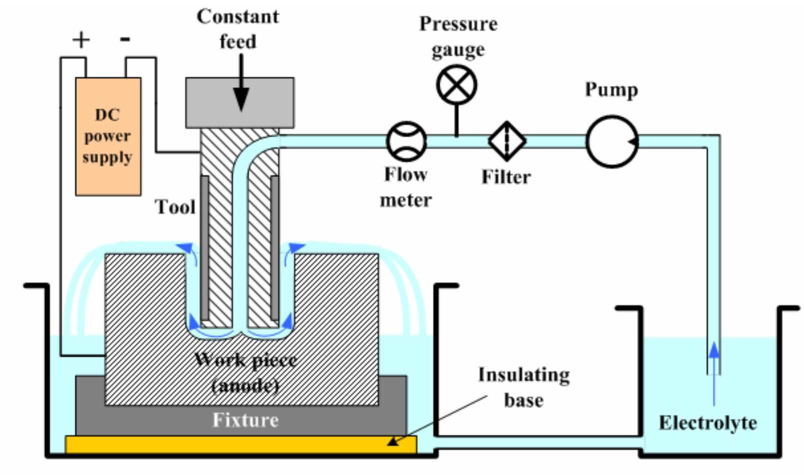
c) Laser beam Machining
d) Plasma Arc Machining

4 Chemical Energy

a) Chemical Machining.

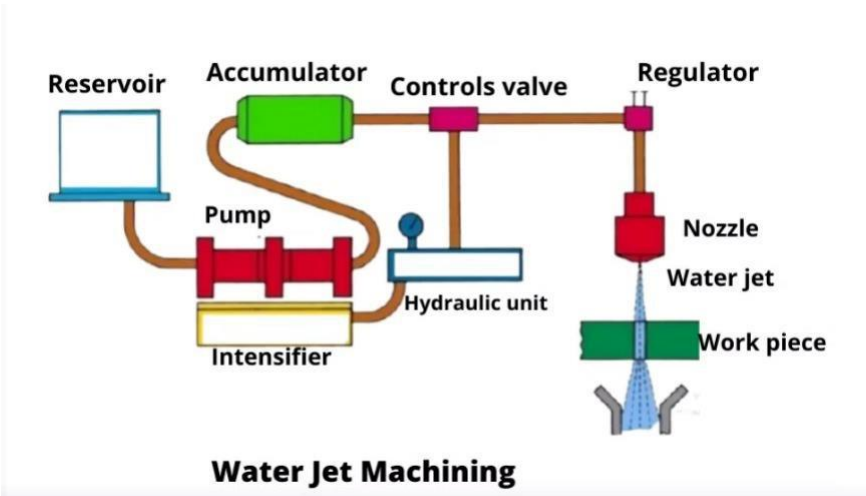
2.1 ELECTRO-CHEMICAL MACHINING

Electrochemical Machining works on the principle of Faraday's Law. In this, we make the same type of tool as the work piece to be made. In this, the tool can be of less hardness but it must be a good electrical conductor. In this, the work piece is made as anode and tool cathode in it. An electrolyte is used for electrolysis, which is recycled with the help of a pump. This method is very useful for precision cutting.



2.2 Water Jet Machining (WJM)

Water jet machining works on the principle of hydraulic turbine. In this, a reservoir is used to supply water. In this intensifier is used to increase pressure of water. The work of accumulator is used for constant flow of water, after this it is sent through a nozzle which does the cutting of metal.



2.3 Abrasive Water Jet Machining (AWJM)

Abrasive Water Jet Machining works on the same principle as Water Jet Machining. To increase the productivity of Water Jet Machining, abrasive particles are mixed with water. In this way, various types of composite materials can be easily machined. It is particularly useful for heat sensitive materials. In this Cutting speeds up to 7.5 meter/minute can be achieved for composite materials.

