iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** V **Month of publication:** May 2024

DOI: https://doi.org/10.22214/ijraset.2024.61587

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue V May 2024- Available at www.ijraset.com

Optimization of Multi-Gate System in Casting Process Based on Experimental Study

Dhaval A Kathad[1], Mitesh A Kubavat[2], Kankesh K Dave[3]
[1]M. Tech Student, [2, 3]Assistant Professor, Department of Mechanical Engineering, Noble University, Junagadh

Abstract: This paper proposes a gating system design for casting process using an experimental study. The principle behind multi-gate system optimization is to eliminate defects such as compression gas inclusions, cold shorts and mixing etc. Industrial and research experience shows that the flow of molten metal in the gating system before entering the extraction cavity significantly influences the quality of the casting. In general, slow filling causes defects like cold shirt and mixing while fast filling causes inclusion of sand and causes defects like holes. A gating system consists of runners, sprue gates and filters. The position, number, size, and shape of these elements play an important role. A systematic methodology for gating design optimization considering filling rate maximization has been developed based on limiting constraints. These include pouring time, gating ratio, modulus of ingate, mold erosion, Reynolds number at ingate section and filling rate of molten metal. Molten metal kinematics viscosity similar to that of liquid water can be used to determine the fillings and flowrate of the molten metal in the mold cavity. Aluminum generally has the same kinematics as water. Thus the water flow can be studied by adding the necessary design improvements to the multi-gate system, from which it will be easier to detect defects and will be easier to detect defects and will greatly improve the overall casting quality.

Keywords: Experimental setup, Flow rate, Flow velocity, water, Aluminium Gate, Sprue,

I. INTRODUCTION

In the casting process, multi gating system play as important role, to produce a good quality casting. The basic components of a horizontal gating system, including pouring basin, sprue, runners, sprue well, runners, and ignites. Multi-gate systems in casting consist of the use of multiple gates or entry points for molten metal to enter a mold cavity. This technique optimizes flow, decreases turbulence, and helps I controlling the solidification process, ensuring high-quality castings. By tactically placing gates, it enhances casting integrity and minimize defects.

A gating system controls mold filling process and flow pattern in the gating system. Multiple gates are required to ensure proper supply of flow along with enough temperature. In general, different sections of casting are required to the same flow rate and fill time, and then remain similar solidification conditions in every portion.

The main function of gating system is to lead clean molten metal and the casting cavity ensuring uniform, smooth as well as complete filling of mold. The design of the gating system is depends on the number, size as well as shape of the casting, which ensure uniform flow of molten metal to every sections

The mold filling is the important process in the casting process. This involves the complex Characteristic flow, The kinematic viscosity of the water is nearly equal to that of aluminum and copper. So that flow of water is considered instead of aluminum, which behaves less or more nearly to the water. The kinematic viscosity of the heavier metals, including copper, are lower than that of water, and hence it may be desirable to scale down the dimensions of the water models and actual system. To decide the proper cross section area and correct location of each gate, we necessity to predict the parallel discharge.

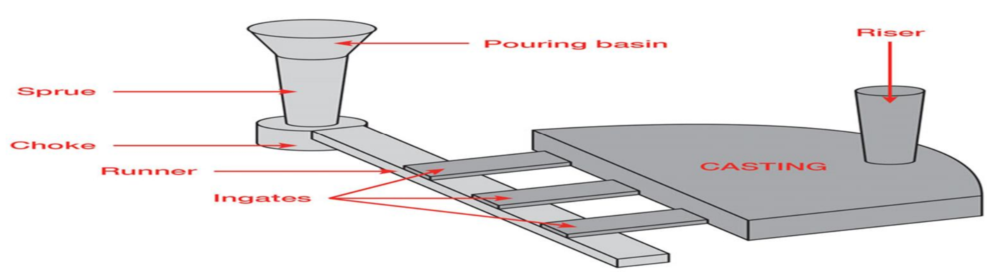

Fig-1.1: Multi Gating system

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The main objective of this work to review in new idea and optimization of multi-gating system recommends minimizing the in-gate velocity of melt, maximizing the yield, and optimizing location of in-gate. This work focuses on the filling rate and difference in flow rate as well as velocity through in-gates. Higher filling rate is useful to increase the production rate castings.

II. METHODOLOGY

Generally, many researchers have studied fluid flow in gating system and mold cavity using transparent models made of plastic or acrylic. In which different methods like end sprue location and center sprue location and by giving taper to the runner.

In which the flow of molten metal is simulated by water and aluminum is substituted the liquid metal, at a temperature of about 700°C it behaves like water and has kinetic viscosity similar to water,

The major advantage of this method is that the flow of water is clearly visible in all parts of the gating system, but in the gating system used in the water model experiment, the results are calculated using simple relation.

Generally, the design of gating system is done based on proper gating ratio and liquid metal characterization where popular gating ratio for Aluminum LM6 is 1:4:4 hence 1:4:4 is chosen to understand its design process.

