Published in the Proceedings of the 16th International Aluminum Alloys Conference (ICAA16) 2018
ISBN: 978-1-926872-41-4
by the Canadian Institute of Mining, Metallurgy & Petroleum

EXCELLENCE IN AN ALUMINIUM ALLOY ROLLING OPERATION THROUGH SIX SIGMA APPLICATION

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ABSTRACT

Aluminium rolling processing from ingots to cold rolled coils comes with a lot of challenges especially in controlling defective products in casting, hot mill and cold mill operations. Hence this study focused on reducing defects at mills and cast-house using six sigma approaches. The use of six sigma approach will help the production experts to determine the gap between its operation and world class process. Practical data from First Aluminium Rolling mills were presented and analysed and mini improvement projects were proposed based on organisation need to achieve excellence. This study encourages aluminium alloy industries to pursue process improvement projects on the basis of analysis on data obtained from their shop floor, hence ensuring that through this, recovery is improved and cost of poor quality is reduced.

KEYWORDS

Excellence, Process, Six-Sigma

INTRODUCTION

Engineer Bill Smith while working at Motorola in 1986 introduced a new concept in which a set of techniques and tools are used for process improvement by controlling variations (defects). These tools and techniques are explained by an acronym DMAIC.

D DEFINE the problem
M MEASURE the variables in the problem
A ANALYSE the variables of the problem
I IMPLEMENT and verify the solution to the problem
C CONTROL the solution to sustain it

Most times in six-sigma approach, variations in the process that results in defects and customers' dissatisfaction are targeted at 3.4 defects per million opportunities. There are numerous methods six sigma application use to achieve quality results and innovative strategies. Improving the quality of process through these methods helps identify and reduce variations which paves way for organisational excellence.

In this study, it is encouraged to use six sigma techniques to improve aluminium rolling operations and other aluminium processing activities, the benefits of such improvement concept include:

- Satisfy the voice of the customer (VOC)
- Minimise costs
- Maximise Profits
- Build Good Team
- Implement Profitable Project

Six Sigma approach points that every customer (internal/external) is a king who values consistent and predictable services and/or products with near zero defects(variations) - 6∂, see Figure 1

Sigma	**DPMO**	**LOG (DPMO)**
1	691462	5.839768
2	308637	5.489448
3	66807	4.824822
4	6210	3.793092
5	233	2.367356
6	3.4	0.531479

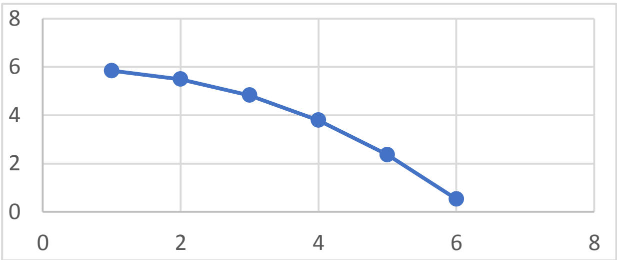

Figure1. Sigma verses Defects per million opportunities

Here six sigma goes beyond defect reduction to cost control and value addition. The overall objective is not to achieve 3.4 DPMO (defects per million opportunity) but to create competitive overall business excellence.

Problem Definition

At **First Aluminium Plc**, Port Harcourt Nigeria (aluminium rolling mills), input materials are virgin metals and scraps melt in the reverberatory furnace and cast into rolling ingots which are rolled into coils of various thicknesses, sometimes the coils are sold as it is or coated for roofing sheet or panels purposes. During the processing into coils (plain and coated), various defects will be noticed at various stages resulting to scraps which affect the cost of production of the organisation. This cost is carried over to the customers because entities are formed to make profit. It is therefore imperative that for better competitiveness, reduction in cost by controlling defects to minimal level aiming at six-sigma continually will definitely lead the organisation to excellence.

In the various stages of plain aluminium alloy coils production system, appreciation of the stages as an interaction of internal customer to satisfy the ultimate external customers (the king) fills the loop in hearing and understanding the voice of the customers (VOC).

