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Review Paper on design of Single Cavity Pressure Die Casting Die Using CAD Tool & Its Manufacturing by HPDC Technology

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Abstract - Manufacturers can create a sharply defined textured or smooth surface of metal parts by using a manufacturing process described in high-pressure die-casting technology. The mechanism under this technology forces and injects molten metal into a reusable metal die at a speed of 27-45 m/s. The manufacturers will use the hot chamber or cold chamber method to inject the metal into the die on the basis of the type of metal chosen to fabricate the part. The designer must incorporate numerous manufacturability-related factors into the design of a die to produce successful castings economically. To achieve this overall design goal, the die fills completely with molten metal, quickly & consistent solidification of molten metal, the part ejects easily from the die without damage, the part requires a minimum of die construction and die maintenance difficulties, the part meets the customer's tolerance requirement. Proper estimation of part manufacturing is essential for tender procurement & reduction in manufacturing lead time. The project gives a brief introduction of design considerations in manufacturing single cavity pressure die casting die. It explains the process flow from quotation to dispatch of the PDC tool. CAD software will be used for doing the work accomplished in design

Keywords — Single Cavity Pressure Die Casting Die

1. INTRODUCTION

This project includes information about design and manufacturing of die. DIE CASTINGS are produced by forcing molten metal under pressure into metal moulds called dies. Mould filling in permanent moulds casting depends on the force of gravity, die casting involves metal flow at high velocities induced by the application of pressure. Because of this high velocity filling, die casting can produce shapes that are more complex than shapes that can be produced by permanent mould casting.

In die casting, die has been closed and locked; molten metal is delivering through plunger or pump. The pump plunger is advanced to drive molten metal too quickly through the feeding system while the air in the die escapes through vents. Sufficient metal is introduced to over flow the die cavities, fill overflow wells and develop some flash. As the extraneous metal solidifies, pressure is applied to the remaining metal and is maintained through a specified dwell time to allow the casting to solidify. The die opens and the casting is then ejected. While the casting die is open, it is cleaned and lubricated as required. Then the die is closed and locked, and the cycle is repeated.

1.1 Objectives

- To study the type and the nature of the process to determining the layout of the die.
- To identify the parameter for die design
- To identify areas of concern for the potential defects in the casting
- To decide upon the type and the location of the gate/ runner/ feeder system
- To design the die for effecting a good quality component (defect free)

2. LITERATURE REVIEW

For this study and observation are focused on existing system. The literature survey has been pioneered effort in this regard. Various machine design concepts and CAD/CAE concepts from literatures help to establish comparative study between existing and new experimentation. The terminologies referred from literatures for designing are discussed as follows:

[1] Bharat Sharma, Casting manufacturing from LPDC, GDC and HPDC process show some defect or you can say some variation in defect quantity. For supplying quality product to customer these defect variation must be reduced.
In this work we try to make logical relation between defect variation and hidden parameter like injection metal temperature, pouring time, ladling time, metal traveling time in shot sleeve. Current problem is that we set all process parameter and run die than validate with minimum defect %. But problem will come after bulk production, we found overall 15-20% rejection. Injection metal temperature is important parameter as compare to melting temperature and die surface temperature. Reduction in temperature variation of injection metal temperature in each cycle through 1. Now in present scenario you make wait to ladle cup at shot sleeve for metal pouring till die lock. Now from today onwards change this culture let the die lock than allow

ladling and let the ladle cup pour without waiting and without so much temperature variation. 2. Minimize ladle forwarding time by optimizing ladling speed. 3. Optimizing pouring speed with laminar stream. 4. Don't use ladle cup size bigger than required. For example shot weight is 2kg than max. Cup size should be 2*1.1=2.2 kg for minimum heat loss.