A. Data collection

Table-2.1. Detailed specification of considered four gating system design

	Runner	Runner's Dimensions	Sprue Position	Gates Dimension
Design 1	Parallel	Ø 5cm throughout length	At end	Ø1.2cm throughout length
Design 2	Parallel	Ø 5cm throughout length	Central	Ø1.2cm throughout length
Design 3	Parallel	Ø 5cm throughout length	Central	Ø1.4cm at one end & Ø1cm at the other end

Design-1 zig-zag type end sprue multi gating system

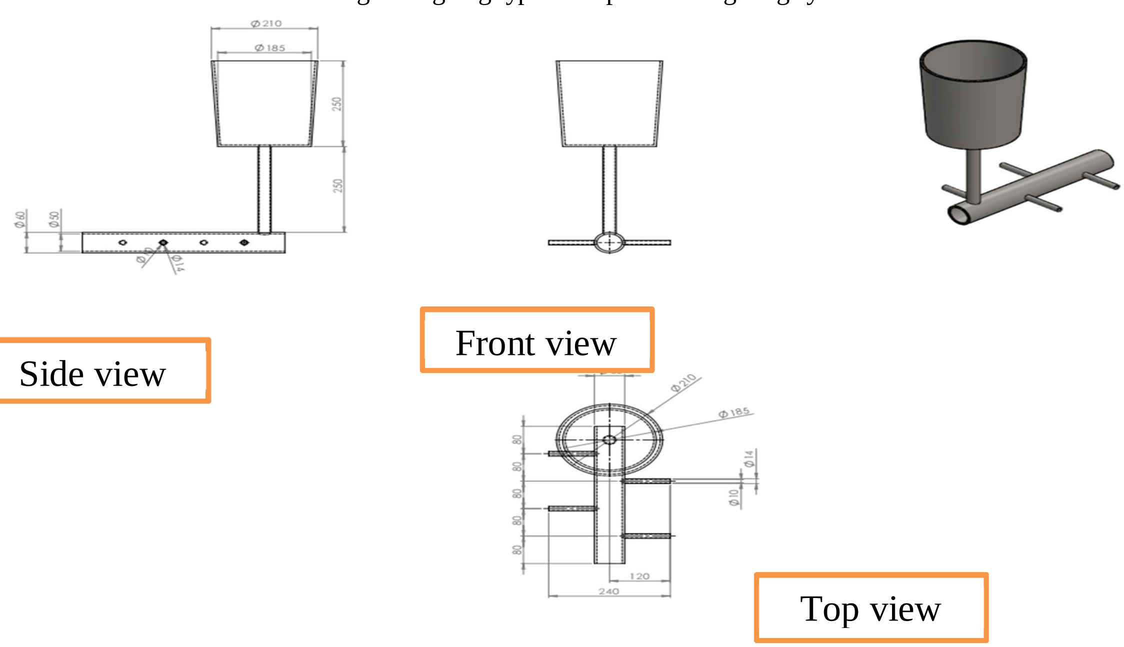

Fig-2.1: End sprue Gating system

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Design-2 zig-zag type center sprue multi gating system

