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# Parametric Optimization of Manufacturing of Aluminum Die Casting Hot Die Steel Inserts

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**ABSTRACT**

This paper focuses on providing economical methods for manufacturing of hot die steel inserts, for various optimized solutions developed the constraint of the existing manufacturing setup is also considered. The techniques are implemented on a pressure die casting moving die insert component. The present optimized solution is derived for manufacturing rope length minimization of the die casting inserts (moving and fixed die) to get optimized solutions at every stage. The implementation of combined electrode, combined assembly machining and the cluster plate machining techniques are the key development done in the research. Combined electrodes, assembly machining along with cluster machining of the electrodes reduce the total physical operational time of the die which will ultimately leads to saving the overall manufacturing cost and increase the profit The proposed solution opens up new avenues for similar automobile components by setting benchmark to decrease the rope length associated to manufacturing and increase the profit.

**Keywords: assembly machining concept, cluster plate machining, combined sparking, electrode discharge machining**

## I. INTRODUCTION

Aluminum [1] [2][3][4] is the general alloy used for manufacturing of die-casting inserts process[5][6] today. The main significant benefit of aluminum die cast parts is due to its light weight, the lightness of aluminum die cast parts makes automotive and aerospace applications as the basic ideal choice.

In mass and batch production system these are also mainly used in die casting process for development of several products principally automobile component (Refer Figure 1).The manufacturing rope length[7] depend upon the complexity and hardness [8] of the job. All the activities are interrelated with each other. Any addition of activity leads to the addition of the manufacturing cost as well as the increasing rope length.

Possible optimized techniques are made considering that even an addition of activities by any manufacturing section, will not allow creation of bottle neck in the system. The overall effect of the optimize design will try to nullify the effects of the increased task left out by any manufacturing section and as well as increase the efficiency and profit of the manufacturing setup.

The optimization is brought by three major concepts viz: Combine electrode concept[9], combined assembly machining concept and cluster plate concept which allows the effect combined sparking and combined machining. All of

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the above methods of optimization are not possible to implement on one single insert. Depending upon the span area of the component area and the total machining depth, the suitable technique may be applied. Hence the concept is made to be understood by taking bay various different inserts.

## II. GENERAL STEPS IN DIE CASTING DIE DESIGN

The general steps that are observed in the tool room where all kinds of complicated manufacturing of inserts are done. These components may be in form of crank cases, engine head cover, butterfly valve, steering column, carburetors and so on. The general process followed by the tool room is as follows:

Fig.1. Aluminum Die Casted Automobile Component.

a) Design data provided by the customer to the design department.
b) Simulation and study of the component.
c) Die design layout.
d) Process engineering of the die.
e) Material procurement.
f) 2D and3D machining of the die.

i. Insert programming
ii. Stock model creation of the left out material
iii. Electrode Design.
iv. Electrode Programming.
v. Electrode Sparking[10][11][12][13]

h) Assembly of the machined components.
i) Spotting of the manufactured inserts on spotting machine.
j) First trial and post trial corrections.
k) Die finalization.
m) Die dispatch.

Hence from the above operations which are mandatory for manufacturing the scope for optimization can be found where there is bottle neck observed in the manufacturing line. Hence the optimization can be done on: electrode design, electrode programming, electrode sparking and the operation related to it which stands the objective of the paper.

## III. COMPONENTS UNDER ANALYSIS

There are two components under discussion for the explaining the above mentioned concepts. The combined electrode concept is made to understand with the help of crank case of two- wheeler whereas the cluster plate machining and combined sparking are made to understand by plastic mould used for street lighting. Figure 2a, 2b and 3 shows the same.

