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Common Defects in Grey Cast Iron Products, their Causes and Remedies - Case Study

Farooq Ahmed [a], Saood Ali [a], Zakaullah Zaka [b]
[a] Department of Mechanical Engineering, Teerthankar Mahaveer University, Moradabad, Uttar Pradesh, India
[b] Department of Mechanical Engineering, University polytechnic, Integral University, Lucknow, Uttar Pradesh, India

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Abstract

Whilst most foundries today recognise the types of defect found in grey cast iron appreciation of the causes and therefore cures is not always apparent.
This paper will examine some of the common defects, which have been found during examination of rejected castings in a foundry in Agra (U.P).
Two mains categories of defects viz. solidification related defects and flow related defects were observed during the examination of castings, hence both of the types were analysed and remedies suggested.

1. Introduction

Casting process is also known as process of uncertainty. Even in a completely controlled process, defects in casting are found out which challenges explanation about the cause of casting defects. The complexity of the process is due to the involvement of the various disciplines of science and engineering with casting. The cause of defects is often a combination of several factors rather than a single one. When these various factors are combined, the root cause of a casting defect can actually become a mystery. It is important to correctly identify the defect symptoms prior to assigning the cause to the problem. False remedies not only fail to solve the problem, they can confuse the issues and make it more difficult to cure the defect.

Today's highly competitive and cyclical manufacturing environment finds customers consistently demanding higher and higher quality while suppliers strive to reduce operating cost to remain profitable. Often, foundries respond to customers' quality demands by implementing total quality management or continuous improvement teams to identify ways to increase customer satisfaction. A tremendous amount of productivity is lost through these defective castings. Therefore it is necessary to overcome these defects as it produces huge rejections of casted parts. For the reducing the number of defective parts a disciplined approach should be applied to understand the nature of defects, the mechanism of defect formation and controlling the key process variables.

Two distinct journeys must be taken to correct sporadic defects. They are "the diagnostic journey from symptom to cause and the remedial journey from cause to remedy". There is a temptation to attempt to diagnose a defect by the possible causes; but, an incorrect diagnosis of the root cause can lead to an incomplete identify the defects symptoms prior to assigning the cause to the problem. In general, a casting defect is defined as an observable and unplanned variation of a specification. The identity of a particular casting defect is based upon the specific shape, appearance, location and dimension or profile of the anomaly. The proper identification of a specific defect is the prerequisite to correcting and controlling the quality of castings.

Corresponding Author,
E-mail address: farooqahmed333@gmail.com

Types of Defects

There are many types of defects which result from many different causes. Some of the solutions to certain defects can be the cause for another type of defect.

Surface defects	Internal defects	Visible defects
Blow	Blow holes	Wash
Scar	Porosity	Rat tail
Blister	Pin holes	Swell
Drop	Inclusions	Mis-run
Scab	Dross	Hot tear
Penetration		Cold shut

2. Literature Survey

A lot of work has been done on defects of casting and they also give suggestions for minimizing them. Such as porosity, blow holes, pin holes, shrinkage, cracks, slag inclusion, cold shut, mould shift etc.

Porosity defects are "chemical in nature" and result when liquid metal becomes supersaturated with dissolved gases during melting or pouring. The ensuing discontinuities are present as discreet voids that may be rounded or irregularly shaped in the solidified casting and generally lie just under the casting surface. Conversely, "blows" or "blowholes" are a physical or mechanical problem related to the inability of decomposed core and mold gases to escape from the mold cavity, either through permeability or venting [1]. The appearance of the subsurface porosity defects resulting from the preceding sources may take numerous shapes but usually form as either small, spherical holes (sometimes elongated or pear-shaped) and called pinholes, or larger, irregularly rounded holes or irregularly shaped fissure type defects [2,3]. In the open literature the influence of porosity on the fatigue properties casted materials has been investigated earlier by Mayer H et al.[4] and he concluded that fatigue strength is decreased by the presence of porosity. One of the critical elements that have to be considered for producing a high quality in sand casting product is the gating design. Many extensive research efforts have been made in attempts to study the effect of gating design on the flow pattern of melt entering the mould [5]. It has been shown by Masoumi et al. [6] that an optimum gating system design could reduce the turbulence in the melt flow; minimize air entrapment, sand inclusion, oxide film and dross. It have been suggested by Hu, B.H et.al.[8] that the formation of various casting defects could be directly related to fluid flow phenomena involved in the stage of mold filling, for instance, vigorous streams could cause mold erosion; highly turbulent flows could result in air and inclusions entrapments; and relatively slower filling might generate cold shuts. Furthermore, Dai, X et.al.[10] conducted a study on gating system design and suggested that, porosity which is a common defect in casting could also result from improper design of gating system and the existence of porosity defect could decrease the mechanical properties of the product. Therefore, runner system design plays important rules on determining the tensile strength of aluminum cast alloy.