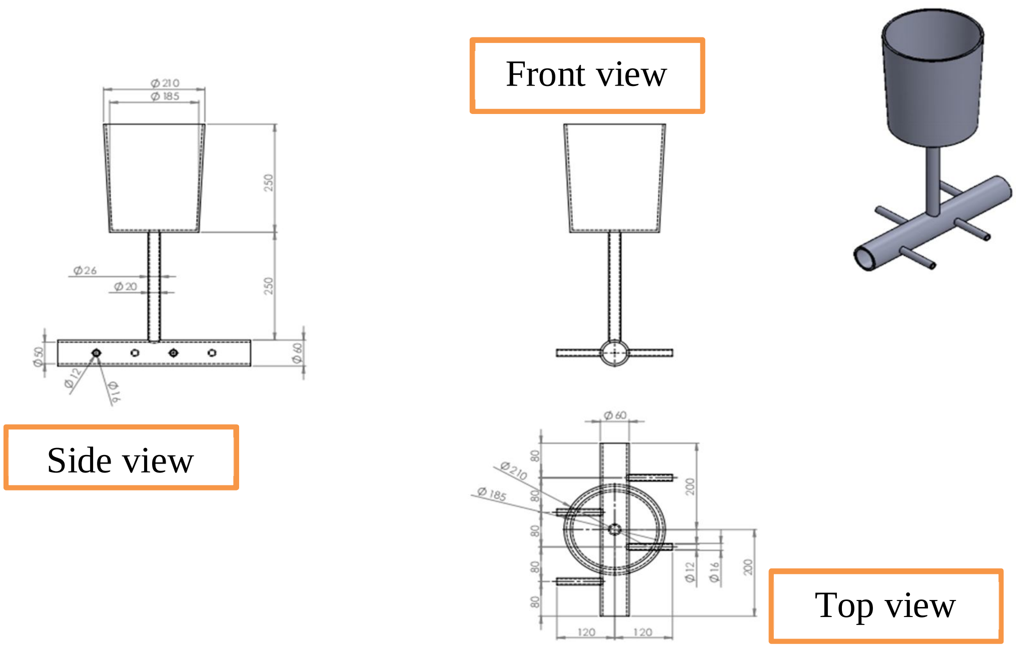

Fig-2.2: Center sprue Gating system

Design-3 zig-zag type center sprue multi gating system with taper gate

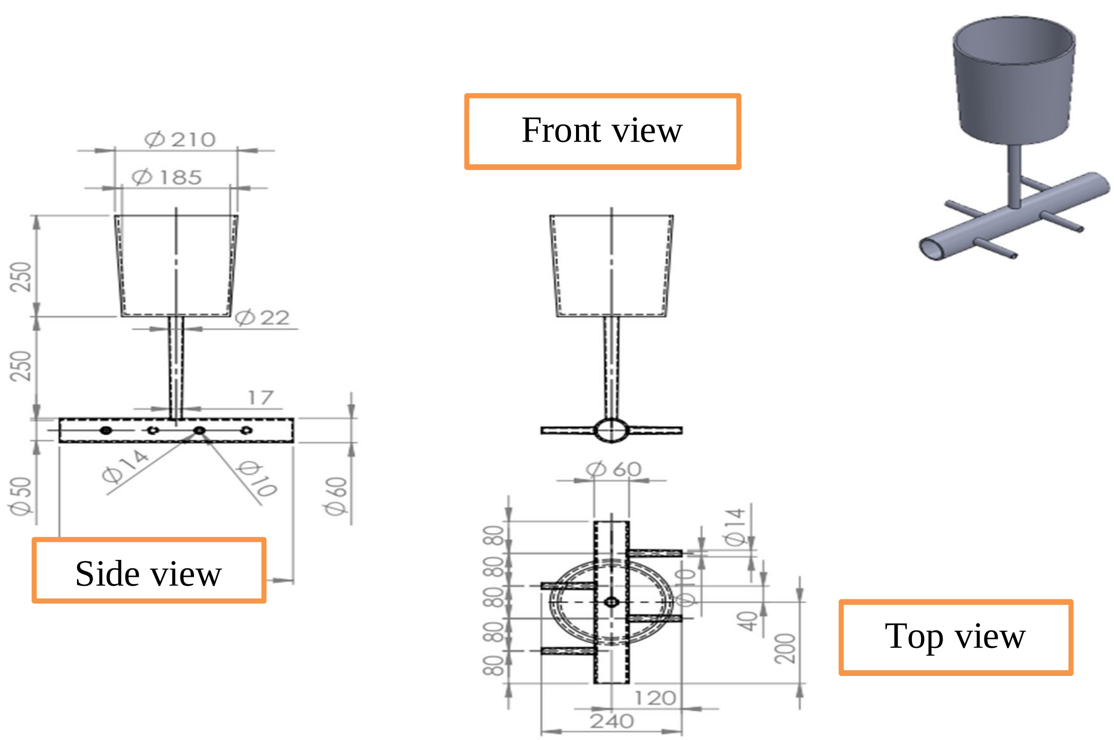

Fig-2.3: Center sprue Gating system with taper

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B. *Design optimization of Multi Gates System*

Optimizing a multi-gate system in casting, which involves a design approach to improve manufacturing efficiency and quality of final product. A well-engineered system can expressively maximize yield and minimize defects.

In multi-gate casting, concern of gate placement, Geometry and size plays a important role in casting. Proper located gates ensures uniform metal flow. Reduce potential defects and turbulence like air entrapment incomplete fillings.

By using advanced computer simulations software aid in calculating the flow of molten metal, permitting for modifications to gate design before actual casting. By simulations study achieving balanced flow rates between the multiple gates and avoiding issues like premature solidification and mold erosion.

The optimization also achieving a balance between gating design, material features, and process parameters is crucial for a effective multi casting. Ultimately, optimized multi-gate system maximize production and reduces material wastage, and improve overall quality of cast parts, making it a fundamental aspect of modern casting methodologies.

(a) End sprue gating system

(b) Center sprue gating system

Fig-2.4: 3D Model for gating system (a) & (b)

C. *Experimental Setup of Water Modelling*

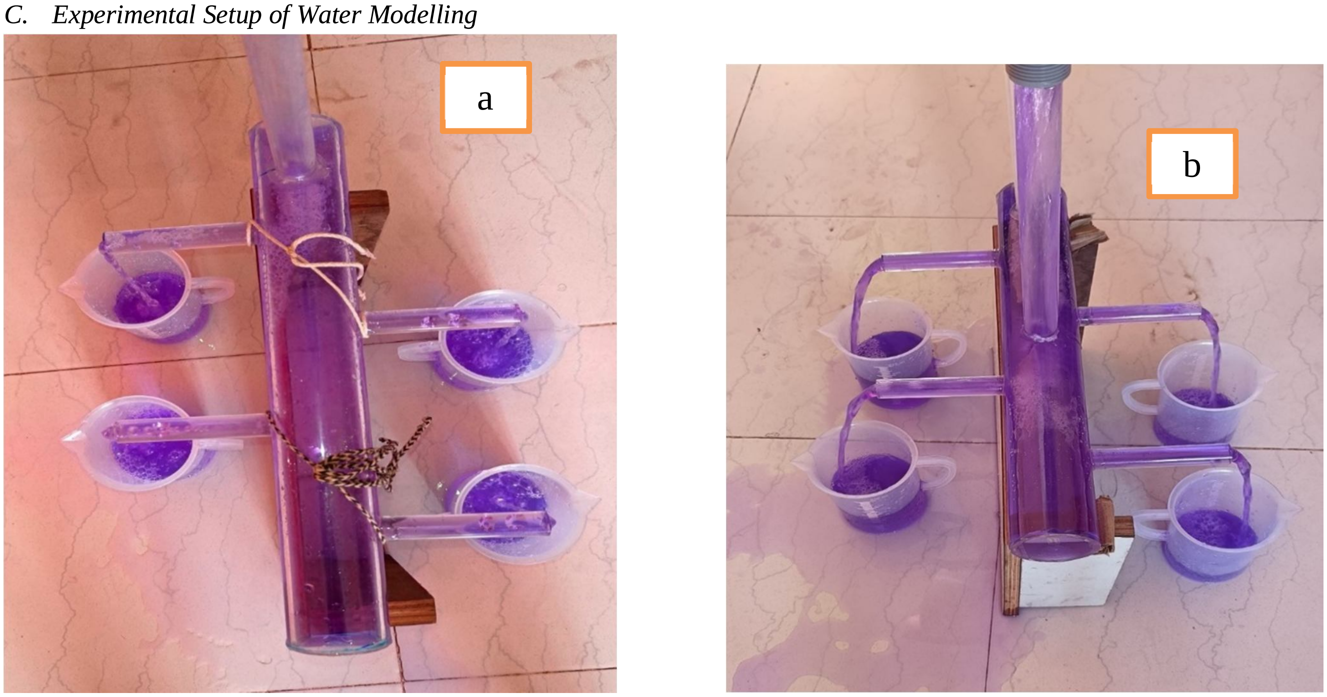

Fig-2.5: Experimental setup of water modelling

Here a transparent model made of acrylic as the material of the gating system is used and with the help of this transparent model the fluid flow in the gating system and mold cavity is studied.

