

The effect of material productivity on scrap reduction on aluminum reduction pot process

L N Huda*

Industrial Engineering Department, Faculty of Engineering, Universitas Sumatera Utara, Jl. Almamater Kampus USU Medan 20155, Indonesia

*Email: lnurulh@gmail.com

Abstract. Scrap in the production process is defined as part of production that can not be accepted as the final product due to production failure. The amount of scarp occurring in the reduction pot production process of one of the aluminum smelting furnaces exceeds the acceptance standard of 5 to 10%. This affects the amount of production produced. The purpose of this study is to reduce the amount of scrap produced to increase the productivity of the materials used. The solution is carried-out by making improvements using Lean Six Sigma method. In the initial calculation, material productivity ranged from 0.88. Based on the study, the factors that cause the high amount of scrap produced is the use of Na₂O which is inserted into the alumina is different in size and the influence of noise that occurs in pots that are difficult to control. The analysis base on Lean Six Sigma obtained process cycle efficiency (PCE) equal to 86,92% for actual condition. Process improvement is carried-out through define, measure, analyze, improve and control procedure on Na₂O feeding process and PCE value decrease 6,05%. This indicates that increased process capability will reduce scrap. A decrease in scrap amount of about 6% will be able to increase material productivity by 0.05%. This indicates that continuous process control is needed to decrease the number of scraps and increase productivity.

1. Introduction

Aluminum is one of the metals whose usefulness can almost be found in every human activity. Aluminum metal is widely used because of some advantages compared with other metals. Non ferrous metals, aluminum have scrap that can be recycled [1].

Scrap in the production process is defined as part of production that can not be accepted as the final product due to production failure. The process of smelting aluminum reduction pot produces at 11.88% of scrap. The amount of scrap has exceeded the standard that is 5%-10%. The cause of the large amount of scrap generated is Na₂O levels in alumina and noise. The amount of scrap that exceeds the standard limit will reduce the amount of aluminum production so the productivity of material is declining.



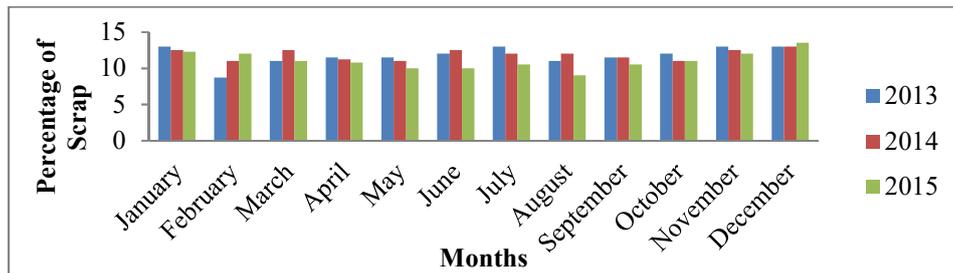


Figure 1. Percentage of *Scrap* in 2013-2015 Years

The average reduction in aluminum smelting pot produces the amount of scrap exceeded the standards that lead to material productivity becomes lower and reduced the number of production (Figure 1). It is therefore necessary to reduce the amount of scrap produced, smoothen the flow of the production process and improving the productivity of materials using lean six sigma.

Lean Six Sigma (LSS) method promotes, in organizations, the continuous improvement of products (and/or services) and processes that aligns with the business strategy to maximize the value of products [2]. Six Sigma is a business strategy that seeks a statistical approach to identify and eliminate causes of errors or defects, defined as anything which could lead to customer dissatisfaction or failures in business processes by focusing on outputs that are critical to customers; it uses various distributions and a strong relationship between product NonConformities, defects and product yield, inventory, schedule, etc [3]. Six Sigma methodology has two approaches: 1. DMAIC (D-Define, M-Measure, A-Analyze, I-Improve, C-Control). 2. DMADV (D-Define, M-Measure, A-Analyze, D-Design, V-verify) [4]. Six Sigma DMAIC methodology has been used in the manufacturing industries like automotive part manufacturing, metal processing, gloves manufacturing, file manufacturing, laser mouse manufacturing, semiconductor manufacturing, grinding operations, rolling mills [5]. DMAIC methodology is applicable to existing product or Phases six sigma implemented include the define, measure, analyze, improve, control [6]. Productivity is a measure of the ability of one unit of input in producing the output [7]. The purpose of this study is to reduce the amount of scrap produced to increase the productivity of the materials used. Similar Research has also been done in [8], [9], & [10].

