PRESENT APPROACHES FOR ANALYSIS OF CASTING DEFECTS: A REVIEW

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ABSTRACT

Analysis of Casting Defects is very important for a systematic examination and evaluation of data or information, by breaking it into its component part to uncover their interrelationships. The separation of an intellectual or material whole into its constituent part for individual study and to understand cause-effect relationships, thus providing basis for problem solving and decision making. At present, casting defect analysis is carried out using techniques like Computerized Simulations (CAE),Holistic approach, `Historical analysis, Pareto analysis, cause-effect diagrams, design of experiments, if-then rules (expert systems), and artificial neural networks (ANN). In this paper an attempt has been made to list different approaches for analysis of Casting Defects. This paper also aims to provide correct guideline to quality control department to find casting defects which are not desirable.

Keywords: pareto analysis, cause-effect diagrams, design of experiments, artificial neural network.

1. INTRODUCTION

The principle of manufacturing a casting involves creating a cavity inside a sand mould and then pouring the molten metal directly into the mould. Casting is a very versatile process and capable of being used in mass production. The size of components is varied from very large to small, with intricate designs. Out of the several steps involved in the casting process, moulding and melting processes are the most important stages. Improper control at these stages results in defective castings, which reduces the productivity of a foundry industry. Generally, foundry industry suffers from poor quality and productivity due to the large number of process parameters, combined with lower penetration of manufacturing automation and shortage of skilled workers compared to other industries. Also, Global buyers demand defect-free castings and strict delivery schedule, which foundries are finding it very difficult to meet. 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. The defects need to be diagnosed correctly for appropriate remedial measures; otherwise new defects may be introduced. Unfortunately, this is not an easy task, since casting process involves complex interactions among various parameters and operations related to metal composition, methods design, molding, melting, pouring, shake-out, fettling and machining. Casting rejections cannot be attributed to poor method and process variability alone. Most Castings are designed for manufacturing, not for manufacturability. Many defects originate from poorly designed part features (isolated junction, constrained internal feature, long thin sections etc. The proper classification and identification of a particular defect is the basic need to correct and control the quality of casting.

Present approaches for analysis of casting defect

1. Computerized Simulations
2. Holistic approach,
3. Historical analysis
4. Pareto analysis
5. Cause-Effect diagrams
6. Design of Experiments (DOE) (Taguchi method)
7. If-Then rules (expert systems)
8. Artificial Neural Networks (ANN)

2. COMPUTERIZED SIMULATIONS

It is the discipline of designing a model of an actual or theoretical physical system, executing the model on a digital computer, and analyzing the execution output. Simulation embodies the principle of “learning by doing”- to learn about a system we must first build a model of some sort and then operate the model.

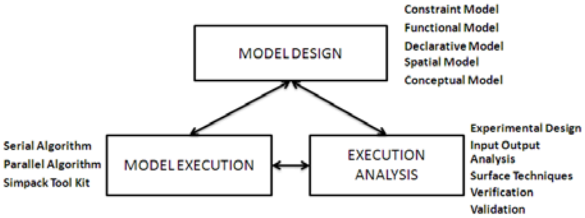

Figure-1. Computerized simulation model.

3. HOLISTIC APPROACH

Many defects like shrinkage porosity, hot tear, and cold shut originate from poorly designed part features.

Foundry engineers partially tackle the problem by tweaking the part design, but incur additional and avoidable costs of machining and productivity loss. Ideally, design for manufacturability (DFM) should be carried out early by product engineers (foresight), instead of late DFM currently practiced by casting suppliers (hindsight). Unfortunately, designers lack foundry knowledge, and foundry engineers lack design rights. A holistic approach is a collaborative system for achieving perfect castings - high quality with frugality - by integrating part, tooling, methods and process optimization, and providing feedback loops to part design. Major control parameters include: wall thickness, junctions and hole diameter, parting line, cores and mold cavity layout, feeding and gating system, and process settings (manufacturing). Each subsequent phase provides more information and feedback regarding part quality and cost to the designer, allowing design improvements for manufacturability without affecting functionality. A secure web-based project management system enables rapid and seamless collaboration between casting lifecycle engineers. Direct benefits include: first-time right castings, consistent quality, and low cost of tooling and manufacturing. Other benefits include better relations between OEM and supplier, knowledge capture and reuse for future projects, and ease of training fresh engineers.