The advantage of this method is that the liquid pattern is clearly visible in the gating system and its floating parts.

In this water model, the flow rate and velocity of water over various gates are calculated using faucet and storage system.

Table-2.2. Data For water model (a)

Modified Design	Flow rate (ml/s)	Flow velocity (m/s)
Gate 1	14.99	0.132
Gate 2	24.78	0.219
Gate 3	23.05	0.204
Gate 4	17.87	0.153

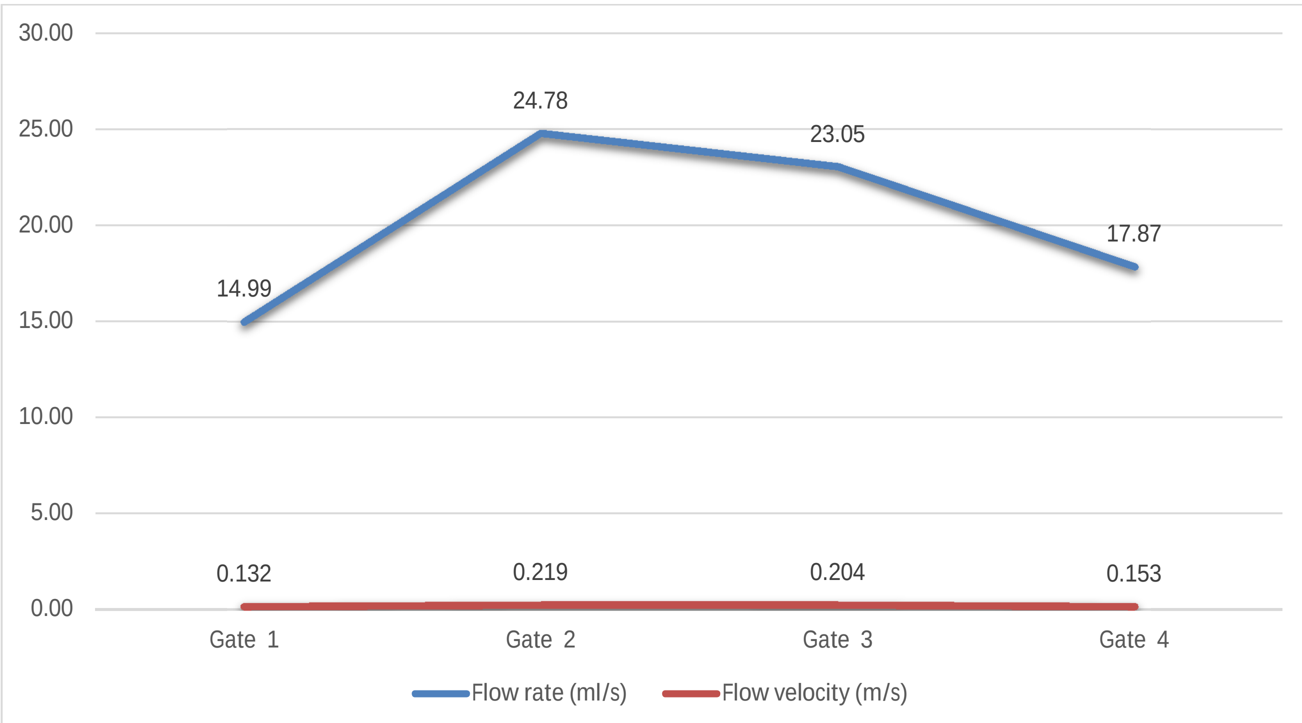

Fig-2.6: Flow rate and velocity chart for model (a)

Table-2.3. Data For water model (b)

Modified Design	Flow rate (ml/s)	Flow velocity (m/s)
Gate 1	17.91	0.158
Gate 2	21.49	0.191
Gate 3	20.90	0.184
Gate 4	18.81	0.166

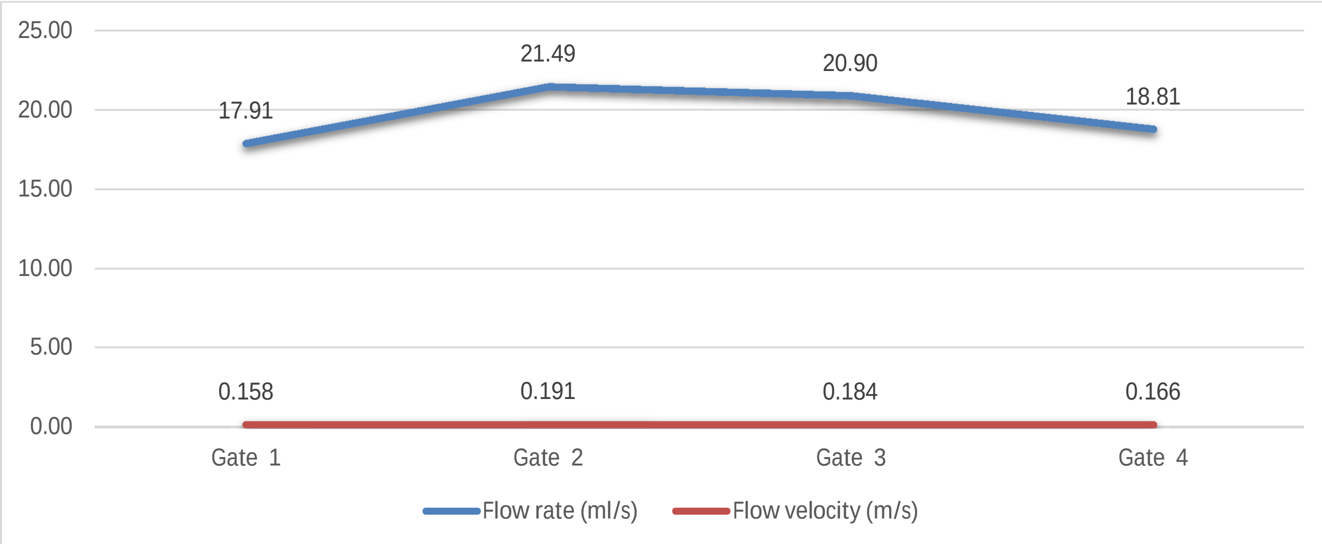

Fig-2.7: Flow rate and velocity chart for model (b)

From the above study it is proved that model (b) is more systematic than model (a) and it gives better results.
The central position of the sprue minimizes the variation in velocity and flow and the rate and streamlines the flow and the flow rate remains almost the same at all gates which is essential for good casting. It can be observed that design (b) is superior to design (a).

