Journal Of Harmonized Research (JOHR)

Journal Of Harmonized Research in Engineering
3(4), 2015, 122-130

ISSN 2347 – 7393

Original Research article

ANALYSIS OF DEFECTS IN MANUFACTURING OF PRESSURE DIE CASTING

Ratnesh Kumar Dewangan[1], AmitVishvakarma[2], Ashish Kumar Khandelwal[3]

Mechanical Engineering Department, Chouksey Engineering College, Bilaspur

Abstract - The manufacturing defects of the Die casting samples were decrease the strength and quality of product. In this project a systematic approach has been developed to find the best process for manufacturing die-casting. Form the survey different type of parameter has been taken to manufacture the die casting parts which has to analyses the influence of process parameters on the defects during Die casting of aluminum alloy. Tests carried out on nine design of experiment characterized by different survey on the basis of Temperature, Force exerted by piston and Type of casting process on aluminum alloy that solidify and analysis the defects of shrinkage and porosity due to gases produce during cooling. In this work defects initiation and growth have been analyzed in order to identify the factors causing these very high residual stresses that often produce shrinkage and porosity propagation throughout the casting. The defects were found on every square centimeter by microscope and then take their average. The best outputs were obtained on the basis of results of confirmation experiments reveal that topsis method can effectively optimize an optimal combination of the process parameters. It is perhaps the first attempt of its kind in the area of die-casting which analyze manufacturing parameter, and is expected to be of significant interest and value to the industry.

Keywords: Die-casting, TOPSIS method, shrinkage and porosity.

Introduction: The Die casting process consists of pouring the molten metal at a suitable temperature into a rapidly mould or die. It is essential that pouring temperature of molten metal should be high enough to enable it to reach the farthest point in the mould before solidification commence. The Die casting method was developed after the turn of the 20th century to meet the need for higher standards. The process of Die casting differs from static casting in that the mold itself is spinning during the time, casting is solidifying. Die castings are usually poured while the mold is poured;

For Correspondence:
ratnesh62dewangan@gmail.com
Received on: November 2015
Accepted after revision: November 2015

however, for certain applications, particularly in the case of a vertical casting, it is sometimes preferable that the mold be stationary when pouring begins. Pressure die-casting is the process in which the molten metal is forced with high pressure into the cavity of a steel mould called die. Pressure die-casting is the fastest and most economical way to produce a net shape component out of raw material. According to information, the inner walls of the cylinders are lined with hard chromium to avoid the formation of deposits, which may reduce the cooling efficiency of the roll. In this process of manufacturing the composites, the main emphasize is upon the wetting of the particles by the liquid metal otherwise there are potential areas which could lead to fatal deterioration of the material.

Die casting requires careful handling of molten metal, proper handling and maintenance of intricate and expensive dies, operating a very complex machine under extremely high pressures, critical temperature of dies and molten metal and special safety considerations. The distribution of reinforcement is also achieved by temperature of the melt, the mechanical stirrer speed, way of stirring, the particles size and their density and surface area. The other variables may include design of the mold, proper gating system and temperature of mold before pouring. Commercial grade aluminum is liquefied first and ceramic material is added in the desired manner and magnitude followed by agitation via mechanical means. The difficulty of doing so is that alloying elements that are beneficial for improving the former property are usually detrimental for the latter. In order to achieve reliable results a high number of specimens have to be produced and tested.

