Defect analysis in a casting component and measures to mitigate it using Non-Destructive Testing and Genetic Algorithm

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Abstract: In this paper, defects caused in casting process are identified, analyzed and minimized by obtaining the suitable remedial measures. Defect analysis using Non-destructive Testing (NDT) is an expedient way for controlling defects in Mechanical and Aerospace Systems. Defect Analysis means identifying, locating, interpreting, evaluating and generating corrective and preventive actions.

Keywords: Non-destructive Testing, Casting, Defect Analysis

I. INTRODUCTION

A casting defect is an irregularity in the metal casting process that is much undesired. Some defects can be tolerated while others can be repaired, otherwise they must be eliminated. Casting defect analysis is the process of finding root causes of occurrence of defects in the rejection of casting and taking necessary step to reduce the defects and to improve the casting output. In the process of casting, there is always a chance of defect occurring due to many parameters [1]. Minor defect can be trapped and can been reduced but major defects increases rejection rate which could increase the production cost. Therefore knowledge on types of defect that occur in a casting process and methods to identify the malfunctioned defects, and their preventive ways are mandatory.

II. METHODOLOGY (PHASES IN DEFECT ANALYSIS)

1. Selection of a component (casting component)
2. Trapping the defects (identification of Defects)
3. Analyzing the defects (causes for the defects)
4. Developing defect mitigation plan (remedial measures)
5. Implementing defect mitigation plan
6. Development of a defect free component

1. Casting Component: Cooling blade

Rejected blade used in a pump industry made of pure aluminum and grey cast iron (FG 200) are obtained to carry out defect analysis, the blade is used inside the pump to transmit the cooling stream into the pump casing to remove the heat. Trapping of the defects has been carried out using

Non-destructive testing methods and remedial measures to overcome the defects are developed [2, 3].

Fig.1.Blade made of pure aluminum

Fig.2.Blade made of Grey cast iron

2. *Trapping the Defects*

Defects in the component are being identified using NDT techniques (PT,UT, RT).Non-destructive testing (NDT) is a wide group of analyzing technique used in mechanical industries to evaluate the properties of a material, without damaging it. Initial inspection using NDT shown defects like Blow hole, pin hole and shape related defects on the material due to grinding for surface finish, are present in the component which results in the rejection of the component [3, 4].

Fig.3. Blow hole and Grinding defect

3. *Analyzing the defects*

Defect Analysis is a process carried out to find the nature of the defects and its root causes. In this paper Analysis of the defects is carried out using Non-traditional optimization technique to find the best suitable remedial measure to mitigate the defect. Genetic algorithm approach is selected to solve the problem of selecting the suitable remedial measures for the defects that occurred, as the traditional approach is considered to be improper [5, 6].

Non-destructive testing (Liquid penetrate, Magnetic particle testing and Ultrasonic testing) have been carried out on the blade material, the test revels the following defects:

a) Blow hole and Pin hole

b) Gas porosity

c) Shape defects (grinding defects)

a) Blow hole and Pin hole

Blowhole is a kind of cavities defect, which is also divided into pinhole and subsurface blowhole. Pinhole is very tiny hole. Subsurface blowhole only can be seen after machining. Gases entrapped by solidifying metal on the surface of the casting, which results in a rounded or oval blowhole as a cavity. Frequently associated with slag's or oxides. The defects are nearly always located in the cope part of the mould in poorly vented pockets and undercuts. [1, 7]

Causes:

- Inadequate core venting
- Excessive release of gas from core
- Excessive moisture absorption by the cores
- Moisture content of sand too high, or water released too quickly
- Gas permeability of the sand too low
- Sand temperature too high

Remedial Measures:

- Improve core venting, provide venting channels, ensure core prints are free of dressing
- Reduce amounts of gas.
- Use slow-reacting binder.
- Reduce quantity of binder.
- Use coarser sand if necessary.
- Dry out cores and store dry, thus reducing absorption of water and reducing gas pressure.

b) Gas Porosity:

The gas can be from trapped air, hydrogen dissolved in aluminium alloys, moisture from water based die lubricants or steam from cracked cooling lines. Air is present in the cavity before the shot. It can easily be trapped as the metal starts to fill the cavity. The air is then compressed as more and more metal streams into the cavity and the pressure rises. When the cavity is full it becomes dispersed as small spheres of high pressure air. The swirling flow can cause them to become elongated. [1, 5]

Causes:

- Metal pouring temperature too low.
- Insufficient metal fluidity e.g. carbon equivalent too low.
- Pouring too slow.
- Slag on the metal surface.

- Interruption to pouring during filling of the mould.
- High gas pressure in the mould arising from molding material having high moisture and/or volatile content and/or low permeability.
- Lustrous carbon from the molding process.
- Metal section too thin.
- Inadequately pre-heated metallic moulds.