D. Modification of design

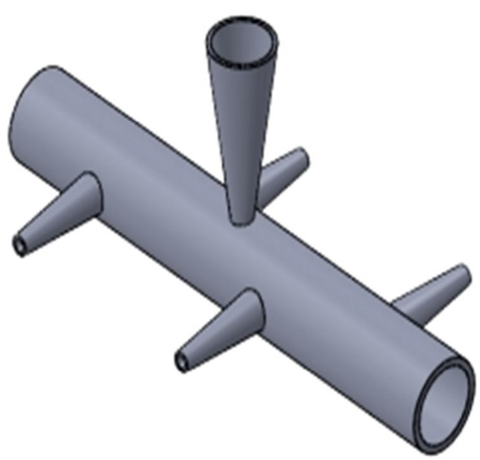

Fig-2.8: Modified 3D design

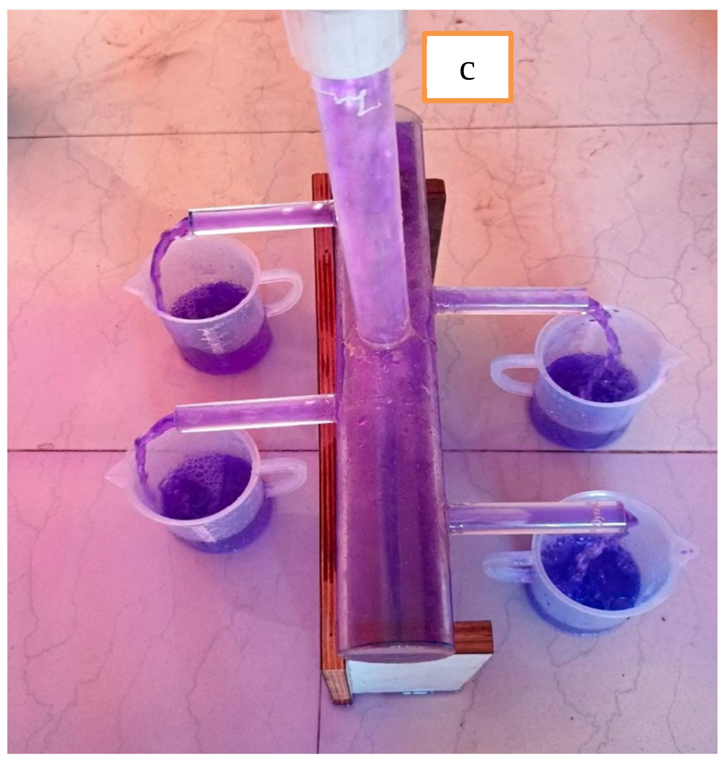

Fig-2.9: Modified acrylic model

Some changes have been made to design three to further optimize the design of the gating system in which all four gates have been tapered to increase the balanced flow and flow velocity and this change has reduced and streamlined the velocity losses.

Table-2.4. Data for water model (c)

Modified Design	Flow rate (ml/s)	Flow velocity (m/s)
Gate 1	16.16	0.206
Gate 2	19.94	0.253
Gate 3	19.40	0.245
Gate 4	16.70	0.212

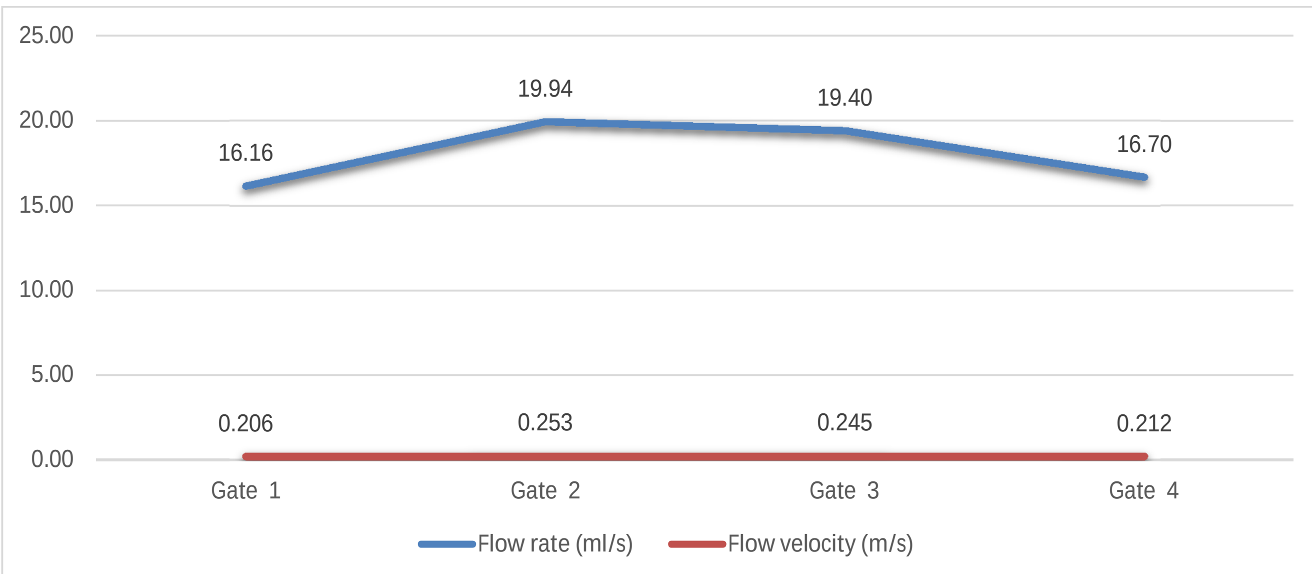

Fig-2.10: Flow rate and velocity chart for model (c)

Based on the observed data of design three, it is proved that the flow rate is close to that of design two, but there is a general increase in the flow velocity which reduces the slow filling rate in the casting cavity and thereby eliminates the defects such as coal-shuts and inclusions.

