Autopsy of Ajaokuta Steel Rolling Mills Functioning with Emphasis on Equipment Availability, Performance and Quality Rate

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Abstract. This study investigates the production defectiveness of Ajaokuta Steel Rolling Mills company for twelve months prior to its short down. The causes of low efficiency were identified and solution for improvement were proffered. Also there were provided pieces of advises on how to avert future occurrence of same defectiveness. In Steel Rolling Mills a lot of evident losses were identified in this study. These losses (exactly 16) should be reduced greatly if not eliminated totally in order to improve the production effectiveness. The strategic decisions considered are: equipment availability, performance rate and quality rate. Each of these strategic decisions has its own attributes for computation. The product of these classified strategic decisions formed the Overall Production Effectiveness (OPE). The higher the OPE the better the company's performance while the lesser it is the higher is the Overall Production Defectiveness (OPD). The data of twelve months of the company's performance before short down in 2007 were collected and used to implement the model developed. The result showed that effectiveness of the company was 37% which means the Defectiveness Steel Rolling Mills was 67%. While the provided solutions to the elimination of such a high defectiveness level must decrease loses and increase effectiveness of work. This model will be a good decision tool for determining overall production effectiveness (OPE) as well as overall performance defectiveness (OPD) of a small medium and large scale industry.

Key words: availability, defectiveness, equipment effectiveness, performance rate, quality rate, steel rolling mills.

Introduction

A machine's efficiency is usually expressed as a percentage. Even a simple device, such as a pair of meshed gears, loses energy (about 1 percent) because of friction, and no machine can be 100 percent efficient (Alan, 1992: 79). For any engine, the efficiency is the ratio of the work that is done per cycle to the energy that is extracted as heat from the high temperature reservoir per cycle. The success and performance of an engine or system is measured by its efficiency (Walker et al., 2008: 543-560). Efficiency in all manufacturing industries determines level of performance (Heintz and Saez, 2009: 54-68). There must be means to determine it, though the methods differ from one company to another. In Steel Rolling Mills a lot of losses are evident. Unless these losses are reduced or totally eliminated, production efficiency in Steel Rolling Mills will be inhibited. Currently going through Steel Rolling Mills in Nigeria, performance evaluation tool model is yet to be put in place for performance justification. Some available computations mostly fail to consider all the sixteen losses which were identified in this study. Few considered losses cannot give the optimal effectiveness of machines.

Therefore, a model needs to be developed which will cater for all identified losses and generate optimal Overall Production Effectiveness (OPE) of Steel Rolling Mills. Having this model developed, the performance level of the mills can be justified and management decision is assisted. This is an identified gap in literature. The (OPE) is determined using various production and equipment criteria. The major required parameters include Equipment Availability (EA), Performance Rate (PR) and Quality Rate

(QR) (Akinnuli, 2009: 185-186). Attributes which are responsible for determination of each parameter were identified for the model development and tested using Ajaokuta Steel Company Rolling Mill as a case study.

The History of the Question

Steel Rolling is one of the most important segments of the steel industry (Rajesh, 2007: 69-94). Steel is marketed in a wide variety of sizes and shapes, such as rods, pipes, railroad rails, tees, channels, and I-beams. These shapes are produced at steel mills by rolling and otherwise forming heated ingots to the required shape. The working of steel mills also improves the quality of the steel by refining its crystalline structure and making the metal tougher. The production process of steel into the aforementioned sizes and shapes was carried out in the steel Rolling Mills (Glenn, 2009: 78-87).

The literature review of this study covered: the historical background of rolling mills, development of rolling mills to date, study of Nigeria rolling mills (Oyebanji and Oluwole, 1971), survey of Ajaokuta steel plant rolling mills, survey related developed models for rolling mills efficiency determination and contribution of computer system to model development. Table 1 shows the summary of some authors' works on the question and their respective contributions which were used in this research study.

Table 1. Summary of the ideas of chosen authors and their contributions into the history of the question under consideration

S/N	Author	Year	Contributions
1	Akinnuli	2009	Wrote on model development for machinery evaluation in manufacturing industries.
2	Allen	2009	Manufacturing process of iron and steel/theory of steel rolling.
3	Jennifer and Semuel	1999	Various means of improving production efficiency.
4	Maxwell	1982	Steel plant technological development: a need for Ajaokuta Steel Company in Nigeria.
5	Oyebanji and Oluwole	1971	Historical development of rolling mills.
6	Rajesh	2007	Worked on energy efficiency in rolling mills.
7	Redmond	2007	Meanings and definitions of efficiency.
8	Schroder	2003	Machine efficiency determination.
9	Schroder	2003	Mechanics of rolling mills and various material requirements for rolling mill rods.
10	Snehil	2004	Various maintenance strategies for improving production efficiency in industries.
11	Heintz and Saez	2009	Status of Ajaokuta Steel Company and other rolling mills in Nigeria
	Umunnakwe,	2010	
12	Schroder	2003	Gave account of Leonarate da uinc as Rolling Mills in 19th century. And how Americans developed on this invention in half of 20th century.

