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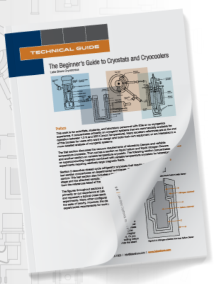

Analytical study of optimization of the cost of a high-pressure die casting(HPDC) die

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Abstract- High pressure die casting (HPDC) is particularly suitable for high production rate and it is applied in various industry actually approximately 50 % of the world production of Low weight metal casting age find out by this technology. In this paper, the process to determine the estimated cost of high-pressure die casting (HPDC) is studied. The study consists of two parts (i)based on comprehensive data analysis,and (ii)based onthe formulation of the algorithms for cost estimation. From these analytical study we find out that the cost is optimized from previous refrences. This paper presents the connection between the algorithms formed for cost estimation and the dimensions and features of the product developed. The study presents accurate results between geometrical features and cost estimation.

Keywords:cost estimation, knowledge comprehension, High-Pressure Die Casting (HPDC)

1. INTRODUCTION

In recent years High pressure die casting process gaining valuable in almost all manufacturing industrial sector . The process of intelligent manufacturing is rootedin the data information available about the product and process throughout the wheel of the life of products and process of manufacturing. About 80 % of the cost of the product including production cost is determined by designers during the phase of design[1]. To improve manufacturing flexibility the most convenient solution is to share the process-related information within the enterprises. In addition to this, the big data available from production plants also supports finding the solution for the feasibility and cost of the products and process [2]. In HPDC is ametal casting process characterized by forcing molten metal under high pressure into mould cavity [3]. Designers may accurately predict the cost of a product while taking into account real-world scenarios thanks to the systematic cost estimation procedure of manufacturing aluminum [4]. In order to perform a manufacturing cast estimation, it is necessary to classify the cast model that could be used to estimate the product costAmong the different techniques created for cost estimation on the part of designers,the best method is the one that is based on knowledge, functions, characteristics, weight, materials used, physical relationships, and similarity laws [5].

The high-pressure die casting (HPDC) systematic model for value estimate is presented in this research . Using high pressure to pour molten metal into a mould is known as HPDC [6].A systematic database system also have been developed and analysed for each feature consists of parameterized geometery,manufacturing information and design limitions [7].The procedure consists of two parts – (i) knowledge comprehension and (ii) formulation of the algorithms

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for the cost estimation [8]. The foremost part involves the description and classification of the cost of the items in generic way which are included in the process of HPDC.It also involves the collection of information fromfirms and literature and its formalization[9]. The next part involves the explanation of algorithms and formulation of equations for the prediction of HPDC manufacturing cost[10]. To define the model the relationship has to be formed between the cost of the items and product features like roughness and thickness, etc of HPDC. This model helps the designers in estimating the cost of the product during the initial phase of the process[11]. Analytical equations have beeb developed for tooling cost and setup cost and other cost which is calculated form referance value given[12].It is necessary to provide the the designer with efficient cost eastimation to available knowledge about the product [13]. The uniqueness of this approach is how it starts by describing the HPDC cost estimating framework from its geometrical behaviour[14] .The methology developed requires only the input of parameters that are available to the desiginer at early concept stage such as material type and geometric charcterstics[15].

The designers can apply the Design to Cost (DTC) criteria in the field of HPDC using the relationship that has been established between the geometrical characteristics of the product and its cost.

2. DIFFERENT COST ESTIMATION METHODS

HPDC is the main process for the production of minimum-cost items having high volumes and can be used in the field of automotive, domestic appliances, and electronics industries. In HPDC liquid metals like magnesium, aluminium, or zinc are fed at a high speed of approximately 450-100m/s and subjected to high pressure into the die-cast along complicated gating and runner systems. There are several steps in the HPDC process from releasing agent sprayto the die to opening and shutting the die.

The process of cost evaluation is completed in stages, such as conceptual, detailed design, etc. The cost approximation is based on grouping the costs of the components for materials and production processes and the cost model estimation. The cost estimation method involves precise firm knowledge, which is learned through experience and compiled business results. It is important to study the planning and production planning characteristics for accurate cost estimation of the manufacturing process. The process of planning involves the creation and picking of the machining process, the order, the criterion, etc. The cost evaluation method can be ordered as following methods: (i) methods based on knowledge whose reference is the experience of the estimators, (ii) Analogical techniques that rely on relationships with already-existing things; (iii) Analytical techniques based on the breakdown of the task;and (iv) parametric methods which is based on the relationship between the cost of the product and its features. Table 1 presents the summary of all the methods.

Table 1. Features of cost estimating techniques.

