Study Impact of Overall Equipment and Resource Effectiveness onto Cement Industry

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Abstract

The existence and development of an organization relies on the employment level of equipment and obtainable resources. Whole the resources as worker, equipment, and raw material are to be employed to the level of manufacture criterion, Also the potential impact this relationship may have on decision-making that contributes to improve the productivity of the manufacturing organization. This research aims to employ two operation performance indicators: overall equipment and resource effectiveness to study impact them onto manufacturing system. AL-Kufa /Iraq Cement plant is employed as a case study, also Bar chart tool is used to assess present results. Results are generated using Minitab Version 17. Results show that finish grinding process has lowest factors of performance, quality rate, availability of material, readiness, and availability of facility which lead to reduce OEE and ORE performance indicators of 65.02 % and 15.45%.

Keywords: OEE, ORE, Performance indicators, Equipment, Resource.

الخلاصة

يعتمد وجود المنظمة وتنميتها على مستوى توظيف المعدات والموارد المتوفرة. جميع الموارد مثل العامل، المعدة، والمواد الاولية سيتم توظيفها إلى مستوى التصنيع المعياري، كذلك قد تكون لهذه العلاقة امكانية التأثير على اتخاذ القرار الذي يسهم في تحسين إنتاجية منظمة التصنيع. تم توظيف مصنع سمنت الكوفة/العراق كحالة دراسية كما تم استخدام مخطط بار لتقييم النتائج الحالية. تم توليد النتائج باستخدام برنامج Minitab الإصدار 17. تظهر النتائج أن عملية الطحن النهائي لها أدنى قيمة لعوامل الأداء،معدل الجودة، توافر المواد، الجاهزية، وتوافر التسهيلات التي تؤدي إلى خفض مؤشرات الاداء لفاعلية المعدات والموارد الكلية الى النسب 65.02 % ، 15.45 %.

الكلمات المفتاحية :- فاعلية المعدات الكلية ، فاعلية الموارد الكلية ، مؤشرات الاداء ، المعدات، الموارد .

1.Introduction

Key Performance Indicators (KPIs) or also known as Key Success Indicators (KSI) is a quantitative measurement tool for the improvement of the performance of an activity that is becoming a key factor in the success of an organization **(Chris , 2000)**. KPI presents a set of measures that focus on aspects of organizational performance is the most important thing for the success of the organization at this time as well as for the future **(Yoniv , 2016)**. An OEE performance indicator of a machine plays an important role in present industrial scenario where customers are more concerned with timely delivery and quality of the product or service **(Harsha , 2009)**. The OEE performance indicator provides a way to measure the effectiveness of manufacturing operations from a single piece of equipment to an entire manufacturing **(Bangar , 2013)**.The OEE performance indicator also plays its vital role in developing collaboration between operations, maintenance and equipment engineering to identify and eliminate the major reasons for poor performance **(Kalpande , 2014)**. ORE performance indicator is the measure of overall effective time of the manufacturing system (resources). Overall Resource Effectiveness is the only approach that takes a holistic view of manufacturing and production. It incorporates manufacturing losses, maintenance losses, productivity issues, planning issues and system issues **(Subramaniam , 2011)**. The aim of this research is to study the effect of overall equipment and resource onto manufacturing system. The next paragraph presents theoretical background, global interest in OEE and ORE performance indicators, and bar tool,. This paragraph is followed by data collected from Al-Kufa Cement plant in 2015 as a case study. These data are further analyzed, two key performance indicators are employed to quantify throughout different processing activities. The last paragraph is summarizing conclusions; also recommendations for future work are reported.