During rolling of aluminium ingots into coils and subsequent coating of coils, defects and process off cuts are generated thereby resulting to a lower ratio of product weight to ingot weight ratio. This ratio when expressed in percentage is commonly referred to as Recovery

Recovery is Total weight of finished Products (output) divided by Total Weight of ingot for their production (input) Expressed in Percentage. This is also yield as in Output weight per ingot divided by input weight expressed in percentage.

Hence low recovery means poor quality and has cost implications. At this point we shall examine the defects that result to lower recovery at each of the machine centers in a rolling mill operation.

Aluminum Rolling Defects

The defects that could result to portion and full scrapping of products at each production stage are listed below. Portion and full scrapping of defective products at any production stage is aimed at avoiding uneconomical effect of processing inputs at next stage into scraps or/and defective products to be sold to the customers.

Cast House (Production of Rolling Ingots): Chemical compositional problem, Surface defects (Cracks, Dross-inclusion, side tearing), Dimensional problem (ingot length)

HOT Mill (Hot rolling of ingots to coils): Bad build up, over gauge, Low coiling temperature, crocodilling, lateral bow

Cold Rolling Mill – 2Hi & 4Hi (Cold rolling of Hot rolled coils to standard gauges): Strip breakage, Edge cuts/rough edge, Buckles/ metal burnt, Holes, Gauge Variations, Roll Marks (excessive reductions)

PAINTLINE (coating and baking of cold rolled coils into various colours): Over baked portions, Under cure, Draglines, Uncoated portions and stains

Measure Yield Variation

Here Yield is expressed in %Recovery. When the Operation Manager is on pressure to reduce cost, his attention should go inward to eliminate defects, moving variation to at least 4 Sigma even further to 6 Sigma will save a lot of resources. This linkage of yield to cost of production should be understood by all in the organisation, its appreciation helps all to contribute to its improvement. Until %Recovery is traced to cost, its appreciation by employees and other stake holders will be low. Hence this study will depict a typical cost relationship to %Recovery in Table 1.

Unit recovery on individual lot production is measured, the reasons for low recovery for each are also outlined by process owner and documented. The most important part of this activity is traceability from casting to finished product and record of reasons for low recovery are taken and maintained, then summed on weekly basis.

Table 1 depicts lost in recovery being expressed in monetary terms, this is the language which the operational managers can use to convince all stake holders especially the organisation financiers to support any improvement projects that could be of help towards goodness of the processes aimed at reducing defects from the production system. When operative figures are not represented in cash its appreciation and subsequent support for improvements may only be a lip service by the management. Increase in recovery reduces production cost, improves service delivery to customers as in meeting their orders, reduces handling cost of WIP thereby reducing customers' complaint. When all these factors are placed in control there will be excellence in aluminium alloy rolling operation, that is, satisfying customers through consistency in process will be excellently achieved at right quality and within delivery time.