[2] Nouri-Borujerdi & J. A. Goldak, performed study in which an analytical model has been developed to describe air pressure and residual air mass variations in pressure die casting for atmospheric venting. During injection of molten metal into a die cavity, air is evacuated from the cavity through vents. In this study, the influences of air velocity and friction factor due to temperature dependent viscosity and vent roughness change have been investigated. The results of the model show that there is a critical area ratio over which a quasi-steady state is reached, therefore, the air pressure in the cavity remains constant. In addition, for each area ratio there is a critical/minimum time ratio below which outlet Mach number is not large enough to create choked flow. In this case, the rate of outflow air mass is not maximum. Finally, the results of the model addresses that the friction factor depends on hydraulic diameter of the vent and assuming a constant value for it is not valid. Porosity is a major issue in die casting. It causes common defects such as pores and reduced thermal and mechanical properties such as yield strength, ductility and modulus of elasticity of parts produced in the pressure die casting.

[3] Raimo Helenius performed the comparsion between the casting experiments and casting simulations to estimate the heat transfer coefficient Microstructures in high-pressure die-cast products (HPDC) are important for the mechanical properties. During filling of the shot sleeve, the liquid metal dissipates superheat and solidification starts. The solidification may result in externally solidified crystals (ESCs) or cold flakes in the product [H.I. Laukli, L. Arnberg, and O. Lohne, Int. J. Cast Metals Res. 18 (2005) 65–72]. The temperature of the melt in the shot sleeve is influenced by several parameters, such as liquid metal superheat, the heat transfer coefficient (HTC), and surface properties of the shot sleeve and alloy composition. In order to get a better quantitative understanding of the heat loss during filling, investigations of the temperature history in both liquid metal and the shot sleeve wall have been carried out. A replica of an industrial shot sleeve was made and filling experiments were carried out. Thermocouples at different locations and depths in the melt and steel cylinder were used to measure the temperatures.

[4] Paul Robbins discussed plunger design of pressure die casting system. No single component of the die casting production process should be examined of evaluated individually. Each interacts closely with at least one other complementary element of the process. If the interacting elements are equally efficient, they will reinforce and enhance the function of each other. Only if the entire process is considered as an integrated system, with all parts working together in common cause, can maximum efficiency be approached. Properly employed, the technique can be guaranteed to improve productivity. The Systems Approach will be discussed in the context of production efficiency in light metal die casting.

[5] Bing Zhou, Yonglin Kang are discussed new machine, forced convection mixing (FCM) device, based on the mechanical stirring and convection mixing theory for the preparation of semisolid slurry in convenience and functionality was proposed to produce the automotive shock absorber part by R-HPDC process. The effect of barrel temperature and rotational speed of the device on the grain size and morphology of semi-solid slurry were extensively studied. In addition, flow behavior and temperature field of the melt in the FCM process was investigated combining computational fluid dynamics simulation. The results indicate that the microstructure and pore defects at different locations of R-HPDC casting have been greatly improved. The vigorous fluid convection in FCM process has changed the temperature field and composition distribution of conventional solidification. Appropriately increasing the rotational speed can lead to a uniform temperature filed sooner. The lower barrel temperature leads to a larger uniform degree of super cooling of the melt that benefits the promotion of nucleation rate. Both of them contribute to the decrease of the grain size and the roundness of grain morphology.

[6] Franco Bonollo, Nicola Gramegna, and Giulio Timelli are discussed contradictions of HPDC Process and the related challenges both the critical aspects and the potential advantages of this foundry technology have been evidenced with reference to the quality requirements coming from the customers. The production rate as well as the process monitoring and control have been critically examined within the European and worldwide scenario. From this work, the most relevant interrelated challenges can be drawn, which must be faced by for HPDC foundry by: Leading to ''zero-defect environment' 'Introducing real-time tools for process control. Monitoring and correlating all the main process variables. Making the process set up and optimization acknowledge-based issue. Implementing multidisciplinary R&D activities. Impacting on HPDC scenario. Performing these actions will allow HPDC foundries to achieve a more mature and efficient approach to large end users and to exploit their relevant potential.

[7] X.P. Niu (Chair.), 2000, discussed the significance of vacuum assisted on HPDC. The experimental investigations on different types of specimens. The results showed that the hole sizes in the castings were drastically reduced in vacuum assisted HPDC system. The paper also highlighted that the mechanical properties strength and ductility of cast product were also improved.