III. RESULTS AND DISCUSSION

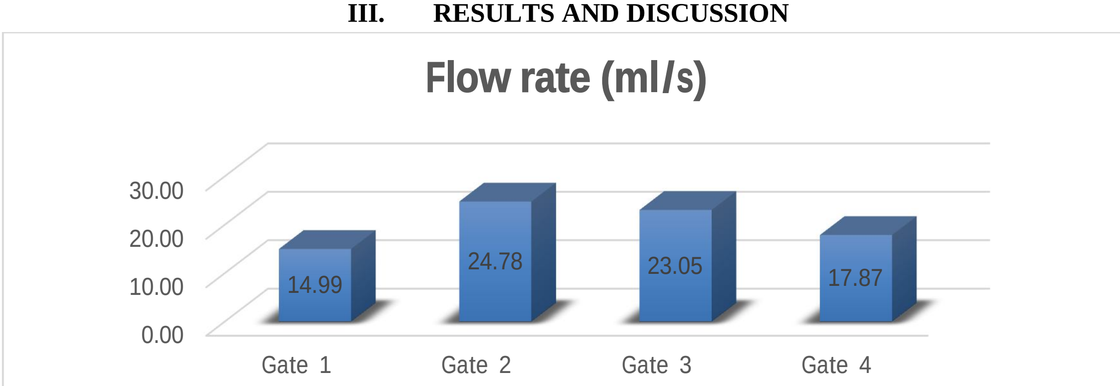

Fig-3.1: Flow rate diagram design 1

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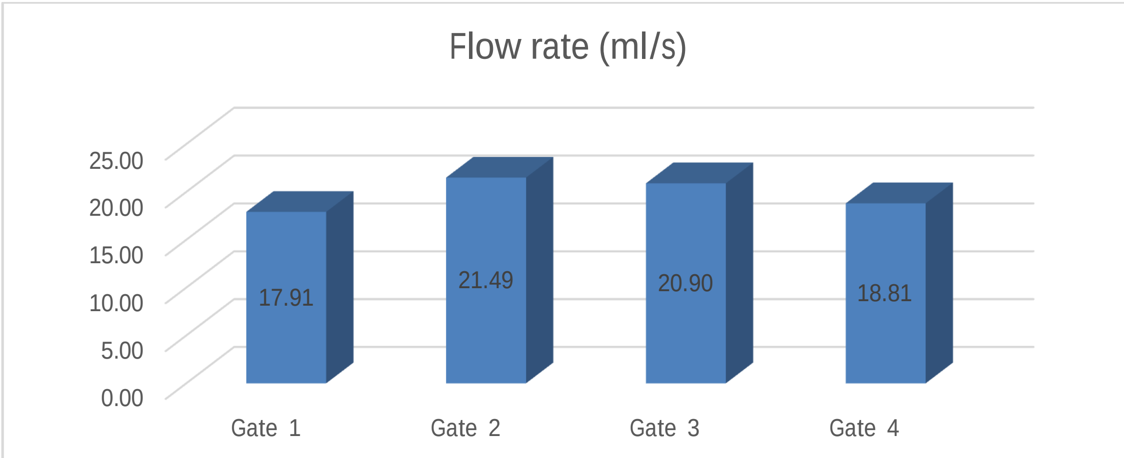

