International Journal of Engineering Research and Development
***e**-ISSN: 2278-067X, **p**-ISSN: 2278-800X, www.ijerd.com*
Volume 3, Issue 4 (August 2012), PP. 58-70

EDM Electrodes Manufacturing Using Rapid Tooling Concept

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Abstract—To survive in today's manufacturing environments companies must push the standards of accuracy and speed to the highest levels possible. Electro Discharge Machining (EDM) has been used for over 50 years and recent developments have seen the use of EDM become much more viable. The aim is to produce and evaluate electrodes produced by different manufacturing methods. The new methods of Rapid tooling concept include Net shape casting, Investment casting and Wire Cut EDM processes has only recently become viable methods of producing usable rapid tooling components. The speed and accuracy as well as the cost of manufacture play a vital role in the tool and mould manufacturing process. The Rapid tooling methods offer an alternate option to traditional manufacturing of electrodes.The two methods in which RP (Rapid Prototyping) master pattern is used are Net shape casting and Investment casting processes ,which helps in the preparation of mould and finished electrode. The strategy in both manufacturing methods was different. Wire Cut EDM offers another alternative method that is much cheaper and relatively faster to manufacture. The used of conventional manufacturing method in this paper are compared to the Rapid Tooling electrode manufacturing methods in terms of total time and total cost. The other alternative comparisons shown between the manufacturing methods, according to the material used for electrode with manufacturing parameters are Dimensional accuracy, material removal rate (MRR), electrode wear rate (EWR), and surface roughness(Ra) at standard machining setting. The experimental results of this research are presented in this paper along with conclusions for different methods of electrode manufacture. The major findings of the research include that the CNC Milling electrode manufacturing cost of component is minimized up to six times that of the Rapid tooling manufacturing method electrode. The total manufacturing time is also reduced up to two times of conventional electrode manufacturing time and it depends on the manufacturing methods adopted. Conventional process requires more time with high cost of manufacturing but there is limitation to complex shape of part. It is found that Net shape casting method requires less time for production of electrode but the manufacturing parameters were greatly affected compared with other manufacturing methods. Investment casting method is more advantageous for complex shapes and geometries with good dimensional accuracy and moderate cost of electrode. Wire Cut EDM method has very good dimensional accuracy but it requires maximum time with moderate cost for manufacturing the electrode.

Keywords—EDM Electrodes; Rapid Tooling; Net shape casting; Investment casting; Wire cut EDM

I. INTRODUCTION

To compete in today's industry environment, companies must keep up with the leading technologies and processes and also push the boundaries and develop new and improved products and processes. The Manufacturing Industry is an area where time, efficiency and accuracy are the major driving forces behind innovation and research. The most competitive companies are those who continually reduce process times, increase efficiency and improve accuracy. Rapid Prototyping and Tooling is an area that has continuing to reduce production time and increase efficiency and accuracy in developing and manufacturing prototypes of electrodes compared to traditional prototype manufacture. The main function of Rapid Prototyping is to give the manufacturing the needed confidence to go on to tooling and mass manufacture of the product they have designed. Once the product has met the design criteria through RP it is then needed to meet the functional criteria and that is where Rapid Prototyping has developed and evolved into Rapid Tooling. RP is an extremely useful process but it cannot always provide the manufacturer with a functional prototype in the material of choice. Rapid Tooling can provide this solution giving the manufacturer a functional prototype in the material of choice and that allows functional testing to be done on the product. The use of Rapid Tooling means a reduction in the time-to-market for a product and also better testing to meet functional criteria. Rapid Tooling is also useful in helping start production and getting the product into the market, while the more expensive and durable traditional tool is being produced for the mass manufacture of the product. Therefore the competition lies in researching possible ways to increase the effectiveness of Rapid Tooling and reducing the time and cost of getting the customers product to market. Electro-Discharge Machining is a manufacturing process that has been affected by developments in Rapid Prototyping and Tooling. EDM is commonly used by toolmakers for complex injection moulds, punch dies and cavities made from hardened tool steels. EDM is ideal for materials and complex shapes that traditional machining processes are unable to perform. In die and mould production, the EDM cycle can account for 25 to 40% of the tool room lead-time. The goal is to reduce the accuracy, time and cost of the EDM cycle and to do this, alternate methods of electrode production is a key area of research. Since conception EDM electrodes have been manufactured from solid conductive metals including copper and tungsten, and also from non-metals mainly graphite. Using traditional machining operations in producing complex electrodes from solid copper or graphite may require the production of several smaller electrodes and joining them together, or running several machining cycles to get the required cavity or shape.

