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# OPTIMIZING PRODUCTIVITY BY ELIMINATING AND MANAGING REJECTION FREQUENCY USING 5S AND KAIZENS PRACTICES: CASE STUDY

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***ABSTRACT***

The worldwide demand of ceramic tiles market is projected to spread about 21,000 million square meters by 2020. The rising infrastructure progress activities in emergent countries is expected to motivate the trade growth throughout the estimated period. The industry has fascinated a number of new competitors owing to the fast demand progress, thus executing the business extremely reasonable. The production of ceramic tiles involves two different stages: pre bisque firing kiln processes and post bisque firing kiln processes. Rejection encountered in pre bisque firing kiln processes can be recycled deprived of much damage to the environment however the post bisque firing kiln rejection cannot be reprocessed. On the other hand, greatest amount of thermal energy is consumed in the bisque firing kiln process. This research paper highlights a case study of frontier ceramic ltd to diminish the post bisque firing kiln rejections frequency during the production of ceramic wall tiles. In this perspective, 5S methodology is used to reorganize the workstations and process flow while the application of kaizens philosophy of continuous improvement has directed to 40% decrease in post bisque firing kiln rejection consequently saving energy and damage to environment.

**Keywords**: rejections rate; 5S methodology; kaizens and lean performs; productivity enhancement

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## 1. INTRODUCTION

Due to tough marketing competitiveness and increase in resource costs, usually low revenue margins are experienced by companies dealing with the manufacturing of ceramic wall tiles, hence they have started to look for suitable alternatives to survive within the market place(STERN et al., 2001).

In this regard, performing revised production planning and control become a helpful tool to review on product's waste reduction during processing, and encourages recycling of finished products that presents a positive influence on the quality of product and overall plant effectiveness(HANDFIELD et al., 2002).

In Pakistan the demand of the ceramic based products such as wall, floor and roof tiles also increased for the most part owing to increase numbers in the real estate business, housing schemes, building and construction division (JURAN et al., 2008).

The economic growth of the ceramic industries in Pakistan is fairly inspiring due to installing and operating of contemporary distinct technologies which have massively enhanced the excellence, output and design features of ceramic tiles products worldwide. Especially single firing procedures effectively abridged the firing time to a maximum of forty minutes (EL MOGAHZY, 2009).

On the other hand, the manufacturers are facing some typical process controlling issues related to production of low class wall tiles, using inadequate raw material composition followed by excessive amount of tiles rejection after firing. Major causes of rejection are generally associated with some sorts of cracks, produced during the firing process (SPARKE et al., 2017).

There are three different technological process stages in which the initial dimensional shape of the ceramic tile is formed as shown in Figure 1. These include hydraulic press or pre kiln process in which the green tile is produced under high pressure with sufficient amount of moisture contents that needed to be removed during the next stage in the dryer kiln at approximately 120 °C (CIULLO, 1996).

The final stage is the bisque kiln where approximately a temperature of 1300 °C is maintained for continuous firing. Convection and radiation are the major heat transmission mechanisms hence the coefficient of heat transfer is also raising constantly (RICHERSEN; LEE, 2005). It is also noticeable that defective and rejected

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tiles received after hydraulic press and dryer kiln operations are desired to be recycled due to the fact that the tile body is in semi-solid position (MCCOLM, 1994).


Figure 1: Technological process for ceramic tile dimensional setup.

But, tiles rejection after the complete firing process is a serious issue due to the facts that these tiles can no longer be recycled (ACERNESE et al., 2015). It is also noticeable that nearly 90 percent of overall production costs associated with energy consumption are getting wasted (RAMBALDI et al., 2007).

On the other hand, it not only grounds, industrial issues in the form of solid waste discarding but also environmental as well. Keeping in view the considerable rejection of ceramic tiles, that contributes a significant impact on economics, social as well as environmental issues, the current work is an initiative to review the present scenario and resolve such issues (MINNE; CRITTENDEN, 2015).

The appropriate way to control the current issues is to provide some motivations for process betterment by exploring the origins of inconsistencies in production process and put on 5S methodology and kaizens approach to eliminate the causes of the tiles rejections (ROZLIN et al., 2018).