Fig-3.2: Flow rate diagram design 2

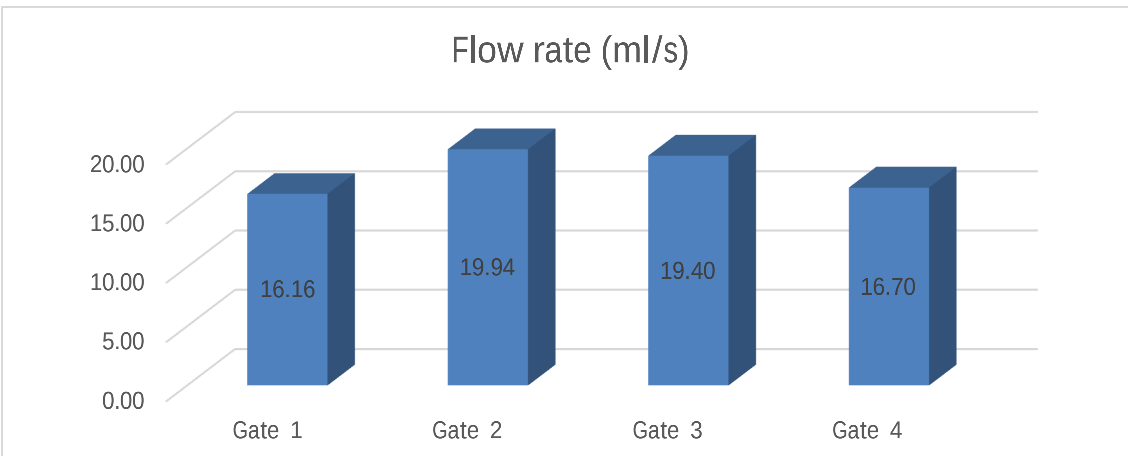

Fig-3.3 Flow rate diagram design 3

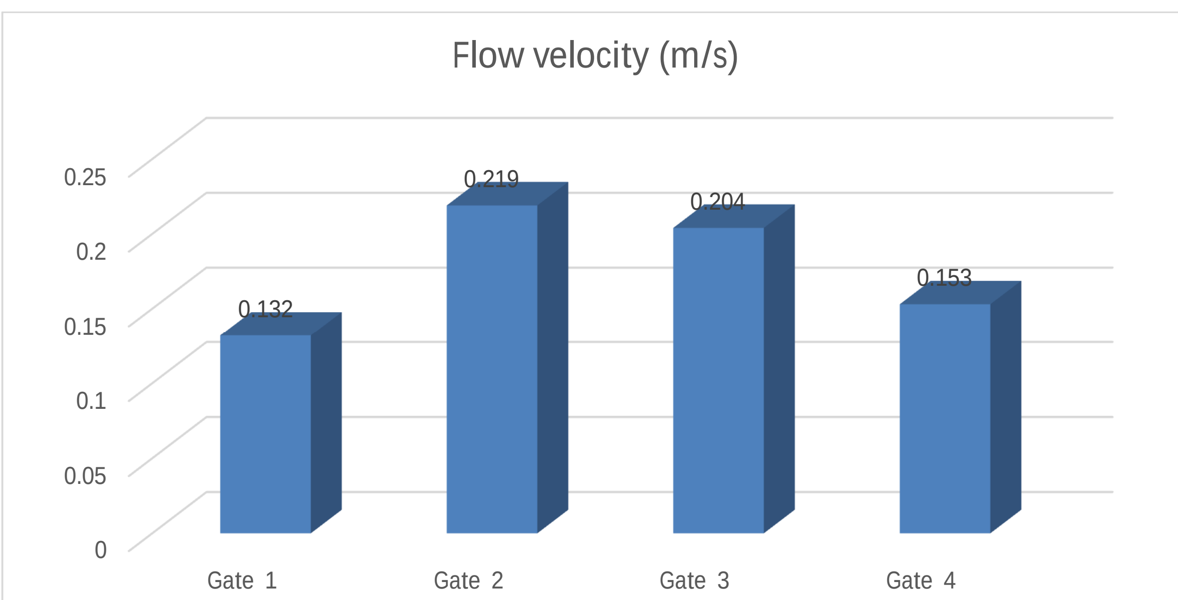

Fig-3.4: Velocity diagram design 1

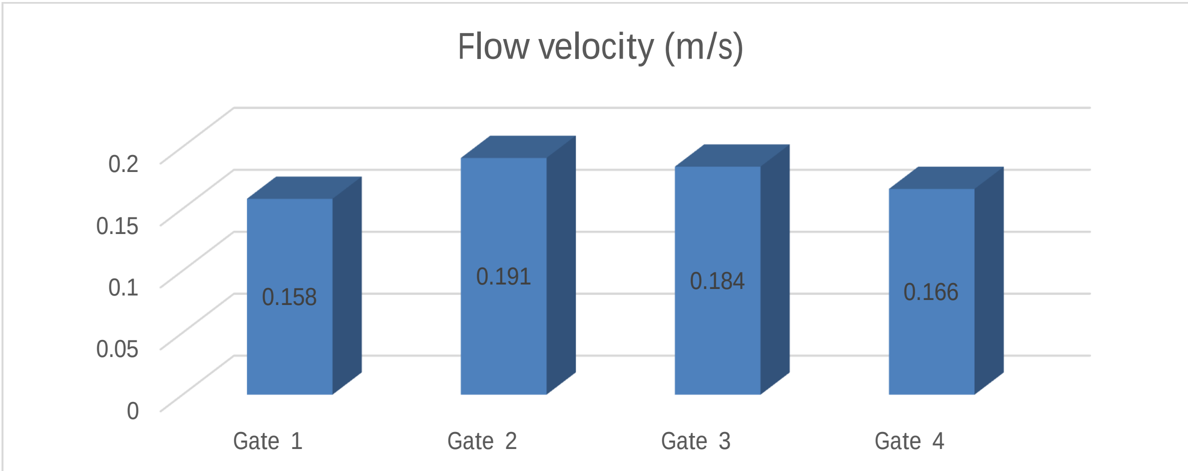

Fig-3.5: Velocity diagram design 2

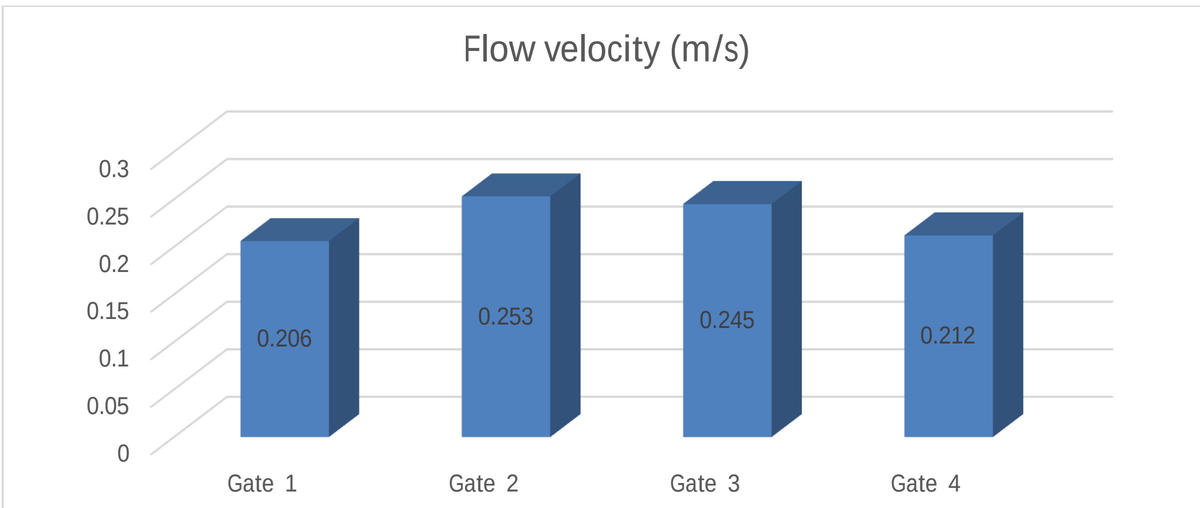

Fig-3.6: Velocity diagram design 3

Comparing the analysis data of the given three designs shows that the flow of design one is different in each gate while the flow of designs 2 and 3 are almost close and the same in each gate.

When we analyze the velocity data of the given three designs, the velocity of the three designs is different. As per the design 1 the velocity of each gate is different.

While the difference in velocity at each gate is less in design 2, the flow velocity is less than the in design 3, which proves that the gate modification in design 3 results in a significant difference in flow velocity.

IV. CONCLUSION

