Enhancing Dimensional Geometry in Sand Casting using Computer Modeling

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Abstract: Sand casting method is used to produce many useful products for many applications. The aim of the study is to manufacture a product with excellent dimensional geometry is achieved in sand casting process at low cost. We would expect manuscripts to show how design and/or manufacturing problems have been solved using computer modeling, simulation and analysis. In this work, the important mechanical properties of hardness and surface roughness are investigated on Aluminum 6063 cast material with and without incorporating the copper tubes as a vent hole in sand casting process. Since copper has high thermal conductivity when compared to other metals, the heat transfer rate will be varying from existing system. The copper tubes have made different diameters of holes on outer surfaces with selective distance of intervals. The specific number of copper tubes with various diameters are designed by CATIA modeling software and analyzed with Taguchi Design of Experiment. Taguchi L9 orthogonal array is used proficiently in the optimal value of hardness and surface roughness. The results are revealed that the maximum hardness value of 104 BHN is attained for 10mm distance of holes made on copper tube with an angle of 90^{o} degree. The minimum surface roughness of 2.11 micron is achieved for 20mm distance of holes made on copper tube with 45^{o} of angle as a vent hole in sand casting process.
Keywords: Sand casting, Modeling, CATIA, DOE, Copper tubes.

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1. Introduction

The purpose of selecting the sand casting are good accuracy cast product, preparation of the patterns, quick solidification time and high production rate when compared with pressure die-casting. The important parameters in casting are vent hole selection, gating design, sprue & riser dimensions, standard pattern allowances and also tolerance. The physical and mechanical properties are affecting the factor of bonding mechanisms, intermetallic compounds of crystal structure. The input process parameters and materials are plays a vital part for the selection quality of the test specimen.The main parameters of the vent holes are mostly used to escape hot flue gases from the sand zone and also works to take out the heat from the mould boxes. The solidification time is reduced by the number of vent holes and vent hole diameters. The vent angle is 90º because the hot gases quickly reach to atmosphere. The solidification time can also be decreased by the 90 º of vent hole. The fastest solidification time is achieved highest hardness. The vent hole is selected for improving the heat transfer rate in sand casting process. The various researchers have analyzed with different sand mould parameters. The literature reviews present the effect of various parameters and performance of sand casting process. The fundamental of casting process is explained as one of the significant essential process parameters and a mathematical analysis is involved. The majority of the researchers explored how various parameters influence various output outcomes and built a numerical equation using response surface approach and DOE software. In general, casting process modeling assists in achieving process parameters with minimal production time and maximum profit. Narasimha Murthy et al [1] investigated sand properties with help of granulated blast furnace in foundry Industry. In this work, the various compositions are analyzed and found best combination of sand properties. A 356 alloys and cast iron are used for this investigation. The both laboratory and industrial tests are completed successfully, results disclose that slag models makes superior surface finish and no surface defects in casting. H. A. Mahrabi et al [2] said that the methods of limited waste and economy energy in outlay casting process. Numerous stages in the casting, by optimizing and amplify efficiency in any one procedure direct to less period of time, energy and cost effective. The improvement of the yield is higher than the existing process and also used for New processes are welding wax pattern, design appropriate gate system, etc.Die casting Jerald R. Brevick et al [3] analyzed the high technology manufacturing process in terms of both economical and energy utilization. It is analyzed various operational decision parameters and calculated the emission and carbon di-oxide. Experimental investigation D. G. Eskin et al [4] is done to find effects of molten hotness and foundry velocity on structure throughout Al-Cu alloys with chill casting. The billets parameters of temperature and melt flow of cast are analyzed. The main defect of porosity is somewhat diverse by selected parameters. Christian W. Schmidtet al [5] the major disadvantages of dual-roll of aluminum lagging entire solidification process. For this reason a heat loss analysis is being calculated in the melting furnace. The heat losses are calculated in various stages of solidification process. The CO2 emission is controlled by this investigation and also heat is minimized and preoccupied. The aim of investment casting Amit Sata [6] reduced internal flaws to make desired mechanical properties. In this work, the quality was examined by various mechanical properties and the selective destructive test. The nontraditional techniques of Artificial Neural Network (ANN) and Multi Variate Regression (MVR) were