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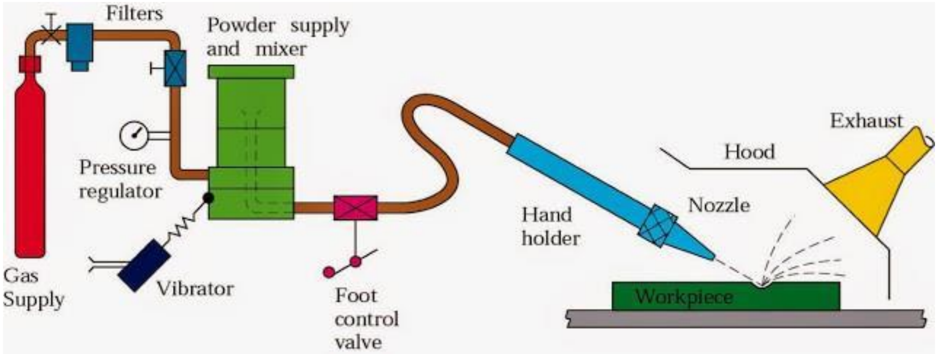
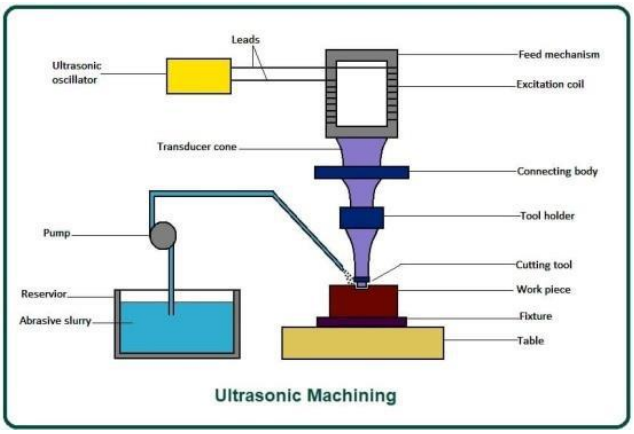


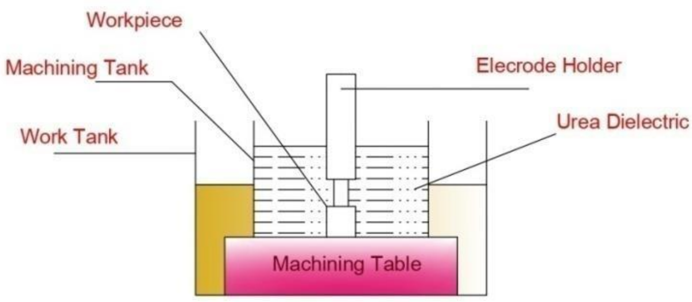
2.4 Ultrasonic Machining (USM)

In ultrasonic machining, mechanical energy is used for machining in the form of vibration. In this, vibrations are created by the transducer. These vibrations are transferred to tool with the help of a connecting body. Through vibration, friction is generated between the work piece and the Tool. Machining of the work piece is done due to friction. The work piece is hold by Fixture which is kept on the table. In this, with the help of a pump, the sullary is continuously supplied to the work piece so that machining can be done.