2. Method and equipment

Research used is the comparative, descriptive study [11]. Step of research includes collecting data allowance and rating factor, NA_2O levels in alumina data, noise data (interference in pot), and the amount of scrap produced, result and discussion, conclusion. The DMAIC methodology can be used for improving the product quality during the injection molding as follows:

a. Define

Define (D) is the first step of the Six Sigma methodology. In this phase selection of projects, initial goals and targets are set and develop a project charter or statement of work is carried out. Cost of quality related to existing process is being calculated. Analysis of SIPOC (Supplier, Input, Process, Output, Customer) and CTQ (Critical To Quality) are listed. Improvements target and goals are set in terms of sigma level and cost associated. This phase includes identification of the key problem areas and defining quality characteristics.[4]

b. Measure

Measure (M) phase is the second step of Six Sigma methodology. In this phase collection and observation of data is carried out and based on that DPMO (Defects Per Million Opportunity) or Process Capability Analysis is estimated based on the features of data (Attribute or Variable) [4]. In the processing measure data calculations will be performed, the time cycle, normal time, standard time, calculation metric lean, determination of Critical to Quality (CTQ), sigma level calculation and DPMO (Defects per Million Opportunities).

Calculation metric lean: [13]

- 1) The calculation of the process cycle efficiency should do the separation process of value-added and employments are not value-added.

$$\text{Process cycle efficiency (PCE)} = \frac{\text{Value Added Time}}{\text{Total Lead Time Manufacturing}} \quad (1)$$

- 2) Process lead time and Process Velocity

$$\text{Process lead time (PLT)} = \frac{\text{Amount of products processed}}{\text{Average speed of completion}} \quad (2)$$

$$\text{Process velocity (PV)} = \frac{\text{Amount of activity on process}}{\text{Process lead time}} \quad (3)$$

c. Analyze

The third step is Analyze (A). The identification of possible causes due to which variation or defects are occurring and which are affecting the output of the process is identified. Most frequently step in Analyze phase is cause and effect diagram[4]. At this stage of the analysis will be done by making a causal diagram (fishbone diagram) and a diagram of the five why used as tools to further analyze the results that have been obtained at this stage of the Measure.

d. Improve

The fourth step is Improve (I). After collecting and analyzing the data suggestion is recommended to reduce the defect or nonconformity, which is critical for customer. In this phase counter measures for root causes are listed out which can be implemented to reduce defects [4].

e. Control

Fifth and last stage of DMAIC methodology is Control (C). In this stage control of improved implementation is done. If process is heading towards out of control, indication of that should be carried out by early signals [4].

3. Result and Discussion

Lean six sigma approach to deliver improvements on the speed of the production process and the quality of the resulting product so that companies are increasingly approaching the ideal circumstances as follows:

a. Define

The problems that plagued the industry aluminum smelting currently is about the amount of production that are generated. This is due to the amount of scrap that occur during the production process takes place that is affected by several factors such as levels of Na₂O in alumina, time cycles, noise, and the skill of the operator when the metal tapping. This research was conducted to improve the speed of process and product quality by reducing the activities that do not add value (non value added) and manage the amount of scrap produced during the production process takes place. SIPOC diagram aims to describe information about suppliers, inputs, process, outputs and the customer is involved in the production of molten aluminum as describe in Figure 2 [15].

There are 8 inputs used in smelting aluminum cathode blocks, namely alumina, carbon anode, kriolit, soda ash, alumina, coke and liquid fluoride bath. The supply is input from the raw materials warehouse and warehouse equipment. The aluminum smelting process there are 6 i.e. reconstruction, baking, start-up, transition, normal operating, cut off. The output resulting from the process of smelting aluminum is liquid alumina which will be distributed to the customer. Value

Stream Mapping is one method of mapping the flow of production and the flow of information on the overall production. In value stream mapping, there are two mapping that should be described that is the making of the current state and future state folder. The making of the current state of the folder is done to map the floor of the actual production conditions. After the identification of waste is carried out, then it can be described a future state map. Future state of the folder is the mapping of the condition of the company in the future as the draft proposal of the improvement of the current state of an existing folder. The number of items contained in the process of production is dictated by the amount of production undertaken by the company. In the production process there are 5 work in process (WIP), namely Coke base waiting to be included, a liquid bath waiting to be put into a pot of molten metal reduction, waiting to be put into the pot, the reduction of material waiting to be entered into upon the molten metal anode, and waiting to be brought to the casting shop.