2. Theoretical Background

2.1 Overall Equipment Effectiveness

The concept of overall equipment effectiveness (OEE) is a measure of TPM to evaluate the effectiveness of equipment. OEE measurement reveals the hidden costs that causes a considerable amount of production loss. The OEE consists of three parameters are availability, performance and quality. It can be calculated as follows **(Nguyen, 2011)**:

$$\textbf{OEE} = \textbf{Availability} \times \textbf{Performance} \times \textbf{Quality} \tag{1}$$

2.1.1 Availability

Availability is the percentage of time that machines are available for scheduled production compared with the amount of time they were actually producing. Scheduled maintenance, planned downtime events, or equipment trials are not considered to be part of the time that machines are available for production. This allows a plant manager to readily identify whether machine downtime issues are part of a known calendar, or if there is a more serious problem, as follows (**Kalpande , 2014**):

$$\textbf{Availability} = \frac{\textbf{Run Time}}{\textbf{Total Time}} \tag{2}$$

2.1.2 Performance

Percentage of total parts produced on the machine to the production rate of the machine. Performance compares the theoretical machine rate with the number of items actually produced on a machine during its operating time. The Performance allows a facility to compare availability downtime with. This can show whether a specific plant is having problems due to low output, or if the problem is excess downtime. In addition, if a machine is recurring efficiency issues, performance measurements can indicate problems with the machine itself, rather than an operator issue, calculated as follows (**Kalpande, 2014**).

$$\textbf{Performance} = \frac{\textbf{Total Count}}{\textbf{Target Counter}} \tag{3}$$

2.1.3 Quality

Quality is a continuous development and improvement. This allows a plant manager to compare consistency between individual machines and, in turn, allows for comparisons between different manufacturers, as well as machine, specifications, and even individual operators. Quality is calculated as follows **[Fabio, 2013]**.

$$\text{Quality} = \frac{\textbf{Good Count}}{\textbf{Total Count}} \quad \textbf{(4)}$$

2.2 Evaluation of Overall Resource Effectiveness (ORE)

The “Overall Resource Effectiveness (ORE)” will be much helpful to the decision maker for further analysis and continually improve the performance of the resources. This is used to identify the current status of manufacturing system and also for benchmarking the manufacturing effectiveness with the World class standard to become a world class organization. ORE is the measure of overall effective time of the manufacturing system (resources). ORE is calculated as follows **[Braglia, 2008]**.

$$\mathbf{ORE = R \times A_f \times C \times A_m \times A_{mp} \times P \times Q \times 100} \quad \textbf{(5)}$$

2.2.1 Readiness (R)

The “Readiness (R)” measure is concerned with the total time that the system is not ready for operation because of planned downtime due to preparatory/ planned activities. Readiness is calculated as follows **(Karuppana, 2013)**.

$$\textbf{Readiness (R)} = \frac{\textbf{Planned Production Time}}{\textbf{Total Time}} \quad \textbf{(6)}$$

Total time = Shift time or period decided by the management
Planned production time = (Total time-Planned down time)

Planned down time includes:

- Preparatory work like cleaning, inspection of machine, initial part inspection, lubrication, tightening, Data collection and updating.
- Meeting, Audit, operator training, Proto sample processing for R and D requirements, Process engineering study.

2.2.2 Availability of Facility (Af)

The “Availability of Facility (Af)” measure is concerned with the total time that the system is not operating due to downtime of facilities. Availability of the facility is calculated as follows **(Garza, 2008)**.

$$\textbf{Availability of Facility } (\mathbf{A_f}) = \frac{\textbf{Loading Time}}{\textbf{Planned Production Time}} \quad \textbf{(7)}$$

Loading time = Planned production time-Facilities down time

Facilities down time includes:

- Downtime of machine and its accessories
- Non-availability of tools, jigs and fixtures
- Non-availability of gauges and instruments, test rigs related to facility

2.2.3 Changeover Efficiency (C)

The Changeover Efficiency (C) measure is concerned with the total time that the system is not operating because of Set-up and adjustments. Changeover efficiency is calculated as follows **(Braglia, 2008)**.

$$\textbf{Changeover Efficiency (C)} = \frac{\textbf{Operating Time}}{\textbf{Loading Time}} \qquad \textbf{(8)}$$

Operation time = Loading time-Set-up and adjustments.

