IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Optimization of Metal Tapping Cycle Operation at INALUM

To cite this article: Ade Buandra 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **505** 012002

Optimization of Metal Tapping Cycle Operation at INALUM

Ade Buandra, Carbon Operation Manager of INALUM

Abstract. PT Indonesia Asahan Aluminium (Persero) "INALUM" as a Holding State-Owned Mining Industry since November 27, 2017 has passed through long journey until now. As Holding Company, INALUM must maintain and improve competitiveness and the culture of continuous improvement. One of the improvements continuously maintained since joint venture Company between Indonesian Goverment and Japan Consortium is Optimization of Metal Tapping (MT) cycle Operation. The objective of the improvement is to minimize equipment utilization such as Anode Changing Crane (ACC), Ladle and Molten Transport Car (MTC), Minimize man hour, Hidrogen Flouride (HF) gas Emission and improve safety condition. By doing Site observation and direct measurement to understand existing system, analized the data, design new system and take into account of new system to calculate cost benefit analysis and implemented the new system. INALUM has managed to get some benefits from production optimization through motion and time study for lean manufacturing. And the benefits are ; optimization of MT cycle operation has successfully reduced ladle utilization for MT until 14 Ladles /day, ACC operation hour 20.5 %, MTC operation hour for ladle transportation 10.5%, Man hour 20.5% for MT work and **10.5** % for ladle transportation, HF Emission gas 20.5 % that caused by MT Operation, balancing operation work and improve safety condition.

Keyword : motion and time study, lean manufacturing

1. Introduction

1.1. INALUM Milestone

In 1919 and 1939 feasibility study of Asahan River utilization by Dutch Colonial Government. The feasibility study of Asahan river was repeated by the Dutch Company, *Maatschappij Tot Exploitatie Va de Waterkracht in de Asahan Rivier* (MEWA).

In 1972 recommendation of feasibility study construction hydro power plant and smelter aluminium was executed together by Indonesian General Work and Electric Department with Nippon Koei. In 1975 The signing of the Master Agreement was held between the Government of Indonesia and a consortium formed by the Japanese Government and 12 Japanese Companies, named Nippon Asahan Aluminum Co., Ltd. (NAA) based in Tokyo. On Januari 06, 1976 Republic of Indonesia Government and NAA signed an agreement forming a joint venture Company PT Indonesia Asahan Aluminium. The negotiations went tough with the lead by Mr. A.R. Soehoed.

On Desember 19, 2013 Signing of INALUM share transfer agreement between the Republic of Indonesia Government and NAA. On April 21, 2014 Minister of SOE through PP. 26 of 2014 appointed INALUM as well as inaugurated the status of INALUM as a State-Owned Enterprise. On Januari 27, 2015 Groundbreaking of several state-owned strategic projects in North Sumatra including INALUM's Diversification Project by President RI, Bapak H. Joko Widodo. In 2017 Aluminum Billet Products (April 13, 2017) and Foundry Alloy (May 17, 2017) were produced for the first time by INALUM and on November 27, 2017 Establishment of BUMN Holding of Mining

IOP Conf. Series: Materials Science and Engineering **505** (2019) 012002 doi:10.1088/1757-899X/505/1/012002

Industry was marked by the signing of the deed of transfer of Series B shares comprising of PT Aneka Tambang (Antam) Tbk by 65%, PT Bukit Asam Tbk by 65.02%, PT Timah Tbk by 65%, and 9.36% shares of PT Freeport Indonesia owned by the Government to INALUM.

INALUM as a Holding State-Owned Mining Industry since Nov. 27. 2017. Objective of Establishment Holding SOEs Mining Industry is:

a. Mastery of reserves and mineral resources and Indonesian coal
b. Product downstream and local content
c. Become a world-class Company (Fortune Global 500)

