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S.Selvakumar
Associate Professor,
Department of Mechanical Engineering, Kongu Engineering College,
Perundurai, Tamilnadu, India

Casting Defect Analysis on Caliper Bracket using Mold flow Simulation

S.Selvakumar

Abstract
In this work, the computer assisted casting simulation techniques are used to analyze the sand, machine and design related defects in green sand casting. The caliper bracket which is used in car brake drum is selected for the analysis. While manufacturing the caliper bracket the defects like shrinkage, blow holes, mould crush and sand drop are occur in mass production. Here, a 3-step approach is presented to casting defect identification, analysis and rectification. In sand related defects the testing parameters and sand properties are collected and then compare the properties with journals and other standards. In machine related casting defects the machine maintenance is observed and then the changes in the maintenance schedule are made to reduce the brake down time and cost of maintenance. In pattern related, “Autodesk mould flow simulation software” is used to find out the defected area in the pattern and then redesigning of pattern is done to reduce the defects.

Keywords: Casting defects, Mold flow, Simulation, Caliper Bracket

Background
Metal casting is one of the direct methods of manufacturing the desired geometry of component. Casting defects result in increased unit cost and lower morale of shop floor personnel.

Vijaya Ramnath (2014) dealt with the optimization of the gating system which reduces the manufacturing lead time ignificantly.. Prabhakara Rao et al (2011) discussed about the simulation process of casting solidification with the aid of ProCAST software. Kermanpur et al (2010) have studied the metal flow and solidification behaviors in a multi-cavity casting mould of two automotive cast parts using FLOW-3D simulation software and validated the simulation model. Nandi et al (2914) studied plate castings to investigate the solidification behavior of aluminum alloy (LM6) with different sizes of feeders based on conventional methods and computer simulation technique. Gajbhiye (2014) performed a Solidification simulation analysis in AutoCAST-X environment according to the design dimensions obtained for pattern with allowances, gating system and feeder. Masoumi (2005) employed direct observation was employed to experimentally observe the flow pattern for the mold filling.

Dabade (2013) proposed a new method of casting defect analysis is proposed and studied which is a combination of design of experiments method (Taguchi method) and computer aided casting simulation technique for analysis of rejection of casting due to defects related to sand, moulding, methoding, filling and solidification in green sand casting. Rajesh Rajkolhe (2014) and Vipul Vasava (2013) presented that Casting simulation technology become a powerful tool for casting defect troubleshoot in and method optimization. Guharaja (2006) proved that, by improving the quality by Taguchis method of parameter design at the lowest possible cost. Based on the review, computer assisted casting simulation techniques are used in this work to analyze the design related defects in green sand casting.

Methodology
This chapter deals with the methodology which is used in this project. Figure 1 shows flow chart of workwork flow. The work regarding casting defects deals with three main

Correspondence:
S.Selvakumar
Associate Professor,
Department of Mechanical Engineering, Kongu Engineering College,
Perundurai, Tamilnadu, India

parameters namely pattern design, machine maintenance, and sand properties. A study has been made on the existing pattern design and some changes are made on the pattern design.