Set-up and adjustments include:

- Changeover time of tools, dies, jigs and fixtures
- Minor adjustments after the changeover

2.2.4 Availability of Material (Am)

In manufacturing scenario, sometimes, the raw materials, components, sub-assembliesare not available due to shortages and various other reasons. The “Availability of Material (Am)” measure is concerned with the total time that the system is not operating because of material shortages. Availability of material is calculated as follows **(Karuppana , 2013)**.

$$\textbf{Availability of Material } (\mathbf{A_m}) = \frac{\textbf{Running Time}}{\textbf{Operating Time}} \qquad \textbf{(9)}$$

Running time = Operation time-Material shortages.

Material shortage includes:

- Non-availability of raw materials, consumables, parts and sub-assemblies
- Non-availability of WIP

2.2.5 Availability of Manpower (Amp)

In manufacturing system, sometimes, the operator/s may not be available at work station due to absenteeism, discussions. The “Availability of Manpower (Amp)” measure is concerned with the total time that the system is not operating because of absence of manpower. Availability of manpower is calculated as follows **(Garza, 2008)**.

$$\textbf{Availability of Manpower } (\mathbf{A_{mp}}) = \frac{\textbf{Actual Running Time}}{\textbf{Running Time}} \qquad \textbf{(10)}$$

Actual Running time = Running time-Manpower absence time.

Man’s power absence includes:

- Permission, Leave and absenteeism
- Discussion with supervisor, team leader
- Medical related

2.2.6 Performance Efficiency (P)

The “Performance efficiency (P)” measures the total time that the operator how efficiently utilizes. It is the time earned in producing the product as against the Actual running time. Performance efficiency is calculated as follows **(Braglia, 2008)**.

$$\textbf{Earned Time} = \frac{\textbf{Cycle Time}}{\textbf{Unit X Quantity Produced}} \quad \textbf{(11)}$$

$$\textbf{Performance Efficiency (P)} = \frac{\textbf{Earned Time}}{\textbf{Actual Running Time}} \quad \textbf{(12)}$$

2.2.7 Quality Rate (Q)

The “Quality rate” is the rate of quality products produced by the system. Quality rateing is calculated as follows **(Karuppana, 2013)**.

Quantity of parts accepted = Quantity produced-Quantity rejected **(13)**

$$\textbf{Quality Rate (Q)} = \frac{\textbf{Quantity of Parts Accepted}}{\textbf{Quantity of Parts Produced}} \quad \textbf{(14)}$$

3. Literature survey

Due to it, is closely circulation in industrial employ and effectiveness as a performance measure for individual resource and equipment. More researchers have attempted to extend the implementation field of OEE and ORE to whole manufacturing processes, workshops, and plants . In addition, its evaluating field has also been extended throughout the implying of further detailed factors of performance than just availability, performance and quality.

(Garza-Reyes, 2010) Defined overall equipment effectiveness (OEE) that is a quantitative metric that endeavors to identify indirect and “hidden” productivity and quality costs, in the form of production losses.

Subramaniam *et.al.*, 2011)Studied automotive component unit which is not able to meet the demand because of sudden increase in requirement. Their aimed to improve overall resource effectiveness of the organization using industrial engineering tools with minimum possible additional investments. They used ERP, Ergonomics study, Poka Yoke. Their results all the bottleneck areas have been identified and simple solutions provided for the problems.

(Karuppana and Pidugun , 2013) proposed method of effectiveness calculation differs from the existing one and new factors known as Readiness, Availability of Facility, Changeover Efficiency, Availability of Material, Availability of Man power are included in the calculation. Their results modified term Overall Equipment Effectiveness (OEE) into term Overall Resource Effectiveness (ORE) since the new methodology addresses the losses associated with the resources (man, machine, material, method) individually. Inclusion of these new factors, enable us to more detailed and stratified classification of the resource losses.

(Raghuram , 2014) shown that OEE of a CNC machine has increased from 75% to 79% by the implementation of TPM tools in an Indian based fastener company which uses a powder metallurgy process for the production of components that are used in transmission systems. They concluded that OEE can be improved by the reduction in downtime which can be achieved by carrying out the preventive maintenance at regular intervals.