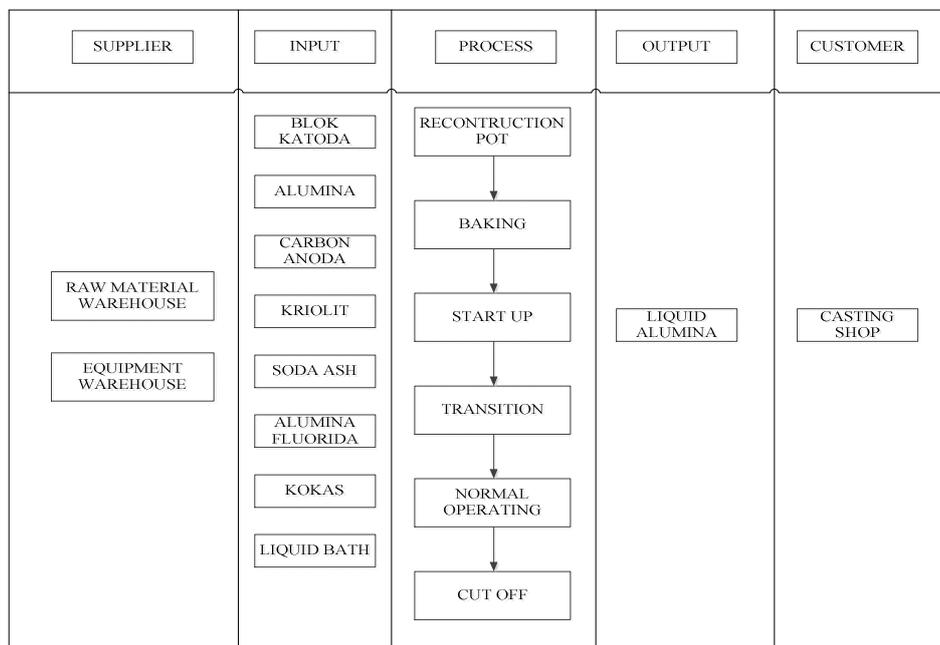


Figure 2. SIPOC Diagram of Liquid Aluminum's Process

b. Measure

Manufacturing lead time calculation is done by summing the entire time the labor process consisting of 40 work process. Description of the work process and the raw time can be seen in Table 1.

Table 1. Manufacturing Lead Time Calculation Based On Raw Time

Process	Average Cycle Time (hours)	Average Cycle Time (minutes)	Rating Factor	Normal Time (minutes)	Allowance	Standard Time (minutes)
1	2.28	136.5	1	136.5	5%	143.68
2	72.00	4320	1	4320	21.50%	5503.18
3	0.14	8.22	1	8.22	17.50%	9.96
4	0.13	7.8	1	7.8	21.50%	9.94
5	0.26	15.3	1	15.3	5%	16.11
6	0.15	8.76	1	8.76	21.50%	11.16

Table 1. Manufacturing Lead Time Calculation Based On Raw Time (Continued)