## 2. CASE STUDY OF FRONTIER CERAMICS LTD

The current study has been carried out in frontier ceramics ltd to study, analyze and eliminate the ceramic tiles rejections frequency in post bisque firing kiln rejection operation in order to optimize the production rate and profitability. The company is ISO certified, playing a leading role in the manufacturing of high quality ceramic wall tiles of various dimensions.

It was incorporated in 1982 as a public limited company which maintains its competitiveness through continuing technological advancement, R&D and capital investment. The company is equipped with Spanish and Italian machinery and 300 skilled employees.

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It has an annual throughput of 25 million USD based on three working shifts that consume 755.624 MT of raw material on a monthly basis. Its extensive range of major products is commercial tableware, wall tiles, industrial ceramics, and refractories.

Owing to high levels of post bisque firing kiln rejection issue, the company is struggling to achieve the demands of the trades by selecting certain initiatives such as reviewing alternative manufacturing techniques, application of knowledge, skills, tools and techniques to overcome the rejection issues.

In this standpoint a monitoring team of expertise physically visited the project unit to examine the production activities regarding tiles defects and rejections and to explore the main causes of this particular issue by means of implementing 5S and kaizens practices to take initiative steps to improve the production rate.

Business data of company's four major ceramic products were carefully inspected and evaluated on the basis of the volumetric production capacity followed with annual return and poor quality costs (PQC). However, the rejections rate comparison revealed that on average, scheduled rejections of all four types of the products resulted in PQC of roughly 22,500 USD per annum.

Similarly, PQC for these different types of products was 60 % (wall tiles), 30 % (commercial tableware), 9 % (industrial ceramics) and 1 % (refractories) respectively. Figure 2 shows the graphical comparison of rejection costs of the critical products in Pakistani currency.

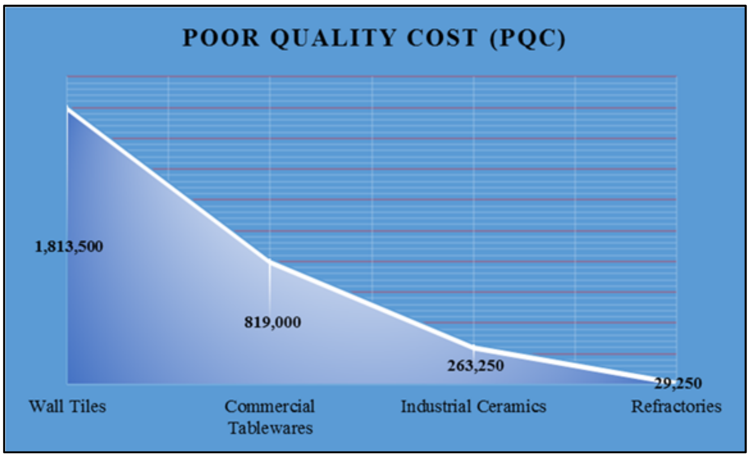


Figure 2: Quality costs comparison

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Owing to high quality costs associated with a high rejection rate of wall tiles, the basic objective is to select it for model scheme. Additionally, process wise data of rejections was also considered to distinguish the influence of numerous flaws.

## 3. CERAMIC WALL TILES PROCESS FLOW

As per Figure 3 illustration, the process flow of ceramic wall tiles comprises of a series of different technological phases including Pre firing, primary firing, post primary firing and final firing operations.