(Vijayakumar and Gajendran, 2014) shown that OEE of the injection moulding machine in an Indian based automobile manufacturing sector has increased from 61% to 81% through the implementation of TPM.

(Chen *et.al.*, 2015) proposed a set of novel indices for Overall Resource Effectiveness (ORE) and drive various improvement directions for total resource management. A number of case studies are reviewed for illustration, while the proposed methodology is extended for medical instrument for cross validation. Their results have showed practical viability of the proposed ORE to drive collaborative efforts to enhance total productivity and overall resource effectiveness.

(Ramachandra *et.al*, 2016)studied the measurement of effectiveness of TPM implementation in manufacturing and service industries. Their results shown TPM increases the availability, performance rate and the quality rate and thereby results in the improvement of the overall equipment effectiveness of the equipment.

4. Case Study

There are (21) factories of Cement in Iraq, of production approximately (12 million) Tons on 2015 year, while the local demand is (18) million Tons per year. AL-Kufa Cement Plant is one of these plants that produce different types of Cement such as ordinary, sulphate resistant (currently is producing sulphate resistant) throughout wet process as this plant suffers from reduction of equipment and resource effectiveness, therefore manufacturing system activities are considered.. Flow diagram of AL- Kufa Cement plant and brief description of each process are shown in Figure (1) and table (1).

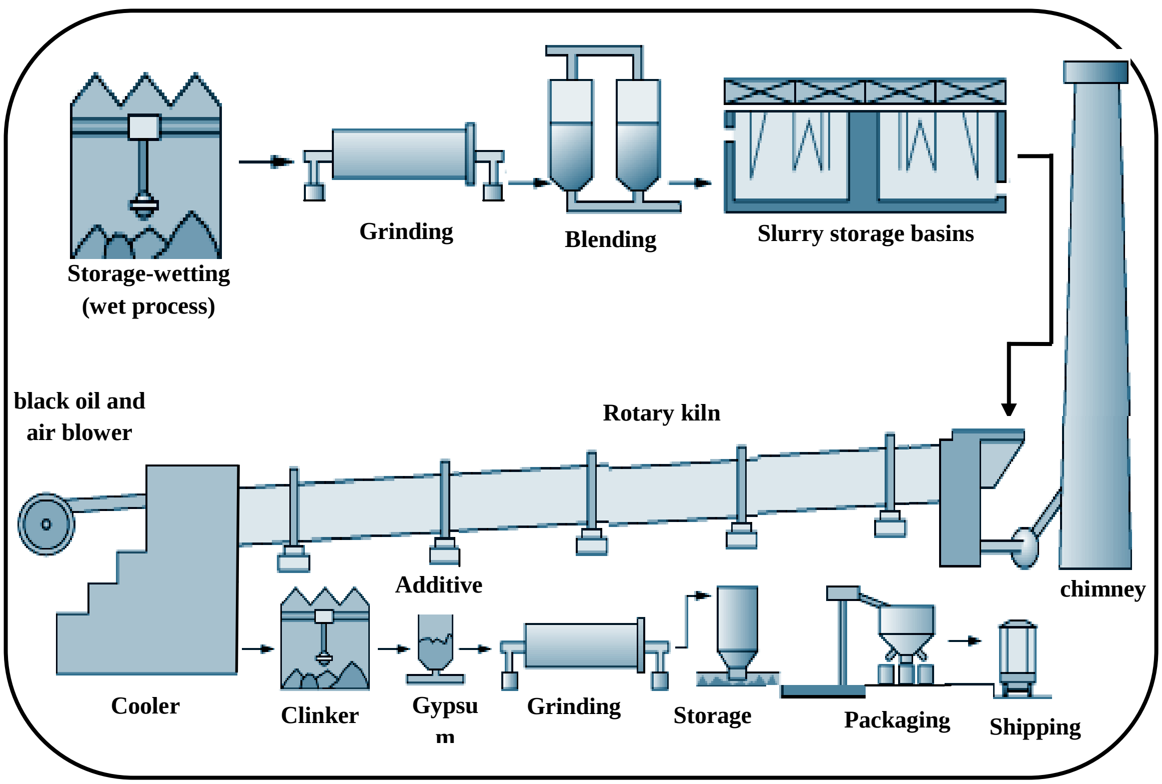

Figure (1) AL-kufa cement plant (wet process)

