Investigation of Shrinkage Defect in Castings by Quantitative Ishikawa Diagram

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Abstract

Metal casting process involves processes such as pattern making, moulding and melting etc. Casting defects occur due to combination of various processes even though efforts are taken to control them. The first step in the defect analysis is to identify the major casting defect among the many casting defects. Then the analysis is to be made to find the root cause of the particular defect. Moreover, it is especially difficult to identify the root causes of the defect. Therefore, a systematic method is required to identify the root cause of the defect among possible causes, consequently specific remedial measures have to be implemented to control them. This paper presents a systematic procedure to identify the root cause of shrinkage defect in an automobile body casting (SG 500/7) and control it by the application of Pareto chart and Ishikawa diagram. It was found that the root causes were larger volume section in the cope, insufficient feeding of riser and insufficient poured metal in the riser. The necessary remedial measures were taken and castings were reproduced. The shrinkage defect in the castings was completely eliminated.

Keywords: Casting, Shrinkage defect, Pareto chart, Ishikawa diagram

1. Introduction

Casting defects occur while manufacturing casting due to the involvement of processes like pattern making, core box making, moulding, core making, core setting, mould closing, melting, metal pouring, heat treatment, and fettling. Generally, variations found in these processes make the task especially difficult to control the defects even in a more controlled process. The initial step in the defect analysis is to identify the major casting defect among the many defects. Then the analysis is to be made to find the root cause of the particular defect. Proper care is to be taken to identify the actual root cause among many probable causes in the tools as well as manufacturing processes. In order to minimize the casting defects, it is essential to identify the root causes for each casting defect. Generally casting defects occur in the production areas such as pattern, sand, mould, core, mould closing, melting, pouring, heat treatment and finishing. In this paper, shrinkage casting defect in an automobile body casting (SG 500/7) is discussed.

The shrinkage defect in SG iron casting can be avoided by an external feeding to the casting along with graphitization expansion. These two factors compensate volumetric shrinkage of the spheroidal graphite iron (SG) casting. In general riser feeding was adopted as the main method in foundries to avoid shrinkage in SG iron castings. Even though failures are found in riser feeding method, causes of failures can be found by proper analysis to reduce the shrinkage defect in castings.

This paper identifies and analyzes the major shrinkage casting defect in an automobile body SG Iron body casting (SG 500/7) using the flowchart [1-2] as shown in the Figure 1.
2. Methodology

The production and rejection details for automobile body casting for 4 months’ period were collected. All the major defects occurred in the casting were studied and is shown as bar chart [3-5] in Fig. 2 (Abbreviations: WT- Wall Thickness Variation, BH- Blow Holes, SH- Shrinkage Defect, SI- Sand Inclusion, MD- Mould Damage).

A Pareto chart was drawn for all the defects occurred and the shrinkage defect was found as the major defect among the all the defects as shown in Fig.3.

3. Results and discussion

Shrinkage associated casting defects occur in the heaviest section of the casting that solidify later and do not have liquid metal flow either from the riser or adjoining sections after mould was completely filled. The first step in the defect analysis is to identify the possible key variables that cause the defect. The simple method used to determine the cause is the use of Ishikawa diagram. The strength of this technique is that the collective information related to the tools and processes used to manufacture the casting are available in graphical form. The identified possible main causes for the shrinkage defect for this casting are casting design, pattern, gating, Risering, melting, pouring and moulding. [6-8]. The most effective remedial measures have to be taken only after analyzing the probable sub causes of the defect. Generally, Ishikawa diagram may not have quantitative data for the further analysis [5]. Weights for each cause in the diagram were added and percentages of influence of each cause for the defect were identified. This cause and effect diagram with Weightage used to find the major influencing causes that lead to the occurrence of the defect. The data for the shrinkage defect was collected and used to make the matrix diagram of the shrinkage defect. Initially the main causes for the shrinkage defect were identified (abbreviations are represented in brackets) and are given in the Table 1. Subsequently the sub-causes were determined using comparison matrix and are given in Table 2 [6-17].

| Table 1. Relative weights of main causes |
|----------------------------------------|
| Factor                        | $\Sigma n$ | $\Sigma n$ |
| Casting Design (CD) | 1.75 | 0.1186 |
| Pattern (PN)            | 3.0  | 0.2033 |
| Gating and Risering (GR) | 3.5  | 0.2373 |
| Melting (ME)           | 2.5  | 0.1695 |
| Pouring (PG)            | 2.5  | 0.1695 |
| Moulding (MO)           | 1.5  | 0.1017 |
| Total                   | 14.75 | ≈1     |

n- Relative weight

| Table 2. Sub-Causes leading to the defect |
|------------------------------------------|
| Sub-Causes                           | $\Sigma n$ | $\Sigma n$ |
| Isolated heavy section               | 0.25 | 0.143 |
| Change in section size               | 0.5  | 0.286 |
| Too small fillets                    | 0.5  | 0.286 |
| Lesser area for feeding              | 0.5  | 0.286 |
| Total                                | 1.75 | ≈1     |
| Larger volume section in cope        | 1.75 | 0.583 |
| Use of lesser height cope            | 1.0  | 0.333 |
| Insufficient area of core prints     | 0.25 | 0.083 |
| Total                                | 3.0  | ≈1     |
| Smaller diameter/height riser        | 0.25 | 0.071 |
| Improper design of neck              | 0.25 | 0.071 |
| No funnel pipe formed in riser       | 1.25 | 0.357 |
| Improper location of riser           | 0.5  | 0.143 |
| Insufficient feeding                 | 1.25 | 0.357 |
| Total                                | 3.5  | ≈1     |
### 3.1. Ishikawa diagram

The diagram consists of contribution of main causes and their sub-causes which includes their weights for the occurrence of the shrinkage defect. The standardized weights of the major factors are placed in Ishikawa diagram as shown in Fig.4 in circles under the titles casting design, Pattern, Gating and Riser, Melting, Pouring and Moulding. The upper value in the circle indicates the relative weight referred to a given factor. whereas the lower value indicates the absolute weight referred to the whole group. A comparison matrix was used to determine the sub-causes of the main causes. Their relative weight and absolute weight are indicated in the circles positioned in the Ishikawa diagram. The major causes and their sub-causes contributing to the shrinkage defect in castings with their percentage are given in Table 3.