4. HISTORICAL ANALYSIS

This analysis focuses the study of history based on integral component and entails interpretation and understanding of various historical events, documents and processes. The goal of historical analysis is to develop a narrative about a specific topic based on the evidence at hand. Often this necessitates answering questions of ‘how’ or ‘why’ something happened the way it did. Historical analysis requires not only reviewing and interpreting sources, but also encompasses a wide range of analytical skills. Both primary sources, created during the time under study, and secondary, scholarly sources should be utilized in order to develop a fuller understanding of the subject matter. Historical analysis frequently requires grasping the scholarly debate on a certain subject and coming to personal conclusions and determinations based on one’s own reading of the materials at hand. From a methodological perspective, it is often useful to begin by formulating historical questions and then attempting to answer them through a thorough review of the sources at hand, recognizing both gaps in available information and both the context and perspective of the topic of analysis. Though much historical analysis is qualitative and based on inferences from written or material sources as well as images, it can also be quantitative, using data and statistics to draw broader conclusions.

5. PARETO ANALYSIS

Pareto Analysis is a simple technique for prioritizing possible changes by identifying the problems that will be resolved by making these changes. Pareto Analysis uses the Pareto Principle - also known as the "80/20 Rule" - which is the idea that 20 percent of causes generate 80 percent of results.

5.1 When to use pareto chart

i. When there is causes in the process
ii. When there are many causes and problems and want to focus on most significant
iii. For analyzing specific component for broad causes.

5.2 How to use the tool:

Step 1: Identify and List Problems
Step 2: Identify the Root Cause of Each Problem
Step 3: Score Problems
Step 4: Group Problems Together By Root Cause
Step 5: Add up the Scores for Each Group
Step 6: Take Action

5.3 How to identify the principle causes

1. Create a vertical bar chart with causes on the x-axis and count (number of occurrences) on the y-axis.
2. Arrange the bar chart in descending order of cause importance, that is, the cause with the highest count first.
3. Calculate the cumulative count for each cause in descending order.
4. Calculate the cumulative count percentage for each cause in descending order. (Percentage calculation: {Individual Cause Count} / {Total Causes Count} *100)
5. Create a second y-axis with percentages descending in increments of 10 from 100% to 0%.
6. Plot the cumulative count percentage of each cause on the x-axis.
7. Join the points to form a curve.

Draw a line at 80% on the y-axis running parallel to the x-axis. Then drop the line at the point of intersection with the curve on the x-axis. This point on the x-axis separates the important causes on the left from the less important causes on the right.

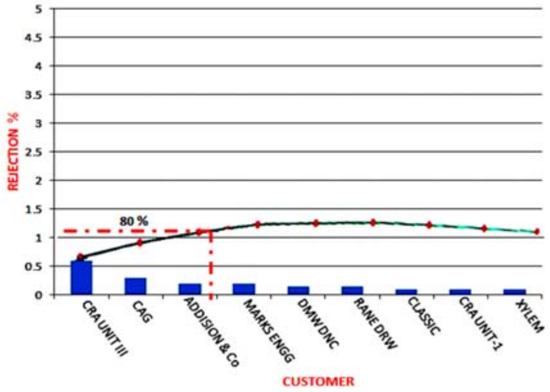

Figure-2. Pareto chart for customer rejection.

It enables you to see what 20% of cases are causing 80% of the problems and where efforts should be focused to achieve the greatest improvement. In this case, we can see that CRA unit III, CAG and admission and co should be the focused. The above chart is taken from CPC foundry, Coimbatore. This chart reviews those 20% produce 80% of our result. Identify and focus on those things first, but don't entirely ignore the remaining 80% of causes.