The goal was and continues to be the reduction of energy, man power, financial investment, etc., thereby lowering production costs but at the same time increasingly yield (relation of weight of good finished strip to weight of material before rolling) and strip quality (Schroder, 2003).

Ajaokuta steel company in glance (case study)

The operations at Ajaokuta Steel Company are straight forward. The raw materials section consists mainly of open yards and silos to store the ores, coal, lime, etc. A plethora of separators, crushes, and sieves remove unwanted foreign matter, size the output and segregate the materials before sending them to process units. To prepare coke, the plant has 49 ovens for each of two oven batteries (5.5m high, with a useful volume of 30.3 m^3). The capacity of the batteries is 9.0 x 105 t/year. The sintering plant has two machines to produce 100% self – fluxed sinter (2.64 x 106 t/year). The plant is part of raw materials' preparation and designed to use iron ore from the Itakpe mines.

Iron-making is a single blast furnace, 2.0 x 103 m^3 capacity. It has been adapted with facilities for natural gas injection to reduce coke consumption. This produces pig iron, 1.5 x 105 t annually for use in foundries while the remaining molten iron is sent to the steel shop. The 5 x 105 t of slag produced annually as by – product is used in cement. The steel making shop consists of two Linz-Donawitz (LD) converters of 130t capacity each, three two strand continuous machines, and the lime shop. There are four rolling mills in Ajaokuta steel company, these are; 320 mm light section mill (LSM);150 mm wire-rod mill (WRM); 900/63 mm billet mill (BM) and 700mm medium section and structural mill (MSSM).

The Greenfield nature of the plant, the unreliability of public utilities and the dearth of small–scale suppliers in the immediate environment of the plant meant that the development of the steel works had to include special provisions for spare parts manufacturing facilities, power plants, etc. Prominent among the facilities for Ajaokuta were a comprehensive repair complex with its own Foundry, forge shop, and Heat Treatment and Hard Surfacing Shops; a Thermal Power Plant (TPP) and Turbo Blower station; an Oxygen Plant; Refractory Shops and a Lime Plant and laboratories and transport facilities. In addition, are facilities generally referred to as the external infrastructure, made up of railways, roads, port facilities and electric power systems. For example, there was a proposal to construct a line from Onne port through Port Harcourt to Ajaokuta, although it was shelved for financial reasons. A lime between Itakpe and Ajaokuta was created to carry Iron ore; and the line running from Obi through Lafia and Makurdi is to carry local coal (Umunnakwe, 2010: 2-11).

Evaluation improvement of production productivity performance was researched by Azizi (2015: 182-190), using statistical process control, overall equipment efficiency and autonomous maintenance. Raguram (2014) applied overall equipment effectiveness OEE for decision making while Puvanazvaran et al. (2013) made consideration in overall equipment effectiveness on equipment with constant process time. Review of study of improvement of overall equipment effectiveness in construction equipment was done by Ayane and Gudadhe (2015: 487-490). While Nayak et al., (2013: 54-62) evaluate OEE in a continue process industry on an insulation line in a cable manufacturing unit. While Baluch et al., (2012: 733-743) measuring overall equipment effectiveness in Malaysian Oil Mills. The Ajaokuta Steel Company Rolling Mills Production Statistics from Commissioning till Date when production stopped finally is shown in table 2.

Table 2. The production details of both LSM and WRM at Ajaokuta Steel Company between 1983 and 2007

S/N	Year	WRM (Mt)	LSM (Mt)	Total (Mt)
1	1983	Nil	3,983	3,983
2	1984	14,239	9,415	23,654
3	1985	15,805	8,782	24,587
4	1986	28,825	68,960	97,785
5	1987	16,270	7,892	23,962
6	1988	5,456	10,008	15,464
7	2004	730	Nil	730
8	2005	40,112	39,387	79,499
9	2006	65,848	77,603	143,452
10	2007	8,029	33,035	41,064

Source: (Umunnakwe, 2010: 8).

Ajaokuta plant that was programmed to last five/ six years lingered, limped and repeatedly got grounded over the period. Hence, autopsy of the plant is required.