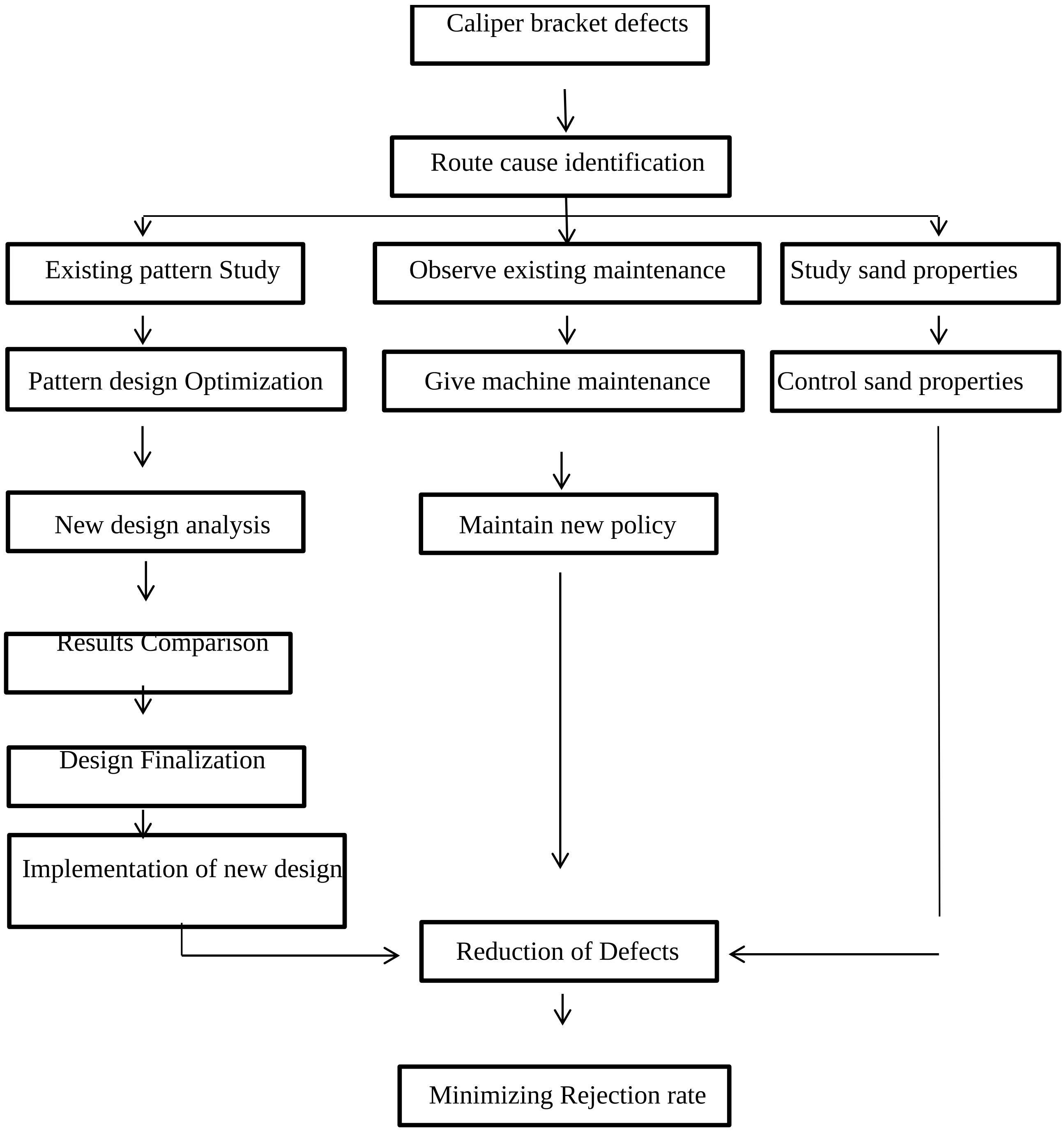

Fig. 1: Workflow

Cause and Effect Diagram

The major casting defects occurring in caliper bracket are listed below,

- Shrinkage
- Blowhole
- Mould crush
- Sand drop

The cause-effect diagram for shrinkage is shown in Figure 2. Suggested remedies are as follows:

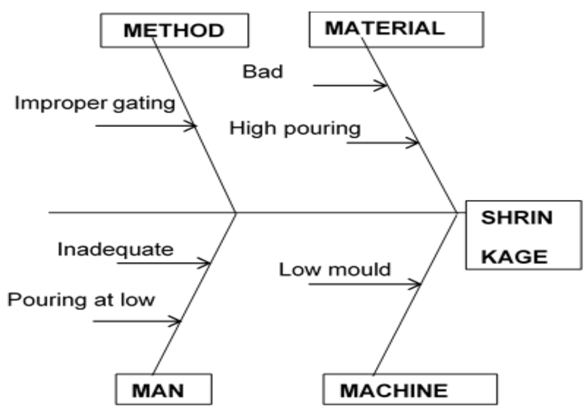

Fig. 2: Cause and Effect diagram for Shrinkage

Details of Rejected Castings

Table 1 shows the details of rejected castings.