Therefore increasing the complexity of the electrode increases the electrode production time and also increases the machining time if several machining cycles are required. Investigation into alternate methods of electrode production is required to reduce cost and time. To gain a good comparison of the various electrode manufacturing methods, the experiments include the use of Net shape casting process, Investment casting process and Wire Cut EDM process for different material tested under constant machining Condition. Rapid Tooling can be employed to produce electrodes with complex shapes that in the past would require the use of several conventional techniques that might include machining, pressing and welding to manufacture a similar electrode. As a different rapid prototyping technology and quick production technology; Net Shape casting, Wire cut EDM, investment casting are used in a flexible system for producing small numbers of parts. When comparing the different electrode manufacturing methods, the performance of the EDM process is measured with respect to Dimensional Accuracy, material removal rate, electrode wear, and surface finish of the workpiece (Ra). In the production of EDM electrodes, many RP processes have been previously used. The most promising process involves the use of stereolithography and producing models as either positive or negative master patterns. Stereolithography (SL) uses information from a computer generated three-dimensional model to produce a solid three-dimensional model from various types of laser-curing polymer resins. The Stereolithography apparatus builds the three-dimensional solid model layer by layer. The computer file is broken down to layers and the SLA reproduces the layer on the surface of the resin. The part is then lowered by the relative layer thickness, and the process is repeated until the completed model is produced. The Stereolithography apparatus used is developed and marketed by 3D Systems Inc, Valencia, California, USA. The machines produce models with high detail and accuracy and have the ability to produce multiple parts simultaneously. Using the positive master pattern is termed as “Direct Rapid Tooling Electrode Manufacture” in that the SL pattern is plated with a conductive material and used as the electrode. Alternatively, using the SL pattern as a negative and removing the solids part is termed as “Indirect Rapid Tooling Electrode Manufacture”. Research in the area of Direct Rapid Tooling Electrode Manufacturing process have shown advantages in that the electrodes are comparable to traditional solid electrodes and electrode production time is reduced as large quantities of electrodes can be produced simultaneously. The results also concluded disadvantages of high tool wear ratio and low material removal rate, and lack of dimensional accuracy. The non-uniform distribution of electrodeposited material resulting in unknown plating thickness, EDM machining time is quite high, the SL master pattern is sacrificial and the electrodes are prone to premature failure if the plating thickness is less than 50 µm. Alternatively the area of Indirect Electrode Manufacture has been researched and developed by Escola Superior de Technologic, Portugal [1].Advantages for using indirect electrode manufacture include relatively low manufacturing cost, multiple electrodes can be produced simultaneously, the master pattern can be reused multiple times and the electrodes can be manufactured to high accuracy and quality. Design group, School of design, Engineering and Computing, Bournemouth University, Bournemouth, UK were also able to show that the performance is comparable to solid electrodes [2]. Laboratory of Tribology and Materials, Faculty from Mechanical Engineering, Federal University of Uberlandia observes an increase of machining velocity and this technique is not advantageous to the electrical discharge machining [3]. In Germany, University of Technology Chemnitz, Department of Manufacturing Engineering mainly concentrates on the extension of the processable materials [4]. It has been shown from a number of case studies that the system has a high potential to reduce further the cycle and cost of die development while minimizing error introduction [5]. Rapid Prototyping and tooling is a continuation from three-dimensional CAD modelling. RP uses the CAD data to produce layer information that is fed into RP machines to produce a three dimensional solid model from a chosen process and material. Common RP processes include Stereolithography, Selective Laser Sintering (SLS), Laminated Object Manufacturing (LOM) and Fused Deposition Modelling (FDM). The majority of RP processes involve the conversion of the CAD data into cross-sectional information and the model is built layer-by-layer [5]. Experiments were performed to determine parameters effecting Surface Roughness (Ra) along with structural analysis of surfaces with respect to material removal parameters [6]. The objective is to study the influence of operating parameters of tungsten carbide on the machining characteristics such as surface quality, material removal rate and electrode wear. It is followed by optimizing the machining condition for confirmation test purposes [7]**.** The scenario of EDM techniques in Malaysian industries based on a survey conducted in a few industries in Selangor area. The extent to which Malaysian industries utilize the global techniques are explored. Current practices on fabricating EDM tools in the required shape and finish are presented. The occupational health problems associated with EDM operators and problems faced by industries in EDM machining are highlighted [8].

To study the proposed second-order polynomial mode for MRR, we used the central composite experimental design to estimation the model coefficients of the three factors, which are believed to influence the MRR in EDM process [9]. An attempt has been made to develop a ZrB_2–Cu composite as an EDM tool material to overcome the poor resistance and dense composite is developed by a pressureless sintering [10].

II. METHOLOGY

With the integration of rapid prototyping and rapid tooling for edm electrode, it is very advantageous and optimum to get electrode with complex shapes including the good manufacturing parameters. Fig. 1 shows a flow chart of manufacturing methology adopted for edm electrode. The physical model of the electrode with Reverse engineering application can be performed on the electrode. The dimensional analysis parameters help in changing the physical appearance of the electrode. The Re-design of the electrode as per the aesthetic looks and ergonomics design is the most important consideration in this paper because the further summary of the manufacturing process and the comparison of electrode based on time and cost are discussed. The modelling of the edm electrode is done on the package of Pro-Engineer Wildfire 4.0 software. This was done more specific and more reliable electrodes and which was accepted. This was followed by two strategies i.e. RP based and W-EDM based. The RP based electrode was distinguished with Net shape casting and Investment casting processes where as the W-EDM based on wire cut EDM part. In RP based electrode strategy, RP pattern is used as the master pattern for EDM electrode. After the strategy was decided, finishing is done on the electrode surface i.e. lapping makes the surface attractive. Finally the machining of manufacturing electrode is done on die-sinking edm machine. The various experiments with different material used for the electrode followed by different manufacturing strategy are performed to get the edm electrode. The comparison was made on the parameters like Cost, time and manufacturing parameters.

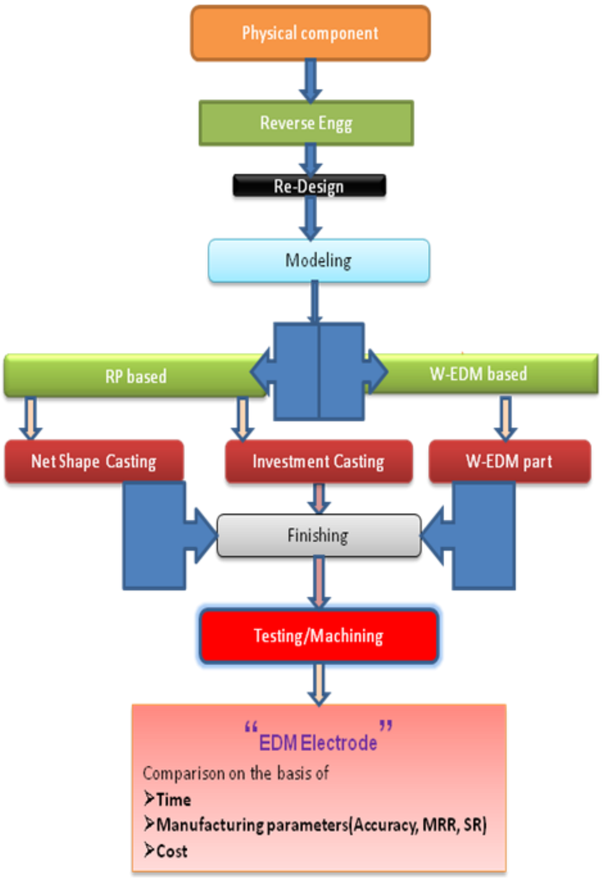

Fig. 1. Flow chart of manufacturing methologies adopted for edm Electrode.

III. EXPERIMENTAL DETAILS

The experiments in this research are based on a similar procedure EDM performance is dictated by the machine parameters and the optimisation of those parameters has been the basis of research by the majority of research groups in the field of EDM. Many researches have used methods such as neural networks and Taguchi method to optimise performance characteristics and machine parameters. A comparison of the three electrodes process (Net shape casting, Investment casting and W-EDM) will be made using the same machining condition and measuring the performance attributes. The performance attributes measured include material removal rate, electrode wear ratio, dimensional accuracy and surface roughness. The electrodes will give the machining on workpiece as fast as possible with the adjustment of jig and fixture in the Edm machine for each manufacturing methology.