1.2. INALUM facility and flow process

To produce aluminium ingot, billet and alloy INALUM consist of many plant and main facility such as:

a. Carbon Plant has a function to produce anode that used as electode in Hall-Heroult process. This plant consists of three main facilities: Green, Baking and Rodding Plant.
b. Reduction Plant has a function to reduce alumina to be molten aluminium through Hall-Heroult electrolysis process. This Plant consists of three buildings and each building consists of 170 reduction pots and total of 510 reduction pots. To clean the gas from Hall-Heroult process Reduction Plant equiped with Gas Cleaning with function to clean emission gas by reacted flouride gas with alumina through dry scrubber system.
c. Casting Plant has a function to casting molten aluminum into aluminum bars (Ingot), Billets and Alloys. This Plant consists of 10 units of holding furnaces with each furnace capacity 30 tons molten aluminium, 7 units of ingot casting and a set of billet and alloy casting.
d. Port connected with trestle along 2.5 km consists of three docks; Pier A for unloading raw materials of production, Pier B for shipping aluminum bars, Pier C was transfered to the Indonesian Government in 1984.
e. Regulating Dam of Siruar which located 14.5 km downstream of Lake Toba functions to regulate the constant and steady flow of river water from Lake Toba to the Asahan River. Sigura-gura Dam which located 8.8 Km from the Siruar Dam, serves to arrange water supplies to Siguragura Power Station. Tangga Dam which located 4.9 Km from Siguragura Dam, serves to arrange water supply to the Stations Power Station. This is the first arc dam in Indonesia.
f. Siguragura power station has 4 sets of generators with installed capacity 286 MW. Indonesia's first underground power station, location: 200 meters below ground level. Tangga power station has 4 sets of generators with installed capacity of 317 MW. The electricity produced transmitted to the Smelter at Kuala Tanjung through 271 units of 275 kV transmission towers with spanning 120 km.

Flow process of INALUM Operation is started from :

a. Port where all main material such as Alumina, Aluminium Flouride, Calcine Petroleum Coke (CPC), Coal Tar Pitch (CTP) is unloading and transfered to the silos by conveyor.
b. CPC crushing and sieving to achieve certain granulometry and then mixing with CTP that already heat up to form pasta and in the end forming green block (GB) with shaking machine as the final product of Green Plant. GB sent to the Baking Plant with conveyor to be baked with flue gas with final temperature around 1250 ^{0}C to produce baked block (BB) as final product of Baking Plant. BB sent to the Rodding Plant to be attached with rod and spray with

aluminium to prevent from airburn and then deliver to the Reduction building with Anode Transport Car (ATC) to be used as electrode in the Hall Heroult process.

c. In Reduction pot, alumina reduce to be molten aluminium with kriolit as electrolite in temperature 960 ^{0}C and using Direct Current (DC) that produce from Siguragura and Tangga power station with DC consumption to produce one ton molten aluminium around 14200 kWH. Molten aluminium transported to the Casting plant with MTC as final product of Reduction Plant.

d. In Casting plant, molten aluminium is casted to be aluminium Ingot, Alloy and Billet as final product of Casting Plant that ready to be sell to our customer.

1.3. Background

INALUM produces molten aluminium with prebaked anode type furnace (PAF) technology with anode and alumina as main raw material with DC 183 kA. At Reduction Plant, there are 510 pots, distributed in three-pot line and each line consist of four multipurpose crane (ACC). Daily operation handling by four team with three shift for shift work such as metal tapping, anode-changing operation, raw material charging and etc.

Metal tapping is process tapping of molten aluminium as much as reduce metal that produced. Amount of reduce metal that produced by reduction pot is depend on line current, current efficiency (CE) and duration. The amount of reduced metal can be calculated with the equation as below:

$$\text{Reduced Metal} = 0.3354 \times I \times t \times CE \times 10^{-3}$$

Where: I = DC (kA),
t = Duration (hour),
CE = Current Efficiency *(%)*
Reduce Metal = Ton. Al

By the existing line current 183 kA, CE 93 % and cycle time of metal tapping is every 24 hour or every three shift, average of metal quantity in ladle only 5.7 ton/ladle instead of 7.5 ton/ladle of capacity. This condition is deemed not optimum due to low utilization of ladle capacity, only 76 %, so there is still an opportunity for Optimization. There are two main activities at Reduction operation namely Metal Tapping and Anode Changing. Anode Changing is an activity to replace the old anode that already used for certain day in Hall-Heroult process. Reduction operation consists of three bulding where each building consists of two station. Each station is operated by four teams that handle four block (group of pots). The existing cycle four block should be devided into three zone of Tapping that lead to some time there are two kind of work at the same row (metal tapping and anode changing.