Table (1) Brief Description of Al-Kufa Wet Cement Manufacturing

Process	Process Descriptión
1- Grinding and blending	Limestone, Clay, Sand, Iron Ore and Water are entered to grinding and blending machine with a particular percentage for each it to obtain wet slurry.
2- Kiln production and cooling	Wet slurry is fed to the rotary kiln to obtain Clinker that is passed through cooling system to reduce temperature up to 150 C^o.
3 - Finish grinding	Clinker with a particular percentage of Gypsum is fed to finish milling so as to obtain cement that is pumped to the packaging silos in order to be distributed.
4 - Packaging	Packaging system consists of seven filling machines, one for bulking and rest for packaging, each machine consists of many pipes move with rotary to package cement inside the paper bag with 50 kg or supplier cars.

5. Data collection, Anylsis and Discussion

Key Performance Indicators (KPI) are employed; two operational overall equipment and resource effectiveness.

5.1 Overall Equipment Effectiveness (OEE)

The collected information about manufacturing processes of cement is used to analyse the Overall Equipment Effectiveness (OEE) for one month in year 2015, which change with the different values of variables for each of availability, performance and quality. In our work here, the Overall Equipment Effectiveness, a widely adopted and proven metric is used to monitor the efficiency of manufacturing processes of cement. The factors availability, perfomance, quality and OEE of manufacturing activities for January month on year 2015 is calculated using the equations (1, 2, 3, and 4) respectively, and results of OEE are collected in table (2).

Table (2) Individual Result of OEE Through January 2015

No.	Process / Factors	Grinding and blending	Kiln production and cooling	Finish grinding	Packaging
1	Change over time (min)	8	15	5	30
2	Down time (min)	5	4	5	1.6
3	Working hours (min)	1440	1440	1440	480
4	Rate of breaks (min)	688	551	1107	363
5	Number of operators	109	163	83	69
6	Run time	744	874	328	87
7	total time	757	893	338	118.6
8	cycle time	25	150	17	1.6
9	Target counter	30.28	5.95	19.88	74.13
10	performance loss rate %	28.95	24.07	29.47	2.28
11	total count	21.51	4.52	14.02	72.44
12	defective rate %	1	4	5	1.5
13	good count	21.29	4.34	13.32	71.35
14	Availability %	98.28	97.87	97.04	73.36

15	Perfomance %	71.04	75.97	70.52	97.72
16	Quality %	98.98	96.02	95.01	98.50
17	Overall equipment effectiveness %	69.12	71.47	65.02	70.61

5. 2 Overall Resource Effectiveness (ORE)

Overall Resource Effectiveness classifies into seven factors to improve activities towards enhancing the overall performance of the manufacturing resources for each category of losses and thus achieve the business excellence by effective utilization of the manufacturing activities. The factors readiness, availability of facilities, changeover efficiency, availability of material, availability of manpower, performance efficiency, quality rate and ORE of manufacturing activities for January month on year 2015 is calculated using the equations (5, 6, 7, 8, 9, 10, 11, 12, 13, and 14). To evaluate ORE, the data required are collected from manufacturing line as shown in table (3).