Using the same machine parameters for all six electrodes will allow a good comparison to be made. The Percentage deviation (Dimensional Accuracy) can be measured by difference between maximum dimension and minimum dimension to maximum dimension. MRR can be measured by the change in weight or change in volume of the electrode and the work-piece. Determining MMR was measured in grams per minute as it was more accurate to measure change in mass than change in volume with the equipment that was available at the time of the experiments. The mass of the electrodes and work pieces was measured on standard electronic scales which measures before and after the experiment in the range from 0 to 120g. EWR can be measure by weight of the electrode before machining to the weight of the electrode after machining. The measurements can be made by weight and also the use of a coordinate measuring Machine. The Ra is measured using a machine such as a Surface Roughness measuring instrument. The range of the instrument is 350 µm (-200 µm to +150 µm). A several measurements are made on each electrode and test piece to give and average roughness of the whole machined surfaces. The surface roughness is measured to the very fine increments of 0.01µ m. The measuring probe scans a 4mm section of the surface and then determines the average surface roughness.

Measurements for the experiments were made on equipment available but the measurements such as the masses and thickness could have been measured to greater accuracy with more advanced machines. The volume is one method that was unable to be used but if a three dimensional scanner was available it would have been possible to measure the change of volume. The total cost of the electrode through different manufacturing process has to be estimated with the less reduction in the scrap. The total cost includes manufacturing cost and the carrying cost of the electrode material. The detail study helps in reducing the individual cost of electrode i.e. customized EDM electrode in which rapid tooling placed a vital role in the minimizing the cost and time of electrode.

IV. EXPERIMENTAL PROCEDURE

The experimental results compare the performance of the different electrode manufacturing methods at the constant machine settings. The aim is to compare the electrode performance at different material on the electrode from finishing cuts. The constant settings help to use the different material of electrode, so that the depth of cut must be same. This was to prevent the machining time from climbing too high.

4.1 Manufacturing methology no:-1(Net shape casting electrode process)

This methology helps in developing the mould and cast part by RP part as the master Pattern within the last time at optimised cost with good dimensional accuracy. The flow process chart gives the information from the process. In that chart, the various materials are not mentioned which are used for manufacturing the electrode. They are Aluminium, Copper, Copper-Brass and Copper titanium. In copper-brass electrode, the percentage weight of copper and brass is 80:20. The other copper-titanium includes weight proportion of 70:30. The EDM machine is Die-Sinking EDM machine with model no:- VMS P-35A (V- 5030).The workpiece material is constant i.e. High Carbon High Chromium Resistance Steel (HCHCRS) D3 grade plate. The machining has performed on the workpiece with the constant machine parameters (I=9A), depth of cut is 1mm and die-electric fluid used is IT-W grade.

4.1.1. Rapid aluminium electrode manufacturing method

Aluminium electrode is the cheapest material used for manufacturing the edm electrode. The flow chart (fig. 1) shows the various stages used for making the electrodes. The rapidity of the process shows the problems to develop the electrode. The stress releases in the moulding sand in the cavity of electrode should be able to withstand the molten metal flow. In Fig. 2, the manufacturing methology for rapid aluminium electrode are shown. The difference between sand casting and net shape casting manufacturing methods was the master pattern used. Sand casting uses a wooden pattern where as the net shape casting uses a RP pattern. With modern manufacturing methods, RP patterns are widely used in most of the casting industry. The physical model with reverse engineering helps in Re-design the electrode. The Re-design was done on the modelling software. The .stl file format is transfer to RP machine. The RP electrode is ready with the time of 12 min. Then in the foundry, aluminium cast part was obtained by forming mould, mould cavity with molten metal. Then finishing process was done on that electrode. Finally machining was done on the workpiece and results.

4.1.2. Rapid copper electrode manufacturing method

The use of edm copper in mould making is as old as EDM machining itself. Copper is much more common than graphite as an electrode material in Europe and Asia, though this is changing. Copper has many advantages, as well as many disadvantages, when compared to graphite as a material for edm machining. Copper is frequently used to make female electrodes on a Wire EDM for subsequent use in reverse burning punches and cores in the Sinker EDM. The alternative research work carried out to develop the electrode by casting process which is fast and time consuming with good surface finish and cost benefits. The better grades of Copper Tungsten are made by the Press-Sinter-Infiltrate process, which virtually eliminates porosity. The remaining process was same as that of rapid aluminum electrode. Fig. 2 shows the manufacturing methology for rapid copper electrode. Copper is also commonly used for tubing for certain brands of High Speed Small Hole Machines. Copper electrodes are also the preferred material for all High Speed Small Hole applications involving aerospace alloys as well as Carbide.

4.1.3. Rapid copper-brass electrode manufacturing method

Copper-brass electrode leads to the new development of alloys for edm electrode. The copper electrode has good thermal and electrical conductivity which helps in improving the machining parameters with just addition of 20% of weight of brass in electrode. Today almost 90% of all brass alloys are recycled. Because brass is not ferromagnetic, it can be separated from ferrous scrap by passing the scrap near a powerful magnet. Brass scrap is collected and transported to the foundry where it is melted and recast into electrode. The percentage of copper was added to the pouring ladle by measuring scale provided on the outer surface of the ladle by approximation. The rapid Copper-brass electrode gives moderate dimensional accuracy and surface finish. Fig. 2 shows the manufacturing methology for Copper-brass electrode.

4.1.4. Rapid copper-titanium electrode manufacturing method

The rapid Copper-titanium electrode material has the significance of performing the machining to the very hardest material. This combination of two alloys has newly introduced and research in the field was also carried out. The titanium was firstly used as the electrode with the copper alloy to evaluate the various machining parameters and the manufacturing cost and time should be evaluated. As titanium is the hardest material. The time required for manufacturing will almost time taken activity. The electrodes will also more enough to withstand the stress produced during machining. In fig.2, the small cavity was observed from casing to machining is the defect of casting i.e. shrinkage cavity. This copper titanium electrode advances the behaviour of electrode in the casting and machining operation. It is the hardest material after graphite for machining the material like molybdenum, tungsten, and carbide.