6. CAUSE AND EFFECT DIAGRAM

It is also known as Fishbone Diagrams, Ishikawa Diagrams, Herringbone Diagrams, and Fishikawa Diagrams. The fishbone diagram identifies many possible causes for an effect or problem. It can be used to structure a brainstorming session. It immediately sorts ideas into useful categories.

6.1 When to use a fishbone diagram

i. To identify possible causes in a problem.
ii. A routine or a pattern of behaviour that becomes unproductive in nature.

6.2 Fishbone diagram procedure

Materials needed: flipchart or whiteboard, marking pens. Agree on a problem statement (effect). Write it at the center right of the flipchart or whiteboard. Draw a box around it and draw a horizontal arrow running to it.

The major categories of cause of the problem is Brainstorming. The brainstorming session was held for finding different causes behind the defects and identifying the main causes those are responsible for the maximum damage. There are five members in brainstorming session from different foundry departments which includes Lab In-charge, Quality manager, Furnace supervisor, Worker working in furnace and mould checking supervisor. Use generic headings, if it is difficult.

Methods, Machines (equipment), People (manpower), Materials, Measurement, Environment. Write the categories of causes as branches from the main arrow.

6.3 Benefits of fishbone diagram

- Helps determine root causes
- Encourages group participation
- Uses an orderly, easy-to-read format
- Indicates possible causes of variation
- Increases process knowledge
- Identifies areas for collecting data

Brainstorm all the possible causes of the problem. Ask: "Why does this happen?" As each idea is given, the facilitator writes it as a branch from the appropriate category. Causes can be written in several places if they relate to several categories. Again ask "why does this happen?" about each cause. Write sub–causes branching off the causes. Continue to ask "Why?" and generate deeper levels of causes. Layers of branches indicate causal relationships.

When the group runs out of ideas, focus attention to places on the chart where ideas are few.

6.4 Fishbone diagram example

This fishbone diagram was drawn by a manufacturing team to try to understand the source of periodic iron contamination. The team used the six generic headings to prompt ideas. Layers of branches show thorough thinking about the causes of the problem.

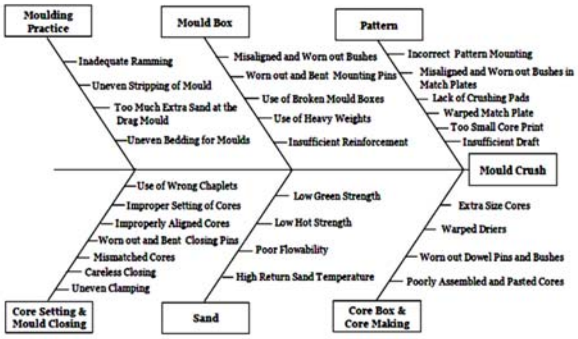

Figure-3. Cause and effect diagram for mould crush defect.

7. DESIGN OF EXPERIMENTS (TAGUCHI METHOD)

Design of experiments (DOE) it is a systematic, rigorous approach to engineering problem-solving that applies principles and techniques at the data collection stage so as to ensure the generation of valid, defensible, and supportable engineering conclusions.

There are four general engineering problem areas in which DOE may be applied:

- Comparative
- Screening/Characterizing
- Modeling
- Optimizing

7.1 Comparative: In the first case, the engineer is interested in assessing whether a change in a single factor has in fact resulted in a change/improvement to the process as a whole.

7.2 Screening characterization: In the second case, the engineer is interested in "understanding" the process as a whole in the sense that he/she wishes (after design and analysis) to have in hand a ranked list of important through unimportant factors (most important to least important) that affect the process.

7.3 Modeling: In the third case, the engineer is interested in functionally modeling the process with the output being a good-fitting (= high predictive power) mathematical function, and to have good (= maximal accuracy) estimates of the coefficients in that function.

7.4 Optimizing: In the fourth case, the engineer is interested in determining optimal settings of the process factors; that is, to determine for each factor the level of the factor that optimizes the process response.

