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MULTI-OBJECTIVE OPTIMIZATION OF PROCESS PARAMETERS IN GRAVITY CASTING METHOD BY USING INSPIRE CAST

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Abstract - Gravity die casting was one of the very earliest processes to be invented for metal and light alloy die casting. In this process which can be fully automated, the molten metal is poured directly from a ladle into a semi-permanent or permanent die. The goal is to fill the die with minimum turbulence through one or more channels to reduce oxidation and foaming. This minimizes porosity and inclusions, giving optimum metal characteristics in the final casting. Gravity die casting equipment can have a vertical or horizontal mould opening, or tilting technology with 0/90 ° or 0/120 ° tilting provides an alternative. The aim of this project is to perform the Gravity casting process to identify the optimum process parameters. Altair Inspire Cast simulation software is used to perform the casting process in-ordered to identify the optimum process parameters. Taguchi's Design of experiments method is used to frame the experiments, L09 orthogonal array is used to conduct the casting process. Input parameters like Inlet-position, Number of Raisers, Filling time has taken. The analyzed Output parameters are Filling temperature, cold-shuts, solidification temperature, solidification time, porosity, Total shrinkage volume. Grey Relation Analysis is adopted to perform multi-objective optimization. The results reveal that the optimum condition is Side-inlet, 0 Raisers, 15 seconds filling time.

Key Words: Multi-objective optimization, Gravity Casting, Altair inspire cast, .

1. INTRODUCTION

A liquid substance is often poured into a mold that has a hollow chamber in the desired form during the casting manufacturing process, and the material is then let to harden. Castings are the solidified component that are expelled or broken out of the mold to finish the process. Typically, casting materials consist of metals or a variety of materials with long curing times; examples include epoxy, concrete, plaster, and clay. Casting is most often used to create intricate forms that would be difficult or expensive to create using other techniques. Instead of manufacturing by combining several tiny parts, heavy equipment like machine tool beds, ship propellers, etc. may be readily cast in the needed size. A 7,000-year-old practice is casting. Metal casting is now a difficult, sophisticated operation that needs precise chemistry and perfect execution. Despite the fact that modern techniques may be relatively recent in the context of human civilization, the earliest metal castings date all the way back to roughly 4000 BC, because to its malleability, gold was the first metal to be cast during that era, and because to the difficulties in acquiring pure ore, metal from tools and decorations was reused. The earliest known casting, a copper frog, is said to have been created in Mesopotamia (modern-day Iraq) about 3200 BC. Due to its stiffness compared to gold, bronze later emerged as the preferred metal for casting. Using permanent stone molds, bronze was melted and cast into a variety of tools and weapons. By 2800 BC, casting had reached Egypt, and the efficient execution of this procedure had a significant impact on their rise to prominence throughout the Bronze Age. The Shang Dynasty in China was the first to use sand casting while melting metals about 1300 BC. The Zhou Dynasty later introduced cast iron to the globe approximately 500 BC, although it was mostly used by farmers. It took the Qin Dynasty, about 300 years later, for cast iron to be used as a weapon or decorative item.

Gravity Die Casting Process:

Gravity die casting is a kind of casting in which the melt is poured down a sprue and onto a permanent metal mold. By using just the force of gravity, the mold fills. The mold's excellent heat conductivity allows the solidifying melt to cool more quickly. Consequently, a dense, fine-grained structure with better mechanical characteristics is produced.

Automated gravity die casting: With the wide product selection of robots, software tools, deburring systems, casting carousels, casting machines, systems for pre-machining, and the necessary ancillary equipment, holistic automation ideas for gravity die casting are a primary emphasis. The revolutionary driving, operational, and control concepts of the tilting gravity die casting machines provide you the foundation you need for exceptional casting quality. The robot's pouring action and the casting machine's tilting motion are synchronized via a software feature in the KRC ROBOT star. These are the ideal conditions for an exact filling procedure.

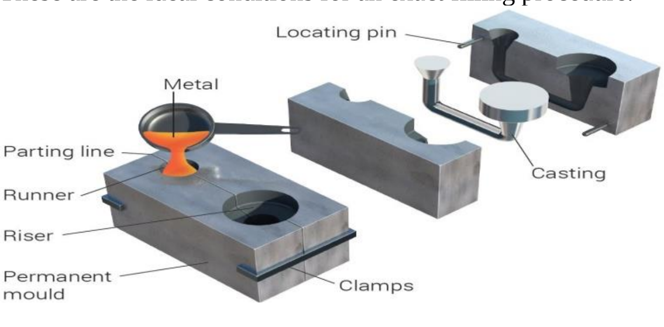

Figure 1.1: Gravity casting process

Merits:

- The surface finish of the material produced is high.
- Excellent accuracy of the product produced.
- Mechanical & physical properties are higher than other types of casting.
- Parts can be made of internal inserts and core.

Demerits:

- Certain alloys have a lower production rate.
- Tools and equipment required are of higher cost.

Brake Caliper

The brake system of the car must have brake calipers. To slow down or stop the car, brake calipers press the brake pads up against the braking rotor's surface. Nowadays, the majority of automobiles feature disc brakes, at least on the front wheels. However, many automobiles and trucks these days also have disc brakes at the back. The wheels of the automobile are fastened to metal discs (rotors) in a disc-braking system, which spin concurrently with the wheels. The caliper's function is to slow the wheel of the vehicle by generating friction with the rotors.

Figure 1.2: Brake Caliper

The brake caliper clamp-like attaches to the rotor. The brake pads are a pair of metal plates that are linked together within each caliper and are made of friction material. Inboard brake pads are on the inside of the rotors (facing the car), while outboard brake pads are on the outside (facing the curb). The master cylinder's braking fluid exerts hydraulic pressure on one or more pistons in the brake caliper when the brake pedal is depressed, pressing the brake pads against the rotor. The rotor is slowed down or perhaps completely stopped by the high-friction surfaces of the brake pads. Due to its connection, when the rotor slows or stops, the wheel also does. Drum brakes, which reduce the rotation of the wheels via friction between a revolving drum and brake shoes installed within the drum, were used on older automobiles and trucks. This friction led to a buildup of heat and gases within the drum, which often led to brake fade, a reduction in braking effectiveness. As opposed to drum-based braking systems, disc brake systems' brake pads are external to the disc, making them easier to ventilate and less likely to overheat. Due to this, disc brakes have generally taken the role of drum brakes in contemporary automobiles; nevertheless, some less priced vehicles still use drum brakes for the rear wheels, where less stopping force is needed.