Table 1. Optimum Metal Tapping Cycle

MT Cycle	Red Metal	N. Pot	Red. Metal/ldl	N. Ladle	Pot MT
Shift	Ton/pot	Pot	Ton/ladle	Ladle/day	Pot/day
3	1.366	5	6.83	100	501
4	1.822	4	7.29	94	376
5	2.28	3	6.83	100	301
6	2.73	2	5.47	125	251

Source data : SRO 2004

From table 1. we can see that the optimum cycle of metal tapping is four shift, because with the four shift cycle, utilization of ladle capacity is increased and utilization of ladle can be decreased around 6 ladle /day. By the above calculation, the existing condition is still not optimum, there is an opportunity for more optimal utilization of ladle by optimizing MT cycle operation.

As we know in Industrial Engineering, we have Lean manufacturing method to solve the value chain problem. By Lean thinking, we will transform the waste into the value based on customer perspective. We want to produce the right product at the right time in the right quantity for our customer. By three basic principles of lean called Mura, Muri, and Muda, we try to eliminate waste, overburden and unevenness load of work line.

By the development of aluminium smelter technology and connected to INALUM technical improvement program hence it is necessary to improve working method with motion and time study and lean manufacturing to gain effective and low cost aluminium production. By optimizing tapping cycle time, some objectives can be achieved, such as:

1. Minimize equipment utilization such as ACC, Ladle and MTC
2. Minimize man hour
3. Minimize Hidrogen Fluoride (HF) gas emission
4. Improve safety condition
5. Balancing Operation work

2. Methods

The data collection techniques used in this study are:

1. Direct obsevation and measurement for example motion and time study to get standard time
2. Study the documentation that is collecting and studying supporting data from INALUM

Types and Data Sources

The types of data used in this study are as follows:

1. Primary Data is data obtained or collected directly from the source data through direct obsevation and measurement
2. Secondary data is data that support the primary data obtained through study documentation at INALUM.

For improvement method used to implemented and the step are bellow:

1. Site observation and direct measurement to understand existing system
2. Analizing the data and making new system design
3. Taking into account of new system to calculate cost benefit analysis
4. Implementing the new system
5. Monitoring and report

3. Result and Discussion

3.1. Result

By using motion and time study, we measure time needed by average skilled operator to do metal tapping work for each ladle that consists of maximum 5 pots. After prolong metal tapping cycle time from every three shift to be every four shift we also doing measurement of standard working time for metal tapping with the same way with the previouse one. The result of measurement is shown below:

Table 2. Standard time for Metal Tapping

Activity	Existing			Improvement		
	Freq(a)	Dur (b)	a x b	Freq(a)	Dur (b)	a x b
	Times	Second		Times	Second	
Take Huk	1	50	50	1	50	50
Take MT Ladle	1	40	40	1	40	40
Move MT ladle to pot	1	50	50	1	50	50
Set Ejector Hose	1	30	30	1	30	30

Set Air Hose	3	30	90	2	30	60
OpenTap door	5	10	50	4	10	40
Break Crust Tap Side	5	30	150	4	30	120
Set Nozzle to pot	5	30	150	4	30	120
Blow	5	30	150	4	30	120
Set Checker	5	30	150	4	30	120
Tapping (Charging Alumina)	5	150	750	4	200	800
Take out Nozzle from pot	5	30	150	4	30	120
Move to next pot	4	20	80	3	20	60
Cleaning Crust	5	30	150	4	30	120
Measuring bath/ metal	5	30	150	4	30	120
Open Air Hose	3	30	90	2	30	60
Open Ejector Hose	1	30	30	1	30	30
Closing Tap door	5	10	50	4	10	40
Move ladle to pallet	1	50	50	1	50	50
Put ladle to pallet	1	40	40	1	40	40
Return huk	1	50	50	1	50	50
Total	68	800	39.2	55	850	35.3

Source data : Direct measurement on January 2004 at Reduction Operation Section

Based on table above, there are decreasing of number activities of metal tapping/ladle from 68 into 55 activities resulted from decreasing of number of pot tapping for each ladle. Tapping duration also decreases 50 second due to decreasing of number of pot that should be tapped for each ladle. The result of combination from activity and duration has succeed to decrease metal tapping standard time from 39.2 into 35.3 minutes/ ladle.