4.2 Manufacturing methology no:-2(Rapid Investment casting brass electrode process)

In investment casting, a shape is formed (usually out of RP Pattern) and placed inside a metal cylinder called a flask. Wet plaster is poured into the cylinder around the wax shape. After the plaster has hardened, the cylinder containing the RP pattern and plaster is placed in a furnace and is heated until the wax has fully vaporized. After the RP has fully burnt-out, the flask is removed from the furnace, and molten metal is poured into the cavity left by the RP pattern. When the metal has cooled, plaster is chipped away, and the metal casting is revealed. The material used for the electrode was Brass. One big advantage of raid investment casting is that it can allow for undercuts in the pattern, while net shape casting does not. In Net shape casting, the pattern needs to be pulled out of the sand after it is packed, whereas in investment casting the pattern is vaporized with heat. Hollow castings and thinner sections can also be made more readily with investment casting, and a better surface finish is generally achieved. On the other hand, investment casting is a much more timely and expensive process, and can have a lower success rate than sand casting does since there are more steps in the process and more opportunities for things to go wrong.

The various stages up to the RP pattern were same shown in fig. 1. After the RP Electrode model was generated by RP machine. This model has to be placed in the container. The container is circular of X-ray Sheet which helps in supporting the Slurry mixture. The riser and gating system was developed according to the position of the electrode. The moulding wax is used for riser and gating design. The Zirconium sand or powder has the adhesive property and has the fastest setting property has mixed with chemical agent, stirred it and poured into the container and after sometime, the mixture are hard and removing the X-ray sheet, we placed in the furnace for baking. The maximum temperature in finance was 550°C. While removing from the furnace, the zirconium mixture is cool in the atmospheric air for some time. After that the mould was generated inside the cylinder. The Abs pattern has vaporised inside the cylinder and the cavity appears as same as the master pattern of RP electrode. The mould has to be carried to the foundry and the molten metal was poured inside the cavity. The cast part was obtained by breaking the mould from the outside. Then finishing and testing were carried out on the electrode and also the machining parameters with cost and time are to be calculated. Fig. 2 shows the manufacturing of the brass electrode by Investment casting process.

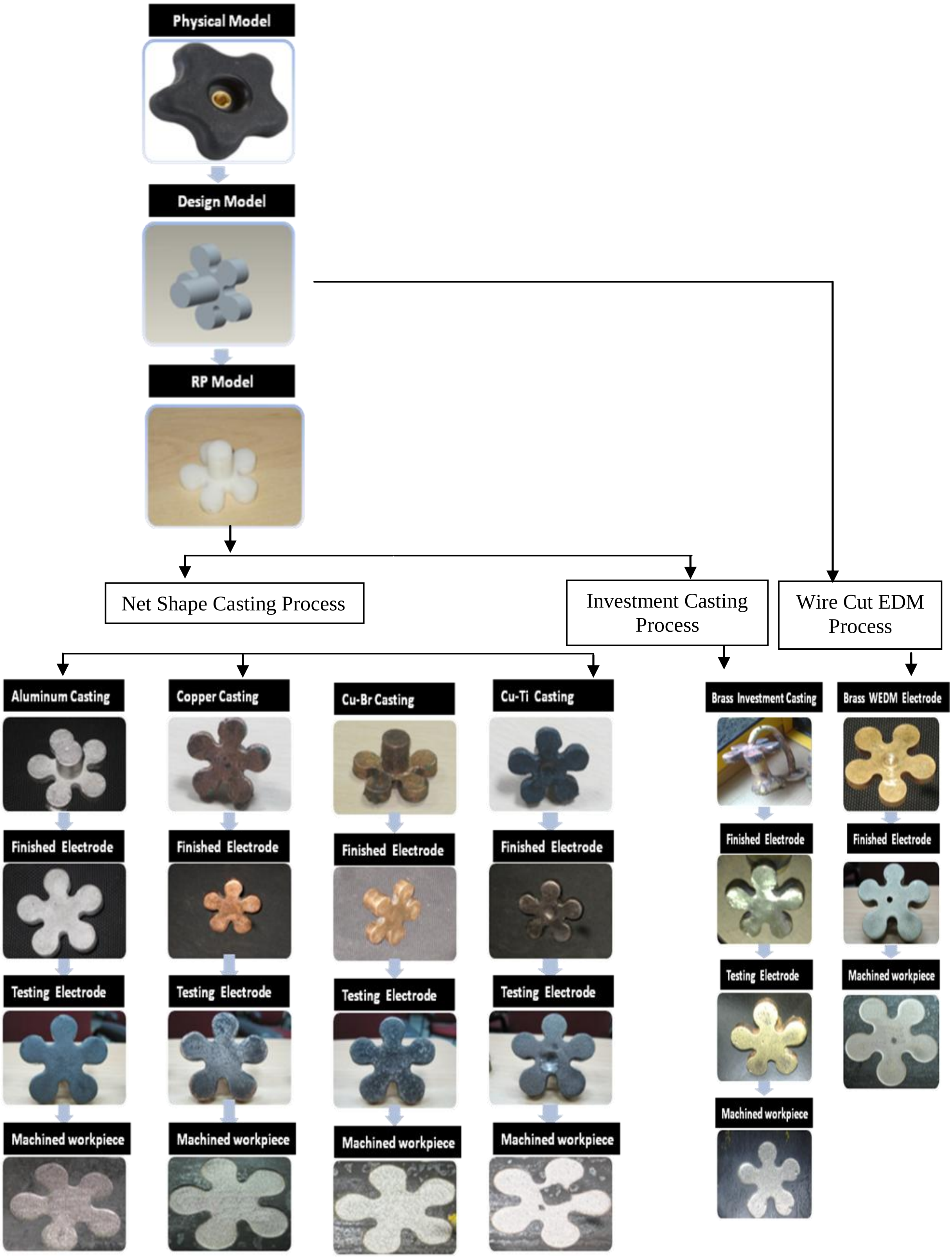

Fig 2 Manufacturing of EDM electrodes using different manufacturing methodologies

4.3 Manufacturing methology no:-3(Rapid Wire cut EDM brass electrode process)

As the rapid wire cut EDM machine has more advantageous then the conventional machining, so we have considered for the manufacturing of rapid EDM Electrode in this paper. The wire cut EDM process shown in the flow process diagram in manufacturing methology uses the brass material for edm electrode manufacturing. The main purpose is to compare the different processes with different material used. The geometry of the electrode is considered only. The dimensions and geometry is same but there were change in the appearance. The wire cut only cut the 2D shape and the wire moves along the defined path so complex curvature shape and geometry was unable to manufacture. The physical model with which we are manufacturing on wire cut EDM machine has to be Re-design as per the application of the electrode. The Reverse Engg and Co-ordinate measuring machine (CMM) is used for the dimensions analysis and making the product more attractive and aesthetic importance. The rectangular brass plate with 10mm thickness is used for cutting the electrode from the plate. The next step was to change the file format .prt to .dxf.As the file in the .dxf format and it is import this file into the RRAPT software. It gives the wire guide path and generates the NC program. As we generate the RRW file which is the file for under the EZEECUT PLUS wire cut machine. We load the program in the software and cut the Brass electrode. The dimensions of electrode were measured on the CMM machine. After cutting the EDM Electrode, finishing and testing is done on Die-sinking EDM machine. During the manufacturing process, the cylinder was not required in that electrode for fixing the electrode in holder. Instead of that, a hole is drilled on the top side of electrode and after that M8 drill tap (thread) is made to hold the electrode in holder.