Table 1. Weekly %Recovery Monitoring at an Aluminium Rolling Mill Plant

ACTUAL							TARGET RECOVERY OF 80%		
WEEK	INPUT (KG)	OUTPUT (KG)	RECOV (%)	Ave. Wt of RI (KG)	NO OF PLAIN COILS	Scrap generated (KG)	RECOV (%)	OUTPUT (Kg)	SCRAP GENERATED (KG)
1	167541	113928	68	1805	93	53613	80	134033	33508
2	157891	116839	74	2002	79	41052	80	126313	31578
3	211457	152249	72	2005	105	59208	80	169166	42291
4	184570	138428	75	2006	92	46143	80	147656	36914
5	201453	157133	78	2213	91	44320	80	161162	40291
6	145805	107896	74	2004	73	37909	80	116644	29161
7	142005	92303	65	1840	77	49702	80	113604	28401
8	202854	160255	79	2261	90	42599	80	162283	40571
9	230156	186426	81	2400	96	43730	80	184125	46031
10	197824	154303	78	2357	84	43521	80	158259	39565
11	184725	145933	79	2402	77	38792	80	147780	36945
12	195544	148613	76	2311	85	46931	80	156435	39109
13	223410	167558	75	2000	112	55853	80	178728	44682
14	215842	172674	80	2451	88	43168	80	172674	43168
15	223575	169917	76	2302	97	53658	80	178860	44715
16	245817	191737	78	2385	103	54080	80	196654	49163
17	214783	161087	75	2100	102	53696	80	171826	42957
18	235625	167294	71	1950	121	68331	80	188500	47125
19	241222	166443	69	1900	127	74779	80	192978	48244
20	260941	193096	74	2010	130	67845	80	208753	52188
21	202543	147856	73	2008	101	54687	80	162034	40509
22	178259	137259	77	2203	81	41000	80	142607	35652
23	186457	128655	69	1947	96	57802	80	149166	37291
24	165224	112352	68	1892	87	52872	80	132179	33045
25	179245	130849	73	2001	90	48396	80	143396	35849
26	195428	140708	72	1942	101	54720	80	156342	39086
27	198715	147049	74	2001	99	51666	80	158972	39743
28	212500	161500	76	2175	98	51000	80	170000	42500
29	256912	202960	79	2405	107	53952	80	205530	51382
30	251642	196281	78	2394	105	55361	80	201314	50328
31	243119	182339	75	2204	110	60780	80	194495	48624
32	215864	161898	75	2215	97	53966	80	172691	43173
33	194788	148039	76	2298	85	46749	80	155830	38958
34	188231	146820	78	2324	81	41411	80	150585	37646
35	180114	142290	79	2412	75	37824	80	144091	36023
36	179125	132553	74	1998	90	46573	80	143300	35825
37	160248	116981	73	2007	80	43267	80	128198	32050
38	159889	119917	75	2178	73	39972	80	127911	31978
39	172312	134403	78	2410	71	37909	80	137850	34462
40	285752	225744	79	2429	118	60008	80	228602	57150
41	202900	164349	81	2483	82	38551	80	162320	40580
42	236481	170266	72	2204	107	66215	80	189185	47296
43	211113	156224	74	2118	100	54889	80	168890	42223
44	195470	142693	73	1954	100	52777	80	156376	39094
45	175983	140786	80	2481	71	35197	80	140786	35197
46	159344	114728	72	2081	77	44616	80	127475	31869
47	189453	134512	71	2004	95	54941	80	151562	37891
48	174521	120419	69	1820	96	54102	80	139617	34904
49	164742	123557	75	2200	75	41186	80	131794	32948
50	158936	123970	78	2405	66	34966	80	127149	31787
51	126285	99765	79	2406	52	26520	80	101028	25257
52	110253	79382	72	2119	52	30871	80	88202	22051
	10194888	**7651218**	**75**	**2162**	**91**	**2543670**	**80**	**8155910**	**2038978**

Analyse Shop Floor Data

Next, we check the capability of the process to produce plain coils from RI at LCL of 78% and UCL of 82% recovery and mean of 80% from Table 1. The data from column four of Table 1 were analysed using MACROS EXCEL package. This has shown us need for improvement and the chances which we have to improve. Hence in Figure 2 below, the Process Capability Curve for recovery per week is plotted using MACROS EXCEL, the sigma is 1.33, Cp is 0.3, while Cpk is –0.1.