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The shape and size of all the components are different. The aesthetic changes in the shape of the components are observed due to customer's feedback and technical trouble shooting while working. This leads to alteration of the component area does not have a major impact on the manufacturing rope length of the job. Re-visiting the old machined geometries (insert programming), the electrode design [14][15] and electrode programming [15][16] will be allowing of exploring of implementation of new techniques that which can increase the productivity along with the profit

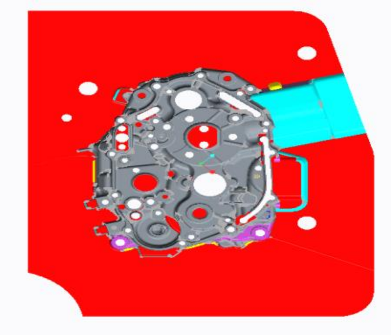

Fig.2a. Crankcase of two-wheeler (Fixed die)

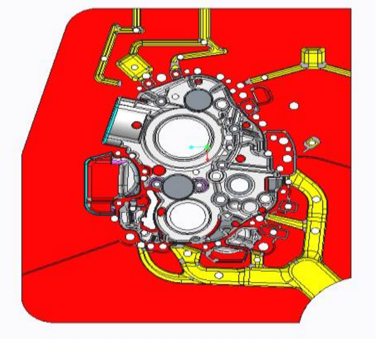

Fig.2b. Crankcase of two-wheeler (Moving die)

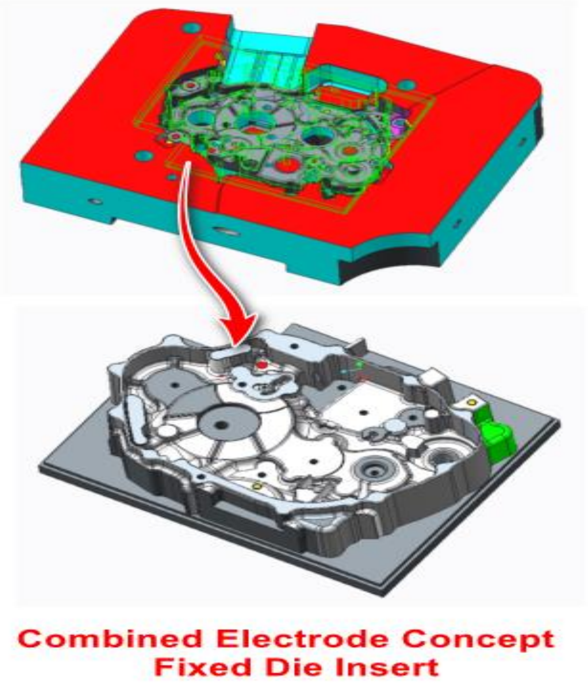


Fig.3. Combined electrode concept for fixed die insert

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.Hence the combined electrode concept which is mentioned in section 4 is an outcome of revised design for couple of time and the presented design is the most optimized design, whereas the cluster machining explained in section 5 is exceptional case of the cluster machining and combined sparking.

## IV. COMBINED ELECTRODE CONCEPT

Figure 3 and Figure 4 shows the combined electrode concept which was implemented on both the fixed as well on the moving die insert. From figures 3 and 4, it is clear that combined electrode concept has a major advantage over the separate electrode designed over the same place. Combined electrode [17][18][19] concept addresses the concept increasing the sparking area in one single go(during sparking), rather than covering the same area in multiple numbers of electrodes. The advantage obtained in such designed is majorly observed in roughing and finishing electrodes. Insert which has thin ribs to be sparked, having depths around 90~120mm shows the actual benefit of the using the combined electrode concept. Sparking single rib on Electrode discharge machining (EDM) machine may take around 8 hours by the EDM process where as sparking 10 ribs [20] simultaneously make take around 10 hours.

