Application of Quality Tools for Process Improvement to Reduce Scrap in an Aluminum Smelter

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Abstract. This paper presents a use of quality tools for the improvement of an aluminum smelting process under pressure by reducing the waste. This type of analysis has been useful in a developing country like Brazil, with the present example shown in such promising reality. The main tool used was the cause and effect diagram, enabling the discovery of the main causes of the problem, the removal of which led to a reduction in scrap that is of extreme relevance to the organization, as statistically proven.

Keywords: Quality tools, Cause and Effect Diagram, Scrap reduction, Productivity, Process improvement.

1 Introduction

Upon market opening and globalization, companies needed to upgrade and become more competitive, being forced to eliminate wastes in the entire production process, so the processes have become more streamlined, accurate and efficient.

Such reality was experienced in Brazil as a developing country and became stronger with the phenomenon of globalization and, in the specific case of this nation, with the market opening policy adopted in 1990, during the term of President Fernando Collor de Mello.

With the increasing requirements for high quality, an issue raised involving the entire organization and work project, defined as the function of specifying the activities for an individual or group in the organizational environment [1].

Scrap, represented by parts rejected by quality control which are impossible to be reworked, is considered one of the biggest problems in the industry, as it demonstrates the inefficiency of the process. Also, we cannot disregard it or manipulate the numbers so they can be satisfactory; if such problem exists, it should be treated and minimized to the maximum extend possible

This article presents a case of process improvement in an aluminum smelter using appropriate techniques, in particular the cause and effect diagram, whose methodology is attributed to Kaoru Ishikawa.

2 Theoretical background

The advancement in failure minimization for optimization can generate great rewards. For many companies, something that begins as an attempt to minimize a problem gradually evolves and becomes a coordinated effort to develop creative valuable solutions [2].

Obviously all production processes deal with wastes, but they must be measured within standard limits for the production of a particular material. In the event of a product failure, a new set of customer needs arises: how to get service restored and how to be compensated for associated unwanted losses [3].

Deming emphasized the importance of product cost, which often does not consider such loss, thus directly affecting the company, burdening the product and passing the value to the customer [4].

All people involved in the organization must be aware of the problems and how they impact the company. The overall quality and operational performance planning, as well as its implementation, focuses completely on the needs and development of the entire labor force [5].

Factors such as manpower, raw materials, customer service, energy, etc. should be considered and evaluated, taking into account the delivery of the final product to the client, having the continuous improvement as an integral part of the quality management system [6]. Regarding labor force, behavioral issues need to be closely linked to production processes for the development of a work design that is associated with the concept of empowerment involving work organization based on team. It occurs when employees that usually have juxtaposed skills collectively perform a specific task and possess high degree of description of how to actually perform the task [7].

Reducing the cost of production, material and shoddy products increases the contribution margin, taking into account higher profits. The development of a customer-oriented operational strategy begins with a corporate strategy that aligns the overall goals of the company with its essential processes.

Observing Figure 1, it is possible to understand the flow of competitive priorities: link between corporate strategy and operational strategy.

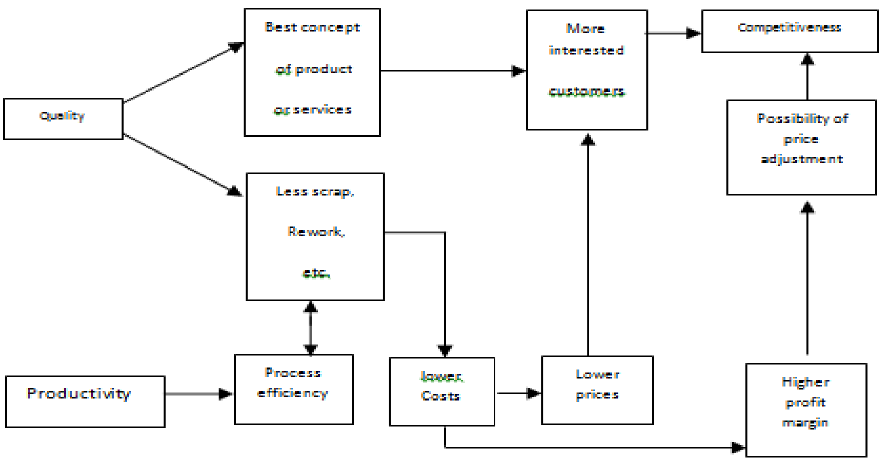

Figure 1: Quality, productivity and competitiveness. Adapted from [8].