There are logical suggestions given by some scientists, but some time because of lots of factors, the suggestion is not up to mark. The reason behind them is that there are lots of variables which govern these defects such as mould material, ramming, moisture content, refractoriness of mould material, binders, material of cores, composition of sand, pouring temperature, fluidity of pouring material, improper design of gating system and more. So to consider all these factors in analyzing the defects is not an easy task.

3. Methodology

The Case Study was conducted to find out casting defects in the parts manufactured in “INDU ENGINEERING AND TEXTILES LTD.” Agra. In this industry, mainly automobile parts were manufactured by sand casting. The production was on mass scale and the products were categorized as rejected. Finding out the correct remedy of these defects can minimize the rejection of parts and it will improve the productivity. The defects being observed are analyzed to find out the possible causes and thereafter their respective remedies are also suggested. During the study the products were examined with whole batch and product were observed to identify the defective parts and the defects of these parts were analyzed in a logical and reasonable way. The Study was done on five types products namely:

1. Escort Hub
2. L R Cover
3. Motherson body
4. Oil sump
5. Pinion cover

Observations

In the above products we found that the defects which normally occur are blow hole, pin hole, shrinkage, slag inclusion, cold shut, crack, shift etc.

3.1 Escort Hub

Figure below shows the complete drawing and three dimensional view of escort hub.

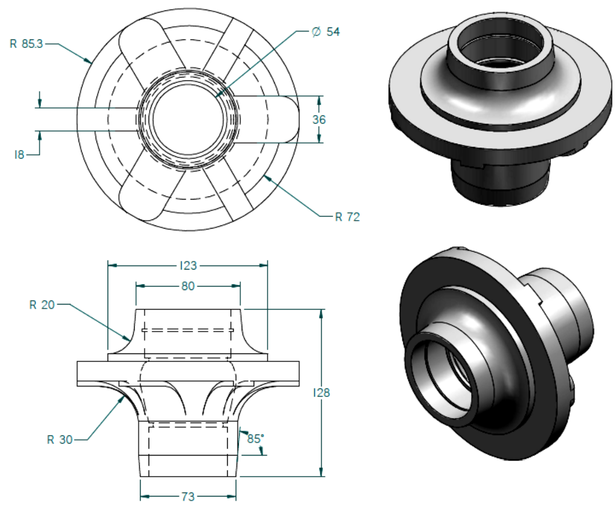

Fig: 1. Escort Hub

The defects present in this product are:

- Shrinkage
- Sand drop
- Crack
- Blow Holes

3.1.2 L R Cover

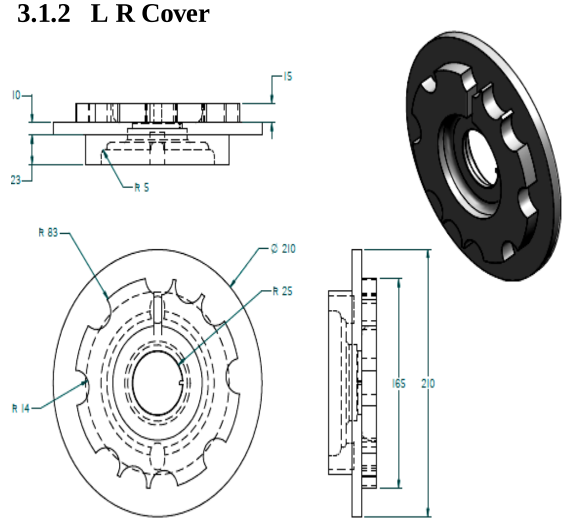

Fig: 2. L R Cover

The defects occurring in this component are:

- Extra Material
- Shrinkage
- Cold Shut
- Core Shift
- Pin Holes
- Sand Drop

3.1.3 Mother-Son Body

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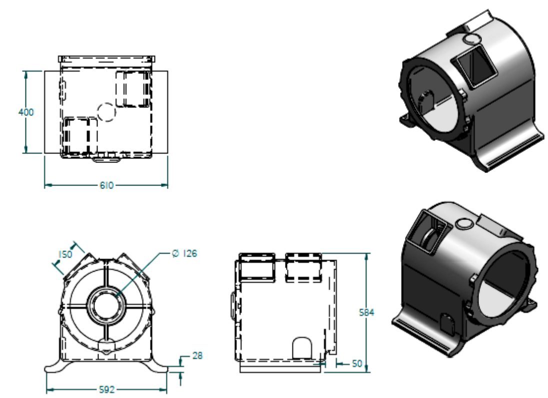

Fig: 3. Mother-son Body

The defects occurring in this component were:

- Crack
- Blow Holes
- Sand Drop
- Pin holes

3.1.4 Oil Sump

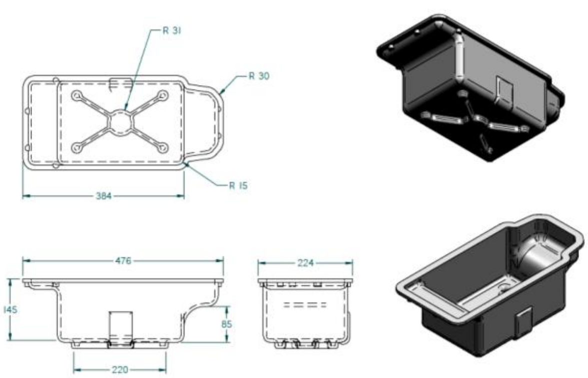

Fig: 4. Oil Sump

The defects present in this product are:

- Shrinkage
- Sand drop
- Crack
- Blow Holes
- Pinhole

3.1.5 Pinion Cover

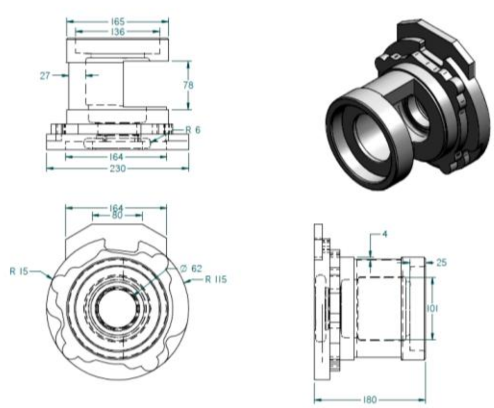

Fig: 5. Pinion Cover

The defects present in this product are:

- Shrinkage
- Sand drop
- Crack
- Blow Holes

Table: 2. Showing Rejection Percent of the Selected Products

Name of part	Cost per part (Rs.)	No. of part per batch	Percentage rejection %
Escort Hub	312	60	9-10
L R Cover	299	40	12-15
Motherson Body	585	20	8-9
Oil Sump	550	32	7-8
Pinion Cover	876	20	9-10

4. Analysis of Defects

From the above observations, It have been found that defects which are present in the parts are as follows:

1. Blow holes
2. Pin holes
3. Slag Inclusion
4. Cold Shut
5. Shrinkage
6. Drop
7. Mold & Core shift

4.1 Blow Holes

Fig: 6. Blow Holes

Possible causes:

- Moisture content of sand too high, or water released too quickly.
- Gas permeability of the sand too low.
- Sand temperature too high.
- Bentonite content too high.
- Too much gas released from lustrous carbon producer.
- Compaction of the mould too high.
- Casting temperature too low.
- Metallostatic pressure too low when pouring.