Factors such as the location of gates in a multi gating system as well as their junction method and how the gate is connected to the runner and their sprue to gate distance etc. affect the flow results.

From the flow measurement experiment we found that the gate needs to be tapered to increase the flow at the end of the gate and the sprue needs to be centered to keep the travel and parallel.

In zig-zag type gating system, the flow rates in gate 1 and gate 4 are generally low, but the flow rates and velocities in gates 2 and 3 are increased, which is quite different from the previous modified model.

Two designs of a multi gating system in which design 1 has very different flow rates while design 2 gives essentially the same flow rate design 1 is the worst based on flow criteria and design two gives satisfactory results.

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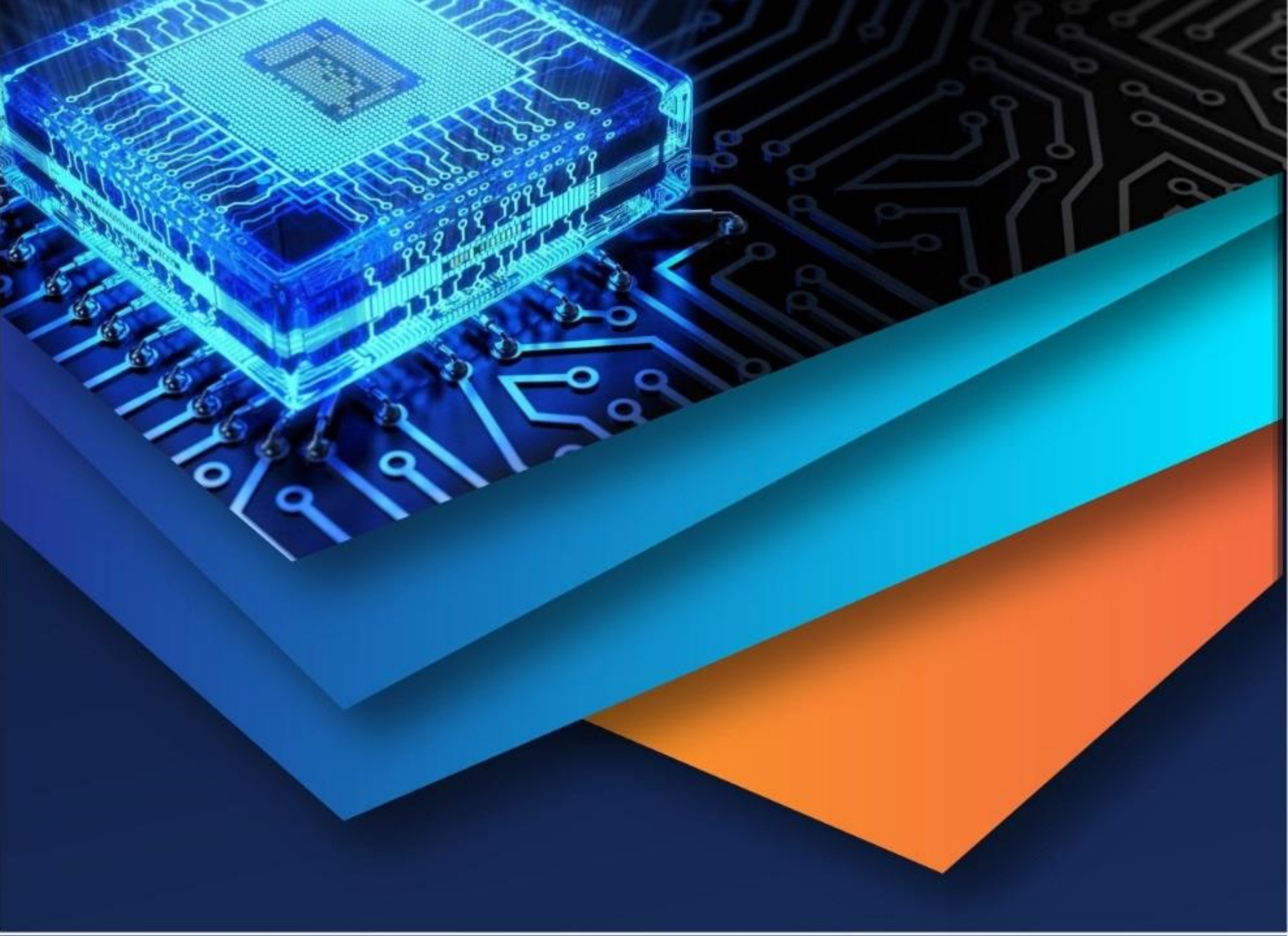

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