[8] Rajesh Rajkolhe, J. G. Khan (2014), conducted an organized study on casting defects and its remedies. It was observed that even in totally controlled procedure defects were observed in casting. The study gave root cause for casting defects which could help in analyzing the defects.

[9] Mohammad B. NDALIMAN, 2007, described the effect of pouring temperature of aluminum alloys at different

temperature and speed. Different type of experiments were conducted by varying temperature. The results showed that best surface finish was obtained from range of 680-700 °C. The alloys were free from internal defects when the pouring temperature was less than 730 °C. For both mechanical and quality property assessments, for aluminum best temperature range was between 700-750°C, and the speed was 2.0cm/s and 2.8cm/s. For magnesium the pouring temperature is from 620-730◦C and for copper it is from 1150-1290◦C. The optimization processes highlighted the values that should be used for the product to get better quality and less defects. There are different types of optimization methods all will give the best results. Depending on the components should be designed the tool can be selected.

[10] Shuhua Yue, 2003, discussed the concept of Concurrent Engineering (CE), CAD/CAE/CAM integrated system established, applied in the primary stage of casting. The platform of CAD/CAM software and MAGMASOFT simulation software was also considered. The integrated system was applied for both Al and Mg alloys, such as the water pump. It was observed that use of this type of system integration could shorten the cycle of die design and manufacture and also results in the production of high quality die castings is a shorter time. The lead-time also of die castings was also shortened.

[11] Vaibhav Ingle, 2017, studied different types of cold shut defects and their causes and remedies. It was observed that the defectwas formed due to the mixing of two different metals or improper fusing, lack of fluidity in metal design and improper gating design. The defects could be eliminated with good design and proper gating system and with proper control of fluidity.

[12] Ch. S., 2017, worked on temperature defects aroused in components like the optimum filling time, injection pressure and die temperature for improved solidification of the filling component are analyzed by taking the input parameters molten metal temperature, velocity at spreader, injection time and die temperature. Solidification analysis is done in Ansys CFD. The results were applied for practical method by this method we could avoid trial and error method practically in this way temperature defects are reduced.

3. PROBLEM IDENTIFICATIONS

For high volume needs sand casting proves to be a slow process. Components for mass production invariably need a process like high Pressure Die Casting (HPDC) to support the production. The die design for HPDC is a critical task to deploy. The inputs required could be in the form of die layout and flow simulation to arrive at the best configuration of the design. Expertise over the CAD and CAE is crucial to handle the challenges during the design phase.

Figure 1: High Pressure Die Casting Die

3.1 Design Consideration

Press Tools:

- Size, shape & material of the component.
- Operations to be performed on the component.
- Selection of the tool such as progressive, compound etc. depending upon the operations to be performed on component.
- Selection for the suitable tool layout.
- If progressive tool the strip layout must cover all the stages at proper sequence, considering the rigidity of the die in mind.
- Determine the tonnage required & the tool related calculations, such as economy factor, plate thicknesses, etc.
- Possibly construct the tool that can be easily modified.
- Shank location must be possibly to the centre of the tool.
- Tool must be rigid considering its involvement in the type of production such as mass, batch etc.
- Re-sharpening allowance must be added to punch and die cutting edges.
- Tool must withstand all the lateral thrust during operation.

Moulds:

- Material used for the component, its applications.
- Shrinkage of the material.
- Calculate the weight of the component.
- Study the detail of the component.
- Type of mould required for the component to be produced.
- Machine available for the component.
- Injection pressure required.
- Type of runner system & gate required.
- Type of ejection system weather blade, stripper etc.
- Split and side core consideration if the component is having any groove or notch on its sides.
- Cycle time required for the component for complete fill.

- ⇨ Effective cooling in a short duration is necessary.
- ⇨ Cooling channels must be lick proof.
- ⇨ Selection of the material for core & cavity.
- ⇨ Adding of shrinkage to core & cavity dimensions.
- ⇨ Parts in the assembly must not foul with each other in operation.
- ⇨ The layout of the tool must not be oversized.