Remedies:

- Reduce moisture content of sand. Improve conditioning of the sand. Reduce inert dust content.
- Improve gas permeability. Endeavour to use coarser sand. Reduce bentonite and carbon carrier content.

- Reduce sand temperature. Install a sand cooler if necessary. Increase sand quantity.
- Reduce bentonite content.
- Reduce compaction of the moulds. Ensure more uniform mould compaction through better sand distribution.
- Increase pouring temperature. Reduce the pouring rate as appropriate.

4.2 Pin Holes

Fig: 7. Pin Holes

Possible Causes

- Nitrogen content in the melt too high due to the charge composition.
- Proportion of oxides, hydroxides (rust) and other impurities in the charge materials too high
- Manganese and sulphur contents in the melt too high.
- Nitrogen content in the sand too high.
- Moisture content of the sand too high.
- Lustrous carbon production in the moulding sand too low.
- Pouring passages too long.
- Too much turbulence and slag formation during pouring.

Remedies

- Use charge components with low nitrogen content, e.g. reduce the quantity of steel scrap.
- Use scrap and return material free of rust, water and oil impurities. Use circulating materials free of impurities adhering to sand and feeder auxiliaries.
- Deoxidize melts as well as possible.
- Reduce the formation of slag.
- Reduce nitrogen content in the sand. Reduce the quantity of inflowing nitrogen-containing core sand. If necessary, add new sand to the circulating sand.
- Reduce the moisture content of the sand.
- Lower the bentonite content. Improve development of the moulding sand. If necessary, reduce inert dust content. Keep amount of lustrous carbon carrier at the minimum level.
- With an oxidizing atmosphere in the mould cavity, if necessary increase the quantity of lustrous carbon producer in the moulding sand. Avoid adding too much.
- Increase pouring temperature.
- Reduce flow rate into the mould.
- Avoid turbulence when pouring.

4.3 Slag Inclusions

Fig: 8. Slag Inclusion

Irregular-shape, non-metallic inclusions, frequently on upper casting surfaces, which may occur in association with gas blow-holes. Slag is not only found at the microstructure grain boundaries but also on the surface of the casting. Slag may often appear in association with gas cavities. Highly viscous slags more frequently appear in the microstructure of the casting. Low-viscosity slags rise more quickly to the surface of the casting. However, in the event of severe turbulence and a short solidification time, low-viscosity slag may also be included in the casting. During the casting of iron-carbon alloys, oxide inclusions and slag with a high oxidation potential (e.g. high manganese and ferrous oxide contents) react with the graphite, resulting in the formation of CO blowholes.

Possible Causes

- Oxide content of the charge too high.
- High impurity levels of oxides and hydroxides in charge materials.
- Poor or slow dissolution of inoculants.
- Ladle lining too highly reactive.
- Poor deslagging of the molten metal.
- Casting temperature too low and pouring rate too slow.
- Too much turbulence when pouring and poor slag precipitation.
- Proportion of inert dust too high.
- Proportion of bentonite too low, bentonite poorly developed or has poor binding capacity.
- Oxygen contents in mould cavity too high.
- Proportion of low-melting-point compounds too high.

Remedies

- Keep contents of elements which strongly react with oxygen as low as possible, e.g. aluminium, magnesium, manganese; if necessary reduce them; use materials without impurities
- Optimize the use of inoculants; avoid slagging; in case of failure to dissolve, reduce grain size.
- Dry ladle prior to use; hold molten metal in the ladle for shortest possible time; avoid alloying in the ladle; skim ladles carefully; use slag binders; if necessary use teapot ladles.
- Increase pouring temperature and shorten pouring times.
- Improve gating, keep pouring basin full, use slag traps; avoid turbulence when pouring; install strainer core.

- Reduce proportion of inert dust; if necessary add new sand and reduce dust recirculation.
- Use bentonites with increased binding capacity and high montmorillonite content – if necessary increase proportion; improve development of bentonite.
- Increase lustrous carbon production in the moulding sand or use carbon carriers with higher lustrous carbon producing capacity.