used in this investigation. The more heat impression are accumulated by deviation of different selective constrains. A variety of ANN models, momentum & adaptive were explained in this investigation. The result is compared with Artificial Neural Network (ANN) and Multi Variate Regression (MVR).The defect in the casting D. Benny Karunakar [7] were discussed and analyzed back-propagation neural network. The sand Parameters like Green Shear Strength (GSS), Green Compression Strength (GCS), melting conditions, composition of the charge, permeability and moisture content are expertise using neural network. Fuzzy logic (FL) approaches of 3 types M. B. Parappagoudar [8] were used to carry out forward and reverse mappings on metals, which establish inexpensive and dimensionally precise. The input values such as amount of cement, testing time, mechanical properties and hardness can be discussed in forward analyses of mapping process. The latest approaches performance are experienced with test cases and found to be convincing. Ganesh .G et al [9] discussed the various sand properties and selected best level of sand parameters in sand casting process. The neural network applied with parameters such as inputs and the appearance non appearance of flaws as output by using MATLAB software. Priyank et al [10] analyzed the most favorable process constraints by Design of experiments and Artificial Neural Network and described that the vent wire was normally used to output the gases from the foundry box. Paul De Garmo [11] investigated the properties yola sand & moisture content. The ordinary sand of yola has been considered for the percentage of moisture level from 1 to 8 %. The investigator strongly recommended that the best compression strength of118.6 KN/m2 and the moisture content of 5 %. Farzaneh et al concluded that heat is the main role and it is clearly analyzed the solidification time the mould boxes. Noorul Haq et al calculated the input constrains were optimized to get better an unexpected quality in final cast products. It shows the various defects and the most favorable results were also suggested. The important materials like bentonite and zircon clay properties were nominated in addition to sand mix with percentage of weight. Saliu et al investigated the various compositions and physical properties of silica sand in different foundry industries. The various level of additives are introduced in this investigation.The important additives clay Coal dust, corn flour blended with water and some binders are used. Nigeria Charnnarong Saikaew analyzed the synthetic and imported binders in Foundry industries. It is clear that the various types of special sand are recommended in foundry industries. The importance of the casting are calculated by the constrains like permeability, moisture, mould hardness, compatibility,s hatter index and sand compressive strength in molding sand Himanshu Khandelwal. Bose Narayanasamy and Palanikumar Dhanabalan investigated the surface roughness for the material of titanium alloy graded 5 using grinding machine. The various cutting parameters are analyzed by L27 orthogonal array of Taguchi method. John et.al analyzed an impact energy & hardness of Al alloy with key factors pouring & mould temperature, runner size are evaluated. Mekonnen et. al examined the surface defects of single and dual blank aluminum in casting yield. The chemical composition of clay content, grain size, moisture content and mould preparations are considered. The optimum result for this aluminum blank is conceded out by using Taguchi robust method of optimization. Guharaja et .al studied cast flaws of values of Spheroidal Graphite by cast iron. Taguchi method implemented for this effort and also minimized the casting flaws. The input parameters such asmoisture content, green strength, mould hardness and permeability were considered in this work. Nagurbabu, et .al determined best mixture of clay bounded modeling by Neuro fuzzy model Artificial Neural Network. The input parameters such as coal dust, clay, pouring time and moisture were deliberated. The permeability outcomes are carried out by the ANN method. From the literature review, it is well-known that the most of the researchers investigated various parameters in sand casting. It is clear that the vent hole parameters have not taken for all constraints. It is necessary to concentrate the proper solidification and also mechanical properties of the material. In this work to be considered on optimization of vent hole parameter is analyzed with copper tubes.

2. Experimental Method

Aluminum, Bronze, brass and cast iron materials are using in 60% of Indian small scale foundry industries. However, maximum of sand casting industries are utilizing Aluminum as a cast material. This work is systematically based on Aluminum 6063 and experimental work is done using sand casting process. This research purpose is to optimize the vent hole parameters and to improve the mechanical properties. The copper tubes with same diameter and same size of holes are made at different intervals. Copper tubes with 6mm diameter are drilled with 2mm diameter holes at an interval of 10mm, 15mm, and 20mm respectively. This copper tube is introduced into the sand instead of vent holes and allows the Aluminum 6063 to solidify. The allowances remains same and the standard design procedure is followed for gating system, runner, riser, sprue, sprue basin.The chemical composition of work piece (Aluminum 6063) is given in the Table 1.