2. LITERATURE REVIEW

Irawan Malik. et.al. [1]. have published a paper entitled Study on using Casting Simulation Software for Design and Analysis of Riser Shapes in a Solidifying Casting Component. In this research, emphasis is placed on the use of casting simulation software, which aids foundry businesses in designing and analyzing the riser's size and form. Grain size of mold green sand, casting material quality, and casting process parameters are deemed same for all design schemes in this research with the intention of simplifying simulation. For the purpose of analyzing faults, only the form and dimensional variations of sprues and risers are taken into account. It has been shown that risers and gating systems directly influence defects such micro and shrinkage porosities and incorrect solidification.

Rajeshwari Jadhav. et.al. [2]. have done the research and published a paper entitled Design and Analysis of Gating System at Various Orientation for Rear Break Drum by Using Casting Simulation Software. Applying the proper input parameters, the ALTAIR INSPIRE CAST program simulates the casting of the Break Rear Drum at several orientations. Gating systems are built at different casting sites to increase casting yield. This casting simulation shows potential casting flaws such as porosity, shrinkage and solidification duration, temperature distribution, and solidification percentage that may appear after casting solidification. The cost of casting manufacturing is reduced through simulation software, which also decreases production time and reject rates on the shop floor. These redesigned designs will provide more efficiency, better output, and higher revenues.

Rudianto Raharjo1. et.al. [3]. have published a paper on casting, the name of the paper is “Multilevel Pulley Analysis of Sand-Casting Process Results for Metal Casting Simulation Using Altair Inspire Cast”. According to the study, problems such porosity, shrinkage, and mold erosion that are caused by castings during the production process and simulation findings are identical. Other flaws in castings include gas flaws, shifts, misruns, tilted cores, swells, sand inclusions, and fin flaws. The results of the simulations are used to derive defect equations for multilayer pulleys, including those for porosity, mold erosion, gas defects, and shrinkage.

Sirawit Namchanthra. et.al. [4]. have presented a paper titled “A CFD investigation into molten metal flow and its solidification under gravity sand moulding in plumbing components”. The simulation demonstrates how various pouring temperatures impact the runner and how the behavior of the molten metal flow was affected by the pouring temperature, leading to flaws in the finished product. Additionally, the runner and its number had an impact on the flow of the liquid metal and the position of the flaw during the solidification process. Future study will compare the simulation findings with the experimental results and further examine potential fault areas on the workpiece's surface, which might be a crucial consideration in further talks.

Chul Kyu Jin [5]. Has published a paper, which is “Gating system design and casting simulation application for the grooved worm wheel by using zinc alloy sand casting process”. A zinc alloy sand casting was used to create a worm wheel using a bottom-up gated filling technique. Two worm wheels were simultaneously cast in a symmetrical configuration, and the worm wheel was elevated in the direction of gravity using a gating system into which molten zinc alloy was poured from below. 60% of the planned mold cavity was recovered. To ensure that the worm wheel was progressively filled without turbulent flow when the molten zinc alloy flowed through the gate, casting analysis was done. Although the molten zinc alloy first flowed at an unstable pace, the continual intake caused it to stabilize and maintain a consistent speed. Directional solidification's findings were verified. A 3D-printed integrated mold cavity template was created, and sand molds were made in accordance with it. Sand casting might be used to create a solid worm wheel free of flaws.

3. METHODOLOGY

To ensure that the experimental data is collected under the best possible circumstances, this study employs the Taguchi robust design technique. Results for the Analysis of Mean (ANOM) and Analysis of Variance (ANOVA) are obtained using the statistical program Minitab 15.0. In order to authenticate the findings, the confirmation test is carried out under ideal circumstances. The foundation of the engineering design activity is knowledge of scientific phenomena and prior experience with comparable product designs and production techniques. However, a lot of engineering work is expended on carrying out experiments (either with hardware or by simulation) to generate the data necessary to inform these decisions. These decisions relate to the specific design, the process architecture, and the parameters of the manufacturing processes. Meeting marketing deadlines, keeping development and production costs low, and having high-quality goods all depend on how efficiently this information is produced. An engineering technique called robust design aims to increase productivity throughout design and development so that high-quality goods may be manufactured affordably.

Signal-to-Noise ratio (S/N ratio):

To assess a system's performance, Dr. Taguchi created the notion of the Signal-to-Noise ratio in resilient design. This is a translation of the data to a different value that represents a measurement of the level of variation. The S/N ratio shows how predictable a process or product performs in the presence of noise effects. The variation of predictable performance and the variance of unexpected performance are combined into a signal measure via the S/N ratio.

In order to make performance less vulnerable to noise effects and hence increase product quality, robust design improves the S/N ratio in the area of control factor. Depending on the kind of feature, there are three significant forms of S/N ratios.

- Smaller the better
- Larger the better
- Nominal the best

Smaller-the-better type:

The quality attribute in this case is continuous and non-negative, meaning that it may take any value between 0 and. Zero is the preferred value. Examples of this kind include the number of surface flaws, air pollution from power plants, EM radiation from telecommunications networks, and metal corrosion, among others.

$$S/N\ ratio\ (\eta) = -10\log_{10}(\text{mean square quality characteristic})$$

$$-10\log_{10}\left[\left(\frac{1}{n}\right)\sum_{i=1}^{n} y_i^2\right] \quad \text{.........................} (3.1)$$

where,

n: no. of tests in trial (no. of repetitions regardless of noise levels);

yi: is the ith observation of the quality characteristic.

Larger-the-better type:

The quality attribute in this case is constant and non-negative. The optimum value should be as high as it can be. There is no adjustment factor present. Examples of this kind are the miles travelled per gallon of gasoline for a vehicle carrying a certain amount of weight and the mechanical strength of a wire per unit cross-section area. By taking into account the reciprocal of the quality feature, this issue may be converted into a smaller, better sort of problem.

$$\eta = -10\log_{10}\ (\text{mean square reciprocal quality characteristic})$$

$$\eta = -10\log_{10}\left[\left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(\frac{1}{y_i^2}\right)\right] \quad \text{.........................} (3.2)$$

Nominal-the-best type:

The quality characteristic of this type is continuous, non-negative, and may take any value between 0 and ; nevertheless, its goal value must be non-zero and finite. When the mean for these types of issues equals zero, the variances likewise equal zero. Engineering designs commonly have issues of this kind. To obtain a desired paint thickness on the surface is an example of this kind.