	Accuracy of the approach at actual cost	**Robustness**	**Subjectivity**
Knowledge-based methods	Minimum	Minimum	High
Analogical methods	Minimum	Minimum	Moderate
Analysis techniques	Maximum	Maximum	Minimum
Parametric techniques	Moderate	Maximum	Minimum

Among various cast processes, the cost estimation can be drafted with the help of parametricmodelsor models based on a rule which comprisescasting shape and weight complexity. The parametric model is mainly evolved for implementing the cost which can be calculated from the part solid model and is required for the part complexity. In some cases of parametric methods, the basis for cost estimation is the use of geometric parameters like a hole, slot, rib, etc. of the product and tools. To perform the comparative cost analysis at the design phase of various casting processes, the most suitable method is the literature model of cost estimation. However, the details of this method are notenough for the logical development of the product features. Each casting process has some abnormalities and requires a certain cost model.

Commercial software like aPriori and CustomPartare used for cost estimation for minimumdie-cast but these analytical approachesare insufficient to anticipate the cost breakdown of the products based onbasic operations of the product. They are inadequate in determining the product features associated with the process immanency and are hence known as “black boxes”. The results of the cost estimation of the HPDC process are more accurate than the presently used method. To develop a real tool for design activities A thorough structure for cost analysis and development must link the cost estimation method and DTC guidelines.

2.1. Cost Estimation Model

The cost estimating model is the culmination of research from academia and industry, as well as the expertise of experts like production technologists, cost engineers, designers, and plant managers. To implement the current model a spreadsheet has been used. The cost model includes the raw materials(C_{raw}), the accessory operation ($C_{accessory}$), the transformation process (C_{pro}), and set up operations (C_{setup}). The minimum section presents the details of the cost item.

$$C_{tot}=C_{mat}+ C_{pro}+ C_{accessory}+ C_{setup} \quad (1)$$

2.2. Cost of Raw material

The most crucial element in determining the total cost is the price of the raw materials. In actuality, this portion of the cost of the goods costs much more than 50%. It includes the cost price of the raw material, the melting operations (C_{rawtra}), and the returns from the scraps and discarded parts (C_{rawscr}). While performing calculation defect rate $D(_{rate})$ is considered as some molten pieces are not part of the molten metal.

$$C_{mat}= (V_{raw}.p.CU_{raw}+ C_{rawtra}- C_{rawscr}). (1+ D_{rate}/ 100) \quad (2)$$

The volume of raw materials (Vraw) is defined as the system for volume filling, the overminimum, and the parts.International organizations like London Metal Exchange and national organizations like ASSOMET for Italy have defined the unit value of the cost of raw material (CUraw).Manufacturing companies might obtain molten metal from external or internal furnaces.

$$C_{rawtran}= C_{ene} + C_{lost} + C_{lab} + C_{ope}+ C_{depr} \quad (3)$$

There are two furnaces in the melting process (i) used to melt solid alloyand (ii) to hold the liquid alloy. The foremost process is executed with the help of centralized furnaces in case the firm has specialization in a few alloys i.e., less than 6 materials, and has high production volumes of more than 1990 tons/year. For this process reverberatory, stack, and crucible furnaces are used. During the casting process, the holding phase cost is included as these furnaces are linked with high-pressure die-casting cells.

The cost of energy (C_{ene}) is calculated with the help of thermodynamics formulas required for melting the materials. It is the function of the raw material weight, the heat capacity, The cost of the material lost during a furnace's operation is determined using the melting and degassing yields (C_{lost}). Its annual value is determined by the alloy that is melted in a furnace each year. For various furnaces, depending on the temperature and pressure settings, the values are as follows. 0.07 – 0.01 for a reverberatory furnace having a production rate of 290 – 4300 tons/year

(i) 0.65 – 0.35 for a crucible furnace which has a production rate of 210 – 1˙400tons/year, and

(ii) 0.026 – 0.024 for a stack furnace which supportsthe price of 3˙600 – 12˙000 (1000kg per one year) [1].

The melting and degassing yields (C_{lost}) are used to calculate the cost of material lost during the operation of a furnace. The alloy that is melted in a furnace each year determines its annual value. Its values for various furnaces, depending on temperature and pressure settings, are as follows[2]. The labor cost is computed by calculating the labor involved in the melting process. The operation cost includes overhead costsandmaintenance costs. The hourly cost which is determined by enterprises based onthe dimensions of the furnace is a constant value. The furnace depreciation cost considers the furnace lifespan which is generally10 years, the yearly working hours are 8˙560hours with the idle time and depreciation index removed are roughly 3%. The cost of the raw materials comprises the return (Crawscr) from the scraps of the filling systems and over minimal, as well as the defective parts, which are calculated by the defect rate. Drate. The sample alsocategorizes contaminated lubricant and uncontaminated materials like filling systems, gates, and die-cast components. Since contaminated products cannot be employed in the production of new products, the cost of the two scraps differs.