Table 1.Chemical composition for Aluminum (6063)

Element	Mn	Cu	Cr	Mg	Fe	Al
%	0.24	0.23	0.32	0.68	0.23	98.30

Aluminum 6063 has 650^{o}C as minimum melting point and it is comfortable to melt in crucible furnace [21]. Temperature level in the furnace is calculated by using the instrument of infrared thermometer. The important parameters like Vent holes, holding the temperature for desired time and molten temperature are control factors which has more significance in the furnace. The sand casting industries consider these parameters to develop a product without any defects at proper solidification.The various sample copper tubes which are replaced instead of vent holes are presented in Figure 1,

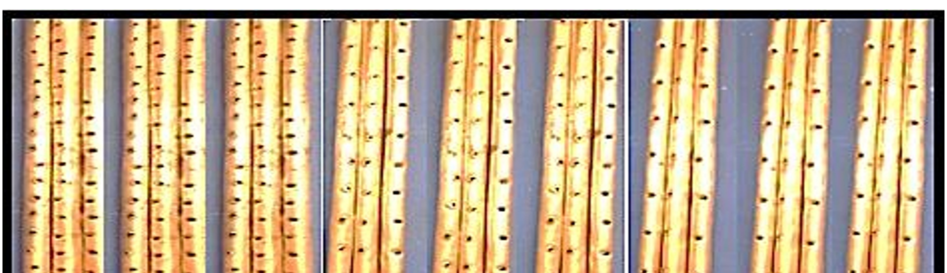

Figure 1. Copper tubes with 2mm holes at an interval of 10mm, 15mm and 20mm

The standard procedure of sand preparation is prepared in the mould boxes and it is shown in Figure 2(a). There are 16 copper tubes are inserted into the cope mould box and allows Aluminum 6063 is to solidify with specifications of 6mm diameter with 2mm concentric holes drilled at an interval of 10mm shown in Figure 4.2(b)

Figure 2 (a) Without copper tube (b) With copper tube

The standard process is followed by the design of sprue basin, riser, gating system and allowances in the cope and drag box.. The dimensions of the mould boxes are 450X450X100mm and work piece was 50mm cube taken for this experimental investigation. The location of the vent hole angle of 45°, 60° & $90^\circ$is made with respect to Figure 3.

Figure 3 (a) 90° vent hole (b) 60° vent hole (c) 45° vent hole

3. Methodology

The vent holes are mainly used for the hot gases to escape from the molded sand. It is also helps to extract the heat from the mould box. The solidification time is concentrated by the number of vent holes and vent hole diameters. The vent angle is normally formed at 90° to enable the hot gases to reach the atmosphere. The solidification time can also be reduces by the 90° of vent hole. Maximum hardness can be achieved when solidification time is minimum. The minimum solidification time at 60° and 45° of vent hole angle is achieved for the better surface finish. Similarly the diameter of vent holes also influencing the hardness and surface roughness of the materials. Normally the diameter of vent hole for sand casting process is 3mm for 450 mm square mould box. The vent hole diameters can be varied based on the size of the mould box and cavity volume. In this Chapter, the vent hole diameter and vent hole angles are considered. the major input process parameters manipulating the hardness are vent hole diameter and vent hole angle to produce the good eminence of the test specimens as mentioned in Table 2.

Table 2.Vent hole Input parameters and Levels

S.NO	Input Parameters	Units	Levels		
			1	2	3
1	Vent hole angle	OC	45	60	90
2	Distance between holes	mm	10	15	20

The various vent angles of 90,60 and 45 degree and distance between 3mm holes made on copper tubesare selected for this investigation. The main purpose of 3mm holes on copper tubes is to escape the unwanted gases and it also helps to quick heat transfer from the mould sand. the Cu tube has good thermal conductivity which absorb heat from the body. The number of copper tubes may increase the mechanical properties of the cast material. The vent hole diameter and position of vent holes are trailed as per the foundry standard technique. The experiments are accompanied based on the L9 OA in Taguchi approach mentioned in Table 3.

Table 3.Design of experiments by L9 orthogonal array

Exp.No	Input parameters	
	Vent hole angle	Distance between holes in copper tube
1	90	10
2	90	15
3	90	20
4	60	10
5	60	15
6	60	20
7	45	10
8	45	15
9	45	20

4. Results and discussion

The influences of mould attributes on sand casting process are discussed in this experimental work. The important characteristic like melting temperature in furnace and the various vent hole dimensions on sand casting measured for this inspection are evaluated by L9 orthogonal array (DOE). The Brinell hardness tester and surface roughness tester are used for output value parameters. The crucible furnace has been used for melting the material in sand casting. In this research, the comparison results of hardness and surface roughness are presented. The best possible parameters are chosen and genuine by using DOE experiments.