Table 1: Cost of Rejection.

Date	Weight (Kg) (A)	Production Quantity	Rejection Quantity (B)	Cost Per Kg (Rs.) (C)	Cost of Rejection Rs. (A×B×C)
01.01.15	25	475	20	50	25,000
08.01.15	25	395	15	50	18,750
09.01.15	25	208	08	50	16,000
10.01.15	25	490	30	50	37,500
17.01.15	25	436	14	50	17,500
18.01.15	25	935	32	50	40,000
25.01.15	25	495	10	50	12,500
30.01.15	25	890	10	50	12,500
14.02.15	25	415	10	50	12,500
27.02.15	25	1618	14	50	17,500

Modal Calculation of OEE (Reading taken on **09.01.2015**)

Availability = {(TOTAL TIME – DOWN TIME) / (TOTAL TIME)} × 100%
= {(1395-228) / (1395)} × 100%
= 83.66%

Performance = {(TOTAL POURED TIME) / (TOTAL PRODUCED TIME)} × 100%
= {(4725 × 9) / (4807 × 9)} × 100%
= 98.29%

Quality = {(NO. OF POURED MOULDES) / (NO. OF PRODUCED MOULDES)} ×100%
= (4725) / (4807) × 100%
= 98.29

OEE = (AVAIBLITY × PERFORMANCE × QUALITY) × 100%
= (0.8366 × 0.9829 × 0.9829) × 100%
= 80.81%

Table 2: “Availability, Performance, Quality, OEE” of existing system.

DATE	Availability %	Performance %	Quality %	OEE %
01.01.15	89.24	98.2	98.2	85.6
08.01.15	83.93	98.22	98.22	83.93
09.01.15	83.66	98.29	98.29	80.81
10.01.15	95.91	92.53	92.53	82.12
17.01.15	88.67	98.38	98.38	85.82
18.01.15	86.37	97.98	97.98	82.92
25.01.15	90.54	98.37	98.37	87.61
30.01.15	84.59	97.74	97.74	80.81
14.02.15	90.75	97.87	97.87	86.75
27.02.15	88.82	98.29	98.29	85.81

OEE GRAPH (Existing)

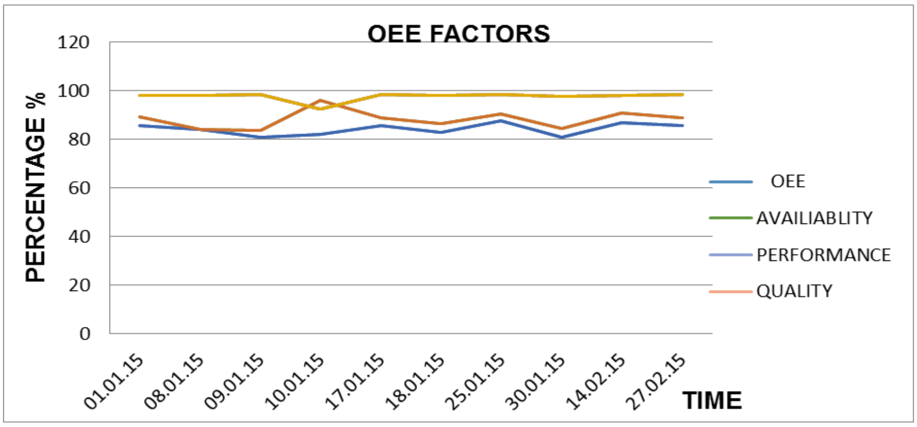

Fig. 3: OEE Factors of existing system.