The historical development of Nigeria Steel industry can be found in Ojobor and Ugwunwa (1986) while information on the Nigeria Steel Development Authority (NSDA) can be found in Umunnakwe, (2010).

Material and Methods

The methodology under this research work covered the identified criteria for steel rolling mills production effectiveness, mathematical model developed for each criterion, integrated flow chart required for software development, the software development and applications of the developed software.

Criteria for steel rolling mills' production efficiency determination: the development of empirical model for determining overall production effectiveness in steel rolling mills was obtained using the identified sixteen major losses that affect, the effectiveness of production in the rolling mills. The sixteen major losses were summarized thus:

1. Seven Major Losses that can Equipment Efficient (Oyebanji and Oluwole, 1971)
1.1. Failure loss.
1.2. Setup/Adjustment loss.
1.3. Sharing tool loss.
1.4. Start up loss.
1.5. Minor Stoppage/Idling loss.
1.6. Speed loss.
1.7. Defect and Rework loss.
2. Loss that can impede machine loading time (Alan, 1992: 79)
2.1. Shutdown loss.
3. Loss that can be impede human working efficiency (Rajesh, 2007: 69-94)
3.1. Management loss.
3.2. Motion loss.
3.3. Line organization losses.
3.4. Failure to automate/logistics loss.
3.5. Measurement and adjustment loss.
4. Loss that impede Effective use of production resources.
4.1. Yield loss.

4.2. Energy loss.
4.3. Tackle loss.

They were found hampering the production of manufacturing industries and were used as criteria for effective production determination in Steel Rolling Mills and these losses impedes: equipment effectiveness, machine loading time, effective use of production resources and human work efficiency.

Nomenclature

EA =Equipment Availability
PR =Performance Rate
QR = Quality Rate
OPE = Overall Production Efficiency
L_h =Loading Hours
D_t =Down Time
P_u =Processed Units
D_u =Defective Units
A_{pr}=Actual Production Rate
D_c = Design Capacity of Shop.

Used model for Equipment Availability (EA), Performance Rate (PR) Quality Rate, (QR) Overall Production Effectiveness (OPE), Overall Production Defectiveness (OPD) are shown in equations: 1,2,3,4 and 5 respectively.

$$\text{Equipment availability:} (\mathrm{EA}) = \frac{\mathrm{Lh - Dt}}{\mathrm{Lh}} \qquad (1)$$

$$\text{Performance Rate: } (\mathrm{PR}) = \frac{Apr}{Dc} \qquad (2)$$

$$\text{Quality Rate: } (\mathrm{QR}) = \frac{Pu - Du}{Pu} \qquad (3)$$

The product of equation 1, 2, 3 gave the Overall Production Effectiveness (OPE) as shown in equation 4 written below.

$$\mathrm{OPE} = \mathrm{EA} \times \mathrm{PR} \times \mathrm{QR} \times 100 \qquad (4)$$

The overall defectiveness of the Steel Rolling Mills (OPD) is determined using equation 5

$$\mathrm{OPD} = 100 - \mathrm{OPE} \qquad (5)$$

The data collected for implementation of the models developed are shown in Table 3

Table 3. Collected data for model implementation

Month/Year	D_t (min)	L_h (min)	A_{pr} (mt/Hr)	D_c (mt/Hr)	P_u (mt)	D_u (mt)
June, 2006	6945	43,200	32	55	30240	262
July, 2006	6385	44,640	32	55	24500	207
August, 2006	9901	44,640	32	55	18334	178
September, 2006	17715	43,200	22	55	9400	180
October, 2006	13450	44,640	29.7	55	49.99	162
November, 2006	9499	43200	32	55	18334	178
December, 2006	10,100	44,640	32	55	9400	180
January, 2007	8,050	44,640	32	55	18334	178
February, 2007	11,110	40,320	29.7	55	18334	178
March, 2007	14,050	44,640	22	55	18334	178
April, 2007	15,550	43,200	22	55	30240	262
May, 2007	26059	44,640	22	55	4999	162

The data in Table 3 were used to compute the monthly equipment availability, performance rate, quality rate, overall production effectiveness as well as the overall production defectiveness.

Results

The results to these computations are shown in Table 4.

