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An Evaluation of Actual Costs of Rework and Scrap in Manufacturing Industry

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***Abstract*— In manufacturing sector, rework and scrap can result from errors, omissions, failures, damages, change orders, machine breakdown, poor maintenance practices, unmotivated employees, poor quality management, poor design of products and services; and the costs involved in rework process or scrapping of defective products can be overwhelming. This study evaluates in totality the actual costs of rework and scrap in the industry under study using cost volume analysis. The cost benefit of rework over scrap was analyzed in order to suggest to the management the need to embark on rework process if necessary when there is defective product rather than outright scrapping of the defective product. This study also recommends effective prevention strategies that could be implemented to improve products and process performance in terms of cost, time and quality in the industry under study and hence forestall the excessive cases of rework being experienced.**

Keywords—Cost of Rework; Cost of Scrap; Cost Benefit Analysis; Quality; Rework.

I. INTRODUCTION

Quality has become one of the most important competitive strategic tools which many organizations have realized as a key to development of products and services that will ensure continuing success. Quality is a universal value and has become a global issue. In order to survive and be able to provide customers with good products, manufacturing organizations are required to ensure that their processes are continuously monitored and product quality improved. Quality control is a process that evaluates output relative to a standard and takes corrective action when the output doesn't meet the standard [1][2]. If the results are acceptable, no further action is required; unacceptable results call for corrective action. Whenever an organization fails to take its quality management seriously, it always results to products being scraped, reworked or returned by customers.

Reference [3] sees rework as the process by which an item is made to conform to the original requirement by completion or correction. It can also be seen as the unnecessary effort of redoing a process or an activity that was incorrectly implemented [4]. Reference [5] defined rework as quality deviations, that is to say, that rework and quality interact with each other. Where quality control and management has not been implemented adequately rework happens, and when it occurs, the output quality will reduce. Essentially, rework can result from errors, omissions, failures, damages, and change orders throughout the procurement process, as can be seen in [6][7]. References [6],[8],[9] and [10] categorized causes of rework into three types of rework factors (technical factors, quality factors, and human resource factors) and found out the severity index of the variables. There are always quality costs involved in ensuring that products or services conform to the standards and also, there are costs that are involved whenever there is a rework. References [11],[12] and [13] stressed the importance of measuring the costs of rework as a part of quality cost. While References [14], [15] and [16] maintained that rework is the major contributor to cost and time overruns in project delivery process.

Rework costs are determined from the point where rework is identified to that time when rework is completed and the activity has returned to the condition or state it was in original. The duration of the cost tracking includes the length of the standby/ relocation time once rework is identified, the time required to carry out the rework, and the time required to gear up to carry on with the original scope of the activity [17]. Earlier studies have shown that rework costs vary between 3 and 15 percent of projects contract values [5][13][18][19].

The increasing cases of rework in some manufacturing industries have been raising some issues among management and staff. In the manufacturing industry under study, the questions have been: What actually brings about defective products? How much do we actually spend monthly in reworking of defective products? Should we actually rework defective products or scrap them out rightly? What is the cost benefit of rework over scrap? It is essential to identify the costs and causes of manufacturing rework in order to amend the performance of products [20]. Determining the level of rework can be utilized by management to evaluate how quality has been managed and to discover problems within the manufacturing process.

Having critically considered the above issues of interest in the company, this study will achieve the following objectives: (1) Identify the actual causes of defective products in the company (2) Evaluate the costs of rework in the company (3) Determine the cost of scrap and (4) Evaluate the cost benefit of rework over scrap in the manufacturing industry. It is believed that achieving the above objectives will enable the management identify effective prevention strategies that can be implemented to improve products and process performance in terms of cost, time and quality. Cost volume analysis will be utilized in this study to achieve the above objectives.

II. RESEARCH METHODOLOGY

A. *Research Design*

For the purpose of the research presented in this paper, rework is defined as the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time [16]. The data used for this analytical study were collected from the records in Quality control (quality data) and Account (cost data) Departments in the First Aluminum Mill Plc; and other information were collected through direct observation of production processes, interviews with production and quality control personnel. The data obtained were analyzed using Cost Volume Analysis. The results obtained are shown in tabular and graphical forms.

B. *Methods of Data Analysis*

Cost Volume Analysis: Cost Volume Analysis focuses on the relationship between cost, revenue and volume output. The technique requires the identification of all costs related to the production of a product. This method was employed in calculating the individual costs involved in rework based on the data collected from the account department. The costs considered are labour cost, energy cost and weight loss.