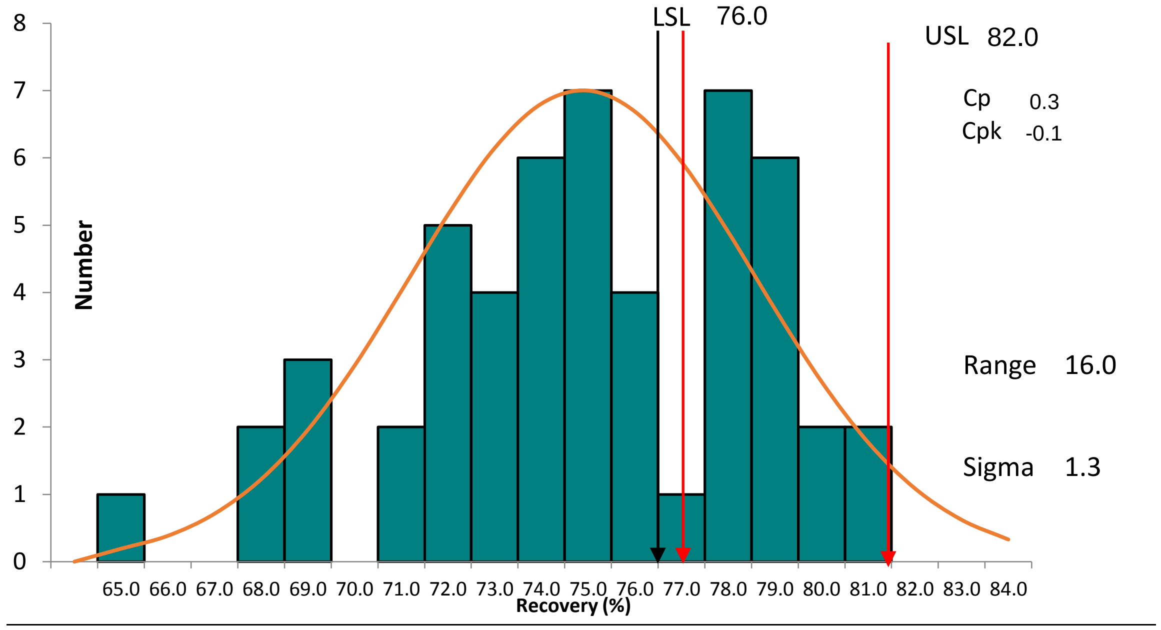

Figure 2. Process Capability Curve of Plain Coils Recovery

The graph speaks volume for its self and need to improve the process to bring it under profitable control is clearly outlined by the analysis obtained.

Process capability is the ability of the combination of men, machines, methods, materials and measurement to produce a product that will consistently meet the design requirements and customers' expectation.

Process Capability ratio Cp and Process Capability Index Cpk are quantitative expressions that personify the variability of the process (its natural limits) relative to its specification limits and customers' requirements respectively.

Cpk is greater than 1.33 (highly capable process) less than 64 ppm defects
Cpk 1 – 1.33 barely capable process greater than 64 ppm but less than 2700 defects
Cpk less than 1 means the process is not capable produces more than 27000 ppm defects

Improve the Process

In order to improve the process for system excellence we need to use factual methods, using data obtained from the shop floor to stress process inadequacies and technically demonstrate new way in which these deficiencies are eliminated for overall internal and external customers' satisfaction. When the customers are happy the organisation profitability is assured as far as cost elements are kept on check.

Table 1, column 5 shows variation in the weight of Rolling Ingots (RI), this variation is the first consideration to see its effects on %Recovery, Figure 3 below shows this relationship, which indicates that as RI weight increases, % Recovery also increases. Investigation shows that there are process offcuts which must be generated at each stage of manufacturing that is constant irrespective of the RI weight. Where there is capacity it is advisable to use optimal and consistent RI weight.

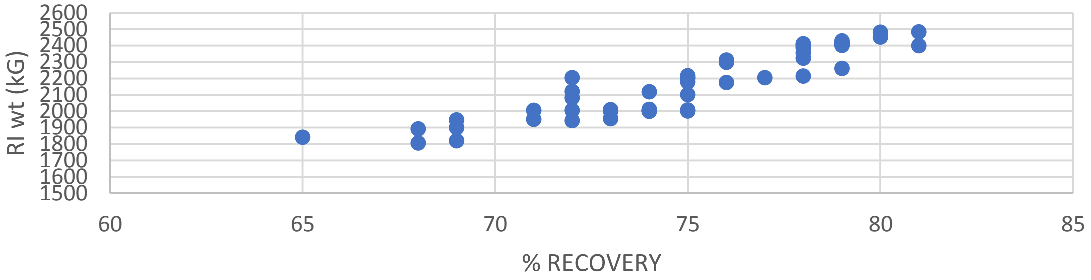

Figure 3. Relationship between RI weight and % Recovery

Improvement Project from the Figure 3: Increase RI weight to consistent 2.5 $\pm$ 0.1 tons to achieve % Recovery increase. It is not only the ingot weight that determines recovery in an aluminium rolling mill plant, therefore we check further into those defects that results in full or portion offcuts in a plain coil. The patrol Inspectors and Process owners took data collection seriously to get cause and effects of defects on recovery. The data are compressed to Table 2.