Due to miss-alignment of the drill with work piece, a through hole is developed inside the electrode. The error in the electrode was reflected on the work piece after machining also. The fig. 2 shows the wire cut EDM Brass Electrode manufacturing.

V. EXPERIMENTAL RESULTS

A total of three experiments were carried out. In these three experiments, total six electrodes were produced. As explained earlier the Net shape casting, investing casting, Wire Cut EDM process perform good surface, better dimensional accuracy and all other different parameters. As the Brass Electrode developed by the Wire Cut EDM has performance parameters more than that of other manufacturing methology.

Table 1 shows the Time required for all electrode manufacturing**.** The average production time gives the idea about the different methology used with different material used. Table 2 relates the machining time for EDM electrode for all the process. The time difference between the depth of cut of 1.5mm and 1mm with different methology are shown. Table 3 gives the dimensional accuracy of EDM electrode. The dimensional accuracy is in the form of Total percentage deviation from the RP model to the testing of electrode. Table 4 shows the material removal rate for all the process. Table 5 shows the electrode wear rate for all the process. The machining time and weigh of the electrode is also considered for the obtaining the EWR. Table 6 shows the surface roughness for all Edm electrode process. The values are obtained from the surface roughness tester on the machined surface. Finally Table 7 gives the comparison of total time and total cost with different manufacturing methology.

***Table 1 :* Time required for all electrode manufacturing**

Manufacturing methology	Electrode Material	Total production time (min)	Average total production time (min)
Net shape casting process	Aluminium	65	
	Copper	70	73
	Copper-brass	75	
	Copper-titanium	80	
Investment casting process	Brass	130	130
Wire Cut EDM process	Brass	135	135

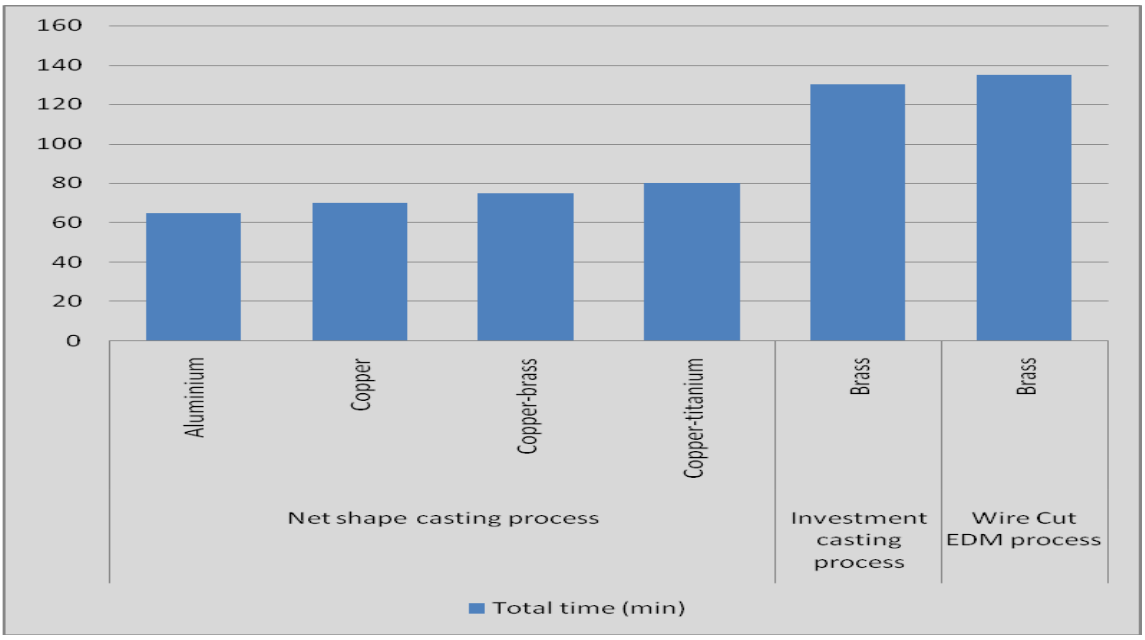

Fig 3. Time required for all electrode manufacturing

Table 2 : EDM electrodes Machinining time for all process.

Manufacturing methology	Electrode Material	DC Voltage (volt)	DC Current (Amps)	Total machining time for 0.5mm depth (min)	Total machining time for 1mm depth (min)
Net shape casting process	Aluminium	45-50	9	20	75
	Copper	45-50	9	16	60
	Copper-brass	45-50	9	8	17
	Copper-titanium	45-50	9	15	35
Investment casting process	Brass	45-50	9	18	30
Wire Cut EDM process	Brass	45-50	9	7	40

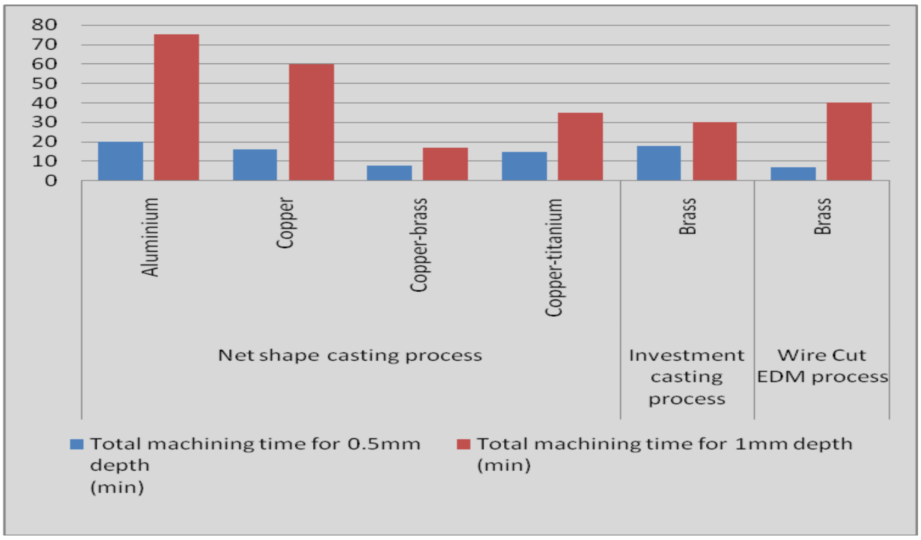

Fig 4 EDM electrodes Machinining time for all process

Table 3 : Dimensional Accuracy of EDM electrode.