Die casting dies:

- ⇨ Shape, size & alloy to be cast, Shrinkage of the alloy.
- ⇨ Type of casting weather sand, hot chamber or cold-chamber & also weather the machine is horizontal or vertical.
- ⇨ Weight & tonnage calculations.
- ⇨ Selection of parting line.
- ⇨ Selection of runner and gate layout.
- ⇨ Determine core & cavity required.
- ⇨ Select the proper layout of the mould base.
- ⇨ Determine the ejection type to be adopted.
- ⇨ Core & cavity dimensions must include shrinkage value.
- ⇨ The material of core & cavity must withstand high melting temperature.
- ⇨ While deciding cooling layout care must be taken that water must not enter to core & cavity & also other system.

3.2 Guidelines for Design:

Advice on designing die castings is usually based upon desirable practices or situations to avoid. However, like most rules, there are exceptions. These affect costs, appearance and or quality of final products. Listed below are guides which should be considered when designing for die casting?

- Specify thin sections which can easily be die cast and still provide adequate strength and stiffness. Use ribs wherever possible to attain maximum strength, minimum weight.
- Keep sections as uniform as possible. Where sections must be varied, make transitions gradual to avoid stress concentration.
- Keep shapes simple and avoid nonessential projections.
- A slight crown is more desirable than a large flat surface, especially on plated or highly finished parts.
- Specify coring for holes or recesses where savings in metal and overall costs outweighs tooling costs.
- Design cores for easy withdrawal to avoid complicated die construction and operation.
- Avoid small cores. They can be easily bent or broken necessitating frequent replacement. Drilling or piercing small holes in die castings is often cheaper than the cost of maintaining small cores.
- Avoid use of undercuts which increase die or operating costs unless savings in metal or other advantages fully warrant these extra costs.
- Provide sufficient draft on side walls and cores to permit easy removal of the die casting from the die without distortion.
- Provide fillets at all inside corners and avoid sharp outside corners. Deviation from his practice may be warranted by special consideration.
- Die casting design must provide for location of ejector pins. Take into consideration the effect of resultant ejector marks on appearance and function. The location of ejector pins is largely determined by the location and magnitude of metal shrinkage on die parts as metal cools in the die.
- Specify die cast threads over cut threads when a net savings will result.
- Die castings which affect the appearance of a finished product may be designed for aesthetics, and to harmonize with mating parts.
- Inserts should be designed to be held firmly in place with proper anchorage provided to retain them in the die casting.
- Design parts to minimize flash removal costs.
- Never specify dimensional tolerances closer than essential. This increases costs.
- Designs die castings to minimize machining.
- Where machining is specified, allow sufficient metal for required cuts.
- Consider contact areas for surfaces which are to be polished or buffed. Avoid deep recesses and sharp edges.
- Dies can be produced for simple and complex parts. Parts having external undercuts or projections on side walls often require slides which increase costs. In many cases, however, resultant savings of metal or other advantages such as uniform wall sections offset the extra cost or affect a net economy in overall costs. This is especially true when large quantities are involved.

3.3 Process Flow (From Quotation to Dispatch)

The basic procedure involved in designing a tool is as follows;