Table 2. Cause and Effects of Aluminium Rolling Mill Defects Analysis

Defects	**Frequency per 100 coils**	**Types**	**Causes**	**Effects on recovery based on patrol inspector records**	**Improvement project**
Holes	10	Chain holes	RI- dross inclusion	3	Improve filtration of molten metal
		Pins holes	damaged rolling tables with protrusions	5	Revamp the Rolling table
		Point holes	Dirty rolling oil	1	put good filtration system for rolling oil
			Particles on rolling table	1	clean rolling table fortnightly
Strip breakages	10		Poor screw setting	2	Develop proper processing path for each gauge
			Wrong strip tensioning during coldwork	3	Develop proper processing path for each gauge
			Lateral bow during hot work	1	Change HM Roll camber per 200 HR coils production
			Faulty x-ray gauge control system	2	Repair and develop proper maintenance and skill for x-ray gauge control
			Unbalanced screw of left and right camber	1	operational error
			Edge rolling	1	operational error
Buckles	8	Side	Wrong screw setting	1	Develop proper processing path for each gauge
		Center	Wrong strip tensioning during coldwork	1	wrong roll camber/operational error
			Improper roll camber	3	change CR Rolls camber per 200 coils production
			Bad build-up of hot rolled coils	1	Power failure/operators error
			Gauge variations of HR coils	2	Put in gauge control for HOT rolling operation

The causes of defects were matched with their effects on recovery as in lost in yield. The technical personnel and project section determines the cost of any improvement project that could eliminate these causes of defects. The aim of any agreed project is to improve recovery, most times a brainstorming cross functional group fully supported by the senior management are formed and given the task to obtain the project tittles and cost. The result of this team work is zipped in Table 3.

Table 3. Cost- Benefit Analysis of Improvement Projects Based on monetary gains

Project	Improvement project	%Recov Gain	Level of success expected	Expected %Recov Gain	Yearly gain for 1% gain in recovery ($)	Yearly gain on recovery for successful project ($)	Project cost ($)	Monetary gain for a year ($)
A	Develop and implement proper processing path for each gauge	6	0.7	4.2	250,000.00	1,050,000.00	883,000.00	167,000.00
B	Revamp rolling table	5	0.65	3.25	250,000.00	812,500.00	700,000.00	112,500.00
C	Change HM roll camber after 200 coils	4	0.8	3.2	250,000.00	800,000.00	523,000.00	277,000.00
D	Train operators	3	0.55	1.65	250,000.00	412,500.00	20,000.00	392,500.00
E	Develop maintenance plan and implement x-ray gauge system	2	0.5	1	250,000.00	250,000.00	600,000.00	-350,000.00
F	Cleaning rolling table fortnightly	1	0.9	0.9	250,000.00	225,000.00	10,000.00	215,000.00
G	Put good filtration unit for rolling oil	1	0.6	0.6	250,000.00	150,000.00	578,000.00	-428,000.00
H	Increase Rolling Ingot weight to 2.5 tons	5	0.72	3.6	250,000.00	900,000.00	514000.00	386,000.00

From Table 1 above, difference in output from actual recovery to 80% target is 50.5 tons, at average cost of aluminium coil per kg of 2.5USD expected revenue improvement at target recovery is 1.26M USD. It is seen that for every 1% increment in recovery, there is a gain of about 250,000USD, based on this, the cost benefit analysis of the accepted improvement projects is tabulated in Table 3. Since every project has its chances of success and failure, the senior management has to assign probability of success of any recommended project to solving a defects recovery problem. This probability is considered to affect recovery improvement success hence will range between 0 and 1.

The improvement as in profitability of each projects, is clearly shown and based on it Figure 4 was developed.