4.4 Crack

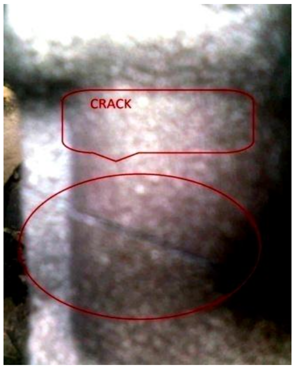

Fig: 9. Crack

Possible Causes

- Rough handling is a predominant cause of crack.
- Such defects are hairline and visually difficult to detect.
- When high levels of residual stress are present, such cracks may wider.
- Uneven cooling in the mould due to highly stressed casting.
- Restriction to metal contraction.
- Cracks in highly stressed castings may be initiated by application of small external forces.
- Unsuitable metal composition.

Remedies

- Avoid excessive application of forces at the knockout, during fettling, removal of cores or adhering sand.
- Prevent formation of excessive flash.
- Design runners and feeders for easy removal.
- Prevent formation of surface cracks during grinding by avoiding use of excessive pressure.
- Handle castings with care at all stages of manufacture, processing and transport.
- Improve mould and core practice to minimize flash around mould joints and core prints.
- Use moulds and cores with good breakdown properties.
- Ensure chills do not restrict contraction.
- Reduce high levels of residual casting stress arising from uneven cooling in the mould by considering modification to casting design to eliminate, for example variations in section thickness, sharp corners and inadequate radii.
- Residual stresses can be reduced by a suitable heat treatment.
- Minimize the risk of cracking by avoiding the formation of chill in the minimum casting thickness by the use of metal of appropriate composition and treatment.
- Avoid the presence of harmful amounts of trace elements which increase the brittleness or reduce the strength of the iron.

4.5 Cold Shut

Fig: 10. Cold Shut

A defect produced as a result of lack of fusion between metal stream and or the presence of slag on the metal surface.

Possible Causes

- Metal pouring temperature too low.
- Insufficient metal fluidity.
- Pouring too slow
- Slag on the metal surface.
- Interruption to pouring during filling of mould.
- High gas pressure in the mould arising from moulding material having high moisture and/or volatile content and/or low permeability.
- Metal section too thin.

Remedies

- Increase metal pouring temperature.
- Modify metal composition to improve fluidity.
- Pour metal as rapidly as possible without interruption.
- Improve mould filling by modification to running and gating system.
- Remove slag from mould surface.
- Reduce gas pressure in the mould by appropriate adjustment to mould material properties and ensuring adequate venting of mould sand cores.
- If possible modify casting design to avoid thin sections.
- Ensure metal moulds are adequately preheated and use insulating coatings.

4.6 Shrinkage

Fig: 11. Shrinkage

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A depression on the casting surface at sections of a casting which are last to solidify. The defect can occur at hot spots caused by a corner, recess or core where it may have a dendritic appearances. In some instances a head of metal having phosphorous level in excess of the parent metal may found in cavity.

Possible Causes

- Inability of mould cavity to resist enlargement arising from molten metal pressure and/ or solidification expansion due to inadequate compaction or use of unsuitable moulding material.
- Enlargement of the mould cavity arising from molten metal pressure and/ or in grey and ductile irons, solidification expansion due to graphite precipitation offsetting the earlier contraction of the liquid metal.
- Pouring temperature too high.
- Excessive inoculation resulting in increased precipitation and consequent solidification expansion.
- Lack of sufficient feed metal to compensate for volumetric contraction during solidification.
- Hot spots resulting from poorly designed running system.
- Poor casting design.

Remedies

Improve mould rigidity by:

a) Harder ramming and/ or improved moulding materials properties.
b) Using rigid moulding boxes with reinforcing bars where necessary.
c) Clamping and weighing moulds adequately.

- Avoid unnecessarily high pouring temperature.
- Restrict the amount of inoculants to the minimum necessary to avoid chill or give the required mechanical properties.
- Provide adequate feed metal.

4.7 Drop

Fig: 12. Drop

An irregularly shaped projection on the cope surface of a casting is called a drop. This is caused by dropping of sand from the cope or other overhanging projections into the mould. An adequate strength of the sand and the use of gaggers can help in avoiding the drops.