8. IF - THEN RULES

These if-then rule statements are used to formulate the conditional statements that comprise fuzzy logic.

A single fuzzy if-then rule assumes the form
if *x* is *A* then *y* is *B*

where *A* and *B* are linguistic values defined by fuzzy sets on the ranges (universes of discourse) X and Y, respectively. The if-part of the rule "*x* is *A*" is called the *antecedent* or premise, while the then-part of the rule "*y* is *B*" is called the *consequent* or conclusion. e.g.
IF casting temperature is cold THEN cold shut
IF casting temperature is medium THEN normal casting
IF casting temperature is hot THEN porosity

9. ARTIFICIAL NEURAL NETWORK

Artificial neural networks are computational models used to obtain complex nonlinear relationships between input and output variables. It is one of the powerful modelling techniques, based on a statistical approach, presently adopted in the field of engineering. An artificial neuron is a computational model inspired in the natural neurons. Natural neurons receive signals through *synapses* located on the dendrites or membrane of the neuron. When the signals received are strong enough (surpass a certain *threshold*), the neuron is *activated* and emits a signal though the *axon*. This signal might be sent to another synapse, and might activate other neurons.

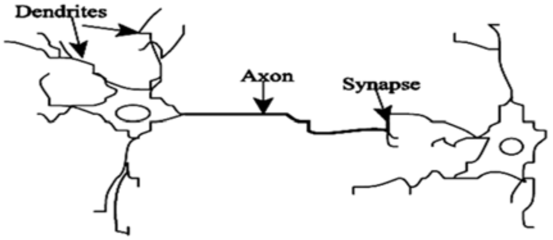

Figure-4. Natural Neurons (artist's Conception).

The complexity of real neurons is highly abstracted when modelling artificial neurons. These basically consist of *inputs* (like synapses), which are multiplied by *weights* (strength of the respective signals), and then computed by a mathematical function which determines the *activation* of the neuron. Another function (which may be the identity) computes the *output* of the artificial neuron. ANNs combine artificial neurons in order to process information.

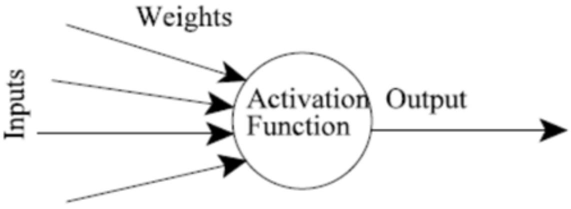

Figure-5. An artificial neuron.

ANN construction procedure

Build a network consisting of four artificial neurons. Two neurons receive inputs to the network, and the other two give outputs from the network.

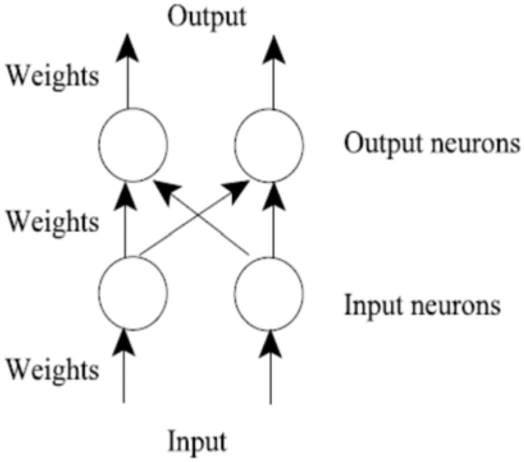

Figure-6. Artificial neuron.

There are weights assigned with each arrow, which represent information flow. These weights are multiplied by the values which go through each arrow, to give more or less strength to the signal which they transmit. The neurons of this network just sum their inputs. Since the input neurons have only one input, their output will be the input they received multiplied by a weight.

CONCLUSION

In this research work present approach for analysis of casting defects are studied. By referring different research papers and articles present approaches for analysis of casting defects are listed. These will help the Quality control departments of various foundries for easy selection and analysis. Rejections of casting on the basis of the casting defect should be as minimized and all the above research is heading in the same direction.

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