Effect Reduction in Injection Moulding using DMAIC Technique

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Abstract— This research demonstrates the empirical application of Six Sigma and DMAIC to reduce product defects within a pressure die casting manufacturing organization. The work follows the DMAIC methodology to investigate defects, root causes and provide a solution to reduce/eliminate these defects. The analysis from employing Six Sigma and DMAIC indicated that the metal melting temperature, die temperature and die holding time influenced the amount of defective items produced. In particular, the design of experiments (DOE) and two-way analysis of variance (ANOVA) techniques were combined to statistically determine the correlation of the metal melting temperature, die temperature and die holding time with defects as well as to define their optimum values needed to reduce/eliminate the defects. As a result, a reduction of 16.93 % to 10.04 % in the terminal cover and 16.62 % to 8.97 % in the din based cover was achieved, which helped the organization studied to reduce its defects per million opportunities (DPMO) and thus improve its Sigma level from 2.53 to 2.79for the terminal cover and 2.55 to 2.85for the din based cover.

Keywords: Define Measure-Analyze-Improve-Control, Defects in Keeping With Million Opportunities, Analysis of Variance, Mean Square Deviation

I. INTRODUCTION

A. Die Casting

Die casting is a manufacturing process that can produce geometrically complex metal parts through the use of reusable molds, called dies. The die casting process involves the use of a furnace, metal, die casting machine, and die. The metal, typically a non-ferrous alloy such as aluminum or zinc, is melted in the furnace and then injected into the dies in the die casting machine. There are two main types of die casting machines - hot chamber machines (used for alloys with low melting temperatures, such as zinc) and cold chamber machines (used for alloys with high melting temperatures, such as aluminum). The differences between these machines will be detailed in the sections on equipment and tooling. However, in both machines, after the molten metal is injected into the dies, it rapidly cools and solidifies into the final part, called the casting. The steps in this process are described in greater detail in the next section.

II. TYPES OF DIE CASTING

The two types of die casting machines are a hot chamber machine and cold chamber machine.

A. Hot Chamber Die Casting Machine

Hot chamber machines are used for alloys with low melting temperatures, such as zinc, tin, and lead. The temperatures required to melt other alloys would damage the pump, which is in direct contact with the molten metal. The metal is contained in an open holding pot which is placed into a Furnace, where it is melted to the necessary temperature. The molten metal then flows into a shot chamber through an inlet and a plunger, powered by hydraulic pressure, forces the molten metal through a gooseneck channel and into the die.

Fig. 1: Hot chamber die casting machine

B. Cold Chamber Die Casting Machine

Cold chamber machines are used for alloys with high melting temperatures that cannot be cast in hot chamber machines because they would damage the pumping system. Such alloys include aluminum, brass, and magnesium. The molten metal is still contained in an open holding pot which is placed into a furnace, where it is melted to the necessary temperature. However, this holding pot is kept separate from the die casting machine and the molten metal is ladled from the pot for each casting, rather than being pumped. The metal is poured from the ladle into the shot chamber through a pouring hole. The injection system in a cold chamber machine functions similarly to that of a hot chamber machine, however it is usually oriented horizontally and does not include a gooseneck channel.

Fig. 2: Cold chamber die casting machine

III. METHODOLOGY

A. Six-Sigma Methodology (DMAIC)

The DMAIC methodology has a core process: Define-Measure-Analyze-Improve- Control (DMAIC) methodology. The five steps to DMAIC approach are:

1) Define Phase

The first stage of the Six Sigma and DMAIC's methodology is "define". This stage aims at defining the project's scope and boundary, identifying the voice of the customer (i.e. customer requirements) and goals of the project.

2) Measure

The "measure" phase of the DMAIC problem solving methodology consists of establishing reliable metrics to help monitoring progress towards the goal(s) [16], which in this research consisted of reducing the number of quality defects in the coolant bottle bottom manufacturing process.

3) Analyse Phase

This phase in the DMAIC improvement methodology involves the analysis of the system, in this case the manufacturing process that produces the coolant bottle bottom, in order to identify ways to reduce the gap between the current performance and the desired goals.

4) Improve Phase

In this phase, Taguchi DOE is conducted with the three process parameters identified from the analysis phase.

5) Control Phase

The real challenge of the Six Sigma implementation is the sustainability of the achieved results. Due to variety of reasons, which includes people changing the job, promotion/ transfer of people operating on the process, converting awareness of the individual to different manner-related problems some other place within the organisation and lack of possession of new humans within the method, pretty often keeping the consequences are extraordinarily hard.