Types of Die Casting: In this research obtained compact tension and tensile specimens via direct Die casting. During specimens manufacturing a large number of them fractured during cooling, while others showed a delayed fracture. Considering that a large number of fractured specimens were available, a study has been carried out with the aim of finding the factors that determine this phenomenon. In this work specimens' structure and composition were analyzed and crack paths were studied in order to identify causes determining high residual stresses that in many cases are able to produce explosive crack propagation throughout the castings.For the die casting of light or heavy metal alloy, there are three types of machines:

1. Horizontal cold chamber machines.
2. Vertical cold chamber machines.
3. Hot chamber machines.

The die design helps the tool maker to understand what the die should be like when it is finished. The features of the die must control the metal flow, heat flow, the forces applied by the machine, and the molten metal. The die also has features which facilitate identification, storage, handling, maintenance, manufacture, operation, longevity and its compatibility to the machine. The solid mold process is mainly used for dental and jewelry castings, currently has only a small role in engineering applications, and as such will not be covered in this chapter. The ceramic shell process has become the predominant technique for a majority of engineering applications, displacing the solid mold process. Nowadays, medium strength titanium alloy, such as Ti-6Al-4V, is widely used in aerospace industry. With the development of new generation aircraft, it is important to develop high strength titanium alloy components. Researchers in United States, Japan, and Britain obtained significant achievements in Ti-15V-3Cr- 3Al-3Sn alloy research and applications Ceramic shell is the key in titanium investment casting. Chinese researchers have mastered main titanium casting shell technologies such as graphite shell, metal surface layered ceramic shell, and oxide surface layered ceramic shell. In this study yttrium oxide surface layered ceramic shell was used. This kind of oxide ceramic shell has high strength and low reactivity. It is suitable for gravity casting and Die casting.

Die Technique: Die casting uses the Die forces generated by rotating the mold to propel the metal and to facilitate filling. Vacuum arc skull furnaces discharge titanium alloy at a temperature just above its melting point, and the Die casting is usually needed to ensure good filling. Dental and jewelry casting use Die casting to fill thin sections and fine detail. The Die technique is used primarily for the production of hollow components, but Die casting is used to create solid parts The Die casting process is generally preferred for producing a superior-quality tubular or cylindrical casting, because the process is economical with regard to casting yield, cleaning room cost, and mold cost. The Die force causes high pressures to develop in the metal, and it contributes to the feeding of the metal, with separation from nonmetallic inclusions and evolved gases. In Die casting of hollow sections, nonmetallic inclusions and evolved gases tend toward the inner surface of the hollow casting. By using the outstanding advantage created by the Die force of rotating molds, castings of high quality and integrity can be produced because of their high density and freedom from oxides, gases, and other nonmetallic inclusions. When casting solid parts, the pressure from rotation allows thinner details to be cast, making surface details of the metal-cast components more prominent. Another advantage of Die casting is the elimination or minimization of gates and risers.

The latter two methods are only done with vertical spinning Horizontal Die casting is mainly used to cast pieces with a high length-to-diameter ratio or with a uniform internal diameter. Products include pipe, tubes, bushings, cylinder leeves (liners), and cylindrical or tubular castings that are simple in shape. The product range for vertical Die casting machines is wider, because noncylindrical (or even nonsymmetrical) parts can be made using vertical Die casting. All vertical Die castings have more or less taper on their inside diameters, depending on the gravitational (g) force applied to the mold and the casting size. On the other hand, vertical Die casting is mainly for castings with a low length-to-diameter ratio (except vertically cast extra long rolls) or with a conical diameter. The inclined Die casting machine bears advantages and disadvantages of both horizontal and vertical castings and can be very useful in certain applications. A disadvantage is the need for more extensive equipment and tooling than for static casting. The spinning axis is usually horizontal, but vertical orientation is sometimes employed for unusual sizes (e.g., large diameters or short lengths). Through long ages, the conventional material for manufacturing poles was wood; however, environmental concerns created the need for a new material for the pole industry. Steel poles constitute a good alternative for poles in terms of having sufficient strength properties with lighter sections. But, high cost of steel production and the requirement of the continuous protection against corrosion make concrete poles more beneficial. Therefore, concrete has been substituted for wood as the main production material of the pole industry. Over the mechanical properties of these alloys either grain refining is to be done by adding grain refining elements or by using cast technology depending upon particular alloys. These are the casting process, which makes use of Die force generated by rotating cylindrical mould to force the molten metal against the mould wall to form the desired shape.