2.5 ELECTRIC DISCHARGE MACHINING (EDM)

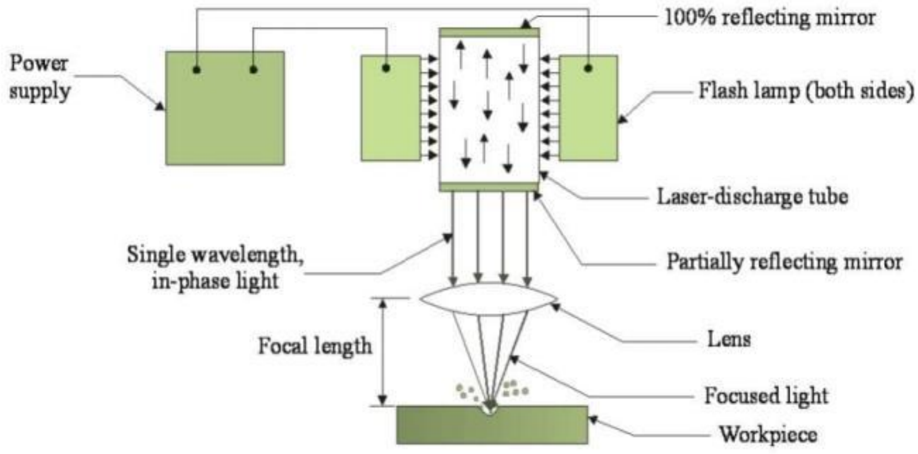
Electric discharge machining works on the principle of reverse of arc welding. In this, the work piece is made anode and the tool is made cathode. A small gap is kept between the work piece and the tool. The small gap is maintained 0.05 mm. The tool and work piece are immersed in a dielectric fluid. When the anode and cathode are connected with a DC voltage, electrons collected between the gaps. The spark causes the focused steam electrons to move at high velocity from the cathode to the anode and then creates a shock wave, due to which the temperature increases up to 10000 degrees centigrade. Due to high temperature, removal of metal occurs and the metal evaporates in the form of a vapors. In this, 50 to 450 DC voltages are used. Current density of 10000 A/cm2 is used. Utility of Electric discharge machining in the industry for making different types of Dies and mould.



Electro Discharge Machining

2.6 LASER BEAM MACHINING (LBM)

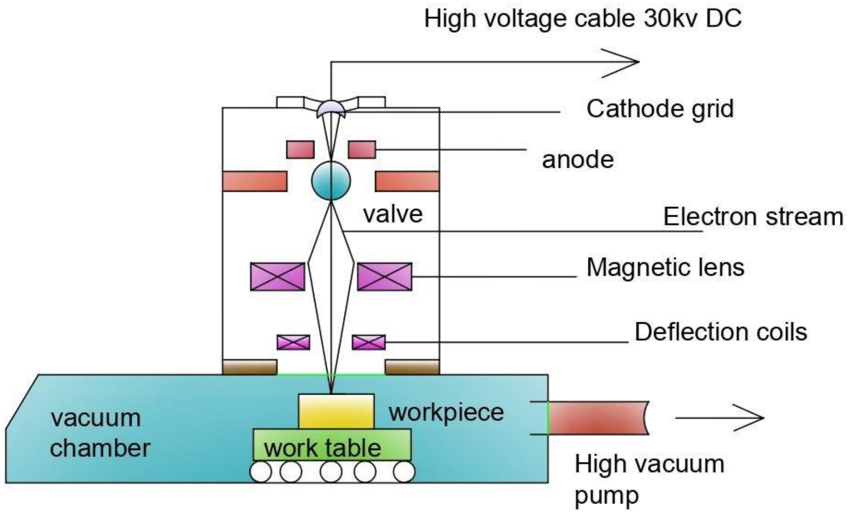
Laser machining is an important machining process of advanced manufacturing method, in which light energy is used for machining. We know each atom have electrons, protons and neutrons. Electrons exist in different energy levels. When they jump from higher energy level to lower energy level. Electrons release the energy in the form of photon. This energy is stimulated in a same face and focused on the work piece. The material can be machined by this focusing energy. Laser – discharge tube is one side partially mirrors and other side 100% reflecting mirror. In this method lens are used to focus light at a focal length.



Laser beam machining schematic

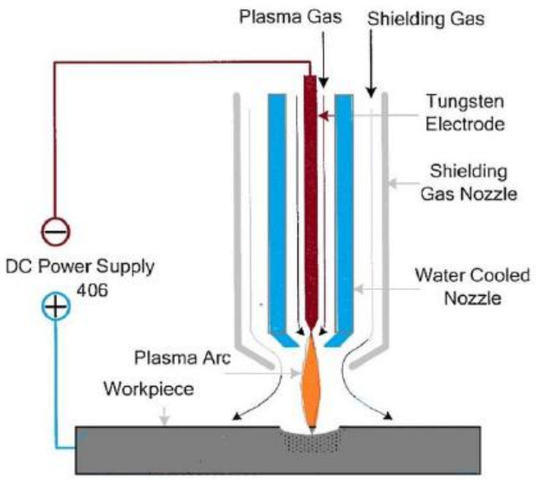
2.7 ELECTRON BEAM MACHINING (EBM)

In this method of manufacturing, the energy of electrons is used for machining. When current is given to a tungsten filament to generate electrons, then electrons are generated in large quantity. This electron steam is focused with the help of magnetic lens and deflection coil. The work piece remains fixed on the work table with fixture. In this method, the work piece requires a vacuum chamber due to which the machining of larger work pieces cannot be done through it, but it can be used for heat sensitive material like PCB.