IV. RESULTS

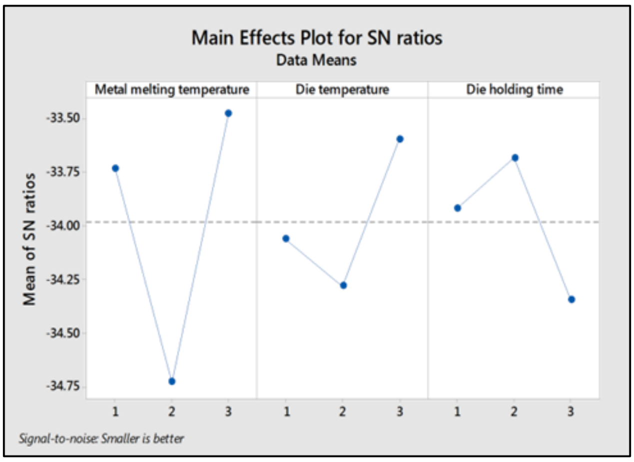

Fig. 3: Main effects plot of S/N ratios for blow holes for coolant bottle swift bottom

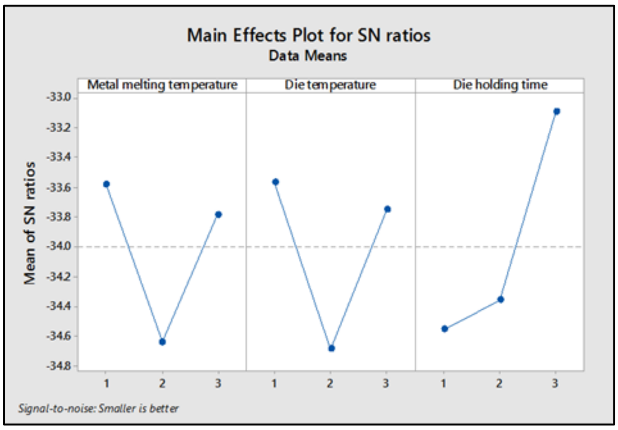

Fig. 4: Main effects plot of S/N ratios for blow holes for coolant bottle swift bottom

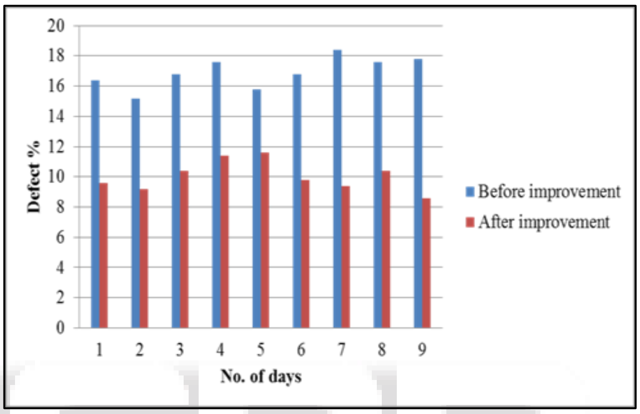

Fig. 5: Rejection trend after implementation for coolant bottle swift bottom

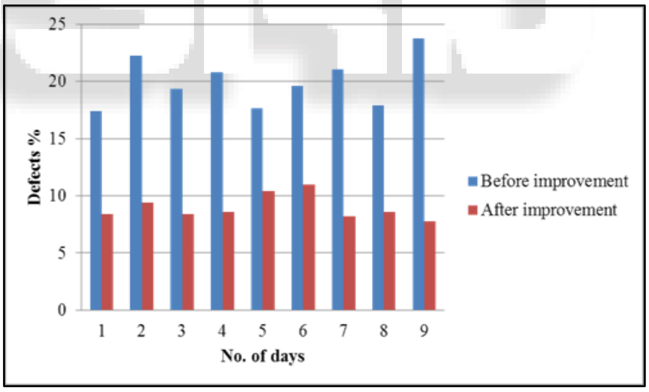

Fig. 6: Rejection trend after implementation for coolant bottle swift bottom

V. CONCLUSION

From the experiment following results were obtained.

A. For Blow Holes Defect for Coolant Bottle Swift Bottom

- From ANOVA analysis, parameters making significant effect on blow holes defect are metal melting temperature.
- Using experiment conducted optimum parameters were determined i.e. metal melting temperature = 650°C, die temperature = 275 °C and die holding time = 85 sec.
- The percentage of rejection decreases from 16.93 % to 10.04 % as shown below.
- Sigma Level improves after study from 2.53 to 2.79.

- Number of defective items was also decreases from 762 to 452.
- Number of good items was also increases from 3738 to 4048.
- Productivity increases from 82.9 % to 90.08 %.
- Rejection trend after study decreases.

B. For Blow Holes Defect For Coolant Bottle Swift Bottom

- From ANOVA analysis, parameters making significant effect on blow holes defect are die holding time.
- Using experiment conducted optimum parameters were determined i.e. metal melting temperature = 650 °C, die temperature = 275 °C and die holding time = 65 sec.
- The percentage of rejection decreases from 16.62 % to 8.97%
- Sigma Level improves after study from 2.55 to 2.85.
- Number of defective items was also decreases from 748 to 404.
- Number of good items was also increases from 3752 to 4096.
- Productivity increases from 82.9 % to 90.08 %.
- Rejection trend after study decreases.

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