Process	Average Cycle Time (hours)	Average Cycle Time (minutes)	Rating Factor	Normal Time (minutes)	Allowance	Standard Time (minutes)
7	0.20	11.94	1	11.94	21.50%	15.21
8	0.74	44.52	1	44.52	5%	46.86
10	0.34	20.34	1	20.34	21.50%	25.91
11	0.15	9.18	1	9.18	21.50%	11.69
12	0.39	23.4	1	23.4	5%	24.63
14	0.11	6.72	1	6.72	21.50%	8.56
15	0.21	12.72	1	12.72	21.50%	16.20
16	0.10	6	1	6	21.50%	7.64
17	0.22	13.02	1	13.02	21.50%	16.59
18	0.13	7.68	1	7.68	21.50%	9.78
19	0.38	22.92	1	22.92	5%	24.13
20	0.14	8.46	1	8.46	21.50%	10.78
21	0.11	6.54	1	6.54	21.50%	8.33
22	0.24	14.16	1	14.16	5%	14.91
23	0.53	31.86	1	31.86	5%	33.54
25	0.20	12.18	1	12.18	21.50%	15.52
26	0.27	16.02	1	16.02	5%	16.86
27	0.23	13.98	1	13.98	21.50%	17.81
28	0.57	34.14	1	34.14	5%	35.94
30	0.33	19.92	1	19.92	21.50%	25.38
31	0.12	7.2	1	7.2	21.50%	9.17
32	0.10	6	1	6	21.50%	7.64
33	0.05	3	1	3	21.50%	3.82
34	0.43	26.04	1	26.04	19.00%	32.15
35	0.12	7.26	1	7.26	21.50%	9.25
36	0.35	20.76	1	20.76	5%	21.85
37	0.24	14.64	1	14.64	21.50%	18.65
39	0.43	25.5	1	25.5	5%	26.84

A firm is said to have executed the program Lean if has a value of process cycle efficiency by 30% which means that the processing time for a work process or activity which is value-added reach 30% of the time the process or activity as a whole.

The results of the calculation process cycle efficiency (Equation 1), process lead time (equation 2), the process velocity (Equation 3) before and after the improvement can be seen in Table 2.

Table 2. The Recap of PCE, PLT, and PV before and after Improvement

Process	Process Cycle Efficiency (PCE)	Process Lead Time (PLT) (Days)	Process Velocity (PE) (Process Per Day)
Before	86,92%	30	1,33
After	92,97%	30	1,23

Sigma level is a measure used to indicate how often the defects which may occur [9]. The calculation of the level of the sigma value obtained of 2.790. This shows the value of the sigma is

still much to be achieved, namely 6 sigma. DPMO value earned 98,500 meaning for each 1 million of times the production possibility of disability is 98,500. To increase the value of the sigma, it needs to be done process improvement in order to reduce the number of defective products are produced so that it can increase the productivity of the material.

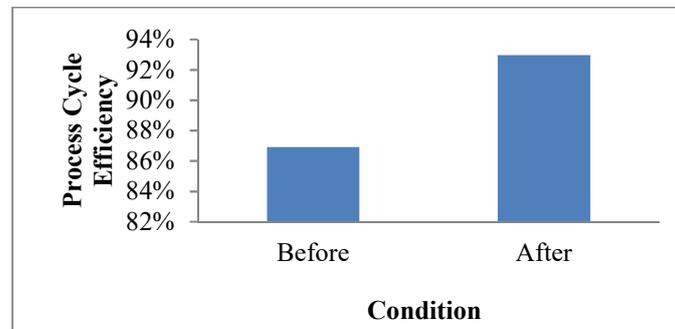


Figure 3. Improvement of Process Cycle Efficiency

Sigma level on the inspection of the condition in production process that are still considerably 2.79 worst with sigma level to be achieved 6 sigma. process cycle efficiency are increased by 6.05% (Figure 4) indicates the capability of a process to reduce the amount of scrap.

c. Analyze

Causal diagram (fishbone diagram) is used to help organize information about the causes of a potential problem. The analysis that will be performed include human analysis, methods of work, and the machinery and equipment against the amount of scrap produced (Figure 4).