Possible Causes

- Low Green Strength of Sand.
- Low Mold Hardness
- In Sufficient Reinforcement in Sand Projection

Remedies

- Increase the Moisture Content up to a optimum level.
- Improve mould rigidity by:

a) Harder ramming and/ or improved mould materials properties.
b) Using rigid mould boxes with reinforcing bars where necessary.
c) Clamping and weighing moulds adequately

4.8 Core Shift

Fig: 13. Core Shift

A variation from specified dimensions of a cored casting section, due to a change in position of the core or misalignment of cores in assembling

Possible Causes

- Excessive rapping of a loose pattern.
- Reversing the cope on the drag.
- Too loose a fit of the pattern pins and dowels.
- Faulty mismatched flasks.
- Too much play between pins and guides.
- Faulty clamping.
- Improper fitting (racked) jackets.
- Improper placing of jackets.
- Not aligning the halves of glued cores true and proper when assembling them.

Remedies

- Use of Chaplets wherever necessary.
- Avoid turbulence when pouring.

5. Conclusion

It can be concluded from the above observations and analysis of defects that the rejection is mainly due to occurrence of defects in the castings. These occurrences of defects have to be minimized in order to decrease the rejection and hence the rejection cost. The defects present are usually process specific and hence the process need to be observed carefully and the factors responsible for the presence of defect have to be taken care of.

Some of the factors occur due to human error but some these are controllable. The remedies suggested in the above analysis of defects should be implemented in order to enhance the quality and hence reduce the rejection cost. Sand quality, moisture content, pouring temperature, binding material quantity etc should be in a controlled amount in order to control the process. During the process steps should be taken to minimize the human interference which will eventually result in increase in quality of products.

Apart from this any rejection problem should be studied in totality. Workmen on shop-floor should be made to involve themselves in solutions. Know-how and know-why should be discussed with open mind. Expert opinion should always be sought in time. Involvement of every one is the key to problem- solving.

References

[1] R. L. Naro, et. al, Gas Evolution of Synthetic Core Binders: Relationship to Casting Blowhole Defects, AFS Transactions, 91, , 1983, 365

[2] J. V. Dawson, J. A. Kilshaw, A. D. Morgan, The Natural and Origin of Gas Holes in Iron Castings Trans. AFS, 73, 1965, 224

[3] J. M. Greenhill, Diagnosis of Causes of Defects in Gray Iron Castings, Foundry Trade Journal, 1970, 603

[4] H. Mayer, M. Papakyriacou, B Zettl, Stanz-Tschegg S E, Influence of porosity on the fatigue limit of die cast magnesium and aluminium alloys. Int. J. Fatigue 25, 2003, 245–256

[5] C. E. Espraza, M. P. Guerro Mata, R. Z. Rios Mercado, Optimal design of gating systems by gradient search methods, Computational Materials Science, 2005

[6] Masoumi, Ammar, Effect of Gating Design on Mold Filling, American Foundry Society, 2007

[7] R. Babaei, J. Abdollahi, P. Homayonifar, N. Varahram, P. Davami, Improved advection algorithm of computational modeling of free surface flow using structured grids, Computer Methods in Applied Mechanics and Engineering, 195, 2006, 775-795

[8] B. H. Hu, K. K. Tong, X. P. Niu, I. Pinwill, Design and optimization of runner and gating systems for the die casting of thin walled magnesium telecommunication parts through numerical simulation, Journal of Materials Processing Technology, 105, 2002, 128-133

[9] E. Attar, P. Homayonifar, R. Babaei, K. Asgari, P. Davami, Modeling of air pressure effects in casting moulds. Journal of Modeling and Simulation in Materials Science and Engineering, 2005, 903-917

[10] X. Dai, X. Yang, J. Campbell, J. Wood, Effects of runner system design on the mechanical strength of Al-7Si-Mg alloy castings. Journal of Materials Science and Engineering, A 354, 2003, 315-325

[11] C. Hartung et al., Research Manager, Elkem AS, Foundry Products Division, Common Metallurgical Defects in Grey Cast Irons, Causes and Cures