Table (3) Individual Results of ORE Through January for 2015

No.	factor \ Process	Grinding and blending	Kiln production and cooling	Finish grinding	Packaging
1	Total time (min)	1440	1440	1440	480
2	Planned downtime (min)	227	182	365	120
3	Planned production time (min)	1213	1285	1074	360
4	Readiness %	84.24	87.36	74.65	75.00
5	Facilities downtime (min)	151	121	244	80
6	Loading time (min)	1062	1164	830	280
7	Availability of facility %	87.55	90.58	77.28	77.77
8	Setup and adjustment time (min)	69	55	111	36
9	Operating time (min)	993	1109	719	244
10	Changeover efficiency %	93.50	95.27	86.63	87.14
11	Material non availability time (min)	193	154	310	102
12	Running time (min)	800	955	409	142
13	Availability of material %	80.56	86.11	56.88	58.20
14	Manpower non availability time (min)	48	39	77	25
15	Actual running time (min)	752	916	332	117
16	Availability of manpower %	94.00	95.92	81.17	82.39
17	Quantity produced (unit)	21.37	4.64	13.77	71.46
18	Cycle time (min)	25	150	17	1.6
19	Earned time (min)	534	696	234	114
21	Performance efficiency %	71.01	75.98	70.48	97.44
22	Accepted quantity (unit)	21.16	4.45	13.08	70.39
23	Quality rate %	99.02	99.78	94.99	98.50
24	Overall resource effectiveness %	36.72	47.21	15.45	23.39

6. Assessment of Operational Performance measurements

6.1 Overall Equipment Effectiveness (OEE)

OEE performance indicator is considered standard approach to measure equipment performance and assess some losses in a manufacturing system. From table (2) for January month on year 2015, Bar chart is used to show the relative size of weighting factors of OEE performance indicator according to manufacturing processes as shown in figure (2). This figure illustrates that finish grinding process has a minor OEE performance indicator of (65.02 %), while kiln production and cooling process has a major OEE performance indicator of (71.47 %). Also, finish grinding process has a minor performance factor of (70.52 %), for January month on year 2015. This minor performance leads to minor OEE performance indicator.

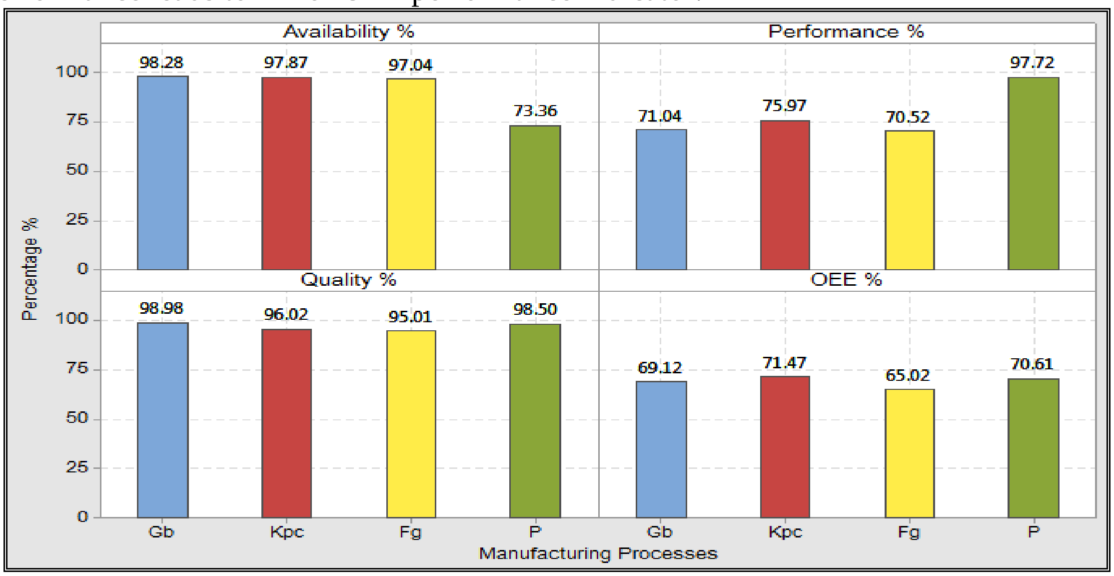

Figure (2) Effect of Manufacturing Processes onto OEE Through January Month-2015

6.2 Overall Resource Effectiveness (ORE)

ORE performance indicator is more effective standard approach from OEE performance indicator to assess losses in a manufacturing system. From table (3) for January month on year 2015, Bar chart is used to show the relative size of weighting factors of ORE and ORE performance indicators according to manufacturing processes as shown in Figure (3). This figure illustrates that finish grinding process has a minor ORE performance indicator of (15.45 %) for January month on year 2015,whereas the kiln production and cooling process has a major ORE performance indicator of (47.21 %). Due to, finish grinding process has the lowest factors of quality rate, availability of material, readiness, and availability of facility which lead to reduce ORE performance indicator.