3 Methodology

This article used the action-research methodology, which is a type of empirically-based social research, designed and carried out in close association with an action or with the solution of a collective problem in which researchers and representative participants in the situation or problem are involved in a cooperative or participatory way [9]. This type of approach may be used in an organization (company or school, for example), in which hierarchy or groups with problematic relationships are present, in order to contribute to the best possible form of problem solving, including the arising of solutions and proposals for actions corresponding to solutions, since they represent the perfect strategy when issues such as how and why are raised, when the researcher has little control over events and when the focus is on contemporary phenomena inserted in some real-life context [10].

This work refers to the description and deepening of knowledge in an industry of aluminum casting under pressure, referring to a particular item labeled as substrate.

After identifying the most relevant nonconformity of the process, the possible causes of non-compliance were mapped using brainstorming tools and Cause and Effect Diagram.

4 Results and discussion

An analysis conducted in company between February and August 2013 showed a high rate of housing product scrap, directly affecting the client and therefore the organization.

The referred values shown in Figure 2 are related to the production, scrap and scrap percentage.

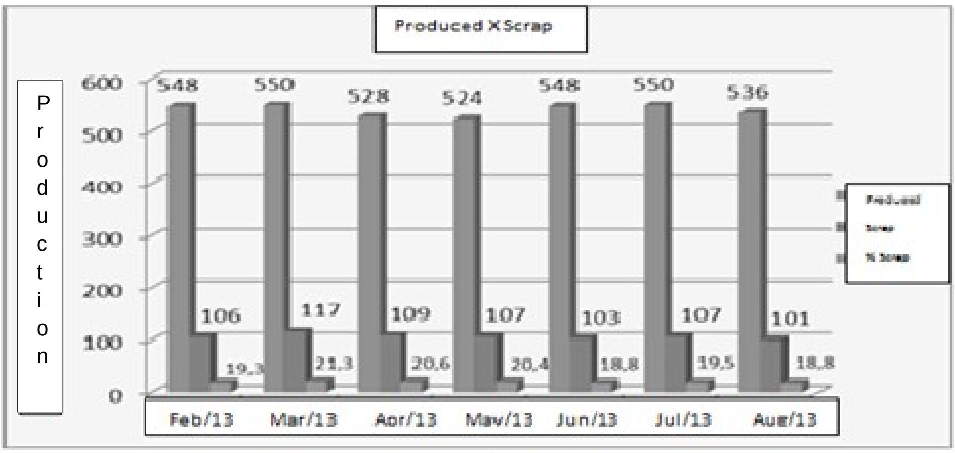

Figure 2: Material produced versus scrap material

For the purposes of analysis and to perfectly know the process, a flow chart was made and is shown in Figure 3.