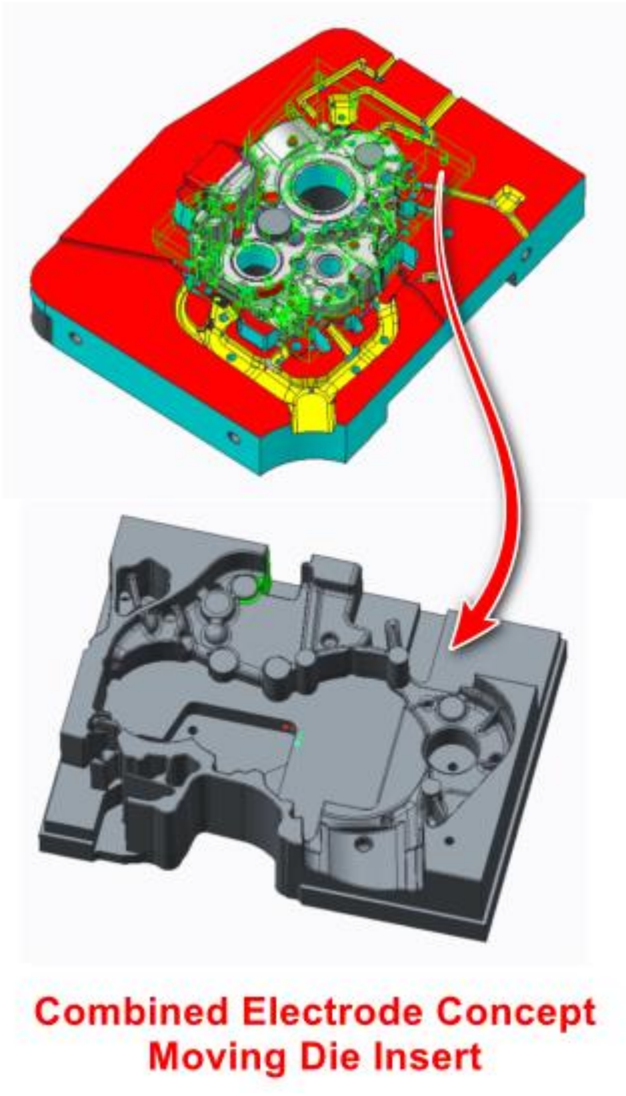


Fig.4. Combined electrode concept for moving die insert

Hence the point here to be notified is that cover more areas in the electrodes in the design. This helps in reducing the all the activities related to a single electrode. The numbers of activities that are related to one single electrode are as follows:
a) Electrode design
b) Electrode manufacturing drawing.
c) Electrode sparking drawing.

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d) Process sheet generating for the designed electrode in Enterprise resource planning (ERP) Software.
e) Band saw cutting of the raw material size for electrode manufacturing.
f) Final sizing of the block for machining.
g) Electrode-programming in computer aided machining (CAM) software.
h) Tool list generation of the tool path made.
i) Dialing of the block on computer numerical control (CNC) machining.
h) Actual manufacturing of electrode.
i) Electrode polishing and de-burring.
j) Electrode dialing on EDM machine.
k) Generating EDM program for desired co-ordinates.
l) Actual sparking on the EDM machine.

Hence even adding one single electrode will increase activities “a-l”. Hence on designing, the electrode by combined electrode concept reduces the actual numbers of individual electrodes designed earlier. This helps in reduces the associated cost for the activities mentioned above.

In the initial design there were around 6 electrodes which were straight away reduced to 1 electrode. Table I shows the benefits which are obtained by implementation of the combined electrode design.