The S/N ratio for nominal-the-best is given by:

The S/N ratio for nominal-the-best is given by:

$$\eta = 10\log_{10}\left[\frac{\mu^2}{\sigma^2}\right] \quad \text{.......................} (3.3)$$

where, $\mu = \frac{1}{n}\sum_{i=1}^{n} y_i$ & $\sigma = \frac{1}{n}\sum_{i=1}^{n}(y_i - \mu)^2$

Multi objective optimization

Many challenging engineering optimization issues may be realistically modeled using multi-objective formulations. purposes taken into account in many real-world issues clash with one another, and maximizing a specific solution with respect to one of the purposes may have undesirable effects with regard to the other objectives. Investigating a collection of solutions, each of which meets the goals at a respectable level without being dominated by any other option, is a viable approach to solving a multi-objective issue. They vary from conventional GA principally in the use of specific fitness functions and the introduction of techniques to encourage solution variety.

Grey Relational Analysis: Taguchi's orthogonal array is used by GRA, a multi-objective optimization approach, to carry out the trials. The number of process factors selected for the investigation and their levels determine the number of experiments that must be run in GRA. Taguchi's orthogonal array must be chosen based on the number of input process parameters and their levels. According to their importance, the following factors will determine which orthogonal array is best for experiments:

1. The number of factors and interactions of interest,
2. The number of levels for the factors of interest.
3. The desired experimental accuracy or cost limitations.

In the study, Higher the - better and is expressed as

$$\mathbf{Xi\ (k)} = \frac{\mathbf{yi(k) - min\ yi(k)}}{\mathbf{max\ yi(k) - min\ yi(k)}}$$

Lower-the-better, can be expressed as

$$\mathbf{Xi\ (k)} = \frac{\mathbf{max\ yi(k) - yi(k)}}{\mathbf{max\ yi(k) - min\ yi(k)}}$$

Where xi (k) is the value after the grey relational generation, min yi (k) is the smallest value of yi (k) for the kth response, and max yi(k) is the largest value of yi(k) for the kth response. The definition of the grey relational grade in the grey relational analysis is to show the relational degree between the nine sequences [x0(k) and xi(k), I =1, 2, . ., 9; k = [1, 2, . . , 9].

The grey relational co-efficient ri(k) can be calculated as

$$ri\ (k) = \frac{\Delta min + \Psi \Delta max}{\Delta 0i(k) + \Psi \Delta max}$$

Where Δ0i =llX0 (k)=Xi(k)ll = difference of the absolute value between X0(k) and Xi(k);
Ψ = distinguishing coefficient (0 to1) generally Ψ =0.5
Δmin = smallest value of Δ0i
Δmax = largest value of Δ0i
After averaging the grey relational coefficients, the grey relational grade γi can be obtained as

$$\gamma i = \sum_{i=0}^{n} ri$$

Where n=number of process responses.
The higher value of the grey relational grade means that the corresponding cutting parameter is closer to optimal. High grey relational grade gives the optimal conditions.

4. EXPERIMENTAL DESIGN AND SETUP

The influence of process factors for gravity casting, such as inlet position, number of raisers, and filling duration, was examined in this research using the Taguchi technique.

Table No.: 4.1 Process Parameters

FACTORS		LEVELS		
		1	2	3
Inlet Position	(A)	Top	Side	Bottom
Number of Raisers	(B)	0	1	2
Filling time	(C)	10 sec	15 sec	20sec

Table 4.2: The L9 orthogonal array with parameters values

Exp.	Inlet Position	No. of Raisers	Filling time
1	Top	0	10
2	Top	1	15
3	Top	2	20
4	Side	0	15
5	Side	1	20
6	Side	2	10
7	Bottom	0	20
8	Bottom	1	10
9	Bottom	2	15

Design of Brake Caliper

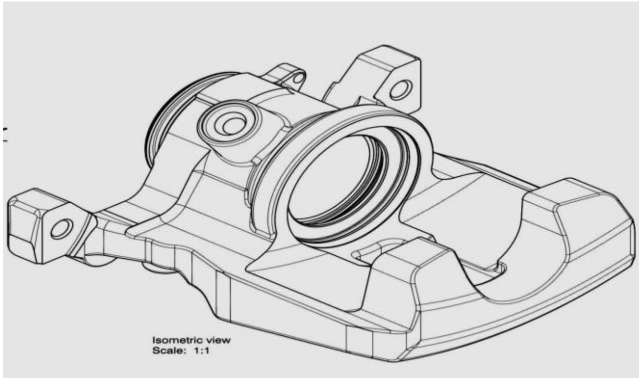

Figure 4.1: Brake Caliper

Condition 1: The results for Top-inlet, 0 Raiser, 10 seconds filling time

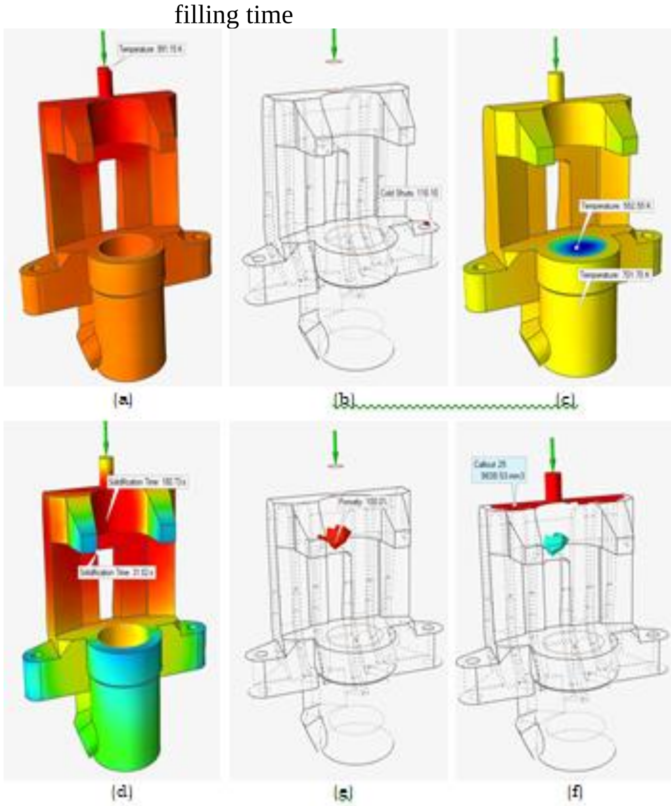

Figure 4.2: Condition 1: (a) Filling temp. (b) Cold shuts (c) Solidification temp. (d) Solidification time (e) Porosity (f) Total shrinkage volume