Cost of rework = Labour cost + Energy cost + weight loss (1)

III. RESULTS AND DISCUSSION

In manufacturing sector, rework and scrap which are the outcome of poor quality in manufacturing can result from errors, omissions, failures, damages, change orders, machine breakdown, poor maintenance practices, unmotivated employees, poor quality management, poor design of products and services etc. The defects in Aluminum Industries can occur in form of holes(H) on the products, dragline/tearing, edge cut(EC)/rough edge(RE), over gauge(OG)/ under gauge(UG), delay temperature(DT), gauge variation(GV) and buckle(BK)/ bad build up(BB) . Tables 1 and 2 show hot mill machine and embosser machine rework processes respectively. Table 3 shows the manpower required and appropriate rework process parameters for both hot mill and embosser machine.

Table 1: Hot mill machine's rework process

S/N	**Defect**	**Rework Process**	**Cost Applicable**
1	Over Gauge	Anneal before use	1. Manpower loss 2. Energy loss
2	Bad Build up	Use as it is/scrap	No cost
3	Gauge Variation	Use as it is/scrap	No cost
4	Buckles	Use as it is/scrap	No cost
5	Delay Temperature	Anneal before use	1. Manpower loss 2. Energy loss
6	Partly Rolled	Scrap	No cost
7	Hole	Use as it is/scrap	No cost
8	Wrong spool setting	Use as it is/scrap	No cost

Table 2: Embosser Machine's rework process

S/N	**Defect**	**Rework Process**	**Cost Applicable**
1	Dragline/tearing	Cut off the affected portion	1. Manpower loss 2. Energy loss 3. Weight loss
2	Edge cut/rough edge	Convert to stucco	1. Manpower loss 2. Energy loss 3. Weight loss
3	Hole	Cut off the affected portion	1. Manpower 2. Energy loss 3. Weight loss
4	Over gauge	Cut off the affected portion	1. Manpower loss 2. Energy loss 3. weight loss
5	Under gauge	Use as it is	Profit loss
6	Buckle/Bad build up	Convert to stucco	1. Manpower loss 2. Energy loss 3. Weight loss
7	Gauge variation	Re-roll to lower gauge	1. Manpower loss 2. Energy loss 3. Weight loss 4. Profit loss

Table 3: Manpower Required and Applicable Rework Process Parameter

Parameter	**Hot mill Furnace**	**Embosser machine**
Manpower involved	1 Engineer per shit @ N1500 per day. 1 Supervisor per shift @ N1000 per day. 2 Operators per shit @N800 /operator/day	1 Engineer per shift @ N1500 per day. 2 Supervisors per shift @N1000/Supervisor/day. 4 Operators per shift @ N 800/operator/day.
Coil processed/rolled	6 per shift	16 per shift
Annual energy consumed	1,012,305.6kwh @ N13.2/kwh	64800kwh@ N13.2/kwh
Average coil produced	Nil	2 coils per hour
Average weight per coil produced	1750 Kg	1300kg
Cost of plain coil	N 512 per kg	N600 per kg
Cost of embossed plain coil	Nil	N615per kg
Cost of embossed coated Coil	Nil	N781.125per kg
Average plain coil cut off from affected portion	Nil	125kg per coil
Average plain coil trimmed off for edge cut	Nil	100kg per coil

A. Cost Volume Analysis

Equation (1) is used in calculation of the costs of rework in both hot mill machine and embosser machine. The data in tables 1 and 3 are utilized in determining the costs of rework at hot mill while tables 2 and 3 are utilized in determining the costs of rework at Embosser machine. The results obtained are summarized in tables 4, 5, 6 and 7 for hot mill machine and embosser machines. The summary of total cost of rework, total cost of scrap and cost benefit of rework over scrap in both hot mill machine and embosser machine is shown in table 8.

Table 4: Costs of rework and Scrap of Over Gauge (OG) and Delay Temperature (DT) at Hot Mill Machine

S/N	Month	OG affected coils	Cost of rework for OG	Cost of Scrap	DT affected coils	Cost of rework for DT	Cost of Scrap
1	Jan	11	123758.8	9869475	9	101257.2	8075025
2	Feb	37	416279.6	33197325	13	146260.4	11663925
3	Mar	52	585041.6	46655700	4	45003.2	3588900
4	Apr	71	798806.6	63702975	6	67504.8	5883350
5	May	31	348774.8	27813975	20	225016	17944500
6	Jun	34	382527.2	30505650	63	708800.4	56525175
7	Jul	83	933816.4	74469675	19	213765.2	17047275
8	Aug	62	697549.6	55627950	26	292520.8	23327850
9	Sept	65	731302	58319625	103	1158832.4	92414175
10	Oct	19	213765.2	17047275	56	630044.8	50244600
11	Nov	1	11250.8	897225	76	855060.8	68189100
12	Dec	1	11250.8	877225	41	461282.8	36786225
	Total	467	5254123.4	419004075	436	4905348.8	391190100