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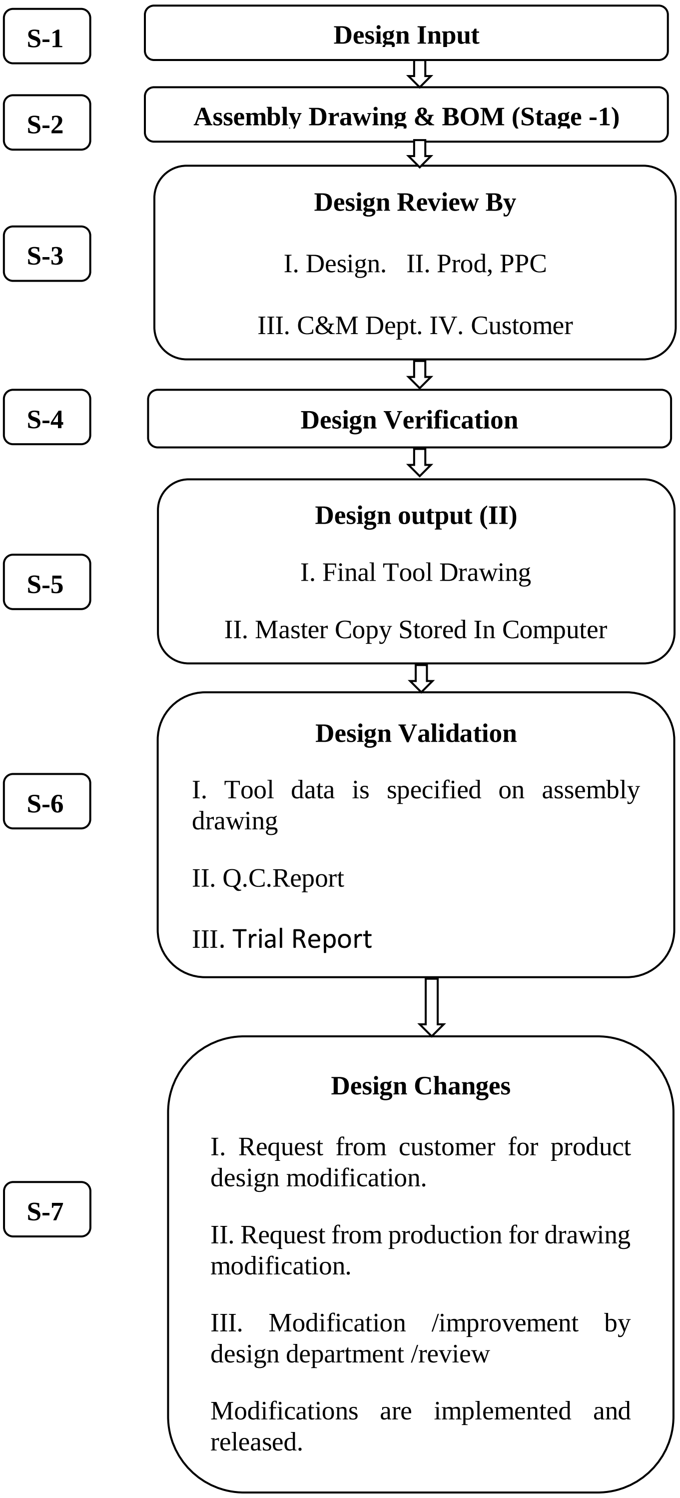
Process Flow (Flow Chart): **S** – (Separator)



4. MATERIAL PLANNING

The importance of materials is very inevitable in almost all the fields of Engineering. It may be a fabrication or textile, mechanical or chemical, cement or Pharmaceutical, electrical, electronics, or computer software/hardware, paint, polymer, Petroleum or leather, food etc.

Materials control is a set of techniques intended to provide manufacturing Shops with materials of right quality, in right quantities and at right time subject to Optimum inventory investment. Materials control function of PPC consists in studying Bill of materials for material specifications and their originating process, deciding Whether a particular item shall be made at the home plant or shall be purchased from Outside suppliers preparing material estimates, indenting requirements or non-stock materials, ascertaining availability of those purchased or manufactured to stock, follow-up with stores and purchase so that materials that are out of stock or are available in insufficient quantities are indented and received from vendors on time, instructing stores to reserve materials against specific shop orders.

4.1 Objectives of Material Planning:

- To reduce material cost.
- Efficient control of inventories, which helps in releasing the working capital for productive purposes.
- Ensure uniform flow of material for production.
- Ensure right quality at right price.
- Establish and maintain good relations with customer.
- Economy in using the imported items and to find their substitutes.

Material planning is very essential part of every tool. Material planning includes all the information about the parts used in the assembly. So, by using it one can get thoroughly knowledge about the assembly. Material planning includes Bill of material which includes part name used in assembly, material for that particular part, dimensions of that part, then quantity and hardness.

4.2 Material Management:

Materials management is a function, which aims for integrated approach towards the management of materials in an industrial undertaking. Its main object is cost reduction and efficient handling of materials at all stages and in all sections of the undertaking.

Importance of Material Management:

Material management is useful for following purposes,

- ⇨ For reducing foreign exchange, by utilizing the imported items to their maximum value and thus help in reducing the imports.
- ⇨ By reducing the cost of finished goods and maintaining the quality, it is possible for Indian manufacturers to compete better in foreign market and earning more foreign exchange.