Condition 2: The results for Top-inlet, 1 Raiser, 15 seconds filling time

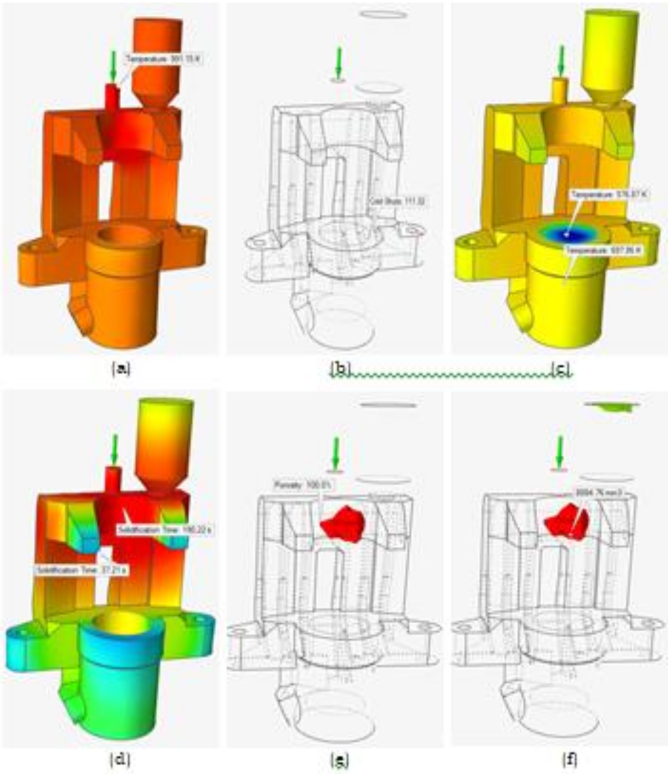

Figure 4.3: Condition 2: (a) Filling temp. (b) Cold shuts (c) Solidification temp. (d) Solidification time (e) Porosity (f) Total shrinkage volume

Condition 3: The results for Top-inlet, 2 Raiser, 20 seconds filling time

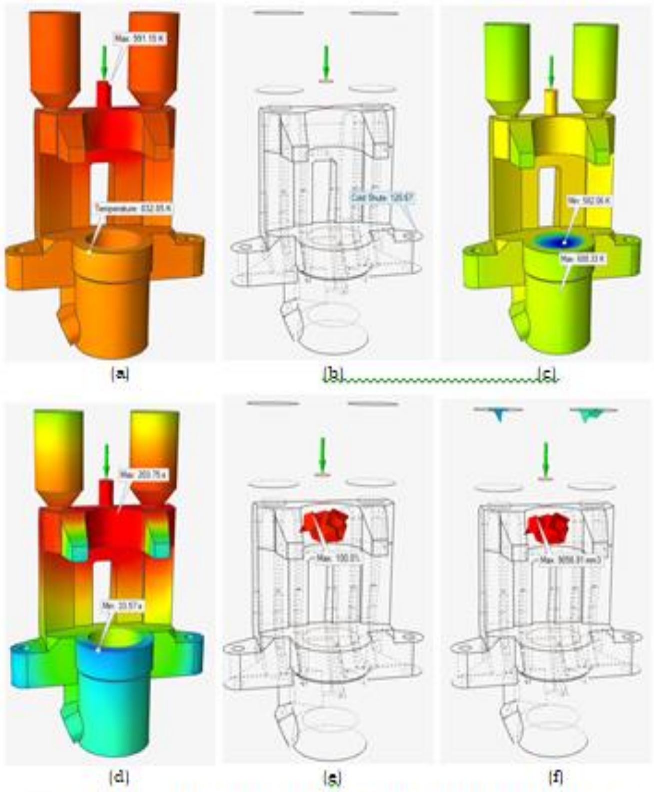

Figure 4.4: Condition 3: (a) Filling temp. (b) Cold shuts (c) Solidification temp. (d) Solidification time (e) Porosity (f) Total shrinkage volume

Condition 4: The results for Side-inlet, 0 Raiser, 15 seconds filling time

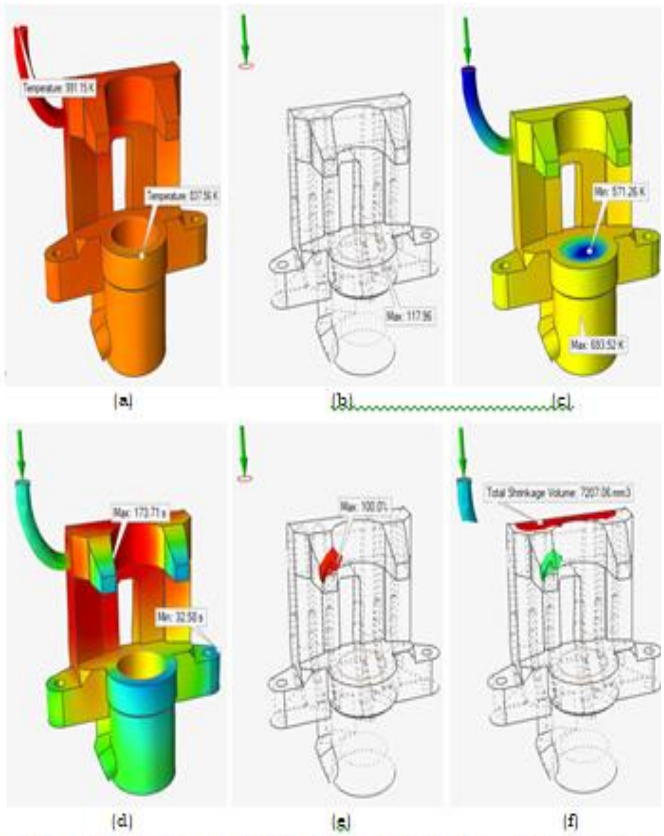

Figure 4.5: Condition 4: (a) Filling temp. (b) Cold shuts (c) Solidification temp. (d) Solidification time (e) Porosity (f) Total shrinkage volume