Table 4. Overall production effectiveness (OPE) and defectiveness (OPD) result based on 12 months' data collected

Month June 2006 to min May 2007	**Down Time (Dt) min**	**LH Lh** $(\frac{Lh-Dt}{Lh})$	**EA**	**PR** $(\frac{Apr}{Dc})$	**QR** $(\frac{Pu-Du}{Pu})$	**OPE** $\left(\frac{EAxPRx}{QRx100}\right)$	**OPD** $(100xOPE)$	**Remark**
June	6.94	43.200	0.84	0.58	0.98	47.75	52.25	Poor
July	6.385	44.640	0.86	0.58	0.99	49.38	50.62	Poor
August	9.901	44.460	0.78	0.58	0.99	44.79	55.21	Poor
September	17.715	43.200	0.58	0.40	0.98	22.74	77.26	Very poor
October	13.450	44.640	0.69	0.54	0.97	36.60	63.40	Very poor
November	9.499	43.200	0.78	0.58	0.99	44.78	55.22	Poor
December	10.100	44.640	0.77	0.58	0.98	43.77	56.23	Poor
January	8.050	44.640	0.82	0.58	0.99	47.06	52.94	Poor
February	11.110	40.320	0.72	0.54	0.99	38.49	61.51	Very poor
March	14.050	44.640	0.68	0.40	0.99	26.93	73.07	Very poor
April	15.550	43.200	0.64	0.40	0.98	25.09	74.91	Very poor
May	26.059	44.640	0.41	0.40	0.97	16.15	83.85	Very poor
AVERAGE	14881 4/12= **12.401**	52560 0/12= **43.800**	8.57/ 12= **0.71**	6.16/ 12= **0.51**	11.8/ 12= **0.98**	443.53/12 =**36.96**	756.47/12 =**63.04**	

Dynamics of Overall Production Effectiveness (OPE) and Overall Production Defectiveness (OPD) is shown as a graph in the fig.1 given below.

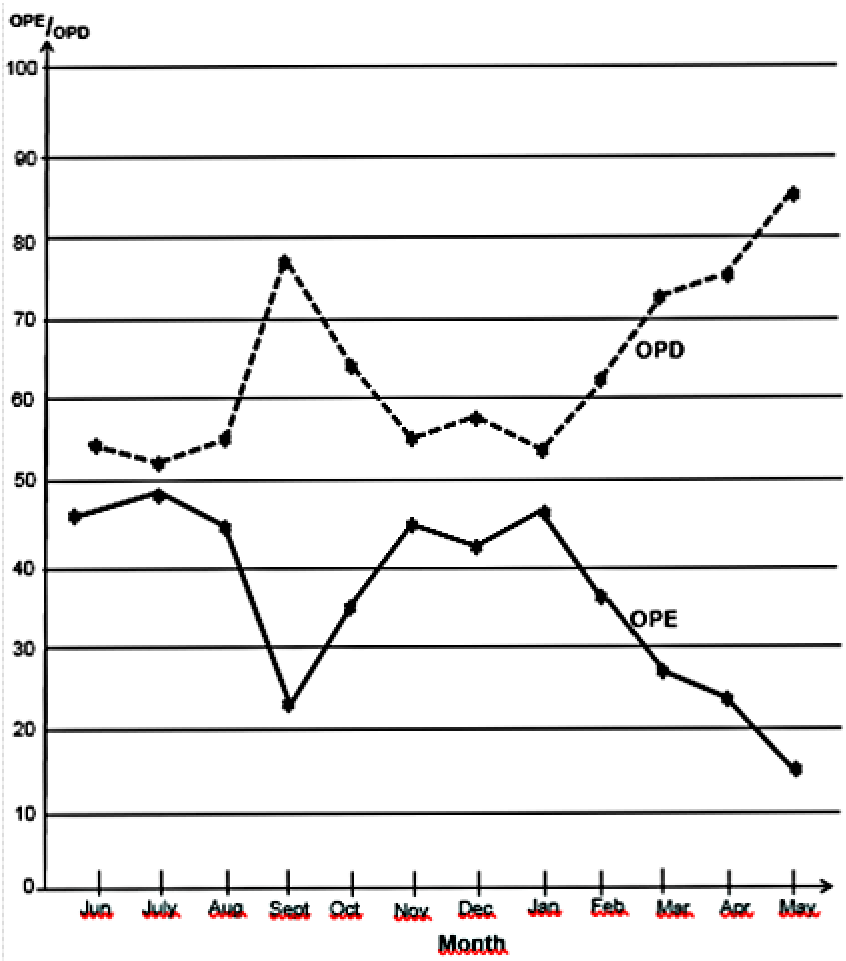

Fig. 1. Graph of Overall Production Effectiveness (OPE) and Overall Production Defectiveness (OPD)

The performance of each of the Strategic decisions from Table 4 (EA, PR and QR, also OPE and OPD) is shown in the figure 2.