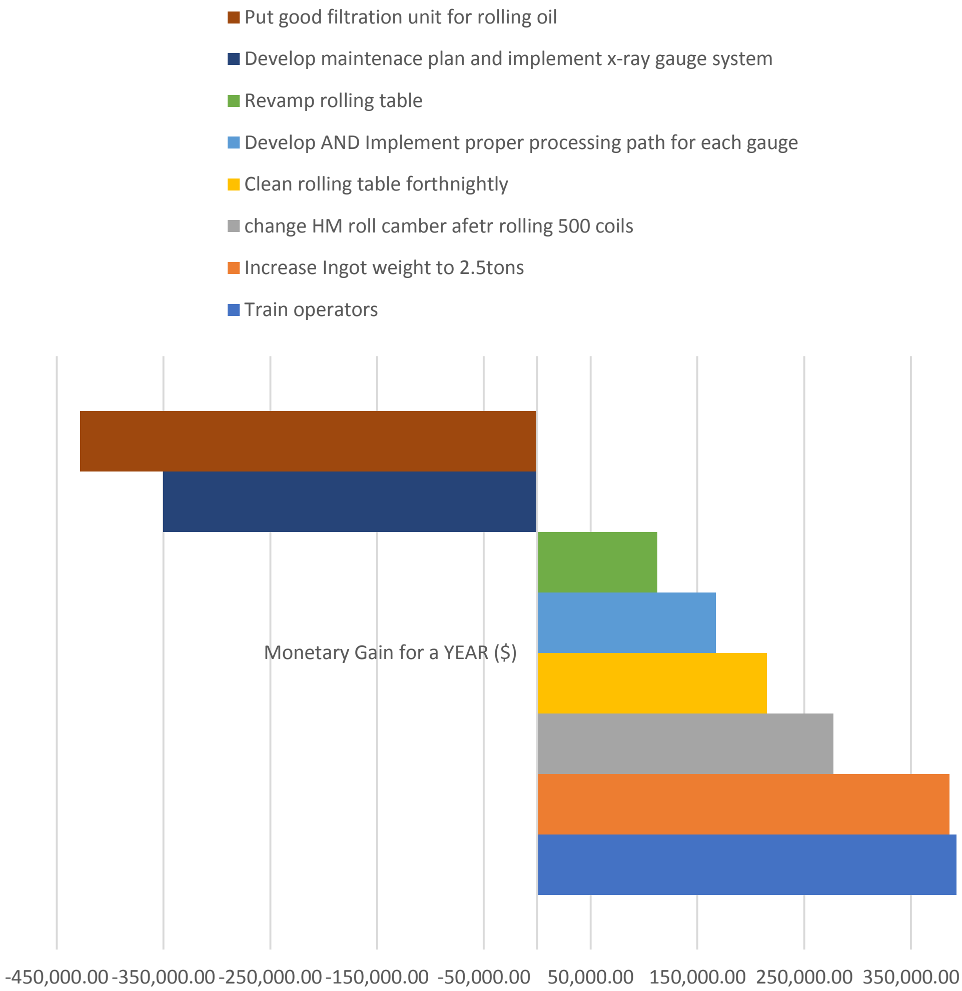

Figure 4. Improvement Project Monetary Gain Chart

Pictorially, Figure 4 shows that for the organisation to move in excellence path progressively in an economic manner it has to implement improvement projects as per its overall profitability contribution to the organisation. This gives senior management factual way in choosing the projects to do depending on budget limits.

CONCLUSIONS

This paper has shown that calculated immediate drop in profitability due to recovery inefficiencies to be 1.26Million USD when comparing actual recovery to target of 80%, therefore it could be deduced that 1% recovery improvement has monetary gain of about 250000USD in the year under review. On further investigation into the root causes of low recovery in a typical aluminium rolling mill using six-sigma approach, eight projects were outlined which shall give an improvement of about 18.4% recovery. This study prioritized these projects using cost benefit analysis.

By combining the use of SPC and cost benefit analysis, management uses factual approach in taking an objective decision on the projects to be carried out for improvement of recovery rather than taking decision based on intuition. Depending on the financial muscle of the organisation improvement projects shall be taken in terms of its contribution to overall profitability of the organisation. The methodology implored in this paper can be applied in any Production company.

Abbreviations

Al	Aluminium
Cp	Process Capability Ratio
Cpk	Process Capability Index
CRC	Cold Rolled coils
HRC	Hot Rolled coils
KG	kilogram
LCL	Lower control limit
Recov	Recovery
RI	Rolling Ingot
UCL	Upper control limit
USD	US Dollar
VOC	Voice of the customer
WK	week
WT	Weight

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