2.8 PLASMA ARC MACHINING (PAM)

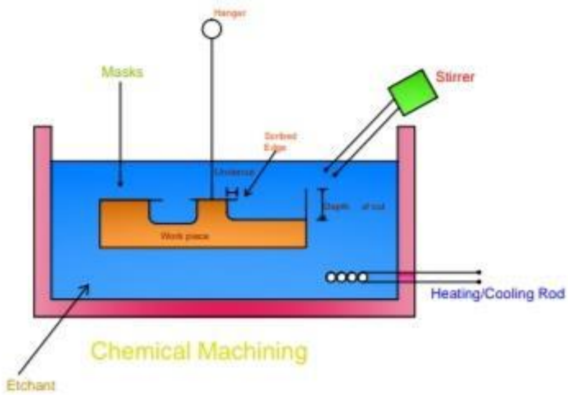
In the plasma method, extremely hot ionized gas is used. Plasma is also called the fourth state of matter. To reach the plasma state, an inert gas like argon is used. In this method, a temperature of up to 15000 degrees centigrade can be achieved. This is enough to melt any composite material, so machining of any hard material can be done easily.



PLASMA ARC MACHINING

2.9 Chemical Machining

In chemical machining, chemical energy is used for machining. First of all, the maskent is placed on the material to be machined. Maskent is removed from a surface where machining is not to be done. Now chemical is placed over the work piece. Now a chemical reaction occurs between work piece and chemical. This method is mainly used by various industries in manufacturing airplane parts and jewelry.



Advantages of Non conventional machining process

1 Material removed without mechanical contact with the work piece.

(ECM, EDM, LBM, CHM)

2 The cutting force does not depend on the hardness of the work piece.

(EDM, ECM, LBM, CHM)

3 The material removal rate does not depend on the hardness of the work piece.

(ECM, EDM, LBM)

4 The material removal rate does not depend on the hardness of the work piece.

(ECM, EDM, LBM, USM, CHM)

5 Tool Wear not a problem

(ECM, LBM, CHM)

6 Any material can be machined

(LBM)

7 Stress free machining

(ECM, ECG, CHM)

8 Burr free machining.
9 Uniform material removed over the entire area simultaneously.
(ECM, CHM)
10 Easy numerical control of machine
11 Micro hole drilling at shallow entrance angle possible.

(EDM, ECM, LBM, EBM)

12 Fine focused micro machining possible.

(EDM, EBM, LBM)

13 Surface integrity is superior.

(ECM, CHM, ECG)

14 Very hard and fragile material can be machined.

(USM)

The following are the characteristics features of non conventional machining process compared with conventional process.

1) Machining is done from the work piece without mechanical contact.
2) In many process removal of metal rate does not of hardness of work.
3) Cutting force is independent of hardness of work.
4) The material of tool does not need to be harder than the material being machined.
5) Almost any material irrespective of its hardness and its strength can be machined.
6) Generally tool wear is negligible hence tool wear is not problem.
7) In most of the cases entire contour or desired shape can be obtained in one stage or one setting.
8) No burr is left on work piece.
9) Non residual stresses are left on the surface.
10) Complex shaped contour and fine machining of precession holes are possible.
11) Non conventional machining methods can be integrated easily with micro processor and numerical control for better control of the process and for improving productivity of machine.
12) In majority of cases surface integrity of surfaces producer by modern machining method is superior.

Process capability of (Source: H.Shan and P.Pandey P.C. (2003) "MMP" 19th Ed.).