Condition 5: The results for Side-inlet, 1 Raiser, 20 seconds filling time

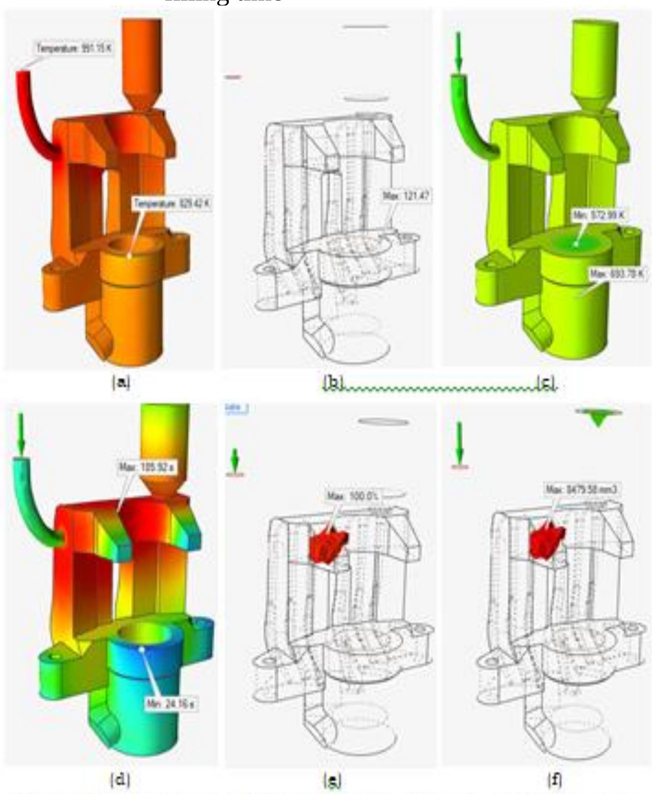

Figure 4.6: Condition 5: (a) Filling temp. (b) Cold shuts (c) Solidification temp. (d) Solidification time (e) Porosity (f) Total shrinkage volume

Condition 6: The results for Side-inlet, 2 Raiser, 10 seconds filling time

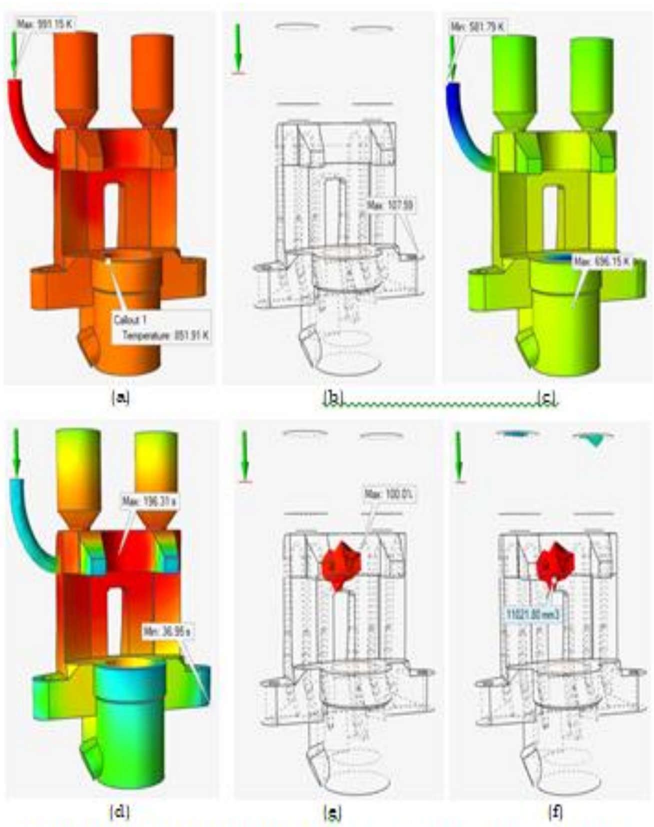

Figure 4.7: Condition 6: (a) Filling temp. (b) Cold shuts (c) Solidification temp. (d) Solidification time (e) Porosity (f) Total shrinkage volume

Condition 7: The results for Bottom-inlet, 0 Raiser, 20 Sec. filling time

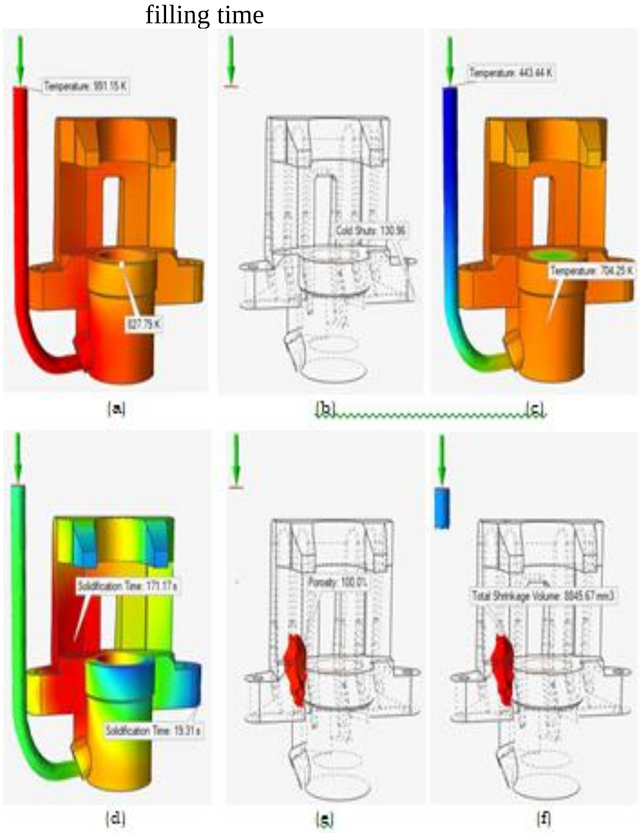

Figure 4.8: Condition 7: (a) Filling temp. (b) Cold shuts (c) Solidification temp. (d) Solidification time (e) Porosity (f) Total shrinkage volume

Condition 8: The results for Bottom-inlet, 0 Raiser, 20 Sec. filling time

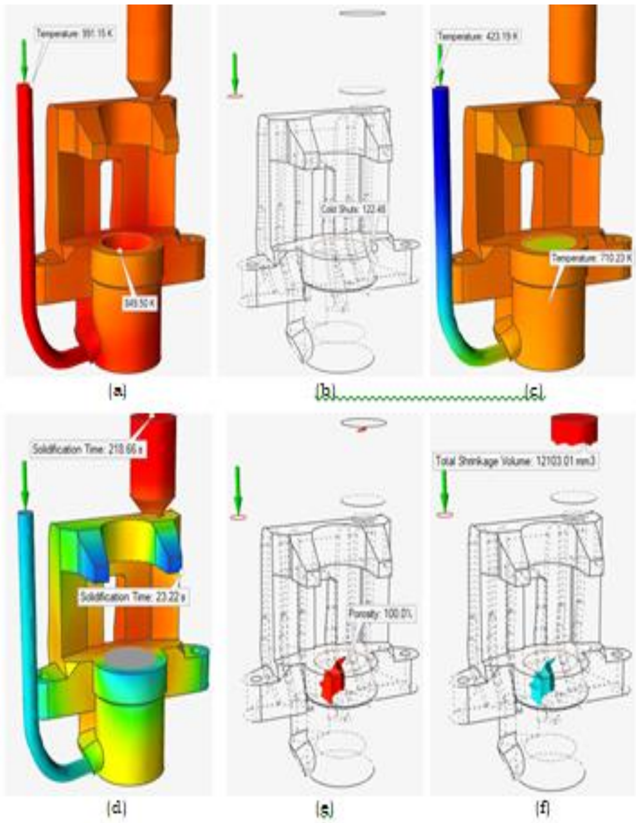

Figure 4.9: Condition 8: (a) Filling temp. (b) Cold shuts (c) Solidification temp. (d) Solidification time (e) Porosity (f) Total shrinkage volume