The figure 3 contains results and conclusions that were obtained after a ten day observation. The graph also clearly states that the value of Overall Equipment Effectiveness (OEE) lied between 80 and 90 throughout the observation.

OEE GRAPH (Proposed)

The below graph contains results and conclusions that were obtained after consideration of proposed design and time. The parameters that were considered for this observation were Overall Equipment Effectiveness (OEE), Machine Availability, Machine Performance and Product Quality. The values of performance and quality were observed to be equal which can be clearly inferred from the graph.

Table 3: "Availability, Performance, Quality, OEE" of proposed system.

Date	Availability%	Performance %	Quality %	OEE %
02.03.15	84.08	98.98	98.98	82.37
05.03.15	89.1	97.9	97.9	85.04
06.03.15	88.24	98.33	98.33	85.4
09.03.15	86.59	98.36	98.36	83.77
14.03.15	91.25	98.32	98.32	88.2
15.03.15	86.73	96.6	96.6	80.93
18.03.15	92.32	97.89	97.89	88.46
20.03.15	91.03	98.7	98.7	88.67

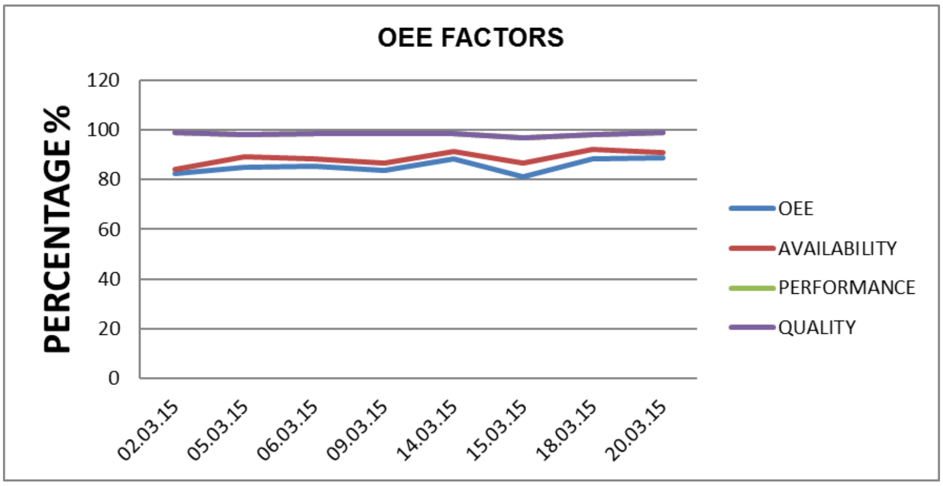

Fig. 4: OEE Factors of proposed system.

With table 3 and figure 4 it is found that the average OEE for proposed method (85.35%) and existing method (84.18%) it is clearly stated the proposed method is 1.17% greater than existing method. Also the pouring time is reduced to 8sec.

Results and Discussion

In this chapter existing and proposed patterns are analyzed with the help of "Autodesk moldflow simulation adviser" software. Properties of gray cast iron are feed in to the software. Different types of parameters are considered and results were compared.

Comparison of Existing and Proposed Pattern Model

In this chapter the existing pattern design and proposed pattern design were compared with the help of analysis results. The existing design Figure 7.1 was carefully studied. In existing design molten metal was vertically poured. Due to fast felling molten metal, turbulence occurs. To reduce turbulence, design was changed. Figure 7.2 shows proposed pattern design. There were totally three new thinks added. So that defects are minimized.

Comparison of Existing and Proposed Design

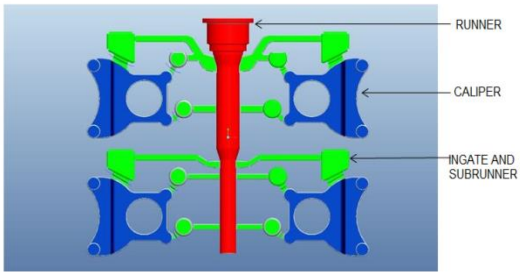

Fig. 5: Existing Pattern Layout.