The Die force imparted to molten metal enables it to be picked up and held in contact with the rotating mould. The mould is allowed to rotate till the casting is completely solidified. Thus the outer shape of casting takes the shape of the inside of the mould and the bore of casting is truly circular and concentric with axis of rotation. In case of Die casting, there is no need of runners and risers. The aging heat treatment programs were systematically performed in the as-received alloy after long-term use. The obtained specimens after various aging conditions were investigated and analyzed. A variety of working rolls according to the dimensions, design and material properties could be chosen for different types of rolling stands. When studying thermo mechanical loads of rolls during one revolution, two types of stress and strain field could be considered in the contact. Stresses in the area between working and back up roll could describe the Hertzian contact theory between two elastic circle bodies and in the area between working roll and rolled metal, which are widespread through the larger contact field. The Die casting method was developed after the turn of the 20th century to meet the need for higher standards. The process of Die casting differs from static casting in that the mold itself is spinning during the time, casting is solidifying. Die castings are usually poured while the mold is spinning; however, for certain applications, particularly in the case of a vertical casting, it is sometimes preferable that the mold be stationary when pouring begins. The machine then accelerates the speed of the rotating mold either during the filling of the mold or after completion of pouring. In other cases, such as horizontal Die casting, it is often desirable to have the mold rotating at a lower speed during pouring, followed by rapid acceleration to a higher speed during the solidification period. The application of Die force to a molten metal as it solidifies can be used to achieve a dense, sound casting. The Die casting process is most widely used for manufacturing of cast iron tubes, pipes, cylinder liners and other axis-symmetry parts. In the process of the electromagnetic Die casting, the molten metal low has a great influence on the quality and the performance of the roll. Since the Die casting is underthe complicated force situation and under the high speed, the high temperature and the opaque environment, it is difficult to know the moving and the filling rule of the molten metal.

Pattern Materials: Pattern materials currently in use are waxes, and plastics, while other pattern materials areused sometimes, and for specific applications. Waxes, blended and developed with differentcompositions, are more commonly used, while use of plastic patterns, generally polystyrene, may sometimes be required, to produce thin- walled, complex - shaped castings, such as in aerospace integrally cast turbine wheels and nozzles. Waxes, in general, are moderately priced, and can easily be blended to suit different requirements. Waxes have low melting points and low melt viscosities, which make them easy to blend, inject, assemble into tree- or cluster-assemblies, and melt out without cracking the thin ceramic shell molds.

Refractory's: Silica, zircon, alumina and various aluminum silicates are commonly used refractories for both slurry and stucco in making ceramic shell molds. Alumina is expensive, and as such used selectively, such as in directional solidification processes. Silica is generally used in the form of fused silica (silica glass). Fused silica is made by melting natural quartz sand and then solidifying it to form a glass, which is crushed and screened to produce stucco particles, and it is ground to a powder for use in slurries. The extremely low coefficient of thermal expansion of fused silica, imparts thermal shock resistance to molds. Its ready solubility in molten caustic solutions provides a means of chemically removing shell material from areas of castings that are difficult to clean by other methods. Silica is sometimes used as naturally occurring quartz, expense of which is very low.

Literature Review: Previous work has suggested that cast properties can be produced which approach those of forgings when the solidification rates and parameters are controlled to achieve the proper microstructure. The purpose of chapter is to present the results from a study of the properties and microstructure of Die castingin past research.

Problem Statement: The problems associated with these castings are unknown to the type of machine, the size of the tube and the type of alloy but the quality of tubular parts obtained during Die casting is strongly influenced by various process parameters like pouring temperature, die-speed, pre-heat temperature of the mould. It is the ability of the iron to undergo the allotropic transformation from ferrite (alpha) to austenite (gamma) during heating, and back to ferrite again during cooling, which makes it possible for the tool steels to develop high hardness and wear resistance.