Table 5: Costs of Rework and Scrap for Hole defect (H) and Gauge Variation (GV) at Embosser Machine

S/N	Month	Hole (H) affected Coil	Actual cost of rework for Hole affected coil	Cost of Scrap Hole affected coil	Gauge variation (GV) affected coil	Actual cost of rework for GV affected coil	Cost of Scrap of GV affected coil
1	Jan	0	0	0	0	0	0
2	Feb	4	313,595.28	3120000	0	0	0
3	Mar	1	78,398.82	780000	0	0	0
4	Apr	2	156,797.64	1560000	3	190,196.46	2,340,000
5	May	0	0	0	12	760,785.84	9,360,000
6	Jun	1	78,398.82	780000	18	1,141,178.76	14,040,000
7	Jul	2	156,797.64	1560000	12	760,785.76	9,360,000
8	Aug	0	0	0	11	697,387.02	8,580,000
9	Sept	4	313,595.28	3120000	7	443,791.74	5,460,000
10	Oct	9	705,589.38	7020000	4	253,595.28	3,120,000
11	Nov	6	470,392.92	4680000	3	190,196.46	2,340,000
12	Dec	2	156,797.64	1560000	1	63,398.82	780,000
	Total	31	2,430,363.42	24,180,000.00	71	4,501,316.22	55,380,000.00

Table 6: Costs of Rework and Scraps of Over Gauge (OG), Bad Build up (BB) and Under Gauge (UG) at Embosser Machine

S/N	***Mon***	**OG Affected Coils**	**Actual Cost Rework of OG**	**Cost of Scrap of OG**	**BB Affected Coils**	**Actual Cost of Rework of BB**	**Cost of Scrap of BB**	**UG Affected Coils**	**Actual Cost of Rework of UG**	**Cost of Scrap of UG**
1	Jan	4	13,595	3,120,000	0	0	0	0	0	0
2	Feb	13	44,185	10,140,000	0	0	0	0	0	0
3	Mar	12	40,785	9,360,000	1	3,398.82	780000	1	3,399	780000
4	Apr	10	33,988	7,800,000	2	6,797.64	1560000	6	20,393	4680000
5	May	18	61,178	14,040,000	1	3,398.82	780000	8	27,190	6240000
6	Jun	20	67,976	15,600,000	5	16,994.10	390000	41	139,351	31980000
7	Jul	8	27, 190	6,240,000	0	0	0	27	91,768	21060000
8	Aug	8	27,190	6,240,000	1	3,398	780000	12	40,785	9360000
9	Sep	5	16,994	3,900,000	5	16,994	390000	18	61,178	14040000
10	Oct	17	57,779	13,260,000	2	6,797	1560000	10	33,988	7800000
11	Nov	19	64,577	14,820,000	0	0	0	5	16,994	3900000
12	Dec	22	74,774	17,160,000	0	0	0	14	47,583	10920000
	Total	156	530,215	121,680,000	17	57,779	13,260,000	142	482,632	110,760,000

Table 7: Costs of Rework and Scrap of Edge Cut/Rough Edge (EC/RE) and Buckle (BK) at Embosser Machine

S/N	**Mon**	**EC/RE Affected Coils**	**Actual Cost of Rework of EC/RE (N)**	**Cost of Scrap of EC/RE (N)**	**BK Affected Coils**	**Actual Cost of Rework of BK (N)**	**Cost of Scrap of BK (N)**
1	Jan	2	559,047.64	1,560,000.00	3	838,571.46	2,340,000.00
2	Feb	20	5,590,476.40	15,600,000.00	19	5,310,952.58	14,820,000.00
3	Mar	11	3,074,762.02	8,580,000.00	18	5,031,428.76	14,040,000.00
4	Apr	28	7,826,666.96	21,840,000.00	17	4,751,904.94	13,260,000.00
5	May	24	6,708,571.68	18,720,000.00	22	6,149,524.04	17,160,000.00
6	Jun	21	5,870,000.22	16,720,000.00	11	3,074,762.02	8,580,000.00
7	Jul	20	5,590,476.40	15,600,000.00	18	5,031,428.76	14,040,000.00
8	Aug	26	7,267,619.32	20,280,000.00	18	5,031,428.76	15,040,000.00
9	Sep	12	3,354,285.84	9,360,000.00	20	5,590,496.40	15,600,000.00
10	Oct	15	4,192,857.30	11,700,000.00	10	2,795,238.20	7,300,000.00
11	Nov	30	8,385,714.60	23,400,000.00	15	4,192,857.30	11,700,000.00
12	Dec	20	5,590,476.40	15,600,000.00	28	7,826,666.96	21,840,000.00
	Total	229	64,010,954.78	178,620,000.00	199	55,625,240.18	155,220,000.00