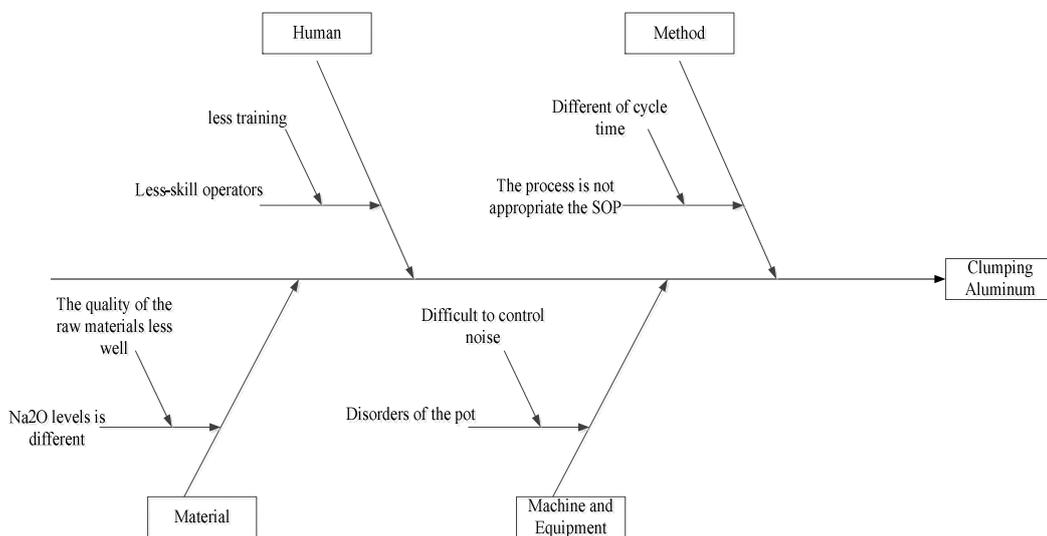


Figure 4. Fishbone Diagram

Diagram of Five Why is a diagram that is used to reveal the root of the problem of the cause of the discrepancy, which is obtained from the causal diagram so that it can be fixed with the right to ask constantly why something mismatch happens to found the root of the problem, see Table 3.

Table 3. Five Why Diagram for Disability Aluminum Lumpy

Problem	Why	Why	Why	Why	Why
Aluminum lumpy	The quality of the raw materials less well	Specification of Sodium oxide (Na ₂ O) on different raw materials	Suppliers of raw materials originating from different countries	-	-
	Less-skilled operators	Carriers do not get enough training	The company does not run a program of continuous training activities	The company does not have a setting to carry out the training program schedule	The company focus is to produce aluminium in order to achieve the target of production
	Disorders of the pot	Difficult to control noise	Levels of Si and Fe in the pot already high	Cathode blocks cracked and eroding bar collector armor	The abundance of scrap generated
	The sequence of the workmanship not in accordance with SOP	Machining cycle time is different	Less supervision towards the operator	-	-

d. Improve

Based on the analysis that has been performed using diagrams Five Why, found problems that cause the amount of high quality i.e. scrap levels in different alumina Na₂O, noise is difficult to control, and the order of the work are not appropriate the SOP.

The resulting kriolit is influenced by kriolit where also influential Na₂O in terms of input and output resulting from the reduction furnace. When the concentration of Na₂O in raw materials is too small, then the kriolit generated from the reaction of Na₂O with AlF₃ will too little so that operation of the pot furnace reduction will experience a shortage of kriolit which resulted in disruption of stability in pot furnaces and reduction in concentrations in Na₂O raw material is too large, then kriolit is generated from the reaction of Na₂O with AlF₃ will too much pot furnace operation so that the reduction will have an excess of kriolit that can exceed the capacity of the pot furnace reduction and destabilize the pot reduction furnace. An excess or deficiency of kriolit will produce too much scrap giving rise to difficulties in the management of scrap. To keep the kriolit generated on the pot furnace reduction remains stable, then the need for a good control on raw materials of alumina. In raw materials of alumina concentration required range Na₂O detail to know input and output that is more appropriate, so there is no problem about the shortage and excess kriolit on the operation of the pot furnace reduction.

Improvements are being made to lower the amount of scrap is Na₂O levels on alumina type KR1116 GOVE subtracted to 0.33% and noise are used of 102mV with the content of Fe and Si respectively 0.034% and 0.085%. The fewer levels of Na₂O and noise are used, and then the amount of scrap produced will be less and less. This indicates a decline in scrap from 11.88% to 6.126% (Figure 5).