Condition 9: The results for Bottom-inlet, 2 Raiser, 15 Sec. filling time

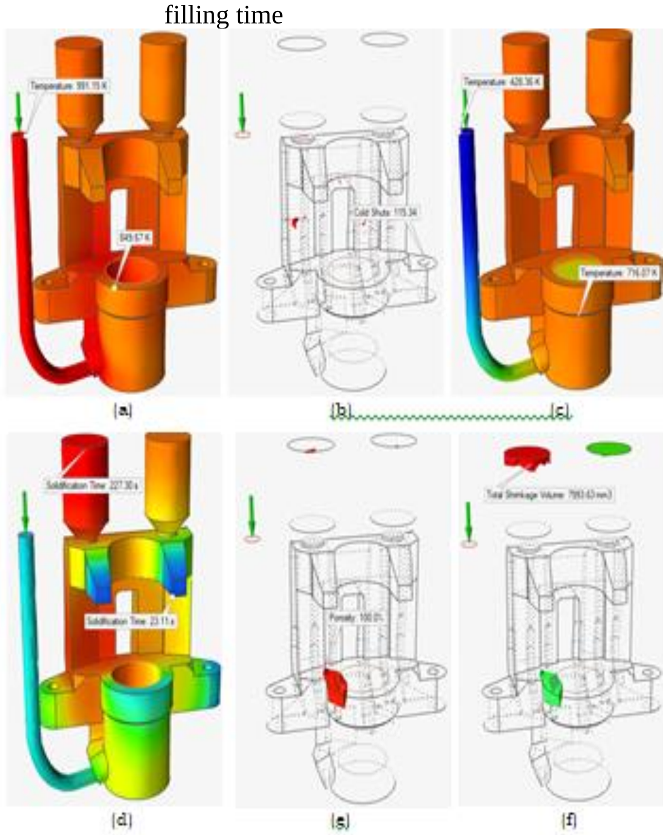

Figure 4.10: Condition 9: (a) Filling temp. (b) Cold shuts (c) Solidification temp. (d) Solidification time (e) Porosity (f) Total shrinkage volume

5. DATA ANALYSIS

Table 5.1: Output parameter results for different conditions

Exp.	Inlet Position	No. of Raisers	Filling time	Filling Tem. (K)	Cold shuts	Solidify Temp. (K)	Solidify Time (sec)	Total Shrinkage volume (mm³)
1	Top	0	10	991.15	118.10	701.70	180.73	9838.53
2	Top	1	15	991.15	111.32	697.86	190.22	8884.76
3	Top	2	20	991.15	120.67	688.33	203.75	9056.91
4	Side	0	15	991.15	117.96	693.52	173.71	7207.06
5	Side	1	20	991.15	121.47	693.78	185.92	8479.58
6	Side	2	10	991.15	107.59	696.15	196.31	11021.80
7	Bottom	0	20	991.15	130.96	704.25	171.17	8845.67
8	Bottom	1	10	991.15	122.48	710.23	218.66	12103.01
9	Bottom	2	15	991.15	115.34	716.07	227.30	7993.63

Optimization of process parameters of Gravity Casting by Grey Relational Analysis

Normalized values: The Cold-shuts, Solidification Temp., Solidification Time, and Total Shrinkage Volume are Lower the-Better.

$$Xi\ (k) = \frac{\max yi(k) - yi(k)}{\max yi(k) - \min yi(k)}$$

Where xi (k) is the value after the grey relational generation, min yi (k) is the smallest value of yi (k) for the k^{th} response, and max yi(k) is the largest value of yi(k) for the k^{th} response.

Table 5.2: Obtained normalized values for Gravity casting

Exp.	Cold shuts	Solidification Temp. (K)	Solidification Time (sec)	Total Shrinkage volume (mm³)
1	0.550	0.518	0.830	0.463
2	0.840	0.656	0.661	0.657
3	0.440	1.000	0.420	0.622
4	0.556	0.813	0.955	1.000
5	0.406	0.804	0.737	0.740
6	1.000	0.718	0.552	0.221
7	0.000	0.426	1.000	0.665
8	0.363	0.211	0.154	0.000
9	0.668	0.000	0.000	0.839

Table 5.3: Obtained Δ0i values for Gravity Casting

Δ0i = 1 – Normalized data

Exp.	Cold shuts	Solidification Temp. (K)	Solidification Time (sec)	Total Shrinkage volume (mm³)
1	0.450	0.482	0.170	0.537
2	0.160	0.344	0.339	0.343
3	0.560	0.000	0.580	0.378
4	0.444	0.187	0.045	0.000
5	0.594	0.196	0.263	0.260
6	0.000	0.282	0.448	0.779
7	1.000	0.574	0.000	0.335
8	0.637	0.789	0.846	1.000
9	0.332	1.000	1.000	0.161

Grey relational Co-efficient:

$$ri\ (k) = \frac{\Delta min + \Psi \Delta max}{\Delta 0i(k) + \Psi \Delta max}$$

Table 5.4: Grey Relation Co-efficient values

Exp.	Cold shuts	Solidification Temp. (K)	Solidification Time (sec)	Total Shrinkage volume (mm³)
1	0.526	0.509	0.746	0.482
2	0.758	0.593	0.596	0.593
3	0.472	1.000	0.463	0.570
4	0.530	0.728	0.917	1.000
5	0.457	0.718	0.655	0.658
6	1.000	0.639	0.527	0.391
7	0.333	0.466	1.000	0.599
8	0.440	0.388	0.371	0.333
9	0.601	0.333	0.333	0.757

Table 5.5: Grey Relation Grade values for Gravity Casting

S. No.	Grey Relation Grade (GRG)
1	0.566
2	0.635
3	0.626
4	**0.794**
5	0.622
6	0.639
7	0.599
8	0.383
9	0.506

The experiment number with the highest value after the GRG indicates the ideal values of the chosen input process parameters. In this study, the Fourth experiment shows increased GRG, and the value of GRG that was acquired is 0.794. The following table lists the ideal process variables.