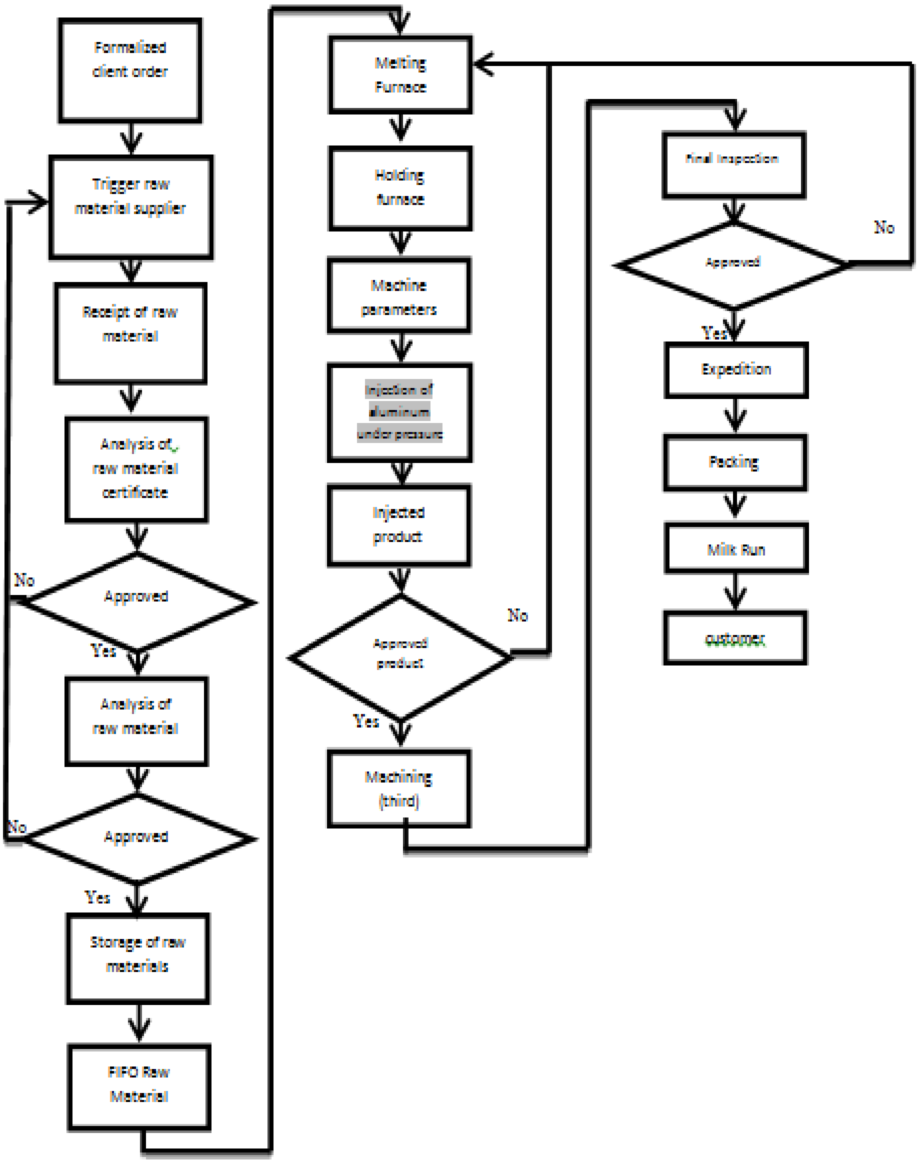

Figure 3: Flow of the customer order-to-delivery process

The flow analysis (Figure 3) led to the conclusion that the critical operation of the process generating the waste was the aluminum injection under pressure.

In fact, the five most relevant problems, their respective sections and the percentage of scrap were identified and are shown in Table 1. A Pareto analysis, even if visual, identified porosity as the problem evidenced in the injection section.

Problem	**Section**	**Percentage**
Porosity	Injection	71%
Cold joint	Injection	12%
Crack	Injection	11%
Breaking	Transportation	4%
Dimensional	Machining	2%

Table 1: Stratification of problems

The rate established by and acceptable to the company for the section of injection is 5% of scrap, the same value reported in product cost spreadsheet shown in Figure 2. In the period considered, such average percentage was 19.81%.

The authors developed a scrap control, shown in Figure 4, to check and indicate the regions with the highest porosity in the part. The verification worksheet details the part per quadrant and region, facilitating the visualization of the most critical point, thus making the scrap reducing action more effective. In the sheet it is possible to identify the area of the part, its cavity, and the total and produced amounts, as well as the percentage of scrap.

CONTROL OF SCRAP					
DATE:	22/ 12/ 2013				
AREA	CAV. 01	CAV. 02	CAV. 03	CAV. 04	TOTA
A	27	16	24	22	89
B	25	23	19	23	90
C	18	24	22	21	85
D	31	32	33	32	128
E	32	33	35	31	131

Figure 4: Scrap control spreadsheet.

The scrap control spreadsheet identifies the number of cavities and the quadrant of the part, facilitating the indication and subsequent analysis of the most critical points of the product. The action focus was porosity, since it corresponds to the highest percentage of rejection. After the completion of data collection, a multidisciplinary team was composed of all the people in charge of all sections involved, in order to work on the existing problems, having porosity as the main focus, since it represents 71% of the problems found in the analyzed parts.

Developing people is not just giving them information so that they improve their knowledge, skills and abilities and become more efficient in what they do; it is above all things giving them basic training so they can develop new attitudes, solutions, ideas, concepts, modify their habits and behaviors and become more effective in what they do. [11]

The team used the Ishikawa diagram, shown in Figure 5, to help in the identification of possible causes and their potential effects on porosity, so that direct action on the issue could be taken.

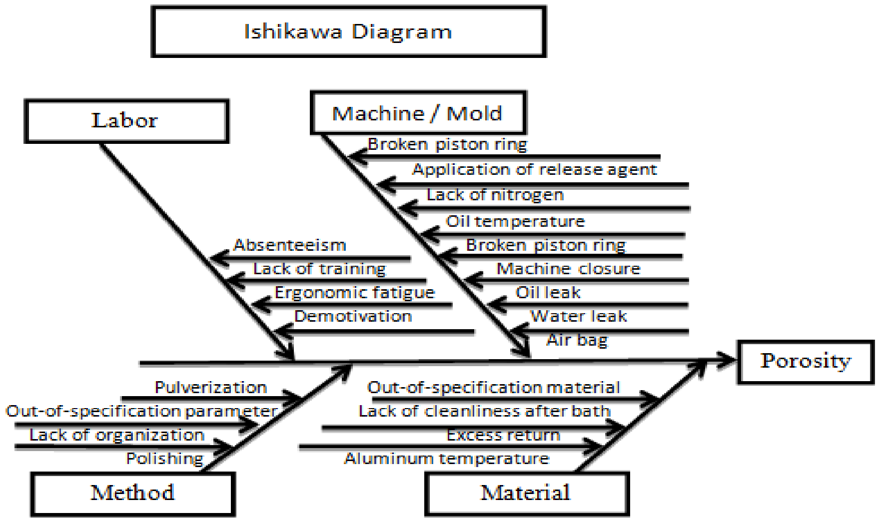

Figure 5: Analysis of the problem using the Cause and Effect Diagram (Ishikawa)

Table 2 of equivalence was used to identify the criticality of the problem, adapted from FMEA 4th edition [12].