	RP EDM Electrode	Net shape casting process				Investment casting process	Wire Cut EDM process
Material	ABS plastic	Aluminium	Copper	Copper-brass	Copper-titanium	Brass	Brass
Total percentage deviation	0.8	2.64	5.21	2.59	3.76	5.45	0.705

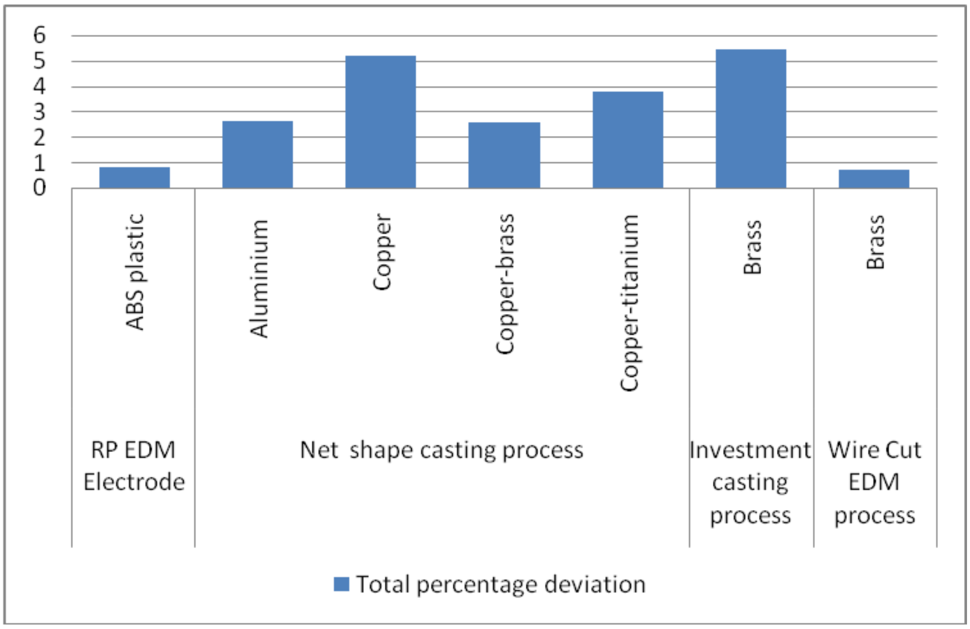

Fig 5 Dimensional Accuracy of EDM electrode.

Table 4 : Material removal rate for all the process.

Manufacturing methology	Electrode Material	Weight of Electrode (gms)	Total machining time (min)	Material removal rate(MRR) (gms/min)
Net shape casting process	Aluminium	30	75	0.4
	Copper	90	60	1.5
	Copper-brass	70	17	4.11
	Copper-titanium	80	35	2.28
Investment casting process	Brass	90	30	3
Wire Cut EDM process	Brass	110	40	2.75

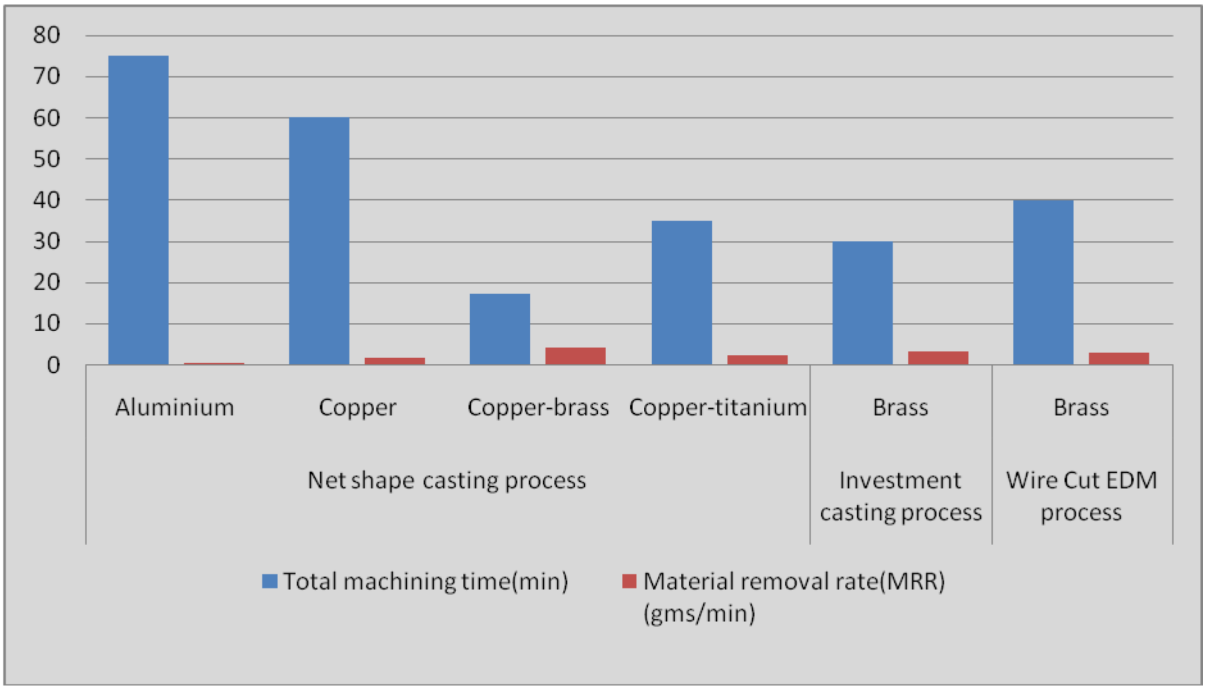

Fig 6 Material removal rate for all the process.

Table 5 : Electrode wear rate for all process.