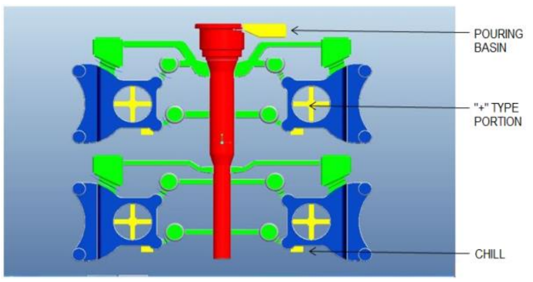

Fig. 6: Proposed Pattern Layout.

Figure 5 shows the existing pattern design. Various parts of the pattern were denoted by different colors. Figure 6 shows the proposed pattern design. Different colors representing various components in proposed pattern design.

- Red color – Runner.
- Green color – Ingate and Sub Runner.
- Blue color – Caliper Bracket.
- Yellow color – Newly added portions.

Modified Runner

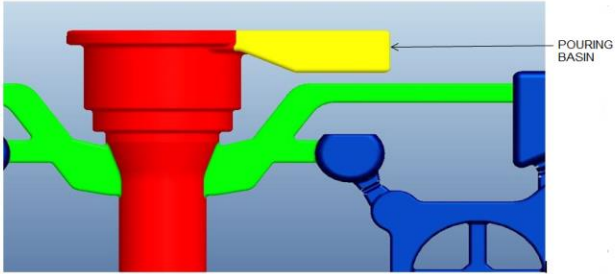

Fig. 7: Modified Runner

Figure 7 clearly shows the modified runner. In this design the molten metal will fill the well first. Then it flows through main runner to caliper. Turbulence will be reduced by this modification.

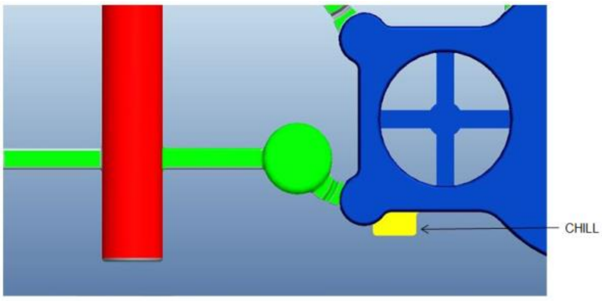

Fig. 8: A Chill Provided at Bottom

Figure 8 shows, a chill is provided at bottom of caliper. This chill was provided to reduce shrinkage and dimensional defects. Also, analysis results proved that there was defects were reduced.

Comparison of Existing and Proposed Design Results

In this section existing and proposed pattern design models were analyzed with help of “Autodesk Simulation Moldflow Adviser 2014”. Properties of gray cast iron were feed into software. Molten metal temperature also entered.

3.4.1 Filling Time.

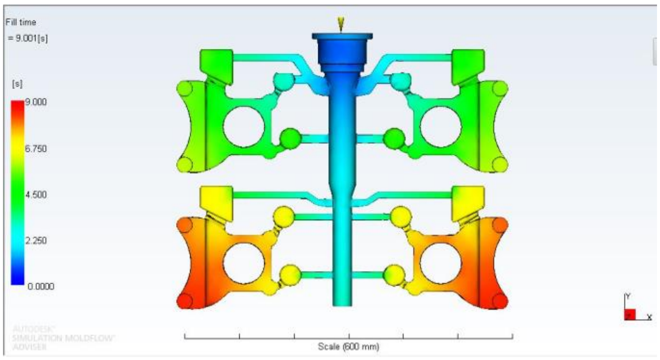

Fig. 9: Filling Time of existing pattern.