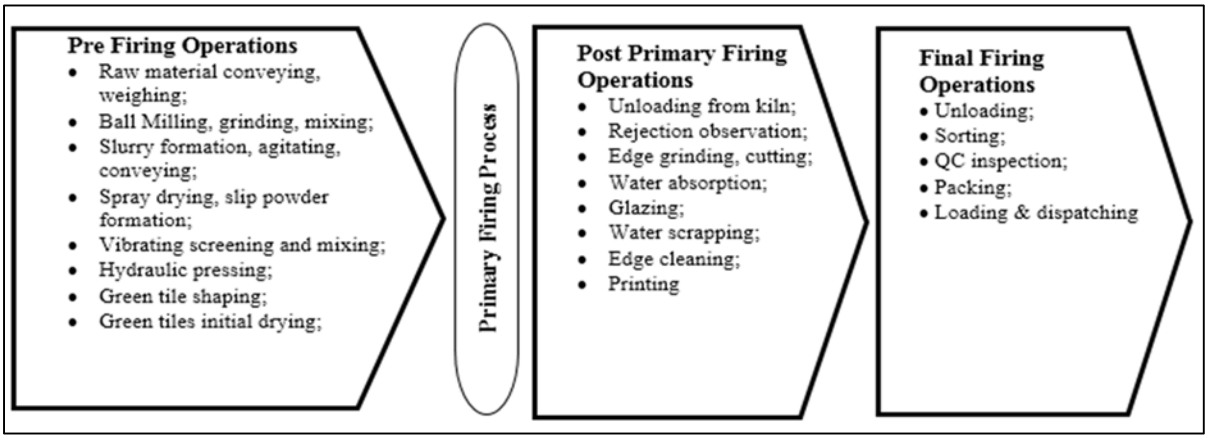


Figure 3: Flow chart of ceramic wall tiles production

The pre firing process starts with body preparation by batching various raw materials which are normally classified as per their essential properties (BEALL et al., no date). Generally, there are two basic groups, namely plastic and non-plastic. Plastic materials reveal plasticity while a large collection of non-plastic materials like minerals and rocks with other chemicals, try to reduce high shrinkage of the tile body during drying and firing.

Plastic raw materials comprise of clay, bentonite and kaolin while non-plastic raw materials include quartz, feldspar, dolomite, limestone, magnesite and talc (SANCHEZ et al., no date). The aim of the grinding and mixing is to obtain smaller particles out of coarser ones.

For instance, there are two conventional techniques of grinding, the wet and dry, however, it is intended to enhance the degree of fineness of the materials in order to remove risky scums that originate spots (STIEF; LAWRUK; WILSON, 1987). Using wet process of grinding, the material is weighed proportionally and passed into the ball mills together with appropriate volume of water to form a liquid mix product known as slurry (ORUMWENSE; FORSSBERG, 1992).

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The slurry is then passed through a spray drying process to convert it to a granulate with a size distribution before the pressing and shaping operation (AGRAFIOTIS; TSOUTSOS, 2001). In this process the slurry is atomized under high pressure, and water is evaporated from the fine droplets using a flow of heated air. In this way a slip powder as shown in Figure 4 is produced that falls to the bottom of the spray dryer where it is shifted to hydraulic press after the screening process (CAMPANATI; FORNASARI; VACCARI, 2003).

Figure 4: Slip powder formation in the spray dryer operation.

The persistence of the hydraulic pressing is to shape the slip powder into a compressed part of green tile using a set of metallic dies through which the size and geometry of the ceramic tile is determined (SÁNCHEZ-MORENO *et al.*, 2003). Figure 5 illustrates a typical hydraulic press. It offers the gain of a comparatively high pressure that could be measured easily and considered best suitable for the manufacture of single-fired ceramic tiles where a constant pressure is authoritative for dimensional accurateness (BAYINDIRLI *et al.*, 2006).

The pressure range varies from 350-450 MPa (SINGER, 2013). Drying process of the green ceramic tile is accomplished between the pressing and primary firing processes in which about 4 to 6% of moisture contents are removed. The aim of the drying process is to enhance the initial strength against damage owing to distortion after being transferred to the bisque kiln (BENTO; LOPES, 2005).

The drying process is achieved using an automatic control system in which the tile body is allowed to travel horizontally (KARA *et al.*, 2006). Primary firing in bisque kiln is normally the concluding process, at which the feeble, green and a pressed part of the tile is converted into a durable and tough product because of the influence of various physical and chemical changes occur inside the green tile body throughout the process.

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It is also noticeable that fast rate of firing confirms completely constant temperature dispersal and high value of the tiles (CAWLEY; LEE, 2006). The primary firing process is usually accomplished using roller type bisque kiln as shown in Figure 6, where a constant range of temperature about 990 °C to 1050 °C is maintained that fully ensures the mass consolidation and the dimensional constancy in the firing temperature intervening (DUNN, 2016).

Post firing kiln operations, establishes the permanent solidification of ceramic tile while the defective and cracked tiles are rejected at this stage. Edge grinding and cutting processes are then carried out to smooth the ends and accommodate the required length of the product for easy handling (RHEAD, 1922).