Table 8: Cost Benefits of Rework over Scrap in both Hot Mill Machine and Embosser Machine considering all the Defects

Machine	Defect	Total Cost of Rework(N)	Total Cost of Scrap (N)	Cost Benefits (N)
Hot Mill	OG	5,254,123.4	419,004,075.00	413,749,951.6
Hot Mill	DT	4,905,348.8	391,190,100.00	386,284,751.2
Embosser	EC/RE	64,010,954.78	178,620,000.00	114,609,045.2
Embosser	BK	55,625,240.18	155,220,000.00	99,594,759.82
Embosser	H	2,430,363.42	24,180,000.00	21,749,636.58
Embosser	OG	530,215.92	121,680,000.00	121,149,784.1
Embosser	BB	57,779.94	13,260,000.00	13,202,220.06
Embosser	UG	482,632.44	110,760,000.00	110,277,367.6
Embosser	GV	4,501,316.22	55,380,000.00	50,878,683.78
	Total	137,797,975.30	1,469,294,175	1,300,021,466.94

From table 4 above, a total of 467 coils were reworked as a result of over gauge and 436 coils were reworked as a result of delayed temperature in hot mill machine. In table 5 above, a total of 31 coils were reworked because of holes on them and 71 coils were reworked because of gauge variation in embosser machine. In table 6 above, a total of 156, 17 and 142 coils were reworked in Embosser machine as a result of over gauge, bad build up and under gauge respectively. In table 7 above, 229 and 199 coils were reworked as a result of edge cut and buckle respectively at Embosser machine. Table 8 shows the cost of rework for each defect. From table 8, the edge cut(EC)/rough edge(RE) contributed the highest amount of costs of rework (N64,010,954.78) while bad build up(BB) contributed the lowest amount of costs of rework (N57,779.94). The total cost spent in rework for the year under review as shown in table 8 is N137, 797,975.30. This is the amount of money incurred for not doing things right at the first place in the company under study. This cost of rework analysis has revealed that the company loses money in their production process which ordinarily would have translated to profit due to non conformity of the product being produced the first time with set standards expected. Indeed this analysis has stressed the importance of producing a good quality product the first time without the need for rework.

B. *Comparison of Cost of Rework and Cost of Scrap in Manufacturing Sector*

Fig. 1 shows the total cost of rework and scrap for the defects at Hot Mill and Embosser machine centers. These plots were used to determine the consistencies of individual defect and period of its peak and lowest level for proper analysis and control. This also shows the cost of rework activities and highlights the defect which accrues the highest amount of money for its rework processes based on the number of coils affected for the year under review. the charts further represents a means of advising the company on the need to reduce all activities giving rise to rework and therefore save cost since the individual cost of each defect was calculated as represented above where over gauge defect in H/M constituted the highest cost benefit. Furthermore, the advantages of rework was greatly shown as OG (H/M) had the highest cost benefit over scrap and therefore rework is better at this stage than scrapping. BB (EMB) showed minimal rework cost benefit over scrap because the recovery rate at this point is rather low, hence a need to completely eliminate all defects causing rework at this stage of production.