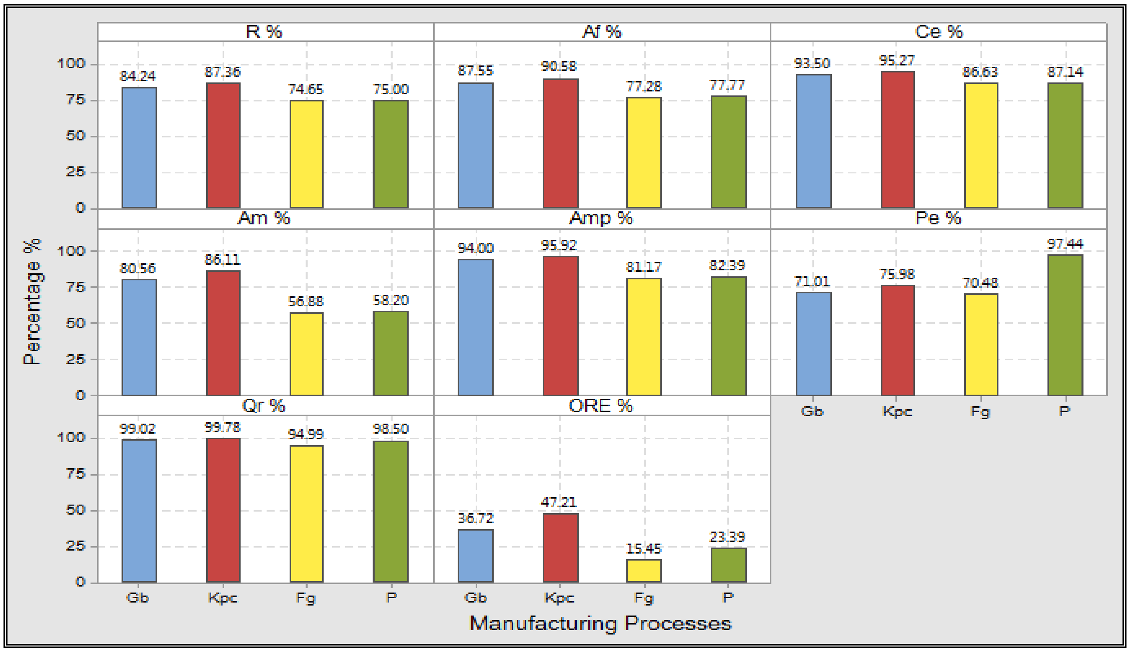

Figure (6.26) Effect of Manufacturing Processes onto ORE Through January Month-2015

7. Conclusions and Further Recommendations

1- Finish grinding process has a minor OEE performance indicator of (65.02 %), while kiln production and cooling process have major OEE performance indicator of (71.47 %). Also, finish grinding process has a minor performance factor of (70.52 %), on years 2015.

2- finish grinding process has a minor ORE performance indicator of (15.45 %) on years 2015,whereas the kiln production and cooling process has a major ORE performance indicator of (47.21 %).

3- Due to, finish grinding process has the lowest factors of performance, quality rate, availability of material, readiness, and availability of facility which lead to reduce OEE and ORE performance indicators.

4-Through processing activities, develop participations systems of processing activity of finsh grinding process that contributes in reduction of air emissions, where control the steel balls from damage of this process that contributes to increase speed flow of raw materials and quality of product, thus increase overall equipment and resource effectiveness.

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