Table 5.7: Optimum process parameters for Gravity Casting

S. No.	Inlet position	No. of raisers	Filling time	Cold shuts	Solidify Temp. (K)	Solidify Time (sec)	Total Shrink vol. (mm³)
1	Side	0	15	117.96	693.52	173.71	7207.06

The optimum condition is *Side inlet, 0 Raisers, 15 sec filling time*.

6. RESULTS AND DISCUSSIONS

The output parameters' results are shown graphically.

6.1. Filling Temperature

The same maximum temperature (991.15 K) is seen under all gravity circumstances. The chemical and physical characteristics of the molten metal will change if it is heated too much, and the casting won't be accurate enough. If the temperature is too low, solidification will prevent the molten metal from flowing into all the holes and apertures of the casting. In order to fully melt the metal, it is typically advised that the cast be at 300K above the metal's flow point. Always use caution to prevent overheating.

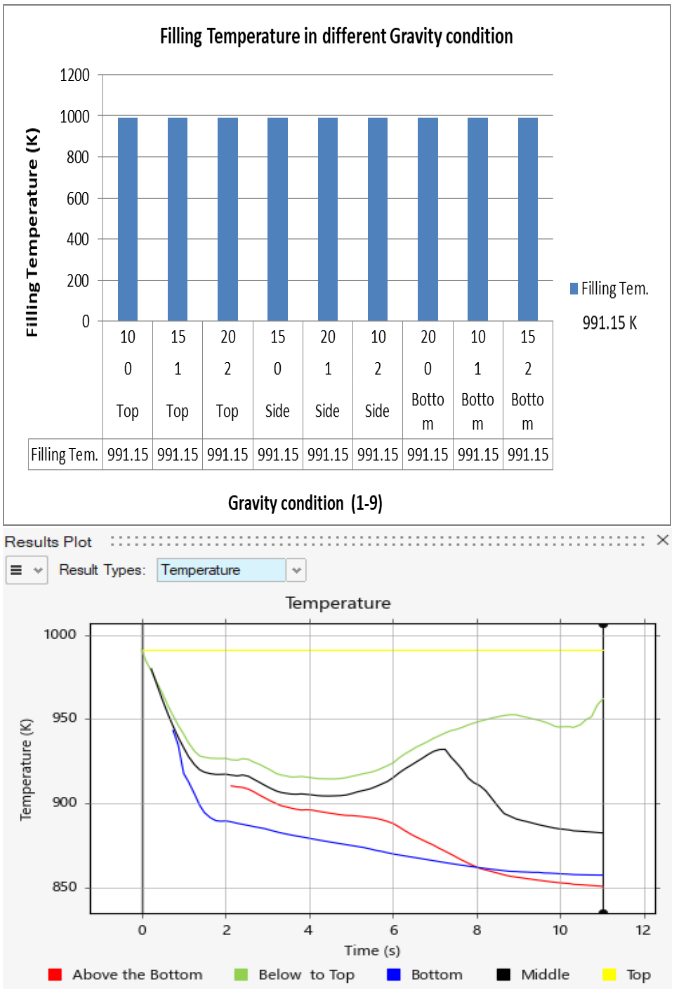

Figure 6.1: Filling Temperature in different Gravity condition

The filling temperature in various time intervals at various casting locations has been displayed on the graph.

6.2: Cold-shuts

All of the castings had cold closes as a result of the molten metal entering the cavity from various angles, which causes cold shuts. This is a significant flaw in castings. The issue is evident to the unaided eye and seems to be a break dividing the two portions. The intake at the bottom with 0 raisers and a 20-second filling period has the highest cold-shut number.

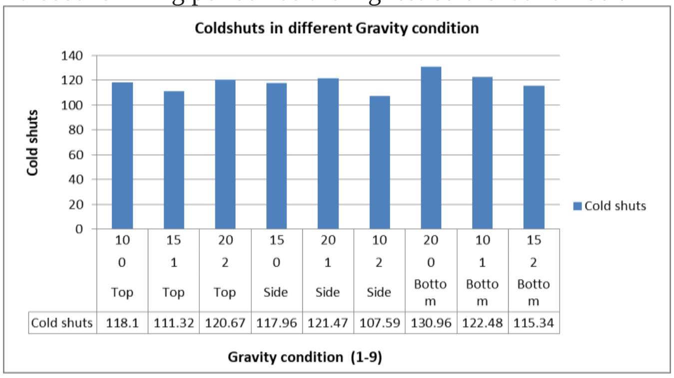

Figure 6.2: Cold-shuts in different Gravity condition.

6.3: Solidification Temperature

In comparison to the filling temperature, the solidification time will be short. Given that the filling temperature is 991.15 K, the solidification period is between 680 and 720 K. The area with the highest solidification temperature (i.e., 716.07K) is the bottom intake with two raisers and a fill time of 15 seconds.

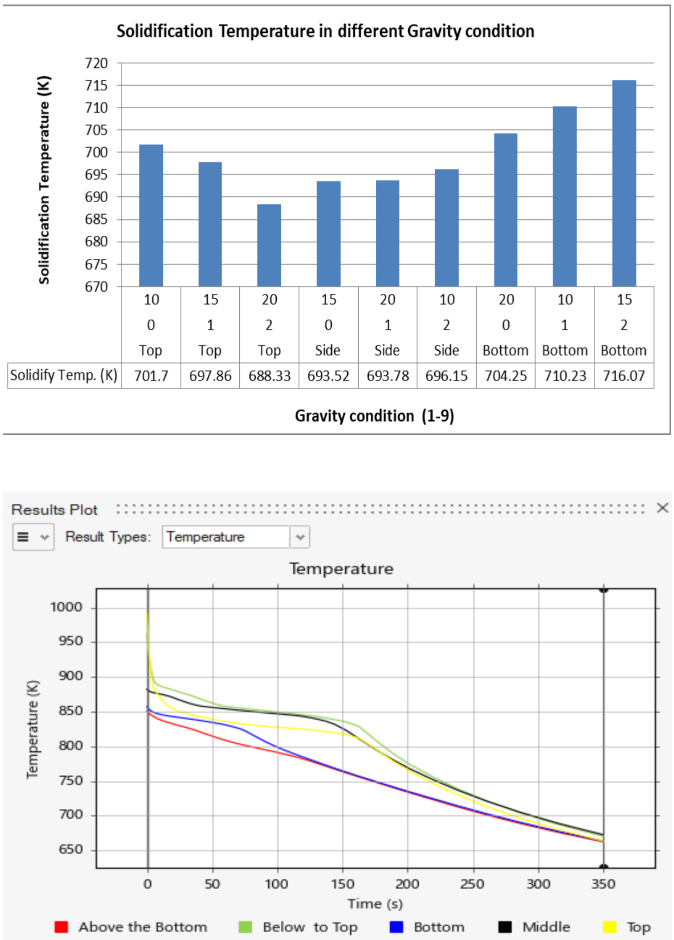

Figure 6.3: Solidification Temperature in different condition

6.4: Solidification time

The most crucial element in the casting process is the solidification time. Under bottom-inlet circumstances, solidification periods are maximum, while they are least for fluid coming from a side-inlet.