Various method are available in the market for optimize casting defect and their optimum parameter, but these method do not make the manufacturing process for thin casting of aluminium alloy. Other than iron, generally carbon, manganese, phosphorus, sulfur, silicon, nickel, chromium, vanadium, tungsten, molybdenum and cobalt are present in the tool steels. Also some amounts of aluminum, titanium and zirconium are added to the steel for the purpose of oxidizing the melt and controlling the grain size of the steel. Tool steels have properties that permit their use as tools for cutting and shaping metals and other materials both hot and cold. It is important to classify tool steels into a relatively small number of groups for purposes of comparison and evaluation and to facilitate the selection of steel for a particular application. The reduced weight of hollow poles creates the advantage of easier transportation which demands less cost. Moreover, a high quality concrete can be manufactured, since the Die casting method has a better capability of compaction. The intention is to provide quantitative results that support the experimental observations in the literature, and so contribute to the solution of the problem. The most preferred production method of concrete poles is the Die casting. A fertilizers manufacturing unit experienced failures in the welded section of primary reformer tubes of ammonia plant. The investigation findings of that failure and remaining life estimate are presented here. Casting, or reforming materials by heating, melting and molding, can be traced back in history six thousand years. As civilization progressed and the use of metals became more advanced, the technology of casting metals advanced as well.

Material and Method: Pressure die casting in aluminum alloy offers means for very rapid production of engineering and other related component even or intricate design. The technique has obvious advantages when a component is required in large quantities. However, for aeronautic space, defence and automotive applications, mechanical properties and durability are of primary importance It is, therefore, essential that the best features of design should be employed and optimum casting technique with minimum cost be adopted. Die casting is one of the advanced casting techniques widely used in metallurgical industries. However, it is rarely used in ceramic. Few literatures are available on fabrication of ceramic body using Die casting technique. It has been reported that Die technique is very useful for production of functionally graded porous membranes for gas permeable applications. A detailed study of the principle and operations of Die casting machines available commercially suggests that there exist two types of Die casting machine designs.The chemical composition of the Aluminum alloy and the heat treatment details are given in Table 4.1**.** The castings were produced in the form of circular pipe (approximately 2cm thick by 10cmoutside diameter by 8 cm inside diameter) using two different mold rotation speeds, 800 to 1000 rpm.

Table1. Alloy Composition

Composition	Cu	Ni	Mg	Fe	Mn	Si	Zn
Quantity	0.15	0.13	9	0.4	1.2	0.4	0.1

Obtained Defects: Electron microscopy was performed using a Hitachi S900scanning electron microscope (SEM) equipped with a field emission gun and an energy-dispersive X-ray (EDS) microanalyzer. Transmission electron microscopy (TEM) work was carried out using a JEOL2000FX operated at 200 kV, with foils electrolyticallythinned in a 5% perchloric acid–acetic acid mixtureat 40 V dc followed by ion milling for several hours'-ray mapping was carried out using a CAMECASX50 electron probe microanalyser. The X-ray diffraction data was obtained using Cr Ka radiation and an operating voltage of 30 kV with a SiemensD5000 diffractmeter. From these microscopic procedures find number of shrinkage defects and pin holes defects in per centimetre of cylindrical parts of respected casting specimens shown in table 4.3. The shrinkage defects are obtained by veneer calliper to measure thickness of cylindrical piece in millimetre. Pin holes or blow holes defect was found by counting of holes through microscope.