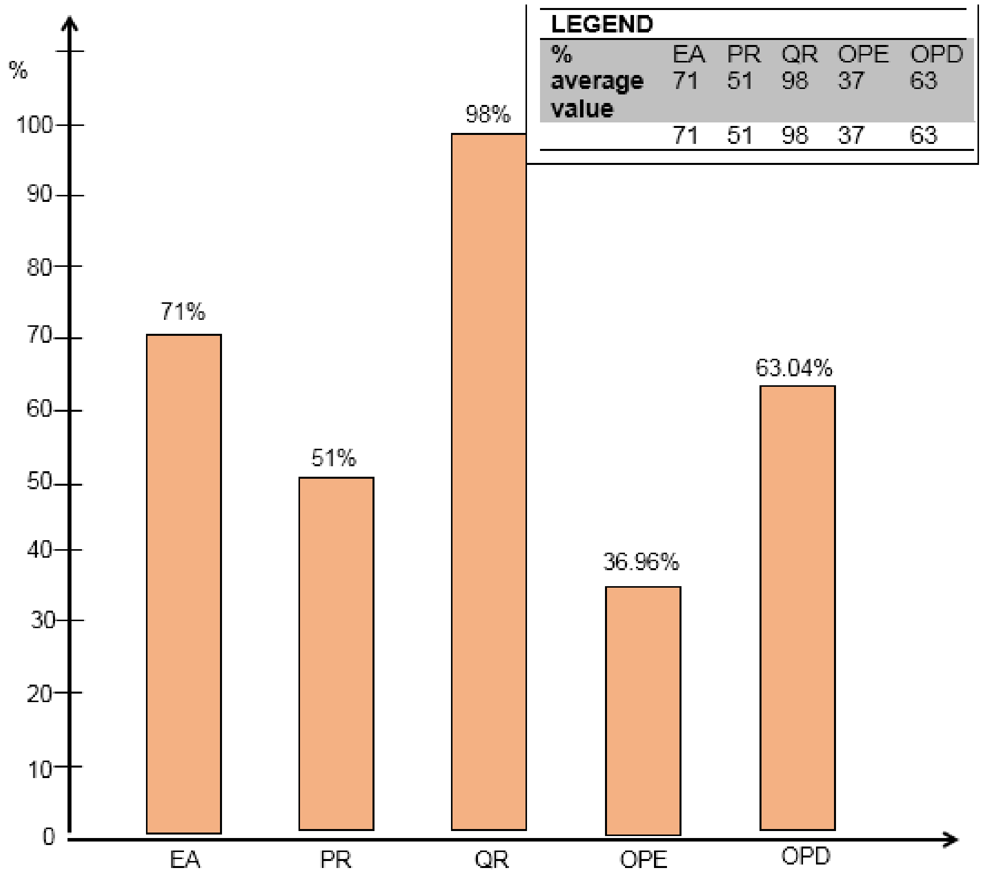

Fig. 2. The performance of each of the Strategic decisions from Table 4

By reasons of the remarks on Table 4, the Rolling mills had not been performing well. The defectiveness was greater than its effectiveness. The OPD graph is far above the OPE graph in figure 2. To show good and promising results OPE graph should be above OPD graph. Thus proofed that the company is only struggling to survive and find it difficult to breakthrough. The average performance of "EA" is fear 71 % and that of QR is very good 98 % but "PR" very poor 51 % it has negative effect on the other two strategic decisions "EA" and QR. Its effect brought down OPE to 36.96 ~ 37 % and this made OPD to increase to 63 %. In order to improve on "PR", its attributes for computation needs to be addressed that is Actual Production Rate (Apr) compared with the Designed capacity 'Dc. the higher the actual production rate the better the (PR). This result gotten from this study is an evidence of underutilization of the facilities. The average down time of (Dt) was 12,401 mins per month. This is too much, it has equivalent of 8 days and 6 hours per month. In order to improve on this, the attributes to down-time needs to be addressed. These are losses that must be reduced, that is, the sixteen losses summed up to determine the down time.

Conclusion

This study had identified the sixteen losses that has negative effect on the production level of Steel Rolling Mills ascertained the strategic decisions that can be used to compute the overall effectiveness and used it to determine the overall defectiveness of the Steel Rolling Mills. The models proofed Ajaokuta Steel Rolling to be 37 % Overall Production Effectiveness (OPE) and 63 % Overall Production Defective (OPD). The study strongly recommends great improvement on performance rate (PR) by reducing the down time 'Dt' of Ajaokuta Steel Rolling Mills. Software to this model needs to be developed for easy computation, reduction of drudgery and results delivered at a very short time.

This model will be a good decision tool for determining overall production effectiveness (OPE) as well as overall performance defectiveness (OPD) of a small medium and large scale industry.

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