NCMP	MRR	Tolerance	Finish	Damage	Radius
USM	300	0.0075	0.0005	0.025	0.025
AJM	0.8	0.05	0.0012	0.0025	0.1
ECM	1500	0.05	0.0025	0.005	0.025
CHM	15	0.05	0.0025	0.05	0.125
EDM	800	0.015	0.0125	0.125	0.025
EBM	1.6	0.025	0.0025	0.25	2.5
LBM	0.1	0.025	0.00125	0.125	2.5

3. LITRATURE REVIEW:

From the literature it has been determined that extraordinary multi-standards choice making (MCDM) strategies were implemented for fixing NCMP choice issues. MCDM is involved with the ones conditions wherein a choice maker has to rank a fixed of aggressive options and pick the great opportunity even as thinking about a fixed of conflicting standards. Aggarwal and Kumar in their research paper used moora method to optimize the electric discharge machining, electrochemical machining, laser machining and abrasive water jet machining , in which machining in abrasive water jet was found to be the best solution and it was found that this technique of non-conventional machining is very good for the environment.[1]. Aggarwal and Kumar in their research paper used non-conventional method and obtained the best solution by considering the criteria mainly like work piece material, temperature of cut, economical work piece thickness, machining accuracy, kerf taper, kerf angle, quality of surface reference etc [2]. Milos and Miroslav in his research paper used various types of traditional methods like ROV method and critical method to find out the best solution for a given material.[3]. Atrey and Kumar in their research paper applied the techniques of Taguchi method in Shriram piston and Ring considering various parameters including speed, feed, and depth of cut, nose radius and surface roughness parameters and optimized these parameters [4]. Painful and Gaurav in their research paper, stainless steel material was optimized by Taguchi techniques to improve the performance on vertical milling machine. In this, the parameters feed, depth of cut, speed, and coolant were optimized through experimental study [5].

4. RESEARCH METHODOLOGY:

Moora Method

Step1: Select the required alternates and criteria for step one.

$X= [x_{ij}]_{mxn}$

Step 2: In the second step, we create a decision matrix in which we take alternatives in the rows and criteria in the column.

$x_{ij}^{*}= = x_{ij}/\sqrt{\sum_{i=0}^{m} \mathbf{xij}}$

Step 3: In Step 3, performance measures are normalized for alternate and criteria.
$Y_i^{*} =\sum_{j=1}^{g} xij^{*} - \sum_{j=g+1}^{n} xij^{*}$
Y_i^{*} is the overall performance

Step 4: In this step, all the beneficial criteria are subtracted from the non-beneficial criteria.
$Y_i^{*}=\sum_{j=1}^{g} wjxij^{*} - \sum_{j=g+1}^{n} wjxij^{*}$

Step 5 Ranking is achieved in this last step in which descending order of assessment values is done and we get the rank.

5. RESULTS & DISCUSSION :

In this novel paper, non-conventional methods were optimized by moora method. In this Ultrasonic, Abrasive Jet Machining, Electrochemical, Chemical, Electric Discharge Machining, Electron Beam Machining, Laser were considered as criteria. MRR, Tolerance, Finish, surface damage, corner radius as alternatives .These results further verified by TOPSIS.

Table 2 Process capability of NCMP (Source: H Shan and P Pandey P.C. (2003) “MMP” 19th Ed.)

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Optimization by MOORA Method

NCMP	MRR	Tolerance	Finish	Damage	Radius
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EBM	1.6	0.025	0.0025	0.25	2.5
LBM	0.1	0.025	0.00125	0.125	2.5

NCMP	MRR	Tolerance	Finish	Damage	Radius
USM	90000	5.63E-05	2.5E-07	0.000625	0.000625
AJM	0.64	0.0025	1.44E-06	6.25E-06	0.01
ECM	2250000	0.0025	6.25E-06	0.000025	0.000625
CHM	225	0.0025	6.25E-06	0.0025	0.015625
EDM	640000	0.000225	0.000156	0.015625	0.000625
EBM	2.56	0.000625	6.25E-06	0.0625	6.25
LBM	0.01	0.000625	1.56E-06	0.015625	6.25
	1726.334	0.095033	0.013351	0.311298	3.539420857