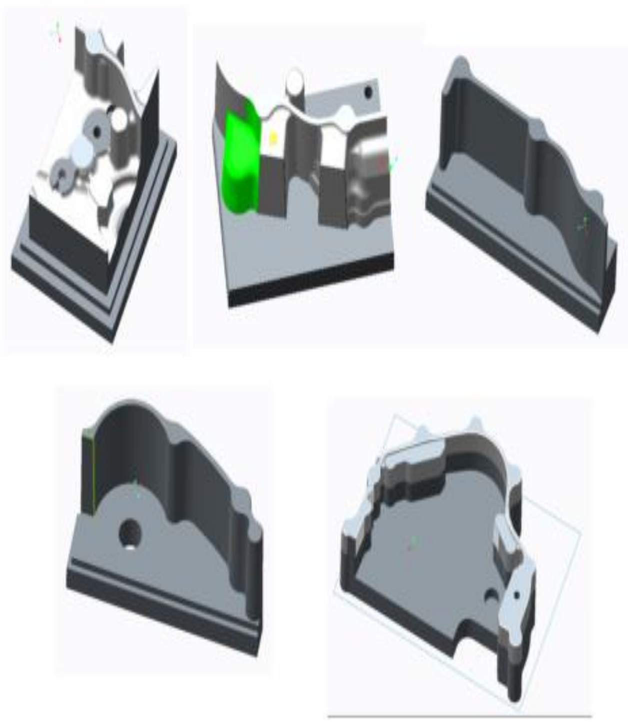

Fig.5. Individual electrode design

TABLE I. COMBINED ELECTRODE SAVINGS

| Summary of the all the processes | Net saving in Rupees |
|---|---|
| 1. Electrodes design | -7772.15 |
| 2. Generation of process sheet | 350.00 |
| 3.Band saw time for rough block cutting | 800.00 |
| 4. Block setting time on CNC machine | 600.00 |

| | |
|---|---|
| 5. Programming with tool list generation | 800.00 |
| 6. Sparking time on EDM | 30,500.00 |
| Total saving | 25,277.85 |
| **Net saving of Combined electrode concept vs. individual old electrode designed at the same place = Rs 25,277.85** | |

The results shows after implementation of combined electrode concept, the physical number of electrode are reduced. Six electrodes are significantly reduced to only one single electrode. The major saving that the manufacturing system gets is the number of hours that are saved in EDM. Sparking of six different individual electrodes will be reduced to only one single electrode in the case of combined concept. Nearly 75% of the total saving is contributed by the EDM sparking. Refer Figure 6.

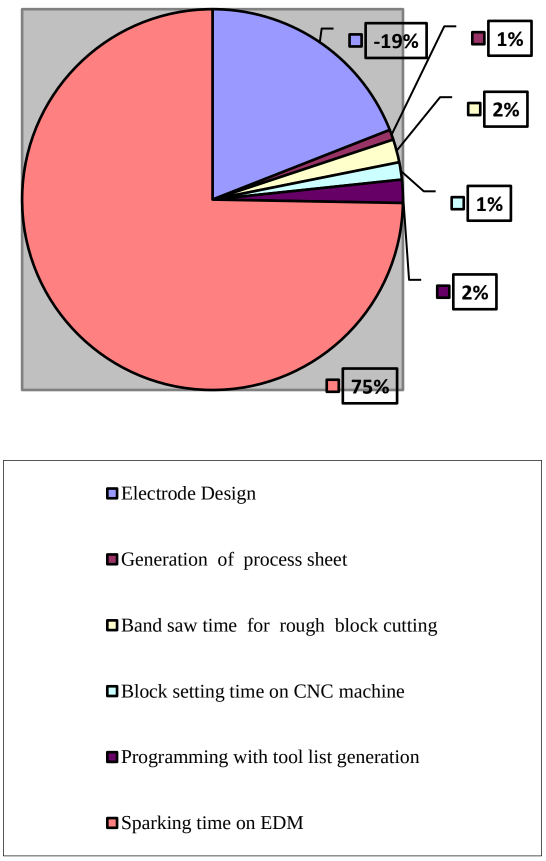


Fig.6. Net savings under combined electrode concept

## V. COMBINED ASSEMBLY MACHINING CONCEPT

Depending upon the physical shape of the inserts (fixed and moving die) and the available space if there is no scope of designing combined electrode, then we can at least take the advantage in savings in all of the activities before the sparking activity of electrode in EDM section. This concept is similar to the combined electrode only the benefit of sparking cannot be taken.