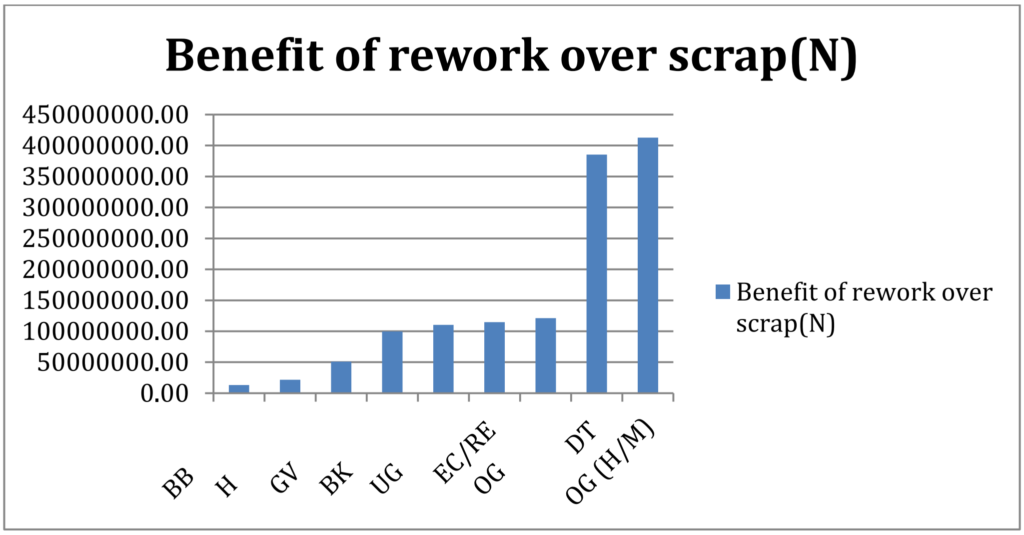

Fig. 1: Cost Benefits of Rework over Scrap for Hot Mill and Embosser Machine

Fig. 2 below shows the cost of rework and the benefit of rework over scrap with a view to presenting the great advantages derived in rework processes instead of scrapping of the coils affected. The immensely ascending nature of benefit of rework over cost of scrap on the above graph clearly represents the need to encourage rework activities where necessary instead of scrapping and loosing the material out rightly. However, Buckle (BK) defect has high cost of rework, which indicates poor rate of returns. Similarly Edge Cut/Rough Edge (EC/RE) defect. This reveals that Bad Build – Up (BB), Hole (H), Gauge Variation (GV), Under Gauge (UG), Over Gauge (OG) and Delay Temperature (DT) defects are projects worth investing upon with the potential of yielding an improved net annual rate of return will be in two columns.

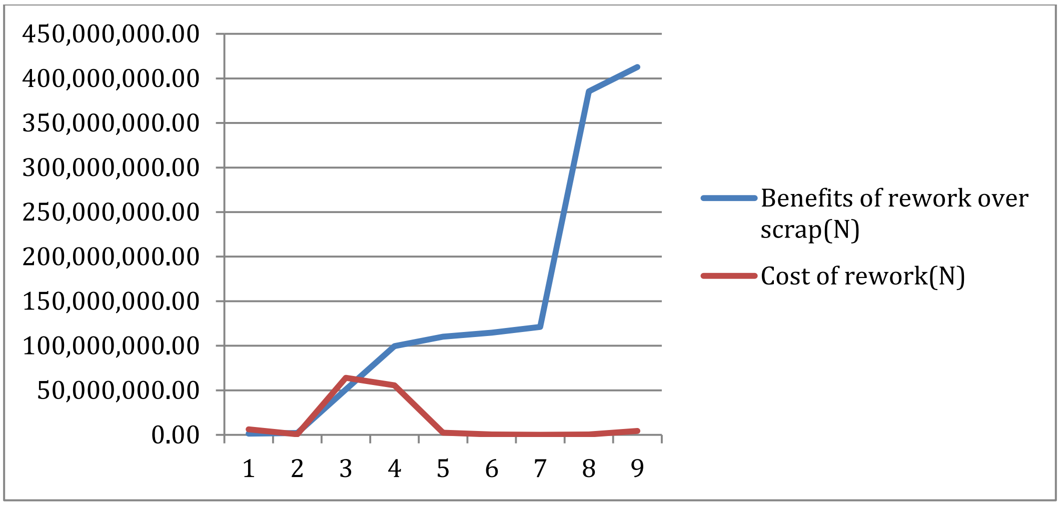

Fig. 2: Benefit of rework over scrap and cost of rework versus defect at Hot Mill and Embosser

IV. CONCLUSION

The research presented in this paper set out to determine the actual costs of rework and scrap in Aluminum industry under study. Two focal points in this study are the cost of rework of affected coils, and cost benefits of rework over scrapping of such affected coils. From the analysis of costs of rework in this company, it revealed that the company spent N137, 797,975.30 on reworking activities in the year under review and scrap value amounts to N1, 469,294,175. From the cost benefit analysis of rework over scrap, there was huge save up to the tune of N 1,300, 021, 466.94 from reworking of defective products when necessary rather than outright scrapping of defective products. So, rather than outright scrapping when there is a defective product, a corrective measure (rework) will be of more economic significant to the company than scrapping.

It is also recommended that Aluminum industries should take the following activities/issues seriously so as to avoid the huge amount of money spend on rework: preventive maintenance, employees training and development, employees incentive and motivation, quality circles, product and service design, purchasing of materials and repair parts. These strategies if properly implemented will help to improve products and process performance in terms of cost, time and quality in manufacturing sector.

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