NCMP	MRR	Tolerance	Finish	Damage	Radius	Yi	Rank
USM	10.42672	0.000118	0.000118	0.000402	3.53165E-05	10.42605	RANK3
AJM	7.41E-05	0.005261	0.005261	4.02E-06	0.002825321	-0.01328	RANK4
ECM	260.668	0.005261	0.005261	1.61E-05	0.000176583	260.6573	RANK 1
CHM	0.026067	0.005261	0.005261	0.001606	0.004414564	0.009523	RANK5
EDM	74.14557	0.000474	0.000474	0.010039	0.000176583	74.13441	RANK2
EBM	0.000297	0.001315	0.001315	0.040154	1.765825612	-1.80831	RANK7
LBM	1.16E-06	0.001315	0.001315	0.010039	1.765825612	-1.77849	RANK6

NCMP	RANK
USM	RANK3
AJM	RANK4
ECM	RANK 1
CHM	RANK5
EDM	RANK2
EBM	RANK7
LBM	RANK6

Results verified by Topsis method

NCMP	MRR	Tolerance	Finish	Damage	Radius
USM	300	0.0075	0.0005	0.025	0.025
AJM	0.8	0.05	0.0012	0.0025	0.1
ECM	1500	0.05	0.0025	0.005	0.025
CHM	15	0.05	0.0025	0.05	0.125
EDM	800	0.015	0.0125	0.125	0.025
EBM	1.6	0.025	0.0025	0.25	2.5
LBM	0.1	0.025	0.00125	0.125	2.5

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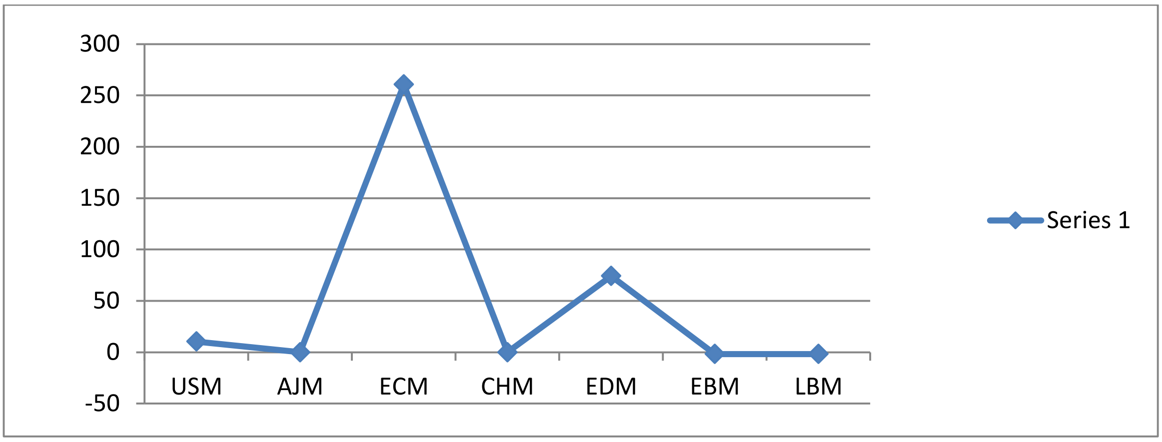
USM	90000	5.63E-05	2.5E-07	0.000625	0.000625
AJM	0.64	0.0025	1.44E-06	6.25E-06	0.01
ECM	2250000	0.0025	6.25E-06	0.000025	0.000625
CHM	225	0.0025	6.25E-06	0.0025	0.015625
EDM	640000	0.000225	0.000156	0.015625	0.000625
EBM	2.56	0.000625	6.25E-06	0.0625	6.25
LBM	0.01	0.000625	1.56E-06	0.015625	6.25
	1726.334	0.095033	0.013351	0.311298	3.539421