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 metal surface.
- Reduce gas pressure in the mould by appropriate adjustment to moulding material properties and ensuring
- Adequate venting of moulds and cores.
- Eliminate lustrous carbon where applicable.
- If possible, modify casting design to avoid thin sections.
- Ensure metal moulds are adequately pre-heated and use insulating coatings.

c) Shape Defects: (Mismatch defect)

Mismatch in mold defect is because of the shifting molding flashes. It will cause the dislocation at the parting line.

Possible causes

- A mismatch is caused by the cope and drag parts of the mould not remaining in their proper position.
- This is caused by loose box pins, inaccurate pattern dowel pins or carelessness in placing the cope on the drag.

Remedies

- Check pattern mounting on match plate and Rectify, correct dowels.
- Use proper molding box and closing pins.

4. Developing defects mitigation plan

Defect mitigation is a process of identifying suitable remedial measures that can be implemented to reduce the percentage of rejection of the component through non-traditional approach [1-4].

Remedial Measures for blow hole

- Improve core venting, provide venting channels, ensure core prints are free of dressing
- Reduce amounts of gas.
- Use slow-reacting binder.
- Reduce quantity of binder.
- Dry out cores and store dry, thus reducing absorption of water and reducing gas pressure.

Remedial Measures For Gas porosity

- Increase metal pouring temperature.
- Pour metal as rapidly as possible without interruption.

- Improve mould filling by modification to running and gating system.
- Reduce gas pressure in the mould by appropriate adjustment to moulding material properties and ensuring
- Adequate venting of moulds and cores.

Remedial Measures For Shape defects

- Check pattern mounting on match plate and Rectify, correct dowels.
- Use proper molding box and closing pins.

5. *Implementing Defect Mitigation Plan*

The execution process is as follows:

- Cooling blade is selected and detect analysis is being carried out.
- Factors in the casting process and defects occurred in the component are studied and analyzed using optimization technique.
- Root causes for the defects will be identified.
- Implementation of remedial measures obtained after optimization process to produce defect free component.
- Report for rejected and defect free component will be generated as per ASNT standards.

6. *Develop Defects Free Component*

The identified remedial measures are implemented and defect free component is produced with same material and die in sand casting**.**LPT and UT were carried out in the component to capture the defects if any after analyzing [1].

III. INSPECTION REPORTS

Fig.4: Liquid penetrant testing in blade-2

Fig.5: Ultrasonic testing in blade-2

Inspection Report: (LPT)

Nest Technical Solutions Pvt. Ltd
13, Kamala Colony, Lakshmipuram
Kamarajar Road, Peelamedu (PO),
Coimbatore - 641 004.
The Symbol of Perfection

Inspec on Report

Client Name: **BHARATH KUMAR. G**	Job type: **ALUMINIUM CASTING BODY**
Job name : **COOLING BLADES**	Job speci ca on: **ALUMINIUM 1050 – 2NOS**
Test Name : **PENETRANT TESTING**	heat treatment: -
Number of components: **2**	wall thickness: **15mm**
Defects absorbed : **CLUSTER & ISOLATED POROSITY**	Remarks:

Equipment Details:

Cleaner : **MR 85 SOLVENT REMOVER**	Penetrant: **MR 62 RED**	Developer: **MR 70 AQUEOUS**

Recorded as: Photography


COOLING BLADE NO: 1


COOLING BLADE NO: 2

Date : **21/02/2015**
Place : **Coimbatore**

Inspected by ASNT LEVEL II
Saravanan.N

Ph: 0422- 4208545
info.cbe@nestndt.com

Inspection Report: (MPT)

Nest Technical Solutions Pvt. Ltd
13, Kamala Colony, Lakshmipuram
Kamarajar Road, Peelamedu (PO),
Coimbatore - 641 004.
The Symbol of Perfection

Inspec on Report

Client Name: **BHARATH KUMAR. G**	Job type: **GREY CAST IRON**
Job name : **COOLING BLADES**	Job speci ca on: **GREY CAST IRON FG 200**
Test Name : **MAGNETIC PARTICAL TESTING**	Heat treatment: -
Number of components: **1**	Wall thickness: **15mm**
Defects absorbed : **CLUSTER & ISOLATED POROSITY**	Remarks:

Equipment Details:

Cleaner : **MR 70 SOLVENT REMOVER**	WHITE CONTRAST: **MR 72 WHITE**	DEVICE: **YOKE (DC)**	MAGNETIS INK: **MR 76 S**

Recorded as: Photography

Date : **21/02/2015**
Place : **Coimbatore**

Inspected by ASNT LEVEL II
Saravanan.N

Ph: 0422- 4208545
info.cbe@nestndt.com

Inspection Report Showing porosity:

Nest Technical Solutions Pvt. Ltd
13, Kamala Colony, Lakshmipuram
Kamarajar Road, Peelamedu (PO),
Coimbatore - 641 004.
The Symbol of Perfection

ULTRASONIC TEST REPORT

Client : Meera. V & Co	Report Date : 23.02.2015	Report No: U T/01	Page No : 1 of 2
Spec No : 1050 no 1	Tested on : 21.02.2015		Tested Complete :21.02.2015
Reference Procedure Specification : ASME SEC VIII			
Surface Condition : Medium Smooth	**Surface Temp : At room temp**	**Scanning :** All Area	
Equipment & Technique			
Model : Modsonic – Einsten II	**SL No : E3422-0812**	**Manufacturer : Modsonic**	
Couplant : Grease	**Cable Type : Big Lemo to Small Lemo**	**Technique : A Scan**	
Basic Calibration Block : V1 IIW			
Range : 0 to 25 mm Mode: SINGLE			

Probe Angle	0°	45°	60°	70°
SL No	0001			
Dimension	10 Dia			
Frequency	4 MHz			
Velocity m/s	5920			
Sensitivity	1.5 mm			
Ref gain	50dB			
Scan gain	58dB			
Range	0 – 10mm			

Item /Mark No	Spec	Test Area	Defects absorbed in one square inch	Remarks
ALUMINIUM	1050	ALL AREA OF THE PLATE	Porosity	-

INSPECTED BY	NAME	SIGNATURE	DATE
ASNT LEVEL II	SARAVANAN. N		23.02.2015

Ph: 0422- 4208545
info.cbe@nestndt.com
www.nesttechnicalsolutions.com

Inspection Report of Defect free component:

Nest Technical Solutions Pvt. Ltd
13, Kamala Colony, Lakshmipuram
Kamarajar Road, Peelamedu (PO),
Coimbatore - 641 004.
The Symbol of Perfection

ULTRASONIC TEST REPORT

Client : BHARATHKUMAR.G	Report Date : 23.02.2015	Report No: U T/02	Page No : 2 of 2
Spec No :1050 no 2	Tested on : 21.02.2015		Tested Complete :21.02.2015
Reference Procedure Specification : ASME SEC VIII			
Surface Condition : Medium Smooth	**Surface Temp : At room temp**	**Scanning :** All Area	
Equipment & Technique			
Model : Modsonic – Einsten II	**SL No : E3422-0812**	**Manufacturer : Modsonic**	
Couplant : Grease	**Cable Type : Big Lemo to Small Lemo**	**Technique : A Scan**	
Basic Calibration Block : V1 IIW			
Range : 0 to 25 mm Mode: SINGLE			

Probe Angle	0°	45°	60°	70°
SL No	0002			
Dimension	10 Dia			
Frequency	4 MHz			
Velocity m/s	5920			
Sensitivity	1.5 mm			
Ref gain	50dB			
Scan gain	58dB			
Range	0 – 10mm			

Item /Mark No	Spec	Test Area	Defects absorbed in one square inch	Remarks
ALUMINIUM	1050	ALL AREA OF THE PLATE	No defects	-

INSPECTED BY	NAME	SIGNATURE	DATE
ASNT LEVEL II	SARAVANAN. N		23.02.2015

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IV. OPTIMIZATION USING GENETIC ALGORITHM

Genetic algorithm is used to identify and mitigate the defects. The input parameters are Material molten temperature, Pouring temperature, Die material, Casting method and Shape of the component. Genetic Algorithms (GA) are direct, parallel, stochastic method for global search and optimization, which imitates the evolution of the living beings.

The genetic algorithms (G.A.) are typically characterized by the following aspects:

- The G.A. work with the base in the code of the variables group (artificial genetic strings) and not with the variables in themselves.
- The G.A. work with a set of potential solutions (population) instead of trying to improve a single solution.
- The G.A. do not use information obtained directly from the object function, of its derivatives, or of any other auxiliary knowledge of the same one. The G.A. applies probabilistic transition rules, not deterministic rules.
- The genetic algorithm process is quite simple; it only involves a copy string, partial string exchanges or a string mutation, all these in random form. [8]

V. CONCLUSION

In this paper, casting defects for a selected component are studied and analyzed. A non - traditional optimization approach is used to identify and mitigate the defects. It will help the quality control department of casting industries to analysis the casting defects with minimum cost and to improve the production to satisfy the customer needs. If castings are inspected using nontraditional approach, rejections in the foundry can be controlled. If, this non traditional method is introduced in future, the casting defects can be reduced up to 10% by proper selection of Input parameters. Rejection of the casting on the basis of the casting defects should be as minimum as possible for better quality.

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