2.3. Processing cost

The steps that minimized the processingcostof the processare used for evaluating the die casting process. It is done by the die casting procedure. with the assistance of an automatic cell which is made of a holding furnace, the robot removes die cast part from the press, the die-casting process is accomplished with the help of an automatic cell made up ofa holding furnace,the robot used A die-casting press, a water/oil bath to cool the parts, a lubrication system, and a trimming press that can be placed outside the cell for convenience are required to remove the die-casted item from the press [1]. The processing cost is a function of the cell's hourly cost and processing time.

The process cost is increased due to defect rate, which is the function of the complexity and dies wear. Furthermore, for high production, the process cost splits the gross cost into the number of cavities as the die contains more cavities.The die casting process has two parts (i) the die casting part which converts the liquid material into solid and (ii) the part which is responsible for removing the overminimums, splitting the cavities, and filling the system. As all the cycles in the process run parallel so, the length of the whole cycle is decided by the longest running. The penalty factor(Pf) helps in correcting the standard cycle time which is considered for the part roughness, dimensional and geometric tolerances [2].

Numerous formulae have been adopted and modified to calculate various HPDC process variables, including cooling, pouring, filling, opening/closing, lubricating, and extraction times. The pouring time is a constant value and an empirical result of raw material volume. The minimal width of the part has a major impact on the filling time. It is utilized to fill the die before solidification starts. The material determines the temperature needed for various die-casting processes like melting and die temperature. The part can be taken from the die once it has achieved a specific threshold value, hence the cooling time relies on the extreme width of the part. The material's qualities have an impact on the filling time as well.

The front area of the part, which is calculated by extruding the part along with the direction of extraction, determines how long the lubrication will last. The machine's characteristic, or dry-cycle time, determines how long the press needs to open and close the die[1]. Additionally, it is reliant on die convolution. The weight of the part and the general overall dimensions of the part both affect how long it takes to remove the item from the die. The maximum thickness of the item and its material both have an impact on how long it takes to cool the part in a water/oil bath[1].

$$P_f = (P_{roughness} + P_{dimtol}).P_{geotol} \qquad (6)$$

Table 2. The roughness of the portion is penalized

Ragged	It is not difficult to achieve tolerances.	It is tough to establish tolerances.
2.4 – 11.9µm	1.23	1.4

11.9 – 28µm	1.28	1.23
28 – 48µm	.9	1

A Boolean parameter, the difficulty factor states that "tolerances are difficult to get." According to table 2, a smooth surface necessitates a lengthy processing time since the injection pressure must be sustained. The knowledge of several firms that participated in this research is shown in the table. A lengthy cooling process is implied by the dimensional tolerances shown in Table 3 to minimize any distortion outside the die par.

Table 3 penalty for the part's dimensional deviations

Dimensional deviations	**Pimentel**
0.07mm $\leq$ 0.086mm 0	0.31
0.086mm $\leq$ 0.129mm	0.15
0.129mm $\leq$ 0.29mm	0.09
0.29mm $\leq$ 0.39mm	0.04
> 0.39mm	0

The part's shape determines the penalty factor for geometric tolerances [2]. The following are the minimum criteria for its description: I Variations in thickness (ii) Ribs that may have a single direction A frame's shape and the presence of lateral projections are among the last characteristics, which can be multidirectional, radial, concentric, peripheral, or not peripheral. The overview of all the information from this investigation is shown in Table 4.

Table 4: Penalty for the component's geometry

<table>
<tr><td>Feature 1</td><td>Feature 2</td><td>Feature 3</td><td>P_{geotol}</td></tr>
<tr><td rowspan="4">Slender part with constant thickmess if (22%)
If L/W <10 Then Slender Part</td><td>External ribs concentric or directional ribs</td><td>Almost consist Thickness of thin portion</td><td>1.23</td></tr>
<tr><td></td><td>Single or Multi directional ribs</td><td>1.25</td></tr>
<tr><td>No ribs in Peripheri</td><td>Concentricor Directional ribs</td><td>1.27</td></tr>
<tr><td></td><td>Uni directional or radial ribs</td><td>1.29</td></tr>
</table>

2.4. Press selection

The press's function is one of the most important factors in the cost calculation. According to the manufacturer of the press's commercial inventory, the characteristics needed for machine selection are the stroke, clamping force, and maximum die dimension. The pressure used during the filling phase, which is also referred to as the intensification factor and depends on the type of part, the cavity filling system, the front area, and the quantity of cavities, determines the clamping force [1]. The volume of the part, overminimums, and suggested speed of minimum at the gate are added together to calculate the frontal area of the filling systems for a single cavity[1]. The press stroke (Stroke) depends on the part's dimension as well as the direction of extraction and safety tolerances. The number of cavities affects the die's height and width.Counterbalanceis needed for the cavities and final dimension of the part.The validation of the machine is performed if the minimizing conditions are fulfilled: (a) Clamping force of the machine is greater than C_{force};(b) Machine horizontal die dimensionis greater than H_{die}; (c) Machine stroke is greater than Stroke; (d) Machine vertical die dimension is greater than L_{die}.