4.1 Design of Experiments

The Design of Experiments analyses are used for this instigation [22-24]. The equivalent vent inclination and interval of vent holes in copper tube setup are practically worked by L9 orthogonal array. The output values are intended by the consequent values of hardness and surface roughness. The experimental run setup is shown in Table 4. The objective of the exploration is to analyze the outcome of input factors on the hardness for “Larger is Better” form is chosen and the Surface Roughness for “Smaller is better” is preferred [25,26].

Table 4.Experimental Results with Output Responses

Aluminum 6063				
Exp No	**Input Parameters**		**Output Response**	
	Vent hole angle	**Distance between holes in copper tube**	**Hardness**	**Surface roughness**
	Degree	**mm**	**BHN**	**Microns**
1	90	10	104	3.81
2	90	15	86	3.44
3	90	20	92	3.34
4	60	10	77	2.82
5	60	15	86	3.69
6	60	20	92	3.66
7	45	10	85	3.31
8	45	15	72	2.11
9	45	20	77	2.56

The surface roughness experiment were calculated from surface roughness tester instrument and hardness test taken from Brinell hardness machine are shown in Figure 6(a) and 6(b).

Figure 6. (a) Surface Roughness tester, (b) Brinell Hardness Test Machine

The various images of casted work pieces with varying input parameters like vent hole angle and distance between holes are shown in Figure 7.

Figure 7. Cast Materials in Aluminum 6063

4.2 Main Effect Plot

The best possible level of input considerations is discussed with main effect plot for this experimental investigation. The optimum value of input parameters for this experimental study is signified as the maximum value of each level in the main effect plot. The main effect plot for aluminum on hardness and surface roughness are shown in Figure 8. It is signify the greatest level of input parameters such as vent hole angle and distance between holes rates of every level. From Figure 8, it is identified that the effect of input values increases with growth in the level. The best level of parameters for this investigation is vent hole angle 90 º and distance between holes 20mm.

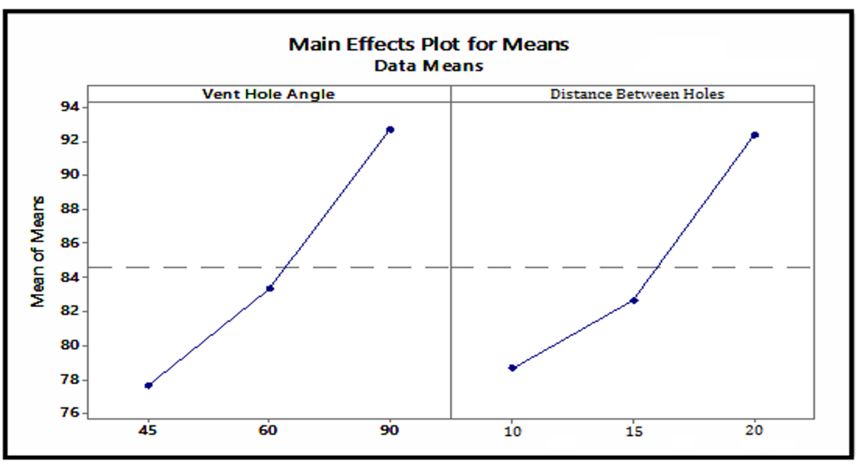

Figure 8. SN Ratio of Hardness in Aluminum 6063

It is analyzed that most excellent surface finish is produced when vent hole parameter angle of 45º, distance between holes 10 mm parameter. The vent hole angle of 90o and distance between holes of 20mm geometry is used to escape the more heat transferred from mould box. The solidification time is reduced of this geometry. The higher hardness is achieved at minimum solidification time of casting process. The main effects of vent hole parameters for Aluminum 6063 are shown in Figure 9.

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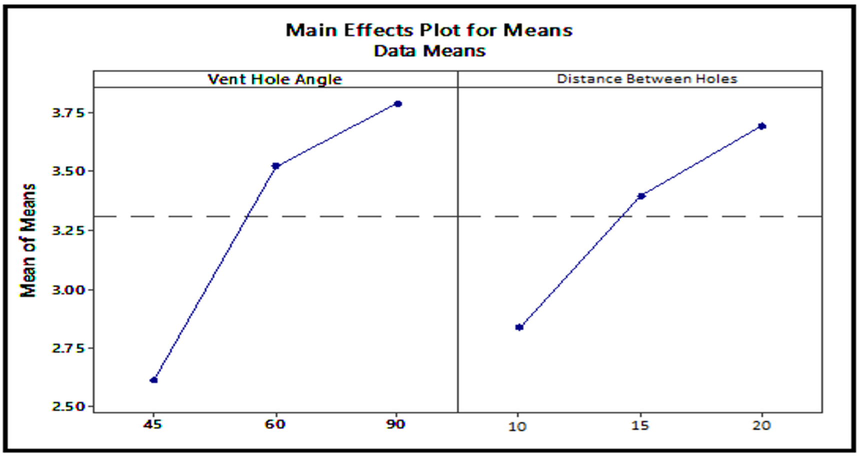