After implementing the improvement, good result has been achieved with the details as follows :

Table 3. Decreasing ladle utilization

MT Freq (Shift)	Red. Metal (ton/pot)	Red.Metal/ladle (ton/ladle)	Red.Metal (ton/day)	Ladle (ladle/day)	Pot MT (pot)
3	1.366	5.70	684.5	120	501
4	1.822	6.45	684.5	106	376
Diff	0.46	0.74	0.0	14	125

Note : MT = Metal Tapping, Red.=Reduce
Source data : Reduction operation section 2004

After increasing metal tapping cycle time from every three shift to be every four shift, the amount of reduced metal to tapping increases from 1.366 ton/pot to be 1.822 ton/pot as well as the amount of reduced metal per ladle from 5.7 ton/ladle up to 6.45 ton/ladle. The number of ladle used for metal tapping also decrease from 120 ladle/day down to 106 ladle/day as well as the number of pot that should be tapped from 501pot/day down to 376 pot/day.

Table 4. Decreasing ACC, MTC utilization, man hour and duration tap door opening

MT Freq (Shift)	ACC operation hour (Minutes/acc/shift)	MTC operation hour (Minutes/mtc/shift)	Man hour (manhour/shift)	Duration tap door opening (minutes)
3	130.6	240	98.4	3360
4	104	212	80.1	2778.6

Diff	26.6	28	18.3	571.4

Note : ACC = Anode changing crane, MTC = Molten Transport Car

By prolonging cycle of metal tapping from three shift to be four shift, ACC used for handling the ladle to do metal tapping work also decreases in operation hour from 130.6 minutes/acc/shift to be 104 minutes/acc/shift. The decreasing number of ladle used /day will lead to decreasing of MTC operation hour from 240 minutes/MTC/shift to be 212 minutes/MTC/shift. Decreasing of working standard time lead to decreasing of man hour from 98.4 man hour/shift to be 80.1 man haour/shift and decreasing tap door opening from 3360 minutes to 2778.6 minutes.

3.2. Discussion

By changing the MT cycle from three shifts to four shifts, there is a reduction of activities that do not provide added value, such as the ladle transportation activity from the ladle parking area to the pot which will be tapping and vice versa, and the ladle transportation activity from the ladle parking lot to the Casting Plant. The reduction of these activities also results in reduced standard time for MT work.

The process of MT is also done by opening of the pot tap door. In the beginning of tapping out the metal, the nozzle will be inserted and the air is also sprayed to avoid the nozzle plug and results in the release of HF gas emissions into the air, by extending this MT cycle, the duration of tap door opening will be reduced and nozzle entry will decrease, so this will have a positive impact to the environment.

At one station, there are four blocks or 82 pots scheduled for tapping, so that for each shift there are about 27 pots that will be tapped. In one station, there are two series where each series consists of 42 pots and each series consists of two blocks that consisting of 21 pots. With such conditions, one-block MT schedule is added with other 6 to 7 pots in the other block. In the block scheduled as tapping area should provide with two ladles for tapping. This causes more ladles to be standbye than MT four shifts, because in case of any MT work in one block, there must be two ladles available in the ladle parking area, one is used and the other for standbye in case the ladle is clogged and must be sent to the ladle cleaning shop. By this improvement, the number of ladle usage can be reduced by two ladles for each station and the ladle parking area can be more spacious which has a positive impact on traffic and safety conditions

By reducing standard time of MT, workload of employees can be automatically reduced and operation hour of equipment such as ACC and MTC increases. Decreasing of operation hour of equipment will lead to decreasing of traffic intensity and give good impact to safety condition.

Table 5. Merit of Optimization MT cycle operation

Item (Minutes/Shift)	Existing	Improvement	Diff	%
ACC	131	104	-27	-20,5
Manhour Reduction	392	312	-80	-20,5
MTC	305	273	-32	-10,5
Manhour Casting	305	273	-32	-10,5
HF Emission	261	208	-53	-20,5

4. Conclusion

After optimizing MT cycle operation from every three shift up to every four shift, we can:

1. Reduce ladle utilization for MT until 14 ladles /day
2. Reduce ACC operation hour for MT 20.5 %
3. Reduce MTC operation hour for ladle transportation 10.5%
4. Reduce Man hour 20.5% for MT work and 10.5 % for ladle transportation
5. Reduce HF Emission gas 20.5 % caused by MT Operation

6. Balance operation work and improve safety condition.

5. References

[1] Ade Buandra 2004 *Metal Tapping 1 x /4 Shift* (Kuala Tanjung-1st Technology Improvement Seminar INALUM).

[2] Fred E. Meyers 1992 *Motion and Time Study for Lean Manufacturing* (New Jersey-Prentice hall)

[3] James P. Womack, Daniel T. Jones 2003 *Lean Thinking: Banish Waste and Create Wealth in Your Corporation, Revised and Updated* (New York- Freepress)