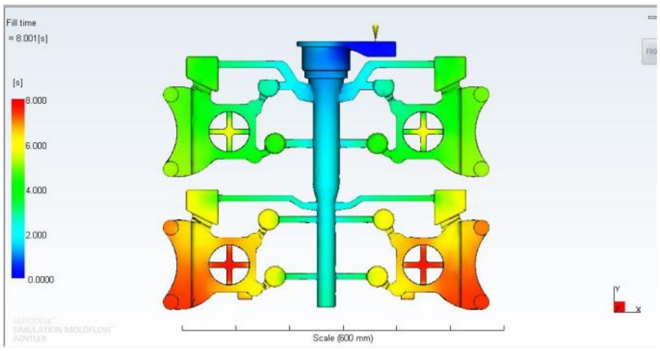

Fig. 10: Filling Time of proposed pattern

Figure 9 shows fill time of existing pattern design. It took 9sec to fill. Top portion took less time to fill but bottom portion took more time than top. The time difference paly major role in cooling time. Time taken for bottom side was higher than top side, because of fill time difference. As already stated the filling time plays major role in cooling time, fill time was reduced to 8sec. So the cooling time variance was reduced. It says even cooling of casting will give good mechanical properties. Figure 10 shows fill time of proposed pattern design.

Temperature

Average temperature of existing design was more or less even, but the temperature at caliper bracket is around 1350^{0}C. It shows there was more temperature difference. This will affect mechanical properties of caliper bracket. Figure 11 shows average temperature. Figure 12 shows average temperature of proposed pattern design.it clearly shows temperature at caliper bracket is around 1450^{0}C. So it helps to get good mechanical properties.

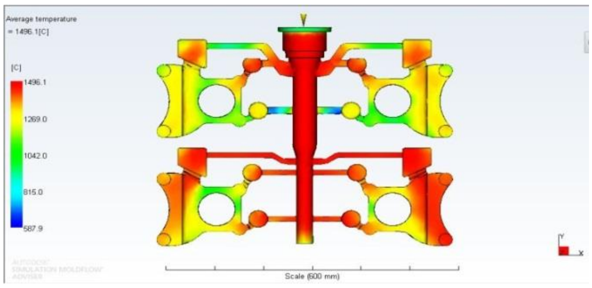

Fig. 11: Temperature Distribution in Existing Design.

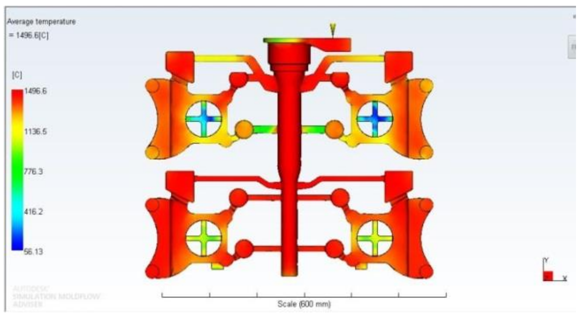

Fig. 12: Temperature Distribution in Proposed Design.

Air Traps

Blow hole is a major problem in caliper bracket casting. Air present inside of the mould cavity was the reason. In analysis, it was found that where air was trapped. Figure 13 shows there were more number of air traps.

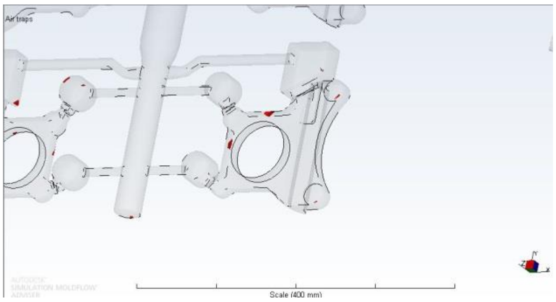

Fig. 13: Air Traps in Existing Design.