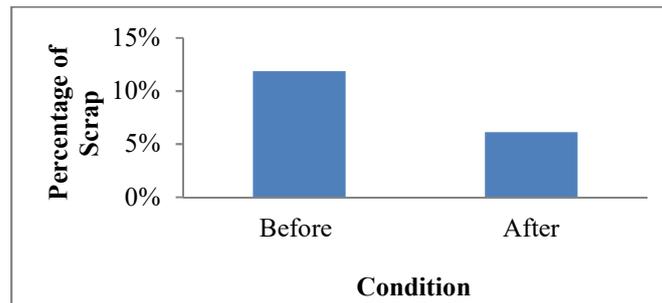


Figure 5. A comparison of Actual and Improvement Scrap

e. **Control**

The control method to reduce amount of scrap is making standard operating procedures (SOP) to control the levels of Na₂O in alumina and tackling noise. Standard operating process is the manual that contains the standard operational procedures that exist in an organization that is used to ensure any decision, action and the use of facilities [14].

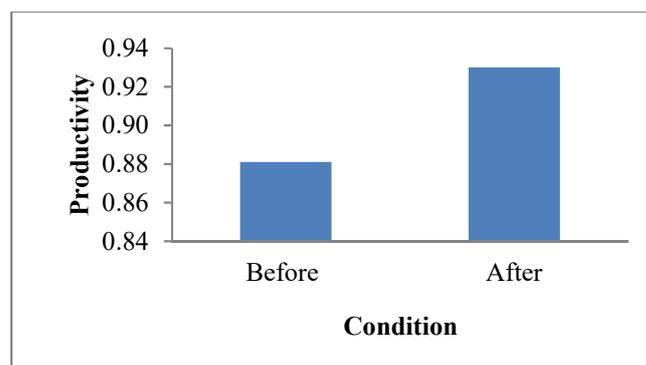


Figure 6. Increased Productivity

The decline in the number of scrap will increase the productivity of materials from 0.88 to 0.93 (Figure 6). Improved productivity gained amounting to 0.05. With increasing productivity and decreasing the amount of scrap material generated then factor in material and Na₂O levels of noise (interference in pot) must continue to watch out for so that the material continues to increase productivity.

4. Conclusions

The increase in scrap is caused by irregular controlling of Na₂O levels and noise. After the improvement is done, this indicates the material productivity experienced an increase of 0.05 and process cycle efficiency experienced an increase of 6.05%. The amount of scrap was declined by 5.75% after doing improvement.

Acknowledgments

The authors gratefully thanks to my student Marina for her assistance for the purposes of this research.

References

- [1] Mubarak A Z and Akhyar 2013 Perancangan dan Pembuatan Dapur Peleburan Logam dengan Menggunakan Bahan Bakar Gas (LPG) ISSN 2301-8224 **1(3)**
- [2] George M L 2002 *Lean Six Sigma - Combining Six Sigma Quality with Lean Speed* USA: McGraw-Hill Professional
- [3] Krishnappa A and Ravishankar D 2016 Lean Management and Six Sigma Practices within Small and Medium Manufacturing Industries ISSN 2348-1439 **3(9)**
- [4] Patel N 2015 A Review on Implementation of Six Sigma in Manufacturing Industries ISSN 2349-5162 **2(2)**
- [5] Jadhav G dkk 2015 Six Sigma DMAIC Literature Review ISSN 2229-5518 **6(12)**
- [6] Coskun A *Six Sigma Projects and Personal Experience* Croatia: Janeza Trdine
- [7] Sinulingga S 2014 *Rekayasa Produktivitas* Indonesia: USU Press
- [8] Valles A et al 2009 Implementation of Six Sigma in Manufacturing Process: A Case Study *International Journal of Industrial Engineering* **16(3)** 171-181
- [9] Hassan M K 2013 Applying Lean Six Sigma for Waste Reduction in a Manufacturing Environment *American Journal of Industrial Engineering* **1(2)** 29-35
- [10] Ferreira J E and Lopes I S 2010 Improvement of Scrap Request Process with Six Sigma Methodology *Proceedings of the World Congress on Engineering* **3**
- [11] Pande P and Holpp L *What is Six Sigma* Unites States of America: McGraw-Hill
- [12] Michael L G dkk 2005 *The Lean Six Sigma Pocket* New York: McGraw-Hill
- [13] Tambunan R 2008 *Standard Operating Procedures* Indonesia: Malestas Publishing
- [14] Praveen G 2005 *The Six Sigma Performance Handbook* New York: McGraw-Hill