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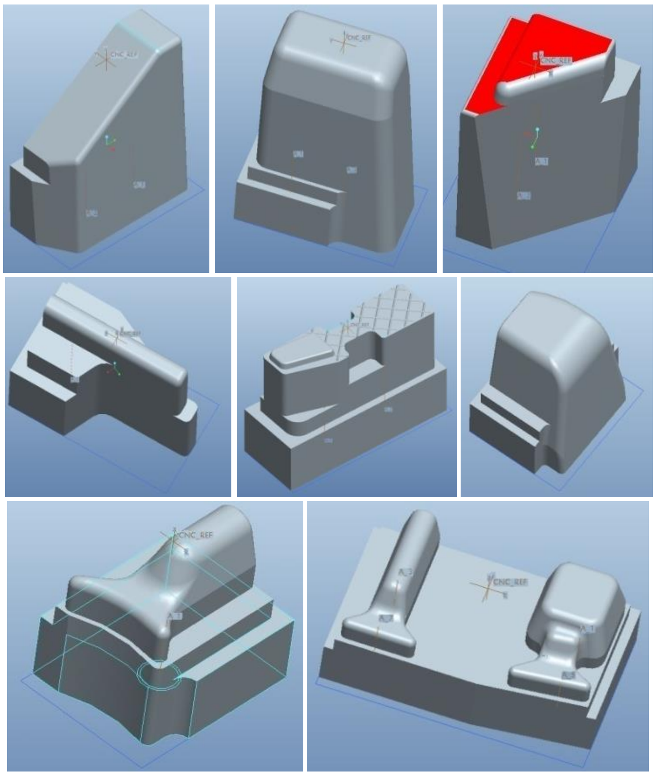