Manufacturing methology	Electrode Material	Weight of electrode before machining (gms)	Weight of electrode after machining (gms)	Total machining time (min)	Electrode wear Rate(EWR) (gms/min)
Net shape casting process	Aluminium	32	30	75	1.06
	Copper	110	90	60	1.22
	Copper-brass	102	70	17	1.45
	Copper-titanium	95	80	35	1.18
Investment casting process	Brass	105	90	30	1.16
Wire Cut EDM process	Brass	100	97	40	1.03

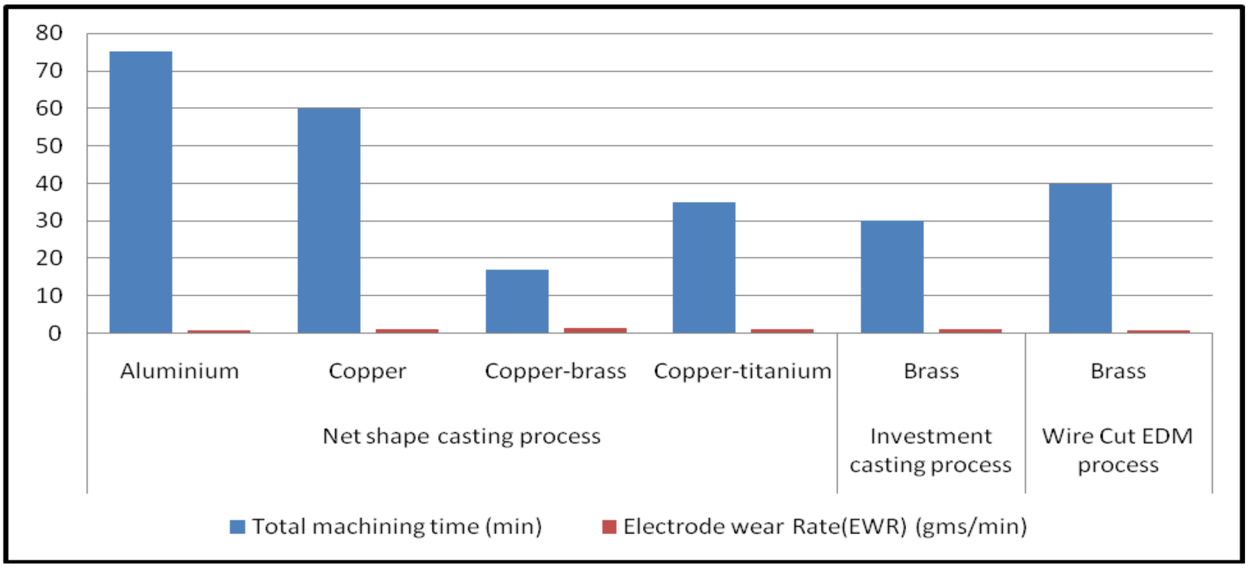

Fig 7 Electrode wear rate for all process.

Table 6 : Surface roughness for all EDM electrode process

Manufacturing methology	Electrode Material	Total machining time(min)	Roughness value (Ra) (µm))
Net shape casting process	Aluminium	20	3.46
	Copper	16	3.67
	Copper-brass	8	3.80
	Copper-titanium	15	3.63
Investment casting process	Brass	18	3.51
Wire Cut EDM process	Brass	7	3.59

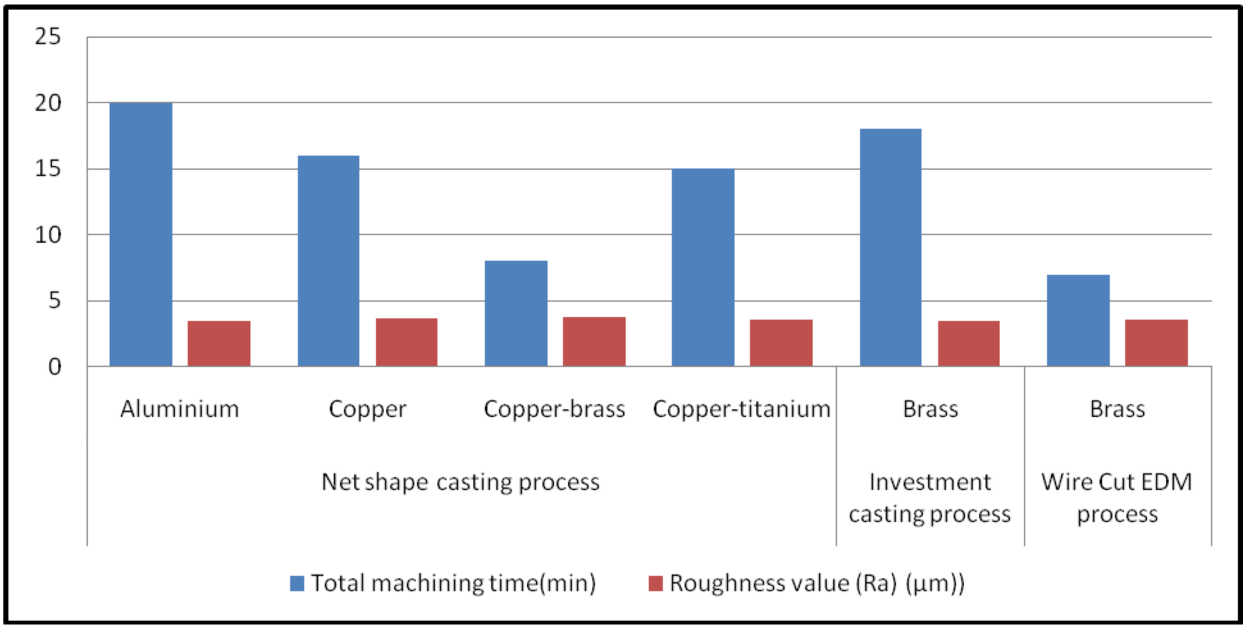

Fig 8 Surface roughness for all EDM electrode process

Table 7 : Total cost and Total time for edm electrode manufacturing

Manufacturing methology	Electrode Material	Total time (min)	Total cost (Rs)
Net shape casting process	Aluminium	65	462
	Copper	70	849
	Copper-brass	75	704
	Copper-titanium	80	755
Investment casting process	Brass	130	730
Wire Cut EDM process	Brass	135	567