5. PROCESS PLANNING

Process planning is the process of establishing the shortest and most economical path that each part is to follow from the point it is received as raw materials until it leaves as a finished part or a finished product. Process planning indicates operations to be performed and their sequence, specifies the machine tool for each indicated operation, shows the necessary tooling's (jigs and fixtures, cutting tools, cams and templates, measuring instruments, and gauges) for each indicated operation, gives manufacturing data such as speeds and feeds, indicates estimated or stop watch based set up and processing times, and incorporates sometimes the specifications of the skill for each operation. The document which incorporates this vital information is called process sheet or route sheet.

The information contained in the process sheet can be put to a variety of uses.

- Scheduling
- Materials movement
- Cost reduction & cost control
- Costing
- Method of working
- Requirement of man power and machines
- Shop efficiency

As work piece quantities and costs in press work are usually high, considerable economy can be affected by choosing an appropriate sequence of operations and the right type of tooling. The process plan should take into account the total cost: material, tooling, labour (time). Process planning generally includes the following considerations.

- Quantity required – total and annual,
- Work piece – shape and size, dimensional tolerances,
- Work piece – material limitations,
- Equipment available for manufacture.

In every tool, the process planning done a vital role and it is followed by above mentioned points. To manufacture the parts of the tool, it is necessary to follow the proper methodology of manufacturing, so that one can get accurate dimensional stability for that particular part within appropriate time. In Die casting dies also all the parts of the tool are manufactured by considering all above mentioned sequence and choosing of machining sequence. Below mentioned sheet expresses all the view of machining sequence of the tool. Similarly all the parts of the tool are manufactured by the same followed suit.

5.1 Manufacturing Processes Planning For Each Part

⇨ All the features of the part with dimensions & their references with respect to the assembly.

⇨ The part is studies and the plans for sequence of process like conventional, non-conventional & CNC machining, heat treatment in process & stage inspection etc.

⇨ Special requirements for the tooling, electrode, and CAD/CAM support for the programs required for the Core & Cavity inserts that are to be machined on the CNC machines etc. are planned in advance to meet the process flow & to maintain the delivery schedule.

⇨ Stage drawings of each parts coming & going out from process are made for the convenience of the machine operator showing the references, tolerance analysis, manufacturing allowances using the ordinate dimensioning and inspection methodology.

⇨ A continuous follow up for the machine availability is made for the completion of the job in the planned time period to maintain the delivery date.

⇨ The above information is applied for all processes related to the part indicating earliest start & finish date of each process with respect to material planning, date of availability of special tooling, electrode, CAD/CAM data, monthly priority list etc.

⇨ The start & finish date can be taken from the job cards the earliest finish date of assembly can be analysed for the first trial and is communicated to all the interface departments about planning and their support.

5.2 Factors Influencing Process Planning

- Order quantity and job life
- Delivery dates of components and products
- Process capability of the machines
- Skill of the available man power
- Material from which part is made
- Originating process of raw material
- Heat treatment process
- Surface finish required
- Accuracy requirements

6. INSPECTION

Inspection can be defined as, the process of checking the characteristics of a product for conformity with the specification through measuring, examining, testing etc. The need of the inspection arises so as to determine the fitment of the component produce. In older days, the craftsman used to be the producer as well as the assembler. There was no separate inspection function as such in the production process. If any fitment not matches at the time of the assembly, the same craftsman used to make the necessary changes in either of the parts to suit with the other.

But, the industrial revolution and the mass production concept, it demands for the Interchangeability of parts. When the large numbers of components of the same parts are being produced, then any part would be required to fit properly into any other mating component part. This purpose cannot be served by the hand fit methods. This requires adding the special function of the inspection to the production process. It gives rise to the modern industrial inspection, which has got a scientific approach.