2.5. Cost of accessories and setup work

Costs associated with the initial setup of the process, maintenance tasks, and materials used in the process are included in the price of the die-cast parts. The setup is the process required to begin production in such a manner that its cost splits into batch size (*Bs*). The value of the time required to perform initial functions like cleaning the press, initializing the parameters of the die-cast, and connection of the cooling systems depends on the press which is a linear function of the size of the press(clamping force).Various scrap is generated during the setup process which is generally discarded. The quantity of the components generated is the characteristics of part complexity which can be determined by various parameters like $P_{roughness}$, $P_{dmintol,}$and P_{geotol}.

$$C_{setup} = \frac{\left(T_{mhpdc}+T_{mtrimming}+T_{initsetup}\right)\cdot\frac{CU_{hpdc}}{3600}+C_{scraps}}{B_s} \tag{7}$$

The product cost and maintenance cost are included in the accessory cost ($C_{accessory}$). The cost of maintaining the press cylinder, piston, casting dies, and trimming dies are used to compute the maintenance cost. According to the maintenance plan, the size of the press affects the cylinder and piston cost. The cost associated with the die is dependent on its complexity, which is a function of the complexity of the machine and the part. The cost of the lubricant needed to cool the part and lubricate the press, which is spent during usage, determines the cost of the consumables.

3. ANALYTICAL MODEL TESTING IN ACTUAL PRODUCTION SITUATIONS

To check the efficiency of the given model studies have been done on various case studies.The table 5 showsone radiator and two gasflame-spreaders as examples of the procedure.

Table 5: Analytical Model Testing In actual Production Situation.

	Flame Spreader 1		Flame Spreader 2		Radiator	
	Calculated value	**Reference value**	**Calculated value**	**Reference value**	**Calculated value**	**Reference value**
Total Cost	0.44	0.49	1.01	1.04	4.59	4.67
Raw material Cost	0.31	0.37	0.51	0.53	3.81	3.91
Processing Cost	0.08	0.06	0.21	0.24	0.56	0.59
Accessory Operation Cost	0.01	0.01	0.01	0.03	0.01	0.03
Set up Operation Cost	0.04	0.05	0.25	0.24	0.21	0.14
HPDC Process Efficiency	48%	36%	55%	52%	50%	48%
Total Casting weight(kg)	1.44	1.62	0.99	1.02	11.01	11.66
Cast Product Weight (kg)	0.70	0.59	0.55	0.54	5.4	5.5

The case studies specified with different dimensions and characteristics presentwide aspects and problems related tothe HPDC manufacturing process. However, In some of the HPDC manufacturing companies involved in this study, these items are currently produced, and a reference value about the actual cost of the product may be obtained for comparison [1]. The findings from the case studies reveal that the cost estimation of the entire cost has an error of about 6%. (Ctot).Specifically, the value obtained represents a significant example representing that total cost isminimumand raw material cost (*Cmat*) is significantly different.

The difference is observed due total weight of the casting and taking into account the parameters of the gating systems whichareovervalued in the real model. The error achieved in the total cost for the next example is around 3%. Thus it can be concluded that the errors in the calculation of raw material can be estimated. The maximum error observed is 40% which is for cost estimation of accessoriesand set-up operations but its part in total cost is only 11%.

4. CONCLUSION

The paper presents the planned process to compute the cost of materials involved in the HPDCprocess. This process takes into account various costs of items and product featuresand parameters of various processes. The case studies present that the results of the cost breakdown are precise for the relationship between geometrical features and the cost of the items. The highest error observed for the proposed process cost is around 6.2% which is due to the cost of the raw material. The results of the accessory are 6.04% and set-up cost items areminimum but their effect on total cost is negligible.The highest efficencey observed for the proposed process are inflame spreader 1 is 48%, 55% for flame spreator 2 and 52% in radiator which is more than the refrance data obtain form previous research.The results observed are according to the results observed in the literature review for various processes. Thus, the paper presented, helps manufacturing companies to makeeffective decisions to adopt a suitable method for variousprocesses in manufacturing.

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