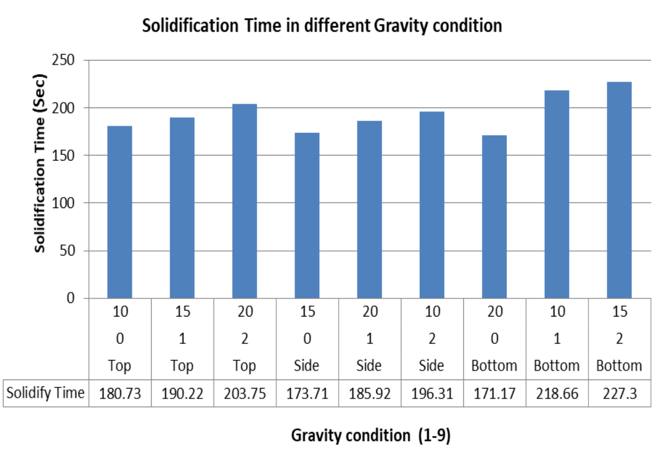

Figure 6.4: Solidification Time in different condition

6.5: Total shrinkage volume

When a metal changes from a liquid state to a solid state at its exposed surface, shrinkage, an internal or external change in volume, takes place. The area with the highest total shrinkage volume (12103.01 mm^3) is the bottom intake, one raiser, and a fill duration of ten seconds.

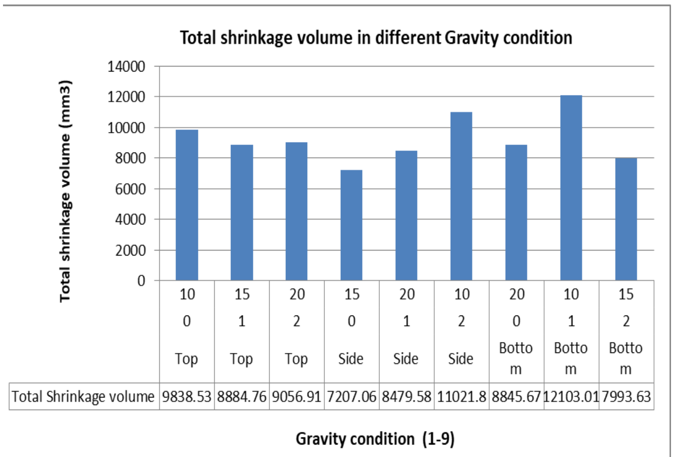

Figure 6.5: Total shrinkage volume in different condition

7. CONCLUSIONS

The following results are reached after the successful completion of the gravity casting process using Grey Relation Analysis.

- The maximum Filling Temperature (991.15K) is the same for all Gravity situations.
- In both top-inlet and side-inlet conditions, moderate cold closes are seen. Due to the intense turbulences seen when the molten metal enters the chamber, high cold-shuts are seen under bottom-inlet circumstances.
- Top-inlet conditions have moderate solidification temperatures, side-inlet conditions have low temperatures, and bottom-inlet conditions have high temperatures.
- In all cases, porosity is seen closer to the cavity inlets, which results in weaker strengths.
- Similar shrinkage volumes are seen across all circumstances.
- The greatest Grey Relation Grade (i.e. 0.794) is observed by Grey Relation Analysis, which may be regarded as the ideal situation. The ideal setting is side-inlet, no raisers, and a fill time of 15 seconds.

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REFERENCES

1. Irawan Malik, "Study on using Casting Simulation Software for Design and Analysis of Riser Shapes in a Solidifying Casting Component", Journal of Physics: Conference Series, IOP Publishing, 2020.

2. Rajeshwari Jadhav, Vinita Mane, "Design and Analysis of Gating system at Various Orientation for Rear Break Drum by Using Casting Simulation Software", International Journal of Research in Engineering, Science and Management, Volume-3, Issue-2, 2020.

3. Rudianto Raharjo, "Multilevel Pulley Analysis of Sand-Casting Process Results for Metal Casting Simulation Using Altair Inspire Cast", Research gate, May- 2023.

4. Sirawit Namchanthra, "A CFD Investigation into Molten Metal Flow and its Solidification under Gravity Sand Moulding in Plumbing Components", International Journal of GEOMATE, Vol.22, Issue 92, pp.100-108, April, 2022.

5. Chul Kyu Jin, "Gating system design and casting simulation application for the grooved worm wheel by using zinc alloy sand casting process", Advances in Mechanical Engineering, Sage Publications, Vol 5, 2023.

6. Samir Chakravarti, "An investigation on the solidification and porosity prediction in aluminium casting process", Journal of Engineering and Applied Science, 2023.

7. C. M. Choudhari, "Design and Analysis of Riser for Sand Casting", International Journal of Students Research in

Technology & Management, Vol 1(2), pp: 176-191, April 2013.

8. Taufrik Roni Sahroni, "Design and Optimization of runner and gating systems for permanent mould casting", Japanese journal, 2014.

9. Vishal S. Jadhao, "Review Paper on Simulation Based Casting", IJIRSET, Vol. 3, Issue 11, November 2014.

10. Rudianto Raharjo, "Software Simulation and Experiment for Production of a Pillow Block Using Sand Casting Process", IJMETA, Article 5, pp: 107-113, 2022.

11. Vasdev Malhotra, "Study of Process Parameters of Gravity Die Casting Defects", IJMET, Volume 7, Issue 2, pp: 208–211, 2016.

12. John Campbell, "Complete Casting Handbook: Metal Casting Processes, Techniques and Design", Elsevier Publisher, 2011.

13. B. Ravi, "Metal Casting Computer-Aided Design and Analysis", PHI Learning publisher, 2005.

14. Altair, "Inspire cast", 2022.

15. G.R. Joshi, "Optimization by Grey Relational Analysis (GRA) and Taguchi Method", Kolhapur Publishers, 2021.

16. Genichi Taguchi, "Total Quality Management", Wiley publishers, 2005.