Fig.7. Individual electrode design

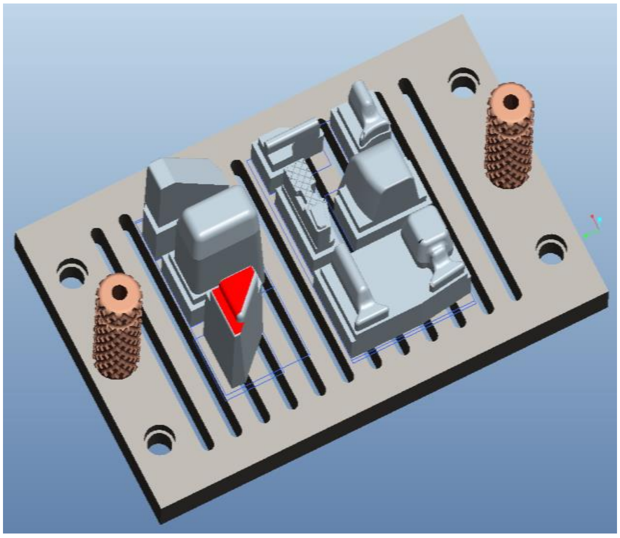

Fig.8. Electrode design in assembly machining concept on cluster plate

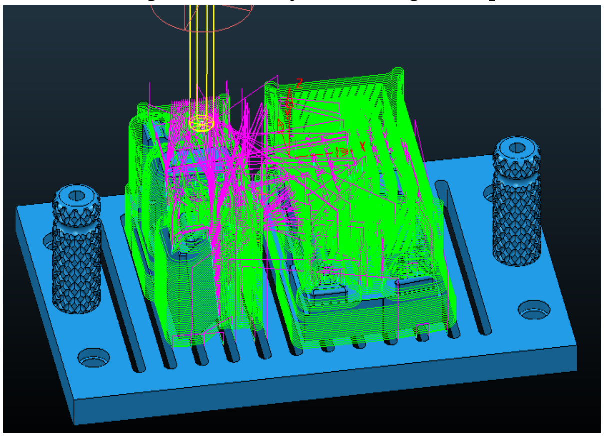

Fig. 9. Assembly machining in DELCAM Software

TABLE II. Net savings offered by assembly machining concept

| **Summary of the all the processes** | **Net saving in Rupees** |
|---|---|
| 1. Electrodes design | 98.61 |
| 2. Generation of process sheet | 175.00 |
| 3.Band saw time for rough block cutting | 400.00 |
| 4. Block setting time on CNC machine | 200.00 |
| 5. Programming with tool list generation | 600.00 |
| 6. Actual tool list generation from DELCAM output | 796.66 |
| Total savings | 2,270.28 |
| Net saving in Cluster plate design vs. individual old electrode = Rs 2,270.28 | |

The electrodes are produced from one block in the same fashion as in case of the combined electrode. Successful running of tool path will churn out multiple electrodes from one single block. The initial rough block/s is placed on the cluster plate which has holes/oblong slots which placed on equidistance with a pitch of 20mm in X direction. Depending upon the location of the electrodes in the block necessary holes is drilled and "heli coils" are inserted in those holes. Screws are used for clamping the electrode on the cluster plate. Figure 7 shows the various small electrodes designed across both the inserts.

Figure 8 shows the individual electrode designed assembled on the cluster plate which is treated as single electrode for programming. As discussed earlier in section 4 that all activities from "a-l" will be applicable for all 8 electrodes shown in figure 8 if machined individually. In the case of the assembly machining concept as shown in Figure 9 the entire 8 electrode will be manufacture from one single block/s. Hence there will be savings of 7 X (a-l) activities. Figure 9 shows the programs made in "DELCAM" interface. Table II shows the total benefits that are obtained using combined machining concept. Figure 10 shows the % gain the across the various processes implemented in the combined electrode design.

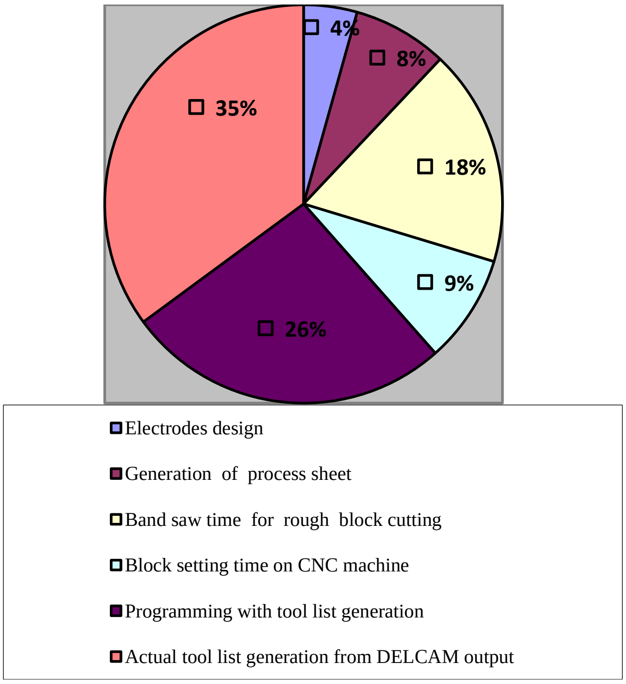


Fig.10. Net savings using assembly machining concept

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Cluster plate machining and sparking

The concept of combined machining is seen in section 5 where the electrodes which are sparked separately are machined together. In cluster plate machining concept the sparking of electrodes on the metal insert is further carried on the machined electrode placed on the cluster plate itself. All the operations of the electrodes placed on the plate (cluster) are carried simultaneously. Figure 11 shows the insert on which the cluster plate machining with the combined sparking is to be performed whereas Figure 12 shows the actual stock model left in CNC machining where electrode design is needed. The pink color zones shown in Figure 12 are actual areas where electrodes are to be designed. Depending upon the area of stretch the electrodes are designed.