Figure 9. SN Ratio of Surface Roughness in Aluminum 6063

4.3 Confirmation Test for Hardness and Surface Roughness

The conventional method of sand casting process with normal vent hole is achieved 97 BHN of hardness. But incorporating the copper tube instead of vent hole is achieved 104 BHN. So it is clear that the high thermal conductivity of copper is a major role of sand casting process. The comparison DOE result of hardness as shown in Figure 10.

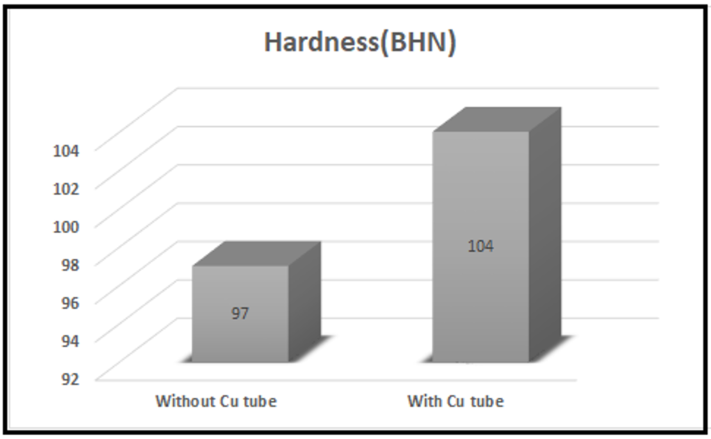

Figure 10. Comparison Result of Hardness in Aluminum 6063

The conventional method of sand casting process with normal vent hole is achieved 3.56 micron of surface roughness. But incorporating the copper tube instead of vent hole the surface roughness is achieved 2.11 micron. So it is clear that the high thermal conductivity of copper is a essential role of foundry process. The comparison DOE result of surface roughness as shown in Figure 11.

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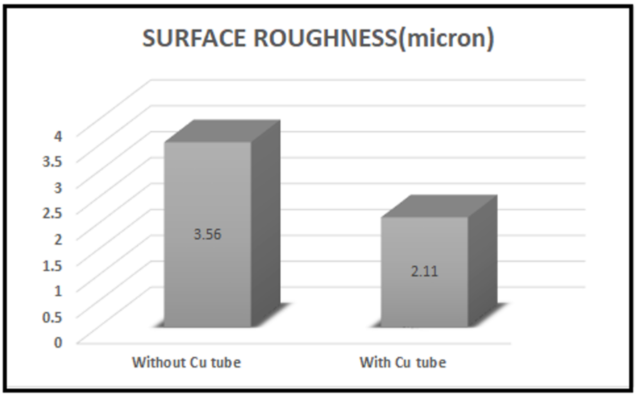

Figure 11. Comparison Result of Surface Roughness in Aluminum 6063

5. Conclusion

Sand casting process is carried out the hardness and surface roughness are analyzed on Aluminum 6063 material. The Taguchi method of L9 orthogonal array is mainly used for the output parameters. The optimum parameters for copper tube instead of vent hole and corresponding output parameters of hardness and surface roughness are listed below.

- Casting of Aluminum (6063) material is used for this investigation and improved mechanical properties.
- Taguchi L9 orthogonal array is used proficiently in the optimal value of hardness and surface roughness in sand casting process.
- The maximum hardness value of 104 BHN is attained for 10mm distance of holes made on copper tube with an angle of 90^{o} degree.
- The minimum surface roughness of 2.11micron is achieved for 20mm distance of holes made on copper tube with 45^{o} of angle as a vent hole in sand casting process.
- Copper tube as a Vent hole and the parameters are additional effective impact in sand casting.
- The following parameters are strongly recommended for small scale foundry industries and also it assistances to enhance the mechanical properties.

The authors described the subsequentimportantinference based on the investigational outcomes of 'larger is better' for the hardness and 'Smaller is better' for the surface roughness. This study is valuable for the researchers to develop the information in sand casting process on Aluminum (6063).

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