Figure 5: Hydraulic Pressing

Further, the accurate and specified tiles pass to the next stages where the rest of the technological processes, including water absorption, glazing, water scrapping, edge cleaning and printing are performed. Post final firing operation includes testing and final inspection, planarity check, quality grades, water absorption and dimensional confirmation are inspected. The quality controlled accepted ceramic tiles are properly packed and dispatched to the desired destination (SHARTSIS; NEWMAN, 1948).

Figure 6: Primary firing roller kiln

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## 4. REJECTION ANALYSIS IN POST BISQUE FIRING KILN PROCESS

In the course of the rejection analysis pertains to the current production process, the waste due to process defects was acknowledged at every stage. The rejection of tiles after the bisque firing kiln process is particularly significant because before this stage ceramic tiles have semi solid structure, hence, any defective or rejected tile may be recycled and stepped back for reprocessing (JOHANSEN *et al.*, 1995).

However, after passing the bisque firing kiln process, the ceramic tiles gain a complete solid structure, hence any defective tile is directly rejected which is a direct financial forfeiture for the company.

On the other hand, around 65% of overall manufacturing costs are associated with inspecting, operating and maintaining the kiln equipment while the energy consumption is an additional factor, hence post bisque kiln firing operation defects investigation is crucial owing to enormous capital engrossment. Figure 7 demonstrates the list of possible types of tiles rejection generated after firing process (STADTLER, 2008).

These include mishandling at kiln exit, planarity defects, overlapping and chipping, cracking inside kiln bottom, surface and side cracks and rejection during breaking strength test.

Figure 7: Defective and rejected tiles receive from bisque kiln

Similarly, Pareto chart analysis as shown in Table 1 are conducted for each production process in order to recognize the frequency of monthly based average rejection tendencies for these defects while the graphical comparison of these

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contributions is graphically analyzed in Figure 8 using a Pareto chart that shows that the major reasons of rejection lie in mishandling process at the exit of bisque kiln and planarity defects issues respectively.

Table 1: Post bisque firing kiln rejection analysis

| Reason of rejection | Monthly average rejection (M.T) | Percent (%) | Cumulative (%) |
|---|---|---|---|
| Mishandling at kiln exit | 0.315 | 47.01 | 47.01 |
| Planarity Defects | 0.159 | 23.73 | 70.75 |
| Overlapping and chipping | 0.078 | 11.64 | 82.39 |
| Inside kiln bottom | 0.053 | 7.91 | 90.30 |
| Surface and side cracks | 0.038 | 5.67 | 95.97 |
| During breaking strength test determination | 0.027 | 4.03 | 100.00 |
| | **0.67** | **100.00** | |

Source: Adapted from Accounts and Finance Department

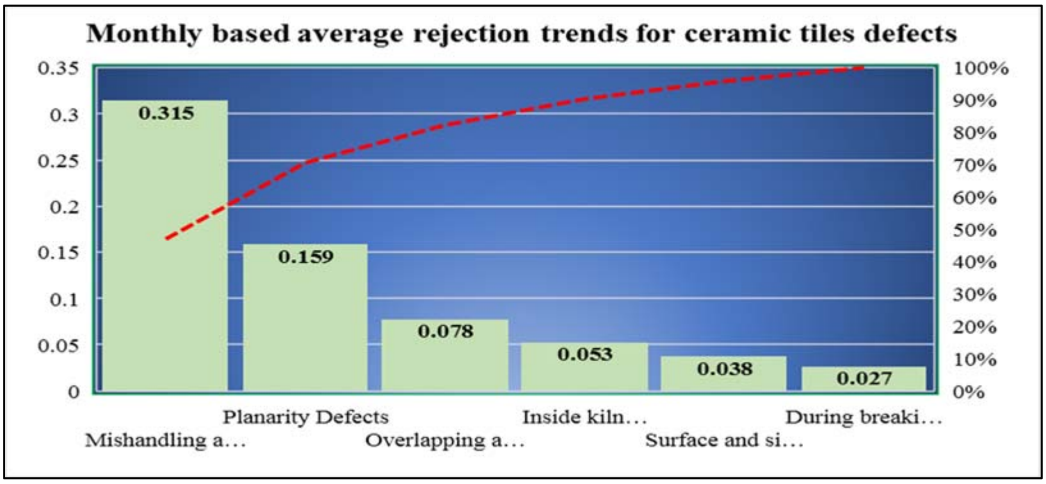


Figure 8: Pareto chart analysis for monthly based rejection comparison

### 4.1. Implementing the 5S Methodology

5S is a viewpoint and the way how to organize, manage the workstation and process flow of a plant in order to enhance its current performance by reducing rejection (RANDHAWA; AHUJA, 2018). This technique was first introduced in early 1980 in Japan for Toyota Production System (TPS). It is an effective and helpful tool, especially realistic in a plant that is beginning to go down the progress path of the culture of continuous development (AOKI, 2008).