Fig.11. Insert on which cluster plate machining and sparking is performed

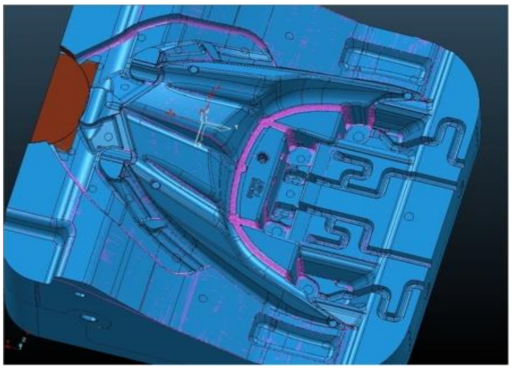

Fig.12. Programming done in DELCAM interface

Figures 13 shows the actual blocks used for electrode machining on the cluster plate. Similarly Figure 14 shows the actual designed electrodes on the cluster plate setup. Figure 15 shows the actual machined electrodes on the CNC machine. The setup shown in Figure 15 is directly used on the EDM machine for sparking the metal insert. The setup gives more advantage in saving the setup time for electrodes where as combined sparking saves times as mentioned in the combined electrode segment. Figure 16 shows the actual sparking done on the EDM machine.

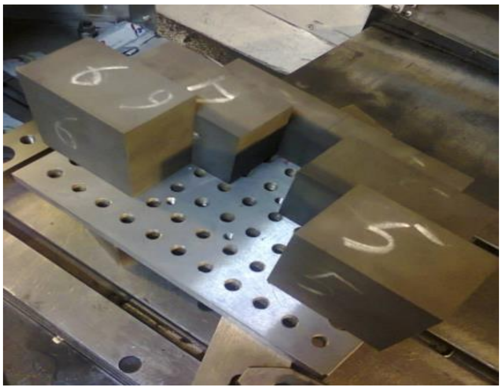

Fig.13. Blocks clamped on cluster plate

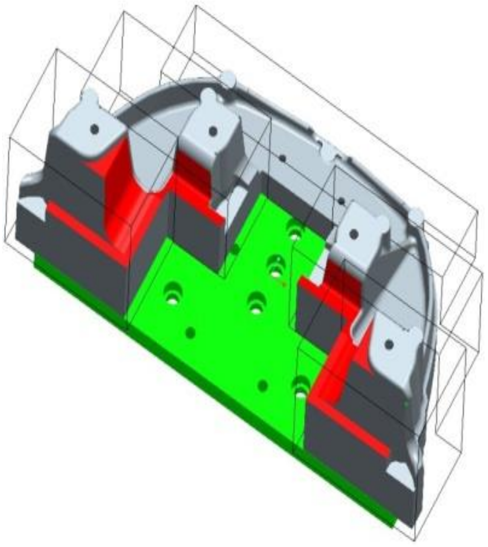

Fig.14. Electrode design in Pro Engineer

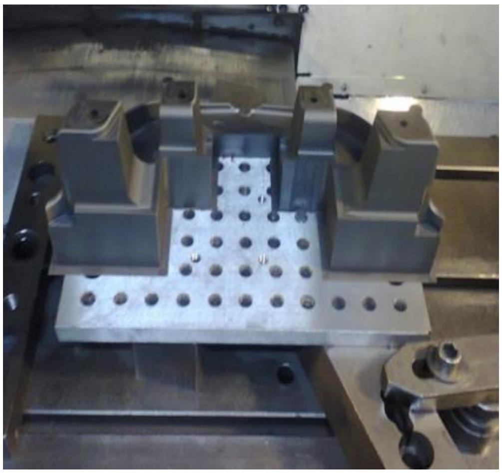

Fig.15. Machined electrodes

Fig.16. Sparking setup on EDM machine

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## VI. Results and Discussion