The major causes of the shrinkage defect identified from the Ishikawa diagram are shown in Fig 5.

### 3.2 Major causes of shrinkage defect

Gating and risering as well as pattern were the major factors causing the shrinkage defect. Consequently, the sub causes were identified and anaysed for these major causes. The sub causes for the shrinkage defect are shown in the Pareto chart Figure.6. Finally, the sub causes causing the shrinkage defect are identified as Larger volume section in cope. No funnel pipe formed in riser. Insufficient feeding, Insufficient metal poured. Low green compressive strength, Use of lesser height copes and Improper composition.

| Melting               | Excessive nodule count | 0.75 | 0.3 |
|-----------------------|------------------------|------|-----|
|                       | Minimum silicon content| 1.0  | 0.4 |
|                       | Tapping cold metal     | 0.25 | 0.1 |
|                       | Too high tapping temper temperature | 0.5 | 0.2 |
|                       | Total                  | 2.5  | ≈1  |

| Pouring              | Pouring cold metal    | 0.5  | 0.2 |
|----------------------|-----------------------|------|-----|
|                      | Too high pouring temp | 0.75 | 0.3 |
|                      | Insufficient metal    | 1.25 | 0.5 |
|                      | Total                 | 2.5  | ≈1  |

| Moulding             | Mould dilation/enlarge| 0.25 | 0.166 |
|----------------------|-----------------------|------|-------|
|                      | Weak soft moulds      | 0.25 | 0.166 |
|                      | Low green compressive | 1.0  | 0.666 |
|                      | Total                 | 1.5  | ≈1    |

![Ishikawa diagram for shrinkage defect](image-url)

Fig. 4. Ishikawa diagram for shrinkage defect
### 3.3 Percentage contribution of major and sub causes

Table 3. Percentage contribution of major and sub causes

| Group               | Subgroup                          | Subgroup (%) in a given group | Subgroup (%) in a given fault |
|---------------------|----------------------------------|-------------------------------|--------------------------------|
| Casting Design      | Isolated heavy section           | 14.2                          | 1.7                            |
|                     | Change in section size           | 28.6                          | 3.4                            |
|                     | Too small fillets               | 28.6                          | 3.4                            |
|                     | Lesser area for feeding         | 28.6                          | 3.4                            |
|                     | Total                            | 100                           | -                              |
|                     | Larger volume section in cope   | 58.3                          | 11.8                           |
| Pattern             | Use of lesser height cope       | 33.3                          | 6.7                            |
|                     | Insufficient area of core prints| 8.4                           | 1.7                            |
|                     | Total                            | 100                           | -                              |
| Moulding            | Excessive nodule count          | 30                            | 5.1                            |
|                     | Minimum silicon content         | 40                            | 6.7                            |
|                     | Tapping cold metal              | 10                            | 1.7                            |
|                     | Too high tapping temperature    | 20                            | 3.4                            |
|                     | Total                            | 100                           | -                              |
| Gating and Riser-ing| Smaller diameter/height riser   | 7.1                           | 1.7                            |
|                     | Improper design of neck         | 7.1                           | 1.7                            |
|                     | No funnel pipe formed in riser  | 35.7                          | 8.5                            |
|                     | Improper location of riser      | 14.4                          | 3.4                            |
|                     | Insufficient feeding            | 35.7                          | 8.5                            |

The shrinkage defect in the castings can be reduced by implementing the corrective actions. Interchanging of cope and drag patterns were made in the match plates so that larger volume section of the casting was kept in the drag. Subsequently the riser was redesigned and a tall tapered riser was used because no funnel pipe formed in the riser indicates insufficient feeding.

Metal is to be poured to the full height of the riser because of variations of the riser height indicated that insufficient metal was poured in the moulds. The cope and drag pattern with these changes made are shown in Fig 7a and 7b respectively.

The components of gating and feeding systems indicated in fig 7a(larger volume), 7b (smaller volume) and fig 8 (poured casting) are,
1. Pattern (Cope)
2. Riser
3. Runner
4. Well
5. Pattern (Drag)
6. Funnel pipe formation
7. Casting
Moreover, metal was poured to the full height of the riser. The metal was poured in the moulds and found that the shrinkage defect was completely eliminated. The poured casting with gating and feeding systems is shown in the Fig 8.

![Fig. 8. Casting with redesigned gating and risering systems](image)

### 4. Conclusions

The identification of the root cause of the casting defect is important to initiate remedial measures to minimize/eliminate defects. This paper adopts a systematic procedure to find the root cause of the major shrinkage defect occurred in an automobile body casting (SG 500/7) by using bar chart Pareto chart and Ishikawa diagram with quantitative Weightage. It was found that the root causes were larger volume section in the cope, insufficient feeding of riser and insufficient poured metal in the riser. The necessary remedial measures were taken and castings were reproduced. The shrinkage defect in the castings was completely eliminated.

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