On the other hand, a plant that has not espoused the 5S methodology is muffled with chips and chips. Tools boxes are located in unknown areas; high accuracy tools are accepted, but not preserved. When a certain piece of tool is needed, it could be difficult to find.

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Similarly, the overall self-confidence of team work is deprived and the plant is fated for distress. Implementing 5S methodology is a progressive technique to invent a plan for enhanced productivity, removal of wasteful practices, and overall improvement (SMITH; HAWKINS, 2004). These include:

I. **Sort:** Focuses on disregarding redundant items from the workstation and categorizing the materials, tools and equipment as necessary, unnecessary and may not necessary.

II. **Set in order:** Set focuses on allocating and ordering of equipment, tools, materials, and resources for fast allocation which can save a considerable expanse of time.

III. **Shine:** Focuses on new values for cleanliness by cleaning each workstation, machines and equipment on a regular basis. It also delivers a safe working environment to make potential glitches more obvious.

IV. **Standardize:** Focuses on engaging the employees to perform steps 1, 2, and 3 on a daily basis by educating them to take part in the improvement of these standards.

V. **Sustain**: Focuses on building structural pledge so as the 5S technique turn out an administrative standard. It also stresses on defining an innovative outlook in different workstations.

5S technique was studied and conducted for each rejection condition to explore the counteractive measures. Rejections reasons and actions were taken accordingly for mishandling at kiln enlisted due to its high rejection frequency in the tables 2.

Similar 5S methodology with necessary actions were performed for the remaining types of process defects and rejection. Possible reasons and necessary actions to control the rejection due to mishandling at kiln exit, planarity defects, overlapping and chipping, cracking inside kiln bottom, surface and side cracks and rejection during breaking strength test are enlisted in Table 3.

### 4.2. Implementing kaizen approach

In order to enhance the current performance of the plant, a number of additional tasks and actions were initiated using kaizen approach excluding those stated earlier (STEPHENS, 2010). These actions are expressed in Table 4.

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Table 2: 5S methodology description for mishandling at kiln exit.

| Rejection Reason | | 5S Actions |
|---|---|---|
| **Mishandling at kiln exit** | | |
| 1. Less space for tiles collection; 2. Lack of working procedure of concerned workers; 3. Rejected tiles are not shifted to the rejected area; 4. Tiles conveyor machine maintaing issues; 5. High temperature at the exit of the kiln | Sort | 1. Make space for respected floor and the workspace. |
| | | 2. The use of worn out gloves is not optional in any case. |
| | | 3. Once rejected tiles are received, it is good idea to put them in the specified area. |
| | | 4. Current design of tiles table conveyor mechanism has become outdated, hence abnormality and blockage issues may be managed by redesigning considerations. |
| | | 5. Placing a Red tag on the fresh batch of tiles just received from kiln to identify no contact with body parts. |
| | Set in order | 1. Allocating a suitable place for needed items. |
| | | 2. Propose a storage place that is well marked so that necessary items can be taken out quickly and used easily. |
| | | 3. Deciding to fix a suitable place to place the hot tiles closer to the process. |
| | Shine | 1. Hanging dirty colth and gloves are not optional in workplace while the participation of the concerned staff must be ensured. |
| | | 2. Pinpointing the causes lack of follow up on the job procedure. Is there available any job description , if yes any steps are initiating to follow them properly.If not then pinpointing the root source of the lack of procedure follow up and taking necessary measures so that the required job may be accomplished properly. |
| | | 3. Ensuring up a standard rejected tile area and nominating an individual with responsibility. Drawing a certain borderline on the floor while nothing should be placed on this line. Also making sure that the broken tiles scrap and chips may not be throw throw out. Every shift incharge should monitor the progress. |
| | Standardize | 4. Eliminating sources of wear such as vibration. Discovering and treating unknown flaws and documenting them with the conveyor machine if it is difficult to repair immediately. Developing an independent maintenance strategy will facilitate any training opportunity for enhancement. |
| | | 5. Even if a suitable place has been selected for storing the hot tiles that should be located ideally closer to the process, unless cleaning it up is necessary with a purpose for better enviroment. |
| | Sustain | In this perspective it is intended that all the plant employees should paly a role model for succeeding to the standards of the first three S's and inspire others individuals to follow them. Make instructions and actions to endorse a good team work environment till the first three S's become second nature for everybody within the plant. |
| | | Once the 5S's technique has been implementd, then it is not recommended to let it disappear. Following steps are helpful in this regards: Step 1 - Maintain 5S awareness: Continued motivation to improve and endorse the program. |