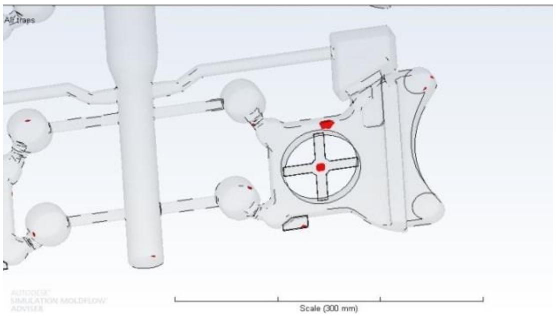

Fig. 14: Air Traps in proposed design

Figure 14 shows less air traps in proposed design. Because of "+" type design, the air was trapped at center of "+" type design. This portion will be removed.

Shrinkage Defect

Shrinkage defect is also a major defect in caliper bracket. The Figure 15 shows that there was more shrinkage defect. This shrinkage defect was acceptable up to some limit. If the shrinkage value exits acceptable value, it needs to remelt the component.

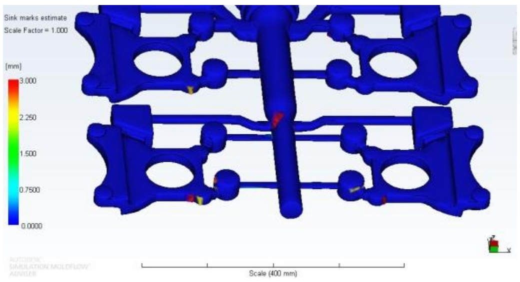

Fig. 15: Shrinkage Defect in Existing Design.

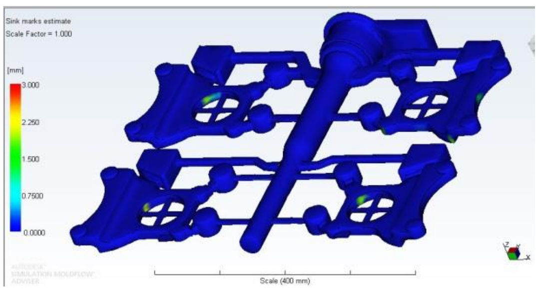

Fig. 16: Shrinkage Defect in Proposed Design.

In proposed pattern design in gate thickness was slightly increased. This will give some more time to pack. Also, a chill provided at bottom of the caliper bracket will restrict lateral length change. Finally, shrinkage was reduced to an acceptable limit. Figure 16 shows that shrinkage was reduced.

Table 4: comparison of existing and proposed method.

SL.NO.	Title	Existing method	Proposed method
1.	Fill time	9sec	8sec
2.	Average temperature	Not uniform	Uniform
3.	Air traps	More air traps	Less air traps
4.	shrinkage	More than 3mm	Up to 2mm

Table 4 shows result comparison of existing pattern design and proposed pattern design. It clearly states that proposed pattern design has fewer casting defects. Fill time is reduced from 9s to 8s. So, the molten metal fills quickly. Temperature distribution is even in proposed design. So proposed design has good mechanical properties and less air trap, less shrinkage defects.

Conclusions

This work aims to identify casting defects using simulation technique to reduce the defects in the industrial components. It offers number of advantages and in the form of intelligent tool to enhance the quality of cast component. This will definitely be helpful in improving the quality and yield of the casting. If casting s defects are inspected with such technological way, it keeps foundry industry to alert condition for control of rejections. In this project, the caliper bracket which is used in car brake drum is selected for the analysis. While manufacturing the caliper bracket, defects like shrinkage, blow holes, mould crush and sand drop are occurred in mass production. Many testings have conducted to find various parameters to get better quality casting s. By proper selecting of sand parameters has successfully reduced the casting defects. One can continuously strive for change in sand mixing process parameters until rejections are under control. Then the performance level of CASTING machine has been raised by providing proper maintenance policy. Due to this OEE of CASTING machine is improved. Finally, a new pattern design is suggested which has more than three modifications. This new pattern design has successfully reduced the casting defects. Rejection of the castings on the basis of the casting defects should be reduced as much as possible for better quality. The analysis result shows the improvement in the product quality. Finally casting rejection rate is reduced.

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