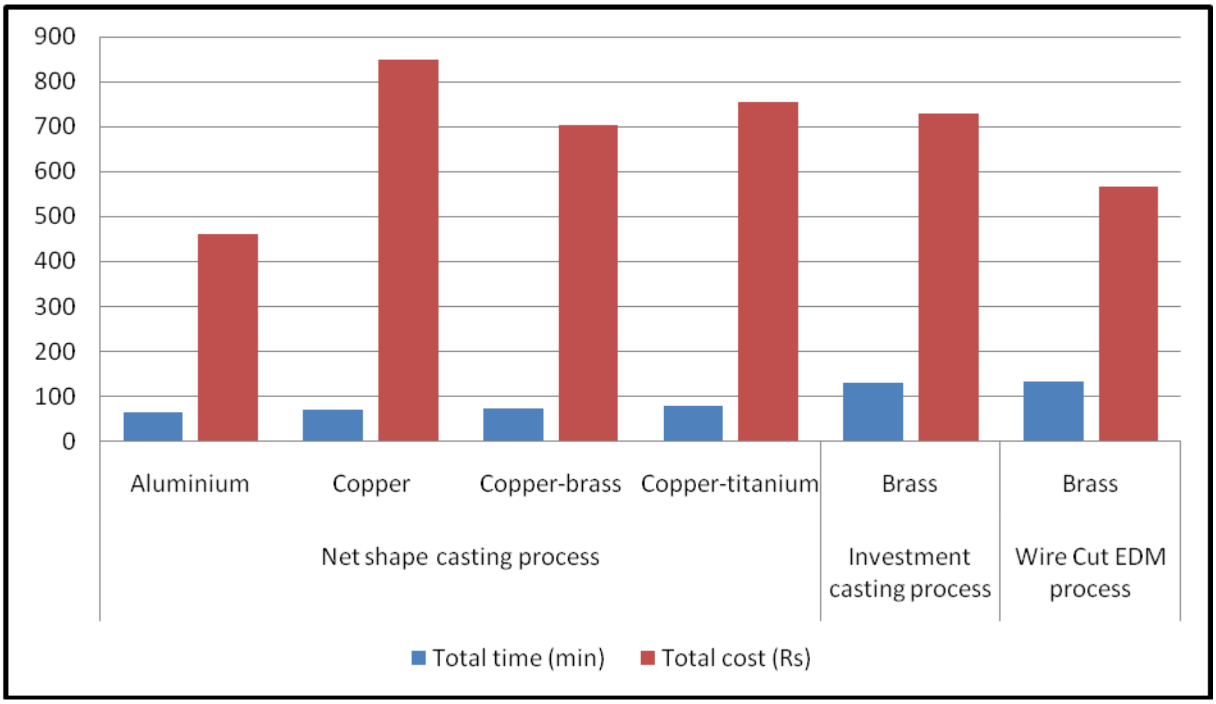

Fig .9 Total cost and Total time for EDM electrode manufacturing

Fig 3. Shows the time required for all electrode manufacturing. The total time required for aluminium electrode in Net shape casting process is less. Most of the foundry uses the aluminium for various applications. This material is considered as the heart of foundry. The technical parameters are greatly affected with the electrode material. The RP pattern avoids the misalignment, errors minimisation, dimensional stability, mould cavity area & almost the cost of electrode to be manufactured. The brass electrode developed by two process compare equally or lesser time to produce the electrode.

Fig 4. Show the EDM electrodes Machinining time for all process. The machining time is very important consideration in the electrode manufacturing. The carbon deposition during machining affect the machining time and the surface finish of electrode. The copper brass electrode has less time required to attend the machining depth of cut. The investment casting and W-EDM process nearer to the time interval to attend the machining time. The difference between the two parameters shows the minimum time required to machining the electrode.

Fig 5. is the important figure which shows the dimensional accuracy of EDM electrode. The dimensional accuracy is shown in the form of Total percentage deviation. The dimensions were measured on CMM machine and all the deviation changes with respect to the stage change of the flow process chart (fig.2). Some assumptions are also considered to improve the accuracy. The brass electrode developed by W-EDM process has very less deviation compared to other manufacturing methology.

Fig 6. Shows the Material Removal rate for all process. The material removal rate of copper brass through Net shape casting is very high with less machining time. The processes are reduced to time consuming and fast machining but lack of dimensional accuracy.

Fig.7 shows the Electrode wear rate for all process. The procedure is difficult to measure but easy to implementation. The weight parameters change the internal behaviour of the electrode and current carrying capacity. The electrode wear rate signifies the electrode eroded with the workpiece. The less electrode wear is observed in brass electrode by W-EDM process which in turns increases the electrode life.

Fig 8 explains the Surface Roughness of all EDM electrode process. The Ra values measured by surface roughness tester which gives the fast response compared to conventional electrode. The comparison shown makes the electrode manufactured by brass with W-EDM process gives the moderate value with machining time.

Fig 9 shows the Total cost and Total times for EDM electrode manufacturing. The aim is to produce the electrode with minimum time and cost are aluminium electrode by Net shape casting process. The investment casting and W-EDM requires moderate time with average cost.

VI. CONCLUSION

The Electrical-Discharge Machine Electrode with Rapid Tooling Concept was achieved. The total six electrodes were manufactured successfully with three different manufacturing methods to perform the various experiments and the outcome results shows the Machining time, Material removal rate, Electrode wear rate, Dimensional accuracy, Total manufacturing time, surface roughness and Total manufacturing cost at standard machining setting.

The following conclusion drawn from the various experiments of manufacturing methods are

1. The performance of Brass Electrode manufactured by Rapid Wire–Cut EDM process proves good dimensional accuracy compared with the net shape casting process and Investment casting process.
2. While manufacturing the EDM Electrode through different manufacturing methods, the electrode manufacture by Net shape casting requires less time for production but the manufacturing parameters were greatly affected compared with other process.
3. As the recent development in the casting process, investment casting is more advantageous for complex shapes and geometries. The Brass electrode performance on an average with respect to other manufacturing methods.As the mould preparation was difficult to conventional method, the better surface finish was achieved and the dimensional accuracy of cast part was nearer.
4. Total manufacturing time and Total cost required for manufacturing the electrode was less in net shape casting process with aluminium electrode. The other process requires higher time then the earlier process.

The Copper- Brass Electrode by Net Shape Casting has highest material removal rate and Electrode wear rate compared to the other manufacturing methology. While machining of EDM electrode by all the process, the spark start continuously between the electrode and the workpiece, due to both surface was not perfect flat so this lead to the error in dimensions. So minimum depth of cut required up to 0.5mm and then uniform material erosion rate was observed between the Electrode and workpiece.

Carbon content in the electrode material lead to the increase in the machining time and affects the machining parameters. The surface roughness value in all manufacturing process was observed in Brass electrode of the wire- cut EDM process. The alternative alloys like Copper-Titanium and Copper Brass results better performance parameters by net shape casting process.

The conventional cost of EDM electrode is reduced up to six times that of net shape casting, investment casting and W-EDM process with also reduction in manufacturing time nearer to two times comparing with the individual manufacturing methology.

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