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| | | |
|---|---|---|
| | | Step 2 - Create occasions to advance the 5S methodology: 5S reflection surveys; performance measures and periodic audits; Step 3 - Create motivation for 5S: Endorse the impression of how the 5S helps to pass the business contenders. Taking a record on semiannual basis and compare to see improvements. |

Table 3: Necessary action plans for minimizing rejection at bisque firing kiln.

| Rejection type | Reasons | Action |
|---|---|---|
| Mishandling at kiln exit | Tiles handling table conveyor poor quality design; less time for maintenance jobs; | Table conveyor mechanical system redesigning, breakdown maintenance review, workers training, installing ventilating facilities. |
| Planarity defects | Drying temperature variation; Removal of water contents at a slow enough rate; shrinkage cracks | Introducing a novel technique of impulse drying that uses throbs of hot air curving in the crosswise direction instead of continuously in the physical flow direction. |
| Overlapping and chipping | The reason of rejection is related with the night shifts when the speed of the tile conveying system is increased to attain the production target in less period of time. | For this purpose, it was recommended to get benefit form installing CCTVs cameras at glaze line section to monitor the production activities. |
| cracking inside kiln bottom | Improper air circulation inside the kiln; uneven pressing pressure during molding; variation in the thickness of tile. | Removal of broken tiles pieces from the bottom of the bisque kiln on weekly basis; Rechecking and Readjusting of hydraulic press pressure; Inspection of tiles mold quality. |
| Surface and side cracks | uneven thickness; drying speed; Slip power moisture issues. | Readjusting drying temperature of spray dryer; Slowing down the drying speed. |
| rejection during breaking test grit | Application of excessive load for sorting out the rejected tile. | Application of fixed load less than 200 N prior to glazing process. |

## 4.3. Other Miscellaneous steps towards process improvement

Being one of the crucial building blocks of TPM, autonomous maintenance, endorses intellectual development of machine operators to perform minor maintenance jobs to keep up their equipment and to prevent it from declining (STEPHENS, 2010).

As per Figure 9 illustration, this comprehensive seven step methodology is flattering progressively significant as industrial units announce more and novel robots fully automated systems. Thus, autonomous maintenance plays an effective role in the contemporary maintenance plan because it well organizes production and maintenance individuals in order to work for a common goal.

However, if properly implemented, it may intensely expand production rate, enhanced quality and minimizes waste related issues. In this perspective the

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concerned operators should carry out their work thoroughly with the maintenance individuals by using following information:

Table 4: Presentation of additional task for process improvement.

| Area | Indicator | Reason | Action |
|---|---|---|---|
| Hydraulic Press | Slow pressure build up | A pressure buildup more than 2 to 3 seconds may be the problem associated with hydraulic pump. | Replacement of the relief valve; Solenoid valves rechecking; Checking rpm of the motor. |
| Spray Dryer | Gradual decline in capacity | Additional inquiry of the pressure drops within the system exposed a high pressure drop across the central air regulated filter | Intensifying of clean filters |
| Diaphragm Pump | Impulsive diaphragm miscarriage | Cavitation | Increasing pipe diameter on suction side of pump |
| Conveyor belt | Material overflow mostly along transfer and loading points | Owing to any mechanical letdowns with the belt while this issue can lead to obstructions at some points that will possess a negative effect and cause other difficulties afterward. | Installation of skirts clamps, impact beds or even a belt plough that will help to minimize wasted material and time consumed on cleaning up which will further minimize the risk of uncertain breakdowns caused by impasses on the belt. |
| Crazing in glazing | Developing of network of fine blows in the glaze exterior. | Possible under firing of bisque tile or mismatched clay types and glaze material. | Reviewing and readjusting by firing temperature. |
| Air Compressor (Atlas Capco) | Air Compressor usually trips during summer | Not enough ventilation facility is provided | Compressor room redesigning and reconstruction resolved the issue successfully. |