Thus industrial inspection assumed its importance due to the necessary of the interchangeability. Due to the great advancement, the continuous improvements in the production methods and increasing quality demands, the Industrial Inspection does not mean fulfilling of the specifications lay down by the manufacturer. Rather the Inspection in real sense is concerned with the checking of a product at various stages of manufacturing, right from the raw material form to the finished products in the hands of the end customer. That is what called as the CUSTOMER SATISFACTION.

Thus, the Inspection led to the development of the precise Inspection instruments which helps to change over from the traditional lesser accurate machines to better design and more precise machines. It also led to the improvements in metallurgy and raw material manufacturing due to high demand of accuracy and precision.

Ultimately it leads to the QUALITY IMPROVEMENT. After manufacturing of all the parts they are transferred to Quality Control department to check the accuracy of profile also it's positioning from the reference. Various geometrical features such as perpendicularity, parallelism, circularity, run out, and etc. if required. Inspection of all the parts are carried out by trained personal and precisely working machines and it is followed by below mentioned path.

6.1 Final Inspection of Die Casting Dies:

- In die casting dies, the final fitting & functioning of tool is checked.
- Tool try out is taken as per the tool try out work instruction. Components after first trial are offered to QA department with trial report, inspection
- Plan of critical dimensions and customer's drawing (approved by customer.)
- QA department carries out inspection of components as per the approved component drawing & makes.

7. ASSEMBLY - PROCESS PLANNING

- First of all the assembly & sub-assembly is to be studied the process is planned considering the functional requirement along with fitment of mating parts showing indications & directions.
- The detail record is maintained of each part required for the assembly right from the material received to the final inspection report.
- The details of the process of each part can be obtained from the job cards. While the dimensions with tolerances can be known from the inspection reports.
- The details of part reaching the assembly can be obtained from the bar chart made before starting the actual manufacturing.

7.1 Assembly – Process:

- ⇨ While assembly of all parts and sub units first of all check the following things.
- ⇨ Study the drawing.
- ⇨ Check the component thoroughly.
- ⇨ Collect and analyze the mating parts and its dimensions.
- ⇨ Check the debarring if not then deburr it.
- ⇨ Before final assembly, check the fault occurring between mating parts.
- ⇨ The Pre-machining & assembly is done in the Assembly & Fitting section. Then centre drilling done on the plates, on NC machine. Then drilling operation, for cooling holes, tapping holes are performed on the bench drilling machines. Then those holes get tapped. Then after the manufacturing of all the parts, actual assembly gets starts. All standard parts available like Allen screw, etc. which is required during assembly are collected.
- ⇨ After manufacturing of Core and Cavity inserts are transferred to Quality Control department to check the accuracy of profile also it's positioning from the reference. Various geometrical features such as perpendicularity, parallelism, circularity, run out, and etc. if required.
- ⇨ For assembly of tool various points which are to be considered are as following.
- ⇨ Check all parts of standard die set and plate thickness for further calculation.
- ⇨ Check all the standard parts which are being used in this tool.
- ⇨ All the inserts are maintained as per drawing for easy fitment.
- ⇨ Check the all alignments and fitments of all matting parts.
- ⇨ Identification marks are marked on each part to avoid further confusion after disassembly.

8. SCOPE OF WORK

Using UNIGRAPHICS NX suitable CAD interface for designing, the project scopes hall extend well beyond solidification modelling. The dissertation work shall include the modelling for the entire casting process. This shall be complimented by Die Design essentials. A new case study to that effect shall be explored to highlight the importance of each stage of the process of design.

Future of high pressure die casting is seems to be better than the other casting process because of its mass production rate and can be used to produce complex shape with less casting defects, but there is research needed regarding this die casting process so as to enhance its productivity and to install additional features so that its efficiencies can be improved more. It is also necessary to make the die casting process economical and to reduce its installation cost.

9. CONCLUSION

In this paper the concept regarding high pressure die Casting (HPDC) is explained. Further in this paper, the advantages of pressure die casting is explained over conventional casting and limitation is also explained so that this limitation can be removed in future to make this casting process more precise and make it useful for large applications also discussion about material planning, manufacturing process planning, inspection & assembly process planning. Application of die casting is in different fields like automobile, household, and thus due to this versatility high pressure die casting (HPDC) is preferred over other casting process.

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