Table2.Defects Found in Specimen

Thickness Shrinkage in mm (Ts)				No. of Porosity defects (P)			
1.4	1.5	1.4	1.6	6	5	3	5
1.1	1.5	1.6	1.6	4	3	2	3
1.6	1.6	1.5	1.4	5	2	4	4
1.5	1.2	1.4	1.5	3	4	3	2
1.7	1.4	1.5	1.6	4	3	5	6
1.5	1.7	1.7	1.4	2	6	4	5
1.3	1.6	1.6	1.4	4	5	3	4
1.6	1.4	1.3	1.4	2	4	6	6
1.3	1.7	1.4	1.2	5	2	4	4

Table 2. Average Defect with their parameters

S No.	Temperature in ^oC	Force Exerted F (KN)	Type of Process (Co)	Ts	P
1	500	50	Vertical	1.475	4.75
2	500	60	Horizontal	1.45	3
3	500	70	Hot chamber	1.525	3.75
4	550	50	Horizontal	1.4	3
5	550	60	Hot chamber	1.55	4.5
6	550	70	Vertical	1.575	4.25
7	600	50	Hot chamber	1.475	4
8	600	60	Vertical	1.425	4.5
9	600	70	Horizontal	1.4	3.75

Topsis Methods: TOPSIS (technique for order preference by similarity to an ideal solution) method is presented. TOPSIS is a multiple criteria method to identify solutions from a finite set of alternatives. The basic principle is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. The procedure of TOPSIS can be expressed in a series of steps:

1. All Experimental Data are converted S/N ratio.
2. The experimental design matrix along with normalized response (R_{ij}) is shown in Table X. R_{ij} is the normalized value and this normalized matrix can be calculated by the equation 2.

$$R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{30} x_{ij}^2}} \quad (2)$$

- Where $x_{ij}$is the experimental value of the i^{th} attribute of the j^{th} experimental run.

3. All attributes of normalized matrix (Rij's) are multiplied byS. D. weights. Resultant matrix is called weighted performance matrix which is denoted by S_{ij} (for i^{th} experimental run and j^{th} response).
4. Now positive ideal solution (S^+) and negative ideal solution are expressed by the following equations and their values are provided in Table.

$$S^+ = [\max (S_{ij})]\ j \in J \text{ or } [\min (S_{ij})\ j \in J'],\ j=1,2,..\ 30 \quad (3)$$

$$i = 1,..,4$$

$$S^- = [\min (S_{ij})]\ j \in J \text{ or } [\max (S_{ij})\ j \in J'] \quad (4)$$

Where J is related to the higher-the-better performances characteristics and J′ is related to the lower-the better performances characteristics. In the present case, all the responses (i.e.Ts and P) are of lower-the-better type, hence J′ is considered.

After calculating the S_{ij}matrix, the next step is to find the distance of positive and negative ideal solutions by using the equation 5 and 6.

$$d_i^+ = \sum_{i=1}^{5} d(S_{ij}, S_j^+),\quad i=1,2,.....30 \quad (5)$$

$$d_i^- = \sum_{i=1}^{5} d(S_{ij}, S_j^-),\quad i=1,2,.....30 \quad (6)$$

$$d(x,y) = \sqrt{\frac{1}{4}[(x_1 - y_1)^2 + ... + (x_4 - y_4)^2]} \quad (7)$$

Where d(x,y) is the distance between two fuzzy numbers. This distance of two values of d+ and d− are shown in Table X. After calculating the distance between the positive and negative ideal solution, the final step is to determine closeness coefficient (CC_i), which is calculated by equation 8. This CC_ivalue indicates the closeness of each the experimental value to the ideal solution that is shown in the same table.