- They must be able to aware maintenance concerned;
- They must be able to communicate precise information;
- They must be able to conduct routine maintenance jobs

Afterwards the autonomous maintenance was hereby conducted in hydraulic press, bisque kiln, spray dryer and testing sections respectively. It is also noticeable that due to working in adverse condition, sometime the concerned workers’ behavior becomes intolerable with their shift supervisors hence being frustrated they commit to skillfully abolishing green and bisque tiles which is a hidden loss to the company.

For this purpose, it was recommended to get benefit from installing CCTVs cameras that may help to avoid such immoral commitment of some workers while keeping their mind that they are being watched.

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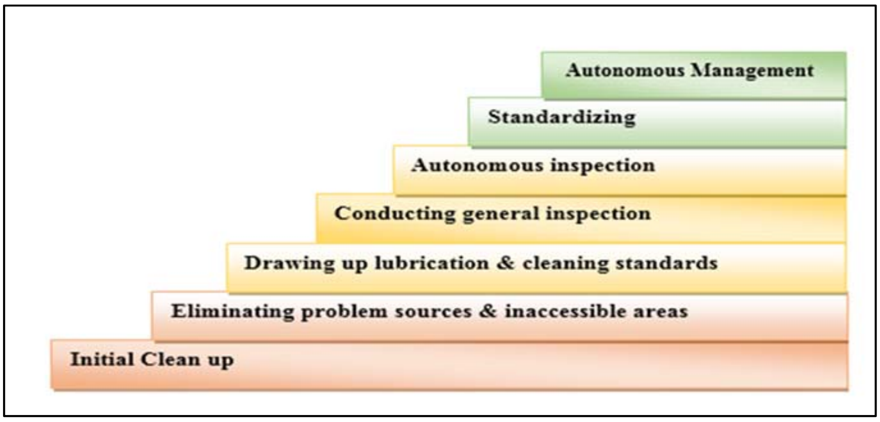


Figure 9: Seven steps of autonomous maintenance approach

## 5. RESULTS AND DISCUSSION

In order to compare the final results regarding optimizing productivity rate to minimize the frequency of tiles rejection, the actual data were analyzed after conducting 5S and kaizen approach implementation. The outcomes of the current work appearances the advances and net business savings due to kaizen methodology are mentioned below:

**Rejection outcomes after firing process in the kiln:** Implementing the actions as shown in Table 3, the associated outcomes as shown in Figure 10, clearly display the improvement in the process by controlling the major six types rejections due to which 50% to 65% reduction in the waste has occurred. Similarly, on the basis of Table 2 and 4, after implementation of 5S strategy for each rejection reason and additional necessary tasks for productivity enhancement, there has been observed a considerable decrease in rejection frequencies related to six major issues by 54%, 40%, 42% 24%, 63%, and 70% respectively as shown in Figure 11. It was also observed that overall monthly based rejection rates were 81.861 MT while after taking performance enhancement strategies it is 49.117 MT showing a positive progress in productivity enhancement about 40%.

**Inclusive financial reimbursements gained from kaizen strategies:** Due to a gradual reduction in rejection of defective tiles, a dramatic capital saving during one financial year gained through the implementation of 5S and kaizens approaches as shown in table 5.