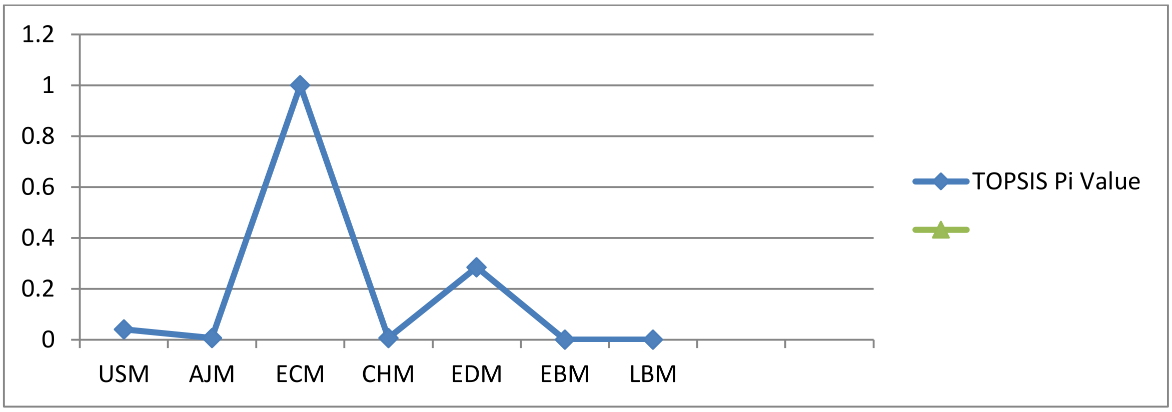
NCMP	MRR	Tolerance	Finish	Damage	Radius	si+	Si-	Si+ +Si-	Pi
USM	10.42672	0.000118	3.75E-06	0.000402	3.53E-05	250.2413	10.5754	260.8167	0.040547
AJM	7.41E-05	0.005261	2.16E-05	4.02E-06	0.002825	260.668	1.764321	262.4323	0.006723
ECM	260.668	0.005261	9.36E-05	1.61E-05	0.000177	0.113139	260.674	260.7871	0.999566
CHM	0.026067	0.005261	9.36E-05	0.001606	0.004415	260.642	1.762888	262.4048	0.006718
EDM	74.14557	0.000474	0.002341	0.010039	0.000177	186.5225	74.16661	260.6891	0.284502
EBM	0.000297	0.001315	9.36E-05	0.040154	1.765826	260.6737	0.055264	260.729	0.000212
LBM	1.16E-06	0.001315	2.34E-05	0.010039	1.765826	260.674	0.062998	260.737	0.000242
Vi+	260.668	0.11838	0.002209	1.61E-05	3.53E-05				
Vi-	1.16E-06	0.005261	0.055216	0.040154	1.765826				

NCMP	RANK
USM	RANK 3
AJM	RANK4
ECM	RANK1
CHM	RANK5
EDM	RANK2
EBM	RANK7
LBM	RANK6

NCMP	RANK
ECM	RANK1
EDM	RANK2
USM	RANK3
AJM	RANK4
CHM	RANK5
LBM	RANK6
EBM	RANK7



GRAPH 1 OF NCPM Vs OPTIMISED MOORA METHOD VALUE.



GRAPH 2 OF NCPM Vs OPTIMISED TOPSIS METHOD VALUES.

5. CONCLUSIONS:

The Moora method is an Excel based simple five step technique that is used to optimize non conventional machining by taking into account seven criteria and five alternates MRR, tolerance, surface finish, surface damage, corner, radius. The results from table and graph Rank one of Electrochemical, Rank 2 of Electric discharge machining, Rank 3 of Ultrasonic Machining, Rank 4 of Abrasive jet marching, Rank 5 of chemical Machining, Rank 6 of Laser and Rank 7 of Electron Beam Machining. To further verify these results TOPSIS method was used. The same rank obtained by Moora method for different processes of non-conventional manufacturing process was also validated by TOPSIS method. In Future the optimized Electro Chemical machining efficiency may be increased by hybrid electrochemical machining with laser.

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