Equivalence	
10 and 9	Extremely serious failure, improper temperature.
8 and 7	Very serious failure, may compromise raw material quality.
6 and 5	Serious failure, verify process sheet.
4 and 3	Medium failure, improper handling.
2 and 1	Minor failure, probably will not affect customer's product.

Table 2: Equivalence of degree of relationship with problem.

In the following analysis, the seriousness problem indicators have been associated with the causes identified in Ishikawa diagram, as shown in Table 3.

CAUSE	EFFECT	RELATIONSHIP WITH PROBLEM
Out-of-spec. parameter	Incorrect adjustment	**8**
Pulverization	Affects the filling of cavities	**3**
Lack of nitrogen	Poor compaction of material	**5**
Machine closure	Leak of material during injection	**8**
Oil leak	Low pressure during injection	**6**
Water leak	Lack of compression and cold joint	**5**
Concentration of release agent	Lack of compression	**6**
Lack of air bag	Accumulation of gases inside the cavity	**6**
Aluminum temperature	Above specification: generates porosity	**10**
	Below specification: generates cold joint	**6**
Excess return	Excess sludge, generating gases in raw material	**9**
Lack of cleanliness in the bath	Gas accumulated in the bottom of the crucible	**8**

Table 3: Degree of relationship with problem

Table 4 summarizes critically the main steps of aluminum injection that should be checked and the direct actions to be taken to improve the score.

Cause	Effect	Relationship
Aluminum temperature	Above specification: generates porosity	10
Excess return	Excess sludge, generating gases in the raw material	9
Lack of cleanliness in the bath	Gas accumulated in the bottom of the crucible	8
Out-of-spec. parameter	Incorrect adjustment	8
Machine closure	Leak of material during the injection, lack of compression	8

Table 4: Ranking of the most critical issues in degree of relationship with the problem.

During September 2013 and January 2014 the improvement actions, which are not detailed in this article, and follow-up for analysis and verification were performed. After the improvements made in the process, were obtained the results shown in Figure 6.

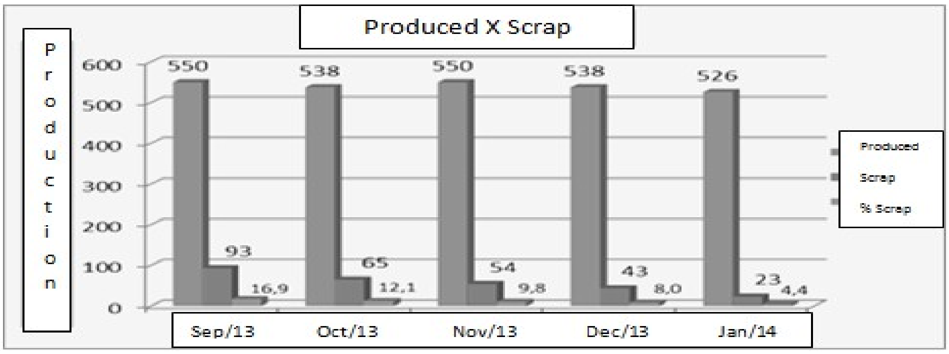

Figure 6: Result after analyzing and taking action.

An Aspin-Welch test, as described in [13], applied not strictly regarding the absolute statistical accuracy, has proven, based on the values $\overline{x_1} = 19.81$, $\overline{x_2} = 10.24$, $s^2_1 = 0.931$, $s^2_2 = 21.783$, $n_1 = 7$, $n_2 = 5$, the significant reduction of the percentage of scrap to the level of significance of 1%, with clearance ($t_4 = 4.516 > t_{4,1\%} = 3.747$). It is worthwhile to mention that the percentage of rejects after improvement actions are clearly decreasing, certainly due to the monitoring and identification of such improvements, reaching the acceptable level in January 2014.

5 - Conclusions

This paper tells as an aimed improvement in process was achieved in an actual industry condition, by using quality tools. To allow such goal, there were some changes in the process under study in relation to labor, process and concepts.

Increased contribution margin can be achieved with the optimization of production processes and a balanced cost reduction strategy that will provide the organization with a better management, thus making it more competitive in the market in which it operates. Furthermore, involving people is crucial for the effective success of the whole process.

There was an effective reduction in scrap, favoring a possible reduction in the price of the item, if necessary, or even a larger effective gain for the company. One should, however, proceed with the analysis so that further improvements are effectively proven.

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