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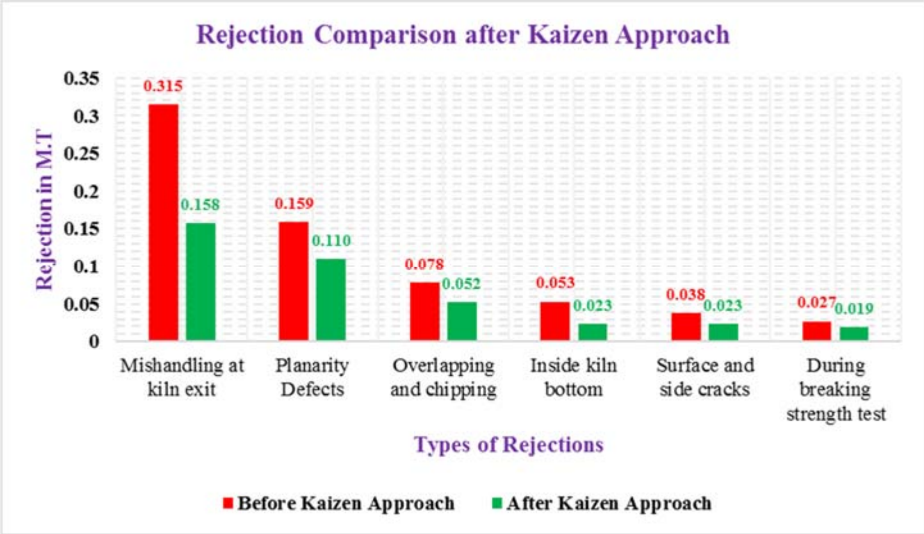


Figure 10. Comparison of post bisque firing kiln rejection using kaizen approach

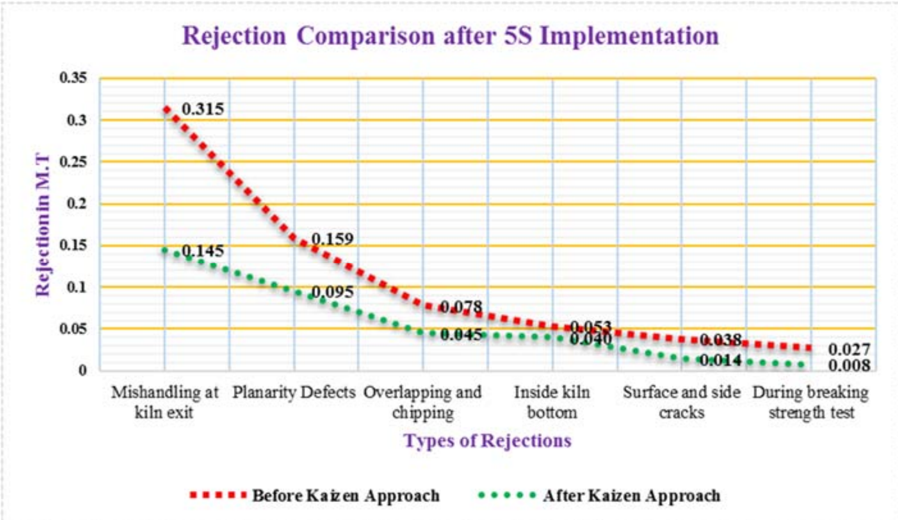


Figure 11. Comparison of post bisque firing kiln rejection using 5S methodology

Table 5. Material salvage and gain in revenue from rejections control

| Description | Material salvage due to rejection control (M.T) | Actual saving in one financial year (US $ million) |
|---|---|---|
| Waste rejection after primary firing in kiln | 32.744 | 0.465 |

Table 6 demonstrates the complete capital gain of USD 0.506 (million) during one fiscal year that is basically the sum of reserves through waste reduction after bisque firing in kiln as per Table 5 findings plus increases in revenue through additional system improvement strategies as described in Table 5 followed by implementation of the seven steps of autonomous maintenance approach respectively.

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Table 6. Complete financial benefits from system enhanced performance

| Description | Actual saving in one year (US $ million) |
|---|---|
| Waste rejection after primary firing in kiln | 0.465 |
| Additional system improvement strategies | 0.017 |
| Implementation of seven steps of the autonomous maintenance approach | 0.024 |
| **Total Saving in (US $ million)** | **0.506** |

## 6. CONCLUSIONS

Current research represents a comprehensive study of frontier ceramic limited, establishing the solicitation of 5S technique and kaizens approach to diminish rejection of tiles received after bisque firing kiln. After successful and well managed application of 5S technique, kaizens approach, seven steps of the autonomous maintenance program and other additional process improvement activities intensely minimized the rejection frequencies through an average of 40% and optimized the financial saving up to US $ 0.506 (million) per year.

Qualitative assistances were also perceived in term of dexterity progression, character building, leader ship, cooperative working environments, and upgraded self-esteem of the organization's workforce. On the other hand, the issues related to waste discarding and energy consumption reduced in the same way, thus decreasing ecological, communal and commercial liabilities.

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