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (8)$$

Table3. Observation value for TOPSIS

Sr. No.	Ts	P	SN Ratio Ts	SN Ratio P	Rij (Ts)	Rij (P)	D-	D+	CCI
1	1.475	4.75	-3.3758	-13.5339	1.12156	5.133332	1.94725	3.53207	0.3554
2	1.45	3	-3.2273	-9.54243	1.02507	2.551953	4.05994	0.87500	0.8227
3	1.525	3.75	-3.6654	-11.4806	1.322211	3.69391	2.07797	2.70413	0.4345
4	**1.4**	**3**	**-2.9225**	**-9.5424**	**0.840593**	**2.551953**	**4.63221**	**0.00000**	**1.0000**
5	1.55	4.5	-3.8066	-13.0643	1.426071	4.783262	0.67060	3.96308	0.1447
6	1.575	4.25	-3.9456	-12.5678	1.532101	4.42662	0.89551	4.04979	0.1811
7	1.475	4	-3.3758	-12.0412	1.12156	4.063448	2.37271	2.33332	0.5042
8	1.425	4.5	-3.0763	-13.0643	0.931355	4.783262	2.88374	2.86000	0.5021
9	1.4	3.75	-2.9225	-11.4806	0.840593	3.69391	3.75296	1.44704	0.7217

Conclusions: Defects were finding in Die casting with the objectives to minimize the thermal stress. The particle size of reinforcement should be finer so that the miss fitting problem can be accommodated accordingly. By using fine particle size, the problem arising from the Die force can also be minimized that produces segregation in the melt due to which the non-uniform properties are attained. This suggests that in order to prevent this phenomenon the charge materials should be degreased and afterwards they should be preheated together with the crucible in a muffle to evaporate surface moisture. Further improvement can be obtained by pouring the alloy in vacuum in a preheated mould, leaving the casting to cool down in a furnace.Die-casting of alloy produced less porosity for mold speeds of 550 rpm with 50 KN exerted force and horizontal process has been preferred. However, the cast microstructure contained carbide and Laves phases, the latter as being generally regarded as deleterious to the mechanical properties of the alloy.

Consequently, it can be concluded that the use of such computational tools may aid the production process and the durability problems can be avoided by conducting a well-designed production phase, thus eliminating segregation of the concrete. Die cast ceramic body likely to have graded microstructure. The inner surface will have high density as compared to the outer surface. The computational analyses have shown that a uniformly casted concrete pole will not suffer from excessive tensile stress formation by uneven shrinkage.

References

[1]. Khalid MahmoodGhauri, Liaqat Ali, Akhlaq Ahmad, Rafiq Ahmad, KashifMeraj Din. Ijaz Ahmad Chaudhary, Ramzan Abdul Karim, “Synthesis and Characterization of Al/SiC Composite Made by Stir Casting Method”, Pak. J. Engg. & Appl. Sci. Vol. 12, Jan., 2013 (p. 102-110).

[2]. R. Tavakoli·P. Davami, Optimal riser design in casting process with evolutionary topology optimization, July 2008.

[3]. P. Shailesh, B. Praveen Kumar, S. Sundarrajan and M. Komariahia, (2012), “Experimental investigation on Die casting of 5500 alloy: A Taguchi approach “, Scientific Research and Essays Vol. 7(44), pp. 3797-3808, 12, ISSN 1992-2248 .

[4]. J. Swaminathan, Raghubir Singh, Swapan Kumar Das and Goutam Das, “Failure

Analysis of Welded Reformer Tubes of a Fertilizer Unit", Proceeding of the International Conference & Exhibition on Pressure Vessels and Piping, "OPE 2006 – CHENNAI", 7-9, February 2006, Chennai, India.

[5]. Lothongkum G., Ratanamahasakul S., Wangyao P." The Relationship Between Heat-Treated Microstructures And Mechanical Properties In Cast Iron-Base Alloy", ActaMetallurgicaSlovaca, 12, 2006, 2 (154 - 166).

[6]. M. Drobne, T. Vuherer, I. Samardžić, S Glodež, "Fatigue Crack Growth And Fracture mechanics Analysis Of A Working Roll Surface Layer Material"Issn 0543-5846, 53(4) 481-484 (2014).

[7]. Cesar R.F. Azevedo , Rafael R. Maia, Edwan A. Ariza, André P. Tschiptschin, "Failure analysis of a martensitic stainless steel (CA-15M) roll manufactured by Die casting. Part I: Material and fractographic characterization", Engineering Failure Analysis 36 (2014) 343–352.