The results generated from the Table I, which is the savings obtained in the combined electrode design. Here from the results generated it is clear that in combined electrode design concept there the cost of the raw block used for manufacturing will be more as compared to individual cost electrodes, hence the negative (Rs -7772.15) value shown Table I, justifies the same. Similarly the high positive value (Rs 30,500.00) is obtained from the electrode sparking activity. This is because the simultaneous sparking of several electrodes which was not in the earlier case. Out of the complete saving in the combined electrode concept, 75% of the complete saving is obtained from combined electrode sparking whereas 19% loss is seen in the case of electrode design. Rest all the activities mentioned in Table I are having almost the same percentage which is around 1%. Also refer pie chart shown in Figure 6.

In the second method, i.e. cluster plate machining concept shows that the electrode design shares around 4% of the complete saving done. Similarly the time required for process sheet generation shows around 8% saving where as the band saw time saved is around 18% of the total savings. The time required for setting the block on CNC machine share around 9%, whereas the time required for tool list generation is around 18% of the total saving. Lastly the saving in time required for generation of the complete tool list from the DELCAM out shares around 35% of the total savings. Refer pie chart shown in Figure 10.

There are 3 methods discussed in the process length optimization of the aluminum die casting inserts made from hot die steel. Methods such as combined electrode concept combined assembly machining setup and cluster plate machining. The combined electrode design reduces manufacturing rope-length by chopping of the numbers of fixed activities associated with lower numbers of electrodes. Hence in combined electrodes the physical numbers of electrodes are also less and the numbers of activities are also less. The area covered in the combined electrode concept is more which also reduces the insert polishing process. If the area covered by the insert is complete as in the case of shown in Figure 3 and 4 in that case the finishing operation done in CNC milling [19][21] [22][23][24] [25][26] [27][28]machine can be completely skipped and the same can be done in EDM. On doing so the cost associated in CNC finishing operation is completely saved. Further there may be some specific areas on the insert which may not be finished in CNC[29][30][31][32] and needs to be finished in EDM machining. In such cases if the span area is less then combined electrodes can't be designed as those may not be economical. Hence a separate electrode has to be designed in such cases. When separate electrodes are designed then the economical advantage can be taken machining then in assembly setup. In assembly machining the numbers of electrode assembled n the cluster plate is treated as a single electrode hence the numbers of individual programs that would have been created are reduced. Hence as the numbers of programs are reduced the physical numbers of all the activities related to the electrodes are also reduced. After machining the electrodes are loosened and sparked individually. Further the advantage which was not possible by assembly machining is completed by the cluster plate machining. In this method the sparking is also done on the metal insert keeping the existing setup undisturbed. The cluster plate is directly clamped on the EDM machine and used for sparking; doing so helps in reducing the dialing and setup time which was required for those individual electrodes which were present in the assembly. The cluster plate machining helps to take the advantage which was not possible in assembly machining. Hence may depicted from all the results generated above that depending upon the component profile area the suitable method may be applied for optimizing the rope length and the cost associate with it. All the three methods have their own advantage over the other.

## VII. Conclusion

Techniques such as combined electrode concept, combined assembly machining concept and cluster machining and sparking concept are used for optimization of manufacturing rope length of aluminum die casting die.

1. Combined electrode concept offers reduction of the total numbers of electrodes as compared to electrodes designed individually at the same span of area.
2. The total numbers tool path programs that are needed for electrode manufacturing are less since the electrodes are combined.
3. Pre manufacturing activities related to electrodes are reduced, hence chocking of the manufacturing system is not observed.
4. In the case of the combined electrode concept the cost of the raw block is greater than that of the individual block used for machining.
5. In the case of combined electrode concept the greatest advantage is observed in saving the sparking and the cost associated with it.

6. Cluster plate machining will again reduce the actual number tool path programs.
7. Total number of physical electrode moving in the manufacturing system is also less.
8. Setup time required for placing the electrode on the CNC machine is also less.

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